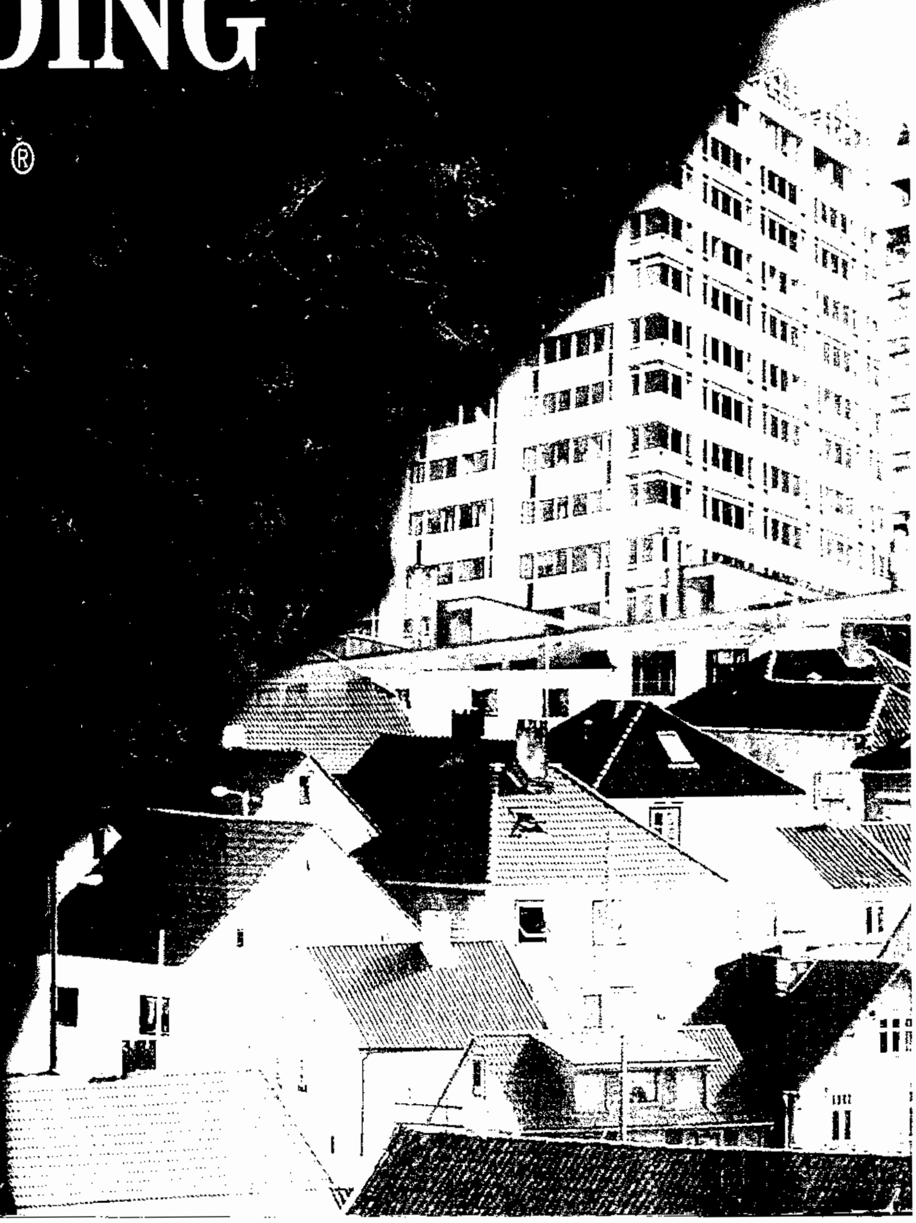
1997

UNIFORM BUILDING CODE®

VOLUME 1

75th Anniversary
1922 ICBO 1997

INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS
UNIFORM BUILDING CODE
1922



1997

UNIFORM BUILDING CODE®

VOLUME 1

ADMINISTRATIVE, FIRE- AND LIFE-SAFETY, AND FIELD INSPECTION PROVISIONS

INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS
UNIFORM BUILDING CODE
1922 ®

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Preface

The *Uniform Building Code*™ is dedicated to the development of better building construction and greater safety to the public by uniformity in building laws. The code is founded on broad-based principles that make possible the use of new materials and new construction systems.

The *Uniform Building Code* was first enacted by the International Conference of Building Officials at the Sixth Annual Business Meeting held in Phoenix, Arizona, October 18-21, 1927. Revised editions of this code have been published since that time at approximate three-year intervals. New editions incorporate changes approved since the last edition.

The *Uniform Building Code* is designed to be compatible with related publications to provide a complete set of documents for regulatory use. See the publications list following this preface for a listing of the complete family of Uniform Codes and related publications.

Code Changes. The ICBO code development process has been suspended by the Board of Directors and, because of this action, changes to the *Uniform Building Code* will not be processed. For more information, write to the International Conference of Building Officials, 5360 Workman Mill Road, Whittier, California 90601-2298. An analysis of changes between editions is published in the *Analysis of Revisions to the Uniform Codes.*

Marginal Markings. Solid vertical lines in the margins within the body of the code indicate a change from the requirements of the 1994 edition except where an entire chapter was revised, a new chapter was added or a change was minor. Where an entire chapter was revised or a new chapter was added, a notation appears at the beginning of that chapter. The letter **F** repeating in line vertically in the margin indicates that the provision is maintained under the code change procedures of the International Fire Code Institute. Deletion indicators (➧) are provided in the margin where a paragraph or item listing has been deleted if the deletion resulted in a change of requirements.

Three-Volume Set. Provisions of the *Uniform Building Code* have been divided into a three-volume set. Volume 1 accommodates administrative, fire- and life-safety, and field inspection provisions. Chapters 1 through 15 and Chapters 24 through 35 are printed in Volume 1 in their entirety. Any appendix chapters associated with these chapters are printed in their entirety at the end of Volume 1. Excerpts of certain chapters from Volume 2 are reprinted in Volume 1 to provide greater usability.

Volume 2 accommodates structural engineering design provisions, and specifically contains Chapters 16 through 23 printed in their entirety. Included in this volume are design standards that have been added to their respective chapters as divisions of the chapters. Any appendix chapters associated with these chapters are printed in their entirety at the end of Volume 2. Excerpts of certain chapters from Volume 1 are reprinted in Volume 2 to provide greater usability.

Volume 3 contains material, testing and installation standards.

Metrication. The *Uniform Building Code* was metricated in the 1994 edition. The metric conversions are provided in parenthesis following the English units. Where industry has made metric conversions available, the conversions conform to current industry standards.

Formulas are also provided with metric equivalents. Metric equivalent formulas immediately follow the English formula and are denoted by "For **SI:**" preceding the metric equivalent. Some formulas do not use dimensions and, thus, are not provided with a metric equivalent. Multiplying conversion factors have been provided for formulas where metric forms were unavailable. Tables are provided with multiplying conversion factors in subheadings for each tabulated unit of measurement.

CODES AND RELATED PUBLICATIONS

The International Conference of Building Officials (ICBO) publishes a family of codes, each correlated with the *Uniform Building Code*™ to provide jurisdictions with a complete set of building-related regulations for adoption. Some of these codes are published in affiliation with other organizations such as the International Fire Code Institute (IFCI) and the International Code Council (ICC). Reference materials and related codes also are available to improve knowledge of code enforcement and administration of building inspection programs. Publications and products are continually being added, so inquiries should be directed to Conference headquarters for a listing of available products. Many codes and references are also available on CD-ROM or floppy disk. These are denoted by (*). The following publications and products are available from ICBO:

CODES

***Uniform Building Code**, Volumes 1, 2 and 3. The most widely adopted model building code in the United States, the performance-based *Uniform Building Code* is a proven document, meeting the needs of government units charged with the enforcement of building regulations. Volume 1 contains administrative, fire- and life-safety and field inspection provisions; Volume 2 contains structural engineering design provisions; and Volume 3 contains material, testing and installation standards.

***Uniform Mechanical Code™.** Provides a complete set of requirements for the design, construction, installation and maintenance of heating, ventilating, cooling and refrigeration systems; incinerators and other heat-producing appliances.

International Plumbing Code™. Provides consistent and technically advanced requirements that can be used across the country to provide comprehensive regulations of modern plumbing systems. Setting minimum regulations for plumbing facilities in terms of performance objectives, the IPC provides for the acceptance of new and innovative products, materials and systems.

International Private Sewage Disposal Code™. Provides flexibility in the development of safety and sanitary individual sewage disposal systems and includes detailed provisions for all aspects of design, installation and inspection of private sewage disposal systems.

International Mechanical Code™. Establishes minimum regulations for mechanical systems using prescriptive and performance-related provisions. It is founded on broad-based principles that make possible the use of new materials and new mechanical designs.

Uniform Zoning Code™. This code is dedicated to intelligent community development and to the benefit of the public welfare by providing a means of promoting uniformity in zoning laws and enforcement.

***Uniform Fire Code™**, Volumes 1 and 2. The premier model fire code in the United States, the *Uniform Fire Code* sets forth provisions necessary for fire prevention and fire protection. Published by the International Fire Code Institute, the *Uniform Fire Code* is endorsed by the Western Fire Chiefs Association, the International Association of Fire Chiefs and ICBO. Volume 1 contains code provisions compatible with the *Uniform Building Code*, and Volume 2 contains standards referenced from the code provisions.

***Urban-Wildland Interface Code™.** Promulgated by IFCI, this code regulates both land use and the built environment in designated urban-wildland interface areas. This newly developed code is the only model code that bases construction requirements on the fire-hazard severity exposed to the structure. Developed under a grant from the Federal Emergency Management Agency, this code is the direct result of hazard mitigation meetings held after devastating wildfires.

Uniform Housing Code™. Provides complete requirements affecting conservation and rehabilitation of housing. Its regulations are compatible with the *Uniform Building Code*.

Uniform Code for the Abatement of Dangerous Buildings™. A code compatible with the *Uniform Building Code* and the *Uniform Housing Code* which provides equitable remedies consistent with other laws for the repair, vacation or demolition of dangerous buildings.

Uniform Sign Code™. Dedicated to the development of better sign regulation, its requirements pertain to all signs and sign construction attached to buildings.

Uniform Administrative Code™. This code covers administrative areas in connection with adoption of the *Uniform Building Code*, *Uniform Mechanical Code* and related codes. It contains provisions which relate to site preparation, construction, alteration, moving, repair and use and occupancies of buildings or structures and building service equipment, including plumbing, electrical and mechanical regulations. The code is compatible with the administrative provisions of all codes published by the Conference.

Uniform Building Security Code™. This code establishes minimum standards to make dwelling units resistant to unlawful entry. It regulates swinging doors, sliding doors, windows and hardware in connection with dwelling units of apartment houses or one- and two-family dwellings. The code gives consideration to the concerns of police, fire and building officials in establishing requirements for resistance to burglary which are compatible with fire and life safety.

Uniform Code for Building Conservation™. A building conservation guideline presented in code format which will provide a community with the means to preserve its existing buildings while achieving appropriate levels of safety. It is formatted in the same manner as the *Uniform Building Code*, is compatible with other Uniform Codes, and may be adopted as a code or used as a guideline.

Dwelling Construction under the Uniform Building Code™. Designed primarily for use in home building and apprentice training, this book contains requirements applicable to the construction of one- and two-story dwellings based on the requirements of the *Uniform Building Code*. Available in English or Spanish.

Dwelling Construction under the Uniform Mechanical Code™. This publication is for the convenience of the homeowner or contractor interested in installing mechanical equipment in a one- or two-family dwelling in conformance with the *Uniform Mechanical Code*.

Supplements to UBC and related codes. Published in the years between editions, the Supplements contain all approved changes, plus an analysis of those changes.

Uniform Building Code—1927 Edition. A special 60th anniversary printing of the first published *Uniform Building Code*.

One and Two Family Dwelling Code. Promulgated by ICC, this code eliminates conflicts and duplications among the model codes to achieve national uniformity. Covers mechanical and plumbing requirements as well as construction and occupancy.

Application and Commentary on the One and Two Family Dwelling Code. An interpretative commentary on the *One and Two Family Dwelling Code* intended to enhance uniformity of interpretation and application of the code nationwide. Developed by the three model code organizations, this document includes numerous illustrations of code requirements and the rationale for individual provisions.

Model Energy Code. This code includes minimum requirements for effective use of energy in the design of new buildings and structures and additions to existing buildings. It is based on American Society of Heating, Refrigeration and Air-conditioning Engineers Standard 90A-1980 and was originally developed jointly by ICBO, BOCA, SBCCI and the National Conference of States on Building Codes and Standards under a contract funded by the United States Department of Energy. The code is now maintained by ICC and is adopted by reference in the *Uniform Building Code*.

National Electrical Code®. The electrical code used throughout the United States. Published by the National Fire Protection Association, it is an indispensable aid to every electrician, contractor, architect, builder, inspector and anyone who must specify or certify electrical installations.

TECHNICAL REFERENCES AND EDUCATIONAL MATERIALS

Analysis of Revisions to the Uniform Codes™. An analysis of changes between the previous and new editions of the Uniform Codes is provided. Changes between code editions are noted either at the beginning of chapters or in the margins of the code text.

***Handbook to the Uniform Building Code.** The handbook is a completely detailed and illustrated commentary on the *Uniform Building Code,* tracing historical background and rationale of the codes through the current edition. Also included are numerous drawings and figures clarifying the application and intent of the code provisions. Also available in electronic format.

***Handbook to the Uniform Mechanical Code.** An indispensable tool for understanding the provisions of the current UMC, the handbook traces the historical background and rationale behind the UMC provisions, includes 160 figures which clarify the intent and application of the code, and provides a chapter-by-chapter analysis of the UMC.

***Uniform Building Code Application Manual.** This manual discusses sections of the *Uniform Building Code* with a question-and-answer format, providing a comprehensive analysis of the intent of the code sections. Most sections include illustrative examples. The manual is in loose-leaf format so that code applications published in *Building Standards* magazine may be inserted. Also available in electronic format.

***Uniform Mechanical Code Application Manual.** As a companion document to the *Uniform Mechanical Code,* this manual provides a comprehensive analysis of the intent of a number of code sections in an easy-to-use question-and-answer format. The manual is available in a loose-leaf format and includes illustrative examples for many code sections.

***Uniform Fire Code Applications Manual.** This newly developed manual provides questions and answers regarding UFC provisions. A comprehensive analysis of the intent of numerous code sections, the manual is in a loose-leaf format for easy insertion of code applications published in IFCI's *Fire Code Journal.*

Quick-Reference Guide to the Occupancy Requirements of the 1997 UBC. Code requirements are compiled in this publication by occupancy groups for quick access. These tabulations assemble requirements for each occupancy classification in the code. Provisions, such as fire-resistive ratings for occupancy separations in Table 3-B, exterior wall and opening protection requirements in Table 5-A-1, and fire-resistive ratings for types of construction in Table 6-A, are tabulated for quick reference and comparison.

Plan Review Manual. A practical text that will assist and guide both the field inspector and plan reviewer in applying the code requirements. This manual covers the nonstructural and basic structural aspects of plan review.

Field Inspection Manual. An important fundamental text for courses of study at the community college and trade or technical school level. It is an effective text for those studying building construction or architecture and includes sample forms and checklists for use in the field.

Building Department Administration. An excellent guide for improvement of skills in departmental management and in the enforcement and application of the Building Code and other regulations administered by a building inspection department. This textbook will also be a valuable aid to instructors, students and those in related professional fields.

Building Department Guide to Disaster Mitigation. This new, expanded guide is designed to assist building departments in developing or updating disaster mitigation plans. Subjects covered include guidelines for damage mitigation, disaster-response management, immediate response, mutual aid and inspections, working with the media, repair and recovery policies, and public information bulletins. This publication is a must for those involved in preparing for and responding to disaster.

Building Official Management Manual. This manual addresses the unique nature of code administration and the managerial duties of the building official. A supplementary insert addresses the budgetary and financial aspects of a building department. It is also an ideal resource for those preparing for the management module of the CABO Building Official Certification Examination.

Legal Aspects of Code Administration. A manual developed by the three model code organizations to inform the building official on the legal aspects of the profession. The text is written in a logical sequence with explanation of legal terminology. It is designed to serve as a refresher for those preparing to take the legal module of the CABO Building Official Certification Examination.

Illustrated Guide to Conventional Construction Provisions of the UBC. This comprehensive guide and commentary provides detailed explanations of the conventional construction provisions in the UBC, including descriptive discussions and illustrated drawings to convey the prescriptive provisions related to wood-frame construction.

Introduction to the Uniform Building Code. A workbook that provides an overview of the basics of the UBC.

Uniform Building Code Update Workbook. This manual addresses many of the changes to the administrative, fire- and life-safety, and inspection provisions appearing in the UBC.

UMC Workbook. Designed for independent study or use with instructor-led programs based on the *Uniform Mechanical Code,* this comprehensive study guide consists of 16 learning sessions, with the first two sessions reviewing the purpose, scope, definitions and administrative provisions and the remaining 14 sessions progressively exploring the requirements for installing, inspecting and maintaining heating, ventilating, cooling and refrigeration systems.

UBC Field Inspection Workbook. A comprehensive workbook for studying the provisions of the UBC. Divided into 12 sessions, this workbook focuses on the UBC combustible construction requirements for the inspection of wood-framed construction.

Concrete Manual. A publication for individuals seeking an understanding of the fundamentals of concrete field technology and inspection practices. Of particular interest to concrete construction inspectors, it will also benefit employees of concrete producers, contractors, testing and inspection laboratories and material suppliers.

Reinforced Concrete Masonry Construction Inspector's Handbook. A comprehensive information source written especially for masonry inspection covering terminology, technology, materials, quality control, inspection and standards. Published jointly by ICBO and the Masonry Institute of America.

You Can Build It! Sponsored by ICBO in cooperation with CABO, this booklet contains information and advice to aid "do-it-yourselfers" with building projects. Provides guidance in necessary procedures such as permit requirements, codes, plans, cost estimation, etc.

Guidelines for Manufactured Housing Installations. A guideline in code form implementing the *Uniform Building Code* and its companion code documents to regulate the permanent installation of a manufactured home on a privately owned, nonrental site. A commentary is included to explain specific provisions, and codes applying to each component part are defined.

Accessibility Reference Guide. This guide is a valuable resource for architects, interior designers, plan reviewers and others who design and enforce accessibility provisions. Features include accessibility requirements, along with detailed commentary and graphics to clarify the provisions; cross-references to other applicable sections of the UBC and the Americans with Disabilities Act Accessibility Guidelines; a checklist of UBC provisions on access and usability requirements; and many other useful references.

Educational and Technical Reference Materials. The Conference has been a leader in the development of texts and course material to assist in the educational process. These materials include vital information necessary for the building official and subordinates in carrying out their responsibilities and have proven to be excellent references in connection with community college curricula and higher-level courses in the field of building construction technology and inspection and in the administration of building departments. Included are plan review checklists for structural, nonstructural, mechanical and fire-safety provisions and a full line of videotapes and automated products.

Table of Contents—Volume 1
Administrative, Fire- and Life-Safety, and Field Inspection Provisions

Table of Contents—Volume 2
Structural Engineering Design Provisions

Table of Contents—Volume 3
Material, Testing and Installation Standards

EFFECTIVE USE OF THE *UNIFORM BUILDING CODE*

The following procedure may be helpful in using the *Uniform Building Code:*

1. Classify the building:

   A. **OCCUPANCY CLASSIFICATION:** Compute the floor area and occupant load of the building or portion thereof. See Sections 207 and 1002 and Table 10-A. Determine the occupancy group which the use of the building or portion thereof most nearly resembles. See Sections 301, 303.1.1, 304.1, 305.1, 306.1, 307.1, 308.1, 309.1, 310.1, 311.1 and 312.1. See Section 302 for buildings with mixed occupancies.

   B. **TYPE OF CONSTRUCTION:** Determine the type of construction of the building by the building materials used and the fire resistance of the parts of the building. See Chapter 6.

   C. **LOCATION ON PROPERTY:** Determine the location of the building on the site and clearances to property lines and other buildings from the plot plan. See Table 5-A and Sections 602.3, 603.3, 604.3, 605.3 and 606.3 for fire resistance of exterior walls and wall opening requirements based on proximity to property lines. See Section 503.

   D. **ALLOWABLE FLOOR AREA:** Determine the allowable floor area of the building. See Table 5-B for basic allowable floor area based on occupancy group and type of construction. See Section 505 for allowable increases based on location on property and installation of an approved automatic fire sprinkler system. See Section 504.2 for allowable floor area of multistory buildings.

   E. **HEIGHT AND NUMBER OF STORIES:** Compute the height of the building, Section 209, and determine the number of stories, Section 220. See Table 5-B for the maximum height and number of stories permitted based on occupancy group and type of construction. See Section 506 for allowable story increase based on the installation of an approved automatic fire-sprinkler system.

2. Review the building for conformity with the occupancy requirements in Sections 303 through 312.

3. Review the building for conformity with the type of construction requirements in Chapter 6.

4. Review the building for conformity with the exiting requirements in Chapter 10.

5. Review the building for other detailed code regulations in Chapters 4, 7 through 11, 14, 15, 24 through 26, and 30 through 33, and the appendix.

6. Review the building for conformity with structural engineering regulations and requirements for materials of construction. See Chapters 16 through 23.

SAMPLE ORDINANCE FOR ADOPTION OF THE *UNIFORM BUILDING CODE,* VOLUMES 1, 2 AND 3 ORDINANCE NO. ________

An ordinance of the ____(jurisdiction)____ adopting the 1997 edition of the *Uniform Building Code,* Volumes 1, 2 and 3, regulating the erection, construction, enlargement, alteration, repair, moving, removal, demolition, conversion, occupancy, equipment, use, height, area and maintenance of all buildings or structures in the ____(jurisdiction)____; providing for the issuance of permits and collection of fees therefor; providing for penalties for the violation thereof, repealing Ordinance No. ______ of the ____(jurisdiction)____ and all other ordinances and parts of the ordinances in conflict therewith.

The ____(governing body)____ of the ____(jurisdiction)____ does ordain as follows:

Section 1. That certain documents, three (3) copies of which are on file and are open for inspection of the public in the office of the ____(jurisdiction's keeper of records)____ of the ____(jurisdiction)____, being marked and designated as:

Uniform Building Code, 1997 Edition, published by the International Conference of Building Officials, including the generic fire-resistive assemblies listed in the *Fire Resistance Design Manual,* Fourteenth Edition, dated April 1994, published by the Gypsum Association as referenced in Tables 7-A, 7-B and 7-C (also reference Appendix Chapter 12, Division II, if adopted) of the specified *Uniform Building Code,* including Appendix Chapters ________. *[Fill in the applicable appendix chapters (see Uniform Building Code Section 101.3, last paragraph). If reference is made to Appendix Chapter 30, an additional reference to ANSI/ASME A17.1, 1987, Safety Code for Elevators and Escalators, including Supplements A17.1a-1988, A17.1b-1989, and to ANSI/ASME A17.3a-1986, Safety Code for Existing Elevators and Escalators, including Supplements A17.3a-1989, published by the American Society of Mechanical Engineers, should be added and three (3) copies of this code should also be on file (see Appendix Sections 3010 and 3012)], and*

Structural Welding Code—Reinforcing Steel, AWS D1.4-92 (UBC Standard 19-1); American National Standard for Accessible and Useable Buildings and Facilities, A117.1-1992 (see *Uniform Building Code* Section 1101.2), published by the Council of American Building Officials; *Load and Resistance Factor Design Specificatians for Structural Steel Buildings,* December 1, 1993 (Chapter 22, Division II); *Specification for Structural Steel Buildings Allowable Stress Design and Plastic Design,* June 1, 1989 (Chapter 22, Division III); *Load and Resistance Factor Design Specification for Cold Formed Steel Structural Members,* 1986 (with December, 1989 Addendum) (Chapter 22, Division VI); *Specification for Design of Cold-Formed Steel Structural Members,* 1986 (Chapter 22, Division VII); *Standard Specification for Steel Joists, K-Series, LH-Series, DLH-Series and Joist Girders,* 1994 (Chapter 22, Division IX); *Structural Applications of Steel Cables for Buildings,* ASCE 17-95 (Chapter 22, Division XI); and *National Design Specification for Wood Construction,* Revised 1991 Edition (Chapter 22, Division III, Part I), as modified or amended in the *Uniform Building Code* referenced herein:

be and the same are hereby adopted as the code of the ____(jurisdiction)____ for regulating the erection, construction, enlargement, alteration, repair, moving, removal, demolition, conversion, occupancy, equipment, use, height, area and maintenance of all buildings or structures in the ____(jurisdiction)____ providing for issuance of permits and collection of fees therefor; and each and all of the regulations, provisions, conditions and terms of such *Uniform Building Code, 1997 Edition,* Volumes 1, 2 and 3, published by the International Conference of Building Officials, and the secondary publications referenced above, all of which are on file in the office of the ____(jurisdiction)____ are hereby referred to, adopted and made a part hereof as if fully set out in this ordinance.

Section 2. (Incorporate penalties for violations. See Section 103.)

Section 3. That Ordinance No. ______ of ____(jurisdiction)____ entitled *(fill in the title of building ordinance or ordinances in effect at the present time)* and all other ordinances or parts of ordinances in conflict herewith are hereby repealed.

Section 4. That if any section, sentence, clause or phrase of this ordinance is, for any reason, held to be invalid or unconstitutional, such decision shall not affect the validity or constitutionality of the remaining portions of this ordinance. The ____(governing body)____ hereby declares that it would have passed this ordinance, and each section, clause or phrase hereof, irrespective of the fact that any one or more sections, sentences, clauses and phrases be declared unconstitutional.

Section 5. That the ____(jurisdiction's keeper of records)____ is hereby ordered and directed to cause this ordinance to be published. *(An additional provision may be required to direct the number of times the ordinance is to be published and to specify that it is to be in a newspaper in general circulation. Posting may also be required.)*

Section 6. That this ordinance and the rules, regulations, provisions, requirements, orders and matters established and adopted hereby shall take effect and be in full force and effect (time period) from and after the date of its final passage and adoption.

Volume 1

Chapter 1
ADMINISTRATION

SECTION 101 — TITLE, PURPOSE AND SCOPE

101.1 Title. These regulations shall be known as the *Uniform Building Code,* may be cited as such and will be referred to herein as "this code."

101.2 Purpose. The purpose of this code is to provide minimum standards to safeguard life or limb, health, property and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location and maintenance of all buildings and structures within this jurisdiction and certain equipment specifically regulated herein.

The purpose of this code is not to create or otherwise establish or designate any particular class or group of persons who will or should be especially protected or benefited by the terms of this code.

101.3 Scope. The provisions of this code shall apply to the construction, alteration, moving, demolition, repair, maintenance and use of any building or structure within this jurisdiction, except work located primarily in a public way, public utility towers and poles, mechanical equipment not specifically regulated in this code, and hydraulic flood control structures.

For additions, alterations, moving and maintenance of buildings and structures, see Chapter 34. For temporary buildings and structures see Section 3103 and Appendix Chapter 31.

Where, in any specific case, different sections of this code specify different materials, methods of construction or other requirements, the most restrictive shall govern. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.

Wherever in this code reference is made to the appendix, the provisions in the appendix shall not apply unless specifically adopted.

SECTION 102 — UNSAFE BUILDINGS OR STRUCTURES

All buildings or structures regulated by this code that are structurally unsafe or not provided with adequate egress, or that constitute a fire hazard, or are otherwise dangerous to human life are, for the purpose of this section, unsafe. Any use of buildings or structures constituting a hazard to safety, health or public welfare by reason of inadequate maintenance, dilapidation, obsolescence, fire hazard, disaster, damage or abandonment is, for the purpose of this section, an unsafe use. Parapet walls, cornices, spires, towers, tanks, statuary and other appendages or structural members that are supported by, attached to, or a part of a building and that are in deteriorated condition or otherwise unable to sustain the design loads that are specified in this code are hereby designated as unsafe building appendages.

All such unsafe buildings, structures or appendages are hereby declared to be public nuisances and shall be abated by repair, rehabilitation, demolition or removal in accordance with the procedures set forth in the Dangerous Buildings Code or such alternate procedures as may have been or as may be adopted by this jurisdiction. As an alternative, the building official, or other employee or official of this jurisdiction as designated by the governing body, may institute any other appropriate action to prevent, restrain, correct or abate the violation.

SECTION 103 — VIOLATIONS

It shall be unlawful for any person, firm or corporation to erect, construct, enlarge, alter, repair, move, improve, remove, convert or demolish, equip, use, occupy or maintain any building or structure or cause or permit the same to be done in violation of this code.

SECTION 104 — ORGANIZATION AND ENFORCEMENT

104.1 Creation of Enforcement Agency. There is hereby established in this jurisdiction a code enforcement agency which shall be under the administrative and operational control of the building official.

104.2 Powers and Duties of Building Official.

104.2.1 General. The building official is hereby authorized and directed to enforce all the provisions of this code. For such purposes, the building official shall have the powers of a law enforcement officer.

The building official shall have the power to render interpretations of this code and to adopt and enforce rules and supplemental regulations to clarify the application of its provisions. Such interpretations, rules and regulations shall be in conformance with the intent and purpose of this code.

104.2.2 Deputies. In accordance with prescribed procedures and with the approval of the appointing authority, the building official may appoint such number of technical officers and inspectors and other employees as shall be authorized from time to time. The building official may deputize such inspectors or employees as may be necessary to carry out the functions of the code enforcement agency.

104.2.3 Right of entry. When it is necessary to make an inspection to enforce the provisions of this code, or when the building official has reasonable cause to believe that there exists in a building or upon a premises a condition that is contrary to or in violation of this code that makes the building or premises unsafe, dangerous or hazardous, the building official may enter the building or premises at reasonable times to inspect or to perform the duties imposed by this code, provided that if such building or premises be occupied that credentials be presented to the occupant and entry requested. If such building or premises be unoccupied, the building official shall first make a reasonable effort to locate the owner or other person having charge or control of the building or premises and request entry. If entry is refused, the building official shall have recourse to the remedies provided by law to secure entry.

104.2.4 Stop orders. Whenever any work is being done contrary to the provisions of this code, or other pertinent laws or ordinances implemented through the enforcement of this code, the building official may order the work stopped by notice in writing served on any persons engaged in the doing or causing such work to be done, and any such persons shall forthwith stop such work until authorized by the building official to proceed with the work.

104.2.5 Occupancy violations. Whenever any building or structure or equipment therein regulated by this code is being used contrary to the provisions of this code, the building official may order such use discontinued and the structure, or portion thereof, vacated by notice served on any person causing such use to be continued. Such person shall discontinue the use within the time prescribed by the building official after receipt of such notice to make the structure, or portion thereof, comply with the requirements of this code.

104.2.6 Liability. The building official charged with the enforcement of this code, acting in good faith and without malice in the discharge of the duties required by this code or other pertinent law or ordinance shall not thereby be rendered personally liable for damages that may accrue to persons or property as a result of an act or by reason of an act or omission in the discharge of such duties. A suit brought against the building official or employee because of such act or omission performed by the building official or employee in the enforcement of any provision of such codes or other pertinent laws or ordinances implemented through the enforcement of this code or enforced by the code enforcement agency shall be defended by this jurisdiction until final termination of such proceedings, and any judgment resulting therefrom shall be assumed by this jurisdiction.

This code shall not be construed to relieve from or lessen the responsibility of any person owning, operating or controlling any building or structure for any damages to persons or property caused by defects, nor shall the code enforcement agency or its parent jurisdiction be held as assuming any such liability by reason of the inspections authorized by this code or any permits or certificates issued under this code.

104.2.7 Modifications. When there are practical difficulties involved in carrying out the provisions of this code, the building official may grant modifications for individual cases. The building official shall first find that a special individual reason makes the strict letter of this code impractical and that the modification is in conformance with the intent and purpose of this code and that such modification does not lessen any fire-protection requirements or any degree of structural integrity. The details of any action granting modifications shall be recorded and entered in the files of the code enforcement agency.

104.2.8 Alternate materials, alternate design and methods of construction. The provisions of this code are not intended to prevent the use of any material, alternate design or method of construction not specifically prescribed by this code, provided any alternate has been approved and its use authorized by the building official.

The building official may approve any such alternate, provided the building official finds that the proposed design is satisfactory and complies with the provisions of this code and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in suitability, strength, effectiveness, fire resistance, durability, safety and sanitation.

The building official shall require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its use. The details of any action granting approval of an alternate shall be recorded and entered in the files of the code enforcement agency.

104.2.9 Tests. Whenever there is insufficient evidence of compliance with any of the provisions of this code or evidence that any material or construction does not conform to the requirements of this code, the building official may require tests as proof of compliance to be made at no expense to this jurisdiction.

Test methods shall be as specified by this code or by other recognized test standards. If there are no recognized and accepted test methods for the proposed alternate, the building official shall determine test procedures.

All tests shall be made by an approved agency. Reports of such tests shall be retained by the building official for the period required for the retention of public records.

104.2.10 Cooperation of other officials and officers. The building official may request, and shall receive, the assistance and cooperation of other officials of this jurisdiction so far as is required in the discharge of the duties required by this code or other pertinent law or ordinance.

SECTION 105 — BOARD OF APPEALS

105.1 General. In order to hear and decide appeals of orders, decisions or determinations made by the building official relative to the application and interpretation of this code, there shall be and is hereby created a board of appeals consisting of members who are qualified by experience and training to pass on matters pertaining to building construction and who are not employees of the jurisdiction. The building official shall be an ex officio member of and shall act as secretary to said board but shall have no vote on any matter before the board. The board of appeals shall be appointed by the governing body and shall hold office at its pleasure. The board shall adopt rules of procedure for conducting its business, and shall render all decisions and findings in writing to the appellant with a duplicate copy to the building official.

105.2 Limitations of Authority. The board of appeals shall have no authority relative to interpretation of the administrative provisions of this code nor shall the board be empowered to waive requirements of this code.

SECTION 106 — PERMITS

106.1 Permits Required. Except as specified in Section 106.2, no building or structure regulated by this code shall be erected, constructed, enlarged, altered, repaired, moved, improved, removed, converted or demolished unless a separate permit for each building or structure has first been obtained from the building official.

106.2 Work Exempt from Permit. A building permit shall not be required for the following:

1. One-story detached accessory buildings used as tool and storage sheds, playhouses, and similar uses, provided the floor area does not exceed 120 square feet (11.15 m^2).

2 Fences not over 6 feet (1829 mm) high.

3. Oil derricks.

4. Movable cases, counters and partitions not over 5 feet 9 inches (1753 mm) high.

5. Retaining walls that are not over 4 feet (1219 mm) in height measured from the bottom of the footing to the top of the wall, unless supporting a surcharge or impounding Class I, II or III-A liquids.

6. Water tanks supported directly upon grade if the capacity does not exceed 5,000 gallons (18 927 L) and the ratio of height to diameter or width does not exceed 2:1.

7. Platforms, walks and driveways not more than 30 inches (762 mm) above grade and not over any basement or story below.

8. Painting, papering and similar finish work.

9. Temporary motion picture, television and theater stage sets and scenery.

10. Window awnings supported by an exterior wall of Group R, Division 3, and Group U Occupancies when projecting not more than 54 inches (1372 mm).

11. Prefabricated swimming pools accessory to a Group R, Division 3 Occupancy in which the pool walls are entirely above the adjacent grade and if the capacity does not exceed 5,000 gallons (18 927 L).

Unless otherwise exempted, separate plumbing, electrical and mechanical permits will be required for the above-exempted items.

Exemption from the permit requirements of this code shall not be deemed to grant authorization for any work to be done in any manner in violation of the provisions of this code or any other laws or ordinances of this jurisdiction.

106.3 Application for Permit.

106.3.1 Application. To obtain a permit, the applicant shall first file an application therefor in writing on a form furnished by the code enforcement agency for that purpose. Every such application shall:

1. Identify and describe the work to be covered by the permit for which application is made.

2. Describe the land on which the proposed work is to be done by legal description, street address or similar description that will readily identify and definitely locate the proposed building or work.

3. Indicate the use or occupancy for which the proposed work is intended.

4. Be accompanied by plans, diagrams, computations and specifications and other data as required in Section 106.3.2.

5. State the valuation of any new building or structure or any addition, remodeling or alteration to an existing building.

6. Be signed by the applicant, or the applicant's authorized agent.

7. Give such other data and information as may be required by the building official.

106.3.2 Submittal documents. Plans, specifications, engineering calculations, diagrams, soil investigation reports, special inspection and structural observation programs and other data shall constitute the submittal documents and shall be submitted in one or more sets with each application for a permit. When such plans are not prepared by an architect or engineer, the building official may require the applicant submitting such plans or other data to demonstrate that state law does not require that the plans be prepared by a licensed architect or engineer. The building official may require plans, computations and specifications to be prepared and designed by an engineer or architect licensed by the state to practice as such even if not required by state law.

EXCEPTION: The building official may waive the submission of plans, calculations, construction inspection requirements and other data if it is found that the nature of the work applied for is such that reviewing of plans is not necessary to obtain compliance with this code.

106.3.3 Information on plans and specifications. Plans and specifications shall be drawn to scale upon substantial paper or cloth and shall be of sufficient clarity to indicate the location, nature and extent of the work proposed and show in detail that it will conform to the provisions of this code and all relevant laws, ordinances, rules and regulations.

Plans for buildings of other than Group R, Division 3 and Group U Occupancies shall indicate how required structural and fire-resistive integrity will be maintained where penetrations will be made for electrical, mechanical, plumbing and communication conduits, pipes and similar systems.

106.3.4 Architect or engineer of record.

106.3.4.1 General. When it is required that documents be prepared by an architect or engineer, the building official may require the owner to engage and designate on the building permit application an architect or engineer who shall act as the architect or engineer of record. If the circumstances require, the owner may designate a substitute architect or engineer of record who shall perform all of the duties required of the original architect or engineer of record. The building official shall be notified in writing by the owner if the architect or engineer of record is changed or is unable to continue to perform the duties.

The architect or engineer of record shall be responsible for reviewing and coordinating all submittal documents prepared by others, including deferred submittal items, for compatibility with the design of the building.

106.3.4.2 Deferred submittals. For the purposes of this section, deferred submittals are defined as those portions of the design that are not submitted at the time of the application and that are to be submitted to the building official within a specified period.

Deferral of any submittal items shall have prior approval of the building official. The architect or engineer of record shall list the deferred submittals on the plans and shall submit the deferred submittal documents for review by the building official.

Submittal documents for deferred submittal items shall be submitted to the architect or engineer of record who shall review them and forward them to the building official with a notation indicating that the deferred submittal documents have been reviewed and that they have been found to be in general conformance with the design of the building. The deferred submittal items shall not be installed until their design and submittal documents have been approved by the building official.

106.3.5 Inspection and observation program. When special inspection is required by Section 1701, the architect or engineer of record shall prepare an inspection program that shall be submitted to the building official for approval prior to issuance of the building permit. The inspection program shall designate the portions of the work that require special inspection and the name or names of the individuals or firms who are to perform the special inspections, and indicate the duties of the special inspectors.

The special inspector shall be employed by the owner, the engineer or architect of record, or an agent of the owner, but not the contractor or any other person responsible for the work.

When structural observation is required by Section 1702, the inspection program shall name the individuals or firms who are to perform structural observation and describe the stages of construction at which structural observation is to occur.

The inspection program shall include samples of inspection reports and provide time limits for submission of reports.

106.4 Permits Issuance.

106.4.1 Issuance. The application, plans, specifications, computations and other data filed by an applicant for a permit shall be reviewed by the building official. Such plans may be reviewed by other departments of this jurisdiction to verify compliance with any applicable laws under their jurisdiction. If the building official finds that the work described in an application for a permit and the plans, specifications and other data filed therewith conform to the requirements of this code and other pertinent laws and ordinances, and that the fees specified in Section 107 have been paid, the building official shall issue a permit therefor to the applicant.

When the building official issues the permit where plans are required, the building official shall endorse in writing or stamp the plans and specifications APPROVED. Such approved plans and specifications shall not be changed, modified or altered without authorizations from the building official, and all work regulated by this code shall be done in accordance with the approved plans.

The building official may issue a permit for the construction of part of a building or structure before the entire plans and specifications for the whole building or structure have been submitted or approved, provided adequate information and detailed statements have been filed complying with all pertinent requirements of this code. The holder of a partial permit shall proceed without assurance that the permit for the entire building or structure will be granted.

106.4.2 Retention of plans. One set of approved plans, specifications and computations shall be retained by the building official for a period of not less than 90 days from date of completion of the work covered therein; and one set of approved plans and specifications shall be returned to the applicant, and said set shall be kept on the site of the building or work at all times during which the work authorized thereby is in progress.

106.4.3 Validity of permit. The issuance or granting of a permit or approval of plans, specifications and computations shall not be construed to be a permit for, or an approval of, any violation of any of the provisions of this code or of any other ordinance of the jurisdiction. Permits presuming to give authority to violate or cancel the provisions of this code or other ordinances of the jurisdiction shall not be valid.

The issuance of a permit based on plans, specifications and other data shall not prevent the building official from thereafter requiring the correction of errors in said plans, specifications and other data, or from preventing building operations being carried on thereunder when in violation of this code or of any other ordinances of this jurisdiction.

106.4.4 Expiration. Every permit issued by the building official under the provisions of this code shall expire by limitation and become null and void if the building or work authorized by such permit is not commenced within 180 days from the date of such permit, or if the building or work authorized by such permit is suspended or abandoned at any time after the work is commenced for a period of 180 days. Before such work can be recommenced, a new permit shall be first obtained to do so, and the fee therefor shall be one half the amount required for a new permit for such work, provided no changes have been made or will be made in the original plans and specifications for such work, and provided further that such suspension or abandonment has not exceeded one year. In order to renew action on a permit after expiration, the permittee shall pay a new full permit fee.

Any permittee holding an unexpired permit may apply for an extension of the time within which work may commence under that permit when the permittee is unable to commence work within the time required by this section for good and satisfactory reasons. The building official may extend the time for action by the permittee for a period not exceeding 180 days on written request by the permittee showing that circumstances beyond the control of the permittee have prevented action from being taken. No permit shall be extended more than once.

106.4.5 Suspension or revocation. The building official may, in writing, suspend or revoke a permit issued under the provisions of this code whenever the permit is issued in error or on the basis of incorrect information supplied, or in violation of any ordinance or regulation or any of the provisions of this code.

SECTION 107 — FEES

107.1 General. Fees shall be assessed in accordance with the provisions of this section or shall be as set forth in the fee schedule adopted by the jurisdiction.

107.2 Permit Fees. The fee for each permit shall be as set forth in Table 1-A.

The determination of value or valuation under any of the provisions of this code shall be made by the building official. The value to be used in computing the building permit and building plan review fees shall be the total value of all construction work for which the permit is issued, as well as all finish work, painting, roofing, electrical, plumbing, heating, air conditioning, elevators, fire-extinguishing systems and any other permanent equipment.

107.3 Plan Review Fees. When submittal documents are required by Section 106.3.2, a plan review fee shall be paid at the time of submitting the submittal documents for plan review. Said plan review fee shall be 65 percent of the building permit fee as shown in Table 1-A.

The plan review fees specified in this section are separate fees from the permit fees specified in Section 107.2 and are in addition to the permit fees.

When submittal documents are incomplete or changed so as to require additional plan review or when the project involves deferred submittal items as defined in Section 106.3.4.2, an additional plan review fee shall be charged at the rate shown in Table 1-A.

107.4 Expiration of Plan Review. Applications for which no permit is issued within 180 days following the date of application shall expire by limitation, and plans and other data submitted for review may thereafter be returned to the applicant or destroyed by the building official. The building official may extend the time for action by the applicant for a period not exceeding 180 days on request by the applicant showing that circumstances beyond the control of the applicant have prevented action from being taken. No application shall be extended more than once. In order to renew action on an application after expiration, the applicant shall resubmit plans and pay a new plan review fee.

107.5 Investigation Fees: Work without a Permit.

107.5.1 Investigation. Whenever any work for which a permit is required by this code has been commenced without first obtaining said permit, a special investigation shall be made before a permit may be issued for such work.

107.5.2 Fee. An investigation fee, in addition to the permit fee, shall be collected whether or not a permit is then or subsequently issued. The investigation fee shall be equal to the amount of the permit fee required by this code. The minimum investigation fee shall be the same as the minimum fee set forth in Table 1-A. The payment of such investigation fee shall not exempt any person from compliance with all other provisions of this code nor from any penalty prescribed by law.

107.6 Fee Refunds. The building official may authorize refunding of any fee paid hereunder which was erroneously paid or collected.

The building official may authorize refunding of not more than 80 percent of the permit fee paid when no work has been done under a permit issued in accordance with this code.

The building official may authorize refunding of not more than 80 percent of the plan review fee paid when an application for a permit for which a plan review fee has been paid is withdrawn or canceled before any plan reviewing is done.

The building official shall not authorize refunding of any fee paid except on written application filed by the original permittee not later than 180 days after the date of fee payment.

SECTION 108 — INSPECTIONS

108.1 General. All construction or work for which a permit is required shall be subject to inspection by the building official and all such construction or work shall remain accessible and exposed for inspection purposes until approved by the building official. In addition, certain types of construction shall have continuous inspection, as specified in Section 1701.5.

Approval as a result of an inspection shall not be construed to be an approval of a violation of the provisions of this code or of other ordinances of the jurisdiction. Inspections presuming to give authority to violate or cancel the provisions of this code or of other ordinances of the jurisdiction shall not be valid.

It shall be the duty of the permit applicant to cause the work to remain accessible and exposed for inspection purposes. Neither the building official nor the jurisdiction shall be liable for expense entailed in the removal or replacement of any material required to allow inspection.

A survey of the lot may be required by the building official to verify that the structure is located in accordance with the approved plans.

108.2 Inspection Record Card. Work requiring a permit shall not be commenced until the permit holder or an agent of the permit holder shall have posted or otherwise made available an inspection record card such as to allow the building official to conveniently make the required entries thereon regarding inspection of the work. This card shall be maintained available by the permit holder until final approval has been granted by the building official.

108.3 Inspection Requests. It shall be the duty of the person doing the work authorized by a permit to notify the building official that such work is ready for inspection. The building official may require that every request for inspection be filed at least one working day before such inspection is desired. Such request may be in writing or by telephone at the option of the building official.

It shall be the duty of the person requesting any inspections required by this code to provide access to and means for inspection of such work.

108.4 Approval Required. Work shall not be done beyond the point indicated in each successive inspection without first obtaining the approval of the building official. The building official, upon notification, shall make the requested inspections and shall either indicate that portion of the construction is satisfactory as completed, or shall notify the permit holder or an agent of the permit holder wherein the same fails to comply with this code. Any portions that do not comply shall be corrected and such portion shall not be covered or concealed until authorized by the building official.

There shall be a final inspection and approval of all buildings and structures when completed and ready for occupancy and use.

108.5 Required Inspections.

108.5.1 General. Reinforcing steel or structural framework of any part of any building or structure shall not be covered or concealed without first obtaining the approval of the building official.

Protection of joints and penetrations in fire-resistive assemblies shall not be concealed from view until inspected and approved.

The building official, upon notification, shall make the inspections set forth in the following sections.

108.5.2 Foundation inspection. To be made after excavations for footings are complete and any required reinforcing steel is in place. For concrete foundations, any required forms shall be in place prior to inspection. All materials for the foundation shall be on the job, except where concrete is ready mixed in accordance with approved nationally recognized standards, the concrete need not be on the job. Where the foundation is to be constructed of approved treated wood, additional inspections may be required by the building official.

108.5.3 Concrete slab or under-floor inspection. To be made after all in-slab or under-floor building service equipment, conduit, piping accessories and other ancillary equipment items are in place, but before any concrete is placed or floor sheathing installed, including the subfloor.

108.5.4 Frame inspection. To be made after the roof, all framing, fire blocking and bracing are in place and all pipes, chimneys and vents are complete and the rough electrical, plumbing, and heating wires, pipes and ducts are approved.

108.5.5 Lath or gypsum board inspection. To be made after all lathing and gypsum board, interior and exterior, is in place, but before any plastering is applied or before gypsum board joints and fasteners are taped and finished.

108.5.6 Final inspection. To be made after finish grading and the building is completed and ready for occupancy.

108.6 Special Inspections. For special inspections, see Chapter 17.

108.7 Other Inspections. In addition to the called inspections specified above, the building official may make or require other inspections of any construction work to ascertain compliance with the provisions of this code and other laws which are enforced by the code enforcement agency.

108.8 Reinspections. A reinspection fee may be assessed for each inspection or reinspection when such portion of work for which inspection is called is not complete or when corrections called for are not made.

This section is not to be interpreted as requiring reinspection fees the first time a job is rejected for failure to comply with the requirements of this code, but as controlling the practice of calling for inspections before the job is ready for such inspection or reinspection.

Reinspection fees may be assessed when the inspection record card is not posted or otherwise available on the work site, the approved plans are not readily available to the inspector, for failure to provide access on the date for which inspection is requested, or for deviating from plans requiring the approval of the building official.

To obtain a reinspection, the applicant shall file an application therefor in writing on a form furnished for that purpose and pay the reinspection fee in accordance with Table 1-A or as set forth in the fee schedule adopted by the jurisdiction.

In instances where reinspection fees have been assessed, no additional inspection of the work will be performed until the required fees have been paid.

SECTION 109 — CERTIFICATE OF OCCUPANCY

109.1 Use and Occupancy. No building or structure shall be used or occupied, and no change in the existing occupancy classification of a building or structure or portion thereof shall be made until the building official has issued a certificate of occupancy therefor as provided herein.

EXCEPTION: Group R, Division 3 and Group U Occupancies.

Issuance of a certificate of occupancy shall not be construed as an approval of a violation of the provisions of this code or of other ordinances of the jurisdiction. Certificates presuming to give authority to violate or cancel the provisions of this code or other ordinances of the jurisdiction shall not be valid.

109.2 Change in Use. Changes in the character or use of a building shall not be made except as specified in Section 3405 of this code.

109.3 Certificate Issued. After the building official inspects the building or structure and finds no violations of the provisions of this code or other laws that are enforced by the code enforcement agency, the building official shall issue a certificate of occupancy that shall contain the following:

1. The building permit number.
2. The address of the building.
3. The name and address of the owner.
4. A description of that portion of the building for which the certificate is issued.
5. A statement that the described portion of the building has been inspected for compliance with the requirements of this code for the group and division of occupancy and the use for which the proposed occupancy is classified.
6. The name of the building official.

109.4 Temporary Certificate. If the building official finds that no substantial hazard will result from occupancy of any building or portion thereof before the same is completed, a temporary certificate of occupancy may be issued for the use of a portion or portions of a building or structure prior to the completion of the entire building or structure.

109.5 Posting. The certificate of occupancy shall be posted in a conspicuous place on the premises and shall not be removed except by the building official.

109.6 Revocation. The building official may, in writing, suspend or revoke a certificate of occupancy issued under the provisions of this code whenever the certificate is issued in error, or on the basis of incorrect information supplied, or when it is determined that the building or structure or portion thereof is in violation of any ordinance or regulation or any of the provisions of this code.

TABLE 1-A—BUILDING PERMIT FEES

TOTAL VALUATION	FEE
\$1.00 to \$500.00	\$23.50
\$501.00 to \$2,000.00	\$23.50 for the first \$500.00 plus \$3.05 for each additional \$100.00, or fraction thereof, to and including \$2,000.00
\$2,001.00 to \$25,000.00	\$69.25 for the first \$2,000.00 plus \$14.00 for each additional \$1,000.00, or fraction thereof, to and including \$25,000.00
\$25,001.00 to \$50,000.00	\$391.25 for the first \$25,000.00 plus \$10.10 for each additional \$1,000.00, or fraction thereof, to and including \$50,000.00
\$50,001.00 to \$100,000.00	\$643.75 for the first \$50,000.00 plus \$7.00 for each additional \$1,000.00, or fraction thereof, to and including \$100,000.00
\$100,001.00 to \$500,000.00	\$993.75 for the first \$100,000.00 plus \$5.60 for each additional \$1,000.00, or fraction thereof, to and including \$500,000.00
\$500,001.00 to \$1,000,000.00	\$3,233.75 for the first \$500,000.00 plus \$4.75 for each additional \$1,000.00, or fraction thereof, to and including \$1,000,000.00
\$1,000,001.00 and up	\$5,608.75 for the first \$1,000,000.00 plus \$3.15 for each additional \$1,000.00, or fraction thereof

Other Inspections and Fees:

1. Inspections outside of normal business hours (minimum charge—two hours)	\$47.00 per hour[1]
2. Reinspection fees assessed under provisions of Section 305.8	\$47.00 per hour[1]
3. Inspections for which no fee is specifically indicated (minimum charge—one-half hour)	\$47.00 per hour[1]
4. Additional plan review required by changes, additions or revisions to plans (minimum charge—one-half hour)	\$47.00 per hour[1]
5. For use of outside consultants for plan checking and inspections, or both	Actual costs[2]

[1]Or the total hourly cost to the jurisdiction, whichever is the greatest. This cost shall include supervision, overhead, equipment, hourly wages and fringe benefits of the employees involved.

[2]Actual costs include administrative and overhead costs.

Chapter 2
DEFINITIONS AND ABBREVIATIONS

SECTION 201 — DEFINITIONS

201.1 General. For the purpose of this code, certain terms, phrases, words and their derivatives shall be construed as specified in this chapter and elsewhere in this code where specific definitions are provided. Terms, phrases and words used in the singular include the plural and the plural the singular. Terms, phrases and words used in the masculine gender include the feminine and the feminine the masculine.

Where terms, phrases and words are not defined, they shall have their ordinary accepted meanings within the context with which they are used. *Webster's Third New International Dictionary of the English Language, Unabridged,* copyright 1986, shall be considered as providing ordinarily accepted meanings.

201.2 Standards of Quality.

201.2.1 General. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards (see Sections 3503 and 3504).

201.2.2 Noncombustible material.

UBC Standard 2-1, Noncombustible Material Test

201.2.3 Burning characteristics of building materials.

1. UBC Standard 8-1, Test Method for Surface-burning Characteristics of Building Materials

2. UBC Standard 23-4, Fire-retardant-treated Wood Tests on Durability and Hygroscopic Properties

3. UBC Standard 26-5, Chamber Method of Test for Measuring the Density of Smoke from the Burning or Decomposition of Plastic Materials

4. UBC Standard 26-6, Ignition Properties of Plastics

201.2.4 Corrosives and irritants.

1. 49 C.F.R. 173, Appendix A, Testing for Corrosiveness

2. 16 C.F.R. 1500.41 and 1500.42, Methods of Testing Primary Irritant Substances and Test for Eye Irritants

201.2.5 Ranking of hazardous materials.

UFC Standard 79-3, Identification of the Health, Flammability and Reactivity of Hazardous Materials

201.2.6 Classification of plastics.

UBC Standard 26-7, Method of Test for Determining Classification of Approved Light-transmitting Plastics

SECTION 202 — A

ACCESS FLOOR SYSTEM is an assembly consisting of panels mounted on pedestals to provide an under-floor space for the installations of mechanical, electrical, communication or similar systems or to serve as an air-supply or return-air plenum.

ACCREDITATION BODY is an approved, third-party organization that initially accredits and subsequently monitors, on a continuing basis, the competency and performance of a grading or inspection agency related to carrying out specific tasks.

ACI is the American Concrete Institute, P.O. Box 9094, Farmington Hills, Michigan 48333.

ADDITION is an extension or increase in floor area or height of a building or structure.

AEROSOL is a product that is dispensed by a propellant from a metal can up to a maximum size of 33.8 fluid ounces (1000 mL) or a glass or plastic bottle up to a size of 4 fluid ounces (118.3 mL), other than a rim-vented container.

AGRICULTURAL BUILDING is a structure designed and constructed to house farm implements, hay, grain, poultry, livestock or other horticultural products. This structure shall not be a place of human habitation or a place of employment where agricultural products are processed, treated or packaged, nor shall it be a place used by the public.

AISC is the American Institute of Steel Construction, Inc., One East Wacker Drive, Suite 3100, Chicago, Illinois 60601-2001.

ALLEY is any public way or thoroughfare less than 16 feet (4877 mm) but not less than 10 feet (3048 mm) in width that has been dedicated or deeded to the public for public use.

ALTER or **ALTERATION** is any change, addition or modification in construction or occupancy.

AMUSEMENT BUILDING. See Section 408.2.

ANSI is the American National Standards Institute, 1430 Broadway, New York, New York 10018.

APARTMENT HOUSE is any building or portion thereof that contains three or more dwelling units and, for the purpose of this code, includes residential condominiums.

APPROVED, as to materials and types of construction, refers to approval by the building official as the result of investigation and tests conducted by the building official, or by reason of accepted principles or tests by recognized authorities, technical or scientific organizations.

APPROVED AGENCY is an established and recognized agency regularly engaged in conducting tests or furnishing inspection services, when such agency has been approved.

APPROVED FABRICATOR is an established and qualified person, firm or corporation approved by the building official pursuant to Section 1701.7 of this code.

AREA. See "floor area."

ASSEMBLY BUILDING is a building or portion of a building used for the gathering together of 50 or more persons for such purposes as deliberation, education, instruction, worship, entertainment, amusement, drinking or dining, or awaiting transportation.

ASTM is the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428.

ATRIUM is an opening through two or more floor levels other than enclosed stairways, elevators, hoistways, escalators, plumbing, electrical, air-conditioning or other equipment, which is closed at the top and not defined as a mall. Floor levels, as used in this definition, do not include balconies within assembly occupancies or mezzanines that comply with Section 507.

AUTOMATIC, as applied to fire-protection devices, is a device or system providing an emergency function without the necessity of human intervention and activated as a result of a predetermined temperature rise, rate of rise of temperature or increase in the level of combustion products.

SECTION 203 — B

BALCONY is that portion of the seating space of an assembly room, the lowest part of which is raised 4 feet (1219 mm) or more above the level of the main floor and shall include the area providing access to the seating area or serving only as a foyer.

BALCONY, EXTERIOR EXIT. See Section 1006.3.

BASEMENT is any floor level below the first story in a building, except that a floor level in a building having only one floor level shall be classified as a basement unless such floor level qualifies as a first story as defined herein.

BOILER, HIGH-PRESSURE, is a boiler furnishing steam at pressures in excess of 15 pounds per square inch (psi) (103.4 kPa) or hot water at temperatures in excess of 250°F (121°C), or at pressures in excess of 160 psi (1103.2 kPa).

BOILER ROOM is any room containing a steam or hot-water boiler.

BUILDING is any structure used or intended for supporting or sheltering any use or occupancy.

BUILDING, EXISTING, is a building erected prior to the adoption of this code, or one for which a legal building permit has been issued.

BUILDING OFFICIAL is the officer or other designated authority charged with the administration and enforcement of this code, or the building official's duly authorized representative.

BULK HANDLING is the transferring of flammable or combustible liquids from tanks or drums into smaller containers for distribution.

SECTION 204 — C

CAST STONE is a precast building stone manufactured from portland cement concrete and used as a trim, veneer or facing on or in buildings or structures.

CENTRAL HEATING PLANT is environmental heating equipment that directly utilizes fuel to generate heat in a medium for distribution by means of ducts or pipes to areas other than the room or space in which the equipment is located.

C.F.R. is the Code of Federal Regulations, a regulation of the United States of America available from the Superintendent of Documents, United States Government Printing Office, Washington, DC 20402.

CHIEF OF THE FIRE DEPARTMENT is the head of the fire department or a regularly authorized deputy.

COMBUSTIBLE LIQUID. See the Fire Code.

CONDOMINIUM, RESIDENTIAL. See "apartment house."

CONGREGATE RESIDENCE is any building or portion thereof that contains facilities for living, sleeping and sanitation, as required by this code, and may include facilities for eating and cooking, for occupancy by other than a family. A congregate residence may be a shelter, convent, monastery, dormitory, fraternity or sorority house, but does not include jails, hospitals, nursing homes, hotels or lodging houses.

CONTROL AREA is a building or portion of a building within which the exempted amounts of hazardous materials may be stored, dispensed, handled or used.

CORROSIVE is a chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. A chemical is considered to be corrosive if, when tested on the intact skin of albino rabbits by the method described in the United States Department of Transportation in Appendix A to 49 C.F.R. 173, it destroys or changes irreversibly the structure of the tissue at the site of contact following an exposure period of four hours. This term shall not refer to action on inanimate surfaces.

COURT is a space, open and unobstructed to the sky, located at or above grade level on a lot and bounded on three or more sides by walls of a building.

SECTION 205 — D

DANGEROUS BUILDINGS CODE is the *Uniform Code for the Abatement of Dangerous Buildings* promulgated by the International Conference of Building Officials, as adopted by this jurisdiction.

DISPENSING is the pouring or transferring of any material from a container, tank or similar vessel, whereby vapors, dusts, fumes, mists or gases may be liberated to the atmosphere.

DISPERSAL AREA, SAFE. See Section 1008.2.

DRAFT STOP is a material, device or construction installed to restrict the movement of air within open spaces of concealed areas of building components such as crawl spaces, floor-ceiling assemblies, roof-ceiling assemblies and attics.

DWELLING is any building or portion thereof that contains not more than two dwelling units.

DWELLING UNIT is any building or portion thereof that contains living facilities, including provisions for sleeping, eating, cooking and sanitation, as required by this code, for not more than one family, or a congregate residence for 10 or less persons.

SECTION 206 — E

EFFICIENCY DWELLING UNIT is a dwelling unit containing only one habitable room.

ELECTRICAL CODE is the *National Electrical Code* promulgated by the National Fire Protection Association, as adopted by this jurisdiction.

ELEVATOR CODE is the safety code for elevators, dumbwaiters, escalators and moving walks as adopted by this jurisdiction (see Appendix Chapter 30).

EMERGENCY CONTROL STATION is an approved location on the premises of a Group H, Division 6 Occupancy where signals from emergency equipment are received and that is continually staffed by trained personnel.

EXISTING BUILDINGS. See "building, existing."

EXIT. See Section 1005.1.

EXIT COURT. See Section 1006.3.5.1.

SECTION 207 — F

FABRICATION AREA (fab area) is an area within a semiconductor fabrication facility and related research and development areas in which there are processes using hazardous production materials. Such areas are allowed to include ancillary rooms or areas such as dressing rooms and offices that are directly related to the fab area processes.

FAMILY is an individual or two or more persons related by blood or marriage or a group of not more than five persons (excluding servants) who need not be related by blood or marriage living together in a dwelling unit.

FIRE ASSEMBLY. See Section 713.2.

FIRE CODE is the *Uniform Fire Code* promulgated by the International Fire Code Institute, as adopted by this jurisdiction.

FIRE RESISTANCE or **FIRE-RESISTIVE CONSTRUCTION** is construction to resist the spread of fire, details of which are specified in this code.

FIRE-RETARDANT-TREATED WOOD is any wood product impregnated with chemicals by a pressure process or other means during manufacture, and which, when tested in accordance with UBC Standard 8-1 for a period of 30 minutes, shall have a flame spread of not over 25 and show no evidence of progressive combustion. In addition, the flame front shall not progress more than $10^1/_2$ feet (3200 mm) beyond the center line of the burner at any time during the test. Materials that may be exposed to the weather shall pass the accelerated weathering test and be identified as Exterior type, in accordance with UBC Standard 23-4. Where material is not directly exposed to rainfall but exposed to high humidity conditions, it shall be subjected to the hygroscopic test and identified as Interior Type A in accordance with UBC Standard 23-4.

All materials shall bear identification showing the fire performance rating thereof. Such identifications shall be issued by an approved agency having a service for inspection of materials at the factory.

FLAMMABLE LIQUID. See the Fire Code.

FLOOR AREA is the area included within the surrounding exterior walls of a building or portion thereof, exclusive of vent shafts and courts. The floor area of a building, or portion thereof, not provided with surrounding exterior walls shall be the usable area under the horizontal projection of the roof or floor above.

FM is Factory Mutual Engineering and Research, 1151 Boston-Providence Turnpike, Norwood, Massachusetts 02062.

FOAM PLASTIC INSULATION is a plastic that is intentionally expanded by the use of a foaming agent to produce a reduced-density plastic containing voids consisting of hollow spheres or interconnected cells distributed throughout the plastic for thermal insulating or acoustical purposes and that has a density less than 20 pounds per cubic foot (320 kg/m^3).

FOOTING is that portion of the foundation of a structure that spreads and transmits loads directly to the soil or the piles.

FRONT OF LOT is the front boundary line of a lot bordering on the street and, in the case of a corner lot, may be either frontage.

SECTION 208 — G

GARAGE is a building or portion thereof in which a motor vehicle containing flammable or combustible liquids or gas in its tank is stored, repaired or kept.

GARAGE, PRIVATE, is a building or a portion of a building, not more than 1,000 square feet (93 m^2) in area, in which only motor vehicles used by the tenants of the building or buildings on the premises are stored or kept. (See Section 312.)

GARAGE, PUBLIC, is any garage other than a private garage.

GAS ROOM is a separately ventilated, fully enclosed room in which only toxic and highly toxic compressed gases and associated equipment and supplies are stored or used.

GRADE (Adjacent Ground Elevation) is the lowest point of elevation of the finished surface of the ground, paving or sidewalk within the area between the building and the property line or, when the property line is more than 5 feet (1524 mm) from the building, between the building and a line 5 feet (1524 mm) from the building.

GRADE (Lumber) is the classification of lumber in regard to strength and utility.

GUARDRAIL is a system of building components located near the open sides of elevated walking surfaces for the purpose of minimizing the possibility of an accidental fall from the walking surface to the lower level.

GUEST is any person hiring or occupying a room for living or sleeping purposes.

GUEST ROOM is any room or rooms used or intended to be used by a guest for sleeping purposes. Every 100 square feet (9.3 m^2) of superficial floor area in a dormitory shall be considered to be a guest room.

SECTION 209 — H

HABITABLE SPACE (ROOM) is space in a structure for living, sleeping, eating or cooking. Bathrooms, toilet compartments, closets, halls, storage or utility space, and similar areas, are not considered habitable space.

HANDLING is the deliberate movement of material by any means to a point of storage or use.

HANDRAIL is a railing provided for grasping with the hand for support. See also "guardrail."

HAZARDOUS PRODUCTION MATERIAL (HPM) is a solid, liquid or gas that has a degree of hazard rating in health, flammability or reactivity of 3 or 4 and that is used directly in research, laboratory or production processes that have, as their end product, materials that are not hazardous.

HEALTH HAZARD is a classification of a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed persons. The term "health hazard" includes chemicals that are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents that damage the lungs, skin, eyes or mucous membranes.

HEIGHT OF BUILDING is the vertical distance above a reference datum measured to the highest point of the coping of a flat roof or to the deck line of a mansard roof or to the average height of the highest gable of a pitched or hipped roof. The reference datum shall be selected by either of the following, whichever yields a greater height of building:

1. The elevation of the highest adjoining sidewalk or ground surface within a 5-foot (1524 mm) horizontal distance of the exterior wall of the building when such sidewalk or ground surface is not more than 10 feet (3048 mm) above lowest grade.

2. An elevation 10 feet (3048 mm) higher than the lowest grade when the sidewalk or ground surface described in Item 1 is more than 10 feet (3048 mm) above lowest grade.

The height of a stepped or terraced building is the maximum height of any segment of the building.

HELIPORT is an area of land or water or a structural surface that is used, or intended for use, for the landing and take-off of helicopters, and any appurtenant areas that are used, or intended for use, for heliport buildings and other heliport facilities.

HELISTOP is the same as a heliport, except that no refueling, maintenance, repairs or storage of helicopters is permitted.

HIGHLY TOXIC MATERIAL is a material that produces a lethal dose or a lethal concentration that falls within any of the following categories:

1. A chemical that has a median lethal dose (LD_{50}) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

2. A chemical that has a median lethal dose (LD_{50}) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each.

3. A chemical that has a median lethal concentration (LC_{50}) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

Mixtures of these materials with ordinary materials, such as water, may not warrant a classification of highly toxic. While this system is basically simple in application, any hazard evaluation that is required for the precise categorization of this type of material shall be performed by experienced, technically competent persons.

HORIZONTAL EXIT. See Section 1005.3.5.

HOTEL is any building containing six or more guest rooms intended or designed to be used, or that are used, rented or hired out to be occupied, or that are occupied for sleeping purposes by guests.

HOT-WATER-HEATING BOILER is a boiler having a volume exceeding 120 gallons (454.2 L), or a heat input exceeding 200,000 Btu/h (149 540 kW), or an operating temperature exceeding 210°F (99°C) that provides hot water to be used externally to itself.

HPM ROOM is a room used in conjunction with or serving a Group H, Division 6 Occupancy that hazardous production materials (HPM) are stored or used and that is classified as a Group H, Division 2, 3 or 7 Occupancy.

SECTION 210 — I

IRRITANT is a chemical that is not corrosive but that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is a skin irritant if, when tested on the intact skin of albino rabbits by the methods of 16 C.F.R. 1500.41 for four hours' exposure or by other appropriate techniques, it results in an empirical score of 5 or more. A chemical is an eye irritant if so determined under the procedure listed in 16 C.F.R. 1500.42 or other appropriate techniques.

SECTION 211 — J

JURISDICTION, as used in this code, is any political subdivision that adopts this code for administrative regulations within its sphere of authority.

SECTION 212 — K

No definitions.

SECTION 213 — L

LINTEL is a structural member placed over an opening or a recess in a wall and supporting construction above.

LIQUID is any material that has a fluidity greater than that of 300 penetration asphalt when tested in accordance with the *Uniform Fire Code* standards. When not otherwise identified, the term "liquid" is both flammable and combustible liquids.

LIQUID STORAGE ROOM is a room classified as a Group H, Division 3 Occupancy used only for the storage of flammable or combustible liquids in a closed condition. The quantities of flammable or combustible liquids in storage shall not exceed the limits set forth in the Fire Code.

LIQUID STORAGE WAREHOUSE is a Group H, Division 3 Occupancy used only for the storage of flammable or combustible liquids in an unopened condition. The quantities of flammable or combustible liquids stored are not limited.

LISTED and **LISTING** are terms referring to equipment or materials included in a list published by an approved testing laboratory, inspection agency or other organization concerned with product evaluation that maintains periodic inspection of current productions of listed equipment or materials. The published list shall state that the material or equipment complies with approved nationally recognized codes, standards or tests and has been tested or evaluated and found suitable for use in a specified manner.

LOADS. See Chapter 16.

LODGING HOUSE is any building or portion thereof containing not more than five guest rooms where rent is paid in money, goods, labor or otherwise.

LOW-PRESSURE HOT-WATER-HEATING BOILER is a boiler furnishing hot water at pressures not exceeding 160 psi (1103.2 kPa) and at temperatures not exceeding 250°F (121°C).

LOW-PRESSURE STEAM-HEATING BOILER is a boiler furnishing steam at pressures not exceeding 15 psi (103.4 kPa).

SECTION 214 — M

MARQUEE is a permanent roofed structure attached to and supported by the building and projecting over public property. Marquees are regulated in Chapter 32.

MASONRY is that form of construction composed of stone, brick, concrete, gypsum, hollow-clay tile, concrete block or tile, glass block or other similar building units or materials or combination of these materials laid up unit by unit and set in mortar.

MASONRY, SOLID, is masonry of solid units built without hollow spaces.

MECHANICAL CODE is the *Uniform Mechanical Code* promulgated by the International Conference of Building Officials, as adopted by this jurisdiction.

MEZZANINE or **MEZZANINE FLOOR** is an intermediate floor placed within a room.

MOTEL shall mean hotel as defined in this code.

MOTOR VEHICLE FUEL-DISPENSING STATION is that portion of a building where flammable or combustible liquids or gases used as motor fuels are stored and dispensed from fixed equipment into the fuel tanks of motor vehicles.

SECTION 215 — N

NONCOMBUSTIBLE, as applied to building construction material, means a material that, in the form in which it is used, is either one of the following:

1. Material of which no part will ignite and burn when subjected to fire. Any material conforming to UBC Standard 2-1 shall be considered noncombustible within the meaning of this section.

2. Material having a structural base of noncombustible material as defined in Item 1, with a surfacing material not over $^{1}/_{8}$ inch (3.2 mm) thick which has a flame-spread rating of 50 or less.

"Noncombustible" does not apply to surface finish materials. Material required to be noncombustible for reduced clearances to flues, heating appliances or other sources of high temperature shall refer to material conforming to Item 1. No material shall be classed as noncombustible, which is subject to increase in combustibility or flame-spread rating, beyond the limits herein established, through the effects of age, moisture or other atmospheric condition.

Flame-spread rating as used herein refers to rating obtained according to tests conducted as specified in UBC Standard 8-1.

SECTION 216 — O

OCCUPANCY is the purpose for that a building, or part thereof, is used or intended to be used.

ORIEL WINDOW is a window that projects from the main line of an enclosing wall of a building and is carried on brackets or corbels.

OWNER is any person, agent, firm or corporation having a legal or equitable interest in the property.

SECTION 217 — P

PANIC HARDWARE. See Section 1002.

PEDESTRIAN WALKWAY is a walkway used exclusively as a pedestrian trafficway.

PERMIT is an official document or certificate issued by the building official authorizing performance of a specified activity.

PERSON is a natural person, heirs, executors, administrators or assigns, and includes a firm, partnership or corporation, its or their successors or assigns, or the agent of any of the aforesaid.

PHOTOLUMINESCENT is the property of emitting light as the result of absorption of visible or invisible light, which continues for a length of time after excitation.

PLASTIC MATERIALS, APPROVED, other than foam plastics regulated under Sections 601.5.5 and 2602, are those plastic materials having a self-ignition temperature of 650°F (343°C) or greater as determined in accordance with UBC Standard 26-6, and a smoke-density rating not greater than 450 when tested in accordance with UBC Standard 8-1, in the way intended for use, or a smoke-density rating not greater than 75 when tested in accordance with UBC Standard 26-5 in the thickness intended for use. Approved plastics shall be classified as either CC1 or CC2 in accordance with UBC Standard 26-7. See also "foam plastic insulation."

PLATFORM. See Section 405.1.2.

PLUMBING CODE is the *Plumbing Code,* as adopted by this jurisdiction.

PROTECTIVE MEMBRANE is a surface material that forms the required outer layer or layers of a fire-resistive assembly containing concealed spaces.

PUBLIC WAY. See Section 1002.

SECTION 218 — Q

No definitions.

SECTION 219 — R

REPAIR is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance.

SECTION 220 — S

SELF-LUMINOUS means powered continuously by a self-contained power source other than a battery or batteries, such as radioactive tritium gas. A self-luminous sign is independent of external power supplies or other energy for its operation.

SENSITIZER is a chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical.

SERVICE CORRIDOR is a fully enclosed passage used for transporting hazardous production materials and for purposes other than required exiting.

SHAFT is an interior space, enclosed by walls or construction, extending through one or more stories or basements that connects openings in successive floors, or floors and roof, to accommodate elevators, dumbwaiters, mechanical equipment or similar devices or to transmit light or ventilation air.

SHAFT ENCLOSURE is the walls or construction forming the boundaries of a shaft.

SHALL, as used in this code, is mandatory.

SMOKE DETECTOR is an approved, listed device that senses visible or invisible particles of combustion.

STAGE. See Chapter 4.

STORY is that portion of a building included between the upper surface of any floor and the upper surface of the floor next above, except that the topmost story shall be that portion of a building included between the upper surface of the topmost floor and the ceiling or roof above. If the finished floor level directly above a usable or unused under-floor space is more than 6 feet (1829 mm) above grade, as defined herein, for more than 50 percent of the total perimeter or is more than 12 feet (3658 mm) above grade, as defined herein, at any point, such usable or unused under-floor space shall be considered as a story.

STORY, FIRST, is the lowest story in a building that qualifies as a story, as defined herein, except that a floor level in a building having only one floor level shall be classified as a first story, provided such floor level is not more than 4 feet (1219 mm) below grade, as defined herein, for more than 50 percent of the total perimeter, or not more than 8 feet (2438 mm) below grade, as defined herein, at any point.

STREET is any thoroughfare or public way not less than 16 feet (4877 mm) in width that has been dedicated or deeded to the public for public use.

STRUCTURAL OBSERVATION means the visual observation of the structural system, for general conformance to the approved plans and specifications, at significant construction stages and at completion of the structural system. Structural observation does not include or waive the responsibility for the inspections required by Section 108, 1701 or other sections of this code.

STRUCTURE is that which is built or constructed, an edifice or building of any kind, or any piece of work artificially built up or composed of parts joined together in some definite manner.

SURGICAL AREA is the preoperating, operating, recovery and similar rooms within an outpatient health-care center.

SECTION 221 — T

TRAVEL DISTANCE. See Section 1004.2.5.

SECTION 222 — U

UBC STANDARDS are those standards published in Volume 3 of the *Uniform Building Code* promulgated by the International Conference of Building Officials, as adopted by this jurisdiction. (See Chapter 35.)

UL is the Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, Illinois 60062.

USE, with reference to flammable or combustible liquids, is the placing in action or service of flammable or combustible liquids whereby flammable vapors may be liberated to the atmosphere.

USE, with reference to hazardous materials other than flammable or combustible liquids, is the placing in action or making available for service by opening or connecting any container utilized for confinement of material whether a solid, liquid or gas.

USE, CLOSED SYSTEM, is use of a solid or liquid hazardous material in a closed vessel or system that remains closed during normal operations where vapors emitted by the product are not liberated outside of the vessel or system and the product is not exposed to the atmosphere during normal operations, and all uses of compressed gases. Examples of closed systems for solids and liquids include product conveyed through a piping system into a closed vessel, system or piece of equipment, and reaction process operations.

USE, OPEN SYSTEM, is use of a solid or liquid hazardous material in a vessel or system that is continuously open to the atmosphere during normal operations and where vapors are liberated, or the product is exposed to the atmosphere during normal operations. Examples of open systems for solids and liquids include dispensing from or into open beakers or containers, dip tank and plating tank operations.

SECTION 223 — V

VALUE or **VALUATION** of a building shall be the estimated cost to replace the building and structure in kind, based on current replacement costs, as determined in Section 107.2.

VENEER. See Section 1403.2.

SECTION 224 — W

WALLS shall be defined as follows:

Bearing Wall is any wall meeting either of the following classifications:

1. Any metal or wood stud wall that supports more than 100 pounds per lineal foot (1.459 kN per lineal meter) of superimposed load.

2. Any masonry or concrete wall that supports more than 200 pounds per lineal foot (2.918 kN per lineal meter) superimposed load, or any such wall supporting its own weight for more than one story.

Exterior Wall is any wall or element of a wall, or any member or group of members, that defines the exterior boundaries or courts of a building and that has a slope of 60 degrees or greater with the horizontal plane.

Faced Wall is a wall in which the masonry facing and backing are so bonded as to exert a common action under load.

Nonbearing Wall is any wall that is not a bearing wall.

Parapet Wall is that part of any wall entirely above the roof line.

Retaining Wall is a wall designed to resist the lateral displacement of soil or other materials.

WATER HEATER is an appliance designed primarily to supply hot water and is equipped with automatic controls limiting water temperature to a maximum of 210°F (99°C).

WEATHER-EXPOSED SURFACES are all surfaces of walls, ceilings, floors, roofs, soffits and similar surfaces exposed to the weather, excepting the following:

1. Ceilings and roof soffits enclosed by walls or by beams, which extend a minimum of 12 inches (305 mm) below such ceiling or roof soffits.

2. Walls or portions of walls within an unenclosed roof area, when located a horizontal distance from an exterior opening equal to twice the height of the opening.

3. Ceiling and roof soffits beyond a horizontal distance of 10 feet (3048 mm) from the outer edge of the ceiling or roof soffits.

WINDOW WELL is a soil-retaining structure at a window having a sill height lower than the adjacent ground elevation.

SECTION 225 — X

No definitions.

SECTION 226 — Y

YARD is an open space, other than a court, unobstructed from the ground to the sky, except where specifically provided by this code, on the lot on which a building is situated.

SECTION 227 — Z

No definitions.

Chapter 3
USE OR OCCUPANCY

SECTION 301 — OCCUPANCY CLASSIFIED

Every building, whether existing or hereafter erected, shall be classified by the building official according to its use or the character of its occupancy, as set forth in Table 3-A, as a building of one of the following occupancy groups:

Group A—Assembly (see Section 303.1.1)

Group B—Business (see Section 304.1)

Group E—Educational (see Section 305.1)

Group F—Factory and Industrial (see Section 306.1)

Group H—Hazardous (see Section 307.1)

Group I—Institutional (see Section 308.1)

Group M—Mercantile (see Section 309.1)

Group R—Residential (see Section 310.1)

Group S—Storage (see Section 311.1)

Group U—Utility (see Section 312.1)

Any occupancy not mentioned specifically or about which there is any question shall be classified by the building official and included in the group that its use most nearly resembles, based on the existing or proposed fire and life hazard.

For changes in use, see Section 3405.

SECTION 302 — MIXED USE OR OCCUPANCY

302.1 General. When a building is used for more than one occupancy purpose, each part of the building comprising a distinct "occupancy," as described in Section 301, shall be separated from any other occupancy as specified in Section 302.4.

EXCEPTIONS: 1. When an approved spray booth constructed in accordance with the Fire Code is installed, such booth need not be separated from Group B, F, H, M or S Occupancies.

2. The following occupancies need not be separated from the uses to which they are accessory:

2.1 Assembly rooms having a floor area of not over 750 square feet (69.7 m^2).

2.2 Administrative and clerical offices and similar rooms that do not exceed 25 percent of the floor area of the major use when not related to Group H, Division 2 and Group H, Division 3 Occupancies.

2.3 Gift shops, administrative offices and similar rooms in Group R, Division 1 Occupancies not exceeding 10 percent of the floor area of the major use.

2.4 The kitchen serving the dining area of which it is a part.

2.5 Customer waiting rooms not exceeding 450 square feet (41.8 m^2) when not related to Group H Occupancies and when such waiting rooms have an exit directly to the exterior.

3. An occupancy separation need not be provided between a Group R, Division 3 Occupancy and a carport having no enclosed uses above, provided the carport is entirely open on two or more sides.

4. A Group S, Division 3 Occupancy used exclusively for the parking or storage of private or pleasure-type motor vehicles need not be separated from a Group S, Division 4 Occupancy open parking garage as defined in Section 311.1.

When a building houses more than one occupancy, each portion of the building shall conform to the requirements for the occupancy housed therein.

An occupancy shall not be located above the story or height set forth in Table 5-B, except as provided in Section 506. When a mixed occupancy building contains a Group H, Division 6 Occupancy, the portion containing the Group H, Division 6 Occupancy shall not exceed three stories or 55 feet (16 764 mm) in height.

302.2 Forms of Occupancy Separations. Occupancy separations shall be vertical or horizontal or both or, when necessary, of such other form as may be required to afford a complete separation between the various occupancy divisions in the building.

Where the occupancy separation is horizontal, structural members supporting the separation shall be protected by equivalent fire-resistive construction.

302.3 Types of Occupancy Separations. Occupancy separations shall be classed as "four-hour fire-resistive," "three-hour fire-resistive," "two-hour fire-resistive" and "one-hour fire-resistive."

1. A four-hour fire-resistive occupancy separation shall have no openings therein and shall not be of less than four-hour fire-resistive construction.

2. A three-hour fire-resistive occupancy separation shall not be of less than three-hour fire-resistive construction. All openings in walls forming such separation shall be protected by a fire assembly having a three-hour fire-protection rating. The total width of all openings in any three-hour fire-resistive occupancy separation wall in any one story shall not exceed 25 percent of the length of the wall in that story and no single opening shall have an area greater than 120 square feet (11 m^2).

All openings in floors forming a three-hour fire-resistive occupancy separation shall be protected by shaft, stairway, ramp or escalator enclosures extending above and below such openings. The walls of such enclosures shall not be of less than two-hour fire-resistive construction and all openings therein shall be protected by a fire assembly having a one- and one-half-hour fire-protection rating.

EXCEPTION: When the walls of such enclosure extending below the three-hour fire-resistive occupancy separation to the foundation are provided with a fire-resistive rating of not less than three hours with openings therein protected as required for walls forming three-hour occupancy separations, the enclosure walls extending above such floor used as the three-hour fire-resistive occupancy separation may have a one-hour fire-resistive rating, provided:

1. The occupancy above is not required to be of Type I or II fire-resistive construction, and

2. The enclosure walls do not enclose an exit stairway, a ramp or an escalator required to have enclosure walls of not less than two-hour fire-resistive construction.

3. A two-hour fire-resistive occupancy separation shall not be of less than two-hour fire-resistive construction. All openings in such separation shall be protected by a fire assembly having a one- and one-half-hour fire-protection rating.

4. A one-hour fire-resistive occupancy separation shall not be of less than one-hour fire-resistive construction. All openings in such separation shall be protected by a fire assembly having a one-hour fire-protection rating.

302.4 Fire Ratings for Occupancy Separations. Occupancy separations shall be provided between the various groups and divisions of occupancies as set forth in Table 3-B. For required separation of specific uses in Group I, Division 1 hospitals and nursing homes, see Table 3-C. See also Section 504.6.1.

EXCEPTIONS: 1. A three-hour occupancy separation may be used between a Group A, Division 1 and a Group S, Division 3 Occupancy used exclusively for the parking or storage of private or pleasure-type motor vehicles provided no repair or fueling is done. A two-hour occupancy separation may be used between a Group A, Division 2, 2.1, 3 or 4 or E or I Occupancy and a Group S, Division 3 Occupancy used exclusively for the parking or storage of private or pleasure-type motor vehicles provided no repair or fueling is done.

2. Unless required by Section 311.2.2, the three-hour occupancy separation between a Group R, Division 1 Occupancy and a Group S, Division 3 Occupancy used only for the parking or storage of private or pleasure-type motor vehicles with no repair or fueling may be reduced to two hours. Such occupancy separation may be further reduced to one hour where the area of such Group S, Division 3 Occupancy does not exceed 3,000 square feet (279 m^2).

3. In the one-hour occupancy separation between Group R, Division 3 and Group U Occupancies, the separation may be limited to the installation of materials approved for one-hour fire-resistive construction on the garage side and a self-closing, tightfitting solid-wood door $1^3/_8$ inches (35 mm) in thickness, or a self-closing, tightfitting door having a fire-protection rating of not less than 20 minutes when tested in accordance with Part II of UBC Standard 7-2, which is a part of this code, is permitted in lieu of a one-hour fire assembly. Fire dampers need not be installed in air ducts passing through the wall, floor or ceiling separating a Group R, Division 3 Occupancy from a Group U Occupancy, provided such ducts within the Group U Occupancy are constructed of steel having a thickness not less than 0.019 inch (0.48 mm) (No. 26 galvanized sheet gage) and have no openings into the Group U Occupancy.

4. Group H, Division 2 and Group H, Division 3 Occupancies need not be separated from Group H, Division 7 Occupancies when such occupancies also comply with the requirements for a Group H, Division 7 Occupancy.

302.5 Heating Equipment Room Occupancy Separation. In Groups A; B; E; F; I; M; R, Division 1; and S Occupancies, rooms containing a boiler, central heating plant or hot-water supply boiler shall be separated from the rest of the building by not less than a one-hour occupancy separation.

EXCEPTIONS: 1. In Groups A, B, E, F, M and S Occupancies, boilers, central heating plants or hot-water supply boilers where the largest piece of fuel equipment does not exceed 400,000 Btu per hour (117.2 kW) input.

2. In Group R, Division 1 Occupancies, a separation need not be provided for such rooms with equipment serving only one dwelling unit.

In Group E Occupancies, when the opening for a heater or equipment room is protected by a pair of fire doors, the inactive leaf shall be normally secured in the closed position and shall be openable only by the use of a tool. An astragal shall be provided and the active leaf shall be self-closing.

In Group H Occupancies, rooms containing a boiler, central heating plant or hot-water supply boiler shall be separated from the rest of the building by not less than a two-hour occupancy separation. In Divisions 1 and 2, there shall be no openings in such occupancy separation except for necessary ducts and piping.

For opening in exterior walls of equipment rooms in Group A, E or I Occupancies, see Sections 303.8, 305.8 and 308.8.

302.6 Water Closet Room Separation. A room in which a water closet is located shall be separated from food preparation or storage rooms by a tightfitting door.

SECTION 303 — REQUIREMENTS FOR GROUP A OCCUPANCIES

303.1 General.

303.1.1 Group A Occupancies defined. Group A Occupancies include the use of a building or structure, or a portion thereof, for the gathering together of 50 or more persons for purposes such as civic, social or religious functions, recreation, education or instruction, food or drink consumption, or awaiting transportation. A room or space used for assembly purposes by less than 50 persons and accessory to another occupancy shall be included as a part of that major occupancy. Assembly occupancies shall include the following:

Division 1. A building or portion of a building having an assembly room with an occupant load of 1,000 or more and a legitimate stage.

Division 2. A building or portion of a building having an assembly room with an occupant load of less than 1,000 and a legitimate stage.

Division 2.1. A building or portion of a building having an assembly room with an occupant load of 300 or more without a legitimate stage, including such buildings used for educational purposes and not classed as Group B or E Occupancies.

Division 3. A building or portion of a building having an assembly room with an occupant load of less than 300 without a legitimate stage, including such buildings used for educational purposes and not classed as Group B or E Occupancies.

Division 4. Stadiums, reviewing stands and amusement park structures not included within other Group A Occupancies. Specific and general requirements for grandstands, bleachers and reviewing stands are to be found in Chapter 10.

303.1.2 Occupancy separations. For occupancy separations, see Table 3-B.

303.1.3 Amusement buildings. Amusement buildings shall conform with the requirements of this code for their occupancy classification in addition to the provisions set forth in Sections 408, 904.2.3 and 1007.2.7.

EXCEPTION: Amusement buildings or portions thereof that are without walls or a roof and constructed to prevent the accumulation of smoke in assembly areas.

303.2 Construction, Height and Allowable Area.

303.2.1 General. Unless otherwise specified in this section, buildings or portions of buildings classed in Group A Occupancy, because of the use or character of the occupancy, shall be limited to the types of construction set forth in Table 5-B, and shall not exceed in area or height the limits specified in Sections 504, 505 and 506.

303.2.2 Special provisions.

The roof-framing system for the roof-ceiling assembly in one-story portions of buildings of Type II One-hour, Type III One-hour or Type V One-hour construction may be of unprotected construction when such roof-framing system is open to the assembly area and does not contain concealed spaces.

Stages and platforms shall be constructed in accordance with the provisions of Section 405.

The slope of the main floor of an assembly room shall not exceed the slopes permitted in Section 1003.3.4.

Group A assembly rooms having an aggregate occupant load of 1,000 or more shall not be located in a basement, except basements in buildings of Type I or Type II-F.R. construction.

Gymnasiums and similar occupancies may have floor surfaces constructed of wood or unprotected steel or iron.

In gymnasiums having an area not greater than 3,200 square feet (297 m^2), 1-inch (25 mm) nominal thickness tight tongue-and-grooved boards or $^3/_4$-inch (19 mm) plywood wall covering may be used on the inner side in lieu of fire-resistive plaster.

For attic space partitions and draft stops, see Section 708.

303.2.2.1 Division 2.1 provisions. Division 2.1 Occupancies with an occupant load of 1,000 or more shall be of Type I, Type II-F.R., Type II One-hour, Type III One-hour or Type IV construction, except that the roof-framing system for one-story portions of buildings of Type II One-hour or Type III One-hour construction may be of unprotected construction when such roof-framing system is open to the assembly area and does not contain concealed spaces.

303.2.2.2 Division 3 provisions. Division 3 Occupancies located in a basement or above the first floor shall not be of less than one-hour fire-resistive construction.

Division 3 Occupancies with an occupant load of 50 or more which are located over usable space shall be separated from such space by not less than one-hour fire-resistive construction.

For Division 3 Occupancies with a Group S, Division 3 parking garage in the basement or first floor, see Section 311.2.2.

303.2.2.3 Division 4 provisions. Grandstands, bleachers or reviewing stands of Type III One-hour, Type IV or Type V One-hour construction shall not exceed 40 feet (12 192 mm) to the highest level of seat boards; 20 feet (6096 mm) in cases where construction is Type III-N or Type V-N; and 12 feet (3658 mm) in cases where construction is with combustible members in the structural frame and located indoors.

Division 4 structures other than Type III-N and Type V-N grandstands, bleachers, reviewing stands and folding and telescoping seating of open skeleton-frametype without roof, cover or enclosed usable space are not limited in area or height.

Erection and structural maintenance shall conform to these special requirements as well as with other applicable provisions of this code.

When the space under a Division 4 Occupancy is used for any purpose, including means of egress, it shall be separated from all parts of such Division 4 Occupancy, including means of egress, by walls, floor and ceiling of not less than one-hour fire-resistive construction.

EXCEPTIONS: 1. A means of egress under temporary grandstands need not be separated.

2. The underside of continuous steel deck grandstands when erected outdoors need not be fire protected when occupied for public toilets.

The building official may cause Division 4 structures to be reinspected at least once every six months.

Grandstands, bleachers or folding and telescoping seating may have seat boards, toeboards, bearing or base pads and footboards of combustible materials regardless of construction type.

Seating and exiting requirements for reviewing stands, grandstands, bleachers, and folding and telescoping seating are provided under Section 1008.

303.3 Location on Property. Buildings housing Group A Occupancies shall front directly on or discharge to a public street not less than 20 feet (6096 mm) in width. The exit discharge to the public street shall be a minimum 20-foot-wide (6096 mm) right-of-way, unobstructed and maintained only as exit discharge to the public street. The main entrance to the building shall be located on a public street or on the exit discharge.

For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 503 and Chapter 6.

303.4 Access and Exit Facilities. Exits shall be provided as specified in Chapter 10. (For special exiting requirements, see Section 1007.2.) Access to, and egress from, buildings required to be accessible shall be provided as specified in Chapter 11.

For amusement buildings, see Section 408.

303.5 Light, Ventilation and Sanitation. Light and ventilation shall be in accordance with Chapter 12. The number of plumbing fixtures shall not be less than specified in Section 2902.2.

303.6 Shaft and Exit Enclosures. Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts and other vertical openings shall be enclosed and the enclosure shall be as specified in Section 711.

303.7 Sprinkler and Standpipe Systems. When required by Section 904.2.1 or other provisions of this code, automatic sprinkler systems and standpipes shall be designed and installed as specified in Chapter 9.

303.8 Special Hazards. Stages shall be equipped with automatic ventilators as required in Section 405.3.3.

Chimneys and heating apparatus shall conform to the requirements of Chapter 31 of this code and the Mechanical Code.

Motion picture machine booths shall conform to the requirements of Section 406.

Proscenium curtains shall conform to the requirements set forth in UBC Standard 4-1, which is a part of this code. (See Chapter 35, Part II.)

Class I, II or III-A liquids shall not be placed or stored in any Group A Occupancy.

When heating equipment rooms are required to be separated in accordance with Section 302.5, exterior openings in a boiler room or room containing central heating equipment if located below openings in another story or if less than 10 feet (3048 mm) from other doors or windows of the same building shall be protected by a fire assembly having a three-fourths-hour fire-protection rating. Such fire assemblies shall be fixed, automatic or self-closing. For heating equipment occupancy separation, see Section 302.5.

303.9 Fire Alarm Systems. An approved fire alarm system shall be installed as set forth in the Fire Code in Group A, Divisions 1, 2 and 2.1 Occupancies.

For amusement building alarm systems, see Section 408.5.1.

SECTION 304 — REQUIREMENTS FOR GROUP B OCCUPANCIES

304.1 Group B Occupancies Defined.

Group B Occupancies shall include buildings, structures, or portions thereof, for office, professional or service-type transactions, which are not classified as Group H Occupancies. Such occupancies include occupancies for the storage of records and accounts, and eating and drinking establishments with an occupant load of less than 50. Business occupancies shall include, but not be limited to, the following:

1. Animal hospitals, kennels, pounds.
2. Automobile and other motor vehicle showrooms.
3. Banks.
4. Barber shops.
5. Beauty shops.
6. Car washes.
7. Civic administration.
8. Outpatient clinic and medical offices (where five or less patients in a tenant space are incapable of unassisted self-preservation).

9. Dry cleaning pick-up and delivery stations and self-service.
10. Educational occupancies above the 12th grade.
11. Electronic data processing.
12. Fire stations.
13. Florists and nurseries.
14. Laboratories—testing and research.
15. Laundry pick-up and delivery stations and self-service.
16. Police stations.
17. Post offices.
18. Print shops.
19. Professional services such as attorney, dentist, physician, engineer.
20. Radio and television stations.
21. Telephone exchanges.

For occupancy separations, see Table 3-B.

304.2 Construction, Height and Allowable Area.

304.2.1 General. Buildings or parts of buildings classed as Group B Occupancies because of the use or character of the occupancy shall be limited to the types of construction set forth in Table 5-B. Such occupancies shall not exceed, in area or height, the limits specified in Sections 504, 505 and 506 and shall comply with the provisions of this section.

304.2.2 Special provisions.

304.2.2.1 Laboratories and vocational shops. Laboratories and vocational shops in buildings used for educational purposes, and similar areas containing hazardous materials, shall be separated from each other and other portions of the building by not less than a one-hour fire-resistive occupancy separation. When the quantities of hazardous materials in such uses do not exceed those listed in Table 3-D or 3-E, the requirements of Sections 307.5 and 307.8 shall apply. When the quantities of hazardous materials in such uses exceed those listed in Table 3-D or 3-E, the use shall be classified as the appropriate Group H Occupancy.

Occupants in laboratories having an area in excess of 200 square feet (18.6 m^2) shall have access to at least two exits or exit-access doors from the room and all portions of the room shall be within 75 feet (22 860 mm) of an exit or exit-access door.

304.2.2.2 Amusement buildings. Amusement buildings with an occupant load of less than 50 shall comply with Section 408.

304.3 Location on Property. For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 503 and Chapter 6.

304.4 Access and Means of Egress Facilities. Means of egress shall be provided as specified in Chapter 10. See also Section 304.2.2.1 for means of egress from laboratories.

Access to, and egress from, buildings required to be accessible shall be provided as specified in Chapter 11.

304.5 Light, Ventilation and Sanitation. Light, ventilation and sanitation shall be in accordance with Chapters 12 and 29 and this section.

304.5.1 Ventilation of flammable vapors. See Section 1202.2.2 for ventilation of flammable vapors.

304.5.2 Sanitation. The number of plumbing fixtures shall not be less than specified in Section 2902.3.

304.6 Shaft and Exit Enclosures. Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts and other openings through floors shall be enclosed, and the enclosure shall be as specified in Section 711.

In buildings housing Group B Occupancies equipped with automatic sprinkler systems throughout, enclosures need not be provided for escalators where the top of the escalator opening at each story is provided with a draft curtain and automatic fire sprinklers are installed around the perimeter of the opening within 2 feet (610 mm) of the draft curtain. The draft curtain shall enclose the perimeter of the unenclosed opening and extend from the ceiling downward at least 12 inches (305 mm) on all sides. The spacing between sprinklers shall not exceed 6 feet (1829 mm).

304.7 Sprinkler and Standpipe Systems. When required by Section 904.2.1 or other provisions of this code, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 9.

304.8 Special Hazards. Chimneys and heating apparatus shall conform to the requirements of Chapter 31 of this code and the Mechanical Code.

Storage and use of flammable and combustible liquids shall be in accordance with the Fire Code.

Devices generating a glow, spark or flame capable of igniting flammable vapors shall be installed such that sources of ignition are at least 18 inches (457 mm) above the floor of any room in which Class I flammable liquids or flammable gases are used or stored.

Stationary lead-acid battery systems used for facility standby, emergency power or uninterrupted power supplies shall be installed and maintained in accordance with the Fire Code.

SECTION 305 — REQUIREMENTS FOR GROUP E OCCUPANCIES

305.1 Group E Occupancies Defined. Group E Occupancies shall be:

Division 1. Any building used for educational purposes through the 12th grade by 50 or more persons for more than 12 hours per week or four hours in any one day.

Division 2. Any building used for educational purposes through the 12th grade by less than 50 persons for more than 12 hours per week or four hours in any one day.

Division 3. Any building or portion thereof used for day-care purposes for more than six persons.

For occupancy separations, see Table 3-B.

305.2 Construction, Height and Allowable Area.

305.2.1 General. Buildings or parts of buildings classed in Group E because of the use or character of the occupancy shall be limited to the types of construction set forth in Table 5-B and shall not exceed, in area or height, the limits specified in Sections 504, 505 and 506, except that the area may be increased by 50 percent when the maximum travel distance specified in Section 1004.2.5 is reduced by 50 percent.

305.2.2 Atmospheric separation requirements.

305.2.2.1 Definitions. For the purpose of this chapter and Section 1007.3, the following definitions are applicable:

COMMON ATMOSPHERE exists between rooms, spaces or areas within a building that are not separated by an approved smoke- and draft-stop barrier.

SEPARATE ATMOSPHERE exists between rooms, spaces or areas that are separated by an approved smoke barrier.

SMOKE BARRIER consists of walls, partitions, floors and openings therein as will prevent the transmission of smoke or gases through the construction. See Section 905.

305.2.2.2 General provisions. The provisions of this section apply when a separate exit system is required in accordance with Section 1007.3.

Walls, partitions and floors forming all or part of an atmospheric separation shall be as required by Section 905.2.3. Glass lights of approved wired glass set in steel frames may be installed in such walls or partitions.

All automatic-closing fire assemblies installed in the atmospheric separation shall be activated by approved smoke detectors.

The specific requirements of this section are not intended to prevent the design or use of other systems, equipment or techniques that will effectively prevent the products of combustion from breaching the atmospheric separation.

305.2.3 Special provisions. Rooms in Divisions 1 and 2 Occupancies used for kindergarten, first- or second-grade pupils, and Division 3 Occupancies shall not be located above or below the first story.

EXCEPTIONS: 1. Basements or stories having floor levels located within 4 feet (1219 mm), measured vertically, from adjacent ground level at the level of exit discharge, provided the basement or story has exterior exit doors at that level.

2. In buildings equipped with an automatic sprinkler system throughout, rooms used for kindergarten, first- and second-grade children or for day-care purposes may be located on the second story, provided there are at least two exterior exit doors for the exclusive use of such occupants.

3. Division 3 Occupancies may be located above the first story in buildings of Type I construction and in Types II-F.R., II One-hour and III One-hour construction, subject to the limitation of Section 506 when:

3.1 Division 3 Occupancies with children under the age of seven or containing more than 12 children per story shall not be located above the fourth floor; and

3.2 The entire story in which the day-care facility is located is equipped with an approved manual fire alarm and smoke-detection system. (See the Fire Code.) Actuation of an initiating device shall sound an audible alarm throughout the entire story. When a building fire alarm system is required by other provisions of this code or the Fire Code, the alarm system shall be connected to the building alarm system.

An approved alarm signal shall sound at an approved location in the day-care occupancy to indicate a fire alarm or sprinkler flow condition in other portions of the building; and

3.3 The day-care facility, if more than 1,000 square feet (92.9 m^2) in area, is divided into at least two compartments of approximately the same size by a smoke barrier with door openings protected by smoke- and draft-control assemblies having a fire-protection rating of not less than 20 minutes. Smoke barriers shall have a fire-resistive rating of not less than one hour. In addition to the requirements of Section 302, occupancy separations between Division 3 Occupancies and other occupancies shall be constructed as smoke barriers. Door openings in the smoke barrier shall be tightfitting, with gaskets installed as required by Section 1004.3.4.3.2, and shall be automatic closing by actuation of the automatic sprinklers, fire alarm or smoke-detection system. Openings for ducts and other heating, ventilating and air-conditioning openings shall be equipped with a minimum Class I, 250°F (121°C) smoke damper as defined and tested in accordance with approved recognized standards. See Chapter 35, Part IV. The damper shall close upon detection of smoke by an approved smoke detector located within the duct, or upon the activation of the fire alarm system; and

3.4 Each compartment formed by the smoke barrier has not less than two exits or exit-access doors, one of which is permitted to pass through the adjoining compartment; and

3.5 At least one exit or exit-access door from the Division 3 Occupancy shall be into a separate means of egress as defined in Section 1007.3; and

3.6 The building is equipped with an automatic sprinkler system throughout.

Stages and platforms shall be constructed in accordance with Chapter 4. For attic space partitions and draft stops, see Section 708.

305.2.4 Special hazards. Laboratories, vocational shops and similar areas containing hazardous materials shall be separated from each other and from other portions of the building by not less than a one-hour fire-resistive occupancy separation. When the quantities of hazardous materials in such uses do not exceed those listed in Table 3-D or 3-E, the requirements of Sections 307.5.2 and 307.8 shall apply. When the quantities of hazardous materials in such uses exceed those listed in Table 3-D or 3-E, the use shall be classified as the appropriate Group H Occupancy.

See Section 1007.3 for means of egress from laboratories in Group E Occupancies.

Equipment in rooms or groups of rooms sharing a common atmosphere where flammable liquids, combustible dust or hazardous materials are used, stored, developed or handled shall conform to the requirements of the Fire Code.

305.3 Location on Property. All buildings housing Group E Occupancies shall front directly on a public street or an exit discharge not less than 20 feet (6096 mm) in width. The exit discharge to the public street shall be a minimum 20-foot-wide (6096 mm) right-of-way, unobstructed and maintained only as access to the public street. At least one required exit shall be located on the public street or on the exit discharge.

For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 503 and Chapter 6.

305.4 Access and Means of Egress Facilities. Means of egress shall be provided as specified in Chapter 10. (For special provisions, see Section 1007.3.)

Access to, and egress from, buildings required to be accessible shall be provided as specified in Chapter 11.

305.5 Light, Ventilation and Sanitation. All portions of Group E Occupancies customarily occupied by human beings shall be provided with light and ventilation, either natural or artificial, as specified in Chapter 12. See Section 1003.2.9 for required means of egress illumination.

The number of urinals and drinking fountains shall be as specified in Section 2902.4.

305.6 Shaft and Exit Enclosures. Exits shall be enclosed as specified in Chapter 10. Elevator shafts, vent shafts and other vertical openings shall be enclosed, and the enclosure shall be as specified in Section 711.

305.7 Sprinkler and Standpipe Systems. When required by Section 904.2.1 or other provisions of this code, automatic sprinkler systems and standpipes shall be designed and installed as specified in Chapter 9.

305.8 Special Hazards. Chimneys and heating apparatus shall conform to the requirements of Chapter 31 of this code and the Mechanical Code.

Motion picture machine rooms shall conform to the requirements of Chapter 4.

All exterior openings in a boiler room or rooms containing central heating equipment, if located below openings in another story or if less than 10 feet (3048 mm) from other doors or windows of the same building, shall be protected by a fire assembly having a three-fourths-hour fire-protection rating. Such fire assemblies shall be fixed, automatic closing or self-closing.

Class I, II or III-A liquids shall not be placed, stored or used in Group E Occupancies, except in approved quantities as necessary in laboratories and classrooms and for operation and maintenance as set forth in the Fire Code.

305.9 Fire Alarm Systems. An approved fire alarm system shall be provided for Group E Occupancies with an occupant load of 50 or more persons. In Group E Occupancies provided with an automatic sprinkler or detection system, the operation of such system shall automatically activate the school fire alarm system, which shall include an alarm mounted on the exterior of the building.

See Chapter 10 for smoke-detection requirements.

For installation requirements, see the Fire Code.

SECTION 306 — REQUIREMENTS FOR GROUP F OCCUPANCIES

306.1 Group F Occupancies Defined. Group F Occupancies shall include the use of a building or structure, or a portion thereof, for assembling, disassembling, fabricating, finishing, manufacturing, packaging, repair or processing operations that are not classified as Group H Occupancies. Factory and industrial occupancies shall include the following:

Division 1. Moderate-hazard factory and industrial occupancies shall include factory and industrial uses that are not classified as Group F, Division 2 Occupancies, but are not limited to facilities producing the following:

1. Aircraft.
2. Appliances.
3. Athletic equipment.
4. Automobiles and other motor vehicles.
5. Bakeries.
6. Alcoholic beverages.
7. Bicycles.
8. Boats.
9. Brooms and brushes.
10. Business machines.
11. Canvas or similar fabric.
12. Cameras and photo equipment.
13. Carpets and rugs, including cleaning.
14. Clothing.
15. Construction and agricultural machinery.
16. Dry cleaning and dyeing.
17. Electronics assembly.
18. Engines, including rebuilding.
19. Photographic film.
20. Food processing.
21. Furniture.
22. Hemp products.
23. Jute products.
24. Laundries.
25. Leather products.
26. Machinery.
27. Metal.
28. Motion pictures and television filming and videotaping.
29. Musical instruments.
30. Optical goods.
31. Paper mills or products.
32. Plastic products.
33. Printing or publishing.
34. Recreational vehicles.
35. Refuse incineration.
36. Shoes.
37. Soaps and detergents.
38. Tobacco.
39. Trailers.
40. Wood, distillation.
41. Millwork (sash and door).
42. Woodworking, cabinet.

Division 2. Low-hazard factory and industrial occupancies shall include facilities producing noncombustible or nonexplosive materials which, during finishing, packing or processing, do not involve a significant fire hazard, including, but not limited to, the following:

1. Nonalcoholic beverages.
2. Brick and masonry.
3. Ceramic products.
4. Foundries.
5. Glass products.
6. Gypsum.
7. Steel products—fabrication and assembly.

For occupancy separations, see Table 3-B.

306.2 Construction, Height and Allowable Area.

306.2.1 General. Buildings or parts of buildings classed as Group F Occupancies because of the use or character of the occupancies shall be limited to the types of construction set forth in Table 5-B and shall not exceed, in area or height, the limits specified in Sections 504, 505 and 506.

306.2.2 Special provisions, Group F, Division 2 roof framing. In Division 2 Occupancies, the roof-framing system may be of unprotected construction.

306.3 Location on Property. For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 503.

306.4 Access and Means of Egress Facilities. Means of egress shall be provided as specified in Chapter 10.

Access to, and egress from, buildings required to be accessible shall be provided as specified in Chapter 11.

306.5 Light, Ventilation and Sanitation. In Group F Occupancies, light, ventilation and sanitation shall be as specified in Chapters 12 and 29.

306.6 Shaft and Exit Enclosures. Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts and other openings through floors shall be enclosed, and the enclosure shall be as specified in Section 711.

EXCEPTION: In Group F, Division 2 Occupancies, exits shall be enclosed as specified in Chapter 10, but other through-floor openings need not be enclosed.

In buildings housing Group F Occupancies equipped with automatic sprinkler systems throughout, enclosures need not be provided for escalators where the top of the escalator opening at each story is provided with a draft curtain and automatic fire sprinklers are installed around the perimeter of the opening within 2 feet (610 mm) of the draft curtain. The draft curtain shall enclose the perimeter of the unenclosed opening and extend from the ceiling downward at least 12 inches (305 mm) on all sides. The spacing between sprinklers shall not exceed 6 feet (1829 mm).

306.7 Sprinkler and Standpipe Systems. When required by Section 904.2 or other provisions of this code, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 9.

306.8 Special Hazards. For special hazards of Group F Occupancies, see Section 304.8.

Storage and use of flammable and combustible liquids shall be in accordance with the Fire Code.

Buildings erected or converted to house high-piled combustible stock or aerosols shall comply with the Fire Code.

Equipment, machinery or appliances that generate finely divided combustible waste or that use finely divided combustible material shall be equipped with an approved method of collection and removal.

SECTION 307 — REQUIREMENTS FOR GROUP H OCCUPANCIES

307.1 Group H Occupancies Defined.

307.1.1 General. Group H Occupancies shall include buildings or structures, or portions thereof, that involve the manufacturing, processing, generation or storage of materials that constitute a high fire, explosion or health hazard. For definitions, identification and control of hazardous materials and pesticides, and the display of nonflammable solid and nonflammable and noncombustible liquid hazardous materials in Group B, F, M or S Occupancies, see the Fire Code. For hazardous materials used as refrigerants or lubricants within closed cycle refrigeration systems and the areas served by them, see Chapter 28 of this code, the Mechanical Code and the Fire Code. For the application and use of control areas, see Footnote 1 of Tables 3-D and 3-E. Group H Occupancies shall be:

Division 1. Occupancies with a quantity of material in the building in excess of those listed in Table 3-D, which present a high explosion hazard, including, but not limited to:

1. Explosives, blasting agents, Class 1.3G (Class B, Special) fireworks and black powder.

EXCEPTIONS: 1. Storage and use of pyrotechnic special effect materials in motion picture, television, theatrical and group entertainment production when under permit as required in the Fire Code. The time period for storage shall not exceed 90 days.

2. Indoor storage and display of smokeless powder, black sporting powder, and primers or percussion caps exceeding the exempt amounts for Group M retail sales need not be classified as a Group H, Division 1 Occupancy where stored and displayed in accordance with the Fire Code.

2. Manufacturing of Class 1.4G (Class C, Common) fireworks.

3. Unclassified detonatable organic peroxides.

4. Class 4 oxidizers.

5. Class 4 or Class 3 detonatable unstable (reactive) materials.

Division 2. Occupancies where combustible dust is manufactured, used or generated in such a manner that concentrations and conditions create a fire or explosion potential; occupancies with a quantity of material in the building in excess of those listed in Table 3-D, which present a moderate explosion hazard or a hazard from accelerated burning, including, but not limited to:

1. Class I organic peroxides.
2. Class 3 nondetonatable unstable (reactive) materials.
3. Pyrophoric gases.
4. Flammable or oxidizing gases.
5. Class I, II or III-A flammable or combustible liquids which are used or stored in normally open containers or systems, or in closed containers or systems pressurized at more than 15-pounds-per-square-inch (psi) (103.4 kPa) gage.

EXCEPTION: Aerosols.

6. Class 3 oxidizers.
7. Class 3 water-reactive materials.

Division 3. Occupancies where flammable solids, other than combustible dust, are manufactured, used or generated.

Division 3 Occupancies also include uses in which the quantity of material in the building in excess of those listed in Table 3-D presents a high physical hazard, including, but not limited to:

1. Class II, III or IV organic peroxides.
2. Class 1 or 2 oxidizers.
3. Class I, II or III-A flammable or combustible liquids that are used or stored in normally closed containers or systems and containers or systems pressurized at 15 psi (103.4 kPa) gage or less, and aerosols.
4. Class III-B combustible liquids.
5. Pyrophoric liquids or solids.
6. Class 1 or 2 water-reactive materials.
7. Flammable solids in storage.
8. Flammable or oxidizing cryogenic fluids (other than inert).
9. Class 1 unstable (reactive) gas or Class 2 unstable (reactive) materials.
10. Storage of Class 1.4G (Class C, Common) fireworks.

Division 4. Repair garages not classified as Group S, Division 3 Occupancies.

Division 5. Aircraft repair hangars not classified as Group S, Division 5 Occupancies and heliports.

Division 6. Semiconductor fabrication facilities and comparable research and development areas in which hazardous production materials (HPM) are used and the aggregate quantity of materials are in excess of those listed in Table 3-D or 3-E. Such facilities and areas shall be designed and constructed in accordance with Section 307.11.

Division 7. Occupancies having quantities of materials in excess of those listed in Table 3-E that are health hazards, including:

1. Corrosives.

EXCEPTION: Stationary lead-acid battery systems.

2. Toxic and highly toxic materials.
3. Irritants.
4. Sensitizers.
5. Other health hazards.

307.1.2 Multiple hazards. When a hazardous material has multiple hazards, all hazards shall be addressed and controlled in accordance with the provisions of this chapter.

307.1.3 Liquid use, dispensing and mixing rooms. Rooms in which Class I, Class II and Class III-A flammable or combustible liquids are used, dispensed or mixed in open containers shall be constructed in accordance with the requirements for a Group H, Division 2 Occupancy and the following:

1. Rooms in excess of 500 square feet (46.5 m^2) shall have at least one exterior exit door approved for fire department access.

2. Rooms shall be separated from other areas by an occupancy separation having a fire-resistive rating of not less than one hour for rooms up to 150 square feet (13.9 m^2) in area and not less than two hours where the room is more than 150 square feet (13.9 m^2) in area. Separations from other occupancies shall not be less than required by Section 302 and Table 3-B.

3. Shelving, racks and wainscoting in such areas shall be of noncombustible construction or wood not less than 1-inch (25 mm) nominal thickness.

4. Liquid use, dispensing and mixing rooms shall not be located in basements.

307.1.4 Liquid storage rooms. Rooms in which Class I, Class II and Class III-A flammable or combustible liquids are stored in closed containers shall be constructed in accordance with the requirements for a Group H, Division 3 Occupancy and to the following:

1. Rooms in excess of 500 square feet (46.5 m^2) shall have at least one exterior exit door approved for fire department access.

2. Rooms shall be separated from other areas by an occupancy separation having a fire-resistive rating of not less than one hour for rooms up to 150 square feet (13.9 m^2) in area and not less than two hours where the room is more than 150 square feet (13.9 m^2) in area. Separations from other occupancies shall not be less than required by Section 302 and Table 3-B.

3. Shelving, racks and wainscoting in such areas shall be of noncombustible construction or wood of not less than 1-inch (25 mm) nominal thickness.

4. Rooms used for the storage of Class I flammable liquids shall not be located in a basement.

307.1.5 Flammable or combustible liquid storage warehouses. Liquid storage warehouses in which Class I, Class II and Class III-A flammable or combustible liquids are stored in closed containers shall be constructed in accordance with the requirements for a Group H, Division 3 Occupancy and the following:

1. Liquid storage warehouses shall be separated from all other uses by a four-hour area separation wall.

2. Shelving, racks and wainscoting in such warehouses shall be of noncombustible construction or wood not less than 1-inch (25 mm) nominal thickness.

3. Rooms used for the storage of Class I flammable liquids shall not be located in a basement.

307.1.6 Requirement for report. The building official may require a technical opinion and report to identify and develop methods of protection from the hazards presented by the hazardous material. The opinion and report shall be prepared by a qualified person, firm or corporation approved by the building official and shall be provided without charge to the enforcing agency.

The opinion and report may include, but is not limited to, the preparation of a hazardous material management plan (HMMP); chemical analysis; recommendations for methods of isolation, separation, containment or protection of hazardous materials or processes, including appropriate engineering controls to be applied; the extent of changes in the hazardous behavior to be anticipated under conditions of exposure to fire or from hazard control procedures; and the limitations or conditions of use necessary to achieve and maintain control of the hazardous materials or operations. The report shall be entered into the files of the code enforcement agencies. Proprietary and trade secret information shall be protected under the laws of the state or jurisdiction having authority.

307.2 Construction, Height and Allowable Area.

307.2.1 General. Buildings or parts of buildings classed in Group H because of the use or character of the occupancy shall be limited to the types of construction set forth in Table 5-B and shall not exceed, in area or height, the limits specified in Sections 504, 505 and 506.

307.2.2 Floors. Except for surfacing, floors in areas containing hazardous materials and in areas where motor vehicles, boats, helicopters or airplanes are stored, repaired or operated shall be of noncombustible, liquid-tight construction.

EXCEPTION: In Group H, Divisions 4 and 5 Occupancies, floors may be surfaced or waterproofed with asphaltic paving materials in that portion of the facility where no repair work is done.

307.2.3 Spill control and secondary containment for the storage of hazardous materials liquids and solids.

307.2.3.1 Applicability. When required by the Fire Code, rooms, buildings or areas used for the storage of liquid or solid hazardous materials shall be provided with spill control and secondary containment in accordance with Section 307.2.3.

See the Fire Code for outdoor storage provisions.

307.2.3.2 Spill control for hazardous materials liquids. Rooms, buildings or areas used for the storage of hazardous materials liquids in individual vessels having a capacity of more than 55 gallons (208.2 L) or when the aggregate capacity of multiple vessels exceeds 1,000 gallons (3785 L) shall be provided with spill control to prevent the flow of liquids to adjoining areas. Floors shall be constructed to contain a spill from the largest single vessel by one of the following methods:

1. Liquid-tight sloped or recessed floors,

2. Liquid-tight floors provided with liquid-tight raised or recessed sills or dikes, or

3. Sumps and collection systems.

Except for surfacing, the floors, sills, dikes, sumps and collection systems shall be constructed of noncombustible material, and the liquid-tight seal shall be compatible with the material stored. When liquid-tight sills or dikes are provided, they are not required at perimeter openings, which are provided with an open-grate trench across the opening that connects to an approved collection system.

307.2.3.3 Secondary containment for hazardous materials liquids and solids. When required by the Fire Code, buildings, rooms or areas used for the storage of hazardous materials liquids or solids shall be provided with secondary containment in accordance with this section when the capacity of an individual vessel or the aggregate capacity of multiple vessels exceeds the following:

Liquids: Capacity of an individual vessel exceeds 55 gallons (208.2 L) or the aggregate capacity of multiple vessels exceeds 1,000 gallons (3785 L).

Solids: Capacity of an individual vessel exceeds 550 pounds (248.8 kg) or the aggregate capacity of multiple vessels exceeds 10,000 pounds (4524.8 kg).

The building, room or area shall contain or drain the hazardous materials and fire-protection water through the use of one of the following methods:

1. Liquid-tight sloped or recessed floors,

2. Liquid-tight floors provided with liquid-tight raised or recessed sills or dikes,

3. Sumps and collection systems, or

4. Drainage systems leading to an approved location.

Incompatible materials shall be separated from each other in the secondary containment system.

Secondary containment for indoor storage areas shall be designed to contain a spill from the largest vessel, plus the design flow volume of fire-protection water calculated to discharge from the fire-extinguishing system over the minimum required system design area or area of the room or area in which the storage is located, whichever is smaller, for a period of 20 minutes.

A monitoring method shall be provided to detect hazardous materials in the secondary containment system. The monitoring method is allowed to be visual inspection of the primary or secondary containment, or other approved means. Where secondary containment is subject to the intrusion of water, a monitoring method for detecting water shall be provided. When monitoring devices are provided, they shall be connected to distinct visual or audible alarms.

Drainage systems shall be in accordance with the Plumbing Code and the following:

1. The slope of floors to drains shall not be less than 1 percent,

2. Drains shall be sized to carry the volume of the fire-protection water as determined by the design density discharged from the automatic fire-extinguishing system over the minimum required system design area or area of the room or area in which the storage is located, whichever is smaller,

3. Materials of construction for drainage systems shall be compatible with the materials stored,

4. Incompatible materials shall be separated from each other in the drainage system, and

5. Drains shall terminate in an approved location away from buildings, valves, means of egress, fire-access roadways, adjoining property and storm drains.

307.2.4 Spill control and secondary containment for use of hazardous materials liquids.

307.2.4.1 Open containers and systems.

307.2.4.1.1 Spill control for hazardous materials liquids. When required by the Fire Code, buildings, rooms or areas where hazardous materials liquids are dispensed into vessels exceeding a 1.1-gallon (4 L) capacity or used in open systems exceeding a 5.3-gallon (20 L) capacity shall be provided with spill control in accordance with Section 307.2.3.2.

307.2.4.1.2 Secondary containment for hazardous materials liquids. When required by the Fire Code, buildings, rooms or areas where hazardous materials liquids are dispensed or used in open systems shall be provided with secondary containment in accordance with Section 307.2.3.3 when the capacity of an individual vessel or system or the capacity of multiple vessels or systems exceeds the following:

Individual vessel or system: Greater than 1.1 gallons (4 L)

Multiple vessels or systems: Greater than 5.3 gallons (20 L)

307.2.4.2 Closed containers and systems.

307.2.4.2.1 Spill control for hazardous materials liquids. When required by the Fire Code, buildings, rooms or areas where hazardous materials liquids are used in individual vessels exceeding a 55-gallon (208.2 L) capacity shall be provided with spill control in accordance with Section 307.2.3.2.

307.2.4.2.2 Secondary containment for hazardous materials liquids. When required by the Fire Code, buildings, rooms or areas where hazardous materials liquids are used in vessels or systems shall be provided with secondary containment in accordance with Section 307.2.3.3 when the capacity of an individual vessel or system or the capacity of multiple vessels or systems exceeds the following:

Individual vessel or system: Greater than 55 gallons (208.2 L)

Multiple vessels or systems: Greater than 1,000 gallons (3785 L)

307.2.5 Smoke and heat vents. Smoke and heat venting shall be provided in areas containing hazardous materials as set forth in the Fire Code in addition to the provisions of this code.

307.2.6 Standby power. Standby power shall be provided in Group H, Divisions 1 and 2 Occupancies and in Group H, Division 3 Occupancies in which Class I or II organic peroxides are stored. The standby power system shall be designed and installed in accordance with the Electrical Code to automatically supply power to all required electrical equipment when the normal electrical supply system is interrupted.

307.2.7 Emergency power. An emergency power system shall be provided in Group H, Divisions 6 and 7 Occupancies. The emergency power system shall be designed and installed in accordance with the Electrical Code to automatically supply power to all required electrical equipment when the normal electrical supply system is interrupted.

The exhaust system may be designed to operate at not less than one half the normal fan speed on the emergency power system when it is demonstrated that the level of exhaust will maintain a safe atmosphere.

307.2.8 Special provisions for Group H, Division 1 Occupancies. Group H, Division 1 Occupancies shall be in buildings used for no other purpose, without basements, crawl spaces or other under-floor spaces. Roofs shall be of lightweight construction with suitable thermal insulation to prevent sensitive material from reaching its decomposition temperature.

Group H, Division 1 Occupancies containing materials, which are in themselves both physical and health hazards in quantities exceeding the exempt amounts in Table 3-E, shall comply with requirements for both Group H, Division 1 and Group H, Division 7 Occupancies.

307.2.9 Special provisions for Group H, Divisions 2 and 3 Occupancies. Group H, Divisions 2 and 3 Occupancies containing quantities of hazardous materials in excess of those set forth in

Table 3-G shall be in buildings used for no other purpose, shall not exceed one story in height and shall be without basements, crawl spaces or other under-floor spaces.

Group H, Divisions 2 and 3 Occupancies containing water-reactive materials shall be resistant to water penetration. Piping for conveying liquids shall not be over or through areas containing water reactives, unless isolated by approved liquid-tight construction.

> **EXCEPTION:** Fire-protection piping may be installed over reactives without isolation.

307.2.10 Special provisions for Group H, Division 4 Occupancies. Group H, Division 4 Occupancies having a floor area not exceeding 2,500 square feet (232 m^2) may have exterior walls of not less than two-hour fire-resistive construction when less than 5 feet (1524 mm) from a property line and not less than one-hour fire-resistive construction when less than 20 feet (6096 mm) from a property line.

307.2.11 Special provisions for Group H, Division 6 Occupancies. See Section 307.11.

307.3 Location on Property. Group H Occupancies shall be located on property in accordance with Section 503, Table 3-F and other provisions of this chapter. In Group H, Division 2 or 3 Occupancies, not less than 25 percent of the perimeter wall of the occupancy shall be an exterior wall.

> **EXCEPTIONS:** 1. Liquid use, dispensing and mixing rooms having a floor area of not more than 500 square feet (46.5 m^2) need not be located on the outer perimeter of the building when they are in accordance with Section 307.1.3.
>
> 2. Liquid storage rooms having a floor area of not more than 1,000 square feet (93 m^2) need not be located on the outer perimeter when they are in accordance with Section 307.1.4.
>
> 3. Spray paint booths that comply with the Fire Code need not be located on the outer perimeter.

307.4 Access and Means of Egress Facilities. Means of egress shall be provided as specified in Chapter 10. (For special provisions, see Section 1007.4.)

Access to, and egress from, buildings required to be accessible shall be provided as specified in Chapter 11.

307.5 Light, Ventilation and Sanitation.

307.5.1 General. Light, ventilation and sanitation in Group H Occupancies shall comply with requirements in this section and Chapters 12 and 29.

307.5.2 Ventilation in hazardous locations. See Section 1202.2.3 for ventilation requirements in hazadous locations.

307.5.3 Ventilation in Group H, Division 4 Occupancies. See Section 1202.2.4 for ventilation requirements in Group H, Division 4 Occupancies.

307.5.4 Sanitation. The number of plumbing fixtures shall not be less than specified in Section 2902.3.

307.6 Shaft and Exit Enclosures. Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts and other openings through floors shall be enclosed, and the enclosure shall be as specified in Section 711.

Doors which are a part of an automobile ramp enclosure shall be equipped with automatic-closing devices.

For Group H, Division 6 Occupancies, see Section 307.11.2.3.

307.7 Sprinkler and Standpipe Systems. When required by Section 904.2.1 or other provisions of this code, automatic fire-extinguishing systems and standpipes shall be designed and installed as specified in Chapter 9.

307.8 Special Hazards. Chimneys and heating apparatus shall conform to the requirements of Chapter 31 of this code and the Mechanical Code.

In Divisions 4 and 5 Occupancies, devices that generate a glow, spark or flame capable of igniting flammable vapors shall be installed with sources of ignition at least 18 inches (457 mm) above the floor. See the Mechanical Code for additional restrictions.

Equipment or machinery that generates or emits combustible or explosive dust or fibers shall be provided with an adequate dust-collecting and exhaust system installed in conformance with the Mechanical Code. Equipment or systems that are used to collect, process or convey combustible dusts or fibers shall be provided with an approved explosion venting or containment system.

Combustible fiber storage rooms with a fiber storage capacity not exceeding 500 cubic feet (14.2 m^3) shall be separated from the remainder of the building by a one-hour fire-resistive occupancy separation. Combustible fiber storage vaults having a fiber storage capacity of more than 500 cubic feet (14.2 m^3) shall be separated from the remainder of the building by a two-hour fire-resistive occupancy separation.

Cellulose nitrate film storage and handling shall be in accordance with Section 407.

307.9 Fire Alarm Systems. An approved manual fire alarm system shall be provided in Group H Occupancies used for the manufacturing of organic coatings. Approved automatic smoke detection shall be provided for rooms used for the storage, dispensing, use and handling of hazardous materials when required by the Fire Code.

For Group H, Division 6 Occupancies, see Section 307.11.

For installation requirements, see the Fire Code.

For aerosol storage warehouses, see the Fire Code.

307.10 Explosion Control. Explosion control, equivalent protective devices or suppression systems; or barricades shall be provided to control or vent the gases resulting from deflagrations of dusts, gases or mists in rooms, buildings or other enclosures as required by the Fire Code so as to minimize structural or mechanical damage. If detonation rather than deflagration is considered likely, protective devices or systems such as fully contained barricades shall be provided, except that explosion venting to minimize damage from less than 2.0 grams of trinitrotoluene (TNT) (equivalence) is permitted. Walls, floors and roofs separating a use from an explosion exposure shall be designed to resist a minimum internal pressure of 100 pounds per square foot (psf) (4.79 kPa) in addition to the loads required by Chapter 16.

Explosion venting shall be provided in exterior walls or roof only. The venting shall be designed to prevent serious structural damage and production of lethal projectiles. The aggregate clear vent relief area shall be regulated by the pressure resistance of the nonrelieving portions of the building and be designed by persons competent in such design. The design shall recognize the nature of the material and its behavior in an explosion. Vents shall consist of any one or any combination of the following to relieve at a maximum internal pressure of 20 psf (958 Pa), but not less than the loads required by Chapter 16:

1. Walls of lightweight material.
2. Lightly fastened hatch covers.
3. Lightly fastened, outward-opening swinging doors in exterior walls.

4. Lightly fastened walls or roof.

Venting devices shall discharge vertically or directly to an unoccupied yard not less than 50 feet (15 240 mm) in width on the same lot. Releasing devices shall be so located that the discharge end shall not be less than 10 feet (3048 mm) vertically and 20 feet (6096 mm) horizontally from window openings or exits in the same or adjoining buildings or structures. The exhaust shall always be in the direction of least exposure and never into the interior of the building unless a suitably designed shaft is provided that discharges to the exterior. See Footnote 12 of Table 3-D.

307.11 Group H, Division 6 Occupancies.

307.11.1 General. In addition to the requirements set forth elsewhere in this code, Group H, Division 6 Occupancies shall comply with the provisions of this section and the Fire Code.

307.11.2 Fabrication area.

307.11.2.1 Separation and location. Fabrication areas, whose sizes are limited by the quantity of hazardous production materials (HPM) permitted by the Fire Code, shall be separated from each other, from corridors, and from other parts of the building by not less than one-hour fire-resistive occupancy separations. Occupied levels of fabrication areas shall be located at or above the first story.

> **EXCEPTIONS:** 1. Doors within such occupancy separation, including doors to corridors, shall be only self-closing fire assemblies having a fire-protection rating of not less than three-fourths hour.
>
> 2. Windows between fabrication areas and corridors may be in accordance with Section 1004.3.4.3.2.2.

307.11.2.2 Floors. Except for surfacing, floors within fabrication areas shall be of noncombustible construction. Openings through floors of fabrication areas may be unprotected when the interconnected levels are used solely for mechanical equipment directly related to such fabrication area. See also Section 307.11.2.3. When forming a part of an occupancy separation, floors shall be liquid tight.

307.11.2.3 Shaft and exit enclosures. Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts and other openings through floors shall be enclosed and the enclosure shall be as specified in Section 711. A fabrication area may have mechanical, duct and piping penetrations that extend through not more than two floors within that fabrication area. The annular space around penetrations for cables, cable trays, tubing, piping, conduit or ducts shall be sealed at the floor level to restrict the movement of air. The fabrication area, including the areas through which the ductwork and piping extend, shall be considered a single conditioned environment.

307.11.2.4 Ventilation. See Section 1202.2.5 for ventilation requirements.

307.11.2.5 Transporting hazardous production materials. Hazardous production materials shall be transported to fabrication areas through enclosed piping or tubing systems that comply with Section 307.11.6, through service corridors or in corridors as permitted in the exception to Section 307.11.3. The handling or transporting of hazardous production materials within service corridors shall comply with the Fire Code.

307.11.2.6 Electrical. Electrical equipment and devices within the fabrication area shall comply with the Electrical Code. The requirements for hazardous locations need not be applied when the average air change is at least four times that set forth in Section 307.11.2.4 and when the number of air changes at any location is not less than three times that required by Section 307.11.2.4 and the Fire Code.

Electrical equipment and devices within 5 feet (1524 mm) of work stations in which flammable or pyrophoric gases or flammable liquids are used shall be in accordance with the Electrical Code for Class I, Division 2 hazardous locations. Work stations shall not be energized without adequate exhaust ventilation. See Section 1202.2.5 for work station exhaust ventilation requirements.

> **EXCEPTION:** Class I, Division 2 hazardous electrical is not required when the air removal from the work station or dilution will provide nonflammable atmospheres on a continuous basis.

307.11.3 Corridors. Corridors shall comply with Section 1004.3.4 and shall be separated from fabrication areas as specified in Section 307.11.2.1. Corridors shall not be used for transporting hazardous production materials except as provided in Section 307.11.6.2.

> **EXCEPTION:** In existing Group H, Division 6 Occupancies when there are alterations or modifications to existing fabrication areas, the building official may permit the transportation of hazardous production materials in corridors subject to the requirements of the Fire Code and as follows:
>
> 1. Exit-access corridors adjacent to the fabrication area where the alteration work is to be done shall comply with Section 1004.3.4 for a length determined as follows:
>
> 1.1 The length of the common wall of the corridor and the fabrication area, and
>
> 1.2 For the distance along the corridor to the point of entry of HPM into the corridor serving that fabrication area.
>
> 2. There shall be an emergency telephone system or a local alarm manual pull station or approved signal device within corridors at not more than 150-foot (45 720 mm) intervals or fraction thereof and at each stair doorway. The signal shall be relayed to the emergency control station and a local signaling device shall be provided.
>
> 3. Sprinkler protection shall be designed in accordance with UBC Standard 9-1 for Ordinary Hazard Group 2, except that when one row of sprinklers is used in the corridor protection, the maximum number of sprinklers that need be calculated is 13. UBC Standard 9-1 is a part of this code. (See Chapter 35, Part II.)
>
> 4. Self-closing doors having a fire-protection rating of not less than one hour shall separate pass-throughs from existing corridors. Pass-throughs shall be constructed as required for the corridors. Pass-throughs shall be protected by an approved automatic fire sprinkler system.

307.11.4 Service corridors. Service corridors shall be classified as Group H, Division 6 Occupancies. Service corridors shall be separated from corridors as required by Section 307.11.2.1.

Service corridors shall be mechanically ventilated as required by Section 307.11.2.4 or at not less than six air changes per hour, whichever is greater.

The maximum travel distance from any point in a service corridor to an exit or door into a fabrication area shall not exceed 75 feet (22 860 mm). Dead ends shall not exceed 4 feet (1219 mm) in length. There shall not be less than two means of egress, and not more than one half of the required means of egress shall be into the fabrication area. Doors from service corridors shall swing in the direction of egress and shall be self-closing.

The minimum clear width of a service corridor shall be 5 feet (1524 mm), or 33 inches (838 mm) wider than the widest cart or truck used in the corridor, whichever is greater.

307.11.5 Storage of hazardous production materials.

307.11.5.1 Construction. The storage of hazardous production materials in quantities greater than those listed in Table 3-D or 3-E shall be in liquid storage rooms, HPM rooms or gas rooms, as required by the Fire Code. HPM rooms and gas rooms shall be separated from all other areas by not less than a two-hour fire-resistive occupancy separation when the area is 300 square feet (27.9 m^2) or more and not less than one-hour fire-resistive occupancy separation when the area is less than 300 square feet (27.9 m^2). The provisions of Section 302.1 shall apply.

Except for surfacing, floors of storage and HPM rooms shall be of noncombustible liquid-tight construction. Raised grating over floors shall be of noncombustible materials. See Section 307.2.3 for sill requirements for liquid storage rooms.

307.11.5.2 Location within building. When HPM rooms are provided, they shall have at least one exterior wall and such wall shall not be less than 30 feet (9144 mm) from property lines, including property lines adjacent to public ways. Explosion control shall be provided when required by Section 307.10.

307.11.5.3 Means of egress. When two means of egress are required from HPM rooms, one shall be directly to the outside of the building. See Section 307.11.2.1, Exception 1.

307.11.5.4 Ventilation. Mechanical exhaust ventilation shall be provided in liquid storage rooms, HPM rooms and gas rooms at the rate of not less than 1 cubic foot per minute per square foot (0.044 L/s/m^2) of floor area or six air changes per hour, whichever is greater, for all categories of material.

Exhaust ventilation for gas rooms shall be designed to operate at a negative pressure in relation to the surrounding areas and direct the exhaust ventilation to an exhaust system.

307.11.5.5 Fire and emergency alarm. An approved manual fire alarm system shall be provided throughout buildings containing Group H, Division 6 Occupancies.

An approved emergency alarm system shall be provided for HPM rooms, liquid storage rooms and gas rooms. Emergency alarm-initiating devices shall be installed outside of each interior door of such rooms. Activation of an emergency alarm-initiating device shall sound a local alarm and transmit a signal to the emergency control station.

For installation requirements, see the Fire Code.

307.11.5.6 Electrical. Electrical wiring and equipment in HPM rooms, gas rooms and liquid storage rooms shall comply with the Electrical Code.

307.11.6 Piping and tubing.

307.11.6.1 General. Hazardous production materials piping and tubing shall comply with this section and shall be installed in accordance with nationally recognized standards. Piping and tubing systems shall be metallic unless the material being transported is incompatible with such system. Systems supplying gaseous HPM having a health hazard ranking of 3 or 4 shall be welded throughout, except for connections, valves and fittings, to the systems which are within a ventilated enclosure. Hazardous production materials supply piping or tubing in service corridors shall be exposed to view.

307.11.6.2 Installations in corridors and above other occupancies. Hazardous production materials shall not be located within corridors or above areas not classified as Group H, Division 6 Occupancies except as permitted by this section.

Hazardous production material piping and tubing may be installed within the space defined by the walls of corridors and the floor or roof above or in concealed spaces above other occupancies under the following conditions:

1. Automatic sprinklers shall be installed within the space unless the space is less than 6 inches (152 mm) in least dimension.

2. Ventilation at not less than six air changes per hour shall be provided. The space shall not be used to convey air from any other area.

3. When the piping or tubing is used to transport HPM liquids, a receptor shall be installed below such piping or tubing. The receptor shall be designed to collect any discharge or leakage and drain it to an approved location. The one-hour enclosure shall not be used as part of the receptor.

4. All HPM supply piping and tubing and HPM nonmetallic waste lines shall be separated from the corridor and from any occupancy other than Group H, Division 6 by construction as required for walls or partitions that have a fire-protection rating of not less than one hour. When gypsum wallboard is used, joints on the piping side of the enclosure need not be taped, provided the joints occur over framing members. Access openings into the enclosure shall be protected by approved fire assemblies.

5. Readily accessible manual or automatic remotely activated fail-safe emergency shutoff valves shall be installed on piping and tubing other than waste lines at the following locations:

5.1 At branch connections into the fabrication area.

5.2 At entries into corridors.

Excess flow valves shall be installed as required by the Fire Code.

EXCEPTION: Occasional transverse crossings of the corridors by supply piping which is enclosed within a ferrous pipe or tube for the width of the corridor need not comply with Items 1 through 5.

307.11.6.3 Identification. Piping, tubing and HPM waste lines shall be identified in accordance with nationally recognized standards to indicate the material being transported.

307.12 Heliports. Heliports may be erected on buildings or other locations if they are constructed in accordance with this chapter and with Section 311.10.

SECTION 308 — REQUIREMENTS FOR GROUP I OCCUPANCIES

308.1 Group I Occupancies Defined. Group I Occupancies shall be:

Division 1.1. Nurseries for the full-time care of children under the age of six (each accommodating more than five children).

Hospitals, sanitariums, nursing homes with nonambulatory patients and similar buildings (each accommodating more than five patients).

Division 1.2. Health-care centers for ambulatory patients receiving outpatient medical care that may render the patient incapable of unassisted self-preservation (each tenant space accommodating more than five such patients).

Division 2. Nursing homes for ambulatory patients, homes for children six years of age or over (each accommodating more than five patients or children).

Division 3. Mental hospitals, mental sanitariums, jails, prisons, reformatories and buildings where personal liberties of inmates are similarly restrained.

For occupancy separations, see Table 3-B.

EXCEPTION: Group I Occupancies shall not include buildings used only for private residential purposes for a family group.

308.2 Construction, Height and Allowable Area.

308.2.1 General. Buildings or parts of buildings classed in Group I because of the use or character of the occupancy shall be limited to the types of construction set forth in Table 5-B and shall not exceed, in area or height, the limits specified in Sections 504, 505 and 506.

EXCEPTIONS: 1. Hospitals and nursing homes classified as Group I, Division 1.1 Occupancies, and health-care centers for ambulatory patients classified as Group I, Division 1.2 Occupancies that are equipped with an automatic sprinkler system throughout shall not exceed one story in height when in Type III One-hour, Type IV or Type V One-hour construction.

2. Hospitals and nursing homes classified as Group I, Division 1.1 Occupancies, and health-care centers for ambulatory patients classified as Group I, Division 1.2 Occupancies that are equipped with automatic sprinkler systems throughout may be five stories when of Type II-F.R. construction and three stories when of Type II One-hour construction. The allowable area increase specified in Section 505.3 applies only when the number of stories in the building is one less than set forth above.

3. Hospitals and nursing homes classified as Group I, Division 1.1 Occupancies, and health-care centers for ambulatory patients classified as Group I, Division 1.2 Occupancies that are equipped with automatic sprinkler systems throughout may be housed within one-story buildings of Type II-N construction. The area of such building shall not exceed 13,500 square feet (1254 m^2) plus the allowable area increase for separation by public space or yards as set forth in Section 505.1.

308.2.2 Specific-use provisions.

308.2.2.1 Group I, Division 1.1 smoke barriers. Floor levels of Group I, Division 1.1 Occupancies used by inpatients for sleeping or treatment, or having an occupant load of 50 or more, shall be divided into at least two compartments by smoke barriers of not less than one-hour fire resistance meeting the requirements of Section 905.2.3. The area within a smoke-control zone shall not exceed 22,500 square feet (2090 m^2) and its width or length shall not exceed 150 feet (45 720 mm). The area of a smoke zone shall not be less than that required to accommodate the occupants of the zone plus the occupants from any adjoining zone. Not less than 30 square feet (2.8 m^2) net clear floor area for bed and litter patients and 6 square feet (0.6 m^2) net clear floor area for other occupants shall be used to compute the required areas.

Doors in smoke barriers shall be tightfitting smoke- and draft-control assemblies having a fire-protection rating of not less than 20 minutes and shall comply with Section 1007.5.1. When doors are installed across corridors, a pair of opposite-swinging doors without a center mullion or horizontal sliding doors that comply with UBC Standard 7-8, which is part of this code (see Chapter 35, Part II), shall be installed. Smoke-barrier doors shall:

1. When installed across corridors, have vision panels. The area of the vision panels shall not exceed that tested.

2. Be closefitting with only the clearance necessary for proper operation and shall be without undercuts, louvers or grilles.

3. Have stops at the head and jambs. Opposite-swinging corridor doors shall have rabbets or astragals at the meeting edges.

4. Have positive latching devices, except on doors installed across corridors.

5. Be automatic closing. Doors installed across corridors shall comply with Section 713.6.1, Item 3, and doors on the floor or in the affected zone shall automatically close if the fire alarm or sprinkler system is activated.

At least two means of egress shall be provided from each smoke zone. Means of egress may pass through adjacent zones, provided the means of egress does not return through the compartment zone from which exiting originated. Exit or exit-access doors at zone boundaries shall be equipped with approved vision panels.

308.2.2.2 Group I, Division 3 Occupancies. Group I, Division 3 Occupancies shall be housed in buildings of Type I or Type II-F.R. construction.

EXCEPTION: Such occupancies may be housed in one-story buildings of Type II One-hour, Type III One-hour or Type V One-hour construction provided the floor area does not exceed 3,900 square feet (362 m^2) between separation walls of two-hour fire-resistive construction with openings protected by fire assemblies having one- and one-half-hour fire-protection rating.

Rooms occupied by inmates or patients whose personal liberties are restrained shall have noncombustible floor surfaces.

308.3 Location on Property. For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 503 and Chapter 6.

308.4 Access and Means of Egress Facilities. Means of egress shall be provided as specified in Chapter 10. (For special provisions, see Section 1007.5.)

Access to, and egress from, buildings required to be accessible shall be provided as specified in Chapter 11.

308.5 Light, Ventilation and Sanitation.

308.5.1 Light and ventilation. All portions of enclosed Group I Occupancies customarily occupied by human beings shall be provided with light and ventilation, either natural or artificial, as specified in Section 1202. See Section 1003.2.9 for required exit illumination.

308.5.2 Sanitation. The number of plumbing fixtures shall not be less than specified in Section 2902.5.

308.6 Shaft and Exit Enclosures. Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts and other vertical openings shall be enclosed, and the enclosure shall be as specified in Section 711.

308.7 Sprinkler and Standpipe Systems. When required by Section 904.2.1 or other provisions of this code, automatic sprinkler systems and standpipes shall be designed and installed as specified in Chapter 9.

308.8 Special Hazards. Chimneys and heating apparatus shall conform to the requirements of Chapter 31 of this code and the Mechanical Code.

Motion picture projection rooms shall conform to the requirements of Section 406.

Specific use areas shall be separated from Group I, Division 1.1 Occupancies used for hospitals or nursing homes in accordance with Table 3-C. Doors shall be maintained self-closing or shall be automatic closing by actuation of a smoke detector.

Storage and handling of flammable and combustible liquids shall be in accordance with the Fire Code.

All exterior openings in a boiler room or room containing central heating equipment if located below openings in another story, or if less than 10 feet (3048 mm) from the other doors or windows of the same building, shall be protected by a fire assembly having a three-fourths-hour fire-protection rating.

308.9 Fire Alarm Systems. An approved manual and automatic fire alarm system shall be provided for Group I Occupancies. Audible alarm devices shall be used in nonpatient areas. Visible alarm devices may be used in lieu of audible devices in patient-occupied areas. For installation requirements, see the Fire Code.

308.10 Smoke Detectors. Smoke detectors that receive their primary power from the building wiring shall be installed in patient sleeping rooms of hospital and nursing homes. Actuation of such detectors shall cause a visual display on the corridor side of the room in which the detector is located and shall cause an audible and visual alarm at the respective nurses' station. When single-station detectors and related devices are combined with a nursing call system, the nursing call system shall be listed for the intended combined use.

EXCEPTION: In rooms equipped with automatic door closers having integral smoke detectors on the room side, the integral detector may substitute for the room smoke detector, provided it performs the required alerting functions.

SECTION 309 — REQUIREMENTS FOR GROUP M OCCUPANCIES

309.1 Group M Occupancies Defined. Group M Occupancies shall include buildings, structures, or portions thereof, used for the display and sale of merchandise, and involving stocks of goods, wares or merchandise incidental to such purposes and accessible to the public. Mercantile occupancies shall include, but are not limited to, the following:

1. Department stores.
2. Drug stores.
3. Markets.
4. Paint stores without bulk handling.
5. Shopping centers.
6. Sales rooms.
7. Wholesale and retail stores.

For occupancy separations, see Table 3-B.

309.2 Construction, Height and Allowable Area.

309.2.1 General. Buildings or parts of buildings classed in Group M Occupancy because of the use or character of the occupancy shall be limited to the types of construction set forth in Table 5-B and shall not exceed, in area or height, the limits specified in Sections 504, 505 and 506.

309.2.2 Special provisions. Storage areas in connection with wholesale or retail sales shall be separated from the public area by a one-hour fire-resistive occupancy separation.

EXCEPTION: Occupancy separations need not be provided when any one of the following conditions exist:

1. The storage area does not exceed 1,000 square feet (93 m^2).
2. The storage area is sprinklered and does not exceed 3,000 square feet (279 m^2), or
3. The building is provided with an approved automatic sprinkler system throughout.

309.3 Location on Property. For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 503.

309.4 Access and Means of Egress Facilities. Means of egress shall be provided as specified in Chapter 10.

Access to, and egress from, buildings required to be accessible shall be provided as specified in Chapter 11.

309.5 Light, Ventilation and Sanitation. In Group M Occupancies, light, ventilation and sanitation shall be as specified in Chapters 12 and 29.

309.6 Shaft and Exit Enclosures. Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts and other openings through floors shall be enclosed, and the enclosure shall be as specified in Section 711.

In buildings housing Group M Occupancies equipped with automatic sprinkler systems throughout, enclosures need not be provided for escalators where the top of the escalator opening at each story is provided with a draft curtain and automatic fire sprinklers are installed around the perimeter of the opening within 2 feet (610 mm) of the draft curtain. The draft curtain shall enclose the perimeter of the unenclosed opening and extend from the ceiling downward at least 12 inches (305 mm) on all sides. The spacing between sprinklers shall not exceed 6 feet (1829 mm).

309.7 Sprinkler and Standpipe Systems. When required by other provisions of this code, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 9.

309.8 Special Hazards. For special hazards of Group M Occupancies, see Section 304.8.

Storage and use of flammable and combustible liquids shall be in accordance with the Fire Code.

Buildings erected or converted to house high-piled combustible stock or aerosols shall comply with the Fire Code.

SECTION 310 — REQUIREMENTS FOR GROUP R OCCUPANCIES

310.1 Group R Occupancies Defined. Group R Occupancies shall be:

Division 1. Hotels and apartment houses.

Congregate residences (each accommodating more than 10 persons).

Division 2. Not used.

Division 3. Dwellings and lodging houses.

Congregate residences (each accommodating 10 persons or less).

For occupancy separations, see Table 3-B.

A complete code for construction of detached one- and two-family dwellings is in Appendix Chapter 3, Division III, of this code. When adopted, as set forth in Section 101.3, it will take precedence over the other requirements set forth in this code.

310.2 Construction, Height and Allowable Area.

310.2.1 General. Buildings or parts of buildings classed in Group R because of the use or character of the occupancy shall be limited to the types of construction set forth in Table 5-B and shall not exceed, in area or height, the limits specified in Sections 504, 505 and 506.

310.2.2 Special provisions. Walls and floors separating dwelling units in the same building, or guest rooms in Group R, Division 1 hotel occupancies, shall not be of less than one-hour fire-resistive construction.

Group R, Division 1 Occupancies more than two stories in height or having more than 3,000 square feet (279 m^2) of floor area above the first story shall not be of less than one-hour fire-resistive construction throughout, except as provided in Section 601.5.2.2.

Storage or laundry rooms that are within Group R, Division 1 Occupancies that are used in common by tenants shall be separated from the rest of the building by not less than one-hour fire-resistive occupancy separation.

For Group R, Division 1 Occupancies with a Group S, Division 3 parking garage in the basement or first story, see Section 311.2.2.

For attic space partitions and draft stops, see Section 708.

310.3 Location on Property. For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 503 and Chapter 6.

310.4 Access and Means of Egress Facilities and Emergency Escapes. Means of egress shall be provided as specified in Chapter 10. (See also Section 1007.6.2 for exit markings.)

Access to, and egress from, buildings required to be accessible shall be provided as specified in Chapter 11.

Basements in dwelling units and every sleeping room below the fourth story shall have at least one operable window or door approved for emergency escape or rescue that shall open directly into a public street, public alley, yard or exit court. The emergency door or window shall be operable from the inside to provide a full, clear opening without the use of separate tools.

EXCEPTION: The window or door may open into an atrium complying with Section 402 provided the window or door opens onto an exit-access balcony and the dwelling unit or guest room has an exit or exit-access doorway that does not open into the atrium.

Escape or rescue windows shall have a minimum net clear openable area of 5.7 square feet (0.53 m^2). The minimum net clear openable height dimension shall be 24 inches (610 mm). The minimum net clear openable width dimension shall be 20 inches (508 mm). When windows are provided as a means of escape or rescue, they shall have a finished sill height not more than 44 inches (1118 mm) above the floor.

Escape and rescue windows with a finished sill height below the adjacent ground elevation shall have a window well. Window wells at escape or rescue windows shall comply with the following:

1. The clear horizontal dimensions shall allow the window to be fully opened and provide a minimum accessible net clear opening of 9 square feet (0.84 m^2), with a minimum dimension of 36 inches (914 mm).

2. Window wells with a vertical depth of more than 44 inches (1118 mm) shall be equipped with an approved permanently affixed ladder or stairs that are accessible with the window in the fully open position. The ladder or stairs shall not encroach into the required dimensions of the window well by more than 6 inches (152 mm).

Bars, grilles, grates or similar devices may be installed on emergency escape or rescue windows, doors or window wells, provided:

1. The devices are equipped with approved release mechanisms that are openable from the inside without the use of a key or special knowledge or effort; and

2. The building is equipped with smoke detectors installed in accordance with Section 310.9.

310.5 Light, Ventilation and Sanitation. Light and ventilation shall be as specified in Chapter 12. The number of plumbing fixtures shall not be less than specified in Section 2902.6.

310.6 Room Dimensions.

310.6.1 Ceiling heights. Habitable space shall have a ceiling height of not less than 7 feet 6 inches (2286 mm) except as otherwise permitted in this section. Kitchens, halls, bathrooms and toilet compartments may have a ceiling height of not less than 7 feet (2134 mm) measured to the lowest projection from the ceiling. Where exposed beam ceiling members are spaced at less than 48 inches (1219 mm) on center, ceiling height shall be measured to the bottom of these members. Where exposed beam ceiling members are spaced at 48 inches (1219 mm) or more on center, ceiling height shall be measured to the bottom of the deck supported by these members, provided that the bottom of the members is not less than 7 feet (2134 mm) above the floor.

If any room in a building has a sloping ceiling, the prescribed ceiling height for the room is required in only one half the area thereof. No portion of the room measuring less than 5 feet (1524 mm) from the finished floor to the finished ceiling shall be included in any computation of the minimum area thereof.

If any room has a furred ceiling, the prescribed ceiling height is required in two thirds the area thereof, but in no case shall the height of the furred ceiling be less than 7 feet (2134 mm).

310.6.2 Floor area. Dwelling units and congregate residences shall have at least one room that shall have not less than 120 square feet (11.2 m^2) of floor area. Other habitable rooms except kitchens shall have an area of not less than 70 square feet (6.5 m^2). Efficiency dwelling units shall comply with the requirements of Section 310.7.

310.6.3 Width. Habitable rooms other than a kitchen shall not be less than 7 feet (2134 mm) in any dimension.

310.7 Efficiency Dwelling Units. An efficiency dwelling unit shall conform to the requirements of the code except as herein provided:

1. The unit shall have a living room of not less than 220 square feet (20.4 m^2) of superficial floor area. An additional 100 square feet (9.3 m^2) of superficial floor area shall be provided for each occupant of such unit in excess of two.

2. The unit shall be provided with a separate closet.

3. The unit shall be provided with a kitchen sink, cooking appliance and refrigeration facilities, each having a clear working space of not less than 30 inches (762 mm) in front. Light and ventilation conforming to this code shall be provided.

4. The unit shall be provided with a separate bathroom containing a water closet, lavatory and bathtub or shower.

310.8 Shaft and Exit Enclosures. Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts, dumbwaiter shafts, clothes chutes and other vertical openings shall be enclosed and the enclosure shall be as specified in Section 711.

In nonsprinklered Group R, Division 1 Occupancies, corridors serving an occupant load of 10 or more shall be separated from corridors and other areas on adjacent floors by not less than approved fixed wired glass set in steel frames or by 20-minute smoke- and draft-control assemblies, which are automatic closing by smoke detection.

310.9 Smoke Detectors and Sprinkler Systems.

310.9.1 Smoke detectors.

310.9.1.1 General. Dwelling units, congregate residences and hotel or lodging house guest rooms that are used for sleeping purposes shall be provided with smoke detectors. Detectors shall be installed in accordance with the approved manufacturer's instructions.

310.9.1.2 Additions, alterations or repairs to Group R Occupancies. When the valuation of an addition, alteration or repair to a Group R Occupancy exceeds $1,000 and a permit is required, or when one or more sleeping rooms are added or created in existing Group R Occupancies, smoke detectors shall be installed in accordance with Sections 310.9.1.3, 310.9.1.4 and 310.9.1.5 of this section.

EXCEPTION: Repairs to the exterior surfaces of a Group R Occupancy are exempt from the requirements of this section.

310.9.1.3 Power source. In new construction, required smoke detectors shall receive their primary power from the building wiring when such wiring is served from a commercial source and shall be equipped with a battery backup. The detector shall emit a signal when the batteries are low. Wiring shall be permanent and without a disconnecting switch other than those required for overcurrent protection. Smoke detectors may be solely battery operated when installed in existing buildings; or in buildings without commercial power; or in buildings which undergo alterations, repairs or additions regulated by Section 310.9.1.2.

310.9.1.4 Location within dwelling units. In dwelling units, a detector shall be installed in each sleeping room and at a point centrally located in the corridor or area giving access to each separate sleeping area. When the dwelling unit has more than one story and in dwellings with basements, a detector shall be installed on each story and in the basement. In dwelling units where a story or basement is split into two or more levels, the smoke detector shall be installed on the upper level, except that when the lower level contains a sleeping area, a detector shall be installed on each level. When sleeping rooms are on an upper level, the detector shall be placed at the ceiling of the upper level in close proximity to the stairway. In dwelling units where the ceiling height of a room open to the hallway serving the bedrooms exceeds that of the hallway by 24 inches (610 mm) or more, smoke detectors shall be installed in the hallway and in the adjacent room. Detectors shall sound an alarm audible in all sleeping areas of the dwelling unit in which they are located.

310.9.1.5 Location in efficiency dwelling units, congregate residences and hotels. In efficiency dwelling units, hotel suites and in hotel and congregate residence sleeping rooms, detectors shall be located on the ceiling or wall of the main room or each sleeping room. When sleeping rooms within an efficiency dwelling unit or hotel suite are on an upper level, the detector shall be placed at the ceiling of the upper level in close proximity to the stairway. When actuated, the detector shall sound an alarm audible within the sleeping area of the dwelling unit or congregate residence, hotel suite, or sleeping room in which it is located.

310.9.2 Sprinkler and standpipe systems. When required by Section 904.2.1 or other provisions of this code, automatic sprinkler systems and standpipes shall be designed and installed as specified in Chapter 9.

310.10 Fire Alarm Systems. Group R, Division 1 Occupancies shall be provided with a manual and automatic fire alarm system in apartment houses three or more stories in height or containing 16 or more dwelling units, in hotels three or more stories in height or containing 20 or more guest rooms and in congregate residences three or more stories in height or having an occupant load of 20 or more. A fire alarm and communication system shall be provided in Group R, Division 1 Occupancies located in a high-rise building.

EXCEPTIONS: 1. A manual fire alarm system need not be provided in buildings not over two stories in height when all individual dwelling units and contiguous attic and crawl spaces are separated from each other and public or common areas by at least one-hour fire-resistive occupancy separations and each individual dwelling unit or guest room has an exit directly to a public way, exit court or yard.

2. A separate fire alarm system need not be provided in buildings that are protected throughout by an approved supervised fire sprinkler system having a local alarm to notify all occupants.

The alarm signal shall be a distinctive sound that is not used for any other purpose other than the fire alarm. Alarm-signaling devices shall produce a sound that exceeds the prevailing equivalent sound level in the room or space by 15 decibels minimum, or exceeds any maximum sound level with a duration of 30 seconds minimum by 5 decibels minimum, whichever is louder. Sound levels for alarm signals shall be 120 decibels maximum.

For the purposes of this section, area separation walls shall not define separate buildings.

310.11 Heating. Dwelling units, guest rooms and congregate residences shall be provided with heating facilities capable of maintaining a room temperature of 70°F (21°C) at a point 3 feet (914 mm) above the floor in all habitable rooms.

310.12 Special Hazards. Chimneys and heating apparatus shall conform to the requirements of Chapter 31 and the Mechanical Code.

The storage, use and handling of flammable and combustible liquids in Division 1 Occupancies shall be in accordance with the Fire Code.

In Division 1 Occupancies, doors leading into rooms in which Class I flammable liquids are stored or used shall be protected by a fire assembly having a one-hour fire-protection rating. Such fire assembly shall be self-closing and shall be posted with a sign on each side of the door in 1-inch (25.4 mm) block letters stating: FIRE DOOR—KEEP CLOSED.

SECTION 311 — REQUIREMENTS FOR GROUP S OCCUPANCIES

311.1 Group S Occupancies Defined. Group S Occupancies shall include the use of a building or structure, or a portion thereof, for storage not classified as a hazardous occupancy. Storage occupancies shall include the following:

Division 1. Moderate hazard storage occupancies shall include buildings or portions of buildings used for storage of combustible materials that are not classified as a Group S, Division 2 or as a Group H Occupancy.

Division 2. Low-hazard storage occupancies shall include buildings, structures, or portions thereof, used for storage of noncombustible materials, such as products on wood pallets or in paper cartons with or without single-thickness divisions, or in paper wrappings and shall include ice plants, power plants and pumping plants. Such products may have a negligible amount of plastic trim such as knobs, handles or film wrapping. Low-hazard storage occupancies shall include, but are not limited to, storage of the following items:

1. Beer or wine (in metal, glass or ceramic containers).
2. Cement in bags.
3. Cold storage and creameries.
4. Dairy products in nonwax-coated paper containers.
5. Dry-cell batteries.
6. Dryers.
7. Dry pesticides in a building not classed as a Group H Occupancy.
8. Electrical coils.
9. Electrical insulators.
10. Electrical motors.
11. Empty cans.
12. Foods in noncombustible containers.
13. Fresh fruits in nonplastic trays or containers.
14. Frozen foods.
15. Glass bottles (empty or filled with nonflammable liquids).
16. Gypsum board.
17. Inert pigments.
18. Meats.
19. Metal cabinets.
20. Metal furniture.
21. Oil-filled distribution transformers.
22. Stoves.
23. Washers.

Division 3. Division 3 Occupancies shall include repair garages where work is limited to exchange of parts and maintenance requiring no open flame or welding, motor vehicle fuel-dispensing stations, and parking garages not classed as Group S, Division 4 open parking garages or Group U private garages.

For the use of flammable and combustible liquids, see Section 307 and the Fire Code.

Division 4. Open parking garages per Section 311.9.

Division 5. Aircraft hangars where work is limited to exchange of parts and maintenance requiring no open flame or welding and helistops.

For occupancy separations, see Table 3-B.

311.2 Construction, Height and Allowable Area.

311.2.1 General. Buildings or parts of buildings classed in Group S Occupancy because of the use or character of the occupancy shall be limited to the types of construction set forth in Table 5-B and shall not exceed, in area or height, the limits specified in Sections 504, 505 and 506.

311.2.2 Special provisions.

311.2.2.1 Group S, Division 3 with Group A, Division 3; Group B; Group M or R, Division 1 Occupancy above. Other provisions of this code notwithstanding, a basement or first story of a building may be considered as a separate and distinct building for the purpose of area limitations, limitation of number of stories and type of construction, when all of the following conditions are met:

1. The basement or first story is of Type I construction and is separated from the building above with a three-hour occupancy separation. See Section 302.3.

2. The building above the three-hour occupancy separation contains only Group A, Division 3; Group B; or Group M or R, Division 1 Occupancies.

3. The building below the three-hour occupancy separation is a Group S, Division 3 Occupancy used exclusively for the parking and storage of private or pleasure-type motor vehicles.

> **EXCEPTIONS:** 1. Entry lobbies, mechanical rooms and similar uses incidental to the operation of the building.
>
> 2. Group A, Division 3 and Group B office, drinking and dining establishments and Group M retail occupancies in addition to those uses incidental to the operation of the building (including storage areas), provided that the entire structure below the three-hour occupancy separation is protected throughout by an automatic sprinkler system.

4. The maximum building height in feet shall not exceed the limits set forth in Table 5-B for the least type of construction involved.

311.2.2.2 Group S, Division 3 Occupancy with Group S, Division 4 Occupancy above. Other provisions of this code notwithstanding, a Group S, Division 3 Occupancy, located in the basement or first story below a Group S, Division 4 Occupancy, as defined in Section 311.9, may be classified as a separate and distinct building for the purpose of determining the type of construction when all of the following conditions are met:

1. The allowable area of the structure shall be such that the sum of the ratios of the actual area divided by the allowable area for each separate occupancy shall not exceed one.

2. The Group S, Division 3 Occupancy is of Type I or II construction and is at least equal to the fire resistance of the Group S, Division 4 Occupancy.

3. The height and the number of the tiers above the basement shall be limited as specified in Table 3-H or Section 311.9.5.

4. The floor-ceiling assembly separating the Group S, Division 3 and Group S, Division 4 Occupancy shall be protected as required for the floor-ceiling assembly of the Group S, Division 3 Occupancy. Openings between the Group S, Division 3 and Group S, Division 4 Occupancy, except exit openings, need not be protected.

5. The Group S, Division 3 Occupancy is used exclusively for the parking or storage of private or pleasure-type motor vehicles, but may contain (i) mechanical equipment rooms incidental to the operation of the building and (ii) an office, and waiting and toilet rooms having a total area of not more than 1,000 square feet (93 m^2).

311.2.3 Specific use provisions.

311.2.3.1 Group S, Divisions 3 and 5 Occupancies. In areas where motor vehicles, boats or aircraft are stored, and in motor vehicle fuel-dispensing stations and repair garages, floor surfaces shall be of noncombustible, nonabsorbent materials. Floors shall drain to an approved oil separator or trap discharging to sewers in accordance with the Plumbing Code.

> **EXCEPTION:** Floors may be surfaced or waterproofed with asphaltic paving materials in areas where motor vehicles or airplanes are stored or operated.

311.2.3.2 Marine or motor vehicle fuel-dispensing stations. Marine or motor vehicle fuel dispensing stations, including canopies and supports over fuel dispensers, shall be of noncombustible, fire-retardant-treated wood or of one-hour fire-resistive construction.

> **EXCEPTIONS:** 1. Roofs of one-story fuel-dispensing stations may be of heavy-timber construction.
>
> 2. Canopies conforming to Section 2603.13 may be erected over pumps.

Canopies under which fuels are dispensed shall have a clear, unobstructed height of not less than 13 feet 6 inches (4114 mm) to the lowest projecting element in the vehicle drive-through area.

A one-hour occupancy separation need not be provided between fuel dispensers covered with a canopy that is open on three or more sides, and a Group M Occupancy retail store having an area of less than 2,500 square feet (232 m^2) when the following conditions exist:

1. The Group M Occupancy is provided with two exits or exit-access doorways separated as required by Section 1004.2.4 and not located in the same exterior wall.

2. Fuel-dispenser islands are not located within 20 feet (6096 mm) of the Group M Occupancy retail store.

311.2.3.3 Parking garage headroom. Parking garages shall have an unobstructed headroom clearance of not less than 7 feet (2134 mm) above the finish floor to any ceiling, beam, pipe or similar obstruction, except for wall-mounted shelves, storage surfaces, racks or cabinets.

311.2.3.4 Group S, Division 2 Occupancy roof framing. In Division 2 Occupancies, the roof-framing system may be of unprotected construction.

311.2.3.5 Vehicle barriers. In parking garages where any parking area is located more than 5 feet (1524 mm) above the adjacent grade, vehicle barriers shall be provided.

> **EXCEPTION:** Parking garages of Group U, Division 1 Occupancies.

Vehicle barriers shall have a minimum vertical dimension of 12 inches (305 mm) and shall be centered at 18 inches (457 mm) above the parking surface. See Table 16-B for load criterion.

311.3 Location on Property. For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 503.

311.4 Access and Means of Egress Facilities. Means of egress shall be provided as specified in Chapter 10.

Access to, and egress from, buildings required to be accessible shall be provided as specified in Chapter 11.

311.5 Light, Ventilation and Sanitation. In Group S Occupancies, light, ventilation and sanitation shall be as contained in Chapters 12 and 29, except as noted below.

311.5.1 Repair and storage garages, aircraft hangars. See Section 1202.2.6 for ventilation requirements for Group S, Division 3 repair garages, storage garages and Group S, Division 5 aircraft hangars.

311.5.2 Parking garages. See Section 1202.2.7 for ventilation requirements for parking garages.

311.6 Shaft and Exit Enclosures. Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts and other openings through floors shall be enclosed, and the enclosure shall be as specified in Section 711.

> **EXCEPTION:** In Group S, Division 2 Occupancies, exits shall be enclosed as specified in Chapter 10, but other through-floor openings need not be enclosed.

In buildings housing Group S Occupancies equipped with automatic sprinkler systems throughout, enclosures need not be provided for escalators where the top of the escalator opening at each story is provided with a draft curtain and automatic fire sprinklers are installed around the perimeter of the opening within 2 feet (610 mm) of the draft curtain. The draft curtain shall enclose the perimeter of the unenclosed opening and extend from the ceiling downward at least 12 inches (305 mm) on all sides. The spacing between sprinklers shall not exceed 6 feet (1829 mm).

311.7 Sprinkler and Standpipe Systems. When required by Section 904.2 or other provisions of this code, automatic sprinkler systems and standpipes shall be installed as specified in Chapter 9.

311.8 Special Hazards. Storage and use of flammable and combustible liquids shall be in accordance with the Fire Code.

Devices generating a glow, spark or flame capable of igniting flammable vapors shall be installed such that sources of ignition are at least 18 inches (457 mm) above the floor of any room in which Class I flammable liquids or flammable gases are used or stored.

Buildings erected or converted to house high-piled combustible stock or aerosols shall comply with the Fire Code.

311.9 Group S, Division 4 Open Parking Garages.

311.9.1 Scope. Except where specific provisions are made in the following sections, other requirements of this code shall apply.

311.9.2 Definitions.

311.9.2.1 General. For the purpose of this section, certain terms are defined as follows:

MECHANICAL-ACCESS OPEN PARKING GARAGES are open parking garages employing parking machines, lifts, elevators or other mechanical devices for vehicles moving from and to street level and in that public occupancy is prohibited above the street level.

OPEN PARKING GARAGE is a structure of Type I or II construction with the openings as described in Section 311.9.2.2 on two or more sides and that is used exclusively for the parking or storage of private or pleasure-type motor vehicles.

> **EXCEPTION:** The grade-level tier may contain an office, and waiting and toilet rooms having a total area of not more than 1,000 square feet (93 m^2). Such area need not be separated from the open parking garage.

RAMP-ACCESS OPEN PARKING GARAGES are open parking garages employing a series of continuously rising floors or a series of interconnecting ramps between floors permitting the movement of vehicles under their own power from and to the street level.

311.9.2.2 Openings. For natural ventilation purposes, the exterior side of the structure shall have uniformly distributed openings on two or more sides. The area of such openings in exterior walls on a tier must be at least 20 percent of the total perimeter wall area of each tier. The aggregate length of the openings considered to be providing natural ventilation shall constitute a minimum of 40 percent of the perimeter of the tier. Interior wall lines and column lines shall be at least 20 percent open with uniformly distributed openings.

311.9.3 Construction. Construction shall be of noncombustible materials. Open parking garages shall meet the design requirements of Chapter 16. For vehicle barriers, see Section 311.2.3.5.

311.9.4 Area and height. Area and height of open parking garages shall be limited as set forth in Table 3-H, except for increases allowed by Section 311.9.5.

In structures having a spiral or sloping floor, the horizontal projection of the structure at any cross section shall not exceed the allowable area per parking tier. In the case of a structure having a continuous spiral floor, each 9 feet 6 inches (2896 mm) of height, or portion thereof, shall be considered a tier.

The clear height of a parking tier shall not be less than 7 feet (2134 mm), except that a lower clear height may be permitted in mechanical-access open parking garages when approved by the building official.

311.9.5 Area and height increases. The area and height of structures with cross ventilation throughout may be increased in accordance with provisions of this section. Structures with sides open on three fourths of the building perimeter may be increased by 25 percent in area and one tier in height. Structures with sides open around the entire building perimeter may be increased 50 percent in area and one tier in height. For a side to be considered open under the above provisions, the total area of openings along the side shall not be less than 50 percent of the interior area of the side at each tier, and such openings shall be equally distributed along the length of the tier.

Open parking garages constructed to heights less than the maximums established by Table 3-H may have individual tier areas exceeding those otherwise permitted, provided the gross tier area of the structure does not exceed that permitted for the higher structure. At least three sides of each such larger tier shall have continuous horizontal openings not less than 30 inches (762 mm) in clear height extending for at least 80 percent of the length of the sides, and no part of such larger tier shall be more than 200 feet (60 960 mm) horizontally from such an opening. In addition, each such opening shall face a street or yard accessible to a street with a width of at least 30 feet (9144 mm) for the full length of the opening, and standpipes shall be provided in each such tier.

Structures of Type II-F.R., Type II One-hour or Type II-N construction, with all sides open, may be unlimited in area when the height does not exceed 75 feet (22 860 mm). For a side to be considered open, the total area of openings along the side shall not be less than 50 percent of the interior area of the side at each tier, and such openings shall be equally distributed along the length of the tier. All portions of tiers shall be within 200 feet (60 960 mm) horizontally from such openings.

311.9.6 Location on property. Exterior walls and openings in exterior walls shall comply with Table 5-A. The distance from an adjacent property line shall be determined in accordance with Section 503.

311.9.7 Stairs and means of egress. Where persons other than parking attendants are permitted, the means of egress shall meet the requirements of Chapter 10, based on an occupant load of 200 square feet (18.6 m^2) per occupant. Where no persons other than parking attendants are permitted, there shall not be less than two 3-foot-wide (914 mm) stairs. Lifts may be installed for use of employees only, provided they are completely enclosed by noncombustible materials.

311.9.8 Standpipes. Standpipes shall be installed when required by the provisions of Chapter 9.

311.9.9 Sprinkler systems. When required by other provisions of this code, automatic sprinkler systems and standpipes shall be installed in accordance with the provisions of Chapter 9.

311.9.10 Enclosure of vertical openings. Enclosure shall not be required for vertical openings except as specified in Section 311.9.7 for lifts.

311.9.11 Ventilation. Ventilation, other than the percentage of openings specified in Section 311.9.2.2, shall not be required.

311.9.12 Prohibitions. The following uses and alterations are not permitted:

1. Automobile repair work.
2. Parking of buses, trucks and similar vehicles.
3. Partial or complete closing of required openings in exterior walls by tarpaulins or any other means.
4. Dispensing of fuel.

311.10 Helistops.

311.10.1 General. Helistops may be erected on buildings or other locations if they are constructed in accordance with this section.

311.10.2 Size. The touchdown or landing area for helicopters of less than 3,500 pounds (1589 kg) shall be a minimum of 20 feet by 20 feet (6096 mm by 6096 mm) in size. The touchdown area shall be surrounded on all sides by a clear area having a minimum average width at roof level of 15 feet (4572 mm) but with no width less than 5 feet (1524 mm).

311.10.3 Design. Helicopter landing areas and supports therefor on the roof of a building shall be of noncombustible construction. Landing areas shall be designed to confine any Class I, II or III-A liquid spillage to the landing area itself and provision shall be made to drain such spillage away from any exit or stairway serving the helicopter landing area or from a structure housing such exit or stairway.

311.10.4 Means of egress. Means of egress from helistops shall comply with the provisions of Chapter 10 of this code, except that all landing areas located on buildings or structures shall have two or more means of egress. For landing platforms or roof areas less than 60 feet (18 288 mm) in length, or less than 2,000 square feet (186 m^2) in area, the second means of egress may be a fire escape or ladder leading to the floor below.

311.10.5 Federal Aviation Administration approval. Before operating helicopters from helistops, approval must be obtained from the Federal Aviation Administration.

SECTION 312 — REQUIREMENTS FOR GROUP U OCCUPANCIES

312.1 Group U Occupancies Defined. Group U Occupancies shall include buildings or structures, or portions thereof, and shall be:

Division 1. Private garages, carports, sheds and agricultural buildings.

> **EXCEPTION:** Where applicable (see Section 101.3) for agricultural buildings, see Appendix Chapter 3.

Division 2. Fences over 6 feet (1829 mm) high, tanks and towers.

For occupancy separations, see Table 3-B.

312.2 Construction, Height and Allowable Area.

312.2.1 General. Buildings or parts of buildings classed as Group U, Division 1 Occupancies because of the use or character of the occupancy shall not exceed 1,000 square feet (92.9 m^2) in area or one story in height except as provided in Section 312.2.2. Any building or portion thereof that exceeds the limitations specified in this chapter shall be classed in the occupancy group other than Group U, Division 1 that it most nearly resembles.

312.2.2 Special area provisions. The total area of a private garage used only as a parking garage for private or pleasure-type motor vehicles where no repair work is done or fuel dispensed may be 3,000 square feet (279 m^2), provided the provisions set forth in Item 1 or 2 are satisfied. More than one 3,000-square-foot (279 m^2) Group U, Division 1 Occupancy may be within the same building, provided each 3,000-square-foot (279 m^2) area is separated by area separation walls complying with Section 504.6.

1. For a mixed-occupancy building, the exterior wall and opening protection for the Group U, Division 1 portion of the building shall be as required for the major occupancy of the building. For such mixed-occupancy building, the allowable floor area of the building shall be as permitted for the major occupancy contained therein.

2. For a building containing only a Group U, Division 1 Occupancy, the exterior wall and opening protection shall be as required for a building classified as a Group R, Division 1 Occupancy.

312.2.3 Headroom clearance. Garages in connection with Group R, Division 1 Occupancies shall have an unobstructed headroom clearance of not less than 7 feet (2134 mm) above the finish floor to any ceiling, beam, pipe or similar construction except for wall-mounted shelves, storage surfaces, racks or cabinets.

312.3 Location on Property. For fire-resistive protection of exterior walls and openings, as determined by location on property, see Section 503 and Chapter 6.

312.4 Special Hazards. Chimneys and heating apparatus shall conform to the requirements of Chapter 31 and the Mechanical Code.

Under no circumstances shall a private garage have any opening into a room used for sleeping purposes.

Class I, II or III-A liquids shall not be stored, handled or used in Group U Occupancies unless such storage or handling shall comply with the Fire Code.

312.5 Garage Floor Surfaces. In areas where motor vehicles are stored or operated, floor surfaces shall be of noncombustible materials or asphaltic paving materials.

312.6 Agricultural Buildings. Where applicable (see Section 101.3) for agricultural buildings, see Appendix Chapter 3.

TABLE 3-A—DESCRIPTION OF OCCUPANCIES BY GROUP AND DIVISION[1]

GROUP AND DIVISION	SECTION	DESCRIPTION OF OCCUPANCY
A-1	303.1.1	A building or portion of a building having an assembly room with an occupant load of 1,000 or more and a legitimate stage.
A-2		A building or portion of a building having an assembly room with an occupant load of less than 1,000 and a legitimate stage.
A-2.1		A building or portion of a building having an assembly room with an occupant load of 300 or more without a legitimate stage, including such buildings used for educational purposes and not classed as a Group E or Group B Occupancy.
A-3		Any building or portion of a building having an assembly room with an occupant load of less than 300 without a legitimate stage, including such buildings used for educational purposes and not classed as a Group E or Group B Occupancy.
A-4		Stadiums, reviewing stands and amusement park structures not included within other Group A Occupancies.
B	304.1	A building or structure, or a portion thereof, for office, professional or service-type transactions, including storage of records and accounts; eating and drinking establishments with an occupant load of less than 50.
E-1	305.1	Any building used for educational purposes through the 12th grade by 50 or more persons for more than 12 hours per week or four hours in any one day.
E-2		Any building used for educational purposes through the 12th grade by less than 50 persons for more than 12 hours per week or four hours in any one day.
E-3		Any building or portion thereof used for day-care purposes for more than six persons.
F-1	306.1	Moderate-hazard factory and industrial occupancies include factory and industrial uses not classified as Group F, Division 2 Occupancies.
F-2		Low-hazard factory and industrial occupancies include facilities producing noncombustible or nonexplosive materials that during finishing, packing or processing do not involve a significant fire hazard.
H-1	307.1	Occupancies with a quantity of material in the building in excess of those listed in Table 3-D that present a high explosion hazard as listed in Section 307.1.1.
H-2		Occupancies with a quantity of material in the building in excess of those listed in Table 3-D that present a moderate explosion hazard or a hazard from accelerated burning as listed in Section 307.1.1.
H-3		Occupancies with a quantity of material in the building in excess of those listed in Table 3-D that present a high fire or physical hazard as listed in Section 307.1.1.
H-4		Repair garages not classified as Group S, Division 3 Occupancies.
H-5		Aircraft repair hangars not classified as Group S, Division 5 Occupancies and heliports.
H-6	307.1 and 307.11	Semiconductor fabrication facilities and comparable research and development areas when the facilities in which hazardous production materials are used, and the aggregate quantity of material is in excess of those listed in Table 3-D or 3-E.
H-7	307.1	Occupancies having quantities of materials in excess of those listed in Table 3-E that are health hazards as listed in Section 307.1.1.
I-1.1	308.1	Nurseries for the full-time care of children under the age of six (each accommodating more than five children), hospitals, sanitariums, nursing homes with nonambulatory patients and similar buildings (each accommodating more than five patients).
I-1.2		Health-care centers for ambulatory patients receiving outpatient medical care which may render the patient incapable of unassisted self-preservation (each tenant space accommodating more than five such patients).
I-2		Nursing homes for ambulatory patients, homes for children six years of age or over (each accommodating more than five persons).
I-3		Mental hospitals, mental sanitariums, jails, prisons, reformatories and buildings where personal liberties of inmates are similarly restrained.
M	309.1	A building or structure, or a portion thereof, for the display and sale of merchandise, and involving stocks of goods, wares or merchandise, incidental to such purposes and accessible to the public.
R-1	310.1	Hotels and apartment houses, congregate residences (each accommodating more than 10 persons).
R-3		Dwellings, lodging houses, congregate residences (each accommodating 10 or fewer persons).
S-1	311.1	Moderate hazard storage occupancies including buildings or portions of buildings used for storage of combustible materials not classified as Group S, Division 2 or Group H Occupancies.
S-2		Low-hazard storage occupancies including buildings or portions of buildings used for storage of noncombustible materials.
S-3		Repair garages where work is limited to exchange of parts and maintenance not requiring open flame or welding, and parking garages not classified as Group S, Division 4 Occupancies.
S-4		Open parking garages.
S-5		Aircraft hangars and helistops.
U-1	312.1	Private garages, carports, sheds and agricultural buildings.
U-2		Fences over 6 feet (1829 mm) high, tanks and towers.

[1]For detailed descriptions, see the occupancy definitions in the noted sections.

TABLE 3-B—REQUIRED SEPARATION IN BUILDINGS OF MIXED OCCUPANCY[1] (HOURS)

	A-1	A-2	A-2.1	A-3	A-4	B	E	F-1	F-2	H-2	H-3	H-4,5	H-6,7[2]	I	M	R-1	R-3	S-1	S-2	S-3	S-5	U-1[3]
A-1		N	N	N	N	3	N	3	3	4	4	4	4	3	3	1	1	3	3	4	3	1
A-2			N	N	N	1	N	1	1	4	4	4	4	3	1	1	1	1	1	3	1	1
A-2.1				N	N	1	N	1	1	4	4	4	4	3	1	1	1	1	1	3	1	1
A-3					N	N	N	N	N	4	4	4	3	2	N	1	1	N	N	3	1	1
A-4						1	N	1	1	4	4	4	4	3	1	1	1	1	1	3	1	1
B							1	N[5]	N	2	1	1	1	2	N	1	1	N	N	1	1	1
E								1	1	4	4	4	3	1	1	1	1	1	1	3	1	1
F-1									1	2	1	1	1	3	N[5]	1	1	N	N	1	1	1
F-2										2	1	1	1	2	1	1	1	N	N	1	1	1
H-1	NOT PERMITTED IN MIXED OCCUPANCIES. SEE SECTION 307.2.8																					
H-2											1	1	2	4	2	4	4	2	2	2	2	1
H-3												1	1	4	1	3	3	1	1	1	1	1
H-4,5													1	4	1	3	3	1	1	1	1	1
H-6,7[2]														4	1	4	4	1	1	1	1	3
I															2	1	1	2	2	4	3	1
M																1	1	1[4]	1[4]	1	1	1
R-1																	N	3	1	3	1	1
R-3																		1	1	1	1	1
S-1																			1	1	1	1
S-2																				1	1	N
S-3																					1	1
S-4	OPEN PARKING GARAGES ARE EXCLUDED EXCEPT AS PROVIDED IN SECTION 311.2																					
S-5																						N

N—No requirements for fire resistance.

[1]For detailed requirements and exceptions, see Section 302.4.

[2]For special provisions on highly toxic materials, see the Fire Code.

[3]For agricultural buildings, see also Appendix Chapter 3.

[4]See Section 309.2.2 for exception.

[5]For Group F, Division 1 woodworking establishments with more than 2,500 square feet (232.3 m^2), the occupancy separation shall be one hour.

TABLE 3-C—REQUIRED SEPARATION OF SPECIFIC-USE AREAS IN GROUP I, DIVISION 1.1 HOSPITAL AND NURSING HOMES

DESCRIPTION	OCCUPANCY SEPARATION
1. Employee locker rooms	None
2. Gift/retail shops	None
3. Handicraft shops	None
4. Kitchens	None
5. Laboratories that employ hazardous materials in quantities less than that which would cause classification as a Group H Occupancy	One hour
6. Laundries greater than 100 square feet (9.3 m^2)[1]	One hour
7. Paint shops employing hazardous substances and materials in quantities less than that which would cause classification as a Group H Occupancy	One hour
8. Physical plant maintenance shop	One hour
9. Soiled linen room[1]	One hour
10. Storage rooms 100 square feet (9.3 m^2) or less in area storing combustible material	None
11. Storage rooms more than 100 square feet (9.3 m^2) storing combustible material	One hour
12. Trash-collection rooms[1]	One hour

[1]For rubbish and linen chute termination rooms, see Section 711.5.

TABLE 3-D—EXEMPT AMOUNTS OF HAZARDOUS MATERIALS PRESENTING A PHYSICAL HAZARD MAXIMUM QUANTITIES PER CONTROL AREA[1]

When two units are given, values within parentheses are in cubic feet (cu. ft.) or pounds (lbs.)

CONDITION		STORAGE[2]			USE[2]—CLOSED SYSTEMS			USE[2]—OPEN SYSTEMS	
		Solid Lbs.[3] (Cu. Ft.)	Liquid Gallons[3] (Lbs.)	Gas Cu. Ft.	Solid Lbs. (Cu. Ft.)	Liquid Gallons (Lbs.)	Gas Cu. Ft.	Solid Lbs. (Cu. Ft.)	Liquid Gallons (Lbs.)
Material	Class	× 0.4536 for kg × 0.0283 for m^3	× 3.785 for L × 0.4536 for kg	× 0.0283 for m^3	× 0.4536 for kg × 0.0283 for m^3	× 3.785 for L × 0.4536 for kg	× 0.0283 for m^3	× 0.4536 for kg × 0.0283 for m^3	× 3.785 for L × 0.4536 for kg
1.1 Combustible liquid[4,5,6,7,8,9]	II	N.A.	120[10]	N.A.	N.A.	120	N.A.	N.A.	30
	III-A	N.A.	330[10]	N.A.	N.A.	330	N.A.	N.A.	80
	III-B	N.A.	13,200[10,11]	N.A.	N.A.	13,200[11]	N.A.	N.A.	3,300[11]
1.2 Combustible fiber (loose) (baled)		(100) (1,000)	N.A. N.A.	N.A. N.A.	(100) (1,000)	N.A. N.A.	N.A. N.A.	(20) (200)	N.A. N.A.
1.3 Cryogenic, flammable or oxidizing		N.A.	45	N.A.	N.A.	45	N.A.	N.A.	10
2.1 Explosives		1[10,13]	(1)[10,13]	N.A.	1/4[12]	(1/4)[12]	N.A.	1/4[12]	(1/4)[12]
3.1 Flammable solid		125[6,10]	N.A.	N.A.	[14]	N.A.	N.A.	[14]	N.A.
3.2 Flammable gas (gaseous) (liquefied)		N.A. N.A.	N.A. 15[6,10]	750[6,10] N.A.	N.A. N.A.	N.A. 15[6,10]	750[6,10] N.A.	N.A. N.A.	N.A. N.A.
3.3 Flammable liquid[4,5,6,7,8,9]	I-A	N.A.	30[10]	N.A.	N.A.	30	N.A.	N.A.	10
	I-B	N.A.	60[10]	N.A.	N.A.	60	N.A.	N.A.	15
	I-C	N.A.	90[10]	N.A.	N.A.	90	N.A.	N.A.	20
Combination I-A, I-B, I-C[15]		N.A.	120[10]	N.A.	N.A.	120	N.A.	N.A.	30
4.1 Organic peroxide, unclassified detonatable		1[10,12]	(1)[10,12]	N.A.	1/4[12]	(1/4)[12]	N.A.	1/4[12]	(1/4)[12]
4.2 Organic peroxide	I	5[6,10]	(5)[6,10]	N.A.	1[6]	(1)[6]	N.A.	1[6]	(1)[6]
	II	50[6,10]	(50)[6,10]	N.A.	50[6]	(50)[6]	N.A.	10[6]	(10)[6]
	III	125[6,10]	(125)[6,10]	N.A.	125[6]	(125)[6]	N.A.	25[6]	(25)[6]
	IV	500[6,10]	(500)[6,10]	N.A.	500[6]	(500)[6]	N.A.	100[6]	(100)[6]
	V	N.L.	N.L.	N.A.	N.L.	N.L.	N.A.	N.L.	N.L.
4.3 Oxidizer	4	1[10,12]	(1)[10,12]	N.A.	1/4[12]	(1/4)[12]	N.A.	1/4[12]	(1/4)[12]
	3[16]	10[6,10]	(10)[6,10]	N.A.	2[6]	(2)[6]	N.A.	2[6]	(2)[6]
	2	250[6,10]	(250)[6,10]	N.A.	250[6]	(250)[6]	N.A.	50[6]	(50)[6]
	1	4,000[6,10]	(4,000)[6,10]	N.A.	4,000[6]	(4,000)[6]	N.A.	1,000[6]	(1,000)[6]
4.4 Oxidizer—gas (gaseous)[6,10] (liquefied)[6,10]		N.A. N.A.	N.A. 15	1,500 N.A.	N.A. N.A.	N.A. 15	1,500 N.A.	N.A. N.A.	N.A. N.A.
5.1 Pyrophoric		4[10,12]	(4)[10,12]	50[10,12]	1[12]	(1)[12]	10[10,12]	0	0
6.1 Unstable (reactive)	4	1[10,12]	(1)[10,12]	10[10,12]	1/4[12]	(1/4)[12]	2[10,12]	1/4[12]	(1/4)[12]
	3	5[6,10]	(5)[6,10]	50[6,10]	1[6]	(1)[6]	10[6,10]	1[6]	(1)[6]
	2	50[6,10]	(50)[6,10]	250[6,10]	50[6]	(50)[6]	250[6,10]	10[6]	(10)[6]
	1	N.L.	N.L.	750[6,10]	N.L.	N.L.	N.L.	N.L.	N.L.
7.1 Water reactive	3	5[6,10]	(5)[6,10]	N.A.	5[6]	(5)[6]	N.A.	1[6]	(1)[6]
	2	50[6,10]	(50)[6,10]	N.A.	50[6]	(50)[6]	N.A.	10[6]	(10)[6]
	1	125[10,11]	(125)[10,11]	N.A.	125[11]	(125)[11]	N.A.	25[11]	(25)[11]

N.A.—Not applicable. N.L.—Not limited.

[1]Control areas shall be separated from each other by not less than a one-hour fire-resistive occupancy separation. The number of control areas within a building used for retail or wholesale sales shall not exceed two. The number of control areas in buildings with other uses shall not exceed four. See Section 204.

[2]The aggregate quantity in use and storage shall not exceed the quantity listed for storage.

[3]The aggregate quantity of nonflammable solid and nonflammable or noncombustible liquid hazardous materials within a single control area of Group M Occupancies used for retail sales may exceed the exempt amounts when such areas are in compliance with the Fire Code.

[4]The quantities of alcoholic beverages in retail sales uses are unlimited provided the liquids are packaged in individual containers not exceeding 4 liters. The quantities of medicines, foodstuffs and cosmetics containing not more than 50 percent of volume of water-miscible liquids and with the remainder of the solutions not being flammable in retail sales or storage occupancies are unlimited when packaged in individual containers not exceeding 4 liters.

[5]For aerosols, see the Fire Code.

[6]Quantities may be increased 100 percent in sprinklered buildings. When Footnote 10 also applies, the increase for both footnotes may be applied.

[7]For storage and use of flammable and combustible liquids in Groups A, B, E, F, H, I, M, R, S and U Occupancies, see Sections 303.8, 304.8, 305.8, 306.8, 307.1.3 through 307.1.5, 308.8, 309.8, 310.12, 311.8 and 312.4.

[8]For wholesale and retail sales use, also see the Fire Code.

[9]Spray application of any quantity of flammable or combustible liquids shall be conducted as set forth in the Fire Code.

[10]Quantities may be increased 100 percent when stored in approved storage cabinets, gas cabinets or exhausted enclosures as specified in the Fire Code. When Footnote 6 also applies, the increase for both footnotes may be applied.

[11]The quantities permitted in a sprinklered building are not limited.

[12]Permitted in sprinklered buildings only. None is allowed in unsprinklered buildings.

[13]One pound of black sporting powder and 20 pounds (9 kg) of smokeless powder are permitted in sprinklered or unsprinklered buildings.

[14]See definitions of Divisions 2 and 3 in Section 307.1.

FOOTNOTES TO TABLE 3-D—(Continued)

[15]Containing not more than the exempt amounts of Class I-A, Class I-B or Class I-C flammable liquids.
[16]A maximum quantity of 200 pounds (90.7 kg) of solid or 20 gallons (75.7 L) of liquid Class 3 oxidizers may be permitted when such materials are necessary for maintenance purposes or operation of equipment as set forth in the Fire Code.

TABLE 3-E—EXEMPT AMOUNTS OF HAZARDOUS MATERIALS PRESENTING A HEALTH HAZARD MAXIMUM QUANTITIES PER CONTROL AREA[1,2]

When two units are given, values within parentheses are in pounds (lbs.)

MATERIAL	STORAGE[3]			USE[3]—CLOSED SYSTEMS			USE[3]—OPEN SYSTEMS	
	Solid Lbs.[4,5,6]	Liquid Gallons[4,5,6] (Lbs.)	Gas Cu. Ft.[5]	Solid Lbs.[4,5]	Liquid Gallons[4,5] (Lbs.)	Gas Cu. Ft.[5]	Solid Lbs.[4,5]	Liquid Gallons[4,5] (Lbs.)
	× 0.4536 for kg	× 3.785 for L × 0.4536 for kg	× 0.028 for m³	× 0.4536 for kg	× 3.785 for L × 0.4536 for kg	× 0.028 for m³	× 0.4536 for kg	× 3.785 for L × 0.4536 for kg
1. Corrosives[10]	5,000	500	810[6]	5,000	500	810[6]	1,000	100
2. Highly toxics[7]	10	(10)	20[8]	10	(10)	20[8]	3	(3)
3. Irritants[9]	N.L.	N.L.	810[6,11]	N.L.	N.L.	810[6,11]	5,000[11]	500[11]
4. Sensitizers[9]	N.L.	N.L.	810[6,11]	N.L.	N.L.	810[6,11]	5,000[11]	500[11]
5. Other health hazards[9]	N.L.	N.L.	810[6,11]	N.L.	N.L.	810[6,11]	5,000[11]	500[11]
6. Toxics[7]	500	(500)	810[6]	500	(500)	810[8]	125	(125)

N.L. = Not limited.

[1]Control areas shall be separated from each other by not less than a one-hour fire-resistive occupancy separation. The number of control areas within a building used for retail or wholesale sales shall not exceed two. The number of control areas in buildings with other uses shall not exceed four. See Section 204.
[2]The quantities of medicines, foodstuffs and cosmetics, containing not more than 50 percent by volume of water-miscible liquids and with the remainder of the solutions not being flammable, in retail sales uses are unlimited when packaged in individual containers not exceeding 4 liters.
[3]The aggregate quantity in use and storage shall not exceed the quantity listed for storage.
[4]The aggregate quantity of nonflammable solid and nonflammable or noncombustible liquid health hazard materials within a single control area of Group M Occupancies used for retail sales may exceed the exempt amounts when such areas are in compliance with the Fire Code.
[5]Quantities may be increased 100 percent in sprinklered buildings. When Footnote 6 also applies, the increase for both footnotes may be applied.
[6]Quantities may be increased 100 percent when stored in approved storage cabinets, gas cabinets or exhausted enclosures as specified in the Fire Code. When Footnote 5 also applies, the increase for both footnotes may be applied.
[7]For special provisions, see the Fire Code.
[8]Permitted only when stored in approved exhausted gas cabinets, exhausted enclosures or fume hoods.
[9]Irritants, sensitizers and other health hazards do not include commonly used building materials and consumer products that are not otherwise regulated by this code.
[10]For stationary lead-acid battery systems, see the Fire Code.
[11]The quantities allowed in a sprinklered building are not limited when exhaust ventilation is provided in accordance with the Fire Code. See Table 8001.15-B, Footnote 12.

TABLE 3-F—MINIMUM DISTANCES FOR BUILDINGS CONTAINING EXPLOSIVE MATERIALS

QUANTITY OF EXPLOSIVE MATERIAL[1]		MINIMUM DISTANCE (feet) × 304.8 for mm		
Pounds Over	Pounds Not Over	Property Lines[2] and Inhabited Buildings[3]		Separation of Magazines[4,5,6]
× 0.4536 for kg		Barricaded[4]	Unbarricaded	
2	5	70	140	12
5	10	90	180	16
10	20	110	220	20
20	30	125	250	22
30	40	140	280	24
40	50	150	300	28
50	75	170	340	30
75	100	190	380	32
100	125	200	400	36
125	150	215	430	38
150	200	235	470	42
200	250	255	510	46
250	300	270	540	48
300	400	295	590	54
400	500	320	640	58
500	600	340	680	62
600	700	355	710	64
700	800	375	750	66
800	900	390	780	70
900	1,000	400	800	72
1,000	1,200	425	850	78
1,200	1,400	450	900	82
1,400	1,600	470	940	86
1,600	1,800	490	980	88
1,800	2,000	505	1,010	90
2,000	2,500	545	1,090	98
2,500	3,000	580	1,160	104
3,000	4,000	635	1,270	116
4,000	5,000	685	1,370	122
5,000	6,000	730	1,460	130
6,000	7,000	770	1,540	136
7,000	8,000	800	1,600	144
8,000	9,000	835	1,670	150
9,000	10,000	865	1,730	156
10,000	12,000	875	1,750	164
12,000	14,000	885	1,770	174
14,000	16,000	900	1,800	180
16,000	18,000	940	1,880	188
18,000	20,000	975	1,950	196
20,000	25,000	1,055	2,000	210
25,000	30,000	1,130	2,000	224
30,000	35,000	1,205	2,000	238
35,000	40,000	1,275	2,000	248
40,000	45,000	1,340	2,000	258
45,000	50,000	1,400	2,000	270
50,000	55,000	1,460	2,000	280
55,000	60,000	1,515	2,000	290
60,000	65,000	1,565	2,000	300
65,000	70,000	1,610	2,000	310
70,000	75,000	1,655	2,000	320
75,000	80,000	1,695	2,000	330
80,000	85,000	1,730	2,000	340
85,000	90,000	1,760	2,000	350
90,000	95,000	1,790	2,000	360
95,000	100,000	1,815	2,000	370

(Continued)

TABLE 3-F—MINIMUM DISTANCES FOR BUILDINGS CONTAINING EXPLOSIVE MATERIALS—(Continued)

QUANTITY OF EXPLOSIVE MATERIAL[1]		MINIMUM DISTANCE (feet) × 304.8 for mm		
Pounds Over	Pounds Not Over	Property Lines[2] and Inhabited Buildings[3]		
× 0.4536 for kg		Barricaded[4]	Unbarricaded	Separation of Magazines[4,5,6]
100,000	110,000	1,835	2,000	390
110,000	120,000	1,855	2,000	410
120,000	130,000	1,875	2,000	430
130,000	140,000	1,890	2,000	450
140,000	150,000	1,900	2,000	470
150,000	160,000	1,935	2,000	490
160,000	170,000	1,965	2,000	510
170,000	180,000	1,990	2,000	530
180,000	190,000	2,010	2,010	550
190,000	200,000	2,030	2,030	570
200,000	210,000	2,055	2,055	590
210,000	230,000	2,100	2,100	630
230,000	250,000	2,155	2,155	670
250,000	275,000	2,215	2,215	720
275,000	300,000	2,275	2,275	770

[1]The number of pounds (kg) of explosives listed is the number of pounds of trinitrotoluene (TNT) or the equivalent pounds (kg) of other explosive.

[2]The distance listed is the distance to property line, including property lines at public ways.

[3]Inhabited building is any building on the same property that is regularly occupied by human beings. When two or more buildings containing explosives or magazines are located on the same property, each building or magazine shall comply with the minimum distances specified from inhabited buildings, and, in addition, they shall be separated from each other by not less than the distances shown for "Separation of Magazines," except that the quantity of explosive materials contained in detonator buildings or magazines shall govern in regard to the spacing of said detonator buildings or magazines from buildings or magazines containing other explosive materials. If any two or more buildings or magazines are separated from each other by less than the specified "Separation of Magazines" distances, then such two or more buildings or magazines, as a group, shall be considered as one building or magazine, and the total quantity of explosive materials stored in such group shall be treated as if the explosive were in a single building or magazine located on the site of any building or magazine of the group, and shall comply with the minimum distance specified from other magazines or inhibited buildings.

[4]Barricades shall effectively screen the building containing explosives from other buildings, public ways or magazines. When mounds or revetted walls of earth are used for barricades, they shall not be less than 3 feet (914 mm) in thickness. A straight line from the top of any side wall of the building containing explosive materials to the eave line of any other building, magazine or a point 12 feet (3658 mm) above the center line of a public way shall pass through the barricades.

[5]Magazine is a building or structure approved for storage of explosive materials. In addition to the requirements of this code, magazines shall comply with the Fire Code.

[6]The distance listed may be reduced by 50 percent when approved natural or artificial barriers are provided in accordance with the requirements in Footnote 4.

TABLE 3-G—REQUIRED DETACHED STORAGE

Material		DETACHED STORAGE IS REQUIRED WHEN THE QUANTITY OF MATERIAL EXCEEDS THAT LISTED: Solids and Liquids (tons)[1,2] × 907.2 for kg	Gases (cubic feet)[1,2] × 0.0283 for m³
1. Explosives, blasting agents, black powder, fireworks, detonatable organic peroxides 2. Class 4 oxidizers 3. Class 4 or Class 3 detonatable unstable (reactives)		Over exempt amounts	Over exempt amounts
4. Oxidizers, liquids and solids	Class 3 Class 2	1,200 2,000	N.A. N.A.
5. Organic peroxides	Class I Class II Class III	Over exempt amounts 25 50	N.A. N.A. N.A.
6. Unstable (reactives)	Class 4 Class 3 Class 2	1/1,000 1 25	20 2,000 10,000
7. Water reactives	Class 3 Class 2	1 25	N.A. N.A.
8. Pyrophoric gases		N.A.	2,000

N.A.—Not applicable.

[1]For materials that are detonable, the distance to other buildings or property lines shall be as specified in Table 3-F based on trinitrotoluene (TNT) equivalence of the material. For all other materials, the distance shall be as indicated in Table 5-A.

[2]Over exempt amounts mean over the quantities listed in Table 3-D.

TABLE 3-H—OPEN PARKING GARAGES AREA AND HEIGHT

TYPE OF CONSTRUCTION	AREA PER TIER (square feet) × 0.0929 for m²	HEIGHT (in tiers)		
		Ramp Access	Mechanical Access	
			Automatic Fire-extinguishing System	
			No	Yes
I	Unlimited	Unlimited	Unlimited	Unlimited
II-F.R.	125,000	12 tiers	12 tiers	18 tiers
II One-hour	50,000	10 tiers	10 tiers	15 tiers
II-N	30,000	8 tiers	8 tiers	12 tiers

Chapter 4
SPECIAL USE AND OCCUPANCY

SECTION 401 — SCOPE

In addition to the occupancy and construction requirements in this code, the provisions of this chapter apply to the special uses described herein.

SECTION 402 — ATRIA

402.1 General. Buildings, of other than Group H Occupancy, with automatic sprinkler protection throughout may have atria complying with the provisions of this section. Such atria shall have a minimum opening area and dimension as set forth in Table 4-A.

402.2 Smoke-control System. A smoke-control system meeting the requirements of Section 905 shall be provided within the atrium and areas open to the atrium. The smoke-control system shall operate automatically upon actuation of the automatic sprinkler system within the atrium or areas open to the atrium and as required by Section 905.9.

402.3 Enclosure of Atria. Atria shall be separated from adjacent spaces by not less than one-hour fire-resistive construction.

EXCEPTIONS: 1. The separation between atria and tenant spaces that are not guest rooms, congregate residences or dwelling units may be omitted at three floor levels.

2. Open exit-access balconies are permitted within the atrium.

Openings in the atrium enclosure other than fixed glazing shall be protected by smoke- and draft-control assemblies conforming to Section 1004.3.4.3.2.

EXCEPTION: Other tightfitting doors that are maintained automatic closing, in accordance with Section 713.2, by actuation of a smoke detector, or self-closing may be used when protected as required for glazed openings in Exception 2.

Fixed glazed openings in the atrium enclosure shall be equipped with fire windows having a fire-resistive rating of not less than three-fourths hour, and the total area of such openings shall not exceed 25 percent of the area of the common wall between the atrium and the room into which the opening is provided.

EXCEPTIONS: 1. In Group R, Division 1 Occupancies, openings may be unprotected when the floor area of each guest room, congregate residence or dwelling unit does not exceed 1,000 square feet (92.9 m^2) and each room or unit has an approved means of egress not entering the atrium.

2. Guest rooms, dwelling units, congregate residences and tenant spaces may be separated from the atrium by approved fixed wired glass set in steel frames. In lieu thereof, tempered or laminated glass or listed glass block may be used, subject to the following:

2.1 The glass shall be protected by a sprinkler system equipped with listed quick-response sprinklers. The sprinkler system shall completely wet the entire surface of the glass wall when actuated. Where there are walking surfaces on both sides of the glass, both sides of the glass shall be so protected.

2.2 The tempered or laminated glass shall be in a gasketed frame so installed that the glazing system may deflect without breaking (loading) the glass before the sprinkler system operates.

2.3 The glass block wall assembly shall be installed in accordance with its listing for a three-fourths-hour fire-resistive rating and Section 2110.

2.4 Obstructions such as curtain rods, drapery traverse rods, curtains, drapes or similar materials shall not be installed between the sprinkler and the glass.

402.4 Escalators and Elevators. Escalators and elevators located entirely within the atrium enclosure need not be enclosed unless required by Chapter 30.

402.5 Means of Egress.

402.5.1 Travel distance. Not more than 100 feet (30 480 mm) of the travel distance allowed by Section 1004.2.5 may be on an open exit-access balcony within the atrium.

402.5.2 Group I Occupancy means of egress. Required means of egress from sleeping rooms in Group I Occupancies other than jails, prisons and reformatories shall not pass through the atrium.

402.5.3 Stairs and ramps. Stairways and ramps in the atrium space shall be enclosed.

EXCEPTIONS: 1. Stairs and ramps not required for egress need not be enclosed.

2. Stairs and ramps connecting only the lowest two floors in the atrium space need not be enclosed.

3. Stairs and ramps connecting floor levels within a story need not be enclosed.

402.6 Occupancy Separation Exceptions. The vertical portion of the occupancy separation that is adjacent to the atrium may be omitted between a Group B Occupancy office, Group M Occupancy sales area or Group A, Division 3 Occupancy and Group R, Division 1 apartment, congregate residence or guest room located on another level.

402.7 Standby Power. Smoke control for the atrium and the smoke-control system for the tenant space shall be provided with standby power as required in Section 905.8.

402.8 Interior Finish. The interior finish of walls and ceilings of the atrium and all unseparated tenant spaces allowed under Exception 1 to the first paragraph of Section 402.3 shall be Class I with no reduction in class for sprinkler protection.

402.9 Acceptance of the Smoke-control System. Acceptance shall be as required by Section 905.15.

402.10 Combustible Furnishings in Atria. The quantity of combustible furnishings in atria shall not exceed that specified in the Fire Code.

SECTION 403 — SPECIAL PROVISIONS FOR GROUP B OFFICE BUILDINGS AND GROUP R, DIVISION 1 OCCUPANCIES

403.1 Scope. This section applies to all Group B office buildings and Group R, Division 1 Occupancies, each having floors used for human occupancy located more than 75 feet (22 860 mm) above the lowest level of fire department vehicle access. Such buildings shall be of Type I or II-F.R. construction and shall be provided with an approved automatic sprinkler system in accordance with Section 403.2.

403.2 Automatic Sprinkler System.

403.2.1 System design. The automatic sprinkler system shall be provided throughout the building as specified by UBC Standard 9-1, and shall be designed in accordance with that standard and the following:

1. Shutoff valves and a water-flow device shall be provided for each floor. The sprinkler riser may be combined with the standpipe riser.

2. In Seismic Zones 2, 3 and 4, in addition to the main water supply, a secondary on-site supply of water equal to the hydraulically calculated sprinkler design demand plus 100 gallons per minute (378.5 L/m) additional for the total standpipe system shall be provided. This supply shall be automatically available if the principal supply fails and shall have a duration of 30 minutes.

403.2.2 Modifications. The following modifications of code requirements are permitted:

1. In buildings of Type I construction, the fire-resistive time periods set forth in Table 6-A may be reduced by one hour for interior-bearing walls, exterior-bearing and nonbearing walls, roofs and the beams supporting roofs, provided they do not frame into columns. In buildings of Type II-F.R. construction, the fire-resistive time period set forth in Table 6-A may be reduced by one hour for interior-bearing walls, exterior-bearing and nonbearing walls, but no reduction is allowed for roofs. The fire-resistive time period reduction as specified herein shall not apply to exterior-bearing and nonbearing walls whose fire-resistive rating is less than four hours.

Shafts other than stairway enclosures and elevator shafts may be reduced to one hour when sprinklers are installed within the shafts at alternate floors.

2. Except for corridors in Group B offices and Group R, Division 1 Occupancies, and partitions separating dwelling units or guest rooms, all interior-nonbearing partitions required to be one-hour fire-resistive construction by Table 6-A may be of noncombustible construction without a fire-resistive time period.

3. Fire dampers, other than those needed to protect floor-ceiling assemblies to maintain the fire resistance of the assembly, are not required.

4. Emergency windows required by Section 310.4 are not required.

403.3 Smoke Detection. Smoke detectors shall be provided in accordance with this section. Smoke detectors shall be connected to an automatic fire alarm system installed in accordance with the Fire Code. The actuation of any detector required by this section shall operate the emergency voice alarm signaling system and shall place into operation all equipment necessary to prevent the recirculation of smoke.

Smoke detectors shall be located as follows:

1. In every mechanical equipment, electrical, transformer, telephone equipment, elevator machine or similar room and in elevator lobbies. Elevator lobby detectors shall be connected to an alarm verification zone or be listed as releasing devices.

2. In the main return-air and exhaust-air plenum of each air-conditioning system. Such detector shall be located in a serviceable area downstream of the last duct inlet.

3. At each connection to a vertical duct or riser serving two or more stories from a return-air duct or plenum of an air-conditioning system. In Group R, Division 1 Occupancies, an approved smoke detector may be used in each return-air riser carrying not more than 5,000 cubic feet per minute (2360 L/s) and serving not more than 10 air inlet openings.

4. For Group R, Division 1 Occupancies in all interior corridors serving as a means of egress for an occupant load of 10 or more.

403.4 Smoke Control. A smoke-control system meeting the requirements of Chapter 9 shall be provided.

403.5 Fire Alarm and Communication Systems.

403.5.1 General. The fire alarm, emergency voice/alarm signaling system and fire department communication systems shall be designed and installed as set forth in this code and the Fire Code.

403.5.2 Emergency voice alarm signaling system. The operation of any automatic fire detector, sprinkler or water-flow device shall automatically sound an alert tone followed by voice instructions giving appropriate information and direction on a general or selective basis to the following terminal areas:

1. Elevators.
2. Elevator lobbies.
3. Corridors.
4. Exit stairways.
5. Rooms and tenant spaces exceeding 1,000 square feet (93 m^2) in area.
6. Dwelling units in apartment houses.
7. Hotel guest rooms or suites.
8. Areas of refuge (as defined in Section 1102).

A manual override for emergency voice communication shall be provided for all paging zones.

403.5.3 Fire department communication system. A two-way, approved fire department communication system shall be provided for fire department use. It shall operate between the central control station and elevators, elevator lobbies, emergency and standby power rooms and at entries into enclosed stairways.

403.6 Central Control Station.

403.6.1 General. A central control station room for fire department operations shall be provided. The location and accessibility of the central control station room shall be approved by the fire department. The central control station room shall be separated from the remainder of the building by not less than a one-hour fire-resistive occupancy separation. The room shall be a minimum of 96 square feet (9 m^2) with a minimum dimension of 8 feet (2438 mm). It shall contain the following as a minimum:

1. The voice alarm and public address system panels.
2. The fire department communications panel.
3. Fire-detection and alarm system annunciator panels.
4. Annunciator visually indicating the location of the elevators and whether they are operational.
5. Status indicators and controls for air-handling systems.
6. Controls for unlocking all stairway doors simultaneously.
7. Sprinkler valve and water-flow detector display panels.
8. Emergency and standby power status indicators.
9. A telephone for fire department use with controlled access to the public telephone system.
10. Fire pump status indicators.
11. Schematic building plans indicating the typical floor plan and detailing the building core, means of egress, fire-protection systems, firefighting equipment and fire department access.
12. Work table.

403.6.2 Annunciation identification. Control panels in the central control station shall be permanently identified as to function.

Alarm. supervisory and trouble signals as required by Items 3 and 7 above shall be annunciated in compliance with the Fire Code in the central control station by means of an audible and visual indicator. For purposes of annunciation, zoning shall be in accordance with the following:

1. When the system serves more than one building, each building shall be considered separately.

2. Each floor shall be considered a separate zone. When one or more sprinkler risers serve the same floor, each riser shall be considered a separate zone.

EXCEPTION: When more than one riser serves the same system on the floor.

403.7 Elevators. Elevators and elevator lobbies shall comply with the provisions of Chapter 30 and the following:

NOTE: A bank of elevators is a group of elevators or a single elevator controlled by a common operating system; that is, all those elevators that respond to a single call button constitute a bank of elevators. There is no limit on the number of cars that may be in a bank or group, but there may not be more than four cars within a common hoistway.

1. Elevators on all floors shall open into elevator lobbies that are separated from the remainder of the building, including corridors and other means of egress, by walls extending from the floor to the underside of the fire-resistive floor or roof above. Such walls shall not be of less than one-hour fire-resistive construction. Openings through such walls shall conform to Section 1004.3.4.3.2.

EXCEPTIONS: 1. The main entrance-level elevator lobby inoffice buildings.

2. Elevator lobbies located within an atrium complying with the provisions of Section 402.

3. In fully sprinklered office buildings, corridors may lead through enclosed elevator lobbies if all areas of the building have access to at least one required means of egress without passing through the elevator lobby.

2. Each elevator lobby shall be provided with approved smoke detector(s) installed in accordance with their listings. When the detector is activated, elevator doors shall not open and all cars serving that lobby are to return to the main floor and be under manual control only. If the main floor detector or a transfer floor detector is activated, all cars serving the main floor or transfer floor shall return to a location approved by the fire department and building official and be under manual control only. The detector may serve to close the lobby doors, additional doors at the hoistway opening allowed in Section 3007 and smoke dampers serving the lobby.

3. Elevator hoistways shall not be vented through an elevator machine room. Each elevator machine room shall be treated as a separate smoke-control zone.

403.8 Standby Power, Light and Emergency Systems.

403.8.1 Standby power. A standby power-generator set conforming to the Electrical Code shall be provided on the premises. The set shall supply all functions required by this section at full power. Set supervisions with manual start and transfer override features shall be provided at the central control station.

An on-premises fuel supply sufficient for not less than two hours' full-demand operation of the system shall be provided.

The standby system shall have a capacity and rating that would supply all equipment required to be operational at the same time. The generating capacity need not be sized to operate all the connected electrical equipment simultaneously.

All power, lighting, signal and communication facilities specified in Sections 403.3, 403.4, 403.5, 403.6, 403.7 and 403.8, as applicable; fire pumps required to maintain pressure, standby lighting and normal circuits supplying exit signs and means of egress illumination shall be transferable to the standby source.

403.8.2 Standby lighting. Standby lighting shall be provided as follows:

1. Separate lighting circuits and fixtures sufficient to provide light with an intensity of not less than 1 footcandle (10.76 lx) measured at floor level in all corridors, stairways, pressurized enclosures, elevator cars and lobbies and other areas that are clearly a part of the escape route.

2. All circuits supply lighting for the central control station and mechanical equipment room.

403.8.3 Emergency systems. The following are classified as emergency systems and shall operate within 10 seconds of failure of the normal power supply:

1. Exit sign and means of egress illumination as required by Sections 1003.2.8 and 1003.2.9.

2. Elevator car lighting.

403.9 Means of Egress. Means of egress shall comply with other requirements of this code and the following:

1. All stairway doors that are locked from the stairway side shall have the capability of being unlocked simultaneously without unlatching upon a signal from the central control station.

2. A telephone or other two-way communications system connected to an approved emergency service that operates continuously shall be provided at not less than every fifth floor in each required stairway where other provisions of this code permit the doors to be locked.

403.10 Seismic Considerations. In Seismic Zones 2, 3 and 4, the anchorage of mechanical and electrical equipment required for life-safety systems, including fire pumps and elevator drive and suspension systems, shall be designed in accordance with the requirements of Section 1626.

SECTION 404 — COVERED MALL BUILDINGS

404.1 General.

404.1.1 Purpose. The purpose of this section is to establish minimum standards of safety for the construction and use of covered mall buildings having not more than three levels

404.1.2 Scope. The provisions of Section 404 shall apply to buildings or structures defined herein as covered mall buildings and shall supersede other similar requirements in other chapters of the code.

EXCEPTIONS: 1. Covered mall buildings conforming with all other applicable provisions of this code.

2. Terminals for transportation facilities and lobbies of hotels, apartments and office buildings.

404.1.3 Definitions. For the purpose of this chapter, certain terms are defined as follows:

ANCHOR BUILDING is an exterior perimeter department store, major merchandising center or Group R, Division 1 Occupancy having direct access to a covered mall building but having all required means of egress independent of the mall.

COVERED MALL BUILDING is a single building enclosing a number of tenants and occupancies such as retail stores, drinking and dining establishments, entertainment and amusement facilities, offices and other similar uses wherein two or more tenants have a main entrance into the mall.

FOOD COURT is a public seating area located in the mall that serves adjacent food preparation tenant spaces.

GROSS LEASABLE AREA is the total floor area designed for tenant occupancy and exclusive use. The area of tenant occupancy is measured from the center lines of joint partitions to the outside of the tenant walls. All tenant areas, including areas used for storage, shall be included in calculating gross leasable area.

MALL is a roofed or covered common pedestrian area within a covered mall building that serves as access for two or more tenants and may have three levels that are open to one another.

404.1.4 Applicability of other provisions. Except as specifically required by this chapter, covered mall buildings shall meet all applicable provisions of this code.

404.1.5 Standards of quality. The standard listed below is a recognized standard. (See Sections 3503 and 3504.)

1. UL 1975, Standard for Fire Tests for Foamed Plastics Used for Decorative Purposes

404.2 Types of Construction and Required Yards for Unlimited Area.

404.2.1 Type of construction. One- and two-level covered mall buildings may be of any type of construction permitted by this code. Three-level covered mall buildings shall be at least Type II One-hour construction.

Anchor buildings and parking garages shall be limited in height and area in accordance with Sections 504, 505 and 506.

404.2.2 Required yards for unlimited area. Covered mall buildings may be of unlimited area, provided the covered mall building, attached anchor buildings and parking garages are adjoined by public ways, streets or yards not less than 60 feet (18 288 mm) in width along all exterior walls.

404.3 Special Provisions.

404.3.1 Automatic sprinkler systems. The covered mall building shall be provided with an automatic sprinkler system conforming to the provisions of UBC Standard 9-1, which is a part of this code. See Chapter 35. In addition to these standards, the automatic sprinkler system shall comply with the following:

1. All automatic sprinkler system control valves shall be electrically supervised by an approved central, proprietary or remote station or a local alarm service that will give an audible signal at a constantly attended location.

2. The automatic sprinkler system shall be complete and operative throughout the covered mall building prior to occupancy of any of the tenant spaces. The separation between an unoccupied tenant space and the covered mall building shall be subject to the approval of the building official and the fire department.

3. Sprinkler protection for the mall shall be independent from that provided for tenant spaces. However, tenant spaces may be supplied by the same system if they can be independently controlled.

The respective increases for area and height for covered mall buildings, including anchor buildings, specified in Sections 311.9, 505 and 506, shall be permitted.

404.3.2 Standpipes. There shall be a combined Class I standpipe outlet connected to a system sized to deliver 250 gallons per minute (946.4 L/m) at the most hydraulically remote outlet. The outlet shall be supplied from the mall zone sprinkler system and shall be hydraulically calculated. Standpipe outlets shall be provided at each of the following locations:

1. Within the mall at the entrance to each exit passage or corridor.

2. At each floor-level landing within enclosed stairways opening directly onto the mall.

3. At exterior public entrances to the mall.

404.3.3 Smoke-control system. A smoke-control system meeting the requirements of Section 905 shall be provided.

> **EXCEPTION:** A smoke-control system need not be provided when both of the following conditions exist:
>
> 1. The mall does not exceed one story, and
>
> 2. The gross leasable area does not exceed 24,000 square feet (2230 m^2).

404.3.4 Fire department access to equipment. Rooms or areas containing controls for air-conditioning systems, automatic fire-extinguishing systems or other detection, suppression or control elements shall be identified for use by the fire department.

404.3.5 Tenant separation. Each tenant space shall be separated from other tenant spaces by a wall having a fire-resistive rating of not less than one hour. The separation wall shall extend from the floor to the underside of the ceiling above. Except as required by other provisions of this code, the ceiling need not be a fire-resistive assembly. A separation is not required between any tenant space and a mall except for occupancy separations required by Section 404.5 or for smoke-control purposes.

404.3.6 Public address system. Covered mall buildings exceeding 50,000 square feet (4645 m^2) in total floor area shall be provided with a public address system accessible for use by the fire department. Covered mall buildings of 50,000 square feet (4645 m^2) or less in total floor area, when provided with a public address system, shall have such system accessible for use by the fire department.

404.3.7 Plastic panels and plastic signs. Within every story or level and from side wall to side wall of each tenant space or mall, plastic panels and plastic signs shall comply with the following:

1. Plastics other than foam plastics shall be approved plastic materials as defined in Section 217.

2. Foam plastics shall have a maximum heat-release rate of 150 kilowatts when tested in accordance with approved recognized standards (see Chapter 35, Part IV) and shall have the following physical characteristics:

   2.1 A density not less than 20 pounds per cubic foot (320.4 kg/m^3) and

   2.2 A thickness not greater than $^1/_2$ inch (12.7 mm).

3. They shall not exceed 20 percent of the wall area facing the mall.

4. They shall not exceed a height of 36 inches (914 mm) except that if the sign is vertical, then the height shall not exceed 96 inches (2438 mm) and the width shall not exceed 36 inches (914 mm).

5. They shall be located a minimum distance of 18 inches (457 mm) from adjacent tenants.

404.3.8 Lease plan. Each covered mall building owner shall provide both the building and fire departments with a lease plan showing the location of each occupancy and its means of egress after the certificate of occupancy has been issued. Such plans shall be kept current. No modifications or changes in occupancy or use shall be made from that shown on the lease plan without prior approval of the building official.

404.3.9 Openings between anchor building and mall. Except for the occupancy separation between Group R, Division 1 sleeping rooms and the mall, openings between anchor buildings of

Type I, Type II-F.R., Type II One-hour or Type II-N construction and the mall need not be protected.

404.3.10 Standby power. Covered mall buildings exceeding 50,000 square feet (4645 m^2) shall be provided with standby power systems that are capable of operating the public address system, the smoke-control activation system and the smoke-control equipment as required by Section 905.

404.4 Means of Egress.

404.4.1 General. Each tenant space and the covered mall building shall be provided with means of egress as required by this section and Chapter 10. Where there is a conflict between the requirements of Chapter 10 and the requirements of this section, the requirements of this section shall apply.

404.4.2 Determination of occupant load. The occupant load permitted in any individual tenant space in a covered mall building shall be determined as required by Section 1002. Means of egress requirements for individual tenant spaces shall be based on the occupant load thus determined.

The occupant load permitted for the covered mall building, assuming all portions, including individual tenant spaces and the mall to be occupied at the same time, shall be determined by dividing the gross leasable area by 30 for covered mall buildings containing up to 150,000 square feet (13 935 m^2) of gross leasable area, by 40 for covered mall buildings containing between 150,001 and 350,000 square feet (13 935 m^2 and 32 515 m^2) of gross leasable area, and by 50 for covered mall buildings containing more than 350,000 square feet (32 515 m^2) of gross leasable area. Means of egress requirements for the mall shall be based on the occupant load thus determined.

The occupant load of a food court shall be determined in accordance with Section 1003.2.2. For purposes of determining the means of egress requirements for the mall, the food court occupant load shall be added to the occupant load of the covered mall building as calculated above.

The occupant load of anchor buildings opening into the mall shall not be included in determining means of egress requirements for the mall.

404.4.3 Number of means of egress. When the distance of travel to the mall exceeds 75 feet (22 860 mm) within the public area of a tenant space or when the occupant load served by the means of egress to the mall exceeds 50, not less than two means of egress shall be provided. The occupant load of a public sales area shall be computed at 30 square feet (2.8 m^2) per occupant. Occupant loads for other areas shall be computed in accordance with Table 10-A.

404.4.4 Arrangement of means of egress. Group A, Divisions 1, 2 and 2.1 Occupancies, other than drinking and dining establishments, shall be so located in the covered mall building that their entrance will be immediately adjacent to a principal entrance to the mall and shall have not less than one half of their required means of egress opening directly to the exterior of the covered mall building.

Required means of egress for anchor buildings shall be provided independently from the mall means of egress system.

Malls shall not egress through anchor buildings. Malls terminating at an anchor building where no other means of egress has been provided shall be considered a dead-end mall.

404.4.5 Travel distance. Within each individual tenant space in a covered mall building the maximum travel distance shall not exceed 200 feet (60 960 mm).

The maximum travel distance from any point within a mall shall not exceed 200 feet (60 960 mm).

404.4.6 Exit access. The means of egress shall be so arranged that it is possible to go in either direction from any point in a mall to a separate exit, except for dead ends not exceeding a length equal to twice the width of the mall measured at the narrowest location within the dead-end portion of the mall.

The minimum width of the means of egress from a mall shall be 66 inches (1676 mm).

Storage is prohibited in exit passageways, which are also used for service to the tenants. Such exit passageways shall be posted with conspicuous signs so stating.

404.4.7 Malls. For the purpose of providing required egress, malls may be considered as corridors but need not comply with the requirements of Sections 1004.3.4.3.1 and 1004.3.4.3.2 when the width of mall is as specified in this section.

The minimum aggregate clear width of the mall shall be 20 feet (6096 mm). There shall be a minimum of 10 feet (3048 mm) clear width to a height of 8 feet (2438 mm) on each side of the mall between any projection from a tenant space bordering the mall and the nearest kiosk, vending machine, bench, display, food court or other obstruction to egress. Kiosks, vending machines and similar uses shall be spaced at least 20 feet (6096 mm) from one another and shall not be more than 300 square feet (28 m^2) in area.

Malls that do not conform to the requirements of this section shall comply with the requirements of Sections 1004.3.4.3.1 and 1004.3.4.3.2.

404.4.8 Security grilles and doors. Horizontal sliding or vertical security grilles or doors that are a part of a required means of egress shall conform to the following:

1. They must remain secured in the full open position during the period of occupancy by the general public.

2. Doors or grilles shall not be brought to the closed position when there are more than 10 persons occupying spaces served by a single exit or 50 persons occupying spaces served by more than one exit.

3. The doors or grilles shall be openable from within without the use of any special knowledge or effort when the space is occupied.

4. When two or more exits are required, not more than one half of the exits may be equipped with horizontal sliding or vertical rolling grilles or doors.

404.5 Occupancy.

404.5.1 General. Covered mall buildings shall be classified as a Group B or M Occupancy and may contain accessory uses consisting of Group A, E or R, Division 1 Occupancies. The area of individual accessory uses within a covered mall building shall not exceed three times the basic area permitted by Table 5-B for the type of construction and the occupancy involved. The aggregate area of all accessory uses within a covered mall building shall not exceed 25 percent of the gross leasable area.

An attached garage for the parking or storage of private or pleasure-type motor vehicles having a capacity of not more than nine persons and open parking garages may be considered as separate buildings when they are separated from the covered mall building by an occupancy separation having a fire-endurance time period of at least two hours.

404.5.2 Mixed occupancy. Individual tenant spaces within a covered mall building that comprise a distinct "occupancy," as described in Chapter 3, shall be separated from any other occupancy as specified in Section 302.4.

EXCEPTIONS: 1. A main entrance that opens onto a mall need not be separated.

2. An occupancy separation is not required between a food court and adjacent tenant spaces or mall.

SECTION 405 — STAGES AND PLATFORMS

405.1 Scope.

405.1.1 Standards of quality. Stages, platforms and accessory spaces in assembly occupancies shall conform with the requirements of Section 405.

The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code.

1. UBC Standard 4-1, Proscenium Firesafety Curtains
2. UBC Standard 7-1, Fire Tests of Building Construction and Materials
3. UBC Standard 8-1, Test Method for Surface-burning Characteristics of Building Materials
4. UBC Standard 9-1, Installation of Sprinkler Systems

405.1.2 Definitions. For the purpose of this chapter, certain terms are defined as follows:

BATTEN is a flown metal pipe or shape on which lights or scenery are fastened.

DROP is a large piece of scenic canvas or cloth that hangs vertically, usually across the stage area.

FLY is the space over the stage of a theater where scenery and equipment can be hung out of view. Also called lofts and rigging lofts.

FLY GALLERY is a raised area above a stage from which the movement of scenery and operation of other stage effects are controlled.

GRIDIRON is the structural framing over a stage supporting equipment for hanging or flying scenery and other stage effects. A gridiron grating shall not be considered a floor.

LEG DROP is a long narrow strip of fabric used for masking. When used on either or both sides of the acting area, it is provided to designate an entry onto the stage by the actors. It is also used to mask the side stage area. They may also be called "wings."

PINRAIL is a rail on or above a stage that has belaying pins to which lines are fastened.

PLATFORM is that raised area within a building used for the presentation of music, plays or other entertainment; the head table for special guests; the raised area for lectures and speakers; boxing and wrestling rings; theater in the round; and similar purposes wherein there are not overhead hanging curtains, drops, scenery or stage effects other than lighting.

PLATFORM, PERMANENT, is a platform used within an area for more than 30 days.

PLATFORM, TEMPORARY, is a platform used within an area for not more than 30 days.

PROSCENIUM WALL is the wall that separates the stage from the auditorium or house.

STAGE is a space within a building used for entertainment or presentations, with a stage height of 50 feet (15 240 mm) or less. Curtains, drops, scenery, lighting devices and other stage effects are hung and not retractable except for a single lighting bank; single main curtain, border and legs; and single backdrop.

STAGE AREAS are the entire performance area and adjacent backstage and support areas not separated from the performance area by fire-resistive construction.

STAGE HEIGHT is the dimension between the lowest point on the stage floor and the highest point of the underside of the roof or floor deck above the stage.

STAGE, LEGITIMATE, is a stage wherein curtains, drops, leg drops, scenery, lighting devices or other stage effects are retractable horizontally or suspended overhead and the stage height is greater than 50 feet (15 240 mm).

THEATER-IN-THE-ROUND is an acting area in the middle of a room with the audience sitting all around it.

405.1.3 Materials and design. Materials used in the construction of platforms and stages shall conform to the applicable materials and design requirements as set forth in this code. All assumed design live loads shall be indicated on the construction documents submitted for approval.

405.2 Platforms. Temporary platforms may be constructed of any materials. The space between the floor and the platform above shall not be used for any purpose other than electrical wiring or plumbing to platform equipment.

Platforms shall be constructed of materials as required for the type of construction of the building in which the platform is located. When the space beneath a raised platform is used for storage or any purpose other than equipment wiring or plumbing, the floor construction shall not be less than one-hour fire-resistive construction. When the space beneath the platform is not used for any purpose other than equipment wiring or plumbing, the underside of the platform shall be fireblocked and may be constructed of any type of materials permitted by this code. The floor finish may be of wood in all types of construction.

405.3 Stages.

405.3.1 Construction. The minimum type of construction for stages shall be as required for the building except that the finish floor, in all types of construction, may be of wood.

Stages having a stage height exceeding 50 feet (15 240 mm) shall be separated from the balance of the building by not less than a two-hour occupancy separation.

EXCEPTION: The opening in the proscenium wall used for viewing performances may be protected by a proscenium firesafety curtain conforming to UBC Standard 4-1.

Where permitted by the building construction type or where the stage is separated from all other areas as required in the paragraph above, the stage floor may be of unprotected noncombustible or heavy-timber framing members with a minimum $1^1/_2$-inch-thick (38 mm) wood deck.

Where a stage floor is required to be of one-hour fire-resistive-rated construction, the stage floor may be unprotected when the space below the stage is sprinklered throughout.

Where the stage height is 50 feet (15 240 mm) or less, the stage area shall be separated from accessory spaces by a one-hour fire-resistive occupancy separation.

EXCEPTION: Control rooms and follow spot rooms may be open to the audience.

405.3.2 Accessory rooms. Dressing rooms, workshops, storerooms and other accessory spaces contiguous to stages shall be separated from one another and other building areas by a one-hour fire-resistive occupancy separation.

EXCEPTION: A separation is not required for stages having a floor area not exceeding 500 square feet (46.5 m^2).

405.3.3 Ventilation. Emergency ventilation shall be provided for all stage areas greater than 1,000 square feet (93 m^2) or with a stage height of greater than 50 feet (15 240 mm) to provide a means of removing smoke and combustion gases directly to the outside in the event of a fire. Ventilation shall be by one or a combination of the following methods in Section 405.3.3.1 and 405.3.3.2.

405.3.3.1 Smoke control. A means shall be provided to maintain the smoke level not less than 6 feet (1829 mm) above the highest level of assembly seating or above the top of the proscenium opening where proscenium wall and opening protection is provided. The system shall be activated independently by each of the following: (1) activation of the sprinkler system in the stage area and (2) by a manually operated switch at an approved location. The emergency ventilation system shall be connected to both normal and standby power. The fan(s) power wiring and ducts shall be located and properly protected to ensure a minimum 20 minutes of operation in the event of activation.

405.3.3.2 Roof vents. Two or more vents shall be located near the center of and above the highest part of the stage area. They shall be raised above the roof and provide a net free vent area equal to 5 percent of the stage area. Vents shall be constructed to open automatically by approved heat-activated devices. Supplemental means shall be provided for manual operation of the ventilator from the stage floor. Vents shall be of an approved type.

405.3.4 Proscenium walls. The proscenium opening shall be protected by an approved fire curtain or an approved water curtain complying with UBC Standard 4-1. The fire curtain shall be designed to close automatically upon automatic detection of a fire and upon manual activation and shall resist the passage of flame and smoke for 20 minutes between the stage area and the audience area.

405.3.5 Gridirons, fly galleries and pinrails. Beams designed only for the attachment of portable or fixed theater equipment, gridirons, galleries and catwalks shall be constructed of materials consistent with the building type of construction. A fire-resistance rating is not required.

> **EXCEPTION:** Combustible materials shall be permitted for use as the floors of galleries and catwalks of all types of construction.

405.3.6 Flame-retardant requirements. Combustible scenery of cloth, film, dry vegetation and similar materials shall meet the requirements of the Fire Code. Foam plastics shall have a maximum heat release rate of 100 kilowatts.

SECTION 406 — MOTION PICTURE PROJECTION ROOMS

406.1 General.

406.1.1 Scope. The provisions of this section shall apply where ribbon-type cellulose acetate or other safety film is used in conjunction with electric arc, xenon or other light-source projection equipment, which develops hazardous gases, dust or radiation. Where cellulose nitrate film is used, projection rooms shall comply with the Fire Code.

406.1.2 Projection room required. Every motion picture machine projecting film as mentioned within the scope of this chapter shall be enclosed in a projection room. Appurtenant electrical equipment, such as rheostats, transformers and generators, may be within the projection room or in an adjacent room of equivalent construction.

There shall be posted on the outside of each projection room door and within the projection room itself a conspicuous sign with 1-inch (25.4 mm) block letters stating: SAFETY FILM ONLY PERMITTED IN THIS ROOM.

406.2 Construction. Every projection room shall be of permanent construction consistent with the construction requirements for the type of building in which the projection room is located. Openings need not be protected.

The room shall have a floor area of not less than 80 square feet (7.4 m^2) for a single machine and at least 40 square feet (3.7 m^2) for each additional machine. Each motion picture projector, floodlight, spotlight or similar piece of equipment shall not be used unless approved and shall have a clear working space not less than 30 inches by 30 inches (762 mm by 762 mm) on each side and at the rear thereof, but only one such space shall be required between two adjacent projectors.

The projection room and the rooms appurtenant thereto shall have a ceiling height of not less than 7 feet 6 inches (2286 mm).

406.3 Means of Egress. Means of egress shall be provided as required in Chapter 10. Motion picture projection rooms used for projection of safety film only are required to have only one exit or exit-access door.

406.4 Projection Ports and Openings. The aggregate of openings for projection equipment shall not exceed 25 percent of the area of the wall between the projection room and the auditorium.

All openings shall be provided with glass or other approved material so as to completely close the opening.

406.5 Ventilation.

406.5.1 General. Ventilation shall be provided in accordance with the provisions of this section.

406.5.2 Projection booth.

406.5.2.1 Supply air. Each projection room shall be provided with adequate air-supply inlets so arranged as to provide well-distributed air throughout the room. Air-inlet ducts shall provide an amount of air equivalent to the amount of air being exhausted by projection equipment. Air may be taken from the outside; from adjacent spaces within the building, provided the volume and infiltration rate is sufficient; or from the building air-conditioning system, provided it is so arranged as to provide sufficient air when other systems are not in operation.

406.5.2.2 Exhaust air. Projection booths may be exhausted through the lamp exhaust system. The lamp exhaust system shall be positively interconnected with the lamp so that the lamp will not operate unless there is the air flow required for the lamp. Exhaust air ducts shall terminate at the exterior of the building in such a location that the exhaust air cannot be readily recirculated into any air-supply system. The projection room ventilation system may also serve appurtenant rooms such as the generator room and the rewind room.

Each projection machine shall be provided with an exhaust duct that will draw air from each lamp and exhaust it directly to the outside of the building. The lamp exhaust may serve to exhaust air from the projection room to provide room air circulation. Such ducts shall be of rigid materials, except for a flexible connector approved for the purpose. The projection lamp or projection room exhaust system or both may be combined but shall not be interconnected with any other exhaust or return system, or both, within the building.

406.5.3 Projection equipment ventilation.

406.5.3.1 General. Each projection machine shall be provided with an exhaust duct that will draw air from each lamp and exhaust it directly to the outside of the building in such a fashion that it will not be picked up by supply inlets. Such a duct shall be of rigid materials, except for a continuous flexible connector approved for the purpose. The lamp exhaust system shall not be interconnected with any other system.

406.5.3.2 Electric arc projection equipment. The exhaust capacity shall be 200 cubic feet per minute (94.4 L/s) for each lamp connected to the lamp exhaust system, or as recommended by the equipment manufacturer. Auxiliary air may be introduced into the system through a screened opening to stabilize the arc.

406.5.3.3 Xenon projection equipment. The lamp exhaust system shall exhaust not less than 300 cubic feet per minute (142 L/s) per lamp or not less than that exhaust volume required or recommended by the equipment manufacturer, whichever is the greater. The external temperature of the lamp housing shall not exceed 130°F (54.4°C) when operating.

406.6 Miscellaneous Equipment. Each projection room shall be provided with rewind and film storage facilities.

A maximum of four containers for flammable liquids not greater than 16-ounce (473.2 mL) capacity and of a nonbreakable type may be permitted in each projection booth.

406.7 Sanitary Facilities. Every projection room shall be provided with a lavatory and a water closet.

> **EXCEPTION:** A projection room where completely automated projection equipment is installed that does not require a projectionist in attendance for projection or rewinding film.

SECTION 407 — CELLULOSE NITRATE FILM

The handling and storage of cellulose nitrate film shall be in accordance with the Fire Code. For exits, see Section 1007.7.4.

SECTION 408 — AMUSEMENT BUILDINGS

408.1 General. Amusement buildings having an occupant load of 50 or more shall comply with the requirements for the appropriate Group A Occupancy and this section. Amusement buildings having an occupant load of less than 50 shall comply with the requirements for a Group B Occupancy and this section.

> **EXCEPTION:** Amusement buildings or portions thereof that are without walls or a roof and constructed to prevent the accumulation of smoke in assembly areas.

For flammable decorative materials, see the Fire Code.

408.2 Definition. For the purposes of this code, the following definition applies:

AMUSEMENT BUILDING is a building or portion thereof, temporary or permanent, used for entertainment or educational purposes and that contains a system that transports passengers or provides a walkway through a course so arranged that the means of egress are not apparent due to theatrical distractions, are disguised or are not readily available due to the method of transportation through the building or structure.

408.3 Means of Egress and Exit Signs. Means of egress and exit signs for amusement buildings shall be approved by the building official and, where practical, shall comply with the requirements specified in Chapter 10. For exit marking, see Section 1007.2.7 for all amusement buildings.

408.4 Automatic Fire-extinguishing Systems. An automatic fire-extinguishing system shall be installed in amusement buildings as set forth in Section 904.2.3.6.

408.5 Alarm Systems.

408.5.1 General. An approved smoke-detection system installed in accordance with the Fire Code shall be provided in amusement buildings.

> **EXCEPTION:** In areas where ambient conditions will cause a smoke-detector system to alarm, an approved alternate type of automatic detector shall be installed.

408.5.2 Alarm system. Activation of any single smoke detector, the automatic sprinkler system or other automatic fire-detection device shall immediately sound an alarm in the building at a constantly supervised location from which the manual operation of systems noted in Section 408.5.3, Items 1, 2 and 3, may be initiated.

408.5.3 System response. The activation of two or more smoke detectors, a single smoke detector monitored by an alarm verification zone, the automatic sprinkler system or other approved automatic fire-detection device shall automatically:

1. Stop confusing sounds and visual effects,
2. Activate an approved directional exit marking, and
3. Cause illumination of the means of egress with light of not less than 1 footcandle (10.76 lx) at the walking surface.

408.5.4 Public address system. A public address system that is audible throughout the amusement building shall be provided. The public address system may also serve as an alarm system.

SECTION 409 — PEDESTRIAN WALKWAYS

409.1 General. A pedestrian walkway shall be considered a building when determining the roof covering permitted by Table 15-A. Pedestrian walkways connecting separate buildings need not be considered as buildings and need not be considered in the determination of the allowable floor area of the connected buildings when the pedestrian walkway complies with the provisions of this section.

409.2 Construction. Pedestrian walkways shall be constructed of noncombustible materials.

> **EXCEPTIONS:** 1. Pedestrian walkways connecting buildings of Type III, IV or V construction may be constructed of one-hour fire-resistive construction or of heavy-timber construction in accordance with Section 605.6.
>
> 2. Pedestrian walkways located on grade having both sides open by at least 50 percent and connecting buildings of Type III, IV or V construction may be constructed with any materials allowed by this code.

409.3 Openings between Pedestrian Walkways and Buildings. Openings from buildings to pedestrian walkways shall conform to the requirements of Table 5-A and Sections 503.3, 602.3, 603.3, 604.3, 605.3 and 606.3. In addition, pedestrian walkways connecting buildings shall be either provided with opening protection at connections to buildings in accordance with Section 1004.3.4.3.2 or constructed with both sides of the pedestrian walkway at least 50 percent open with the open area distributed so as to prevent the accumulation of smoke and toxic gases.

409.4 Width. The unobstructed width of pedestrian walkways shall not be less than 44 inches (1118 mm). The total width of a pedestrian walkway shall not exceed 30 feet (9144 mm).

409.5 Maximum Length. The length of a pedestrian walkway shall not exceed 300 feet (91 440 mm).

> **EXCEPTIONS:** 1. Pedestrian walkways that are fully sprinklered may be 400 feet (121 920 mm) in length.
>
> 2. Unenclosed walkways at grade.

409.6 Multiple Pedestrian Walkways. The distance between any two pedestrian walkways on the same horizontal plane shall not be less than 40 feet (12 192 mm).

409.7 Required Means of Egress. Pedestrian walkways at other than grade shall not be used as a means of egress. Pedestrian walkways at grade level used as required means of egress shall be unobstructed and shall have a minimum width in accordance with Chapter 10.

> **EXCEPTION:** Pedestrian walkways conforming to the requirements of a horizontal exit may be used as a required means of egress.

409.8 Pedestrian Walkways over Public Streets. Pedestrian walkways over public streets shall be subject to the approval of local jurisdictions.

SECTION 410 — MEDICAL GAS SYSTEMS IN GROUPS B AND I OCCUPANCIES

Medical gas systems in Groups B and I Occupancies shall be installed and maintained in accordance with this section and the Fire Code. When nonflammable gas cylinders for such systems are located inside buildings, they shall be in a separate room or enclosure separated from the rest of the building by not less than one-hour fire-resistive construction. Doors to the room or enclosure shall be self-closing smoke- and draft-control assemblies having a fire-protection rating of not less than one hour. Rooms shall have at least one exterior wall in which there are not less than two vents of not less than 36 square inches (0.023 m^2) in area per vent. One vent shall be within 6 inches (152 mm) of the floor and one shall be within 6 inches (152 mm) of the ceiling.

> **EXCEPTION:** When an exterior wall cannot be provided for the room, automatic sprinklers shall be installed within the room and the room shall be vented to the exterior through ducting contained within a one-hour-rated shaft enclosure. Approved mechanical ventilation shall provide six air changes per hour for the room.

SECTION 411 — COMPRESSED GASES

The storage and handling of compressed gases shall comply with the Fire Code.

SECTION 412 — AVIATION CONTROL TOWERS

Where applicable (see Section 101.3) for aviation control towers, see Appendix Chapter 4, Division II.

SECTION 413 — DETENTION AND CORRECTION FACILITIES

Where applicable (see Section 101.3) for detention and correction facilities, see Appendix Chapter 3, Division I.

SECTION 414 — AGRICULTURAL BUILDINGS

Where applicable (see Section 101.3) for agricultural buildings, see Appendix Chapter 3, Division II.

SECTION 415 — GROUP R, DIVISION 3 OCCUPANCIES

Where applicable (see Section 101.3) for Group R, Division 3 Occupancies, see Appendix Chapter 3, Division III.

SECTION 416 — GROUP R, DIVISION 4 OCCUPANCIES

Where applicable (see Section 101.3) for Group R, Division 4 Occupancies, see Appendix Chapter 3, Division IV.

SECTION 417 — BARRIERS FOR SWIMMING POOLS

Where applicable (see Section 101.3) for barriers for swimming pools, see Appendix Chapter 4, Division I.

SECTION 418 — RESERVED

TABLE 4-A—ATRIUM OPENING AND AREA

HEIGHT IN STORIES	MINIMUM CLEAR OPENING[1] (feet) × 304.8 for mm	MINIMUM AREA (square feet) × 0.0929 for m^2
3-4	20	400
5-7	30	900
8 or more	40	1,600

[1]The specified dimensions are the diameters of inscribed circles whose centers fall on a common axis for the full height of the atrium.

Chapter 5
GENERAL BUILDING LIMITATIONS

SECTION 501 — SCOPE

Buildings and structures shall comply with the location on property, area, height and other provisions of this chapter.

For additional limitations or allowances for special uses or occupancies, see the following:

SECTION	SUBJECT
402	Atria
403	High-rise office buildings and Group R, Division 1 Occupancies
404	Malls
311.9	Open parking structures
307	Group H, Division 6 Occupancies
412	Aviation control towers
414	Agricultural buildings
3111	Membrane structures

SECTION 502 — PREMISES IDENTIFICATION

Approved numbers or addresses shall be provided for all new buildings in such a position as to be plainly visible and legible from the street or road fronting the property.

SECTION 503 — LOCATION ON PROPERTY

503.1 General. Buildings shall adjoin or have access to a public way or yard on not less than one side. Required yards shall be permanently maintained.

For the purpose of this section, the center line of an adjoining public way shall be considered an adjacent property line. (See also Section 1203.4.)

503.2 Fire Resistance of Walls.

503.2.1 General. Exterior walls shall have fire resistance and opening protection as set forth in Table 5-A and in accordance with such additional provisions as are set forth in Chapter 6. Distance shall be measured at right angles from the property line. The above provisions shall not apply to walls at right angles to the property line.

Projections beyond the exterior wall shall comply with Section 705 and shall not extend beyond:

1. A point one third the distance to the property line from an assumed vertical plane located where fire-resistive protection of openings is first required due to location on property; or

2. More than 12 inches (305 mm) into areas where openings are prohibited.

503.2.2 Area of openings. When openings in exterior walls are required to be protected due to distance from property line, the sum of the area of such openings shall not exceed 50 percent of the total area of the wall in each story.

503.3 Buildings on Same Property and Buildings Containing Courts. For the purposes of determining the required wall and opening protection and roof-covering requirements, buildings on the same property and court walls of buildings over one story in height shall be assumed to have a property line between them.

EXCEPTION: In court walls where opening protection is required, such protection may be omitted, provided (1) not more than two levels open into the court, (2) the aggregate area of the building including the court is within the allowable area and (3) the building is not classified as a Group I Occupancy.

When a new building is to be erected on the same property as an existing building, the location of the assumed property line with relation to the existing building shall be such that the exterior wall and opening protection of the existing building meet the criteria as set forth in Table 5-A and Chapter 6.

EXCEPTION: Two or more buildings on the same property may be considered as portions of one building if the aggregate area of such buildings is within the limits specified in Section 504 for a single building.

When the buildings so considered house different occupancies or are of different types of construction, the area shall be that allowed for the most restricted occupancy or construction.

503.4 Special Provisions and Exceptions to Table 5-A.

503.4.1 General. The provisions of this section are exceptions to, or special provisions of, the construction requirements of Table 5-A, Chapters 3 and 6.

503.4.2 One-story Groups B, F, M and S Occupancies. In Groups B, F, M and S Occupancies, a fire-resistive time period will not be required for an exterior wall of a one-story, Type II-N building, provided the floor area of the building does not exceed 1,000 square feet (93 m^2) and such wall is located not less than 5 feet (1524 mm) from a property line.

503.4.3 Fire-retardant-treated wood framing. In Types III and IV construction, approved fire-retardant-treated wood framing may be used within the assembly of exterior walls when Table 5-A allows a fire-resistive rating of two hours or less, provided the required fire resistance is maintained and the exposed outer and inner faces of such walls are noncombustible.

503.4.4 Wood columns and arches. In Types III and IV construction, wood columns and arches conforming to heavy-timber sizes may be used externally when exterior walls are permitted to be unprotected, noncombustible construction or when one-hour fire-resistive noncombustible exterior walls are permitted.

503.4.5 Group H Occupancies—minimum distance to property lines. Regardless of any other provisions, Group H Occupancies shall be set back a minimum distance from property lines as set forth in Items 1 through 4. Distances shall be measured from the walls enclosing the occupancy to all property lines, including those on a public way.

1. Group H, Division 1 Occupancies. Not less than 75 feet (22 860 mm) and not less than required by Table 3-F.

2. Group H, Division 2 Occupancies. Not less than 30 feet (9144 mm) when the area of the occupancy exceeds 1,000 square feet (93 m^2) and it is not required to be located in a detached building.

3. Group H, Divisions 2 and 3 Occupancies. Not less than 50 feet (15 240 mm) when a detached building is required. See Table 3-G.

4. Group H, Divisions 2 and 3 Occupancies containing materials with explosive characteristics. Not less than the distances required by Table 3-F.

503.4.6 Group H, Division 1, 2 or 3 Occupancies—detached buildings. When a detached building is required by Table 3-G, there are no requirements for wall and opening protection based on location on property.

503.4.7 Group H, Division 4 Occupancies. Group H, Division 4 Occupancies having a floor area not exceeding 2,500 square feet (232 m^2) may have exterior-bearing walls of not less than two-hour fire-resistive construction when less than 5 feet (1524 mm) from a property line, and not less than one hour when less than 20 feet (6096 mm) from a property line.

503.4.8 Group U, Division 1 Occupancies. In Group U, Division 1 Occupancies, exterior walls that are required to be of one-hour fire-resistive construction due to location on property may be protected only on the exterior side with materials approved for one-hour fire-resistive construction.

When work is exempt from a permit as listed in Section 106.2, Item 1, there are no requirements for wall and opening protection based on location on property when accessory to a Group R, Division 3 Occupancy.

503.4.9 Exterior wall assemblies. Exterior wall assemblies complying with Section 2602.5.2 may be used in all types of construction.

SECTION 504 — ALLOWABLE FLOOR AREAS

504.1 One-story Areas. The area of a one-story building shall not exceed the limits set forth in Table 5-B, except as provided in Section 505.

504.2 Areas of Buildings over One Story. The total combined floor area for multistory buildings may be twice that permitted by Table 5-B for one-story buildings, and the floor area of any single story shall not exceed that permitted for a one-story building.

504.3 Allowable Floor Area of Mixed Occupancies. When a building houses more than one occupancy, the area of the building shall be such that the sum of the ratios of the actual area for each separate occupancy divided by the total allowable area for each separate occupancy shall not exceed one.

> **EXCEPTIONS:** 1. The major occupancy classification of a building may be used to determine the allowable area of such building when the major use occupies not less than 90 percent of the area of any floor of the building and provided that other minor accessory uses shall not exceed the basic area permitted by Table 5-B for such minor uses and that various uses are separated as specified in Section 302.4.
>
> 2. Groups B, F, M and S and Group H, Division 5 Occupancies complying with the provisions of Section 505.2 may contain other occupancies provided that such occupancies do not occupy more than 10 percent of the area of any floor of a building, nor more than the basic area permitted in the occupancy by Table 5-B for such occupancy, and further provided that such occupancies are separated as specified in Section 302.4.

504.4 Mezzanines. Unless considered as a separate story, the floor area of all mezzanines shall be included in calculating the allowable floor area of the stories in which the mezzanines are located.

504.5 Basements. A basement need not be included in the total allowable area, provided such basement does not exceed the area permitted for a one-story building.

504.6 Area Separation Walls.

504.6.1 General. Each portion of a building separated by one or more area separation walls that comply with the provisions of this section may be considered a separate building. The extent and location of such area separation walls shall provide a complete separation.

When an area separation wall also separates occupancies that are required to be separated by an occupancy separation, the most restrictive requirements of each separation shall apply.

504.6.2 Fire resistance and openings. Area separation walls shall not be less than four-hour fire-resistive construction in Types I, II-F.R., III and IV buildings and two-hour fire-resistive construction in Type II One-hour, Type II-N or Type V buildings. The total width of all openings in such walls shall not exceed 25 percent of the length of the wall in each story. All openings shall be protected by a fire assembly having a three-hour fire-protection rating in four-hour fire-resistive walls and one- and one-half-hour fire-protection rating in two-hour fire-resistive walls.

504.6.3 Extensions beyond exterior walls. Area separation walls shall extend horizontally to the outer edges of horizontal projecting elements such as balconies, roof overhangs, canopies, marquees or architectural projections extending beyond the floor area as defined in Section 207.

> **EXCEPTIONS:** 1. When horizontal projecting elements do not contain concealed spaces, the area separation wall may terminate at the exterior wall.
>
> 2. When the horizontal projecting elements contain concealed spaces, the area separation wall need only extend through the concealed space to the outer edges of the projecting elements.
>
> In either Exception 1 or 2, the exterior walls and the projecting elements above shall not be of less than one-hour fire-resistive construction for a distance not less than the depth of the projecting elements on both sides of the area separation wall. Openings within such widths shall be protected by fire assemblies having a fire-protection rating of not less than three-fourths hour.

504.6.4 Terminating. Area separation walls shall extend vertically from the foundation to a point at least 30 inches (762 mm) above the roof.

> **EXCEPTIONS:** 1. Any area separation wall may terminate at the underside of the roof sheathing, deck or slab, provided the roof-ceiling assembly is of at least two-hour fire-resistive construction.
>
> 2. Two-hour area separation walls may terminate at the underside of the roof sheathiug, deck or slab, provided:
>
> 2.1 When the roof-ceiling framing elements are parallel to the walls, such framing and elements supporting such framing shall not be of less than one-hour fire-resistive construction for a width of not less than 5 feet (1524 mm) on each side of the wall.
>
> 2.2 When roof-ceiling framing elements are not parallel to the wall, the entire span of such framing and elements supporting such framing shall not be of less than one-hour fire-resistive construction.
>
> 2.3 Openings in the roof shall not be located within 5 feet (1524 mm) of the area separation wall.
>
> 2.4 The entire building shall be provided with not less than a Class B roof assembly as specified in Table 15-A.
>
> 3. Two-hour area separation walls may terminate at the underside of noncombustible roof sheathing, deck or slabs of roofs of noncombustible construction, provided:
>
> 3.1 Openings in the roof are not located within 5 feet (1524 mm) of the area separation wall.
>
> 3.2 The entire building is provided with not less than a Class B roofing assembly as specified in Table 15-A.

504.6.5 Parapet faces. Parapets of area separation walls shall have noncombustible faces for the uppermost 18 inches (457 mm), including counterflashing and coping materials.

504.6.6 Building of different heights. Where an area separation wall separates portions of a building having different heights, such wall may terminate at a point 30 inches (762 mm) above the lower roof level, provided the exterior wall for a height of 10 feet (3048 mm) above the lower roof is of one-hour fire-resistive construction with openings protected by assemblies having a three-fourths-hour fire-protection rating.

EXCEPTION: Two-hour area separation walls may terminate at the underside of the roof sheathing, deck or slab of the lower roof, provided:

1. When the roof-ceiling framing elements are parallel to the wall, such framing and elements supporting such framing shall not be of less than one-hour fire-resistive construction for a width of 10 feet (3048 mm) along the wall at the lower roof.

2. When the lower roof-ceiling framing elements are not parallel to the wall, the entire span of such framing and elements supporting such framing shall not be of less than one-hour fire-resistive construction.

3. Openings in the lower roof shall not be located within 10 feet (3048 mm) of the area separation wall.

See Chapters 3 and 4 for special occupancy provisions.

504.6.7 Combustible framing in area separation walls. Adjacent combustible members entering into a masonry area separation wall from opposite sides shall not have less than a 4-inch (102 mm) distance between embedded ends. Where combustible members frame into hollow walls or walls of hollow units, all hollow spaces shall be solidly filled for the full thickness of the wall and for a distance not less than 4 inches (102 mm) above, below and between the structural members, with noncombustible materials approved for fireblocking.

SECTION 505 — ALLOWABLE AREA INCREASES

505.1 General. The floor areas specified in Section 504 may be increased by employing one of the provisions of this section.

505.1.1 Separation on two sides. Where public ways or yards more than 20 feet (6096 mm) in width extend along and adjoin two sides of the building, floor areas may be increased at a rate of $1^1/_4$ percent for each foot (305 mm) by which the minimum width exceeds 20 feet (6096 mm), but the increase shall not exceed 50 percent.

505.1.2 Separation on three sides. Where public ways or yards more than 20 feet (6096 mm) in width extend along and adjoin three sides of the building, floor areas may be increased at a rate of $2^1/_2$ percent for each foot (305 mm) by which the minimum width exceeds 20 feet (6096 mm), but the increase shall not exceed 100 percent.

505.1.3 Separation on all sides. Where public ways or yards more than 20 feet (6096 mm) in width extend on all sides of a building and adjoin the entire perimeter, floor areas may be increased at a rate of 5 percent for each foot (305 mm) by which the minimum width exceeds 20 feet (6096 mm). Such increases shall not exceed 100 percent, except that greater increases shall be permitted for the following occupancies:

1. Group S, Division 5 aircraft storage hangars not exceeding one story in height.

2. Group S, Division 2 or Group F, Division 2 Occupancies not exceeding two stories in height.

3. Group H, Division 5 aircraft repair hangars not exceeding one story in height. Area increases shall not exceed 500 percent for aircraft repair hangars except as provided in Section 505.2.

505.2 Unlimited Area. The area of any one- or two-story building of Groups B; F, Division 1 or 2; M; S, Division 1, 2, 3, 4 or 5; and H, Division 5 Occupancies shall not be limited if the building is provided with an approved automatic sprinkler system throughout as specified in Chapter 9, and entirely surrounded and adjoined by public ways or yards not less than 60 feet (18 288 mm) in width.

The area of a Group S, Division 2 or Group F, Division 2 Occupancy in a one-story Type II, Type III One-hour or Type IV building shall not be limited if the building is entirely surrounded and adjoined by public ways or yards not less than 60 feet (18 288 mm) in width.

505.3 Automatic Sprinkler Systems. The areas specified in Table 5-B and Section 504.2 may be tripled in one-story buildings and doubled in buildings of more than one story if the building is provided with an approved automatic sprinkler system throughout. The area increases permitted in this section may be compounded with that specified in Section 505.1.1, 505.1.2 or 505.1.3. The increases permitted in this section shall not apply when automatic sprinkler systems are installed under the following provisions:

1. Section 506 for an increase in allowable number of stories.

2. Section 904.2.6.1 for Group H, Divisions 1 and 2 Occupancies.

3. Substitution for one-hour fire-resistive construction pursuant to Section 508.

4. Section 402, Atria.

SECTION 506 — MAXIMUM HEIGHT OF BUILDINGS AND INCREASES

The maximum height and number of stories of buildings shall be dependent on the character of the occupancy and the type of construction and shall not exceed the limits set forth in Table 5-B, except as provided in this section and as specified in Section 302.1 for mixed occupancy buildings.

EXCEPTIONS: 1. Towers, spires and steeples erected as a part of a building and not used for habitation or storage are limited as to height only by structural design if completely of noncombustible materials, or may extend not to exceed 20 feet (6096 mm) above the height limit in Table 5-B if of combustible materials.

2. The height of one-story aircraft hangars and buildings used for manufacture of aircraft shall not be limited if the building is provided with automatic sprinkler systems throughout as specified in Chapter 9 and is entirely surrounded by public ways or yards not less in width than one- and one-half times the height of the building.

The story limits set forth in Table 5-B may be increased by one story if the building is provided with an approved automatic sprinkler system throughout. The increase in the number of stories for automatic sprinkler systems shall not apply when the automatic sprinkler systems throughout are installed under the following provisions:

1. Section 904.2.6 for Group H, Divisions 1, 2, 3, 6 and 7 Occupancies.

2. Section 505 for an increase in allowable area.

3. Substitution for one-hour fire-resistive construction pursuant to Section 508.

4. Section 402, Atria.

5. Section 904.2.7 for Group I, Divisions 1.1 and 1.2 Occupancies used as hospitals, nursing homes or health-care centers in Type II One-hour, Type III One-hour, Type IV or Type V One-hour construction.

See Chapters 3 and 4 for special occupancy provisions.

SECTION 507 — MEZZANINES

A mezzanine need not be counted as a story for determining the allowable number of stories when constructed in accordance with the following:

1. The construction of a mezzanine shall be consistent with the requirements for the type of construction in which the mezzanine is located, but the fire-resistive time period need not exceed one

hour for unenclosed mezzanines. The clear height above and below the mezzanine floor construction shall not be less than 7 feet (2134 mm).

2. There shall not be more than two levels of mezzanines in a room. However, there is no limitation on the number of mezzanines within a room.

3. The aggregate area of mezzanines within a room shall not exceed one third of the area of the room in which they are located.

4. All portions of a mezzanine shall be open and unobstructed to the room in which they are located, except for columns and posts and protective walls or railings not more than 44 inches (1118 mm) in height.

EXCEPTIONS: 1. Partitioning may be installed if either of the following conditions exist:

1.1 The aggregate floor area of the enclosed space does not exceed 10 percent of the mezzanine area, or

1.2 The occupant load of the enclosed area of the mezzanine does not exceed 10.

2. A mezzanine having two or more means of egress need not be open into the room in which it is located, provided at least one of the means of egress gives direct access to a protected corridor, exit court or exit.

3. In industry facilities, mezzanines used for control equipment may be glazed on all sides.

5. Two means of egress shall be provided from a mezzanine when two are required by Table 10-A.

6. If any required means of egress enters the room below, the occupant load of the mezzanine shall be added to the occupant load of the room in which it is located.

SECTION 508 — FIRE-RESISTIVE SUBSTITUTION

When an approved automatic sprinkler system is not required throughout a building by other sections of this code, it may be used in a building of Type II One-hour, Type III One-hour and Type V One-hour construction to substitute for the one-hour fire-resistive construction. Such substitution shall not waive or reduce the required fire-resistive construction for:

1. Occupancy separations (Section 302.3).

2. Exterior wall protection due to proximity of property lines (Section 503.2).

3. Area separations (Section 504.6).

4. Dwelling unit separations (Section 310.2.2)

5. Shaft enclosures (Section 711).

6. Corridors (Sections 1004.3.4.3.1 and 1004.3.4.3.2).

7. Stair enclosures (Section 1005.3.3).

8. Exit passageways (Section 1005.3.4).

9. Type of construction separation (Section 601.1).

10. Boiler, central heating plant or hot-water supply boiler room enclosures (Section 302.5).

SECTION 509 — GUARDRAILS

509.1 Where Required. Unenclosed floor and roof openings, open and glazed sides of stairways, aisles, landings and ramps, balconies or porches, which are more than 30 inches (762 mm) above grade or floor below, and roofs used for other than service of the building shall be protected by a guardrail. Guardrails shall be provided at the ends of aisles where they terminate at a fascia of boxes, balconies and galleries.

EXCEPTION: Guardrails need not be provided at the following locations:

1. On the loading side of loading docks.

2. On the auditorium side of a stage, raised platforms and other raised floor areas such as runways, ramps and side stages used for entertainment or presentation. Along the side of an elevated walking surface when used for the normal functioning of special lighting or for access and use of other special equipment. At vertical openings in the performance area of stages.

3. Along vehicle service pits not accessible to the public.

509.2 Height. The top of guardrails shall not be less than 42 inches (1067 mm) in height.

EXCEPTIONS: 1. The top of guardrails for Group R, Division 3 and Group U, Division 1 Occupancies and interior guardrails within individual dwelling units, Group R, Division 3 congregate residences and guest rooms of Group R, Division 1 Occupancies may be 36 inches (914 mm) in height.

2. The top of guardrails on a balcony immediately in front of the first row of fixed seats and that are not at the end of an aisle may be 26 inches (660 mm) in height.

3. The top of guardrails for stairways, exclusive of their landings, may have a height as specified in Section 1003.3.3.6 for handrails.

Where an elevation change of 30 inches (762 mm) or less occurs between an aisle parallel to the seats (cross aisle) and the adjacent floor or grade below, guardrails not less than 26 inches (660 mm) above the aisle floor shall be provided.

EXCEPTION: Where the backs of seats on the front of the cross aisle project 24 inches (610 mm) or more above the adjacent floor of the aisle, a guardrail need not be provided.

The top of guardrails at the ends of aisles terminating at the fascia of boxes, balconies and galleries shall extend for the width of the aisle and be no closer than 42 inches (1067 mm) to the closest surface of the aisle where there are steps and 36 inches (914 mm) otherwise.

509.3 Openings. Open guardrails shall have intermediate rails or an ornamental pattern such that a sphere 4 inches (102 mm) in diameter cannot pass through.

EXCEPTIONS: 1. The open space between the intermediate rails or ornamental pattern of guardrails in areas of commercial and industrial-type occupancies which are not accessible to the public may be such that a sphere 12 inches (305 mm) in diameter cannot pass through.

2. The triangular openings formed by the riser, tread and bottom element of a guardrail at the open side of a stairway may be of such size that a sphere 6 inches (152 mm) in diameter cannot pass through.

For guardrail requirements at grandstands, bleachers or other elevated seating facilities, see Section 1008.5.7.

TABLE 5-A—EXTERIOR WALL AND OPENING PROTECTION BASED ON LOCATION ON PROPERTY FOR ALL CONSTRUCTION TYPES[1,2,3]
For exceptions, see Section 503.4.

OCCUPANCY GROUP[4]	CONSTRUCTION TYPE	EXTERIOR WALLS		OPENINGS[5]
		Bearing	Nonbearing	
		Distances are measured to property lines (see Section 503).		
		× 304.8 for mm		
A-1	I-F.R. II-F.R.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
A-1	II One-hour II-N III One-hour III-N IV-H.T. V One-hour V-N	Group A, Division 1 Occupancies are not allowed in these construction types.		
A-2 A-2.1 A-3 A-4	I-F.R. II-F.R. III One-hour IV-H.T.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
A-2 A-2.1[2]	II One-hour	Two-hour N/C less than 10 feet One-hour N/C elsewhere	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
A-2 A-2.1[2]	II-N III-N V-N	Group A, Divisions 2 and 2.1 Occupancies are not allowed in these construction types.		
A-2 A-2.1[2]	V One-hour	Two-hour less than 10 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
A-3	II One-hour	Two-hour N/C less than 5 feet One-hour N/C elsewhere	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
A-3	II-N	Two-hour N/C less than 5 feet One-hour N/C less than 20 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
A-3	III-N	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
A-3	V One-hour	Two-hour less than 5 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
A-3	V-N	Two-hour less than 5 feet One-hour less than 20 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
A-4	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Protected less than 10 feet
A-4	II-N	One-hour N/C less than 10 feet NR, N/C elsewhere	Same as bearing	Protected less than 10 feet
A-4	III-N	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 10 feet
A-4	V One-hour	One-hour	Same as bearing	Protected less than 10 feet
A-4	V-N	One-hour less than 10 feet NR elsewhere	Same as bearing	Protected less than 10 feet
B, F-1, M, S-1, S-3	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C less than 5 feet Two-hour N/C elsewhere	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
B F-1 M S-1, S-3	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
B F-1 M S-1, S-3	II-N[3]	One-hour N/C less than 20 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
B F-1 M S-1, S-3	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
B F-1 M S-1, S-3	V-N	One-hour less than 20 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet

(Continued)

TABLE 5-A—EXTERIOR WALL AND OPENING PROTECTION BASED ON LOCATION ON PROPERTY FOR ALL CONSTRUCTION TYPES[1,2,3]—(Continued)

OCCUPANCY GROUP[4]	CONSTRUCTION TYPE	EXTERIOR WALLS		OPENINGS[5]
		Bearing	Nonbearing	
		Distances are measured to property lines (see Section 503). × 304.8 for mm		
E-1 E-2[6] E-3[6]	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	II One-hour	Two-hour N/C less than 5 feet One-hour N/C elsewhere	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	II-N	Two-hour N/C less than 5 feet One-hour N/C less than 10 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	Two-hour less than 5 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V-N	Two-hour less than 5 feet One-hour less than 10 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
F-2 S-2	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C less than 5 feet Two-hour N/C elsewhere	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 3 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	II-N[3]	One-hour N/C less than 5 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	V-N	One-hour less than 5 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
H-1[2,3]	I-F.R. II-F.R.	Four-hour N/C	NR N/C	Not restricted[3]
	II One-hour	One-hour N/C	NR N/C	Not restricted[3]
	II-N	NR N/C	Same as bearing	Not restricted[3]
	III One-hour III-N IV-H.T. V One-hour V-N	Group H, Division 1 Occupancies are not allowed in buildings of these construction types.		
H-2[2,3] H-3[2,3] H-4[3] H-6 H-7	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 10 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	II One-hour	Four-hour N/C less than 5 feet Two-hour N/C less than 10 feet One-hour N/C elsewhere	Four-hour N/C less than 5 feet Two-hour N/C less than 10 feet One-hour N/C less than 20 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	II-N	Four-hour N/C less than 5 feet Two-hour N/C less than 10 feet One-hour N/C less than 20 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
	V One-hour	Four-hour less than 5 feet Two-hour less than 10 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
	V-N	Four-hour less than 5 feet Two-hour less than 10 feet One-hour less than 20 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet

(Continued)

TABLE 5-A—EXTERIOR WALL AND OPENING PROTECTION BASED ON LOCATION ON PROPERTY FOR ALL CONSTRUCTION TYPES[1,2,3]—(Continued)

OCCUPANCY GROUP[4]	CONSTRUCTION TYPE	EXTERIOR WALLS: Bearing	EXTERIOR WALLS: Nonbearing	OPENINGS[5]
		Distances are measured to property lines (see Section 503). × 304.8 for mm		
H-5[2]	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 40 feet One-hour N/C less than 60 feet NR, N/C elsewhere	Protected less than 60 feet
	II One-hour	One-hour N/C	Same as bearing, except NR, N/C 60 feet or greater	Protected less than 60 feet
	II-N	One-hour N/C less than 60 feet NR, N/C elsewhere	Same as bearing	Protected less than 60 feet
	V One-hour	One-hour	Same as bearing	Protected less than 60 feet
	V-N	One-hour less than 60 feet NR elsewhere	Same as bearing	Protected less than 60 feet
I-1.1 I-1.2 I-2 I-3	I-F.R. II-F.R.	Four-hour N/C	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
I-1.1 I-1.2 I-3[2]	II One-hour	Two-hour N/C less than 5 feet One-hour N/C elsewhere	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	Two-hour less than 5 feet One-hour elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
I-1.1 I-1.2 I-2 I-3	II-N III-N V-N	These occupancies are not allowed in buildings of these construction types.[7]		
I-3	IV-H.T.	Group I, Division 3 Occupancies are not allowed in buildings of this construction type.		
I-1.1 I-1.2 I-2 I-3	III One-hour	Four-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 20 feet
I-1.1 I-1.2 I-2	IV-H.T.	Four-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 20 feet
I-2	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 10 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
R-1	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C less than 3 feet Two-hour N/C elsewhere	Four-hour N/C less than 3 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 3 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet
	II-N	One-hour N/C less than 5 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet
	V-N	One-hour less than 5 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet
R-3	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 3 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 3 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 3 feet
	II-N	One-hour N/C less than 3 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 3 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 3 feet
	V-N	One-hour less than 3 feet NR elsewhere	Same as bearing	Not permitted less than 3 feet

(Continued)

TABLE 5-A—EXTERIOR WALL AND OPENING PROTECTION BASED ON LOCATION ON PROPERTY FOR ALL CONSTRUCTION TYPES[1,2,3]—(Continued)

OCCUPANCY GROUP[4]	CONSTRUCTION TYPE	EXTERIOR WALLS — Bearing	EXTERIOR WALLS — Nonbearing	OPENINGS[5]
		Distances are measured to property lines (see Section 503). × 304.8 for mm		
S-4	I-F.R. II-F.R. II One-hour II-N[3]	One-hour N/C less than 10 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 10 feet
	III One-hour III-N IV-H.T. V One-hour V-N	Group S, Division 4 open parking garages are not permitted in these types of construction.		
S-5	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C less than 5 feet Two-hour N/C elsewhere	Four-hour N/C less than 5 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 5 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 5 feet Protected less than 20 feet
	II-N[3]	One-hour N/C less than 20 feet NR, N/C elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
	V-N[3]	One-hour less than 20 feet NR elsewhere	Same as bearing	Not permitted less than 5 feet Protected less than 20 feet
U-1[3]	I-F.R. II-F.R. III One-hour III-N IV-H.T.	Four-hour N/C	Four-hour N/C less than 3 feet Two-hour N/C less than 20 feet One-hour N/C less than 40 feet NR, N/C elsewhere	Not permitted less than 3 feet Protected less than 20 feet
	II One-hour	One-hour N/C	Same as bearing except NR, N/C 40 feet or greater	Not permitted less than 3 feet
	V One-hour	One-hour	Same as bearing	Not permitted less than 3 feet
	II-N[2]	One-hour N/C less than 3 feet[3] NR, N/C elsewhere	Same as bearing	Not permitted less than 3 feet
	V-N	One-hour less than 3 feet[3] NR elsewhere	Same as bearing	Not permitted less than 3 feet
U-2	All	Not regulated		

N/C — Noncombustible.
NR — Nonrated.
H.T.— Heavy timber.
F.R. — Fire resistive.

[1]See Section 503 for types of walls affected and requirements covering percentage of openings permitted in exterior walls. For walls facing streets, yards and public ways, see also Section 601.5.

[2]For additional restrictions, see Chapters 3 and 6.

[3]For special provisions and exceptions, see also Section 503.4.

[4]See Table 3-A for a description of each occupancy type.

[5]Openings requiring protection in exterior walls shall be protected by a fire assembly having at least a three-fourths-hour fire-protection rating.

[6]Group E, Divisions 2 and 3 Occupancies having an occupant load of not more than 20 may have exterior wall and opening protection as required for Group R, Division 3 Occupancies.

[7]See Section 308.2.1, Exception 3.

TABLE 5-B—BASIC ALLOWABLE BUILDING HEIGHTS AND BASIC ALLOWABLE FLOOR AREA FOR BUILDINGS ONE STORY IN HEIGHT[1]

		TYPES OF CONSTRUCTION								
		I	II			III		IV	V	
		F.R.	F.R.	One-hour	N	One-hour	N	H.T.	One-hour	N
		Maximum Height (feet)								
		UL	160 (48 768 mm)	65 (19 812 mm)	55 (16 764 mm)	65 (19 812 mm)	55 (16 764 mm)	65 (19 812 mm)	50 (15 240 mm)	40 (12 192 mm)
Use Group	Height/Area	Maximum Height (stories) and Maximum Area (sq. ft.) (× 0.0929 for m²)								
A-1	H	UL	4	Not Permitted						
	A	UL	29,900							
A-2, 2.1[2]	H	UL	4	2	NP	2	NP	2	2	NP
	A	UL	29,900	13,500	NP	13,500	NP	13,500	10,500	NP
A-3, 4[2]	H	UL	12	2	1	2	1	2	2	1
	A	UL	29,900	13,500	9,100	13,500	9,100	13,500	10,500	6,000
B, F-1, M, S-1, S-3, S-5	H	UL	12	4	2	4	2	4	3	2
	A	UL	39,900	18,000	12,000	18,000	12,000	18,000	14,000	8,000
E-1, 2, 3[4]	H	UL	4	2	1	2	1	2	2	1
	A	UL	45,200	20,200	13,500	20,200	13,500	20,200	15,700	9,100
F-2, S-2	H	UL	12	4	2	4	2	4	3	2
	A	UL	59,900	27,000	18,000	27,000	18,000	27,000	21,000	12,000
H-1[5]	H	1	1	1	1	Not Permitted				
	A	15,000	12,400	5,600	3,700					
H-2[5]	H	UL	2	1	1	1	1	1	1	1
	A	15,000	12,400	5,600	3,700	5,600	3,700	5,600	4,400	2,500
H-3, 4, 5[5]	H	UL	5	2	1	2	1	2	2	1
	A	UL	24,800	11,200	7,500	11,200	7,500	11,200	8,800	5,100
H-6, 7	H	3	3	3	2	3	2	3	3	1
	A	UL	39,900	18,000	12,000	18,000	12,000	18,000	14,000	8,000
I-1.1, 1.2[6,10]	H	UL	3	1	NP	1	NP	1	1	NP
	A	UL	15,100	6,800	NP	6,800	NP	6,800	5,200	NP
I-2	H	UL	3	2	NP	2	NP	2	2	NP
	A	UL	15,100	6,800	NP	6,800	NP	6,800	5,200	NP
I-3	H	UL	2	Not Permitted[7]						
	A	UL	15,100							
R-1	H	UL	12	4	2[9]	4	2[9]	4	3	2[9]
	A	UL	29,900	13,500	9,100[9]	13,500	9,100[9]	13,500	10,500	6,000[9]
R-3	H	UL	3	3	3	3	3	3	3	3
	A	Unlimited								
S-4[3]	H	See Table 3-H								
	A									
U[8]	H	See Chapter 3								
	A									

A—Building area in square feet.
H—Building height in number of stories.
H.T.—Heavy timber.
NP—Not permitted.
N—No requirements for fire resistance.
F.R.—Fire resistive.
UL—Unlimited.

[1]For multistory buildings, see Section 504.2.
[2]For limitations and exceptions, see Section 303.2.
[3]For open parking garages, see Section 311.9.
[4]See Section 305.2.3.
[5]See Section 307.
[6]See Section 308.2.1 for exception to the allowable area and number of stories in hospitals, nursing homes and health-care centers.
[7]See Section 308.2.2.2.
[8]For agricultural buildings, see also Appendix Chapter 3.
[9]For limitations and exceptions, see Section 310.2.
[10]For Type II F.R., the maximum height of Group I, Division 1.1 Occupancies is limited to 75 feet (22 860 mm). For Type II, One-hour construction, the maximum height of Group I, Division 1.1 Occupancies is limited to 45 feet (13 716 mm).

Chapter 6
TYPES OF CONSTRUCTION

SECTION 601 — CLASSIFICATION OF ALL BUILDINGS BY TYPES OF CONSTRUCTION AND GENERAL REQUIREMENTS

601.1 General. The requirements of this chapter are for the various types of construction and represent varying degrees of public safety and resistance to fire. Every building shall be classified by the building official into one of the types of construction set forth in Table 6-A. Any building that does not entirely conform to a type of construction set forth in Table 6-A shall be classified by the building official into a type having an equal or lesser degree of fire resistance.

A building or portion thereof shall not be required to conform to the details of a type of construction higher than that type that meets the minimum requirements based on occupancy even though certain features of such building actually conform to a higher type of construction.

When specific materials, types of construction or fire-resistive protection are required, such requirements shall be the minimum requirements, and any materials, types of construction or fire-resistive protection that will afford equal or greater public safety or resistance to fire, as specified in this code, may be used.

For additional limitations or allowances for special uses or occupancies, see the following:

SECTION	SUBJECT
402	Atria
403	High-rise office buildings and Group R, Division 1 Occupancies
404	Malls
311	Open parking structures
307.11	Group H, Division 6 Occupancies
411	Aviation control structures
413	Agricultural buildings
3111	Membrane structures

601.2 Mixed Types of Construction. When a building contains more than one distinct type of construction, the area of the entire building shall not exceed the least area permitted for the types of construction involved.

EXCEPTION: Each portion of a building separated by one or more area separation walls as specified in Section 504.6 may be considered a separate building for the purpose of classification of types of construction. The fire-resistive time period for such type of construction separation shall not be less than the most restrictive requirement in Section 504.6.2 based on the types of construction involved.

601.3 Standards of Quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards. (See Sections 3503 and 3504.)

1. **Building paper.**
   1.1 UBC Standard 14-1, Kraft Waterproof Building Paper
   1.2 Underwriters Laboratories Inc. Standard Specification 55A, Materials for Use in Construction of Built-up Roof Coverings
2. **Potential heat of building materials.**
   UBC Standard 26-1, Test Method to Determine Potential Heat of Building Materials
3. **Foam plastic tests.**
   3.1 UBC Standard 26-2, Test Method for the Evaluation of Thermal Barriers
   3.2 Factory Mutual Standard Fire Test Standard for Insulated Roof Deck Construction
   3.3 Underwriters Laboratories Inc. 1256, Fire Test Standard for Insulated Roof Deck Construction
   3.4 UBC Standard 26-3, Room Fire Test Standard for Interior of Foam Plastic Systems
   3.5 UBC Standard 26-4, Method of Test for the Evaluation of Flammability Characteristics of Exterior, Nonload-bearing Wall Panel Assemblies Using Foam Plastic Insulation
   3.6 UBC Standard 26-8, Room Fire Test Standard for Garage Doors Using Foam Plastic Insulation
   3.7 UBC Standard 26-9, Method of Test for the Evaluation of Flammability Characteristics of Exterior Nonload-Bearing Wall Assemblies Containing Combustible Components Using the Intermediate-Scale, Multistory Test Apparatus
4. **Roofing.**
   4.1 Underwriters Laboratories Inc. Standard Specification 55A, Materials for Use in Construction of Built-up Roof Coverings
   4.2 UBC Standard 15-2, Test Method for Determining the Fire Retardancy of Roofing Assemblies
5. **Surface-burning characteristics and fire resistance of building materials and assemblies.**
   5.1 UBC Standard 7-1, Fire Test of Building Construction and Materials
   5.2 UBC Standard 8-1, Test Method for Surface-burning Characteristics of Building Materials
6. **Self-ignition properties of plastics.**
   UBC Standard 26-6, Ignition Properties of Plastics
7. **Fire dampers.**
   UL 555, Fire Dampers

601.4 Structural Frame. The structural frame shall be considered to be the columns and the girders, beams, trusses, and spandrels having direct connections to the columns and bracing members designed to carry gravity loads. The members of floor or roof panels that have no connection to the columns shall be considered secondary members and not a part of the structural frame.

601.5 Exceptions to Table 6-A.

601.5.1 General. The provisions of this section are exceptions to the construction requirements of Table 6-A, Chapter 3 and Sections 602 through 606.

601.5.2 Fixed partitions.

601.5.2.1 Stores and offices. Interior nonload-bearing partitions dividing portions of stores, offices or similar places occupied by one tenant only and that do not establish a corridor that is required to be of fire-resistive construction under the provisions of Section 1004.3.4.3.1 may be constructed of:

1. Noncombustible materials.

2. Fire-retardant-treated wood.

3. One-hour fire-resistive construction.

4. Wood panels or similar light construction up to three fourths the height of the room in which placed; when more than three fourths the height of the room, such partitions shall not have less than the upper one fourth of the partition constructed of glass.

601.5.2.2 Hotels and apartments. Interior nonload-bearing partitions within individual dwelling units in apartment houses and guest rooms or suites in hotels when such dwelling units, guest rooms or suites are separated from each other and from corridors by not less than one-hour fire-resistive construction may be constructed of:

1. Noncombustible materials or fire-retardant-treated wood in buildings of any type of construction; or

2. Combustible framing with noncombustible materials applied to the framing in buildings of Type III or V construction.

Openings to such corridors shall be equipped with doors conforming to Section 1004.3.4.3.2 regardless of the occupant load served.

For use of plastics in partitions, see Section 2603.10.

601.5.3 Folding, portable or movable partitions. Approved folding, portable or movable partitions need not have a fire-resistive rating, provided:

1. They do not block required exits or exit-access doors (without providing alternative conforming exits or exit-access doors) and they do not establish a corridor.

2. Their location is restricted by means of permanent tracks, guides or other approved methods.

3. Flammability shall be limited to materials having a flame-spread classification as set forth in Table 8-B for rooms or areas.

601.5.4 Walls fronting on streets or yards. Regardless of fire-resistive requirements for exterior walls, certain elements of the walls fronting on streets or yards having a width of 40 feet (12 192 mm) may be constructed as follows:

1. Bulkheads below show windows, show-window frames, aprons and showcases may be of combustible materials, provided the height of such construction does not exceed 15 feet (4572 mm) above grade.

2. Wood veneer of boards not less than 1-inch (25 mm) nominal thickness or exterior-type panels not less than $^3/_8$-inch (9.5 mm) nominal thickness may be applied to walls, provided the veneer does not exceed 15 feet (4572 mm) above grade, and further provided such veneer shall be placed either directly against noncombustible surfaces or furred out from such surfaces not to exceed $1^5/_8$ inches (41 mm) with all concealed spaces fire-blocked as provided in Section 708. Where boards, panels and furring as described above comply with Section 207 as fire-retardant-treated wood suitable for exterior exposure, the height above grade may be increased to 35 feet (10 668 mm).

601.5.5 Trim. Trim, picture molds, chair rails, baseboards, handrails and show-window backing may be of wood. Unprotected wood doors and windows may be used except where openings are required to be fire protected.

Foam plastic trim covering not more than 10 percent of the wall or ceiling area may be used, provided such trim (1) has a density of no less than 20 pounds per cubic foot (320.4 kg/m^3), (2) has a maximum thickness of $^1/_2$ inch (12.7 mm) and a maximum width of 4 inches (102 mm), and (3) has a flame-spread rating no greater than 75.

Materials used for interior finish of walls and ceilings, including wainscoting, shall be as specified in Chapter 8.

601.5.6 Loading platforms. Exterior loading platforms may be of noncombustible construction or heavy-timber construction with wood floors not less than 2-inch (51 mm) nominal thickness. Such wood construction shall not be carried through the exterior walls.

601.5.7 Insulating boards. Combustible insulating boards may be used under finished flooring.

601.5.8 Walls within health-care suites. In health-care suites that comply with Section 1007.5, interior nonload-bearing partitions of noncombustible construction need not be of fire-resistive construction. In buildings of combustible construction, interior nonload-bearing partitions within suites may be of combustible framing covered with noncombustible materials having an approved thermal barrier with an index of 15 in accordance with UBC Standard 26-2.

SECTION 602 — TYPE I FIRE-RESISTIVE BUILDINGS

602.1 Definition. The structural elements in Type I fire-resistive buildings shall be of steel, iron, concrete or masonry.

Walls and permanent partitions shall be of noncombustible fire-resistive construction except that permanent nonbearing partitions of one-hour or two-hour fire-resistive construction, which are not part of a shaft enclosure, may have fire-retardant-treated wood (see Section 207) within the assembly.

Materials of construction and fire-resistive requirements shall be as specified in Section 601 and Chapter 7.

602.2 Structural Framework. Structural framework shall be of structural steel or iron as specified in Chapter 22, reinforced concrete as specified in Chapter 19, or reinforced masonry as specified in Chapter 21.

For additional requirements for Group H Occupancies, see Section 307.2.

602.3 Exterior Walls and Openings.

602.3.1 Exterior walls. Exterior walls and all structural members shall comply with the requirements specified in Section 503 and Table 5-A and the fire-resistive provisions set forth in Table 6-A.

602.3.2 Openings in walls. All openings in exterior walls shall conform to the requirements of Section 503.2 and Table 5-A.

602.4 Stairway Construction. Stairways shall be constructed of reinforced concrete, iron or steel with treads and risers of concrete, iron or steel. Brick, marble, tile or other hard noncombustible materials may be used for the finish of such treads and risers.

> **EXCEPTION:** On stairs not required to be enclosed by Section 1005.3.3, the finish material of treads and risers may be of any material permitted by the code.

Stairways shall comply with the requirements of Chapter 10.

602.5 Roofs. Except in retail sales and storage areas classified as Groups M and S, Division 1 Occupancies and in Group H Occupancies, roofs and their members, other than the structural frame, may be of unprotected noncombustible materials when every part of the roof framing, including the structural frame, is 25 feet (7620 mm) or more above the floor, balcony or gallery immediately below. Heavy-timber members in accordance with Section 605.6 may be used for such unprotected members in one-story buildings.

When every part of the structural framework of the roof of a Group A or E Occupancy or of an atrium is not less than 25 feet (7620 mm) above any floor, balcony or gallery, fire protection of all members of the roof construction, including those of the structural frame, may be omitted. Heavy-timber members in accordance with Section 605.6 may be used for such unprotected members in one-story buildings.

Roofs of unprotected noncombustible or heavy-timber construction conforming to Section 605.6.4 may be less than 25 feet (7620 mm) above any floor, balcony or gallery of a Group A, Division 2.1 Occupancy having an occupant load of 10,000 or more when all of the following conditions are met:

1. The building is not more than one story in height, except for multilevel areas located under the roof and used for locker rooms, exiting, concession stands, mechanical rooms and others accessory to the assembly room.

2. The area in which the roof clearance is less than 25 feet (7620 mm) does not exceed 35 percent of the area encompassed by the exterior walls.

3. An approved supervised automatic sprinkler system shall be installed throughout.

Where every part of the structural steel framework of the roof of a Group A or E Occupancy is more than 18 feet (5486 mm) and less than 25 feet (7620 mm) above any floor, balcony or gallery, the roof construction shall be protected by a ceiling of not less than one-hour fire-resistive construction.

Roof coverings shall be as specified in Chapter 15.

SECTION 603 — TYPE II BUILDINGS

603.1 Definition. The structural elements in Type II-F.R. buildings shall be of steel, iron, concrete or masonry.

The structural elements of Type II One-hour or Type II-N buildings shall be of noncombustible materials.

Floor construction of Type II One-hour and Type II-N buildings shall be of noncombustible material, provided, however, that a wood surface or finish may be applied over such noncombustible material.

Walls and permanent partitions of Type II-F.R. buildings shall be of noncombustible fire-resistive construction, except that permanent nonbearing partitions of one-hour or two-hour fire-resistive construction, which are not part of a shaft enclosure, may have fire-retardant-treated wood (see Section 207) within the assembly.

Type II One-hour buildings shall be of noncombustible construction and one-hour fire resistive throughout, except that permanent nonbearing partitions may use fire-retardant-treated wood (see Section 207) within the assembly, provided fire-resistive requirements are maintained.

Walls and permanent partitions of Type II-N buildings shall be of noncombustible materials.

Materials of construction and fire-resistive requirements shall be as specified in Section 601.

For requirements due to occupancy, see Chapter 3.

603.2 Structural Framework. Structural framework shall be as specified in Chapter 22 for iron and steel, Chapter 19 for concrete and Chapter 21 for masonry.

603.3 Exterior Walls and Openings.

603.3.1 Exterior walls. Exterior walls and all structural members shall comply with the requirements specified in Section 503 and Table 5-A and the fire-resistive provisions set forth in Table 6-A.

603.3.2 Openings in walls. All openings in exterior walls shall conform to the requirements of Section 503.2 and Table 5-A.

603.4 Stairway Construction. Stairways of Type II-F.R. buildings shall be constructed of reinforced concrete, iron or steel with treads and risers of concrete, iron or steel. Brick, marble, tile or other hard noncombustible materials may be used for the finish of such treads and risers. Stairways of Type II, One-hour and Type II-N buildings shall be of noncombustible construction.

> **EXCEPTION:** On stairs not required to be enclosed by Section 1005.3.3, the finish material of treads and risers may be of any material permitted by the code.

Stairways shall comply with the requirements of Chapter 10.

603.5 Roofs. Roofs shall be of noncombustible construction, except that in Type II-F.R. and Type II One-hour buildings, roofs may be as specified in Section 602.5.

Roof coverings shall be as specified in Chapter 15.

SECTION 604 — TYPE III BUILDINGS

604.1 Definition. Structural elements in Type III buildings may be of any materials permitted by this code.

Type III One-hour buildings shall be of one-hour fire-resistive construction throughout.

604.2 Structural Framework. Structural framework shall be of steel or iron as specified in Chapter 22, concrete as specified in Chapter 19, masonry as specified in Chapter 21, or wood as specified in Chapter 23 and this chapter.

604.3 Exterior Walls, Openings and Partitions.

604.3.1 Exterior walls. Exterior walls shall be constructed of noncombustible materials and shall comply with the fire-resistive requirements set forth in Section 503 and Tables 5-A and 6-A.

604.3.2 Openings in walls. Openings in exterior walls shall conform to the requirements of Section 503.2 and Table 5-A.

604.3.3 Partitions. Bearing partitions, when constructed of wood, shall comply with Section 2308.

604.4 Stairway Construction.

604.4.1 General. Stairways shall comply with the requirements of Chapter 10.

604.4.2 Interior. Interior stairways serving buildings not exceeding three stories in height may be constructed of any material permitted by this code.

In buildings more than three stories in height, interior stairways shall be constructed as required for Type I buildings.

604.4.3 Exterior. Exterior stairways shall be of noncombustible material except that on buildings not exceeding two stories in height, they may be of wood not less than 2 inches (51 mm) in nominal thickness.

604.5 Roofs. Roof coverings shall be as specified in Chapter 15.

Except in retail sales and storage areas classified as Group M or S, Division 1 Occupancies and in Group H Occupancies, roofs and their members other than the structural frame may be of unprotected noncombustible materials when every part of the roof framing, including the structural frame, is 25 feet (7620 mm) or more above the floor, balcony or gallery immediately below. Heavy-timber members in accordance with Section 605.6 may be used for such unprotected members in one-story buildings.

SECTION 605 — TYPE IV BUILDINGS

605.1 Definition. Structural elements of Type IV buildings may be of any materials permitted by this code.

Type IV construction shall conform to Section 605.6, except that permanent partitions and members of the structural frame may be of other materials, provided they have a fire resistance of not less than one hour.

605.2 Structural Framework. Structural framework shall be of steel or iron as specified in Chapter 22, concrete as specified in Chapter 19, masonry as specified in Chapter 21, or wood as specified in Chapter 23 and this chapter.

605.3 Exterior Walls, Openings and Partitions.

605.3.1 Exterior walls. Exterior walls shall be constructed of noncombustible materials and shall comply with the fire-resistive requirements set forth in Section 503 and Tables 5-A and 6-A.

605.3.2 Openings in walls. Openings in exterior walls shall conform to the requirements of Section 503.2 and Table 5-A.

605.3.3 Partitions. Bearing partitions, when constructed of wood, shall comply with Section 2308.

605.4 Stairway Construction.

605.4.1 General. Stairways shall comply with the requirements of Chapter 10.

605.4.2 Interior. Interior stairways serving buildings not exceeding three stories in height may be constructed of wood or as required for Type I buildings. If constructed of wood, treads and risers shall not be less than 2 inches (51 mm) in thickness, except where built on laminated or plank inclines as required for floors, where they may be of 1-inch (25 mm) thickness. Wood stair stringers shall be a minimum of 3 inches (76 mm) in thickness and not less than 10 inches (254 mm) in depth.

In buildings more than three stories in height, interior stairways shall be constructed as required for Type I buildings.

605.4.3 Exterior. Exterior stairways shall be of noncombustible material except that on buildings not exceeding two stories in height they may be of wood not less than 2 inches (51 mm) in nominal thickness.

605.5 Roofs. Roof coverings shall be as specified in Chapter 15.

605.6 Heavy-timber Construction.

605.6.1 General. Details of heavy-timber construction shall be in accordance with the provisions of this section. Unless otherwise specified, all dimensions are nominal as defined in Section 2302.

605.6.2 Columns. Wood columns may be of sawn timber or structural glued-laminated timber not less than 8 inches (203 mm) in any dimension when supporting roof or floor loads except as specified in Section 605.6.4.

Columns shall be continuous or superimposed and connected in an approved manner.

605.6.3 Floor framing. Beams and girders may be of sawn timber or structural glued-laminated timber and shall not be less than 6 inches (152 mm) in width and not less than 10 inches (254 mm) in depth.

Framed sawn timber or structural glued-laminated timber arches, which spring from the floor line and support floor loads, shall not be less than 8 inches (203 mm) in any dimension.

Framed lumber or structural glued-laminated timber trusses supporting floor loads shall have members of not less than 8 inches (203 mm) in any dimension.

605.6.4 Roof framing. Framed sawn timber arches or structural glued-laminated timber arches for roof construction, which spring from the floor line and do not support floor loads, shall have members not less than 6 inches (152 mm) in width and not less than 8 inches (203 mm) in depth for the lower half of the height and not less than 6 inches (152 mm) in depth for the upper half.

Framed sawn timber or structural glued-laminated timber arches for roof construction, which spring from the top of walls or wall abutments, framed lumber or structural glued-laminated timber trusses, and other roof framing that does not support floor loads, shall have members not less than 4 inches (102 mm) in width and not less than 6 inches (152 mm) in depth. Spaced members may be composed of two or more pieces not less than 3 inches (76 mm) in thickness, when blocked solidly throughout their intervening spaces, or when such spaces are tightly closed by a continuous wood cover plate of not less than 2 inches (51 mm) in thickness, secured to the underside of the members. Splice plates shall not be less than 3 inches (76 mm) in thickness. When protected by an approved automatic sprinkler system under the roof deck, framing members shall not be less than 3 inches (76 mm) in thickness.

605.6.5 Floors. Floors shall be without concealed spaces. Floors shall be of planks, splined or tongue and groove, of not less than 3 inches (76 mm) in thickness covered with 1-inch (25 mm) tongue-and-groove flooring laid crosswise or diagonally, or $^{15}/_{32}$-inch (12 mm) wood structural panels, or of plank not less than 4 inches (102 mm) in width set on edge close together and well spiked, and covered with 1-inch (25 mm) flooring or $^{15}/_{32}$-inch (12 mm) wood structural panels. The lumber shall be laid so that no continuous line of joints will occur except at points of support. Floors shall not extend closer than $^{1}/_{2}$ inch (12.7 mm) to walls. Such $^{1}/_{2}$-inch (12.7 mm) space shall be covered by a molding fastened to the wall and arranged so that it will not obstruct the swelling or shrinkage movements of the floor. Corbeling of masonry walls under floors may be used in place of such molding.

605.6.6 Roof decks. Roofs shall be without concealed spaces and roof decks shall be of planks, splined or tongue and groove, of not less than 2-inch (51 mm) thickness, or $1^{1}/_{8}$-inch (29 mm) tongue-and-groove wood structural panels with exterior glue, or of a double thickness of 1-inch (25 mm) boards with tongue-and-groove joints, or with staggered joints, of lumber not less than 3 inches (76 mm) nominal in width, set on edge close together and laid as required for floors.

605.6.7 Construction details. Approved wall plate boxes or hangers shall be provided where wood beams, girders or trusses rest on masonry or concrete walls.

Girders and beams shall be closely fitted around columns, and adjoining ends shall be cross tied to each other, or intertied by caps or ties, to transfer horizontal loads across the joints. Wood bolsters may be placed on top of columns which support roof loads only.

Where intermediate beams are used to support a floor, they shall rest on top of the girders, or shall be supported by ledgers or blocks securely fastened to the sides of the girders, or they may be supported by approved metal hangers into which the ends of the beams shall be closely fitted.

In heavy-timber roof construction, every roof girder and at least every alternate roof beam shall be anchored to its supporting member; roof decks, where supported by a wall, shall be anchored to such wall at intervals not exceeding 20 feet (6096 mm); every monitor and every sawtooth construction shall be anchored to the main roof construction. Such anchors shall consist of steel or iron bolts of sufficient strength to resist vertical uplift of the roof.

605.6.8 Mechanically laminated floors and roof decks. Mechanically laminated floors and roof decks conforming to Section 2313 may be used as heavy-timber floors or roof decks, provided the minimum thickness and other applicable requirements of the section are followed.

605.6.9 Partitions. Partitions shall be of solid wood construction formed by not less than two layers of 1-inch (25 mm) matched boards or laminated construction of 4-inch (102 mm) thickness, or of one-hour fire-resistive construction.

SECTION 606 — TYPE V BUILDINGS

606.1 Definition. Type V buildings may be of any materials allowed by this code.

Type V One-hour buildings shall be of one-hour fire-resistive construction throughout.

Materials of construction and fire-resistive requirements shall be as specified in Section 601.

For requirements due to occupancy, see Chapter 3.

606.2 Structural Framework. Structural framework shall be of steel or iron as specified in Chapter 22, concrete as specified in Chapter 19, masonry as specified in Chapter 21, or wood as specified in Chapter 23 and this chapter.

606.3 Exterior Walls and Openings. Exterior walls shall comply with fire-resistive requirements set forth in Section 503 and Tables 5-A and 6-A. Openings in exterior walls shall conform to requirements of Section 503.2 and Table 5-A.

606.4 Stairway Construction.

606.4.1 General. Stairways shall comply with the requirements of Chapter 10.

606.4.2 Interior. Interior stairways may be constructed of any materials permitted by this code.

606.4.3 Exterior. Exterior stairways shall be constructed of wood not less than 2 inches (51 mm) in nominal thickness, or may be of noncombustible materials.

606.5 Roofs. Roof coverings shall be as specified in Chapter 15.

Except in retail sales and storage areas classified as Group M or S, Division 1 Occupancies and in Group H Occupancies, roofs and their members other than the structural frame may be of unprotected noncombustible materials when every part of the roof framing, including the structural frame, is 25 feet (7620 mm) or more above the floor, balcony or gallery immediately below. Heavy-timber members in accordance with Section 605.6 may be used for such unprotected members in one-story buildings.

TABLE 6-A—TYPES OF CONSTRUCTION—FIRE-RESISTIVE REQUIREMENTS (In Hours)
For details, see occupancy section in Chapter 3, type of construction sections in this chapter and sections referenced in this table.

BUILDING ELEMENT	TYPE I	TYPE II			TYPE III		TYPE IV	TYPE V	
	Noncombustible				Combustible				
	Fire-resistive	Fire-resistive	1-Hr.	N	1-Hr.	N	H.T.	1-Hr.	N
1. Bearing walls—exterior	4 Sec. 602.3.1	4 Sec. 603.3.1	1	N	4 Sec. 604.3.1	4 Sec. 604.3.1	4 Sec. 605.3.1	1	N
2. Bearing walls—interior	3	2	1	N	1	N	1	1	N
3. Nonbearing walls—exterior	4 Sec. 602.3.1	4 Sec. 603.3.1	1 Sec. 603.3.1	N	4 Sec. 604.3.1	4 Sec. 604.3.1	4 Sec. 605.3.1	1	N
4. Structural frame[1]	3	2	1	N	1	N	1 or H.T.	1	N
5. Partitions—permanent	1[2]	1[2]	1[2]	N	1	N	1 or H.T.	1	N
6. Shaft enclosures[3]	2	2	1	1	1	1	1	1	1
7. Floors and floor-ceilings	2	2	1	N	1	N	H.T.	1	N
8. Roofs and roof-ceilings	2 Sec. 602.5	1 Sec. 603.5	1 Sec. 603.5	N	1	N	H.T.	1	N
9. Exterior doors and windows	Sec. 602.3.2	Sec. 603.3.2	Sec. 603.3.2	Sec. 603.3.2	Sec. 604.3.2	Sec. 604.3.2	Sec. 605.3.2	Sec. 606.3	Sec. 606.3
10. Stairway construction	Sec. 602.4	Sec. 603.4	Sec. 603.4	Sec. 603.4	Sec. 604.4	Sec. 604.4	Sec. 605.4	Sec. 606.4	Sec. 606.4

N—No general requirements for fire resistance.
H.T.—Heavy timber.

[1]Structural frame elements in an exterior wall that is located where openings are not permitted, or where protection of openings is required, shall be protected against external fire exposure as required for exterior-bearing walls or the structural frame, whichever is greater.
[2]Fire-retardant-treated wood (see Section 207) may be used in the assembly, provided fire-resistance requirements are maintained. See Sections 602 and 603.
[3]For special provisions, see Sections 304.6, 306.6, 309.6, 311.6 and 711.

Chapter 7
FIRE-RESISTANT MATERIALS AND CONSTRUCTION

SECTION 701 — SCOPE

This chapter applies to materials and systems used in the design and construction of a building to safeguard against the spread of fire and smoke within a building and the spread of fire to or from buildings.

SECTION 702 — DEFINITIONS

For the purposes of this chapter, the terms, phrases and words listed in this section and their derivatives shall have the indicated meanings.

ANNULAR SPACE is the opening around the penetrating item.

CONCRETE, CARBONATE AGGREGATE, is concrete made with aggregates consisting mainly of calcium or magnesium carbonate, e.g., limestone or dolomite, and containing 40 percent or less quartz, chert or flint.

CONCRETE, LIGHTWEIGHT AGGREGATE, is concrete made with aggregates of expanded clay, shale, slag or slate or sintered fly ash or any natural lightweight aggregate meeting ASTM C 330 and possessing equivalent fire-resistive properties and weighing 85 to 115 pounds per cubic foot (pcf) (1360 to 1840 kg/m^3).

CONCRETE, SAND-LIGHTWEIGHT, is concrete made with a combination of expanded clay, shale, slag or slate or sintered fly ash or any natural lightweight aggregate meeting ASTM C 330 and possessing equivalent fire-resistive properties and natural sand. Its unit weight is generally between 105 and 120 pcf (1680 and 1920 kg/m^3).

CONCRETE, SILICEOUS AGGREGATE, is concrete made with normal-weight aggregates consisting mainly of silica or compounds other than calcium or magnesium carbonate, and may contain more than 40 percent quartz, chert or flint.

F RATING is the time period the penetration firestop system limits the passage of fire through the penetration when tested in accordance with UBC Standard 7-5.

FIREBLOCKING is building material installed to resist the free passage of flame and gases to other areas of the building through small concealed spaces.

FIRE-RESISTIVE JOINT SYSTEM is an assemblage of specific materials or products that are designed, tested and fire resistive in accordance with UBC Standard 7-1 to resist, for a prescribed period of time, the passage of fire through joints.

JOINT is the linear opening between adjacent fire-resistive assemblies. A joint is a division of a building that allows independent movement of the building, in any plane, which may be caused by thermal, seismic, wind loading or any other loading.

MEMBRANE PENETRATION is an opening made through one side (wall, floor or ceiling membrane) of an assembly.

PENETRATION is an opening created in a membrane or assembly to accommodate penetrating items for electrical, mechanical, plumbing, environmental and communication systems.

> **EXCEPTION:** Ducts.

PENETRATION FIRESTOP SYSTEM is an assemblage of specific materials or products that are designed, tested and fire resistive in accordance with UBC Standard 7-5 to resist, for a prescribed period of time, the passage of fire through penetrations.

SPLICE is the result of a factory or field method of joining or connecting two or more lengths of a fire-resistive joint system into a continuous entity.

T RATING is the time period that the penetration firestop system including the penetrating item, limits the maximum temperature rise to 325°F (163°C) above its initial temperature through the penetration on the nonfire side, when tested in accordance with UBC Standard 7-5.

THROUGH-PENETRATION is an opening that passes through both sides of an assembly.

SECTION 703 — FIRE-RESISTIVE MATERIALS AND SYSTEMS

703.1 General. Materials and systems used for fire-resistive purposes shall be limited to those specified in this chapter, unless accepted under the procedure given in Section 703.2 or 703.3.

The materials and details of construction for the fire-resistive systems described in this chapter shall be in accordance with all other provisions of this code except as modified herein.

For the purpose of determining the degree of fire resistance afforded, the materials of construction listed in this chapter shall be assumed to have the fire-resistance rating indicated in Table 7-A, 7-B or 7-C.

As an alternate to Table 7-A, 7-B or 7-C, fire-resistive construction may be approved by the building official on the basis of evidence submitted showing that the construction meets the required fire-resistive classification.

703.2 Qualification by Testing. Material or assembly of materials of construction tested in accordance with the requirements set forth in UBC Standard 7-1 shall be rated for fire resistance in accordance with the results and conditions of such tests.

> **EXCEPTION:** The acceptance criteria of UBC Standard 7-1 for exterior-bearing walls shall not be required to be greater with respect to heat transmission and passage of flame or hot gases than would be required of a nonbearing wall in the same building with the same distance to the property line. The fire exposure time period, water pressure and duration of application for the hose stream test shall be based on the fire-resistive rating determined by this exception.

Fire-resistive assemblies tested under UBC Standard 7-1 shall not be considered to be restrained unless evidence satisfactory to the building official is furnished by the person responsible for the structural design showing that the construction qualifies for a restrained classification in accordance with UBC Standard 7-1. Restrained construction shall be identified on the plans.

703.3 Calculating Fire Resistance. The fire-resistive rating of a material or assembly may be established by calculations. The procedures used for such calculations shall be in accordance with UBC Standard 7-7.

703.4 Standards of Quality. In addition to all the other requirements of this code, fire-resistive materials shall meet the requirements for fire-resistive construction given in this chapter.

The standards listed below labeled a "UBC standard" are also listed in Chapter 35, Part II, and are part of this code. The standards listed below labeled an "Adopted Standard" are also listed in Chapter 35, Part III, and are part of this code. The other standards listed below are recognized standards. (See Sections 3503 and 3504.)

1. UBC Standard 7-1, Fire Tests of Building Construction and Materials

2. UBC Standard 7-2, Fire Tests of Door Assemblies

3. UBC Standard 7-3, Tinclad Fire Doors

4. UBC Standard 7-4, Fire Tests of Window Assemblies

5. UBC Standard 7-5, Fire Tests of Through-penetration Fire Stops

6. UBC Standard 7-6, Thickness, Density Determination and Cohesion/Adhesion for Spray-applied Fire-resistive Fireproofing

7. UBC Standard 7-7, Methods for Calculating Fire Resistance of Steel, Concrete, Wood, Concrete Masonry and Clay Masonry Construction

8. ASTM C 516, Vermiculite Loose-fill Insulation

9. ASTM C 549, Perlite Loose-fill Insulation

10. ANSI/NFPA 80, Standard for Fire Doors and Fire Windows

11. ASTM C 587 and C 588, Gypsum Base for Veneer Plaster and Gypsum Veneer

12. ASTM C 332, Lightweight Aggregates for Insulating Concrete

13. ASTM C 331, Lightweight Aggregates for Concrete Masonry Units

14. UL 555, Fire Dampers

15. UL 555C, Ceiling Dampers

16. UL 555S, Leakage Rated Dampers for Use in Smoke Control Systems

17. UL 33, Heat Response Links for Fire Protection Service

18. UL 353, Limit Controls

19. ASTM E 1399, Cyclic Movement and Measuring the Minimum and Maximum Joint Widths of Architectural Joint Systems

20. Adopted standard—Fire-Resistance Design Manual, Fourteenth Edition

21. Adopted standard—ASTM C 330, Lightweight Aggregates for Structural Concrete

22. Adopted standard—CPSC 16 CFR, Part 1209 Interim Safety Standard for Cellulose Insulation and Part 1404 Cellulose Insulation

SECTION 704 — PROTECTION OF STRUCTURAL MEMBERS

704.1 General. Structural members having the fire-resistive protection set forth in Table 7-A shall be assumed to have the fire-resistance ratings set forth therein.

704.2 Protective Coverings.

704.2.1 Thickness of protection. The thickness of fire-resistive materials required for protection of structural members shall be not less than set forth in Table 7-A, except as modified in this section. The figures shown shall be the net thickness of the protecting materials and shall not include any hollow space back of the protection.

704.2.2 Unit masonry protection. Where required, metal ties shall be embedded in transverse joints of unit masonry for protection of steel columns. Such ties shall be as set forth in Table 7-A or be equivalent thereto.

704.2.3 Reinforcement for cast-in-place concrete column protection. Cast-in-place concrete protection for steel columns shall be reinforced at the edges of such members with wire ties of not less than 0.18 inch (4.6 mm) in diameter wound spirally around the columns on a pitch of not more than 8 inches (203 mm) or by equivalent reinforcement.

704.2.4 Embedment of pipes. Conduits and pipes shall not be embedded in required fire protection of structural members.

704.2.5 Column jacketing. Where the fire-resistive covering on columns is exposed to injury from moving vehicles, the handling of merchandise or other means, it shall be protected in an approved manner.

704.2.6 Ceiling membrane protection. When a ceiling forms the protective membrane for fire-resistive assemblies, the assemblies and their supporting horizontal structural members need not be individually fire protected except where such members support directly applied loads from a floor and roof or more than one floor. The required fire resistance shall not be less than that required for individual protection of members.

704.2.7 Plaster application. Plaster protective coatings may be applied with the finish coat omitted when they comply with the design mix and thickness requirements of Tables 7-A, 7-B and 7-C.

704.2.8 Truss protection. Where trusses are used as all or part of the structural frame and protection is required by Table 6-A, such protection may be provided by fire-resistive materials enclosing the entire truss assembly on all sides for its entire length and height. The required thickness and construction of fire-resistive assemblies enclosing trusses shall be based on the results of full-scale tests or combinations of tests on truss components or on approved calculations based on such tests that satisfactorily demonstrate that the assembly has the required fire resistance.

704.3 Protected Members.

704.3.1 Attached metal members. The edges of lugs, brackets, rivets and bolt heads attached to structural members may extend to within 1 inch (25 mm) of the surface of the fire protection.

704.3.2 Reinforcing. Thickness of protection for concrete or masonry reinforcement shall be measured to the outside of the reinforcement except that stirrups and spiral reinforcement ties may project not more than $^1/_2$ inch (12.7 mm) into the protection.

704.3.3 Bonded prestressed concrete tendons. For members having a single tendon or more than one tendon installed with equal concrete cover measured from the nearest surface, the cover shall not be less than that set forth in Table 7-A.

For members having multiple tendons installed with variable concrete cover, the average tendon cover shall not be less than that set forth in Table 7-A, provided:

1. The clearance from each tendon to the nearest exposed surface is used to determine the average cover.

2. In no case can the clear cover for individual tendons be less than one half of that set forth in Table 7-A. A minimum cover of $^3/_4$ inch (19.1 mm) for slabs and 1 inch (25.4 mm) for beams is required for any aggregate concrete.

3. For the purpose of establishing a fire-resistive rating, tendons having a clear covering less than that set forth in Table 7-A shall not contribute more than 50 percent of the required ultimate moment capacity for members less than 350 square inches (0.226 m^2) in cross-sectional area and 65 percent for larger members. For structural design purposes, however, tendons having a reduced cover are assumed to be fully effective.

704.4 Members Carrying Masonry or Concrete. All members carrying masonry or concrete walls in buildings over one story in height shall be fire protected with one-hour fire protection or the fire-resistive requirement of the wall, whichever is greater.

704.5 Fire-resistive Material Omitted. Fire-resistive material may be omitted from the bottom flange of lintels spanning not over 6 feet (1829 mm), shelf angles or plates that are not a part of the structural frame.

704.6 Spray-applied Fire-resistive Materials. The density and thickness of spray-applied fire-resistive materials shall be determined following the procedures set forth in UBC Standard 7-6.

SECTION 705 — PROJECTIONS

Cornices, eave overhangs, exterior balconies and similar architectural appendages extending beyond the floor area as defined in Section 207 shall conform to the requirements of this section. (See Section 1006 for additional requirements applicable to exterior exit balconies and stairways.)

Projections from walls of Type I or II construction shall be of noncombustible materials.

Projections from walls of Type III, IV or V construction may be of noncombustible or combustible materials.

Combustible projections located where openings are not permitted or where protection of openings is required shall be of one-hour fire-resistive or heavy-timber construction conforming to Section 605.6.

For projections extending over public property, see Chapter 32.

For combustible ornamentation, see Section 601.5.4.

For limitations on projection distances, see Sections 503.2 and 1204.

SECTION 706 — FIRE-RESISTIVE JOINT SYSTEMS

706.1 General. Joints installed in or between fire-resistive walls, fire-resistive floor or floor-ceiling assemblies and fire-resistive roof or roof-ceiling assemblies shall be protected by an approved fire-resistive joint system designed to resist the passage of fire for a time period not less than the required fire-resistance rating of the floor, roof or wall in or between which it is installed. Fire-resistive joint systems shall be tested in accordance with Section 706.2.

> **EXCEPTION:** Fire-resistive joint systems are not required for joints in the following locations:
>
> 1. Floors within a single dwelling unit.
> 2. Floors where the joint is protected by a shaft enclosure in accordance with Section 711.
> 3. Floors with atriums where the space adjacent to the atrium is included in the volume of the atrium for smoke-control purposes.
> 4. Floors within malls.
> 5. Floors within open parking structures.
> 6. Mezzanine floors.
> 7. Walls that are permitted to have unprotected openings.
> 8. Roofs where openings are permitted.

Such material or construction assembly shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to accommodate expected building movements and to resist the passage of fire and hot gases.

706.2 Fire-resistive Joint Systems. Fire-resistive joint systems shall be tested in accordance with UBC Standard 7-1 under the following conditions:

1. Joint systems shall be installed full height in wall assemblies and full length in floor and roof assemblies.

2. Floor and roof assemblies shall be tested with a minimum positive pressure differential of 0.01 inch of water column (2.5 Pa).

3. Wall assemblies shall be tested with a minimum positive pressure differential of 0.01 inch of water column (2.5 Pa) measured at the mid-height of the wall assembly.

4. Joint systems shall contain a splice. For wall assemblies, the splice shall be located above the mid-height of the wall assembly.

5. Joint systems shall be tested at the maximum joint width for which they are designed. Joint systems designed to accommodate movement shall be expanded to the maximum joint opening width for which they are intended to function.

6. Joint systems designed to be load-bearing shall be loaded to the maximum design load in accordance with their intended application.

7. Joint systems designed to accommodate movement shall be preconditioned by cycling between the minimum and the maximum joint opening width for which they are intended to function for the number of cycles specified in Table 7-D.

8. Nonsymmetrical wall joint systems shall be tested in accordance with Sections 706 and 709.5.

SECTION 707 — INSULATION

707.1 General. Thermal and acoustical insulation located on or within floor-ceiling and roof-ceiling assemblies, crawl spaces, walls, partitions and insulation on pipes and tubing shall comply with this section. Duct insulation and insulation in plenums shall conform to the requirements of the Mechanical Code.

> **EXCEPTION:** Roof insulation shall comply with Section 1510.

707.2 Insulation and Covering on Pipe and Tubing. Insulation and covering on pipe and tubing shall have a flame-spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with UBC Standard 8-1.

> **EXCEPTION:** Foam plastic insulation shall comply with Section 2602.

707.3 Insulation. Cellulose loose-fill insulation shall comply with CPSC 16 CFR, Parts 1209 and 1404. All other insulation materials, including facings, such as vapor barriers or breather papers installed within floor-ceiling assemblies, roof-ceiling assemblies, walls, crawl spaces or attics, shall have a flame-spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with UBC Standard 8-1.

> **EXCEPTIONS:** 1. Foam plastic insulation shall comply with Section 2602.
>
> 2. When such materials are installed in concealed spaces of Types III, IV and V construction, the flame-spread and smoke-developed limitations do not apply to facings, provided that the facing is installed in substantial contact with the unexposed surface of the ceiling, floor or wall finish.

SECTION 708 — FIRE BLOCKS AND DRAFT STOPS

708.1 General. In combustible construction, fireblocking and draftstopping shall be installed to cut off all concealed draft openings (both vertical and horizontal) and shall form an effective barrier between floors, between a top story and a roof or attic space, and shall subdivide attic spaces, concealed roof spaces and floor-ceiling assemblies. The integrity of all fire blocks and draft stops shall be maintained.

708.2 Fire Blocks.

708.2.1 Where required. Fireblocking shall be provided in the following locations:

1. In concealed spaces of stud walls and partitions, including furred spaces, at the ceiling and floor levels and at 10-foot (3048 mm) intervals both vertical and horizontal. See also Section 803, Item 1.

> **EXCEPTION:** Fire blocks may be omitted at floor and ceiling levels when approved smoke-actuated fire dampers are installed at these levels.

2. At all interconnections between concealed vertical and horizontal spaces such as occur at soffits, drop ceilings and cove ceilings.

3. In concealed spaces between stair stringers at the top and bottom of the run and between studs along and in line with the run of stairs if the walls under the stairs are unfinished.

4. In openings around vents, pipes, ducts, chimneys, fireplaces and similar openings that afford a passage for fire at ceiling and floor levels, with noncombustible materials.

5. At openings between attic spaces and chimney chases for factory-built chimneys.

6. Where wood sleepers are used for laying wood flooring on masonry or concrete fire-resistive floors, the space between the floor slab and the underside of the wood flooring shall be filled with noncombustible material or fire blocked in such a manner that there will be no open spaces under the flooring that will exceed 100 square feet (9.3 m^2) in area and such space shall be filled solidly under all permanent partitions so that there is no communication under the flooring between adjoining rooms.

> **EXCEPTIONS:** 1. Fire blocking need not be provided in such floors when at or below grade level in gymnasiums.
>
> 2. Fire blocking need be provided only at the juncture of each alternate lane and at the ends of each lane in a bowling facility.

708.2.2 Fire block construction. Except as provided in Item 4 above, fireblocking shall consist of 2 inches (51 mm) nominal lumber or two thicknesses of 1-inch (25 mm) nominal lumber with broken lap joints or one thickness of $^{23}/_{32}$-inch (18.3 mm) wood structural panel with joints backed by $^{23}/_{32}$-inch (18.3 mm) wood structural panel or one thickness of $^{3}/_{4}$-inch (19.1 mm) Type 2-M particleboard with joints backed by $^{3}/_{4}$-inch (19.1 mm) Type 2-M particleboard.

Fire blocks may also be of gypsum board, cement fiber board, batts or blankets of mineral or glass fiber, or other approved materials installed in such a manner as to be securely retained in place. Loose-fill insulation material shall not be used as a fire block unless specifically tested in the form and manner intended for use to demonstrate its ability to remain in place and to retard the spread of fire and hot gases.

Walls having parallel or staggered studs for sound-transmission control shall have fire blocks of batts or blankets of mineral or glass fiber or other approved flexible materials.

708.3 Draft Stops.

708.3.1 Where required. Draftstopping shall be provided in the locations set forth in this section.

708.3.1.1 Floor-ceiling assemblies.

708.3.1.1.1 Single-family dwellings. When there is usable space above and below the concealed space of a floor-ceiling assembly in a single-family dwelling, draft stops shall be installed so that the area of the concealed space does not exceed 1,000 square feet (93 m^2). Draftstopping shall divide the concealed space into approximately equal areas.

708.3.1.1.2 Two or more dwelling units and hotels. Draft stops shall be installed in floor-ceiling assemblies of buildings having more than one dwelling unit and in hotels. Such draft stops shall be in line with walls separating individual dwelling units and guest rooms from each other and from other areas.

708.3.1.1.3 Other uses. Draft stops shall be installed in floor-ceiling assemblies of buildings or portions of buildings used for other than dwelling or hotel occupancies so that the area of the concealed space does not exceed 1,000 square feet (93 m^2) and so that the horizontal dimension between stops does not exceed 60 feet (18 288 mm).

> **EXCEPTION:** Where approved automatic sprinklers are installed within the concealed space, the area between draft stops may be 3,000 square feet (279 m^2) and the horizontal dimension may be 100 feet (30 480 mm).

708.3.1.2 Attics.

708.3.1.2.1 Two or more dwelling units and hotels. Draft stops shall be installed in the attics, mansards, overhangs, false fronts set out from walls and similar concealed spaces of buildings containing more than one dwelling unit and in hotels. Such draft stops shall be above and in line with the walls separating individual dwelling units and guest rooms from each other and from other uses.

> **EXCEPTIONS:** 1. Draft stops may be omitted along one of the corridor walls, provided draft stops at walls separating individual dwelling units and guest rooms from each other and from other uses, extend to the remaining corridor draft stop.
>
> 2. Where approved sprinklers are installed, draftstopping may be as specified in the exception to Section 708.3.1.2.2.

708.3.1.2.2 Other uses. Draft stops shall be installed in attics, mansards, overhangs, false fronts set out from walls and similar concealed spaces of buildings having uses other than dwellings or hotels so that the area between draft stops does not exceed 3,000 square feet (279 m^2) and the greatest horizontal dimension does not exceed 60 feet (18 288 mm).

> **EXCEPTION:** Where approved automatic sprinklers are installed, the area between draft stops may be 9,000 square feet (836 m^2) and the greatest horizontal dimension may be 100 feet (30 480 mm).

708.3.1.3 Draft stop construction. Draftstopping materials shall not be less than $^{1}/_{2}$-inch (12.7 mm) gypsum board, $^{3}/_{8}$-inch (9.5 mm) wood structural panel, $^{3}/_{8}$-inch (9.5 mm) Type 2-M particleboard or other approved materials adequately supported.

Openings in the partitions shall be protected by self-closing doors with automatic latches constructed as required for the partitions.

Ventilation of concealed roof spaces shall be maintained in accordance with Section 1505.

708.4 Draft Stops or Fire Blocks in Other Locations. Fireblocking of veneer on noncombustible walls shall be in accordance with Section 708.2.1, Item 1.

For fireblocking ceilings applied against noncombustible construction, see Section 803, Item 1.

SECTION 709 — WALLS AND PARTITIONS

709.1 General. Fire-resistive walls and partitions shall be assumed to have the fire-resistance ratings set forth in Table 7-B.

Where materials, systems or devices are incorporated into the assembly that have not been tested as part of the assembly, sufficient data shall be made available to the building official to show that the required fire-resistive rating is not reduced. Materials and methods of construction used to protect joints and penetrations in fire-resistive, fire-rated building assemblies shall not reduce the required fire-resistive rating.

709.2 Combustible Members. Combustible members framed into a wall shall be protected at their ends by not less than one half the required fire-resistive thickness of such wall.

709.3 Exterior Walls.

709.3.1 Extension through attics and concealed spaces. In fire-resistive exterior wall construction, the fire-resistive rating shall be maintained for such walls passing through attic areas or other areas containing concealed spaces.

709.3.2 Vertical fire spread at exterior walls.

709.3.2.1 General. The provisions of this section are intended to restrict the passage of smoke, flame and hot gases from one floor to another at exterior walls. See Section 710 for floor penetrations.

709.3.2.2 Interior. When fire-resistive floor or floor-ceiling assemblies are required, voids created at the intersection of the exterior wall assemblies and such floor assemblies shall be sealed with an approved material. Such material shall be securely installed and capable of preventing the passage of flame and hot gases sufficient to ignite cotton waste when subjected to UBC Standard 7-1 time-temperature fire conditions under a minimum positive pressure differential of 0.01 inch of water column (2.5 Pa) for the time period at least equal to the fire-resistance rating of the floor assembly.

709.3.2.3 Exterior. When openings in an exterior wall are above and within 5 feet (1524 mm) laterally of an opening in the story below, such openings shall be separated by an approved flame barrier extending 30 inches (762 mm) beyond the exterior wall in the plane of the floor or by approved vertical flame barriers not less than 3 feet (914 mm) high measured vertically above the top of the lower opening. Flame barriers shall have a fire resistance of not less than three-fourths hour.

EXCEPTIONS: 1. Flame barriers are not required in buildings equipped with an approved automatic sprinkler system throughout.

2. This section shall not apply to buildings of three stories or less in height.

3. Flame barriers are not required on Group S, Division 4 Occupancies.

709.4 Parapets.

709.4.1 General. Parapets shall be provided on all exterior walls of buildings.

EXCEPTION: A parapet need not be provided on an exterior wall when any of the following conditions exist:

1. The wall is not required to be of fire-resistive construction.

2. The wall, due to location on property line, may have unprotected openings.

3. The building has an area of not more than 1,000 square feet (93 m^2) on any floor.

4. Walls that terminate at roofs of not less than two-hour fire-resistive construction or roofs constructed entirely of noncombustible materials.

5. One-hour fire-resistive exterior walls may terminate at the underside of the roof sheathing, deck or slab, provided:

5.1 Where the roof-ceiling framing elements are parallel to the walls, such framing and elements supporting such framing shall not be of less than one-hour fire-resistive construction for a width of 5 feet (1524 mm) measured from the interior side of the wall for Groups R and U Occupancies and 10 feet (3048 mm) for all other occupancies.

5.2 Where roof-ceiling framing elements are not parallel to the wall, the entire span of such framing and elements supporting such framing shall not be of less than one-hour fire-resistive construction.

5.3 Openings in the roof shall not be located within 5 feet (1524 mm) of the one-hour fire-resistive exterior wall for Groups R and U Occupancies and 10 feet (3048 mm) for all other occupancies.

5.4 The entire building shall be provided with not less than a Class B roofing assembly.

709.4.2 Construction. Parapets shall have the same degree of fire resistance required for the wall upon which they are erected, and on any side adjacent to a roof surface, shall have noncombustible faces for the uppermost 18 inches (457 mm), including counterflashing and coping materials. The height of the parapet shall not be less than 30 inches (762 mm) above the point where the roof surface and the wall intersect. Where the roof slopes toward a parapet at slopes greater than 2 units vertical in 12 units horizontal (16.7% slope), the parapet shall extend to the same height as any portion of the roof that is within the distance where protection of wall openings would be required, but in no case shall the height be less than 30 inches (762 mm).

709.5 Nonsymmetrical Wall Construction. Walls and partitions of nonsymmetrical construction shall be tested with both faces exposed to the furnace, and the assigned fire-resistive rating will be the shortest duration obtained from the two tests conducted in conformance with UBC Standard 7-1. When evidence is furnished to show that the wall was tested with the least fire-resistive side exposed to the furnace, subject to acceptance of the building official, the wall need not be subjected to tests from the opposite side.

709.6 Through Penetrations.

709.6.1 General. Through penetrations of the fire-resistive walls shall comply with Section 709.6.2 or 709.6.3.

EXCEPTION: Where the penetrating items are steel, ferrous or copper pipes or steel conduits, the annular space shall be permitted to be protected as follows:

1. In concrete or masonry walls where the penetrating items are a maximum 6-inch (152 mm) nominal diameter and the opening is a maximum 144 square inches (92 903 mm^2) concrete, grout or mortar shall be permitted when installed the full thickness of the wall or the thickness required to maintain the fire rating, or

2. The material used to fill the annular space shall prevent the passage of flame and hot gases sufficient to ignite cotton waste when subjected to UBC Standard 7-1 time-temperature fire conditions under a minimum positive pressure differential of 0.01 inch of water column (2.5 Pa) at the location of the penetration for the time period equivalent to the fire rating of the construction penetrated.

709.6.2 Fire-rated assembly. Penetrations shall be installed as tested in the approved UBC Standard 7-1 rated assembly.

709.6.3 Penetration firestop system. Penetrations shall be protected by an approved penetration firestop system installed as tested in accordance with UBC Standard 7-5 and shall have an F rating of not less than the required rating of the wall penetrated.

709.7 Membrane Penetrations. Membrane penetrations of the fire-resistive walls shall comply with Section 709.6.

EXCEPTIONS: 1. Steel electrical boxes that do not exceed 16 square inches (10 323 mm^2) in area, provided that the area of such openings does not exceed 100 square inches for any 100 square feet (694 mm^2/m^2) of wall area. Outlet boxes on opposite sides of the wall shall be separated by a horizontal distance of not less than 24 inches (610 mm). Membrane penetrations for electrical outlet boxes of any material are permitted, provided that such boxes are tested for use in fire-resistive assemblies and installed in accordance with the tested assembly.

2. The annular space created by the penetration of a fire sprinkler shall be permitted to be unprotected, provided such space is covered by a metal escutcheon plate.

Noncombustible penetrating items shall not be connected to combustible materials on both sides of the membrane unless it can be confirmed that the fire-resistive integrity of the wall is maintained in accordance with UBC Standard 7-1.

709.8 Joints. The protection of joints shall comply with the requirements of Section 706.

SECTION 710 — FLOOR CEILINGS OR ROOF CEILINGS

710.1 General. Fire-resistive floors, floor-ceiling or roof-ceiling assemblies shall be assumed to have the fire-resistance ratings set forth in Table 7-C. When materials are incorporated into an otherwise fire-resistive assembly that may change the capacity for heat dissipation, fire test results or other substantiating data shall be made available to the building official to show that the required fire-resistive time period is not reduced.

Where the weight of lay-in ceiling panels used as part of fire-resistive floor-ceiling or roof-ceiling assemblies is not adequate to resist an upward force of 1 pound per square foot (0.048 kN/m^2), wire holddowns or other approved devices shall be installed above the panels to prevent vertical displacement under such upward force.

710.2 Through Penetrations.

710.2.1 General. Through penetrations of fire-resistive horizontal assemblies shall be enclosed in fire-resistive shaft enclosures in accordance with Section 711.1 or shall comply with Section 710.2.2 or 710.2.3.

EXCEPTIONS: 1. Steel, ferrous or copper conduits, pipes, tubes, vents, concrete, or masonry penetrating items that penetrate a single fire-rated floor assembly where the annular space is protected with materials that prevent the passage of flame and hot gases sufficient to ignite cotton waste when subjected to UBC Standard 7-1 time-temperature fire conditions under a minimum positive pressure differential of 0.01 inch of water column (2.5 Pa) at the location of the penetration for the time period equivalent to the fire-resistive rating of the construction penetrated. Penetrating items with a maximum 6-inch (152 mm) nominal diameter shall not be limited to the penetration of a single-fire-resistive floor assembly, provided that the area of the penetration does not exceed 144 square inches in any 100 square feet (100 000 mm^2 in 10 m^2) of floor area.

2. Penetrations in a single concrete floor by steel, ferrous or copper conduits, pipes, tubes and vents with a maximum 6-inch (152 mm) nominal diameter provided concrete, grout or mortar is installed the full thickness of the floor or the thickness required to maintain the fire-resistive rating. The penetrating items with a maximum 6-inch (152 mm) nominal diameter shall not be limited to the penetration of a single concrete floor, provided that the area of the penetration does not exceed 144 square inches (92 903 mm^2).

3. Electrical outlet boxes of any material are permitted provided that such boxes are tested for use in fire-resistive assemblies and installed in accordance with the tested assembly.

710.2.2 Fire-rated assemblies. Penetrations shall be installed as tested in the approved UBC Standard 7-1.

710.2.3 Penetration firestop system. Penetration shall be protected by an approved penetration firestop system installed as tested in accordance with UBC Standard 7-5. The system shall have an F rating and a T rating of not less than one hour but not less than the required rating of the floor penetrated.

EXCEPTION: Floor penetrations contained and located within the cavity of a wall do not require a T rating.

710.3 Membrane Penetrations. Penetrations of membranes that are part of a fire-resistive horizontal assembly shall comply with Section 710.2.

EXCEPTIONS: 1. Membrane penetrations of steel, ferrous or copper conduits, electrical outlet boxes, pipes, tubes, vents, concrete, or masonry penetrating items where the annular space is protected in accordance with Section 709.6 or 710.2 or is protected to prevent the free passage of flame and the products of combustion. Such penetrations shall not exceed an aggregate area of 100 square inches in any 100 square feet (694 mm^2/m^2) of ceiling area in assemblies tested without penetrations.

2. Membrane penetrations for electrical outlet boxes of any material are permitted, provided that such boxes are tested for use in fire-resistive assemblies and installed in accordance with the tested assembly.

3. The annular space created by the penetration of a fire sprinkler shall be permitted to be unprotected, provided such space is covered by a metal escutcheon plate.

710.4 Roofs. Fire-resistive roofs may have unprotected openings. See Chapter 24 for skylight construction.

710.5 Wiring in Plenums. Wiring in plenums shall comply with the Mechanical Code.

710.6 Joints. The protection of joints in fire-resistive floors and roofs shall comply with the requirements of Section 706.

SECTION 711 — SHAFT ENCLOSURES

711.1 General. Openings through floors shall be enclosed in a shaft enclosure of fire-resistive construction having the time period set forth in Table 6-A for "shaft enclosures" except as permitted in Sections 711.3, 711.5 and 711.6. See also Section 304.6 for shafts in Group B Occupancies, Section 306.6 for shafts in Group F Occupancies, Sections 307.6 and 307.11.2.3 for shafts in Group H Occupancies, Section 309.6 for shafts in Group M Occupancies and Section 311.6 for shafts in Group S Occupancies.

711.2 Extent of Enclosures. Shaft enclosures shall extend from the lowest floor opening through successive floor openings and shall be enclosed at the top and bottom.

EXCEPTIONS: 1. Shafts extending through or to the underside of the roof sheathing, deck or slab need not be enclosed at the top.

2. Shafts need not be enclosed at the bottom when protected by fire dampers conforming to approved recognized standards, installed at the lowest floor level within the shaft enclosure.

Shaft enclosures shall be constructed to continuously maintain the required fire-resistive integrity.

711.3 Special Provision. In other than Group I Occupancies, openings that penetrate only one floor and are not connected with openings communicating with other stories or basements and that are not concealed within building construction assemblies need not be enclosed.

Exit enclosures shall conform to the applicable provisions of Section 1005.3.3.

In one- and two-story buildings other than Group I Occupancies, gas vents, ducts, piping and factory-built chimneys that extend through not more than two floors need not be enclosed, provided the openings around the penetrations are firestopped at each floor.

EXCEPTION: BW gas vents installed in accordance with their listing.

Gas vents and factory-built chimneys shall be protected as required by the Mechanical Code.

Walls containing gas vents or noncombustible piping that pass through three floors or less need not provide the fire-resistance rating specified in Table 6-A for "shaft enclosures," provided the annular space around the vents or piping is filled at each floor or ceiling with noncombustible materials.

EXCEPTION: BW gas vents installed in accordance with their listing.

Openings made through a floor for penetrations such as cables, cable trays, conduit, pipes or tubing that are protected with approved through-penetration fire stops to provide the same degree of fire resistance as the floor construction need not be enclosed. For floor-ceiling assemblies, see Section 710.

711.4 Protection of Openings. Openings into a shaft enclosure shall be protected by a self-closing or an automatic-closing fire assembly conforming to Section 713 and having a fire-protection rating of one hour for openings through one-hour fire-resistive walls and one and one-half hours for openings through two-hour fire-resistive walls.

> **EXCEPTIONS:** 1. Openings to the exterior may be unprotected when permitted by Table 5-A.
>
> 2. Openings protected by through-penetration fire stops to provide the same degree of fire resistance as the shaft enclosure. See Sections 709 and 710.
>
> 3. Noncombustible ducts, vents or chimneys used to convey vapors, dusts or combustion products may penetrate the enclosure at the bottom.

Openings in shaft enclosures penetrating smoke barriers shall be further protected by smoke dampers conforming with approved recognized standards. See Chapter 35, Part IV.

> **EXCEPTIONS:** 1. Exhaust-only openings serving continuously operating fans and protected using the provisions of Chapter 9.
>
> 2. Smoke dampers are not required when their operation would interfere with the function of a smoke-control system.

711.5 Rubbish and Linen Chute Termination Rooms. In other than Group R, Division 3 Occupancies, rubbish and linen chutes shall terminate in rooms separated from the remainder of the building by an occupancy separation having the same fire resistance as required for the shaft enclosure, but not less than one hour. Openings into chutes and chute termination rooms shall not be located in corridors or stairways. For sprinklers, see Section 904.2.2.

711.6 Chute and Dumbwaiter Shafts. In buildings of Type V construction, chutes and dumbwaiter shafts with a cross-sectional area of not more than 9 square feet (0.84 m^2) may be either of approved fire-resistive wall construction or may have the inside layers of the approved fire-resistive assembly replaced by a lining of not less than 0.019-inch (0.48 mm) No. 26 galvanized sheet gage metal with all joints locklapped. The outside layers of the wall shall be as required for the approved construction. All openings into any such enclosure shall be protected by not less than a self-closing solid-wood door $1^3/_8$ inches (35 mm) thick or equivalent.

SECTION 712 — USABLE SPACE UNDER FLOORS

Usable space under the first story shall be enclosed, and such enclosure, when constructed of metal or wood, shall be protected on the side of the usable space as required for one-hour fire-resistive construction. Doors shall be self-closing, tightfitting of solid-wood construction $1^3/_8$ inches (35 mm) in thickness or self-closing, tightfitting doors acceptable as a part of an assembly having a fire-protection rating of not less than 20 minutes when tested in accordance with Part II of UBC Standard 7-2.

> **EXCEPTIONS:** 1. Group R, Division 3 and Group U Occupancies.
>
> 2. Basements in single-story Group S, Division 3 repair garages where 10 percent or more of the area of the floor-ceiling is open to the first floor.
>
> 3. Underfloor spaces protected by an automatic sprinkler system.

SECTION 713 — FIRE-RESISTIVE ASSEMBLIES FOR PROTECTION OF OPENINGS

713.1 General. Where required by this code for the fire protection of openings, fire assemblies shall meet the requirements of this section.

713.2 Definitions.

FIRE ASSEMBLY is the assembly of a fire door, fire windows or fire damper, including all required hardware, anchorage, frames and sills.

FIRE ASSEMBLY, AUTOMATIC-CLOSING, is a fire assembly that may remain in an open position and that will close automatically when subjected to one or the other of the following:

1. An increase in temperature.

Unless otherwise specified, the closing device shall be one rated at a maximum temperature of 165°F (74°C).

2. Actuation of a smoke detector.

The closing device shall operate by the activation of an approved listed smoke detector. Smoke detectors shall be installed and maintained as set forth in approved nationally recognized standards.

FIRE ASSEMBLY, SELF-CLOSING, is a fire assembly that is kept in a normally closed position and is equipped with an approved device to ensure closing and latching after having been opened for use.

713.3 Identification of Fire Doors, Fire Windows and Fire Dampers. Fire doors, fire windows and fire dampers shall have an approved label or listing mark, indicating the fire-protection rating, which is permanently affixed at the factory where fabrication and assembly are done. Periodic inspections shall be made by an approved inspection agency during fabrication and assembly.

Labels for fire doors used to protect openings into exit enclosures shall indicate that the temperature rise on the unexposed surface does not exceed 450°F (232°C) above ambient at the end of 30 minutes of the fire exposure specified in UBC Standard 7-2 to show compliance with Section 1005.3.

Oversized fire doors may be installed when approved by the building official. The doors shall be labeled or be furnished with a certificate of inspection from an approved agency.

713.4 Installation of Fire Doors, Hardware and Frames, and Fire Dampers. Approved fire door hardware and fire door frames including the anchorage thereof shall be installed in accordance with their listing. Fire dampers shall be fabricated and installed in an approved manner.

713.5 Fire-resistive Tests. The fire-protection rating of all types of required fire assemblies shall be determined in accordance with the requirements specified in UBC Standards 7-2, 7-3 and 7-4. The fire-protection rating of fire dampers shall be determined in accordance with the requirements specified within approved recognized standards.

713.6 Hardware.

713.6.1 Closing devices. Every fire assembly shall be provided with a closing device as follows:

1. Fire assemblies required to have a three-hour fire-protection rating shall be automatic-closing fire assemblies. Automatic-closing fire assemblies to be activated by an increase in temperature shall have one heat-actuating device installed on each side of the wall at the top of the opening and one on each side of the wall at the ceiling height where the ceiling is more than 3 feet (914 mm) above the top of the opening.

2. Fire assemblies required to have a one- and one-half-hour, one-hour or three-fourths-hour fire-protection rating shall be either automatic- or self-closing fire assemblies. Automatic-closing fire assemblies to be activated by an increase in temperature shall have heat-actuating devices located as required in Item 1 or by a single fusible link in the opening incorporated in the closing device.

3. Fire door assemblies required to have fire-protection rating, which are installed across a corridor, shall be automatic-closing fire assemblies. Such fire assemblies shall be activated by a smoke detector. All hold-open devices shall be listed for the purpose and shall release or close the door in the event of a power failure at the device.

4. Fire assemblies required by provisions of Chapter 10 shall have closing devices as specified in Chapter 10.

5. Doors that are a part of an automobile ramp enclosure shall be equipped with automatic-closing devices.

Fire doors that are automatic closing by smoke detection shall not have a closing or reclosing delay of more than 10 seconds.

713.6.2 Hinges. Swinging fire doors shall not have less than two hinges, and when such door exceeds 60 inches (1524 mm) in height, an additional hinge shall be installed for each additional 30 inches (762 mm) of height or fraction thereof. Hinges, except for spring hinges, shall be of the ball-bearing or antifriction type. When spring hinges are used for door-closing purposes, not less than one half of the hinges shall be spring hinges.

713.6.3 Latch. Unless otherwise specifically permitted, all single doors and both leaves of pairs of side-hinged swinging doors shall be provided with an automatic latch that will secure the door when it is closed.

713.7 Glazed Openings in Fire Doors. Glazed openings in fire doors shall not be permitted in a fire assembly required to have a three-hour fire-resistive rating.

The area of glazed openings in a fire door required to have one- and one-half-hour or one-hour fire-resistive rating shall be limited to 100 square inches (64 500 mm^2) with a minimum dimension of 4 inches (102 mm). When both leaves of a pair of doors have observation panels, the total area of the glazed openings shall not exceed 100 square inches (64 500 mm^2) for each leaf.

Glazed openings shall be limited to 1,296 square inches (0.84 m^2) in wood and plastic-faced composite or hollow metal doors, per light, when fire-resistive assemblies are required to have a three-fourths-hour fire-resistive rating.

713.8 Fire Window Size. Fire windows required to have a three-fourths-hour fire-protection rating for protection of openings in exterior walls shall have an area not greater than 84 square feet (7.8 m^2) with neither width nor height exceeding 12 feet (3658 mm) and for protection of openings in interior walls shall be limited in area and size to that tested.

713.9 Glazing. Glazing materials and glass block assemblies shall be qualified by tests in accordance with UBC Standard 7-2 (for fire doors) or UBC Standard 7-4 (for fire windows) as appropriate for the use, and they shall be labeled for the required fire-protection rating and installed in accordance with their listing. Glazing in fire door assemblies and in fire window assemblies subject to human impact in hazardous locations as indicated in Section 2406.4 shall comply with Section 2406.3.

713.10 Smoke Dampers. Not less than Class II, 250°F (121°C) smoke dampers complying with approved recognized standards (see Chapter 35, Part IV) shall be installed and be accessible for inspection and servicing in the following ducted or unducted air openings at:

1. Penetrations of area or occupancy separation walls.

2. Penetrations of the fire-resistive construction of horizontal exit walls or corridors serving as a means of egress.

EXCEPTION: Openings for steel ducts penetrating the required fire-resistive construction of corridors are not required to have smoke dampers when such ducts are of not less than 0.019-inch (0.48 mm) thickness (No. 26 galvanized sheet steel gage) and have no openings serving the corridor.

3. Penetrations of shaft enclosures.

EXCEPTION: Exhaust-only openings serving continuously operating fans and protected using the provisions of Chapter 9.

4. Penetrations of smoke barriers.

5. Penetrations of elevator lobbies required by Section 403.7 or 1004.3.4.5.

6. Penetrations of areas of refuge.

EXCEPTION: Ventilation systems specifically designed and protected to supply outside air to these areas during an emergency.

A smoke damper need not be provided when it can be demonstrated that the smoke damper is not essential to limit the passage of smoke under passive conditions and the proper function of a smoke-control system complying with Chapter 9 does not depend on the operation of the damper. Smoke dampers may be omitted at openings that must be maintained open for proper operation of a mechanical smoke-control system, provided that adequate protection against smoke migration, in the event of system failure, has been provided.

Smoke dampers shall be closed by actuation of a smoke detector installed in accordance with the Fire Code and one of the following applicable methods:

1. Where a damper is installed within a duct, a smoke detector shall be installed in the duct within 5 feet (1524 mm) of the damper with no air outlets or inlets between the detector and the damper. The detector shall be listed for the air velocity, temperature and humidity anticipated at the point where it is installed.

2. Where a damper is installed within an unducted opening in a wall, a spot-type detector listed for releasing service shall be installed within 5 feet (1524 mm) horizontally of the damper.

3. Where a damper is installed in a ceiling, a spot-type detector listed for releasing service shall be installed on the ceiling within 5 feet (1524 mm) of the damper.

4. Where a damper is installed in a corridor wall or ceiling, the damper may be controlled by a smoke-detection system installed in the corridor.

5. When a total-coverage smoke-detection system is provided within all areas served by an HVAC system, dampers may be controlled by the smoke-detection system.

713.11 Fire Dampers. Fire dampers complying with the requirements of approved recognized standards (see Chapter 35, Part IV) shall be installed and be accessible for inspection and servicing in the following ducted and unducted air openings at:

1. Penetrations through area separation walls or occupancy separations.

2. Penetrations of the fire-resistive construction of horizontal exit walls or corridors serving as a means of egress.

EXCEPTION: Openings for steel ducts penetrating the required fire-resistive construction of corridors are not required to have dampers when such ducts are of not less than 0.019-inch (0.48 mm) thickness (No. 26 galvanized sheet steel gage) and have no openings serving the corridor.

3. Penetrations of shaft enclosures.

EXCEPTIONS: 1. Duct penetrations by steel exhaust air subducts extending vertically upward at least 22 inches (559 mm) above the top of the opening in a vented shaft where the airflow is upward.

2. Penetrations of a fire-resistive floor forming the base of a shaft enclosure may be protected by fire dampers listed for installation in the horizontal position.

4. Penetrations of the ceiling of fire-resistive floor-ceiling or roof-ceiling assemblies.

5. Penetrations of an atrium enclosure element.

6. Penetrations of the building exterior required to have protected openings by Section 503.

7. Penetrations of areas of refuge.

EXCEPTION: Ventilation systems specifically designed and protected to supply outside air to these areas during an emergency.

A fire damper is not required where fire tests have demonstrated that fire dampers are not required to maintain the fire resistance of the construction.

The operating temperature of the fire-damper actuating device shall be approximately 50°F (10°C) above the normal temperature within the duct system, but not less than 160°F (71°C). The operating temperature of the actuating device may be increased to not more than 286°F (141°C) when located in a smoke-control system complying with Chapter 9.

713.12 Installation. Fire assemblies shall be installed in accordance with their listing. Only fire dampers labeled for use in dynamic systems shall be installed in heating, ventilation and air-conditioning systems intended to operate with fans on during a fire.

713.13 Signs. When required by the building official, a sign shall be displayed permanently near or on each required fire door in letters not less than 1 inch (25 mm) high to read as follows:

FIRE DOOR
DO NOT OBSTRUCT

SECTION 714 — THROUGH-PENETRATION FIRE STOPS

Through-penetration fire stops required by this code shall have an F or T rating as determined by tests conducted in accordance with UBC Standard 7-5.

Through-penetration fire stops may be used for membrane penetrations.

The F rating shall apply to all through penetrations and shall not be less than the required fire-resistance rating of the assembly penetrated.

The T rating shall apply to those through-penetration locations required to have T ratings as specified in Section 710.2.3 and shall not be less than the required fire-resistance rating of the assembly penetrated.

Where sleeves are used, the sleeves shall be securely fastened to the assembly penetrated. All space between the item contained in the sleeve and the sleeve itself and any space between the sleeve and the assembly penetrated shall be protected. Insulation and coverings on the penetrating item shall not penetrate the assembly unless the specific materials used have been tested as part of the assembly.

EXCEPTION: Fire damper or combination fire damper/smoke damper sleeves shall be installed in accordance with their listing.

TABLE 7-A—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[a]

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR FOLLOWING FIRE-RESISTIVE PERIODS (inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.
1. Steel columns and all members of primary trusses	1-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete, members 6″ by 6″ (152 mm by 152 mm) or greater (not including sandstone, granite and siliceous gravel).[1]	2 1/2	2	1 1/2	1
	1-1.2	Carbonate, lightweight and sand-lightweight aggregate concrete, members 8″ by 8″ (203 mm by 203 mm) or greater (not including sandstone, granite and siliceous gravel).[1]	2	1 1/2	1	1
	1-1.3	Carbonate, lightweight and sand-lightweight aggregate concrete, members 12″ by 12″ (305 mm by 305 mm) or greater (not including sandstone, granite and siliceous gravel).[1]	1 1/2	1	1	1
	1-1.4	Siliceous aggregate concrete and concrete excluded in Item 1-1.1, members 6″ by 6″ (152 mm by 152 mm) or greater.[1]	3	2	1 1/2	1
	1-1.5	Siliceous aggregate concrete and concrete excluded in Item 1-1.1, members 8″ by 8″ (203 mm by 203 mm) or greater.[1]	2 1/2	2	1	1
	1-1.6	Siliceous aggregate concrete and concrete excluded in Item 1-1.1, members 12″ by 12″ (305 mm by 305 mm) or greater.[1]	2	1	1	1
	1-2.1	Clay or shale brick with brick and mortar fill.[1]	3 3/4			2 1/4
	1-3.1	4″ (102 mm) hollow clay tile in two 2″ (51 mm) layers; 1/2″ (12.7 mm) mortar between tile and column; 3/8″ (9.5 mm) metal mesh [0.046″ (1.2 mm) wire diameter] in horizontal joints; tile fill.[1]	4			
	1-3.2	2″ (51 mm) hollow clay tile; 3/4″ (19 mm) mortar between tile and column; 3/8″ (9.5 mm) metal mesh [0.046″ (1.2 mm) wire diameter] in horizontal joints; limestone concrete fill;[1] plastered with 3/4″ (19 mm) gypsum plaster.	3			
	1-3.3	2″ (51 mm) hollow clay tile with outside wire ties [0.08″ (2 mm) diameter] at each course of tile or 3/8″ (9.5 mm) metal mesh [0.046″ (1.2 mm) diameter wire] in horizontal joints; limestone or trap-rock concrete fill[1] extending 1″ (25 mm) outside column on all sides.			3	
	1-3.4	2″ (51 mm) hollow clay tile with outside wire ties [0.08″ (2 mm) diameter] at each course of tile with or without concrete fill; 3/4″ (19 mm) mortar between tile and column.				2
	1-4.1	Cement plaster over metal lath wire tied to 3/4″ (19 mm) cold-rolled vertical channels with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire ties spaced 3″ to 6″ (76 mm to 152 mm) on center. Plaster mixed 1:2 1/2 by volume, cement to sand.			2 1/2[2]	7/8
	1-5.1	Vermiculite concrete, 1:4 mix by volume over paperbacked wire fabric lath wrapped directly around column with additional 2″ by 2″ (51 mm by 51 mm) 0.065 inch/0.065 inch (1.65 mm/1.65 mm) (No. 16/16 B.W. gage) wire fabric placed 3/4″ (19 mm) from outer concrete surface. Wire fabric tied with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire spaced 6″ (152 mm) on center for inner layer and 2″ (51 mm) on center for outer layer.	2			
	1-6.1	Perlite or vermiculite gypsum plaster over metal lath wrapped around column and furred 1 1/4″ (32 mm) from column flanges. Sheets lapped at ends and tied at 6″ (152 mm) intervals with 0.049 inch (1.24 mm) (No. 18 B.W. gage) tie wire. Plaster pushed through to flanges.	1 1/2	1		
	1-6.2	Perlite or vermiculite gypsum plaster over self-furring metal lath wrapped directly around column, lapped 1″ (25 mm) and tied at 6″ (152 mm) intervals with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire.	1 3/4	1 3/8	1	
	1-6.3	Perlite or vermiculite gypsum plaster on metal lath applied to 3/4″ (19 mm) cold-rolled channels spaced 24 inches (610 mm) apart vertically and wrapped flatwise around column.	1 1/2			
	1-6.4	Perlite or vermiculite gypsum plaster over two layers of 1/2″ (12.7 mm) plain full-length gypsum lath applied tight to column flanges. Lath wrapped with 1″ (25.4 mm) hexagonal mesh of No. 20 gage wire and tied with doubled 0.035 inch diameter (0.89 mm) (No. 18 B.W. gage) wire ties spaced 23″ (584 mm) on center. For three-coat work the plaster mix for the second coat shall not exceed 100 pounds (45.4 kg) of gypsum to 2 1/2 cubic feet (0.07 m^3) of aggregate for the three-hour system.	2 1/2	2		
	1-6.5	Perlite or vermiculite gypsum plaster over one layer of 1/2″ (12.7 mm) plain full-length gypsum lath applied tight to column flanges. Lath tied with doubled 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire ties spaced 23″ (584 mm) on center and scratch coat wrapped with 1″ (25 mm) hexagonal mesh 0.035 inch (0.89 mm) (No. 20 B.W. gage) wire fabric. For three-coat work, the plaster mix for the second coat shall not exceed 100 pounds (45.4 kg) of gypsum to 2 1/2 cubic feet (0.07 m^3) of aggregate.		2		
	1-7.1	Multiple layers of 1/2″ (12.7 mm) gypsum wallboard[3] adhesively[4] secured to column flanges and successive layers. Wallboard applied without horizontal joints. Corner edges of each layer staggered. Wallboard layer below outer layer secured to column with doubled 0.049 inch (1.24 mm) (No. 18 B.W. gage) steel wire ties spaced 15″ (381 mm) on center. Exposed corners taped and treated.			2	1

(Continued)

TABLE 7-A—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[a]—(Continued)

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR FOLLOWING FIRE-RESISTIVE PERIODS (inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.
1. Steel columns and all members of primary trusses (cont.)	1-7.2	Three layers of 5/8″ (15.9 mm) Type X gypsum wallboard.[3] First and second layer held in place by 1/8″ (3.2 mm) diameter by 1 3/8″ (35 mm) long ring shank nails with 5/16″ (7.9 mm) diameter heads spaced 24″ (610 mm) on center at corners. Middle layer also secured with metal straps at mid-height and 18″ (457 mm) from each end, and by metal corner bead at each corner held by the metal straps. Third layer attached to corner bead with 1″ (25 mm) long gypsum wallboard screws spaced 12″ (305 mm) on center.			1 7/8	
	1-7.3	Three layers of 5/8″ (15.9 mm) Type X gypsum wallboard,[3] each layer screw attached to 1 5/8″ (41 mm) steel studs 0.018 inch thick (0.46 mm) (No. 25 carbon sheet steel gage) at each corner of column. Middle layer also secured with 0.049 inch (0.12 mm) (No. 18 B.W. gage) double strand steel wire ties, 24″ (610 mm) on center. Screws are No. 6 by 1″ (25 mm) spaced 24″ (610 mm) on center for inner layer, No. 6 by 1 5/8″ (41 mm) spaced 12″ (305 mm) on center for middle layer and No. 8 by 2 1/4″ (57 mm) spaced 12″ (305 mm) on center for outer layer.		1 7/8		
	1-8.1	Wood-fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied over metal lath. Lath lapped 1″ (25 mm) and tied 6″ (152 mm) on center at all ends, edges and spacers with 0.049 inch (0.12 mm) (No. 18 B.W. gage) steel tie wires. Lath applied over 1/2″ (12.7 mm) spacers made of 3/4″ (19 mm) furring channel with 2″ (51 mm) legs bent around each corner. Spacers located 1″ (25 mm) from top and bottom of member and a maximum of 40″ (1016 mm) on center and wire tied with a single strand of 0.049 inch (0.12 mm) (No. 18 B.W. gage) steel tie wires. Corner bead tied to the lath at 6″ (152 mm) on center along each corner to provide plaster thickness.			1 5/8	
2. Webs or flanges of steel beams and girders	2-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete (not including sandstone, granite and siliceous gravel) with 3″ (76 mm) or finer metal mesh placed 1″ (25 mm) from the finished surface anchored to the top flange and providing not less than 0.025 square inch of steel area per foot (53 mm^2 of steel area per meter) in each direction.	2	1 1/2	1	1
	2-1.2	Siliceous aggregate concrete and concrete excluded in Item 2-1.1 with 3″ (76 mm) or finer metal mesh placed 1″ (25 mm) from the finished surface anchored to the top flange and providing not less than 0.025 square inch of steel area per foot (53 mm^2 of steel area per meter) in each direction.	2 1/2	2	1 1/2	1
	2-2.1	Cement plaster on metal lath attached to 3/4″ (19 mm) cold-rolled channels with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire ties spaced 3″ to 6″ (76 mm to 152 mm) on center. Plaster mixed 1:2 1/2 by volume, cement to sand.			2 1/2[2]	7/8
	2-3.1	Vermiculite gypsum plaster on a metal lath cage, wire tied to 0.165 inch (4.19 mm) diameter (No. 8 B.W. gage) steel wire hangers wrapped around beam and spaced 16″ (406 mm) on center. Metal lath ties spaced approximately 5″ (127 mm) on center at cage sides and bottom.		7/8		
	2-4.1	Two layers of 5/8″ (15.9 mm) Type X gypsum wallboard[3] are attached to U-shaped brackets spaced 24″ (610 mm) on center. 0.018 inch (0.46 mm) (No. 25 carbon sheet steel gage) 1 5/8″ deep by 1″ (41 mm deep by 25 mm) galvanized steel runner channels are first installed parallel to and on each side of the top beam flange to provide a 1/2″ (12.7 mm) clearance to the flange. The channel runners are attached to steel deck or concrete floor construction with approved fasteners spaced 12″ (305 mm) on center. U-shaped brackets are formed from members identical to the channel runners. At the bent portion of the U-shaped bracket, the flanges of the channel are cut out so that 1 5/8″ (41 mm) deep corner channels can be inserted without attachment parallel to each side of the lower flange. As an alternate, 0.021 inch (0.41 mm) (No. 24 carbon sheet steel gage) 1″ by 2″ (25 mm by 51 mm) runner and corner angles may be used in lieu of channels, and the web cutouts in the U-shaped brackets may be omitted. Each angle is attached to the bracket with 1/2″ (12.7 mm) long No. 8 self-drilling screws. The vertical legs of the U-shaped bracket are attached to the runners with one 1/2″ (12.7 mm) long No. 8 self-drilling screw. The completed steel framing provides a 2 1/8″ and 1 1/2″ (54 mm and 38 mm) space between the inner layer of wallboard and the sides and bottom of the steel beam, respectively. The inner layer of wallboard is attached to the top runners and bottom corner channels or corner angles with 1 1/4″ (52 mm) long No. 6 self-drilling screws spaced 16″ (406 mm) on center. The outer layer of wallboard is applied with 1 3/4″ (44.5 mm) long No. 6 self-drilling screws spaced 8″ (203 mm) on center. The bottom corners are reinforced with metal corner beads.			1 1/4	

(Continued)

TABLE 7-A—MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[a]—(Continued)

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR FOLLOWING FIRE-RESISTIVE PERIODS (Inches) × 25.4 for mm			
			4 Hr.	3 Hr.	2 Hr.	1 Hr.
2. Webs or flanges of steel beams and girders (cont.)	2-4.2	Three layers of $^5/_8$" (15.9 mm) Type X gypsum wallboard[3] attached to a steel suspension system as described immediately above utilizing the 0.018 inch (0.46 mm) (No. 25 carbon sheet steel gage) 1" by 2" (25 mm by 51 mm) lower corner angles. The framing is located so that a $2^1/_8$" and 2" (54 mm and 51 mm) space is provided between the inner layer of wallboard and the sides and bottom of the beam, respectively. The first two layers of wallboard are attached as described immediately above. A layer of 0.035 inch (0.89 mm) (No. 20 B.W. gage) 1" (25 mm) hexagonal galvanized wire mesh is applied under the soffit of the middle layer and up the sides approximately 2" (51 mm). The mesh is held in position with the No. 6 $1^5/_8$" (41 mm) long screws installed in the vertical leg of the bottom corner angles. The outer layer of wallboard is attached with No. 6 $2^1/_4$" (57 mm) long screws spaced 8" (203 mm) on center. One screw is also installed at the mid-depth of the bracket in each layer. Bottom corners are finished as described above.		$1^7/_8$		
3. Bonded pretensioned reinforcement in prestressed concrete[5]	3-1.1	Carbonate, lightweight, sand-lightweight and siliceous[6] aggregate concrete Beams or girders Solid slabs[8]	 4[7]	 3[7] 2	 $2^1/_2$ $1^1/_2$	 $1^1/_2$ 1
4. Bonded or unbonded posttensioned tendons in prestressed concrete[5,9]	4-1.1	Carbonate, lightweight, sand-lightweight and siliceous aggregate concrete Unrestrained members: Solid slabs[8] Beams and girders[10] 8 in. (203 mm) wide > 12 in. (305 mm) wide	 3	 2 $4^1/_2$ $2^1/_2$	 $1^1/_2$ $2^1/_2$ 2	 $1^3/_4$ $1^1/_2$
	4-1.2	Carbonate, lightweight, sand-lightweight and siliceous aggregate Restrained members:[11] Solid slabs[8] Beams and girders[10] 8 in. (203 mm) wide > 12 in. (305 mm) wide	 $1^1/_4$ $2^1/_2$ 2	 1 2 $1^3/_4$	 $^3/_4$ $1^3/_4$ $1^1/_2$	
5. Reinforcing steel in reinforced concrete columns, beams, girders and trusses	5-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete, members 12" (305 mm) or larger, square or round. (Size limit does not apply to beams and girders monolithic with floors.)	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^1/_2$
	5-1.2	Siliceous aggregate concrete, members 12" (305 mm) or larger, square or round. (Size limit does not apply to beams and girders monolithic with floors.)	2	$1^1/_2$	$1^1/_2$	$1^1/_2$
6. Reinforcing steel in reinforced concrete joists[12]	6-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete.	$1^1/_4$	$1^1/_4$	1	$^3/_4$
	6-1.2	Siliceous aggregate concrete.	$1^3/_4$	$1^1/_2$	1	$^3/_4$
7. Reinforcing and tie rods in floor and roof slabs[12]	7-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete.	1	1	$^3/_4$	$^3/_4$
	7-1.2	Siliceous aggregate concrete.	$1^1/_4$	1	1	$^3/_4$

[a]Generic fire-resistance ratings (those not designated as PROPRIETARY* in the listing) in the *Fire-Resistance Design Manual,* Fourteenth Edition, dated April 1994, as published by the Gypsum Association, may be accepted as if herein listed.

[1]Reentrant parts of protected members to be filled solidly.

[2]Two layers of equal thickness with a $^3/_4$-inch (19 mm) air space between.

[3]For all of the construction with gypsum wallboard described in Table 7-A, gypsum base for veneer plaster of the same size, thickness and core type may be substituted for gypsum wallboard, provided attachment is identical to that specified for the wallboard and the joints on the face layer are reinforced, and the entire surface is covered with a minimum of $^1/_{16}$-inch (1.6 mm) gypsum veneer plaster.

[4]An approved adhesive qualified under UBC Standard 7-1.

[5]Where lightweight or sand-lightweight concrete having an oven-dry weight of 110 pounds per cubic foot (1762 kg/m^3) or less is used, the tabulated minimum cover may be reduced 25 percent, except that in no case shall the cover be less than $^3/_4$ inch (19 mm) in slabs or $1^1/_2$ inches (38 mm) in beams or girders.

[6]For solid slabs of siliceous aggregate concrete, increase tendon cover 20 percent.

[7]Adequate provisions against spalling shall be provided by U-shaped or hooped stirrups spaced not to exceed the depth of the member with a clear cover of 1 inch (25 mm).

[8]Prestressed slabs shall have a thickness not less than that required in Table 7-C for the respective fire-resistive time period.

[9]Fire coverage and end anchorages shall be as follows: Cover to the prestressing steel at the anchor shall be $^1/_2$ inch (12.7 mm) greater than that required away from the anchor. Minimum cover to steel-bearing plate shall be 1 inch (25 mm) in beams and $^3/_4$ inch (19 mm) in slabs.

[10]For beam widths between 8 inches and 12 inches (203 mm and 305 mm), cover thickness can be determined by interpolation.

[11]Interior spans of continuous slabs, beams and girders may be considered restrained.

[12]For use with concrete slabs having a comparable fire endurance where members are framed into the structure in such a manner as to provide equivalent performance to that of monolithic concrete construction.

TABLE 7-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a,1]

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.
1. Brick of clay or shale	1-1.1	Solid units (at least 75 percent solid).	8		6[3]	4
	1-2.1	Hollow brick units[4] (at least 71 percent solid).		8		
	1-2.2	Hollow brick units (at least 60 percent solid, cells filled with loose-fill insulation).	8			
	1-2.3	Hollow brick units at least 64 percent solid.	12			
	1-2.4	Hollow brick, not filled.	5.0	4.3	3.4	2.3
	1-2.5	Hollow brick unit wall, grout or filled with perlite vermiculite or expanded shale aggregate.	6.6	5.5	4.4	3.0
	1-3.1	Hollow (rowlock[5]).	12		8	
	1-4.1	Cavity wall consisting of two 3″ (76 mm) (actual) solid clay brick units separated by 2″ (51 mm) air space, joint reinforcement every 16″ (406 mm) on center vertically.		8		
	1-4.2	Cavity wall consisting of two 4″ (100 mm) nominal solid clay brick units separated by 2″ (51 mm) air space, $^1/_4$″ (6.4 mm) metal ties for 3 square feet (0.28 m^2) of wall area.	10			
	1-5.1	4″ (102 mm) nominal thick units at least 75 percent solid backed with a hat-shaped metal furring channel $^3/_4$″ (19 mm) thick formed from 0.021″ (0.53 mm) sheet metal attached to the brick wall on 24″ (610 mm) centers with approved fasteners, and $^1/_2$″ (12.7 mm) Type X gypsum wallboard[7] attached to the metal furring strips with 1″ (25 mm) long Type S screws spaced 8″ (203 mm) on center.			5[6]	
2. Hollow clay tile, nonload-bearing	2-1.1	Two cells in wall thickness, units at least 40 percent solid.				8
	2-1.2	Two cells in wall thickness, units at least 43 percent solid.				
	2-1.3	Two cells in wall thickness, units at least 46 percent solid.				8
	2-1.4	Two cells in wall thickness, units at least 49 percent solid.			8	
	2-1.5	Three or four cells in wall thickness, units at least 40 percent solid.				8
	2-1.6	Three or four cells in wall thickness, units at least 43 percent solid.			8	
	2-1.7	Three or four cells in wall thickness, units at least 48 percent solid.			8	
	2-1.8	Three or four cells in wall thickness, units at least 53 percent solid.		8		
	2-1.9	Three cells in wall thickness, units at least 40 percent solid.			12	
	2-1.10	Three cells in wall thickness, units at least 45 percent solid.		12		
	2-1.11	Three cells in wall thickness, units at least 49 percent solid.		12		
	2-1.12	Two units and three or four cells in wall thickness, units at least 40 percent solid.		12		
	2-1.13	Two units and three or four cells in wall thickness, units at least 45 percent solid.	12			
	2-1.14	Two units and three or four cells in wall thickness, units at least 53 percent solid.	12			
	2-1.15	Two or three units and four or five cells in wall thickness, units at least 40 percent solid.	16			
3. Structural clay tile, load-bearing	3-1.1	One cell in wall thickness, units at least 40 percent solid.[8,9]				4
	3-1.2	One cell in wall thickness, units at least 30 percent solid.[8,9]			6	
	3-1.3	Two cells in wall thickness, units at least 45 percent solid.[10]				6
	3-1.4	One cell in wall thickness, units at least 40 percent solid.[9,10]				4
	3-1.5	One cell in wall thickness, units at least 30 percent solid.[9,10]			6	
4. Hollow structural clay tile, load-bearing	4-1.1	Two cells in wall thickness, units at least 40 percent solid.				8
	4-1.2	Two cells in wall thickness, units at least 49 percent solid.			8	
	4-1.3	Three or four cells in wall thickness, units at least 53 percent solid.		8		
	4-1.4	Two cells in wall thickness, units at least 46 percent solid.				8
	4-1.5	Three cells in wall thickness, units at least 40 percent solid.			12	
	4-1.6	Two units and three cells in wall thickness, units at least 40 percent solid.		12		
	4-1.7	Two units and three or four cells in wall thickness, units at least 45 percent solid.	12			
	4-1.8	Three cells in wall thickness, units at least 45 percent solid.		12		
	4-1.9	Three cells in wall thickness, units at least 49 percent solid.		12		
	4-1.10	Two units and four cells in wall thickness, units at least 43 percent solid.	16			
	4-1.11	Two or three units and four or five cells in wall thickness, units at least 40 percent solid.	16			

(Continued)

TABLE 7-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a,1]—(Continued)

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.
5. Combination of clay brick and load-bearing hollow clay tile	5.1.1	4″ (102 mm) solid brick and 4″ (102 mm) tile (at least 40 percent solid).		8		
	5.1.2	4″ (102 mm) solid brick and 8″ (203 mm) tile (at least 40 percent solid).	12			
6. Concrete masonry units	6-1.1[11, 12]	Expanded slag or pumice.	4.7	4.0	3.2	2.1
	6-1.2[11, 12]	Expanded clay, shale or slate.	5.1	4.4	3.6	2.6
	6-1.3[11]	Limestone, cinders or air-cooled slag.	5.9	5.0	4.0	2.7
	6-1.4[11, 12]	Calcareous or siliceous gravel.	6.2	5.3	4.2	2.8
7. Solid concrete[13, 14]	7-1.1	Siliceous aggregate concrete.	7.0	6.2	5.0	3.5
		Carbonate aggregate concrete.	6.6	5.7	4.6	3.2
		Sand-lightweight concrete.	5.4	4.6	3.8	2.7
		Lightweight concrete.	5.1	4.4	3.6	2.5
8. Glazed or unglazed facing tile, nonload-bearing	8-1.1	One 2″ (51 mm) unit cored 15 percent maximum and one 4″ (102 mm) unit cored 25 percent maximum with $^3/_4$″ (19 mm) mortar-filled collar joint. Unit positions reversed in alternate courses.		$6^3/_8$		
	8-1.2	One 2″ (51 mm) unit cored 15 percent maximum and one 4″ (102 mm) unit cored 40 percent maximum with $^3/_8$″ (9.5 mm) mortar-filled collar joint. Plastered one side with $^3/_4$″ (19 mm) gypsum plaster. Two wythes tied together every fourth course with No. 22 gage corrugated metal ties.		$6^3/_4$		
	8-1.3	One unit with three cells in wall thickness, cored 29 percent maximum.			6	
	8-1.4	One 2″ (51 mm) unit cored 22 percent maximum and one 4″ (102 mm) unit cored 41 percent maximum with $^1/_4$″ (6 mm) mortar-filled collar joint. Two wythes tied together every third course with 0.030 inch (0.76 mm) (No. 22 galvanized sheet steel gage) corrugated metal ties.			6	
	8-1.5	One 4″ (102 mm) unit cored 25 percent maximum with $^3/_4$″ (19 mm) gypsum plaster on one side.			$4^3/_4$	
	8-1.6	One 4″ (102 mm) unit with two cells in wall thickness, cored 22 percent maximum.				4
	8-1.7	One 4″ (102 mm) unit cored 30 percent maximum with $^3/_4$″ (19 mm) vermiculite gypsum plaster on one side.			$4^1/_2$	
	8-1.8	One 4″ (102 mm) unit cored 39 percent maximum with $^3/_4$″ (19 mm) gypsum plaster on one side.				$4^1/_2$
9. Solid gypsum plaster	9-1.1	$^3/_4$″ (19 mm) by 0.055 inch (1.4 mm) (No. 16 carbon sheet steel gage) vertical cold-rolled channels, 16″ (406 mm) on center with 2.5-pound (1.13 kg) flat metal lath applied to one face and tied with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire at 6″ (152 mm) spacing. Gypsum plaster each side mixed 1:2 by weight, gypsum to sand aggregate.				2[6]
	9-1.2	$^3/_4$″ (19 mm) by 0.055 inch (1.4 mm) (No. 16 carbon sheet steel gage) cold-rolled channels 16″ (406 mm) on center with metal lath applied to one face and tied with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire at 6″ (152 mm) spacing. Perlite or vermiculite gypsum plaster each side. For three-coat work, the plaster mix for the second coat shall not exceed 100 pounds (45.4 kg) of gypsum to $2^1/_2$ cubic feet (0.071 m^3) of aggregate for the one-hour system.			$2^1/_2$[6]	2[6]
	9-1.3	$^3/_4$″ (19 mm) by 0.055 inch (1.4 mm) (No. 16 carbon sheet steel gage) vertical cold-rolled channels, 16″ (406 mm) on center, with $^3/_8$″ (9.5 mm) gypsum lath applied to one face and attached with sheet metal clips. Gypsum plaster each side mixed 1:2 by weight, gypsum to sand aggregate.				2[6]
	9-2.1	Studless with $^1/_2$″ (12.7 mm) full-length plain gypsum lath and gypsum plaster each side. Plaster mixed 1:1 for scratch coat and 1:2 for brown coat, by weight, gypsum to sand aggregate.				2[6]
	9-2.2	Studless with $^1/_2$″ (12.7 mm) full-length plain gypsum lath and perlite or vermiculite gypsum plaster each side.			$2^1/_2$[6]	2[6]
	9-2.3	Studless partition with $^3/_8$″ (9.5 mm) rib metal lath installed vertically, adjacent edges tied 6″ (152 mm) on center with No. 18 gage wire ties, gypsum plaster each side mixed 1:2 by weight, gypsum to sand aggregate.				2[6]
10. Solid perlite and portland cement	10-1.1	Perlite mixed in the ratio of 3 cubic feet (0.085 m^3) to 100 pounds (45.4 kg) of portland cement and machine applied to stud side of $1^1/_2$″ (38 mm) mesh by 0.058 inch (1.47 mm) (No. 17 B.W. gage) paper-backed woven wire fabric lath wire-tied to 4″ (102 mm) deep steel trussed wire[15] studs 16″ (406 mm) on center. Wire ties of 0.049 inch (1.24 mm) (No. 18 B.W. gage) galvanized steel wire 6″ (152 mm) on center vertically.			$3^1/_8$[6]	

(Continued)

TABLE 7-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a,1]—(Continued)

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.
11. Solid neat wood fibered gypsum plaster	11-1.1	3/4″ (19 mm) by 0.055 inch (1.4 mm) (No. 16 carbon sheet steel gage) cold-rolled channels, 12″ (305 mm) on center with 2.5-pound (1.13 kg) flat metal lath applied to one face and tied with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire at 6″ (152 mm) spacing. Neat gypsum plaster applied each side.			2[6]	
12. Solid gypsum wallboard partition	12-1.1	One full-length layer 1/2″ (12.7 mm) Type X gypsum wallboard[7] laminated to each side of 1″ (25 mm) full-length V-edge gypsum coreboard with approved laminating compound. Vertical joints of face layer and coreboard staggered at least 3″ (76 mm).			2[6]	
13. Hollow (studless) gypsum wallboard partition	13-1.1	One full-length layer of 5/8″ (15.9 mm) Type X gypsum wallboard[7] attached to both sides of wood or metal top and bottom runners laminated to each side of 1″ by 6″ (25 mm by 152 mm) full-length gypsum coreboard ribs spaced 24″ (610 mm) on center with approved laminating compound. Ribs centered at vertical joints of face plies and joints staggered 24″ (610 mm) in opposing faces. Ribs may be recessed 6″ (152 mm) from the top and bottom.				2 1/4[6]
	13-1.2	1″ (25 mm) regular gypsum V-edge full-length backing board attached to both sides of wood or metal top and bottom runners with nails or 1 5/8″ (41 mm) drywall screws at 24″ (610 mm) on center. Minimum width of runners 1 5/8″ (41 mm). Face layer of 1/2″ (12.7 mm) regular full-length gypsum wallboard laminated to outer faces of backing board with approved laminating compound.			4 5/8[6]	
14. Noncombustible studs—interior partition with plaster each side	14-1.1	3 1/4″ (82 mm) by 0.044 inch (1.12 mm) (No. 18 carbon sheet steel gage) steel studs spaced 24″ (610 mm) on center. 5/8″ (15.9 mm) gypsum plaster on metal lath each side mixed 1:2 by weight, gypsum to sand aggregate.				4 3/4[6]
	14-1.2	3 5/8″ (92 mm) 0.055 inch (1.4 mm) (No. 16 carbon sheet steel gage) approved nailable[16] studs spaced 24″ (610 mm) on center. 5/8″ (15.9 mm) neat gypsum wood fibered plaster each side over 3/8″ (9.5 mm) rib metal lath nailed to studs with 6d common nails, 8″ (203 mm) on center. Nails driven 1 1/4″ (32 mm) and bent over.			5 5/8	
	14-1.3	4″ (102 mm) 0.044 inch (1.12 mm) (No. 18 carbon sheet steel gage) channel-shaped steel studs at 16″ (406 mm) on center. On each side approved resilient clips pressed onto stud flange at 16″ (406 mm) vertical spacing, 1/4″ (6.4 mm) pencil rods snapped into or wire-tied onto outer loop of clips, metal lath wire-tied to pencil rods at 6″ (152 mm) intervals, 1″ (25 mm) perlite gypsum plaster, each side.		7 5/8[6]		
	14-1.4	2 1/2″ (63.5 mm) 0.044 inch (1.12 mm) (No. 18 carbon sheet steel gage) steel studs spaced 16″ (406 mm) on center. Wood fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied on 3.4-pound (1.54 kg) metal lath wire tied to studs, each side. 3/4″ (19 mm) plaster applied over each face, including finish coat.			4 1/4[6]	
15. Wood studs interior partition with plaster each side	15-1.1[17, 18]	2″ by 4″ (51 mm by 102 mm) wood studs 16″ (406 mm) on center with 5/8″ (15.9 mm) gypsum plaster on metal lath. Lath attached by 4d common nails bent over or No. 14 gage by 1 1/4″ by 3/4″ (31.7 mm by 19 mm) crown width staples spaced 6″ (152 mm) on center. Plaster mixed 1:1 1/2 for scratch coat and 1:3 for brown coat, by weight, gypsum to sand aggregate.				5 1/8
	15-1.2[17]	2″ by 4″ (51 mm by 102 mm) wood studs 16″ (406 mm) on center with metal lath and 7/8″ (22 mm) neat wood fibered gypsum plaster each side. Lath attached by 6d common nails, 7″ (178 mm) on center. Nails driven 1 1/4″ (31.7 mm) and bent over.			5 1/2[6]	
	15-1.3[11, 17]	2″ by 4″ (51 mm by 102 mm) wood studs 16″ (406 mm) on center with 3/8″ (9.5 mm) perforated or plain gypsum lath and 1/2″ (12.7 mm) gypsum plaster each side. Lath nailed with 1 1/8″ (28.6 mm) by No. 13 gage by 19/64″ (7.5 mm) head plasterboard blued nails, 4″ (102 mm) on center. Plaster mixed 1:2 by weight, gypsum to sand aggregate.				5 1/4
	15-1.4[11, 17]	2″ by 4″ (51 mm by 102 mm) wood studs 16″ (406 mm) on center with 3/8″ (9.5 mm) Type X gypsum lath and 1/2″ (12.7 mm) gypsum plaster each side. Lath nailed with 1 1/8″ (28.6 mm) by No. 13 gage by 19/64″ (7.5 mm) head plasterboard blued nails, 5″ (127 mm) on center. Plaster mixed 1:2 by weight, gypsum to sand aggregate.				5 1/4
16. Noncombustible studs—interior partition with gypsum wallboard each side	16-1.1	0.018 inch (0.46 mm) (No. 25 carbon sheet steel gage) channel-shaped studs 24″ (610 mm) on center with one full-length layer of 5/8″ (15.9 mm) Type X gypsum wallboard[7] applied vertically attached with 1″ (25 mm) long No. 6 drywall screws to each stud. Screws are 8″ (203 mm) on center around the perimeter and 12″ (305 mm) on center on the intermediate stud. The wallboard may be applied horizontally when attached to 3 5/8″ (92 mm) studs and the horizontal joints are staggered with those on the opposite side. Screws for the horizontal application shall be 8″ (203 mm) on center at vertical edges and 12″ (305 mm) on center at intermediate studs.				2 7/8[6]
	16-1.2	0.018 inch (0.46 mm) (No. 25 carbon sheet steel gage) channel-shaped studs 24″ (610 mm) on center with two full-length layers of 1/2″ (12.7 mm) Type X gypsum wallboard[7] applied vertically each side. First layer attached with 1″ (25 mm) long, No. 6 drywall screws, 8″ (203 mm) on center around the perimeter and 12″ (305 mm) on center on the intermediate stud. Second layer applied with vertical joints offset one stud space from first layer using 1 5/8″ (41.3 mm) long, No. 6 drywall screws spaced 9″ (229 mm) on center along vertical joints, 12″ (305 mm) on center at intermediate studs and 24″ (610 mm) on center along top and bottom runners.			3 5/8[6]	

(Continued)

TABLE 7-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a,1]—(Continued)

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (inches) × 25.4 for mm			
			4 Hr.	3 Hr.	2 Hr.	1 Hr.
16. Noncombustible studs—interior partition with gypsum wallboard each side (cont.)	16-1.3	0.055 inch (1.40 mm) (No. 16 carbon sheet steel gage) approved nailable metal studs[16] 24" (610 mm) on center with full-length 5/8" (15.9 mm) Type X gypsum wallboard[7] applied vertically and nailed 7" (178 mm) on center with 6d cement-coated common nails. Approved metal fastener grips used with nails at vertical butt joints along studs.				4 7/8
17. Wood studs—interior partition with gypsum wallboard each side	17-1.1[13, 18]	2" by 4" (51 mm by 102 mm) wood studs 16" (406 mm) on center with two layers of 3/8" (9.5 mm) regular gypsum wallboard[7] each side, 4d cooler[19] or wallboard[19] nails at 8" (203 mm) on center first layer, 5d cooler[19] or wallboard[19] nails at 8" (203 mm) on center second layer with laminating compound between layers. Joints staggered. First layer applied full length vertically, second layer applied horizontally or vertically.				5
	17-1.2[17, 18]	2" by 4" (51 mm by 102 mm) wood studs 16" (406 mm) on center with two layers 1/2" (12.7 mm) regular gypsum wallboard[7] applied vertically or horizontally each side, joints staggered. Nail base layer with 5d cooler[19] or wallboard[15] nails at 8" (203 mm) on center, face layer with 8d cooler[19] or wallboard[19] nails at 8" (203 mm) on center.				5 1/2
	17-1.3[17, 18]	2" by 4" (51 mm by 102 mm) wood studs 24" (610 mm) on center with 5/8" (15.9 mm) Type X gypsum wallboard[7] applied vertically or horizontally nailed with 6d cooler[19] or wallboard[19] nails at 7" (178 mm) on center with end joints on nailing members. Stagger joints each side.				4 3/4
	17-1.4[17]	2" by 4" (51 mm by 102 mm) fire-retardant-treated wood studs spaced 24" (610 mm) on center with one layer of 5/8" (15.9 mm) thick Type X gypsum wallboard[7] applied with face paper grain (long dimension) parallel to studs. Wallboard attached with 6d cooler[19] or wallboard[19] nails at 7" (178 mm) on center.				4 3/4[6]
	17-1.5[17, 18]	2" by 4" (51 mm by 102 mm) wood studs 16" (406 mm) on center with two layers 5/8" (15.9 mm) Type X gypsum wallboard[7] each side. Base layers applied vertically and nailed with 6d cooler[19] or wallboard[19] nails at 9" (229 mm) on center. Face layer applied vertically or horizontally and nailed with 8d cooler[19] or wallboard[19] nails at 7" (178 mm) on center. For nail-adhesive application, base layers are nailed 6" (152 mm) on center. Face layers applied with coating of approved wallboard adhesive and nailed 12" (305 mm) on center.			6	
	17-1.6[17]	2" by 3" (51 mm by 76 mm) fire-retardant-treated wood studs spaced 24" (610 mm) on center with one layer of 5/8" (15.9 mm) thick Type X gypsum wallboard[7] applied with face paper grain (long dimension) at right angles to studs. Wallboard attached with 6d cement-coated box nails spaced 7" (178 mm) on center.				3 5/8[6]
18. Exterior or interior walls	18-1.1[17, 18]	Exterior surface with 3/4" (19 mm) drop siding over 1/2" (12.7 mm) gypsum sheathing on 2" by 4" (51 mm by 102 mm) wood studs at 16" (406 mm) on center; interior surface treatment as required for one-hour-rated exterior or interior 2" by 4" (51 mm by 102 mm) wood stud partitions. Gypsum sheathing nailed with 1 3/4" (44.5 mm) by No. 11 gage by 7/16" (11.1 mm) head galvanized nails at 8" (203 mm) on center. Siding nailed with 7d galvanized smooth box nails.				Varies
	18-1.2[17, 18]	2" by 4" (51 mm by 102 mm) wood studs 16" (406 mm) on center with metal lath and 3/4" (19 mm) cement plaster on each side. Lath attached with 6d common nails 7" (178 mm) on center driven to 1" (25 mm) minimum penetration and bent over. Plaster mix 1:4 for scratch coat and 1:5 for brown coat, by volume, cement to sand.				5 3/8
	18-1.3[17, 18]	2" by 4" (51 mm by 102 mm) wood studs 16" (406 mm) on center with 7/8" (22 mm) cement plaster (measured from the face of studs) on the exterior surface with interior surface treatment as required for interior wood stud partitions in this table. Plaster mix 1:4 for scratch coat and 1:5 for brown coat, by volume, cement to sand.				Varies
	18-1.4	3 5/8" (92 mm) No. 16 gage noncombustible studs 16" (406 mm) on center with 7/8" (22 mm) cement plaster (measured from the face of the studs) on the exterior surface with interior surface treatment as required for interior, nonbearing, noncombustible stud partitions in this table. Plaster mix 1:4 for scratch coat and 1:5 for brown coat, by volume, cement to sand.				Varies[6]
	18-1.5[18]	2 1/4" by 3 3/4" (57 mm by 95 mm) clay face brick with cored holes over 1/2" (12.7 mm) gypsum sheathing on exterior surface of 2" by 4" (51 mm by 102 mm) wood studs at 16" (406 mm) on center and two layers 5/8" (15.9 mm) Type X gypsum wallboard[7] on interior surface. Sheathing placed horizontally or vertically with vertical joints over studs nailed 6" (152 mm) on center with 1 3/4" (44.5 mm) by No. 11 gage by 7/16" (11.1 mm) head galvanized nails. Inner layer of wallboard placed horizontally or vertically and nailed 8" (203 mm) on center with 6d cooler[19] or wallboard[19] nails. Outer layer of wallboard placed horizontally or vertically and nailed 8" (203 mm) on center with 8d cooler[19] or wallboard[19] nails. All joints staggered with vertical joints over studs. Outer layer joints taped and finished with compound. Nail heads covered with joint compound. 0.035 inch (0.91 mm) (No. 20 galvanized sheet gage) corrugated galvanized steel wall ties 3/4" by 6 5/8" (19 mm by 168 mm) attached to each stud with two 8d cooler[19] or wallboard[19] nails every sixth course of bricks.			10	

(Continued)

TABLE 7-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a,1]—(Continued)

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.
18. Exterior or interior walls (cont.)	18-1.6[17, 18]	2″ by 6″ (51 mm by 152 mm) fire-retardant-treated wood studs 16″ (406 mm) on center. Interior face has two layers of $^5/_8$″ (15.9 mm) Type X gypsum wallboard[7] with the base layer placed vertically and attached with 6d box nails 12″ (305 mm) on center. The face layer is placed horizontally and attached with 8d box nails 8″ (203 mm) on center at joints and 12″ (305 mm) on center elsewhere. The exterior face has a base layer of $^5/_8$″ (15.9 mm) Type X gypsum wallboard placed vertically with 6d box nails 8″ (203 mm) on center at joints and 12″ (305 mm) on center elsewhere. An approved building paper is next applied, followed by self-furred exterior lath attached with $2^1/_2$″ (63.5 mm), No. 12 gage galvanized roofing nails with a $^3/_8$″ (9.5 mm) diameter head and spaced 6″ (152 mm) on center along each stud. Cement plaster consisting of a $^1/_2$″ (12.7 mm) brown coat is then applied. The scratch coat is mixed in the proportion of 1:3 by weight, cement to sand with 10 pounds (4.54 kg) of hydrated lime and 3 pounds (1.36 kg) of approved additives or admixtures per sack of cement. The brown coat is mixed in the proportion of 1:4 by weight, cement to sand with the same amounts of hydrated lime and approved additives or admixtures used in the scratch coat.			$8^1/_4$	
	18-1.7[17, 18]	2″ by 6″ (51 mm by 152 mm) wood studs 16″ (406 mm) on center. The exterior face has a layer of $^5/_8$″ (15.9 mm) Type X gypsum wallboard[7] placed vertically with 6d box nails 8″ (203 mm) on center at joints and 12″ (305 mm) on center elsewhere. An approved building paper is next applied, followed by 1″ (25 mm) by No. 18 gage self-furred exterior lath attached with 8d by $2^1/_2$″ (63.5 mm) long galvanized roofing nails spaced 6″ (152 mm) on center along each stud. Cement plaster consisting of a $^1/_2$″ (12.7 mm) scratch coat, a bonding agent and a $^1/_2$″ (12.7 mm) brown coat and a finish coat is then applied. The scratch coat is mixed in the proportion of 1:3 by weight, cement to sand with 10 pounds (4.54 kg) of hydrated lime and 3 pounds (1.36 kg) of approved additives or admixtures per sack of cement. The brown coat is mixed in the proportion of 1:4 by weight, cement to sand with the same amounts of hydrated lime and approved additives or admixtures used in the scratch coat. The interior is covered with $^3/_8$″ (9.5 mm) gypsum lath with 1″ (25 mm) hexagonal mesh of 0.035 inch (0.89 mm) (No. 20 B.W. gage) woven wire lath furred out $^5/_{16}$″ (8 mm) and 1″ (25 mm) perlite or vermiculite gypsum plaster. Lath nailed with $1^1/_8$″ (28.6 mm) by No. 13 gage by $^{19}/_{64}$″ (7.5 mm) head plasterboard blued nails spaced 5″ (127 mm) on center. Mesh attached by $1^3/_4$″ (44.5 mm) by No. 12 gage by $^3/_8$″ (9.5 mm) head nails with $^3/_8$″ (9.5 mm) furrings, spaced 8″ (203 mm) on center. The plaster mix shall not exceed 100 pounds (45.4 kg) of gypsum to $2^1/_2$ cubic feet (0.071 m^3) of aggregate.			$8^3/_8$	
	18-1.8[17, 18]	2″ by 6″ (51 mm by 152 mm) wood studs 16″ (406 mm) on center. The exterior face has a layer of $^5/_8$″ (15.9 mm) Type X gypsum wallboard[7] placed vertically with 6d box nails 8″ (203 mm) on center at joints and 12″ (305 mm) on center elsewhere. An approved building paper is next applied, followed by $1^1/_2$″ (38 mm) by No. 17 gage self-furred exterior lath attached with 8d by $2^1/_2$″ (63.5 mm) long galvanized roofing nails spaced 6″ (153 mm) on center along each stud. Cement plaster consisting of a $^1/_2$″ (12.7 mm) scratch coat, and a $^1/_2$″ (12.7 mm) brown coat is then applied. The plaster may be placed by machine. The scratch coat is mixed in the proportion of 1:4 by weight, plastic cement to sand. The brown coat is mixed in the proportion of 1:5 by weight, plastic cement to sand. The interior is covered with $^3/_8$″ (9.5 mm) gypsum lath with 1″ (25 mm) hexagonal mesh of No. 20 gage woven wire lath furred out $^5/_{16}$″ (8 mm) and 1″ (25 mm) perlite or vermiculite gypsum plaster. Lath nailed with $1^1/_8$″ (28.6 mm) by No. 13 gage by $^{19}/_{64}$″ (7.5 mm) head plasterboard blued nails spaced 5″ (127 mm) on center. Mesh attached by $1^3/_4$″ (44.5 mm) by No. 12 gage by $^3/_8$″ (9.5 mm) head nails with $^3/_8$″ (9.5 mm) furrings, spaced 8″ (203 mm) on center. The plaster mix shall not exceed 100 pounds (45.4 kg) of gypsum to $2^1/_2$ cubic feet (0.071 m^3) of aggregate.			$8^3/_8$	
	18-1.9	4″ (102 mm) No. 18 gage, nonload-bearing metal studs, 16″ (406 mm) on center, with 1″ (25 mm) portland cement lime plaster [measured from the back side of the 3.4-pound (1.54 kg) expanded metal lath] on the exterior surface. Interior surface to be covered with 1″ (25 mm) of gypsum plaster on 3.4-pound (1.54 kg) expanded metal lath proportioned by weight—1:2 for scratch coat, 1:3 for brown, gypsum to sand. Lath on one side of the partition fastened to $^1/_4$″ (6.4 mm) diameter pencil rods supported by No. 20 gage metal clips, located 16″ (406 mm) on center vertically, on each stud. 3″ (76 mm) thick mineral fiber insulating batts friction fitted between the studs.			$6^1/_2$[6]	

(Continued)

TABLE 7-B—RATED FIRE-RESISTIVE PERIODS FOR VARIOUS WALLS AND PARTITIONS[a,1]—(Continued)

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[2] (inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.
18. Exterior or interior walls (cont.)	18-1.10	Steel studs 0.060″ (1.52 mm) thick, 4″ deep (102 mm) or 6″ (152 mm) at 16″ (244 mm) or 24″ (610 mm) centers, with $^1/_2$″ (12.7 mm) Glass Fiber Reinforced Concrete (GFRC) on the exterior surface. GFRC is attached with flex anchors at 24″ (610 mm) on center, with 5″ (127 mm) leg welded to studs with two $^1/_2$″-long (12.7 mm) flare-bevel welds, and 4″ (102 mm) foot attached to the GFRC skin with $^5/_8$″ (16 mm) thick GFRC bonding pads that extend $2^1/_2$″ (63.5 mm) beyond the flex anchor foot on both sides. Interior surface to have two layers of $^1/_2$″ (12.7 mm) Type X gypsum wallboard.[7] The first layer of wallboard to be attached with 1-inch-long (25 mm) Type S buglehead screws spaced 24″ (610 mm) on center and the second layer is attached with $1^5/_8$-inch-long (40 mm) Type S screws spaced at 12″ (305 mm) on center. Cavity is to be filled with 5″ (127 mm) of 4 pcf (64 kg/m^3) (nominal) mineral fiber batts. GFRC has $1^1/_2$″ (38 mm) returns packed with mineral fiber and caulked on the exterior.			$6^1/_2$	
	18-1.11	Steel studs 0.060″ (1.52 mm) thick, 4″ deep (102 mm) or 6″ (152 mm) at 16″ (406 mm) or 24″ (610 mm) centers, with $^1/_2$″ (12.7 mm) Glass Fiber Reinforced Concrete (GFRC) on the exterior surface. GFRC is attached with flex anchors at 24″ (610 mm) on center, with 5″ (127 mm) leg welded to studs with two $^1/_2$″-long (12.7 mm) flare-bevel welds, and 4″ (102 mm) foot attached to the GFRC skin with $^5/_8$″ (16 mm) thick GFRC bonding pads that extend $2^1/_2$″ (63.5 mm) beyond the flex anchor foot on both sides. Interior surface to have one layer of $^5/_8$″ (16 mm) Type X gypsum wallboard,[7] attached with $1^1/_4$-inch-long (32 mm) Type S buglehead screws spaced 12″ (305 mm) on center. Cavity is to be filled with 5″ (127 mm) of 4 pcf (64 kg/m^3) (nominal) mineral fiber batts. GFRC has $1^1/_2$″ (38 mm) returns packed with mineral fiber and caulked on the exterior.				$6^1/_8$

[a]Generic fire-resistance ratings (those not designated as PROPRIETARY* in the listing) in the *Fire-Resistance Design Manual,* Fourteenth Edition, dated April 1994, as published by the Gypsum Association, may be accepted as if herein listed.

[1]Staples with equivalent holding power and penetration may be used as alternate fasteners to nails for attachment to wood framing.

[2]Thickness shown for brick and clay tile are nominal thicknesses unless plastered, in which case thicknesses are net. Thickness shown for concrete masonry and hollow clay or shale brick is equivalent thickness defined as the average thickness of solid material in the wall and is represented by the formula:

$$T_E = \frac{V}{L \times H}$$

WHERE:

H = height of block or brick using specified dimensions as defined in Chapter 21, in inches (mm).

L = length of block or brick using specified dimensions as defined in Chapter 21, in inches (mm).

T_E = equivalent thickness, in inches (mm).

V = net volume (gross volume less volume of voids), in cubic inches (mm^3).

When all cells are solid grouted or filled with silicone-treated perlite loose-fill insulation; vermiculite loose-fill insulation; or expanded clay, shale or slate lightweight aggregate, the equivalent thickness shall be the thickness of the block or brick using specified dimensions as defined in Chapter 21. Equivalent thickness may also include the thickness of applied plaster and lath or gypsum wallboard, where specified.

[3]Single-wythe brick.

[4]Hollow brick units 4-inch by 8-inch by 12-inch (102 mm by 203 mm by 305 mm) nominal with two interior cells having a $1^1/_2$-inch (38 mm) web thickness between cells and $1^3/_4$-inch-thick (44.5 mm) face shells.

[5]Rowlock design employs clay brick with all or part of bricks laid on edge with the bond broken vertically.

[6]Shall be used for nonbearing purposes only.

[7]For all of the construction with gypsum wallboard described in this table, gypsum base for veneer plaster of the same size, thickness and core type may be substituted for gypsum wallboard, provided attachment is identical to that specified for the wallboard, and the joints on the face layer are reinforced and the entire surface is covered with a minimum of $^1/_{16}$-inch (1.6 mm) gypsum veneer plaster.

[8]Ratings are for hard-burned clay or shale tile.

[9]Cells filled with tile, stone, slag, cinders or sand mixed with mortar.

[10]Ratings are for medium-burned clay tile.

[11]The fire-resistive time period for concrete masonry units meeting the equivalent thicknesses required for a two-hour fire-resistive rating in Item 6, and having a thickness of not less than $7^5/_8$ inches (194 mm) is four hours when cores which are not grouted are filled with silicone-treated perlite loose-fill insulation; vermiculite loose-fill insulation; or expanded clay, shale or slate lightweight aggregate, sand or slag having a maximum particle size of $^3/_8$ inch (9.5 mm).

[12]For determining the fire-resistance rating of concrete masonry units composed of a combination of aggregate types or where plaster is applied directly to the concrete masonry, see UBC Standard 7-7, Part III. Lightweight aggregates shall have a maximum combined density of 65 pounds per cubic foot (1049 kg/m^3).

[13]See also Footnote 2. The equivalent thickness may include the thickness of cement plaster or 1.5 times the thickness of gypsum plaster applied in accordance with the requirements of Chapter 25.

[14]Concrete walls shall be reinforced with horizontal and vertical temperature reinforcement as required by Sections 1914.3.2 and 1914.3.3.

[15]Studs are welded truss wire studs with 0.18 inch (4.57 mm) (No. 7 B.W. gage) flange wire and 0.18 inch (4.57 mm) (No. 7 B.W. gage) truss wires.

[16]Nailable metal studs consist of two channel studs spot welded back to back with a crimped web forming a nailing groove.

[17]Wood structural panels may be installed between the fire protection and the wood studs on either the interior or exterior side of the wood-frame assemblies in this table, provided the length of the fasteners used to attach the fire protection are increased by an amount at least equal to the thickness of the wood structural panel.

[18]The design stress of studs shall be reduced to 78 percent of allowable F'_c with the maximum not greater than 78 percent of the calculated stress with studs having a slenderness ratio l_e/d of 33.

[19]For properties of cooler or wallboard nails, see approved nationally recognized standards.

TABLE 7-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,1]

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches) × 25.4 for mm				MINIMUM THICKNESS OF CEILING (inches) × 25.4 for mm			
			4 Hr.	3 Hr.	2 Hr.	1 Hr.	4 Hr.	3 Hr.	2 Hr.	1 Hr.
1. Siliceous aggregate concrete	1-1.1	Slab (no ceiling required). Minimum cover over nonprestressed reinforcement shall not be less than 3/4 inch (19 mm).[2]	7.0	6.2	5.0	3.5				
2. Carbonate aggregate concrete	2-1.1		6.6	5.7	4.6	3.2				
3. Sand-lightweight concrete	3-1.1		5.4	4.6	3.8	2.7				
4. Lightweight concrete	4-1.1		5.1	4.4	3.6	2.5				
5. Reinforced concrete joists	5-1.1	Slab with suspended ceiling of vermiculite gypsum plaster over metal lath attached to 3/4″ (19 mm) cold-rolled channels spaced 12″ (305 mm) on center. Ceiling located 6″ (152 mm) minimum below joists.	3	2			1	3/4		
	5-2.1	3/8 (9.5 mm) Type X gypsum wallboard[3] attached to 0.018 inch (0.53 mm) (No. 25 carbon sheet steel gage) by 7/8″ deep by 2 5/8″ (22.2 mm deep by 66.7 mm) hat-shaped galvanized steel channels with 1″ (25 mm) long No. 6 screws. The channels are spaced 24″ (610 mm) on center, span 35″ (889 mm) and are supported along their length at 35″ (889 mm) intervals by 0.033 inch (0.84 mm) (No. 21 galvanized sheet gage) galvanized steel flat strap hangers having formed edges that engage the lips of the channel. The strap hangers are attached to the side of the concrete joists with 5/32″ by 1 1/4″ (4 mm by 31.8 mm) long powder-driven fasteners. The wallboard is installed with the long dimension perpendicular to the channels. All end joints occur on channels and supplementary channels are installed parallel to the main channels, 12″ (305 mm) each side, at end joint occurrences. The finish ceiling is located approximately 12″ (305 mm) below the soffit of the floor slab.			2 1/2				5/8	
6. Steel joists constructed with a poured reinforced concrete slab on metal lath forms or steel form units.[4,5]	6-1.1	Gypsum plaster on metal lath attached to the bottom cord with single No. 16 gage or doubled No. 18 gage wire ties spaced 6″ (152 mm) on center. Plaster mixed 1:2 for scratch coat, 1:3 for brown coat, by weight, gypsum to sand aggregate for two-hour system. For three-hour system plaster is neat.			2 1/2	2 1/4			3/4	5/8
	6-2.1	Vermiculite gypsum plaster on metal lath attached to the bottom chord with single No. 16 gage or doubled 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire ties 6″ (152 mm) on center.		2				5/8		
	6-3.1	Cement plaster over metal lath attached to the bottom chord of joists with single No. 16 gage or doubled 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire ties spaced 6″ (152 mm) on center. Plaster mixed 1:2 for scratch coat, 1:3 for brown coat for one-hour system and 1:1 for scratch coat, 1:1 1/2 for brown coat for two-hour system, by weight, cement to sand.				2				5/8[6]

(Continued)

TABLE 7-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,1]—(Continued)

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.	MINIMUM THICKNESS OF CEILING (inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.
6. Steel joists constructed with a poured reinforced concrete slab on metal lath forms or steel form units.[4,5] (cont.)	6-4.1	Ceiling of $^5/_8$" (15.9 mm) Type X wallboard[3] attached to $^7/_8$" deep by $2^5/_8$" (22.2 mm deep by 66.7 mm) by 0.021 inch (0.53 mm) (No. 25 carbon sheet steel gage) hat-shaped furring channels 12" (305 mm) on center with 1" (25 mm) long No. 6 wallboard screws at 8" (203 mm) on center. Channels wire tied to bottom chord of joists with doubled 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire or suspended below joists on wire hangers.[7]			$2^1/_2$				$^5/_8$	
6. Steel joists constructed with a poured reinforced concrete slab on metal lath forms or steel form units.[4,5] (cont.)	6-5.1	Wood-fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied over metal lath. Lath tied 6" (152 mm) on center to $^3/_4$" (19 mm) channels spaced $13^1/_2$" (343 mm) on center. Channels secured to joists at each intersection with two strands of 0.049 inch (1.24 mm) (No. 18 B.W. gage) galvanized wire.			$2^1/_2$				$^3/_4$	
7. Reinforced concrete slab and joists with hollow clay tile fillers laid end to end in rows $2^1/_2$" (63.5 mm) or more apart; reinforcement placed between rows and concrete cast around and over tile.	7-1.1	$^5/_8$" (15.9 mm) gypsum plaster on bottom of floor or roof construction.			8[8]				$^5/_8$	
7. Reinforced concrete slab and joists with hollow clay tile fillers laid end to end in rows $2^1/_2$" (63.5 mm) or more apart; reinforcement placed between rows and concrete cast around and over tile.	7-1.2	None.				$5^1/_2$[9]				
8. Steel joists constructed with a reinforced concrete slab on top poured on a $^1/_2$"-deep (12.7 mm) steel deck.[5]	8-1.1	Vermiculite gypsum plaster on metal lath attached to $^3/_4$" (19 mm) cold-rolled channels with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire ties spaced 6" (152 mm) on center.	$2^1/_2$[10]				$^3/_4$			
9. 3" (76 mm) deep cellular steel deck with concrete slab on top. Slab thickness measured to top of cells.	9-1.1	Suspended ceiling of vermiculite gypsum plaster base coat and vermiculite acoustical plaster on metal lath attached at 6" (152 mm) intervals to $^3/_4$" (19 mm) cold-rolled channels spaced 12" (305 mm) on center and secured to $1^1/_2$" (38 mm) cold-rolled channels spaced 36" (914 mm) on center with 0.065 inch (1.65 mm) (No. 16 B.W. gage) wire. $1^1/_2$" (38 mm) channels supported by No. 8 gage wire hangers at 36" (914 mm) on center. Beams within envelope and with a $2^1/_2$" (63.5 mm) air space between beam soffit and lath have a 4-hour rating.	$2^1/_2$				$1^1/_8$[11]			
10. $1^1/_2$"-deep (38 mm) steel roof deck on steel framing. Insulation board, 30 pcf density (480 kg/m³), composed of wood fibers with cement binders of thickness shown bonded to deck with unified asphalt adhesive. Covered with a Class A or B roof covering.	10-1.1	Ceiling of gypsum plaster on metal lath. Lath attached to $^3/_4$" (19 mm) furring channels with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire ties spaced 6" (152 mm) on center. $^3/_4$" (19 mm) channel saddle-tied to 2" (51 mm) channels with doubled 0.065 inch (1.65 mm) (No. 16 B.W. gage) wire ties. 2" (51 mm) channels spaced 36" (914 mm) on center suspended 2" (51 mm) below steel framing and saddle-tied with 0.165 inch (4.19 mm) (No. 8 B.W. gage) wire. Plaster mixed 1:2 by weight, gypsum to sand aggregate.			$1^7/_8$	1			$^3/_4$[12]	$^3/_4$[12]

(Continued)

TABLE 7-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,1]—(Continued)

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches) × 25.4 for mm				MINIMUM THICKNESS OF CEILING (inches) × 25.4 for mm			
			4 Hr.	3 Hr.	2 Hr.	1 Hr.	4 Hr.	3 Hr.	2 Hr.	1 Hr.
11. $1\frac{1}{2}$"-deep (38 mm) steel roof deck on steel-framing wood fiber insulation board, 17.5 pcf density (280 kg/m^3) on top applied over a 15-lb. (6.8 kg) asphalt-saturated felt. Class A or B roof covering.	11-1.1	Ceiling of gypsum plaster on metal lath. Lath attached to $\frac{3}{4}$" (19 mm) furring channels with 0.049 inch (1.24 mm) (No. 18 B.W. gage) wire ties spaced 6" (152 mm) on center. $\frac{3}{4}$" (19 mm) channels saddle tied to 2" (51 mm) channels with doubled 0.065 inch (1.65 mm) (No. 16 B.W. gage) wire ties. 2" (51 mm) channels spaced 36" (914 mm) on center suspended 2" (51 mm) below steel framing and saddle tied with 0.165 inch (4.19 mm) (No. 8 B.W. gage) wire. Plaster mixed 1:2 for scratch coat and 1:3 for brown coat, by weight, gypsum to sand aggregate for one-hour system. For two-hour system plaster mix is 1:2 by weight, gypsum to sand aggregate.			$1\frac{1}{2}$	1			$\frac{7}{8}$[7]	$\frac{3}{4}$[12]
12. $1\frac{1}{2}$"-deep (38 mm) steel roof deck on steel-framing insulation of rigid board consisting of expanded perlite and fibers impregnated with integral asphalt waterproofing; density 9 to 12 pcf (144 to 192 kg/m^3) secured to metal roof deck by $\frac{1}{2}$" (12.7 mm) wide ribbons of waterproof, cold-process liquid adhesive spaced 6" (152 mm) apart. Steel joist or light steel construction with metal roof deck, insulation, and Class A or B built-up roof covering.[5]	12-1.1	Gypsum-vermiculite plaster on metal lath wire tied at 6" (152 mm) intervals to $\frac{3}{4}$" (19 mm) furring channels spaced 12" (305 mm) on center and wire tied to 2" (51 mm) runner channels spaced 32" (813 mm) on center. Runners wire tied to bottom chord of steel joists.			1				$\frac{7}{8}$	
13. Double wood floor over wood joists spaced 16" (406 mm) on center.[13,14]	13-1.1	Gypsum plaster over $\frac{3}{8}$" (9.5 mm) Type X gypsum lath. Lath initially applied with not less than four $1\frac{1}{8}$" (28.6 mm) by No. 13 gage by $\frac{19}{64}$" (7.5 mm) head plasterboard blued nails per bearing. Continuous stripping over lath along all joist lines. Stripping consists of 3" (76 mm) wide strips of metal lath attached by $1\frac{1}{2}$" (38 mm) by No. 11 gage by $\frac{1}{2}$" (12.7 mm) head roofing nails spaced 6" (152 mm) on center. Alternate stripping consists of 3" wide 0.049" (76 mm 1.24 mm) diameter wire stripping weighing 1 pound per square yard (0.38 kg/m^2) and attached by No. 16 gage by $1\frac{1}{2}$" by $\frac{3}{4}$" (38 mm by 19 mm) crown width staples, spaced 4" (102 mm) on center. Where alternate stripping is used, the lath nailing may consist of two nails at each end and one nail at each intermediate bearing. Plaster mixed 1:2 by weight, gypsum to sand aggregate.								$\frac{7}{8}$
	13-1.2	Cement or gypsum plaster on metal lath. Lath fastened with $1\frac{1}{2}$" (38 mm) by No. 11 gage by $\frac{7}{16}$" (11.1 mm) head barbed shank roofing nails spaced 5" (127 mm) on center. Plaster mixed 1:2 for scratch coat and 1:3 for brown coat, by weight, cement to sand aggregate.								$\frac{5}{8}$
	13-1.3	Perlite or vermiculite gypsum plaster on metal lath secured to joists with $1\frac{1}{2}$" (38 mm) by No. 11 gage by $\frac{7}{16}$" (11.1 mm) head barbed shank roofing nails spaced 5" (127 mm) on center.								$\frac{5}{8}$

(Continued)

TABLE 7-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,1]—(Continued)

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (Inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.	MINIMUM THICKNESS OF CEILING (Inches) × 25.4 for mm 4 Hr.	3 Hr.	2 Hr.	1 Hr.
13. Double wood floor over wood joists spaced 16″ (406 mm) on center.[13,14] (cont.)	13-1.4	$^1/_2$″ (12.7 mm) Type X gypsum wallboard[3] nailed to joists with 5d cooler[15] or wallboard[15] nails at 6″ (152 mm) on center. End joints of wallboard centered on joists.								$^1/_2$
14. Plywood stressed skin panels consisting of $^5/_8$″ (15.9 mm) thick interior C-D (exterior glue) top stressed skin on 2″ by 6″ (51 mm by 152 mm) nominal (minimum) stringers. Adjacent panel edges joined with 8d common wire nails spaced 6″ (152 mm) on center. Stringers spaced 12″ (305 mm) maximum on center.	14-1.1	$^1/_2$″-thick (12.7 mm) wood fiberboard weighing 15 to 18 pounds per cubic foot (240 to 288 kg/m^3) installed with long dimension parallel to stringers or $^3/_8$″ (9.5 mm) C-D (exterior glue) plywood glued and/or nailed to stringers. Nailing to be with 5d cooler[15] or wallboard[15] nails at 12″ (305 mm) on center. Second layer of $^1/_2$″ (12.7 mm) Type X gypsum wallboard[3] applied with long dimension perpendicular to joists and attached with 8d cooler[15] or wallboard[15] nails at 6″ (152 mm) on center at end joints and 8″ (203 mm) on center elsewhere. Wallboard joints staggered with respect to fiberboard joints.								1
15. Vermiculite concrete slab proportioned 1:4 (portland cement to vermiculite aggregate) on a 1$^1/_2$″-deep (38 mm) steel deck supported on individually protected steel framing. Maximum span of deck 6′ 10″ (2083 mm) where deck is less than 0.019 inch (0.48 mm) (No. 26 carbon steel sheet gage) and 8′ 0″ (2438 mm) where deck is 0.019 inch (0.48 mm) (No. 26 carbon steel sheet gage) or greater. Slab reinforced with 4″ by 8″ (102 mm by 203 mm) 0.109/0.083 inch (0.277/0.211 mm) (No. 12/14 B.W. gage) welded wire mesh.	15-1.1	None.				3[10]				
16. Perlite concrete slab proportioned 1:6 (portland cement to perlite aggregate) on a 1$^1/_4$″-deep (32 mm) steel deck supported on individually protected steel framing. Slab reinforced with 4″ by 8″ (102 by 203 mm) 0.109/0.083 inch (0.277/0.211 mm) (No. 12/14 B.W. gage) welded wire mesh.	16-1.1	None.				3$^1/_2$[10]				
17. Perlite concrete slab proportioned 1:6 (portland cement to perlite aggregate) on a $^9/_{16}$″-deep (14 mm) steel deck supported by steel joists 4′ (1219 mm) on center. Class A or B roof covering on top.	17-1.1	Perlite gypsum plaster on metal lath wire tied to $^3/_4$″ (19 mm) furring channels attached with 0.065 inch (1.65 mm) (No. 16 B.W. gage) wire ties to lower chord of joists.		2[16]	2[16]			$^7/_8$	$^3/_4$	

(Continued)

TABLE 7-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,1]—(Continued)

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches) × 25.4 for mm				MINIMUM THICKNESS OF CEILING (inches) × 25.4 for mm			
			4 Hr.	3 Hr.	2 Hr.	1 Hr.	4 Hr.	3 Hr.	2 Hr.	1 Hr.
18. Perlite concrete slab proportioned 1:6 (portland cement to perlite aggregate) on 1 1/4"-deep (32 mm) steel deck supported on individually protected steel framing. Maximum span of deck 6′ 10″ (2083 mm) where deck is less than 0.019 inch (0.48 mm) (No. 26 carbon sheet steel gage) and 8′ 0″ (2438 mm) where deck is 0.019 inch (0.48 mm) (No. 26 carbon sheet steel gage) or greater. Slab reinforced with 0.042 inch (1.07 mm) (No. 19 B.W. gage) hexagonal wire mesh. Class A or B roof covering on top.	18-1.1	None.			2 1/4[16]					
19. Floor and beam construction consisting of 3″-deep (76 mm) cellular steel floor units mounted on steel members with 1:4 (proportion of portland cement to perlite aggregate) perlite-concrete floor slab on top.	19-1.1	Suspended envelope ceiling of perlite gypsum plaster on metal lath attached to 3/4″ (19 mm) cold-rolled channels, secured to 1 1/2″ (38 mm) cold-rolled channels spaced 42″ (1067 mm) on center supported by 0.203 inch (5.16 mm) (No. 6 B.W. gage) wire 36″ (914 mm) on center. Beams in envelope with 3″ (76 mm) minimum air space between beam soffit and lath have a 4-hour rating.	2[16]				1[12]			
20. Perlite concrete proportioned 1:6 (portland cement to perlite aggregate) poured to 1/8-inch (3 mm) thickness above top of corrugations of 1 5/16-inch-deep (33 mm) galvanized steel deck maximum span 8′ 0″ (2438 mm) for 0.024 inch (0.61 mm) (No. 24 galvanized sheet gage) or 6′ 0″ (1829 mm) for 0.019 inch (0.48 mm) (No. 26 galvanized sheet gage) with deck supported by individually protected steel framing. Approved polystyrene foam plastic insulation board having a flame spread not exceeding 75 [1″ to 4″ (25 mm to 102 mm) thickness with vent holes that approximate 3 percent of the board surface area] placed on top of perlite slurry. A 2′ by 4′ (610 mm by 1219 mm) insulation board contains six 2 3/4″ (70 mm) diameter holes. Board covered with 2 1/4″ (57 mm) minimum perlite concrete slab. Slab reinforced with mesh consisting of 0.042 inch (1.07 mm) (No. 19 B.W. gage) galvanized steel wire twisted together to form 2″ (51 mm) hexagons with straight 0.065 inch (1.65 mm) (No. 16 B.W. gage) galvanized steel wire woven into mesh and spaced 3″ (76 mm). Alternate slab reinforcement may consist of 4″ by 8″ (102 mm by 203 mm), 0.109/0.238 inch (2.77/6.05 mm) (No. 12/4 B.W. gage), or 2″ by 2″ (51 mm by 51 mm), 0.083/0.083 inch (2.11/2.11 mm) (No. 14/14 B.W. gage) welded wire fabric. Class A or B roof covering on top.	20-1.1	None.			Varies					

(Continued)

TABLE 7-C—MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,1]—(Continued)

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches) × 25.4 for mm				MINIMUM THICKNESS OF CEILING (inches) × 25.4 for mm			
			4 Hr.	3 Hr.	2 Hr.	1 Hr.	4 Hr.	3 Hr.	2 Hr.	1 Hr.
21. Wood joist, floor trusses and roof trusses spaced 24″ (610 mm) o.c. with $^1/_2$″ (12.7 mm) wood structural panels with exterior glue applied at right angles to top of joist or truss with 8d nails. The wood structural panel thickness shall not be less than $^1/_2$″ (12.7 mm) nor less than required by Chapter 23.	21-1.1	Base layer $^5/_8$″ (15.9 mm) Type X gypsum wallboard applied at right angles to joist or truss 24″ (610 mm) o.c. with $1^1/_4$″ (32 mm) Type S or Type W drywall screws 24″ (610 mm) o.c. Face layer $^5/_8$″ (15.9 mm) Type X gypsum wallboard or veneer base applied at right angles to joist or truss through base layer with $1^7/_8$″ (48 mm) Type S or Type W drywall screws 12″ (305 mm) o.c. at joints and intermediate joist or truss. Face layer joints offset 24″ (610 mm) from base layer joints. $1^1/_2$″ (38 mm) Type G drywall screws placed 2″ (51 mm) back on either side of face layer end joints, 12″ (305 mm) o.c.				Varies				$1^1/_4$

[a]Generic fire-resistance ratings (those not designated as PROPRIETARY* in the listing) in the *Fire-Resistance Design Manual,* Fourteenth Edition, dated April 1994, as published by the Gypsum Association, may be accepted as if herein listed.
[1]Staples with equivalent holding power and penetration may be used as alternate fasteners to nails for attachment to wood framing.
[2]When the slab is in an unrestrained condition, minimum reinforcement cover shall not be less than $1^5/_8$ inches (41 mm) for four-hour (siliceous aggregate only); $1^1/_4$ inches (32 mm) for four- and three-hour; 1 inch (25 mm) for two-hour (siliceous aggregate only); and $^3/_4$ inch (19.1 mm) for all other restrained and unrestrained conditions.
[3]For all of the construction with gypsum wallboard described in this table, gypsum base for veneer plaster of the same size, thickness and core type may be substituted for gypsum wallboard, provided attachment is identical to that specified for the wallboard, and the joints on the face layer are reinforced and the entire surface is covered with a minimum of $^1/_{16}$-inch (1.6 mm) gypsum veneer plaster.
[4]Slab thickness over steel joists measured at the joists for metal lath form and at the top of the form for steel form units.
[5](a) The maximum allowable stress level for H-Series joists shall not exceed 22,000 psi (152 MPa).
(b) The allowable stress for K-Series joists shall not exceed 26,000 psi (179 MPa), the nominal depth of such joist shall not be less than 10 inches (254 mm) and the nominal joist weight shall not be less than 5 pounds per lineal foot (7.4 kg/m).
[6]Cement plaster with 15 pounds (6.8 kg) of hydrated lime and 3 pounds (1.4 kg) of approved additives or admixtures per bag of cement.
[7]Gypsum wallboard ceilings attached to steel framing may be suspended with $1^1/_2$-inch (38 mm) cold-formed carrying channels spaced 48 inches (1219 mm) on center, which are suspended with No. 8 SWG galvanized wire hangers spaced 48 inches (1219 mm) on center. Cross-furring channels are tied to the carrying channels with No. 18 SWG galvanized wire (double strand) and spaced as required for direct attachment to the framing. This alternative is also applicable to those steel framing assemblies recognized under Footnote a.
[8]Six-inch (152 mm) hollow clay tile with 2-inch (51 mm) concrete slab above.
[9]Four-inch (102 mm) hollow clay tile with $1^1/_2$-inch (38 mm) concrete slab above.
[10]Thickness measured to bottom of steel form units.
[11]Five-eighths inch (15.9 mm) of vermiculite gypsum plaster plus $^1/_2$ inch (12.7 mm) of approved vermiculite acoustical plastic.
[12]Furring channels spaced 12 inches (305 mm) on center.
[13]Double wood floor may be either of the following:
(a) Subfloor of 1-inch (25 mm) nominal boarding, a layer of asbestos paper weighing not less than 14 pounds per 100 square feet (0.7 kg/m^2) and a layer of 1-inch (25 mm) nominal tongue-and-groove finish flooring; or
(b) Subfloor of 1-inch (25 mm) nominal tongue-and-groove boarding or $^{15}/_{32}$-inch (11.9 mm) wood structural panels with exterior glue and a layer of 1-inch (25 mm) nominal tongue-and-groove finish flooring or $^{19}/_{32}$-inch (15.1 mm) wood structural panel finish flooring or a layer of Type I Grade M-1 particleboard not less than $^5/_8$ inch (15.9 mm) thick.
[14]The ceiling may be omitted over unusable space, and flooring may be omitted where unusable space occurs above.
[15]For properties of cooler or wallboard nails, see approved nationally recognized standards.
[16]Thickness measured on top of steel deck unit.

TABLE 7-D—PRECONDITIONING CYCLES FOR FIRE-RESISTIVE JOINT SYSTEMS

TYPE OF JOINT SYSTEM	NUMBER OF CYCLES
Expansion/contraction	500
Seismic	100
Wind sway	500

Chapter 8
INTERIOR FINISHES

SECTION 801 — GENERAL

801.1 Scope. Interior wall and ceiling finish shall mean the exposed interior surfaces of buildings including, but not limited to, fixed or movable walls and partitions, interior wainscoting, paneling or other finish applied structurally or for decoration, acoustical correction, surface insulation, sanitation, structural fire resistance or similar purposes. Requirements for finishes in this chapter shall not apply to trim defined as picture molds, chair rails, baseboards and handrails; or to doors and windows or their frames; or to materials that are less than $^{1}/_{28}$ inch (0.9 mm) in thickness applied directly to the surface of walls or ceilings.

Foam plastics shall not be used as interior finish except as provided in Section 2602. For foam plastic trim, see Section 601.5.5.

See Section 1403 for veneer.

801.2 Standards of Quality. The standards listed below labeled a "UBC standard" are also listed in Chapter 35, Part II, and are part of this code.

1. UBC Standard 8-1, Test Method for Surface-burning Characteristics of Building Materials

2. UBC Standard 8-2, Standard Test Method for Evaluating Room Fire Growth Contribution of Textile Wall Covering

801.3 Veneer. Veneers shall comply with Section 1403.

SECTION 802 — TESTING AND CLASSIFICATION OF MATERIALS

802.1 Testing. Tests shall be made by an approved testing agency to establish surface-burning characteristics and to show that materials when cemented or otherwise fastened in place will not readily become detached when subjected to room temperatures of 300°F (149°C) for 25 minutes. Surface-burning characteristics shall be determined by one of the following methods:

1. The surface-burning characteristics as set forth in UBC Standard 8-1.

2. Any other recognized method of test procedure for determining the surface-burning characteristics of finish materials that will give comparable results to those specified in method Item 1.

3. The room fire growth contribution for textile wall coverings as set forth in UBC Standard 8-2.

802.2 Classification. The classes of materials based on their flame-spread index shall be as set forth in Table 8-A. The smoke density shall be no greater than 450 when tested in accordance with UBC Standard 8-1 in the way intended for use.

SECTION 803 — APPLICATION OF CONTROLLED INTERIOR FINISH

Interior finish materials applied to walls and ceilings shall be tested as specified in Section 802 and regulated for purposes of limiting surface-burning by the following provisions:

1. When walls and ceilings are required by any provision in this code to be of fire-resistive or noncombustible construction, the finish material shall be applied directly against such fire-resistive or noncombustible construction or to furring strips not exceeding $1^{3}/_{4}$ inches (44 mm) applied directly against such surfaces. The intervening spaces between such furring strips shall be filled with inorganic or Class I material or shall be fire blocked not to exceed 8 feet (2438 mm) in any direction. See Section 708 for fireblocking.

2. Where walls and ceilings are required to be of fire-resistive or noncombustible construction and walls are set out or ceilings are dropped distances greater than specified in Item 1 of this section, Class I finish materials shall be used except where the finish materials are protected on both sides by automatic sprinkler systems or are attached to a noncombustible backing or to furring strips installed as specified in Item 1. The hangers and assembly members of such dropped ceilings that are below the main ceiling line shall be of noncombustible materials except that in Types III and V construction, fire-retardant-treated wood may be used. The construction of each set-out wall shall be of fire-resistive construction as required elsewhere in this code. See Section 708 for fire blocks and draft stops.

3. Wall and ceiling finish materials of all classes as permitted in this chapter may be installed directly against the wood decking or planking of Type IV heavy-timber construction, or to wood furring strips applied directly to the wood decking or planking installed and fire blocked as specified in Item 1.

4. An interior wall or ceiling finish that is less than $^{1}/_{4}$ inch (6.4 mm) thick shall be applied directly against a noncombustible backing.

> **EXCEPTIONS:** 1. Class I materials.
>
> 2. Materials where the qualifying tests were made with the material suspended or furred out from the noncombustible backing.

SECTION 804 — MAXIMUM ALLOWABLE FLAME SPREAD

804.1 General. The maximum flame-spread class of finish materials used on interior walls and ceilings shall not exceed that set forth in Table 8-B.

> **EXCEPTIONS:** 1. Except in Group I Occupancies and in enclosed vertical exits, Class III may be used in other means of egress and rooms as wainscoting extending not more than 48 inches (1219 mm) above the floor and for tack and bulletin boards covering not more than 5 percent of the gross wall area of the room.
>
> 2. When a sprinkler system complying with UBC Standard 9-1 or 9-3 is provided, the flame-spread classification rating may be reduced one classification, but in no case shall materials having a classification greater than Class III be used.
>
> 3. The exposed faces of Type IV-H.T., structural members, and Type IV-H.T., decking and planking, where otherwise permissible under this code, are excluded from flame-spread requirements.

804.2 Carpeting on Ceilings. When used as interior ceiling finish, carpeting and similar materials having a napped, tufted, looped or similar surface shall have a Class I flame spread.

SECTION 805 — TEXTILE WALL COVERINGS

When used as interior wall finish, textile wall coverings, including materials such as those having a napped, tufted, looped, nonwoven, woven or similar surface shall comply with the following:

1. Textile wall coverings shall have a Class I flame spread and shall be protected by automatic sprinklers complying with UBC Standard 9-1 or 9-3, or

2. The textile wall covering shall meet the acceptance criteria of UBC Standard 8-2 when tested using a product mounting system, including adhesive, representative of actual use.

SECTION 806 — INSULATION

Thermal and acoustical insulation installed on walls or ceilings shall comply with Section 707.

SECTION 807 — SANITATION

807.1 Floors and Walls in Water Closet Compartment and Showers.

807.1.1 Floors. In other than dwelling units, toilet room floors shall have a smooth, hard nonabsorbent surface such as portland cement, concrete, ceramic tile or other approved material that extends upward onto the walls at least 5 inches (127 mm).

807.1.2 Walls. Walls within 2 feet (610 mm) of the front and sides of urinals and water closets shall have a smooth, hard nonabsorbent surface of portland cement, concrete, ceramic tile or other smooth, hard nonabsorbent surface to a height of 4 feet (1219 mm), and except for structural elements, the materials used in such walls shall be of a type that is not adversely affected by moisture. See Section 2512 for other limitations.

EXCEPTIONS: 1. Dwelling units and guest rooms.

2. Toilet rooms that are not accessible to the public and that have not more than one water closet.

In all occupancies, accessories such as grab bars, towel bars, paper dispensers and soap dishes, provided on or within walls, shall be installed and sealed to protect structural elements from moisture.

807.1.3 Showers. Showers in all occupancies shall be finished as specified in Sections 807.1.1 and 807.1.2 to a height of not less than 70 inches (1778 mm) above the drain inlet. Materials other than structural elements used in such walls shall be of a type that is not adversely affected by moisture. See Section 2512 for other limitations.

807.1.4 Shower doors. For shower doors, see Sections 2406.4 and 2407.

807.2 Water Closet Room Separation. See Section 302.6 for requirements to separate water closet rooms.

TABLE 8-A—FLAME-SPREAD CLASSIFICATION

MATERIAL QUALIFIED BY:	
Class	Flame-spread Index
I	0-25
II	26-75
III	76-200

TABLE 8-B—MAXIMUM FLAME-SPREAD CLASS[1]

OCCUPANCY GROUP	ENCLOSED VERTICAL EXITWAYS	OTHER EXITWAYS[2]	ROOMS OR AREAS
A	I	II	II[3]
B	I	II	III
E	I	II	III
F	II	III	III
H	I	II	III[4]
I-1.1, I-1.2, I-2	I	I[5]	II[6]
I-3	I	I[5]	I[6]
M	I	II	III
R-1	I	II	III
R-3	III	III	III[7]
S-1, S-2	II	II	III
S-3, S-4, S-5	I	II	III
U	NO RESTRICTIONS		

[1]Foam plastics shall comply with the requirements specified in Section 2602. Carpeting on ceilings and textile wall coverings shall comply with the requirements specified in Sections 804.2 and 805, respectively.
[2]Finish classification is not applicable to interior walls and ceilings of exterior exit balconies.
[3]In Group A, Divisions 3 and 4 Occupancies, Class III may be used.
[4]Over two stories shall be of Class II.
[5]In Group I, Divisions 2 and 3 Occupancies, Class II may be used.
[6]Class III may be used in administrative spaces.
[7]Flame-spread provisions are not applicable to kitchens and bathrooms of Group R, Division 3 Occupancies.

Chapter 9
FIRE-PROTECTION SYSTEMS

SECTION 901 — SCOPE

This chapter applies to the design and installation of fire-extinguishing systems, smoke-control systems and smoke and heat venting systems.

For requirements on fire alarm systems, see the following:

SECTION	SUBJECT
303.9	Group A, Divisions 1 and 2 Occupancies
305.2.3, 305.9	Group E Occupancies
307.9	Group H Occupancies
308.9	Group I Occupancies
310.10	Group R Occupancies
403.5	High-rise buildings
408.5	Amusement buildings
307.11.5.5	Group H, Division 6 Occupancies

For smoke detectors in Group R Occupancies, see Section 310.9.

SECTION 902 — STANDARDS OF QUALITY

Fire-extinguishing systems, including automatic sprinkler systems, Class I, Class II and Class III standpipe systems, special automatic extinguishing systems, basement pipe inlets, smoke-control systems, and smoke and heat vents shall be approved and shall be subject to such periodic tests as may be required.

The standards listed below labeled a "UBC standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards (see Sections 3503 and 3504).

1. **Fire-extinguishing system.**

   1.1 UBC Standard 9-1, Installation of Sprinkler Systems

   1.2 UBC Standard 9-3, Installation of Sprinkler Systems in Group R Occupancies Four Stories or Less

2. **Standpipe systems.**

   UBC Standard 9-2, Standpipe Systems

3. **Smoke control.**

   3.1 UBC Standard 7-2, Fire Tests of Door Assemblies

   3.2 UL 555, Fire Dampers

   3.3 UL 555C, Ceiling Dampers

   3.4 UL 555S, Leakage Rated Dampers for Use in Smoke Control Systems

   3.5 UL 33, Heat Response Links for Fire Protection Service

   3.6 UL 353, Limit Controls

4. **Smoke and heat vents.**

   UBC Standard 15-7, Automatic Smoke and Heat Vents

SECTION 903 — DEFINITIONS

For the purpose of this chapter, certain terms are defined as follows:

AUTOMATIC FIRE-EXTINGUISHING SYSTEM is an approved system of devices and equipment that automatically detects a fire and discharges an approved fire-extinguishing agent onto or in the area of a fire.

FIRE DEPARTMENT INLET CONNECTION is a connection through which the fire department can pump water into a standpipe system or sprinkler system.

PRESSURIZATION is the creation and maintenance of pressure levels in zones of a building, including elevator shafts and stairwells that are higher than the pressure level at the smoke source, such pressure levels being produced by positive pressures of a supply of uncontaminated air, by exhausting air and smoke at the smoke source, or by a combination of these methods.

PRESSURIZED STAIRWAY ENCLOSURE is a type of smoke-control system in which stairway enclosures are mechanically pressurized to minimize smoke contamination of them during a fire incident.

SMOKE is the airborne solid and liquid particulates and gases evolved when a material undergoes pyrolysis or combustion, including the quantity of air that is entrained or otherwise mixed into the mass.

SMOKE BARRIER is a continuous membrane, either vertical or horizontal, such as a wall, floor or ceiling assembly that is designed and constructed to restrict the movement of smoke.

SMOKE-CONTROL MODE is a predefined operational configuration of a system or device for the purpose of smoke control.

SMOKE-CONTROL SYSTEM, MECHANICAL, is an engineered system that uses mechanical fans to produce pressure differences across smoke barriers or establish airflows to limit and direct smoke movement.

SMOKE-CONTROL SYSTEM, PASSIVE, is a system of smoke barriers arranged to limit the migration of smoke.

SMOKE-CONTROL ZONE is a space within a building enclosed by smoke barriers.

SMOKE DAMPER is a device that meets the requirements of approved recognized standards, and is designed to resist the passage of air or smoke. A combination fire and smoke damper shall meet the requirements of approved recognized standards. See Chapter 35, Part IV.

SMOKE EXHAUST SYSTEM is a mechanical or gravity system intended to move smoke from the smoke zone to the exterior of the building, including smoke removal, purging and venting systems, as well as the function of exhaust fans utilized to reduce the pressure in a smoke zone.

STACK EFFECT is the vertical airflow within buildings caused by temperature differences.

STANDPIPE SYSTEM is a wet or dry system of piping, valves, outlets and related equipment designed to provide water at specified pressures and installed exclusively for the fighting of fires, including the following:

Class I is a standpipe system equipped with $2^{1}/_{2}$-inch (63.5 mm) outlets.

Class II is a standpipe system directly connected to a water supply and equipped with $1^{1}/_{2}$-inch (38.1 mm) outlets and hose.

Class III is a standpipe system directly connected to a water supply and equipped with $2^{1}/_{2}$-inch (63.5 mm) outlets or $2^{1}/_{2}$-inch (63.5 mm) and $1^{1}/_{2}$-inch (38.1 mm) outlets when a $1^{1}/_{2}$-inch (38.1 mm) hose is required. Hose connections for Class III systems may

F
F
F be made through $2^1/_2$-inch (63.5 mm) hose valves with easily removable $2^1/_2$-inch by $1^1/_2$-inch (63.5 mm by 38.1 mm) reducers.

TENABLE ENVIRONMENT is an environment in which the quantity and location of smoke is limited or otherwise restricted to allow for ready evacuation through the space.

ZONED SMOKE CONTROL is a smoke-control system utilizing pressure differences between adjacent smoke-control zones.

SECTION 904 — FIRE-EXTINGUISHING SYSTEMS

904.1 Installation Requirements.

904.1.1 General. Fire-extinguishing systems required in this code shall be installed in accordance with the requirements of this section.

Fire hose threads used in connection with fire-extinguishing systems shall be national standard hose thread or as approved by the fire department.

The location of fire department hose connections shall be approved by the fire department.

In buildings used for high-piled combustible storage, fire protection shall be in accordance with the Fire Code.

904.1.2 Standards. Fire-extinguishing systems shall comply with UBC Standards 9-1 and 9-2.

EXCEPTIONS: 1. Automatic fire-extinguishing systems not covered by UBC Standard 9-1 or 9-2 shall be approved and installed in accordance with approved standards.

2. Automatic sprinkler systems may be connected to the domestic water-supply main when approved by the building official, provided the domestic water supply is of adequate pressure, capacity and sizing for the combined domestic and sprinkler requirements. In such case, the sprinkler system connection shall be made between the public water main or meter and the building shutoff valve, and there shall not be intervening valves or connections. The fire department connection may be omitted when approved by the fire department.

3. Automatic sprinkler systems in Group R Occupancies four stories or less may be in accordance with UBC Standard 9-3.

904.1.3 Modifications. When residential sprinkler systems as set forth in UBC Standard 9-3 are provided, exceptions to, or reductions in, code requirements based on the installation of an automatic fire-extinguishing system are not allowed.

904.2 Automatic Fire-extinguishing Systems.

904.2.1 Where required. An automatic fire-extinguishing system shall be installed in the occupancies and locations as set forth in this section.

For provisions on special hazards and hazardous materials, see the Fire Code.

904.2.2 All occupancies except Group R, Division 3 and Group U Occupancies. Except for Group R, Division 3 and Group U Occupancies, an automatic sprinkler system shall be installed:

1. In every story or basement of all buildings when the floor area exceeds 1,500 square feet (139.4 m^2) and there is not provided at least 20 square feet (1.86 m^2) of opening entirely above the adjoining ground level in each 50 lineal feet (15 240 mm) or fraction thereof of exterior wall in the story or basement on at least one side of the building. Openings shall have a minimum dimension of not less than 30 inches (762 mm). Such openings shall be accessible to the fire department from the exterior and shall not be obstructed in a manner that firefighting or rescue cannot be accomplished from the exterior.

When openings in a story are provided on only one side and the opposite wall of such story is more than 75 feet (22 860 mm) from such openings, the story shall be provided with an approved automatic sprinkler system, or openings as specified above shall be provided on at least two sides of an exterior wall of the story.

If any portion of a basement is located more than 75 feet (22 860 mm) from openings required in this section, the basement shall be provided with an approved automatic sprinkler system.

2. At the top of rubbish and linen chutes and in their terminal rooms. Chutes extending through three or more floors shall have additional sprinkler heads installed within such chutes at alternate floors. Sprinkler heads shall be accessible for servicing.

3. In rooms where nitrate film is stored or handled.

4. In protected combustible fiber storage vaults as defined in the Fire Code.

5. Throughout all buildings with a floor level with an occupant load of 30 or more that is located 55 feet (16 764 mm) or more above the lowest level of fire department vehicle access.

EXCEPTIONS: 1. Airport control towers.

2. Open parking structures.

3. Group F, Division 2 Occupancies.

904.2.3 Group A Occupancies.

904.2.3.1 Drinking establishments. An automatic sprinkler system shall be installed in rooms used by the occupants for the consumption of alcoholic beverages and unseparated accessory uses where the total area of such unseparated rooms and assembly uses exceeds 5,000 square feet (465 m^2). For uses to be considered as separated, the separation shall not be less than as required for a one-hour occupancy separation. The area of other uses shall be included unless separated by at least a one-hour occupancy separation.

904.2.3.2 Basements. An automatic sprinkler system shall be installed in basements classified as a Group A Occupancy when the basement is larger than 1,500 square feet (139.4 m^2) in floor area.

904.2.3.3 Exhibition and display rooms. An automatic sprinkler system shall be installed in Group A Occupancies that have more than 12,000 square feet (1115 m^2) of floor area that can be used for exhibition or display purposes.

904.2.3.4 Stairs. An automatic sprinkler system shall be installed in enclosed usable space below or over a stairway in Group A, Divisions 2, 2.1, 3 and 4 Occupancies. See Section 1005.3.3.6.

904.2.3.5 Multitheater complexes. An automatic sprinkler system shall be installed in every building containing a multitheater complex.

904.2.3.6 Amusement buildings. An automatic sprinkler system shall be installed in all amusement buildings. The main waterflow switch shall be electrically supervised. The sprinkler main cutoff valve shall be supervised. When the amusement building is temporary, the sprinkler water-supply system may be of an approved temporary type.

EXCEPTION: An automatic sprinkler system need not be provided when the floor area of a temporary amusement building is less than 1,000 square feet (92.9 m^2) and the exit travel distance from any point is less than 50 feet (15 240 mm).

904.2.3.7 Stages. All stages shall be provided with an automatic sprinkler system. Such sprinklers shall be provided throughout the stage and in dressing rooms, workshops, storerooms and other accessory spaces contiguous to such stages.

EXCEPTIONS: 1. Sprinklers are not required for stages 1,000 square feet (92.9 m^2) or less in area and 50 feet (15 240 mm) or less in height where curtains, scenery or other combustible hangings are not retractable vertically. Combustible hangings shall be limited to a single main curtain, borders, legs and a single backdrop.

2. Under stage areas less than 4 feet (1219 mm) in clear height used exclusively for chair or table storage and lined on the inside with $^5/_8$-inch (16 mm) Type X gypsum wallboard or an approved equal.

904.2.3.8 Smoke-protected assembly seating. All areas enclosed with walls and ceilings in buildings or structures containing smoke-protected assembly seating shall be protected with an approved automatic sprinkler system.

EXCEPTION: Press boxes and storage facilities less than 1,000 square feet (92.9 m^2) in area and in conjunction with outdoor seating facilities where all means of egress in the seating area are essentially open to the outside.

904.2.4 Group E Occupancies.

904.2.4.1 General. An automatic fire sprinkler system shall be installed throughout all buildings containing a Group E, Division 1 Occupancy.

EXCEPTIONS: 1. When each room used for instruction has at least one exterior exit door at ground level and when rooms used for assembly purposes have at least one half of the required exits directly to the exterior ground level, a sprinkler system need not be provided.

2. When area separation walls, or occupancy separations having a fire-resistive rating of not less than two hours subdivide the building into separate compartments such that each compartment contains an aggregate floor area not greater than 20,000 square feet (1858 m^2), an automatic sprinkler system need not be provided.

904.2.4.2 Basements. An automatic sprinkler system shall be installed in basements classified as Group E, Division 1 Occupancies.

904.2.4.3 Stairs. An automatic sprinkler system shall be installed in enclosed usable space below or over a stairway in Group E, Division 1 Occupancies. See Section 1005.3.3.6.

904.2.5 Group F Occupancies.

904.2.5.1 Woodworking occupancies. An automatic fire sprinkler system shall be installed in Group F woodworking occupancies over 2,500 square feet (232.3 m^2) in area that use equipment, machinery or appliances that generate finely divided combustible waste or that use finely divided combustible materials.

904.2.6 Group H Occupancies.

904.2.6.1 General. An automatic fire-extinguishing system shall be installed in Group H, Divisions 1, 2, 3 and 7 Occupancies.

904.2.6.2 Group H, Division 4 Occupancies. An automatic fire-extinguishing system shall be installed in Group H, Division 4 Occupancies having a floor area of more than 3,000 square feet (279 m^2).

904.2.6.3 Group H, Division 6 Occupancies. An automatic fire-extinguishing system shall be installed throughout buildings containing Group H, Division 6 Occupancies. The design of the sprinkler system shall not be less than that required under UBC Standard 9-1 for the occupancy hazard classifications as follows:

LOCATION	OCCUPANCY HAZARD CLASSIFICATION
Fabrication areas	Ordinary Hazard Group 2
Service corridors	Ordinary Hazard Group 2
Storage rooms without dispensing	Ordinary Hazard Group 2
Storage rooms with dispensing	Extra Hazard Group 2
Corridors	Ordinary Hazard Group 2[1]

[1]When the design area of the sprinkler system consists of a corridor protected by one row of sprinklers, the maximum number of sprinklers that needs to be calculated is 13.

904.2.7 Group I Occupancies. An automatic sprinkler system shall be installed in Group I Occupancies. In Group I, Division 1.1 and Group I, Division 2 Occupancies, approved quick-response or residential sprinklers shall be installed throughout patient sleeping areas.

EXCEPTION: In jails, prisons and reformatories, the piping system may be dry, provided a manually operated valve is installed at a continuously monitored location. Opening of the valve will cause the piping system to be charged. Sprinkler heads in such systems shall be equipped with fusible elements or the system shall be designed as required for deluge systems in UBC Standard 9-1.

904.2.8 Group M Occupancies. An automatic sprinkler system shall be installed in rooms classed as Group M Occupancies where the floor area exceeds 12,000 square feet (1115 m^2) on any floor or 24,000 square feet (2230 m^2) on all floors or in Group M Occupancies more than three stories in height. The area of mezzanines shall be included in determining the areas where sprinklers are required.

904.2.9 Group R, Division 1 Occupancies. An automatic sprinkler system shall be installed throughout every apartment house three or more stories in height or containing 16 or more dwelling units, every congregate residence three or more stories in height or having an occupant load of 20 or more, and every hotel three or more stories in height or containing 20 or more guest rooms. Residential or quick-response standard sprinklers shall be used in the dwelling units and guest room portions of the building.

904.3 Sprinkler System Monitoring and Alarms.

904.3.1 Where required. All valves controlling the water supply for automatic sprinkler systems and water-flow switches on all sprinkler systems shall be electrically monitored where the number of sprinklers are:

1. Twenty or more in Group I, Divisions 1.1 and 1.2 Occupancies.

2. One hundred or more in all other occupancies.

Valve monitoring and water-flow alarm and trouble signals shall be distinctly different and shall be automatically transmitted to an approved central station, remote station or proprietary monitoring station as defined by national standards, or, when approved by the building official with the concurrence of the chief of the fire department, sound an audible signal at a constantly attended location.

EXCEPTION: Underground key or hub valves in roadway boxes provided by the municipality or public utility need not be monitored.

904.3.2 Alarms. An approved audible sprinkler flow alarm shall be provided on the exterior of the building in an approved location. An approved audible sprinkler flow alarm to alert the occupants shall be provided in the interior of the building in a normally occupied location. Actuation of the alarm shall be as set forth in UBC Standard 9-1.

904.4 Permissible Sprinkler Omissions. Subject to the approval of the building official and with the concurrence of the chief of the fire department, sprinklers may be omitted in rooms or areas as follows:

1. When sprinklers are considered undesirable because of the nature of the contents or in rooms or areas that are of noncombustible construction with wholly noncombustible contents and that are not exposed by other areas. Sprinklers shall not be omitted from any room merely because it is damp, of fire-resistive construction or contains electrical equipment.

2. Sprinklers shall not be installed when the application of water or flame and water to the contents may constitute a serious life or fire hazard, as in the manufacture or storage of quantities of alu-

minum powder, calcium carbide, calcium phosphide, metallic sodium and potassium, quicklime, magnesium powder and sodium peroxide.

3. Safe deposit or other vaults of fire-resistive construction, when used for the storage of records, files and other documents, when stored in metal cabinets.

4. Communication equipment areas under the exclusive control of a public communication utility agency, provided:

4.1 The equipment areas are separated from the remainder of the building by one-hour fire-resistive occupancy separation;

4.2 Such areas are used exclusively for such equipment;

4.3 An approved automatic smoke-detection system is installed in such areas and is supervised by an approved central, proprietary or remote station service or a local alarm that will give an audible signal at a constantly attended location; and

4.4 Other approved fire-protection equipment such as portable fire extinguishers or Class II standpipes are installed in such areas.

5. Other approved automatic fire-extinguishing systems may be installed to protect special hazards or occupancies in lieu of automatic sprinklers.

904.5 Standpipes.

904.5.1 General. Standpipes shall comply with the requirements of this section and UBC Standard 9-2.

904.5.2 Where required. Standpipe systems shall be provided as set forth in Table 9-A.

904.5.3 Location of Class I standpipes. There shall be a Class I standpipe outlet connection at every floor-level landing of every required stairway above or below grade and on each side of the wall adjacent to the exit opening of a horizontal exit. Outlets at stairways shall be located within the exit enclosure or, in the case of pressurized enclosures, within the vestibule or exterior balcony, giving access to the stairway.

Risers and laterals of Class I standpipe systems not located within an enclosed stairway or pressurized enclosure shall be protected by a degree of fire resistance equal to that required for vertical enclosures in the building in which they are located.

EXCEPTION: In buildings equipped with an approved automatic sprinkler system, risers and laterals that are not located within an enclosed stairway or pressurized enclosure need not be enclosed within fire-resistive construction.

There shall be at least one outlet above the roof line when the roof has a slope of less than 4 units vertical in 12 units horizontal (33.3% slope).

In buildings where more than one standpipe is provided, the standpipes shall be interconnected at the bottom.

904.5.4 Location of Class II standpipes. Class II standpipe outlets shall be accessible and shall be located so that all portions of the building are within 30 feet (9144 mm) of a nozzle attached to 100 feet (30 480 mm) of hose.

In Group A, Divisions 1 and 2.1 Occupancies, with occupant loads of more than 1,000, outlets shall be located on each side of any stage, on each side of the rear of the auditorium and on each side of the balcony.

Fire-resistant protection of risers and laterals of Class II standpipe systems is not required.

904.5.5 Location of Class III standpipes. Class III standpipe systems shall have outlets located as required for Class I standpipes in Section 904.5.3 and shall have Class II outlets as required in Section 904.5.4.

Risers and laterals of Class III standpipe systems shall be protected as required for Class I systems.

EXCEPTIONS: 1. In buildings equipped with an approved automatic sprinkler system, risers and laterals that are not located within an enclosed stairway or pressurized enclosure need not be enclosed within fire-resistive construction.

2. Laterals for Class II outlets on Class III systems need not be protected.

In buildings where more than one Class III standpipe is provided, the standpipes shall be interconnected at the bottom.

904.6 Buildings under Construction.

904.6.1 General. During the construction of a building and until the permanent fire-extinguishing system has been installed and is in service, fire protection shall be provided in accordance with this section.

904.6.2 Where required. Every building four stories or more in height shall be provided with not less than one standpipe for use during construction. Such standpipes shall be installed when the progress of construction is not more than 35 feet (10 668 mm) in height above the lowest level of fire department access. Such standpipe shall be provided with fire department hose connections at accessible locations adjacent to usable stairs and the standpipe outlets shall be located adjacent to such usable stairs. Such standpipe systems shall be extended as construction progresses to within one floor of the highest point of construction having secured decking or flooring.

In each floor there shall be provided a $2^1/_2$-inch (63.5 mm) valve outlet for fire department use. Where construction height requires installation of a Class III standpipe, fire pumps and water main connections shall be provided to serve the standpipe.

904.6.3 Temporary standpipes. Temporary standpipes may be provided in place of permanent systems if they are designed to furnish a minimum of 500 gallons of water per minute (1893 L) at 50 pounds per square inch (345 kPa) pressure with a standpipe size of not less than 4 inches (102 mm). All outlets shall not be less than $2^1/_2$ inches (63.5 mm). Pumping equipment sufficient to provide this pressure and volume shall be available at all times when a Class III standpipe system is required.

904.6.4 Detailed requirements. Standpipe systems for buildings under construction shall be installed as required for permanent standpipe systems.

904.7 Basement Pipe Inlets. For basement pipe inlet requirements, see Appendix Section 907.

SECTION 905 — SMOKE CONTROL

905.1 Scope and Purpose. This section applies to mechanical or passive smoke-control systems when they are required by other provisions of this code. The purpose of this section is to establish minimum requirements for the design, installation and acceptance testing of smoke-control systems that are intended to provide a tenable environment for the evacuation or relocation of occupants. These provisions are not intended for the preservation of contents or for assistance in fire-suppression or overhaul activities. Smoke-control systems need not comply with the requirements of Section 609 in the Mechanical Code unless their normal use would otherwise require compliance. Nothing within these requirements is intended to apply when smoke control is not otherwise required by this code. Smoke-control systems are not a substitute for sprinkler protection.

905.2 Design Methods.

905.2.1 General. Buildings or portions thereof required by this code to have a smoke-control system shall have such systems designed in accordance with the requirements of this section.

EXCEPTION: Smoke and heat venting required by Section 906.

905.2.2 Rationality.

905.2.2.1 General. Systems or methods of construction to be used in smoke control shall be based on a rational analysis in accordance with well-established principles of engineering. The analysis shall include, but not be limited by, Sections 905.2.2.2 through 905.2.2.6.

905.2.2.2 Stack effect. The system shall be designed such that the maximum probable normal or reverse stack effects will not adversely interfere with the system's capabilities. In determining the maximum probable stack effects, altitude, elevation, weather history and interior temperatures shall be used.

905.2.2.3 Temperature effect of fire. Buoyancy and expansion caused by the design fire (Section 905.6) shall be analyzed. The system shall be designed such that these effects do not adversely interfere with the system's capabilities.

905.2.2.4 Wind effect. The design shall consider the adverse effects of wind. Such consideration shall be consistent with the requirements of Chapter 16, Division III—Wind Design.

905.2.2.5 HVAC systems. The design shall consider the effects of the heating, ventilating and air-conditioning (HVAC) systems on both smoke and fire transport. The analysis shall include all permutations of systems status. The design shall consider the effects of the fire on the heating, ventilating and air-conditioning systems.

905.2.2.6 Climate. The design shall consider the effects of low temperatures on systems, property and occupants. Air inlets and exhausts shall be located so as to prevent snow or ice blockage.

905.2.3 Smoke barrier construction. A smoke barrier may or may not have a fire-resistive rating. Smoke barriers shall be constructed and sealed to limit leakage areas exclusive of protected openings. Maximum allowable leakage area shall be the aggregate area calculated using the following leakage area ratios:

1. Walls: $A/A_W = 0.00100$
2. Exit enclosures: $A/A_W = 0.00035$
3. All other shafts: $A/A_W = 0.00150$
4. Floors and roofs: $A/A_F = 0.00050$

WHERE:

A = total leakage area, square feet (m²).
A_F = unit floor or roof area of barrier, square feet (m²).
A_W = unit wall area of barrier, square feet (m²).

Total leakage area of the barrier is the product of the smoke barrier gross area times the allowable leakage area ratio. Compliance shall be determined by achieving the minimum air pressure difference across the barrier with the system in the smoke-control mode for mechanical smoke-control systems. Passive smoke-control systems may be tested using other approved means such as door fan testing.

905.2.4 Opening protection. Openings in smoke barriers shall be protected by self-closing devices or automatic-closing devices actuated by the required controls for the mechanical smoke-control system.

EXCEPTIONS: 1. Passive smoke-control systems may have automatic-closing devices actuated by spot-type smoke detectors listed for releasing service.

2. The airflow method may be used to protect openings fixed in a permanently open position which are located between smoke zones.

Door openings shall be protected in accordance with Section 1004.3.4.3.2.

EXCEPTIONS: 1. In Group I, Division 1 Occupancies when such doors are installed across corridors, a pair of opposite-swinging doors without a center mullion shall be installed having vision panels with approved fire-rated glazing materials in approved fire-rated frames, the area of which shall not exceed that tested. The doors shall be close fitting within operational tolerances, and shall not have undercuts, louvers or grilles. The doors shall have head and jamb stops, astragals or rabbets at meeting edges and automatic-closing devices. Positive latching devices may be omitted.

2. Group I, Division 3 Occupancies.

Duct and other heating, ventilating and air-conditioning openings shall be equipped with a minimum Class II, 250°F (121°C) smoke damper as defined and tested in accordance with approved recognized standards. See Chapter 35, Part IV.

905.2.5 Duration of operation. All portions of active or passive smoke-control systems shall be capable of continued operation after detection of the fire event for not less than 20 minutes.

905.3 Pressurization Method.

905.3.1 General. The primary means of controlling smoke shall be pressure differences across smoke barriers. Maintenance of a tenable environment is not required in the smoke-control zone of fire origin.

905.3.2 Minimum pressure difference. The minimum pressure difference across a smoke barrier shall be 0.05 inch water gage (12.4 Pa) in fully sprinklered buildings.

EXCEPTION: Smoke-control systems serving other than fully sprinklered buildings may be approved by the building official, provided the system is designed to achieve pressure differences at least two times the maximum calculated pressure difference produced by the design fire.

905.3.3 Maximum pressure difference. The maximum air pressure difference across a smoke barrier shall be determined by required door-opening forces. The actual force required to open exit doors when the system is in the smoke-control mode shall be in accordance with Section 1003.3.1.5. The calculated force to set a side-hinged, swinging door in motion shall be determined by:

$$F = F_{dc} + K(WA\Delta P)/2(W - d) \qquad (5\text{-}1)$$

WHERE:

A = door area, square feet (m²).
d = distance from door handle to latch edge of door, feet (m).
F = total door opening force, pounds (N).
F_{dc} = force required to overcome closing device, pounds (N).
K = 5.2 (9.6).
W = door width, feet (m).
ΔP = design pressure difference, inches water gage (Pa).

Opening forces for other doors shall be determined by standard engineering methods for the resolution of forces and reactions.

905.4 Airflow Method.

905.4.1 General. When approved by the building official, smoke may be prevented from migrating through openings fixed in a permanently open position, which are located between smoke-control zones by the use of the airflow method. The design airflows shall be in accordance with this section.

905.4.2 Velocity. The minimum average velocity through a fixed opening shall not be less than:

$$v = 217.2\ [h\ (T_f - T_o)/(T_f + 460)]^{1/2} \qquad (5\text{-}2)$$

For SI: $v = 119.9\ [h\ (T_f - T_o)/T_f]^{1/2}$

WHERE:

h = height of opening, feet (m).

T_f = temperature of smoke, °F (K).

T_o = temperature of ambient air, °F (K).

v = air velocity, feet per minute (m/s).

Airflow shall be directed to limit smoke migration from the fire zone. The geometry of openings shall be considered to prevent flow reversal from turbulent effects.

905.4.3 Prohibited conditions. This method shall not be employed where either the quantity of air or the velocity of the airflow will adversely affect other portions of the smoke-control system, unduly intensify the fire, disrupt plume dynamics or interfere with exiting. In no case shall airflows toward the fire exceed 200 feet per minute (60 960 mm per minute). Where Formula (5-2) requires airflows to exceed this limit, the airflow method shall not be used.

905.5 Exhaust Method.

905.5.1 General. When approved by the building official, for large enclosed volume, such as in atria or malls, the exhaust method may be used. The design exhaust volumes shall be in accordance with this section.

905.5.2 Exhaust rate.

905.5.2.1 General. The height of the lowest horizontal surface of the accumulating smoke layer shall be maintained at least 10 feet (3048 mm) above any walking surface within the smoke zone. The required exhaust rate for the zone shall be the largest of the calculated plume mass flow rates for the possible plume configurations. Provisions shall be made for natural or mechanical supply of outside air to make up an equal volume of the air exhausted at flow rates not to exceed 200 feet per minute (60 960 mm per minute) toward the fire.

905.5.2.2 Axisymmetric plumes. The plume mass flow rate [m_p, lbs./sec. (kg/s)] shall be determined by placing the design fire center on the axis of the space being analyzed. The limiting flame height shall be determined by:

$$z_l = 0.533 Q_c^{2/5} \qquad (5\text{-}3)$$

For SI: $z_l = 0.166 Q_c^{2/5}$

WHERE:

Q = total heat output.

Q_c = convective heat output, Btu/s (kW). (The value of Q_c shall not be taken as less than $0.70Q$.)

z = height from top of fuel surface to bottom of smoke layer, feet (m).

z_l = limiting flame height, feet (m). (z_l must be greater than the fuel equivalent diameter. See Section 905.6.)

for $z > z_l$

$$m_p = 0.022 Q_c^{1/3} z^{5/3} + 0.0042 Q_c \qquad (5\text{-}4)$$

For SI: $m_p = 0.071 Q_c^{1/3} z^{5/3} + 0.0018 Q_c$

for $z = z_l$

$$m_p = 0.011 Q_c \qquad (5\text{-}5)$$

For SI: $m_p = 0.035 Q_c$

for $z < z_l$

$$m_p = 0.0208 Q_c^{3/5} z \qquad (5\text{-}6)$$

For SI: $m_p = 0.032 Q_c^{3/5} z$

To convert m_p from pounds per second of mass flow to a volumetric rate, the following formula shall be used:

$$V = 60 m_p/\rho \qquad (5\text{-}7)$$

WHERE:

V = volumetric flow rate, cubic feet per minute (m³/s).

ρ = density of air at the temperature of the smoke layer, lbs./ft.³ (T: in °F) [kg/m³ (T: in°C)].

905.5.2.3 Balcony spill plumes. The plume mass flow rate (m_p) for spill plumes shall be determined using the geometrically probable width based on architectural elements and projections in the following formula:

$$m_p = 0.124(QW^2)^{1/3}(z_b + 0.3H)$$
$$[1 + 0.063(z_b + 0.6H)/W]^{2/3} \qquad (5\text{-}8)$$

For SI: $m_p = 0.41(QW^2)^{1/3}(z_b + 0.3H)$
$[1 + 0.063(z_b + 0.6H)/W]^{2/3}$

WHERE:

H = height above fire to underside of balcony, feet (m).

W = plume width at point of spill, feet (m).

z_b = height from balcony, feet (m).

905.5.2.4 Window plumes. The plume mass flow rate (m_p) shall be determined from:

$$m_p = 0.077(A_w H_w^{1/2})^{1/3}(z_w + a)^{5/3} + 0.18 A_w H_w^{1/2} \qquad (5\text{-}9)$$

For SI: $m_p = 0.68(A_w H_w^{1/2})^{1/3}(z_w + a)^{5/3} + 1.5 A_w H_w^{1/2}$

WHERE:

A_w = area of the opening, square feet (m²).

H_w = height of the opening, feet (m).

z_w = height from the top of the window or opening to the bottom of the smoke layer, feet (m).

$$a = 2.4 A_w^{2/5} H_w^{1/5} - 2.1 H_w \qquad (5\text{-}10)$$

905.5.2.5 Plume contact with walls. When the axisymmetric plume contacts the surrounding walls, the mass flow rate may be considered to be constant from the point of contact and beyond provided that contact remains constant. Use of this provision requires calculation of the plume diameter, which shall be calculated by:

$$d = 0.48\ [(T_c + 460)/(T_a + 460)]^{1/2} z \qquad (5\text{-}11)$$

For SI: $d = 0.48\ (T_c/T_a)^{1/2} z$

WHERE:

d = plume diameter, feet (m).

T_a = ambient air temperature, °F (K).

T_c = plume center line temperature, °F (K).

= $(318\ Q_c^{2/3} H^{-5/3}) + T_c$

For SI: $(23.3\ Q_c^{2/3} H^{-5/3} + 273.15) + T_a$

z = height at which T_c is determined, feet (m).

905.6 Design Fire.

905.6.1 General. The design fire shall be based on a Q of not less than 5,000 Btu per second (5275 kW) unless a rational analysis is performed by the designer and approved by the building official.

905.6.2 Rational analysis.

905.6.2.1 Factors considered. The engineering analysis shall include the characteristics of the fuel, fuel load, effects included by the fire, whether the fire is likely to be steady or unsteady.

905.6.2.2 Separation distance. Determination of the design fire shall include consideration of the type of fuel, fuel spacing and configuration. The design fire shall be increased if other combustibles are within the separation distance as determined by:

$$R = [Q/(12\pi q'')]^{1/2} \qquad (5\text{-}12)$$

WHERE:

Q = heat release from fire, Btu/s (kW).

q'' = incident radiant heat flux required for nonpiloted ignition, Btu/ft^2·s (W/m^2).

R = separation distance from target to center of fuel package, feet (m).

The ratio of the separation distance to the fuel equivalent radius shall not be less than 4. The fuel equivalent radius shall be the radius of a circle of equal area to floor area of the fuel package.

905.6.2.3 Heat-release assumptions. The analysis shall make use of best available data and shall not be based on excessively stringent limitations of combustible material. For offices, the heat release rate shall be 25 Btu/ft.^{2}·s (284 kW/m^2) or greater. For mercantile and residential occupancies, the heat release rate shall be 50 Btu/ft.^{2}·s (567 kW/m^2) or greater.

905.6.2.4 Sprinkler effectiveness assumptions. The effect of sprinklers may be assumed to have halted fire growth at time of activation only upon a documented engineering analysis.

905.7 Equipment.

905.7.1 General. Equipment such as, but not limited to, fans, ducts and balance dampers shall be suitable for their intended use, suitable for the probable temperatures to which they may be exposed and approved by the building official.

905.7.2 Exhaust fans. Components of exhaust fans shall be rated and certified by the manufacturer for the probable temperature rise to which the components may be exposed. This temperature rise shall be computed by:

$$T_s = (Q_c/mc) + (T_a) \qquad (5\text{-}13)$$

WHERE:

c = specific heat of smoke at smoke-layer temperature, Btu/lb.°F (kJ/kg-K).

m = exhaust rate, pounds per second (kg/s).

Q_c = convective heat output of fire, Btu/sec. (kW).

T_a = ambient temperature, °F (K).

T_s = smoke temperature, °F (K).

EXCEPTION: T_s may be reduced if dilution air is ensured and the new T_s is calculated.

905.7.3 Ducts. Duct materials and joints shall be capable of withstanding the probable temperatures and pressures to which they are exposed as determined by Formula (5-13). Ducts shall be constructed and supported in accordance with the Mechanical Code. Ducts shall be leak tested to 1.5 times the maximum design pressure in accordance with nationally accepted practices. Measured leakage shall not exceed 5 percent of design flow. Results of such testing shall be a part of the documentation procedure. Ducts shall be supported by substantial, noncombustible supports.

EXCEPTION: Flexible connections, for the purpose of vibration isolations complying with the Mechanical Code, may be used if constructed of approved fire-resistive materials.

905.7.4 Equipment, inlets and outlets. Equipment shall be located so as to not expose uninvolved portions of the building to an additional fire hazard. Outside air inlets shall be located so as to minimize the potential for introducing smoke or flame into the building. Exhaust outlets shall be located so as to minimize reintroduction of smoke into the building and to limit exposure of the building or adjacent buildings to an additional fire hazard.

905.7.5 Automatic dampers. Automatic dampers installed within the smoke-control system shall be listed and conform to the requirements of approved recognized standards. See Chapter 35, Part IV.

905.7.6 Fans. In addition to other requirements, belt-driven fans shall have 1.5 times the number of belts required for the design duty with the minimum number of belts being two. Fans shall be selected for stable performance based on normal temperature and, where applicable, elevated temperature. Calculations and manufacturer's fan curves shall be part of the documentation procedures. Fans shall be supported and restrained by noncombustible devices in accordance with the requirements of Chapter 16. Motors driving fans shall not be operating beyond their name plate horsepower (kW) as determined from measurement of actual current draw. Motors driving fans shall have a minimum service factor of 1.15.

905.8 Power Systems.

905.8.1 General. The smoke-control system shall be supplied with two sources of power. Primary power shall be the normal building power systems. Secondary power shall be from an approved standby source complying with the Electrical Code. The standby power source and its transfer switches shall be in a separate room from the normal power transformers and switchgear and shall be enclosed in a room of not less than one-hour fire-resistive construction, ventilated directly to and from the exterior. Power distribution from the two sources shall be by independent routes.

Transfer to full standby power shall be automatic and within 60 seconds of failure of the primary power. The systems shall comply with the Electrical Code.

905.8.2 Power sources and power surges. Elements of the smoke-management system relying on volatile memories or the like shall be supplied with uninterruptable power sources of sufficient duration to span 15-minute primary power interruption. Elements of the smoke-management system susceptible to power surges shall be suitably protected by conditioners, suppressors or other approved means.

905.9 Detection and Control Systems.

905.9.1 General. Fire-detection and control systems for mechanical smoke-control systems shall be supervised in accordance with the Fire Code. Supervision shall further provide positive confirmation of actuation, testing of devices, manual override mechanisms, and the presence of power downstream of all disconnects. When supervision requires the sensing of damper position, it shall be accomplished by limit or proximity switches. When supervision requires sensing of air flow, it shall be by differential pressure transmitters. Required supervision shall be indicated at the Fire Fighter's Control Panel. The fire-detection and control system shall be listed.

905.9.2 Wiring. In addition to meeting requirements of the Electrical Code, all wiring, regardless of voltage, shall be fully enclosed within continuous raceways.

905.9.3 Activation. Smoke-control systems shall be activated as follows:

1. Mechanical smoke-control systems, using the pressurization method, serving buildings having no occupied floor more than 300 feet (91 440 mm) above or 75 feet (22 860 mm) below exit grade shall have automatic control of pressurized stairwell enclosure systems. All other portions of the smoke-control system may be manual in accordance with Section 905.13.

EXCEPTION: When required in Group I Occupancies, they shall be entirely automatic.

2. Mechanical smoke-control systems, using the pressurization method, serving buildings having occupied floors more than 300 feet (91 440 mm) above or 75 feet (22 860 mm) below exit grade shall have completely automatic control.

3. Mechanical smoke-control systems using the airflow or exhaust method shall have completely automatic control.

4. Passive smoke-control systems may be actuated by approved spot-type detectors listed for releasing service.

905.9.4 Automatic control. Whenever completely automatic control is required or used, the automatic-control sequences shall be initiated from an appropriately zoned automatic sprinkler system meeting the requirements of UBC Standard 9-1 or from an appropriately zoned, total coverage smoke-detection system meeting the requirements of the Fire Code.

905.9.5 Smoke detection. Smoke detectors shall be listed and shall be installed in accordance with the Fire Code.

905.10 Control Air Tubing.

905.10.1 General. Control-air tubing shall be of sufficient size to meet the required response times. Tubing shall be flushed clean and dry prior to final connections. Tubing shall be adequately supported and protected from damage. Tubing passing through concrete or masonry shall be sleeved and protected from abrasion and electrolytic action.

905.10.2 Materials. Control-air tubing shall be hard drawn copper, Type L, ACR, see ASTM B 42-92, B 43-91, B 68-88, B 88-92, B 251-88 and B 280-92. Fittings shall be wrought copper or brass, solder type, see ANSI B16.22-89 or ANSI B16.18-84. Changes in direction may be made with appropriate tool bends. Brass, compression-type fittings may be used at final connection to devices; other joints shall be brazed using a $BCuP_5$ brazing alloy with solidus above 1,100°F (593°C) and liquidus below 1,500°F (816°C). Brazing flux shall be used on copper to brass joints only.

EXCEPTION: Nonmetallic tubing may be used within control panels and at the final connection to devices, providing all of the following conditions are met:

1. Tubing shall be listed by an approved agency for flame and smoke characteristics.

2. Tubing and connected device shall be completely enclosed within galvanized or paint grade steel enclosure of not less than 0.030 inch (0.76 mm) (No. 22 galvanized sheet gage) thickness. Entry to the enclosure shall be by copper tubing with a protective grommet of neoprene or teflon or by suitable brass compression to male barbed adapter.

3. Tubing shall be identified by appropriately documented coding.

4. Tubing shall be neatly tied and supported within enclosure. Tubing bridging cabinet and door or movable device shall be of sufficient length to avoid tension and excessive stress. Tubing shall be protected against abrasion. Tubing serving devices on doors shall be fastened along hinges.

905.10.3 Isolation from other functions. All control tubing serving other than smoke-control functions shall be isolated by automatic isolation valves or shall be an independent system.

905.10.4 Testing. Test all control-air tubing at three times operating pressure for not less than 30 minutes without any noticeable loss in gage pressure prior to final connection to devices.

905.11 Marking and Identification. The detection and control systems shall be clearly marked at all junctions, accesses and terminations.

905.12 Control Diagrams. Identical control diagrams showing all devices in the system and identifying their location and function shall be maintained current and kept on file with the building official, the fire department and with the firefighter's control panel in an approved format and manner.

905.13 Firefighter's Control Panel.

905.13.1 General. A firefighter's control panel shall be provided for manual control or override of automatic control for mechanical smoke-control systems. Such panel shall be designed to graphically depict the building arrangement and smoke-control system zones served by the systems. The status of each smoke-control zone shall be indicated by lamps and appropriate legends.

Fans, major ducts and dampers within the building that are portions of the smoke-control systems shall be shown on the firefighter's control panel and shall be shown connected to their respective ducts with a clear indication of the direction of airflow.

Devices, switches, indicators and the like shall bear plain English identifying legends having a size and stroke equivalent to 12-point helvetica bold.

Status indicators shall be provided for all smoke-control equipment by pilot lamp-type indicators as follows:

1. Fans, dampers and other operating equipment in their normal status—GREEN.

2. Fans, dampers and other operating equipment in their off or closed status—RED.

3. Fans, dampers and other operating equipment in a fault status—YELLOW.

Provision for testing the pilot lamp on the firefighter's control panel by means of one or more "lamp test" momentary push buttons or other self-restoring means shall be included.

The fault status shall be further identified by pulsing the indicator lamp.

EXCEPTION: Light-emitting diodes may be used in lieu of pilot lamps with prior approval.

The firefighter's control panel layout shall be submitted at full scale for approval prior to installation.

905.13.2 Smoke-control capability. The firefighter's control panel shall provide control capability over the complete smoke-control system equipment within the building as follows:

1. **ON-AUTO-OFF** control over each individual piece of operating smoke-control equipment that can also be controlled from other sources within the building. This includes stairway pressurization fans; smoke exhaust fans; supply, return and exhaust fans; elevator shaft fans; and other operating equipment used or intended for smoke-control purposes.

2. **OPEN-AUTO-CLOSE** control over all individual dampers relating to smoke control and that are also controlled from other sources within the building.

3. **ON-OFF** or **OPEN-CLOSE** control over all smoke-control and other critical equipment associated with a fire or smoke emer-

gency and that can only be controlled from the firefighter's control panel.

EXCEPTIONS: 1. For complex systems, with prior approval, the controls and indicators may be combined to control and indicate all elements of a single smoke zone as a unit.

2. For complex systems, with prior approval, the control may be accomplished by computer interface using approved, plain English commands.

905.13.3 Control action and priorities. The firefighter's control panel actions shall be as follows:

1. **ON-OFF, OPEN-CLOSE** control actions shall have the highest priority of any control point within the building. Once issued from the firefighter's control panel, no automatic or manual control from any other control point within the building shall contradict the control action.

Where automatic means is provided to interrupt normal, nonemergency equipment operation or produce a specific result to safeguard the building or equipment (i.e., duct freezestats, duct smoke detectors, high-temperature cutouts, temperature-actuated linkage and similar devices), such means shall be capable of being overridden by the firefighter's control panel control action and the last control action as indicated by each firefighter's control panel switch position shall prevail.

EXCEPTION: Power disconnects required by the Electrical Code.

2. Only the AUTO position of each three-position firefighter's control panel switch shall allow automatic or manual control action from other control points within the building. The AUTO position shall be the NORMAL, nonemergency, building control position. When a firefighter's control panel is in the AUTO position, the actual status of the device (on, off, open, closed) shall continue to be indicated by the status indicator described above.

905.14 Response Time. Smoke-control system activation shall be initiated immediately after receipt of an appropriate automatic or manual activation command. Smoke-control systems shall activate individual components (such as dampers and fans) in the sequence necessary to prevent physical damage to the fans, dampers, ducts and other equipment. The total response time for individual components to achieve their desired operating mode shall not exceed the following:

1. Control air isolation valves	Immediately
2. Smoke damper closing	15 seconds
3. Smoke damper opening	15 seconds maximum
4. Fan starting (energizing)	15 seconds maximum
5. Fan stopping (de-energizing)	Immediately
6. Fan volume modulation	30 seconds maximum
7. Pressure control modulation	15 seconds maximum
8. Temperature control safety override	Immediately
9. Positive indication of status	15 seconds maximum

For purposes of smoke control, the firefighter's control panel response time shall be the same for automatic or manual smoke-control action initiated from any other building control point.

905.15 Acceptance Testing.

905.15.1 General. Devices, equipment, components and sequences shall be individually tested. These tests, in addition to those required above or by other provisions of this code, shall consist of determination of function, sequence and, where applicable, capacity of their installed condition.

905.15.2 Detection devices. Smoke or fire detectors that are a part of a smoke-control system shall be tested in accordance with the Fire Code in their installed condition. When applicable, this testing shall include verification of airflow in both minimum and maximum conditions.

905.15.3 Ducts. Ducts that are part of a smoke-control system shall be traversed using generally accepted practices to determine actual air quantities.

905.15.4 Dampers. Dampers shall be tested for function in their installed condition.

905.15.5 Inlets and outlets. Inlets and outlets shall be read using generally accepted practices to determine air quantities.

905.15.6 Fans. Fans shall be examined for correct rotation. Measurements of voltage, amperage, revolutions per minute and belt tension shall be made.

905.15.7 Smoke barriers. Measurements using inclined manometers shall be made of the pressure differences across smoke barriers. Such measurements shall be conducted for each possible smoke-control condition.

905.15.8 Controls. Each smoke zone, equipped with an automatic initiation device, shall be put into operation by the actuation of one such device. Each additional such device within the zone shall be verified to cause the same sequence but the operation of fan motors may be bypassed to prevent damage.

Control sequences shall be verified throughout the system, including verification of override from the firefighter's control panel and simulation of standby power conditions.

905.15.9 Reports. A complete report of testing shall be prepared by the required special inspector or special inspection agency. The report shall include identification of all devices by manufacturer, nameplate data, design values, measured values and identification tag or mark. The report shall be reviewed by the responsible designer, and when satisfied that the design intent has been achieved, the responsible designer shall affix the designer's signature and date to the report with a statement as follows:

> I have reviewed this report and by personal knowledge and on-site observation certify that the smoke-control system is in substantial compliance with the design intent, and to the best of my understanding complies with requirements of the code.

A copy of the final report shall be filed with the building official and an identical copy shall be maintained in an approved location at the building.

905.15.10 Identification and documentation. Charts, drawings and other documents identifying and locating each component of the smoke-control system, and describing their proper function and maintenance requirements shall be maintained on file at the building with the above-described report.

Devices shall have an approved identifying tag or mark on them consistent with the other required documentation and shall be dated indicating the last time they were successfully tested and by whom.

905.16 Acceptance. Buildings, or portions thereof, required by this code to comply with this section shall not be issued a certificate of occupancy until such time that the building official determines that the provisions of this section have been fully complied with and that the fire department has received satisfactory instruction on the operation, both automatic and manual, of the system.

EXCEPTION: In buildings of phased construction, the building official may issue a temporary certificate of occupancy if those portions of the building to be occupied meet the requirements of this section and that the remainder does not pose a significant hazard to the safety of the proposed occupants or adjacent buildings.

SECTION 906 — SMOKE AND HEAT VENTING

906.1 When Required. Smoke and heat vents complying with UBC Standard 15-7 or fixed openings shall be installed in accordance with the provisions of this section as follows:

1. In single-story Groups B, F, M and S, Divisions 1 and 2 Occupancies having over 50,000 square feet (4645 m^2) in undivided area.

EXCEPTIONS: 1. Office buildings and retail sales areas where storage does not exceed 12 feet (3658 mm) in height.

2. Group S, Division 2 Occupancies used for bulk frozen food storage when the building is protected by a complete automatic sprinkler system.

2. In Group H, Divisions 1, 2, 3, 4 or 5 Occupancies any of which are over 15,000 square feet (1394 m^2) in single floor area.

For requirements on smoke and heat venting in buildings with high-piled combustible stock, see the Fire Code.

906.2 Mixed Occupancies. Venting facilities shall be installed in buildings of mixed occupancy on the basis of the individual occupancy involved.

906.3 Types of Vents. Vents shall be fixed in the open position or vents shall be activated by temperature and shall open automatically in the event of fire.

Fixed openings may consist of skylights or other openings that provide venting directly to exterior above the plane of the main roof in which they are located. Vents shall meet the design criteria of this section regarding elevation, and Section 906.5 regarding venting area, dimensions, spacing and venting ratios. The building official may require documentation of the design to ensure proper performance of required venting.

Temperature activation of vents shall be at or near the highest elevation of the ceiling and in no case lower than the upper one third of the smoke curtain. Where plain glass is used, provisions shall be made to protect the occupants from glass breakage. In no case shall vents be located closer than 20 feet (6096 mm) to an adjacent property line.

906.4 Releasing Devices. Release devices shall be in accordance with UBC Standard 15-7.

906.5 Size and Spacing of Vents.

906.5.1 Effective venting area. The effective venting area is the minimum cross-sectional area through which the hot gases must pass en route to atmosphere. The effective venting area shall not be less than 16 square feet (1.5 m^2) with no dimension less than 4 feet (1219 mm), excluding ribs or gutters whose total width does not exceed 6 inches (152 mm).

906.5.2 Spacing. The maximum center-to-center spacing between vents within the building shall be:

1. In Groups B, F, M and S Occupancies: 120 feet (36 576 mm).
2. In Group H Occupancies: 100 feet (30 480 mm).

906.5.3 Venting ratios. The following ratios of effective area of vent openings to floor areas shall be:

1. In Groups B, F, M and S Occupancies: 1:100.
2. In Group H Occupancies: 1:50.

906.6 Curtain Boards.

906.6.1 General. Curtain boards shall be provided to subdivide a vented building in accordance with the provisions of this section.

906.6.2 Construction. Curtain boards shall be sheet metal, asbestos board, lath and plaster, gypsum wallboard or other approved materials that provide equivalent performance that will resist the passage of smoke. All joints and connections shall be smoke tight.

906.6.3 Location and depth. Curtain boards shall extend down from the ceiling for a minimum depth of 6 feet (1829 mm), but need not extend closer than 8 feet (2438 mm) to the floor. In Group H Occupancies, the minimum depth shall be 12 feet (3658 mm) except that it need not be closer than 8 feet (2436 mm) to the floor, provided the curtain is not less than 6 feet (1829 mm) in depth.

906.6.4 Spacing. The distance between curtain boards shall not exceed 250 feet (76 200 mm) and the curtained area shall be limited to 50,000 square feet (4645 m^2). In Group H Occupancies, the distance between curtain boards shall not exceed 100 feet (30 480 mm) and the curtained area shall be limited to 15,000 square feet (1394 m^2).

TABLE 9-A—STANDPIPE REQUIREMENTS

OCCUPANCY	NONSPRINKLERED BUILDING[1]		SPRINKLERED BUILDING[2,3]	
× 304.8 for mm × 0.0929 for m^2	Standpipe Class	Hose Requirement	Standpipe Class	Hose Requirement
1. Occupancies exceeding 150 feet in height and more than one story	III	Yes	I	No
2. Occupancies four stories or more but less than 150 feet in height, except Group R, Division 3[6]	[I and II[4]] (or III)	5 Yes	I	No
3. Group A Occupancies with occupant load exceeding 1,000[7]	II	Yes	No requirement	No
4. Group A, Division 2.1 Occupancies over 5,000 square feet in area used for exhibition	II	Yes	II	Yes
5. Groups I; H; B; S; M; F, Division 1 Occupancies less than four stories in height but greater than 20,000 square feet per floor[6]	II[4]	Yes	No requirement	No
6. Stages more than 1,000 square feet in area	II	No	III	No

[1]Except as otherwise specified in Item 4 of this table, Class II standpipes need not be provided in basements having an automatic fire-extinguishing system throughout.

[2]The standpipe system may be combined with the automatic sprinkler system.

[3]Portions of otherwise sprinklered buildings that are not protected by automatic sprinklers shall have Class II standpipes installed as required for the unsprinklered portions.

[4] In open structures where Class II standpipes may be damaged by freezing, the building official may authorize the use of Class I standpipes that are located as required for Class II standpipes.

[5]Hose is required for Class II standpipes only.

[6]For the purposes of this table, occupied roofs of parking structures shall be considered an additional story. In parking structures, a tier is a story.

[7]Class II standpipes need not be provided in assembly areas used solely for worship.

Chapter 10
MEANS OF EGRESS

NOTE: This chapter has been revised in its entirety.

SECTION 1001 — ADMINISTRATIVE

1001.1 Scope. Every building or portion thereof shall be provided with a means of egress as required by this chapter. A means of egress is an exit system that provides a continuous, unobstructed and undiminished path of exit travel from any occupied point in a building or structure to a public way. Such means of egress system consists of three separate and distinct elements:

1. The exit access,
2. The exit, and
3. The exit discharge.

1001.2 Standards of Quality. The standards listed below which are labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code.

1. **Power doors.**

   1.1 UBC Standard 10-1, Power-operated Egress Doors

   1.2 UBC Standard 7-8, Horizontal Sliding Fire Doors Used in a Means of Egress

2. **Stairway numbering system.**

   UBC Standard 10-2, Stairway Identification

3. **Hardware.**

   UBC Standard 10-4, Panic Hardware

SECTION 1002 — DEFINITIONS

For the purpose of this chapter, certain terms are defined as follows:

AISLE ACCESSWAYS are that portion of an exit access that leads to an aisle.

EXIT. See Section 1005.1.

EXIT ACCESS. See Section 1004.1.

EXIT DISCHARGE. See Section 1006.1.

EXIT DOOR. See Section 1003.3.1.1.

MEANS OF EGRESS. See Section 1001.1.

MULTITHEATER COMPLEX is a building or portion thereof containing two or more motion picture auditoriums that are served by a common lobby.

PANIC HARDWARE is a door-latching assembly incorporating an unlatching device, the activating portion of which extends across at least one half the width of the door leaf on which it is installed.

PHOTOLUMINESCENT is the property of emitting light as the result of absorption of visible or invisible light, which continues for a length of time after excitation.

PRIVATE STAIRWAY is a stairway serving one tenant only.

PUBLIC WAY is any street, alley or similar parcel of land essentially unobstructed from the ground to the sky that is deeded, dedicated or otherwise permanently appropriated to the public for public use and having a clear width of not less than 10 feet (3048 mm).

SELF-LUMINOUS means powered continuously by a self-contained power source other than a battery or batteries, such as radioactive tritium gas. A self-luminous sign is independent of external power supplies or other energy for its operation.

SMOKE-PROTECTED ASSEMBLY SEATING is seating served by a means of egress system and is not subject to blockage by smoke accumulation within or under a structure.

SECTION 1003 — GENERAL

1003.1 Means of Egress. All portions of the means of egress shall comply with the applicable requirements of Section 1003.

1003.2 System Design Requirements. The general design requirements specified in this section shall apply to all three elements of the means of egress system, in addition to those specific design requirements for the exit access, the exit and the exit discharge detailed elsewhere in this chapter.

1003.2.1 Use.

1003.2.1.1 General. The building official shall assign a use category as set forth in Table 10-A to all portions of a building. When an intended use is not listed in Table 10-A, the building official shall establish a use based on a listed use that most nearly resembles the intended use.

1003.2.1.2 Change in use. No change in use or occupancy shall be made to any existing building or structure unless the means of egress system is made to comply with the requirements of this chapter for the new use or occupancy. See Section 3405.

1003.2.2 Occupant load.

1003.2.2.1 General. The basis for the design of the means of egress system is the occupant load served by the various components of such system.

1003.2.2.2 Determination of occupant load. Occupant loads shall be determined in accordance with the requirements of this section.

1003.2.2.2.1 Areas to be included. In determining the occupant load, all portions of a building shall be presumed to be occupied at the same time.

> **EXCEPTION:** Accessory use areas that ordinarily are used only by persons who occupy the main areas of an occupancy shall be provided with means of egress as though they are completely occupied, but their occupant load need not be included when computing the total occupant load of the building.

1003.2.2.2.2 Areas without fixed seats. For areas without fixed seats, the occupant load shall not be less than the number determined by dividing the floor area under consideration by the occupant load factor assigned to the use for such area as set forth in Table 10-A.

The occupant load for buildings or areas containing two or more uses or occupancies shall be determined by adding the occupant loads of the various use areas as computed in accordance with the applicable requirements of Section 1003.2.2.2.

Where an individual area has more than one proposed use, the occupant load for such area shall be determined based on that use that yields the largest occupant load.

1003.2.2.2.3 Areas with fixed seats. For areas having fixed seats, the occupant load for such areas shall be determined by the number of fixed seats installed therein.

For areas having fixed benches or pews, the occupant load shall not be less than the number of seats based on one person for each 18 inches (457 mm) of length of pew or bench. Where fixed booths are used in dining areas, the occupant load shall be based on one person for each 24 inches (610 mm) of booth length. Where fixed benches, pews or booths are curved, the larger radius shall determine the booth length.

1003.2.2.2.4 Outdoor areas. The occupant load of yards, patios, courts and similar outdoor areas shall be assigned by the building official in accordance with their anticipated use. Such outdoor areas accessible to and usable by the building occupants shall be provided with a means of egress as required by this chapter. Where an outdoor area exits only through a building, the occupant load of such outdoor area shall be considered in the design of the means of egress system of that building.

1003.2.2.2.5 Reviewing stands, grandstands and bleachers. The occupant load for reviewing stands, grandstands and bleachers shall be calculated in accordance with Section 1003.2.2.2 and the specific requirements contained in Section 1008.

1003.2.2.3 Maximum occupant load.

1003.2.2.3.1 Assembly occupancies. The maximum occupant load for an assembly occupancy shall not exceed the occupant load determined in accordance with Section 1003.2.2.2.

> **EXCEPTION:** When approved by the building official, the occupant load for an assembly occupancy may be increased, provided the maximum occupant load served does not exceed the capacity of the means of egress system for such increased number of occupants.

For temporary increases of occupant loads in places of assembly, see the Fire Code.

1003.2.2.3.2 Other occupancies. For other than assembly occupancies, an occupant load greater than that determined in accordance with Section 1003.2.2.2 is permitted; however, the means of egress system shall comply with the requirements of this chapter for such increased occupant load.

1003.2.2.4 Minimum occupant load. An occupant load less than that determined in accordance with Section 1003.2.2.2 shall not be used.

1003.2.2.5 Revised occupant load. No increase in occupant load shall be made to any existing building or structure unless the means of egress system is made to comply with the requirements of this chapter for such increased occupant load. See Section 3405.

1003.2.3 Width.

1003.2.3.1 General. The width of the means of egress system or any portion thereof shall be based on the occupant load served.

1003.2.3.2 Minimum width. The width, in inches (mm), of any component in the means of egress system shall not be less than the product determined by multiplying the total occupant load served by such component by the applicable factor set forth in Table 10-B. In no case shall the width of an individual means of egress component be less than the minimum required for such component as specified elsewhere in this chapter.

Where more than one exit or exit-access doorway serves a building or portion thereof, such calculated width shall be divided approximately equally among the means of egress components serving as exits or exit-access doorways for that area.

1003.2.3.3 Maintaining width. If the minimum required width of the means of egress system increases along the path of exit travel based on cumulative occupant loads served, such width shall not be reduced or otherwise diminished to less than the largest minimum width required to that point along the path of exit travel.

> **EXCEPTION:** In other than Group H, Divisions 1, 2, 3 and 7 Occupancies, the width of exterior exit doors from an exit enclosure may be based on the largest occupant load of all levels served by such exit enclosure multiplied by a factor of 0.2 (5.08) inches per person.

1003.2.3.4 Exiting from adjacent levels. No cumulative or contributing occupant loads from adjacent building levels need be considered when determining the required width of means of egress components from a given level.

Where an exit enclosure from an upper floor and a lower floor converge at an intermediate floor, the width of the exit from the intermediate floor shall be based on the sum of the occupant loads of such upper and lower floors.

1003.2.3.5 Two-way exits. Where exit or exit-access doorways serve paths of exit travel from opposite directions, the width of such exit or exit-access doorways shall be based on the largest occupant load served. Where such exit or exit-access doorways are required to swing in the direction of exit travel by Section 1003.3.1.5, separate exit width for each path of exit travel shall be provided based on the occupant load of the area that is served.

1003.2.4 Height. Except as specified elsewhere in this chapter, the means of egress system shall have a clear height of not less than 7 feet (2134 mm) measured vertically from the walking surface to the lowest projection from the ceiling or overhead structure.

> **EXCEPTION:** Sloped ceilings permitted by Section 310.6.1.

1003.2.5 Exit continuity. The path of exit travel along a means of egress shall not be interrupted by any building element other than a means of egress component as specified in this chapter. Obstructions shall not be placed in the required width of a means of egress except projections permitted by this chapter. The required capacity of a means of egress system shall not be diminished along the path of exit travel.

1003.2.6 Changes in elevation. All exterior elevation changes and interior elevation changes of 12 inches (305 mm) or more along the path of exit travel shall be made by steps, stairs or stairways conforming with the requirements of Section 1003.3.3.3 or ramps conforming with the requirements of Section 1003.3.4.

Interior elevation changes of less than 12 inches (305 mm) along the path of exit travel serving an occupant load of 10 or more shall be by ramps conforming with the requirements of Section 1003.3.4.

> **EXCEPTIONS:** 1. In Group R, Division 3 Occupancies and within individual dwelling units of Group R, Division 1 Occupancies.
> 2. Along aisles adjoining seating areas.

1003.2.7 Elevators or escalators. Elevators or escalators shall not be used as a required means of egress component.

1003.2.8 Means of egress identification.

1003.2.8.1 General. For the purposes of Section 1003.2.8, the term "exit sign" shall mean those required signs that indicate the path of exit travel within the means of egress system.

1003.2.8.2 Where required. The path of exit travel to and within exits in a building shall be identified by exit signs conforming to the requirements of Section 1003.2.8. Exit signs shall be readily visible from any direction of approach. Exit signs shall be located as necessary to clearly indicate the direction of egress travel. No point shall be more than 100 feet (30 480 mm) from the nearest visible sign.

EXCEPTIONS: 1. Main exterior exit doors that obviously and clearly are identifiable as exit doors need not have exit signs when approved by the building official.

2. Rooms or areas that require only one exit or exit access.

3. In Group R, Division 3 Occupancies and within individual units of Group R, Division 1 Occupancies.

4. Exits or exit access from rooms or areas with an occupant load of less than 50 where located within a Group I, Division 1.1, 1.2 or 2 Occupancy or a Group E, Division 3 day-care occupancy.

1003.2.8.3 Graphics. The color and design of lettering, arrows and other symbols on exit signs shall be in high contrast with their background. Exit signs shall have the word "EXIT" on the sign in block capital letters not less than 6 inches (152 mm) in height with a stroke of not less than $^3/_4$ inch (19 mm). The word "EXIT" shall have letters having a width of not less than 2 inches (51 mm) except for the letter "I" and a minimum spacing between letters of not less than $^3/_8$ inch (9.5 mm). Signs with lettering larger than the minimum dimensions established herein shall have the letter width, stroke and spacing in proportion to their height.

1003.2.8.4 Illumination. Exit signs shall be internally or externally illuminated. When the face of an exit sign is illuminated from an external source, it shall have an intensity of not less than 5 footcandles (54 lx) from either of two electric lamps. Internally illuminated signs shall provide equivalent luminance and be listed for the purpose.

EXCEPTION: Approved self-luminous signs that provide evenly illuminated letters that have a minimum luminance of 0.06 foot lambert (0.21 cd/m^2).

1003.2.8.5 Power source. All exit signs shall be illuminated at all times. To ensure continued illumination for a duration of not less than $1^1/_2$ hours in case of primary power loss, the exit signs shall also be connected to an emergency electrical system provided from storage batteries, unit equipment or an on-site generator set, and the system shall be installed in accordance with the Electrical Code. For high-rise buildings, see Section 403.

EXCEPTION: Approved self-luminous signs that provide continuous illumination independent of an external power source.

1003.2.9 Means of egress illumination.

1003.2.9.1 General. Any time a building is occupied, the means of egress shall be illuminated at an intensity of not less than 1 footcandle (10.76 lx) at the floor level.

EXCEPTIONS: 1. In Group R, Division 3 Occupancies and within individual units of Group R, Division 1 Occupancies.

2. In auditoriums, theaters, concert or opera halls, and similar assembly uses, the illumination at the floor level may be reduced during performances to not less than 0.2 footcandle (2.15 lx), provided that the required illumination be automatically restored upon activation of a premise's fire alarm system when such system is provided.

1003.2.9.2 Power supply. The power supply for means of egress illumination shall normally be provided by the premises' electrical supply. In the event of its failure, illumination shall be automatically provided from an emergency system for Group I, Divisions 1.1 and 1.2 Occupancies and for all other occupancies where the means of egress system serves an occupant load of 100 or more. Such emergency systems shall be installed in accordance with the Electrical Code.

For high-rise buildings, see Section 403.

1003.2.10 Building accessibility. In addition to the requirements of this chapter, means of egress, which provide access to, or egress from, buildings for persons with disabilities, shall also comply with the requirements of Chapter 11.

1003.3 Means of egress components. Doors, gates, stairways and ramps that are incorporated into the design of any portion of the means of egress system shall comply with the requirements of this section. These means of egress components may be selectively included in the exit access, the exit or the exit discharge portions of the means of egress system.

1003.3.1 Doors.

1003.3.1.1 General. For the purposes of Section 1003.3.1, the term "exit door" shall mean all of those doors or doorways along the path of exit travel anywhere in a means of egress system.

Exit doors serving the means of egress system shall comply with the requirements of Section 1003.3.1. Where additional doors are installed for egress purposes, they shall conform to all requirements of this section. Buildings or structures used for human occupancy shall have at least one exterior exit door that meets the requirements of Section 1003.3.1.3.

Exit doors shall be readily distinguishable from the adjacent construction and shall be easily recognizable as exit doors. Mirrors or similar reflecting materials shall not be used on exit doors, and exit doors shall not be concealed by curtains, drapes, decorations and similar materials.

1003.3.1.2 Special doors. Revolving, sliding and overhead doors serving an occupant load of 10 or more shall not be used as required exit doors.

EXCEPTIONS: 1. Approved revolving doors having leaves that will collapse under opposing pressures may be used, provided

1.1 Such doors have a minimum width of 6 feet 6 inches (1981 mm).

1.2 At least one conforming exit door is located adjacent to each revolving door.

1.3 The revolving door shall not be considered to provide any required width when computing means of egress width in accordance with Section 1003.2.3.

2. Horizontal sliding doors complying with UBC Standard 7-8 may be used

2.1 In elevator lobby separations.

2.2 In other than Groups A and H Occupancies, where smoke barriers are required.

2.3 In other than Group H Occupancies, where serving an occupant load of less than 50.

Power-operated doors complying with UBC Standard 10-1 may be used for egress purposes. Such doors, where swinging, shall have two guide rails installed on the swing side projecting out from the face of the door jambs for a distance not less than the widest door leaf. Guide rails shall not be less than 30 inches (762 mm) in height with solid or mesh panels to prevent penetration into door swing and shall be capable of resisting a horizontal load at top of rail of not less than 50 pounds per lineal foot (730 N/m).

EXCEPTIONS: 1. Walls or other types of separators may be used in lieu of the above guide rail, provided all the criteria are met.

2. Guide rails in industrial or commercial occupancies not accessible to the public may comply with the exception to Section 509.3.

3. Doors swinging toward flow of traffic shall not be permitted unless actuating devices start to function at least 8 feet 11 inches (2718 mm) beyond the door in an open position and guide rails extend 6 feet 5 inches (1956 mm) beyond the door in an open position.

Clearances for guide rails shall be as follows:

1. Six inches (152 mm) maximum between rails and leading edge of door at the closest point in its arc of travel.

2. Six inches (152 mm) maximum between rails and the door in an open position.

3. Two inches (51 mm) minimum between rail at hinge side and door in an open position.

4. Two inches (51 mm) maximum between freestanding rails and jamb or other adjacent surface.

1003.3.1.3 Width and height. Every required exit doorway serving an occupant load of 10 or more shall be of a size to permit the installation of a door not less than 3 feet (914 mm) in nominal width and not less than 6 feet 8 inches (2032 mm) in nominal height. Where installed, exit doors shall be capable of opening such that the clear width of the exit is not less than 32 inches (813 mm). In computing the exit width as required by Section 1003.2.3, the net dimension of the doorway shall be used.

1003.3.1.4 Door leaf width. A single leaf of an exit door serving an occupant load of 10 or more shall not exceed 4 feet (1219 mm) in width.

1003.3.1.5 Swing and opening force. Exit doors serving an occupant load of 10 or more shall be of the pivoted, balanced or side-hinged swinging type. Exit doors shall swing in the direction of the path of exit travel where the area served has an occupant load of 50 or more. The door shall swing to the fully open position when an opening force not to exceed 30 pounds (133.45 N) is applied to the latch side. For other door opening forces, see Section 905.3 and Chapter 11. See Section 3207 for doors swinging over public property.

EXCEPTIONS: 1. Group I, Division 3 Occupancy used as a place of detention.

2. Doors within or serving an individual dwelling unit.

3. Special doors conforming to Section 1003.3.1.2.

Double-acting doors shall not be used as exits where any of the following conditions exist:

1. The occupant load served by the door is 100 or more.

2. The door is part of a fire assembly.

3. The door is part of a smoke- and draft-control assembly.

4. Panic hardware is required or provided on the door.

A double-acting door shall be provided with a view panel of not less than 200 square inches (0.129 m^2).

1003.3.1.6 Floor level at doors. Regardless of the occupant load served, there shall be a floor or a landing on each side of a door. Where access for persons with disabilities is required by Chapter 11, the floor or landing shall not be more than $^1/_2$ inch (12.7 mm) lower than the threshold of the doorway. Where such access is not required, the threshold shall not exceed 1 inch (25 mm). Landings shall be level except that exterior landings may have a slope not to exceed $^1/_4$ unit vertical in 12 units horizontal (2% slope).

EXCEPTIONS: 1. In Group R, Division 3, and Group U Occupancies and within individual units of Group R, Division 1 Occupancies:

1.1 A door may open at the top step of an interior flight of stairs, provided the door does not swing over the top step.

1.2 A door may open at a landing that is not more than 8 inches (203 mm) lower than the floor level, provided the door does not swing over the landing.

1.3 Screen doors and storm doors may swing over stairs, steps or landings.

2. Doors serving building equipment rooms that are not normally occupied.

1003.3.1.7 Landings at doors. Regardless of the occupant load served, landings shall have a width not less than the width of the door or the width of the stairway served, whichever is greater. Doors in the fully open position shall not reduce a required dimension by more than 7 inches (178 mm). Where a landing serves an occupant load of 50 or more, doors in any position shall not reduce the landing dimension to less than one half its required width. Landings shall have a length measured in the direction of travel of not less than 44 inches (1118 mm).

EXCEPTION: In Group R, Division 3, and Group U Occupancies and within individual units of Group R, Division 1 Occupancies, such length need not exceed 36 inches (914 mm).

A landing that has no adjoining door shall comply with the requirements of Section 1003.3.3.5.

1003.3.1.8 Type of lock or latch. Regardless of the occupant load served, exit doors shall be openable from the inside without the use of a key or any special knowledge or effort.

EXCEPTIONS: 1. In Groups A, Division 3; B; F; M and S Occupancies and in all churches, key-locking hardware may be used on the main exit where the main exit consists of a single door or pair of doors where there is a readily visible, durable sign on or adjacent to the door stating, "THIS DOOR MUST REMAIN UNLOCKED DURING BUSINESS HOURS." The sign shall be in letters not less than 1 inch (25 mm) high on a contrasting background. When unlocked, the single door or both leaves of a pair of doors must be free to swing without operation of any latching device. The use of this exception may be revoked by the building official for due cause.

2. Exit doors from individual dwelling units; Group R, Division 3 congregate residences; and guest rooms of Group R Occupancies having an occupant load of 10 or less may be provided with a night latch, dead bolt or security chain, provided such devices are openable from the inside without the use of a key or tool and mounted at a height not to exceed 48 inches (1219 mm) above the finished floor.

Manually operated edge- or surface-mounted flush bolts and surface bolts or any other type of device that may be used to close or restrain the door other than by operation of the locking device shall not be used. Where exit doors are used in pairs and approved automatic flush bolts are used, the door leaf having the automatic flush bolts shall have no doorknob or surface-mounted hardware. The unlatching of any leaf shall not require more than one operation.

EXCEPTIONS: 1. Group R, Division 3 Occupancies.

2. Where a pair of doors serving a room not normally occupied is needed for the movement of equipment, manually operated edge- or surface-mounted bolts may be used.

1003.3.1.9 Panic hardware. Panic hardware, where installed, shall comply with the requirements of UBC Standard 10-4. The activating member shall be mounted at a height of not less than 30 inches (762 mm) nor more than 44 inches (1118 mm) above the floor. The unlatching force shall not exceed 15 pounds (66.72 N) when applied in the direction of travel.

Where pivoted or balanced doors are used and panic hardware is required, panic hardware shall be of the push-pad type and the pad shall not extend across more than one half of the width of the door measured from the latch side.

1003.3.1.10 Special egress-control devices. When approved by the building official, exit doors in Group B; Group F; Group I, Division 2; Group M; Group R, Division 1 congregate residences serving as group-care facilities and Group S Occupancies may be equipped with approved listed special egress-control devices of the time-delay type, provided the building is protected throughout by an approved automatic sprinkler system and an approved automatic smoke-detection system. Such devices shall conform to all the following:

1. The egress-control device shall automatically deactivate upon activation of either the sprinkler system or the smoke-detection system.

2. The egress-control device shall automatically deactivate upon loss of electrical power to any one of the following:

2.1 The egress-control device itself.

2.2 The smoke-detection system.

2.3 Means of egress illumination as required by Section 1003.2.9.

3. The egress-control device shall be capable of being deactivated by a signal from a switch located in an approved location.

4. An irreversible process that will deactivate the egress-control device shall be initiated whenever a manual force of not more than 15 pounds (66.72 N) is applied for two seconds to the panic bar or other door-latching hardware. The egress-control device shall deactivate within an approved time period not to exceed a total of 15 seconds. The time delay established for each egress-control device shall not be field adjustable.

5. Actuation of the panic bar or other door-latching hardware shall activate an audible signal at the door.

6. The unlatching shall not require more than one operation.

A sign shall be provided on the door located above and within 12 inches (305 mm) of the panic bar or other door-latching hardware reading:

KEEP PUSHING. THIS DOOR WILL OPEN IN
_____ SECONDS. ALARM WILL SOUND.

Sign lettering shall be at least 1 inch (25 mm) in height and shall have a stroke of not less than $^1/_8$ inch (3.2 mm).

Regardless of the means of deactivation, relocking of the egress-control device shall be by manual means only at the door.

1003.3.1.11 Safety glazing identification. Regardless of the occupant load served, glass doors shall conform to the requirements specified in Section 2406.

1003.3.2 Gates.

1003.3.2.1 General. Gates serving a means of egress system shall comply with the requirements of Section 1003.3.2.

1003.3.2.2 Detailed requirements. Gates used as a component in a means of egress system shall conform to the applicable requirements of Section 1003.3.1.

EXCEPTION: Gates surrounding stadiums may be of the horizontal sliding or swinging type and may exceed the 4-foot (1219 mm) maximum leaf width limitation.

1003.3.3 Stairways.

1003.3.3.1 General. Every stairway having two or more risers serving any building or portion thereof shall comply with the requirements of Section 1003.3.3. For the purposes of Section 1003.3.3, the term "stairway" shall include stairs, landings, handrails and guardrails as applicable. Where aisles in assembly rooms have steps, they shall comply with the requirements in Section 1004.3.2.

EXCEPTION: Stairs or ladders used only to attend equipment or window wells are exempt from the requirements of this section.

For the purpose of this chapter, the term "step" shall mean those portions of the means of egress achieving a change in elevation by means of a single riser. Individual steps shall comply with the detailed requirements of this chapter that specify applicability to steps.

1003.3.3.2 Width. The width of stairways shall be determined as specified in Section 1003.2.3, but such width shall not be less than 44 inches (1118 mm), except as specified herein and in Chapter 11. Stairways serving an occupant load less than 50 shall not be less than 36 inches (914 mm) in width.

Handrails may project into the required width a distance of $3^1/_2$ inches (89 mm) from each side of a stairway. Stringers and other projections such as trim and similar decorative features may project into the required width $1^1/_2$ inches (38 mm) from each side.

1003.3.3.3 Rise and run. The rise of steps and stairs shall not be less than 4 inches (102 mm) nor more than 7 inches (178 mm). The greatest riser height within any flight of stairs shall not exceed the smallest by more than $^3/_8$ inch (9.5 mm). Except as permitted in Sections 1003.3.3.8.1, 1003.3.3.8.2 and 1003.3.3.8.3, the run shall not be less than 11 inches (279 mm) as measured horizontally between the vertical planes of the furthermost projection of adjacent treads or nosings. Stair treads shall be of uniform size and shape, except the largest tread run within any flight of stairs shall not exceed the smallest by more than $^3/_8$ inch (9.5 mm).

EXCEPTIONS: 1. Private steps and stairways serving an occupant load of less than 10 and stairways to unoccupied roofs may be constructed with an 8-inch-maximum (203 mm) rise and a 9-inch-minimum (229 mm) run.

2. Where the bottom or top riser adjoins a sloping public way, walk or driveway having an established grade (other than natural earth) and serving as a landing, the bottom or top riser may be reduced along the slope to less than 4 inches (102 mm) in height with the variation in height of the bottom or top riser not to exceed 1 unit vertical in 12 units horizontal (8.3% slope) of stairway width.

1003.3.3.4 Headroom. Every stairway shall have a headroom clearance of not less than 6 feet 8 inches (2032 mm). Such clearances shall be measured vertically from a plane parallel and tangent to the stairway tread nosings to the soffit or other construction above at all points.

1003.3.3.5 Landings. There shall be a floor or a landing at the top and bottom of each stairway or stair run. Every landing shall have a dimension measured in the direction of travel not less than the width of the stairway. Such dimension need not exceed 44 inches (1118 mm) where the stair has a straight run. At least one intermediate landing shall be provided for each 12 feet (3658 mm) of vertical stairway rise measured between the horizontal planes of adjacent landings. Landings shall be level except that exterior landings may have a slope not to exceed $^1/_4$ unit vertical in 12 units horizontal (2% slope). For landings with adjoining doors, see Section 1003.3.1.7.

EXCEPTIONS: 1. In Group R, Division 3, and Group U Occupancies and within individual units of Group R, Division 1 Occupancies, such length need not exceed 36 inches (914 mm) where the stair has a straight run.

2. Stairs serving an unoccupied roof are exempt from these requirements.

1003.3.3.6 Handrails. Stairways shall have handrails on each side, and every stairway required to be more than 88 inches (2235 mm) in width shall be provided with not less than one intermediate handrail for each 88 inches (2235 mm) of required width. Intermediate handrails shall be spaced approximately equally across with the entire width of the stairway.

EXCEPTIONS: 1. Stairways less than 44 inches (1118 mm) in width or stairways serving one individual dwelling unit in Group R, Division 1 or 3 Occupancy or a Group R, Division 3 congregate residence may have one handrail.

2. Private stairways 30 inches (762 mm) or less in height may have a handrail on one side only.

3. Stairways having less than four risers and serving one individual dwelling unit in Group R, Division 1 or 3, or a Group R, Division 3 congregate residence or Group U Occupancies need not have handrails.

The top of handrails and handrail extensions shall not be placed less than 34 inches (864 mm) nor more than 38 inches (965 mm) above landings and the nosing of treads. Handrails shall be continuous the full length of the stairs and at least one handrail shall extend in the direction of the stair run not less than 12 inches (305 mm) beyond the top riser nor less than 12 inches (305 mm) beyond the bottom riser. Ends shall be returned or shall have rounded terminations or bends.

EXCEPTIONS: 1. Private stairways do not require handrail extensions.

2. Handrails may have starting or volute newels within the first tread on stairways in Group R, Division 3 Occupancies and within individual dwelling units of Group R, Division 1 Occupancies.

The handgrip portion of handrails shall not be less than $1^{1}/_{4}$ inches (32 mm) nor more than 2 inches (51 mm) in cross-sectional dimension or the shape shall provide an equivalent gripping surface. The handgrip portion of handrails shall have a smooth surface with no sharp corners. Handrails projecting from a wall shall have a space of not less than $1^{1}/_{2}$ inches (38 mm) between the wall and the handrail.

1003.3.3.7 Guardrails. Stairways open on one or both sides shall have guardrails as required by Section 509.

1003.3.3.8 Alternative stairways.

1003.3.3.8.1 Circular stairways. Circular stairways conforming to the requirements of this section may be used as a means of egress component in any occupancy. The minimum width of run shall not be less than 10 inches (254 mm) and the smaller stairway radius shall not be less than twice the width of the stairway.

1003.3.3.8.2 Winding stairways. In Group R, Division 3 Occupancies and in private stairways in Group R, Division 1 Occupancies, winding stairways may be used if the required width of run is provided at a point not more than 12 inches (305 mm) from the side of the stairway where the treads are narrower, but in no case shall the width of run be less than 6 inches (152 mm) at any point.

1003.3.3.8.3 Spiral stairways. In Group R, Division 3 Occupancies and in private stairways within individual units of Group R, Division 1 Occupancies, spiral stairways may be installed. A spiral stairway is a stairway having a closed circular form in its plan view with uniform section shaped treads attached to and radiating about a minimum diameter supporting column. Such stairways may be used as a required means of egress component where the area served is limited to 400 square feet (37.16 m^2).

The tread shall provide a clear walking area measuring at least 26 inches (660 mm) from the outer edge of the supporting column to the inner edge of the handrail. The effective tread is delineated by the nosing radius line, the exterior arc (inner edge of railing) and the overlap radius line (nosing radius line of tread above). Effective tread dimensions are taken along a line perpendicular to the center line of the tread. A run of at least $7^{1}/_{2}$ inches (191 mm) shall be provided at a point 12 inches (305 mm) from where the tread is the narrowest. The rise shall be sufficient to provide a headroom clearance of not less than 6 feet 6 inches (1981 mm); however, such rise shall not exceed $9^{1}/_{2}$ inches (241 mm).

1003.3.3.9 Interior stairway construction. Interior stairways shall be constructed based on type of construction requirements as specified in Sections 602.4, 603.4, 604.4, 605.4 and 606.4.

Except where enclosed usable space under stairs is prohibited by Section 1005.3.3.6, the walls and soffits of such enclosed space shall be protected on the enclosed side as required for one-hour fire-resistive construction.

Stairways exiting directly to the exterior of a building four or more stories in height shall be provided with a means for emergency entry for fire department access. (See the Fire Code.)

1003.3.3.10 Protection of exterior wall openings. All openings in the exterior wall below and within 10 feet (3048 mm), measured horizontally, of openings in an interior exit stairway serving a building over two stories in height or a floor level having such openings in two or more floors below, shall be protected by fixed or self-closing fire assemblies having a three-fourths-hour fire-protection rating. See Section 1006.3.3.1.

EXCEPTIONS: 1. Group R, Division 3 Occupancies.

2. Protection of exterior wall openings is not required where the exterior openings in the interior stairway are protected by fixed or self-closing fire assemblies having a three-fourths-hour fire-protection rating.

3. Protection of openings is not required for open parking garages conforming to Section 405.

1003.3.3.11 Stairway to roof. In buildings four or more stories in height, one stairway shall extend to the roof surface, unless the roof has a slope steeper than 4 units vertical in 12 units horizontal (33% slope).

1003.3.3.12 Roof hatches. All required interior stairways that extend to the top floor in any building four or more stories in height shall have, at the highest point of the stair shaft, an approved hatch openable to the exterior not less than 16 square feet (1.5 m^2) in area and having a minimum dimension of 2 feet (610 mm).

EXCEPTION: A roof hatch need not be provided on pressurized enclosures or on stairways that extend to the roof with an opening onto that roof.

1003.3.3.13 Stairway identification. Stairway identification signs shall be located at each floor level in all enclosed stairways in buildings four or more stories in height. Such signs shall identify the stairway, indicate whether or not there is roof access, the floor level, and the upper and lower terminus of the stairway. The sign shall be located approximately 5 feet (1524 mm) above the landing floor in a position that is readily visible when the door is in either the open or closed position. Signs shall comply with requirements of UBC Standard 10-2.

1003.3.4 Ramps.

1003.3.4.1 General. Ramps used as a component in a means of egress system shall conform to the requirements of Section 1003.3.4.

EXCEPTION: Ramped aisles within assembly rooms shall conform to the requirements in Section 1004.3.2.

1003.3.4.2 Width. The width of ramps shall be determined as specified in Section 1003.2.3, but shall not be less than 44 inches (1118 mm), except as specified herein and in Chapter 11. Ramps serving an occupant load of less than 50 shall not be less than 36 inches (914 mm) in width.

Handrails may project into the required width a distance of $3^{1}/_{2}$ inches (89 mm) from each side of a ramp. Other projections, such as trim and similar decorative features, may project into the required width $1^{1}/_{2}$ inches (38 mm) from each side.

1003.3.4.3 Slope. The slope of ramps required by Chapter 11 that are located within an accessible route of travel shall not be steeper than 1 unit vertical in 12 units horizontal (8.3% slope). The slope of other ramps shall not be steeper than 1 unit vertical in 8 units horizontal (12.5% slope).

1003.3.4.4 Landings. Ramps having slopes steeper than 1 unit vertical in 20 units horizontal (5% slope) shall have landings at the top and bottom, and at least one intermediate landing shall be provided for each 5 feet (1524 mm) of vertical rise measured between the horizontal planes of adjacent landings. Top landings and intermediate landings shall have a dimension measured in the direction of ramp run of not less than 5 feet (1524 mm). Landings at the bottom of ramps shall have a dimension in the direction of ramp run of not less than 6 feet (1829 mm).

Doors in any position shall not reduce the minimum dimension of the landing to less than 42 inches (1067 mm) and shall not reduce the required width by more than 7 inches (178 mm) when fully open.

Where ramp access is provided to comply with the requirements of Chapter 11 and a door swings over a landing, the landing shall extend at least 24 inches (610 mm) beyond the latch edge of the door, measured parallel to the door in the closed position, and shall have a length measured in the direction of travel through the doorway of not less than 5 feet (1524 mm).

1003.3.4.5 Handrails. Ramps having slopes steeper than 1 unit vertical in 20 units horizontal (5% slope) shall have handrails as required for stairways, except that intermediate handrails shall not be required. Ramped aisles serving fixed seating shall have handrails as required in Section 1004.3.2.

1003.3.4.6 Guardrails. Ramps open on one or both sides shall have guardrails as required by Section 509.

1003.3.4.7 Construction. Ramps shall be constructed as required for stairways.

1003.3.4.8 Surface. The surface of ramps shall be roughened or shall be of slip-resistant materials.

SECTION 1004 — THE EXIT ACCESS

1004.1 General. The exit access is that portion of a means of egress system between any occupied point in a building or structure and a door of the exit. Components that may be selectively included in the exit access include aisles, hallways and corridors, in addition to those means of egress components described in Section 1003.3.

1004.2 Exit-access Design Requirements.

1004.2.1 General. The exit access portion of the means of egress system shall comply with the applicable design requirements of Section 1004.2. For the purposes of Section 1004.2, the term "exit-access doorway" shall mean the point of entry to one portion of the building or structure from another along the path of exit travel. An exit-access doorway occurs where access to all exits is not direct (see Section 1004.2.3). An exit-access doorway does not necessarily include a door. When a detailed requirement specifies an "exit-access door," however, then a door shall be included as a portion of the doorway.

1004.2.2 Travel through intervening rooms. The required access to exits from any portion of a building shall be directly from the space under consideration to an exit or to a corridor that provides direct access to an exit. Exit access shall not be interrupted by intervening rooms.

EXCEPTIONS: 1. Access to exits may occur through foyers, lobbies and reception rooms.

2. Where access to only one exit is required from a space under consideration, exit access may occur through an adjoining or intervening room, which in turn provides direct access to an exit or to a corridor that provides direct access to an exit.

3. Rooms with a cumulative occupant load of less than 10 may access exits through more than one intervening room.

4. Where access to more than one exit is required from a space under consideration, such spaces may access one required exit through an adjoining or intervening room, which in turn provides direct access to an exit or to a corridor that provides direct access to an exit. All other required access to exits shall be directly from the space under consideration to an exit or to a corridor that provides direct access to an exit.

5. In a one- or two-story building classified as a Group F, Group S or Group H, Division 5 Occupancy, offices and similar administrative areas may have access to two required exits through an adjoining or intervening room, which in turn provides direct access to an exit or to a corridor that provides direct access to an exit, if the building is equipped with an automatic sprinkler system throughout and is provided with smoke and heat ventilation as specified in Section 906. Such areas shall not exceed 25 percent of the floor area of the major use.

6. Rooms within dwelling units may access exits through more than one intervening room.

Hallways shall be considered as intervening rooms.

Interior courts enclosed on all sides shall be considered as interior intervening rooms.

EXCEPTION: Such courts not less than 10 feet (3048 mm) in width and not less than the width determined as specified in Section 1003.2.3 and providing direct access to the exit need not be considered intervening rooms.

In other than dwelling units, a means of egress shall not pass through kitchens, storerooms, restrooms, closets or spaces used for similar purposes.

A means of egress serving other than Group H Occupancies shall not pass through rooms that contain Group H Occupancies.

1004.2.3 Access to exits.

1004.2.3.1 General. Exits shall be provided from each building level. Additionally, access to such exits shall be provided from all occupied areas within building levels. The maximum number of exits required from any story, basement or individual space shall be maintained until arrival at grade or the public way.

1004.2.3.2 From individual floors. For the purposes of Section 1004.2, floors, stories, occupied roofs and similar designations of building levels other than basements and mezzanines shall be considered synonymous.

Every occupant on the first story shall have access to not less than one exit and not less than two exits when required by Table 10-A. Every occupant in basements and on stories other than the first story shall have access to not less than two exits.

EXCEPTIONS: 1. Second stories having an occupant load less than 10 may be provided with access to only one exit.

2. Two or more dwelling units on the second story or in a basement may have access to only one exit where the total occupant load served by that exit does not exceed 10.

3. Except as provided in Table 10-A, access to only one exit need be provided from the second floor or a basement within an individual dwelling unit or a Group R, Division 3 congregate residence.

4. Where the third floor within an individual dwelling unit or a Group R, Division 3 congregate residence does not exceed 500 square feet (46.45 m^2), access to only one exit need be provided from that floor.

5. Occupied roofs on Group R, Division 3 Occupancies may have access to only one exit where such occupied areas are less than 500 square feet (46.45 m^2) and are located no higher than immediately above the second story.

6. Floors and basements used exclusively for the service of the building may have access to only one exit. For the purposes of this exception, storage rooms, laundry rooms, maintenance offices and similar uses shall not be considered as providing service to the building.

No cumulative or contributing occupant loads from adjacent levels need be considered when determining the number of required exits from a given level.

1004.2.3.3 From individual spaces. All occupied portions of the building shall have access to not less than one exit or exit-access doorway. Access to not less than two exits, exit-access doorways or combination thereof shall be provided when the individual or cumulative occupant load served by a portion of the exit access is equal to, or greater than, that listed in Table 10-A.

EXCEPTIONS: 1. Elevator lobbies may have access to only one exit or exit-access doorway provided the use of such exit or exit-access doorway does not require keys, tools, special knowledge or effort.

2. Storage rooms, laundry rooms and maintenance offices not exceeding 300 square feet (27.87 m^2) in floor area may be provided with access to only one exit or exit-access doorway.

1004.2.3.4 Additional access to exits. Access to not less than three exits, exit-access doorways or combination thereof shall be provided when the individual or cumulative occupant load served by the exit access is 501 to 1,000.

Access to not less than four exits, exit-access doorways or combination thereof shall be provided when the individual or cumulative occupant load served by the exit access exceeds 1,000.

1004.2.4 Separation of exits or exit-access doorways. Where two or more exits or exit-access doorways are required from any level or portion of the building, at least two of the exits or exit-access doorways shall be placed a distance apart equal to not less than one half of the length of the maximum overall diagonal dimension of the area served measured in a straight line between the center of such exits or exit-access doorways. Additional exits or exit-access doorways shall be arranged a reasonable distance apart so that if one becomes blocked, the others will be available.

> **EXCEPTION:** The separation distance determined in accordance with this section may be measured along a direct path of exit travel within a fire-resistive corridor complying with Section 1004.3.4.3.1 serving exit enclosures. The walls of any such exit enclosure shall not be less than 30 feet (9144 mm), measured in a straight line, from the walls of another exit enclosure.

1004.2.5 Travel distance.

1004.2.5.1 General. Travel distance is that distance an occupant must travel from any point within occupied portions of the exit access to the door of the nearest exit. Travel distance shall be measured in a straight line along the path of exit travel from the most remote point through the center of exit-access doorways to the center of the exit door. Travel distance shall include that portion of the path of exit travel through or around permanent construction features and building elements. Travel around tables, chairs, furnishings, cabinets and similar temporary or movable fixtures or equipment need not be considered as the normal presence of such items is factored into the permitted travel distance.

Unless prohibited elsewhere in this chapter, travel within the exit access may occur on multiple levels by way of unenclosed stairways or ramps. Where the path of exit travel includes unenclosed stairways or ramps within the exit access, the distance of travel on such means of egress components shall also be included in the travel distance measurement. The measurement along stairways shall be made on a plane parallel and tangent to the stair tread nosings in the center of the stairway.

1004.2.5.2 Maximum travel distance. The travel distance to at least one exit shall not exceed that specified in this section.

Special travel distance requirements are contained in other sections of this code as follows:

1. For atria, see Section 402.5.
2. For Group E Occupancies, see Section 1007.3.
3. For Group H Occupancies, see Section 1007.4.
4. For malls, see Sections 404.4.3 and 404.4.5.

1004.2.5.2.1 Nonsprinklered buildings. In buildings not equipped with an automatic sprinkler system throughout, the travel distance shall not exceed 200 feet (60 960 mm).

1004.2.5.2.2 Sprinklered buildings. In buildings equipped with an automatic sprinkler system throughout, the travel distance shall not exceed 250 feet (76 200 mm).

1004.2.5.2.3 Corridor increases. The travel distances specified in Sections 1004.2.5.2.1, 1004.2.5.2.2, 1004.2.5.2.4 and 1004.2.5.2.5 may be increased up to an additional 100 feet (30 480 mm) provided that the last portion of exit access leading to the exit occurs within a fire-resistive corridor complying with Section 1004.3.4.3.1. The length of such corridor shall not be less than the amount of the increase taken, in feet (mm).

1004.2.5.2.4 Open parking garages. In a Group S, Division 4 open parking garage as defined in Section 311.9, the travel distance shall not exceed 300 feet (91 440 mm) in a building not equipped with an automatic sprinkler system throughout and 400 feet (121 920 mm) in a building equipped with an automatic sprinkler system throughout. The travel distance may be measured to open stairways, which are permitted in accordance with Section 1005.3.3.1.

1004.2.5.2.5 Factory, hazardous and storage occupancies. In a one-story building classified as a Group H, Division 5 aircraft repair hangar, or as a Group F or Group S Occupancy, the travel distance shall not exceed 300 feet (91 440 mm) and may be increased to 400 feet (121 920 mm) if the building is equipped with an automatic sprinkler system throughout and is also provided with smoke and heat ventilation as specified in Section 906.

1004.2.6 Dead ends. Where more than one exit or exit-access doorway is required, the exit access shall be arranged such that there are no dead ends in hallways and corridors more than 20 feet (6096 mm) in length.

1004.3 Exit-access Components.

1004.3.1 General. Exit-access components incorporated into the design of the exit-access portion of the means of egress system shall comply with the requirements of Section 1004.3.

1004.3.2 Aisles.

1004.3.2.1 General. Aisles serving as a portion of an exit access in the means of egress system shall comply with the requirements of Section 1004.3.2. Aisles shall be provided from all occupied portions of the exit access that contain seats, tables, furnishings, displays, and similar fixtures or equipment.

1004.3.2.2 Width in occupancies without fixed seats. The width of aisles in occupancies without fixed seats shall be determined in accordance with the following:

1. In areas serving employees only, the minimum aisle width shall be 24 inches (610 mm), but not less than the width determined as specified in Section 1003.2.3.

2. In public areas of Groups B and M Occupancies, and in assembly occupancies without fixed seats, the minimum clear aisle width shall be 36 inches (914 mm) where seats, tables, furnishings, displays and similar fixtures or equipment are placed on only one side of the aisle and 44 inches (1118 mm) where such fixtures or equipment are placed on both sides of the aisle.

The required width of aisles shall be unobstructed.

> **EXCEPTION:** Handrails and doors, when fully opened, shall not reduce the required width by more than 7 inches (178 mm). Doors in any position shall not reduce the required width by more than one half. Other nonstructural projections such as trim and similar decorative features may project into the required width $1^1/_2$ inches (38 mm) from each side.

1004.3.2.3 Occupancies with fixed seats. Aisles in occupancies with fixed seats shall comply with the requirements of this section.

1004.3.2.3.1 Width. The clear width of aisles shall be based on the number of fixed seats served by such aisles. The required width of aisles serving fixed seats shall not be used for any other purpose.

The minimum clear width of aisles in buildings without smoke-protected assembly seating shall be in accordance with Table 10-C.

The minimum clear width of aisles in buildings where smoke-protected assembly seating has been provided, and for which an approved life-safety evaluation has also been conducted, shall be in accordance with Table 10-D. For Table 10-D, the number of seats specified must be within a single assembly place, and interpolation shall be permitted between the specified values shown.

For both tables, the minimum clear widths shown shall be modified in accordance with the following:

1. Where risers exceed 7 inches (178 mm) in height, multiply the stairway width in the tables by factor A, where:

$$A = 1 + \frac{(\text{riser height} - 7.0 \text{ inches})}{5} \qquad (4\text{-}1)$$

For **SI**:

$$A = 1 + \frac{(\text{riser height} - 178 \text{ mm})}{127}$$

Where risers do not exceed 7 inches (178 mm) in height, $A = 1$.

2. Stairways not having a handrail within a 30-inch (762 mm) horizontal distance shall be 25 percent wider than otherwise calculated, i.e., multiply by $B = 1.25$. For all other stairs, $B = 1$.

3. Ramps steeper than 1 unit vertical in 10 units horizontal (10% slope) where used in ascent shall have their width increased by 10 percent, i.e., multiply by $C = 1.10$. For ramps not steeper than 1 unit vertical in 10 units horizontal (10% slope), $C = 1$.

Where fixed seats are arranged in rows, the clear width of aisles shall not be less than set forth above or less than the following minimum widths:

Forty-eight inches (1219 mm) for stairways having seating on both sides.

Thirty-six inches (914 mm) for stairways having seating on one side.

Twenty-three inches (584 mm) between a stairway handrail and seating where the aisles are subdivided by the handrail.

Forty-two inches (1067 mm) for level or ramped aisles having seating on both sides.

Thirty-six inches (914 mm) for level or ramped aisles having seating on one side.

Twenty-three inches (584 mm) between a stairway handrail and seating where an aisle does not serve more than five rows on one side.

Where exit access is possible in two directions, the width of such aisles shall be uniform throughout their length. Where aisles converge to form a single path of exit travel, the aisle width shall not be less than the combined required width of the converging aisles.

1004.3.2.3.2 Seat spacing. Where seating rows have 14 or less seats, the minimum clear width of aisle accessways shall not be less than 12 inches (305 mm) measured as the clear horizontal distance from the back of the row or guardrail ahead and the nearest projection of the row behind. Where seats are automatic or self-rising, measurement may be made with the seats in the raised position. Where seats are not automatic or self-rising, the minimum clear width shall be measured with the seat in the down position.

The clear width shall be increased as follows:

1. For rows of seating served by aisles or doorways at both ends, there shall be no more than 100 seats per row. The minimum clear width of 12 inches (305 mm) for aisle accessways shall be increased by 0.3 inch (7.6 mm) for every additional seat beyond 14, but the minimum clear width need not exceed 22 inches (559 mm). If the aisles are dead-ended, see Section 1004.3.2.4 for further limitations.

EXCEPTION: For smoke-protected assembly seating, the row length limits, beyond which the minimum clear width of 12 inches (305 mm) must be increased, may be in accordance with Table 10-E.

2. For rows of seating served by an aisle or doorway at one end only, the minimum clear width of 12 inches (305 mm) for aisle accessways shall be increased by 0.6 inch (15 mm) for every additional seat beyond seven, but the minimum clear width need not exceed 22 inches (559 mm).

EXCEPTION: For smoke-protected assembly seating, the row length limits, beyond which the minimum clear width of 12 inches (305 mm) must be increased, may be in accordance with Table 10-E.

In addition, the distance to the point where the occupant has a choice of two directions of travel to an exit shall not exceed 30 feet (9144 mm) from the point where the occupant is seated.

EXCEPTION: For smoke-protected assembly seating, the distance to the point where the occupant has a choice of two directions of travel to an exit may be increased to 50 feet (15 240 mm) from the point where the occupant is seated.

1004.3.2.4 Aisle termination. Aisles shall terminate at a cross aisle, vomitory, foyer or doorway. Aisles shall not have a dead end more than 20 feet (6096 mm) in length.

EXCEPTIONS: 1. A longer dead-end aisle is permitted where seats served by the dead-end aisle are not more than 24 seats from another aisle measured along a row of seats having a minimum clear width of 12 inches (305 mm) plus 0.6 inch (15 mm) for each additional seat above seven in a row.

2. When seats are without backrests, dead ends in vertical aisles shall not exceed a distance of 16 rows.

3. For smoke-protected assembly seating, the dead ends in vertical aisles shall not exceed a distance of 21 rows.

4. For smoke-protected assembly seating, a longer dead-end aisle is permitted where seats served by the dead-end aisle are no more than 40 seats from another aisle, measured along a row of seats having an aisle accessway with a minimum clear width of 12 inches (305 mm) plus 0.3 inch (7.6 mm) for each additional seat above seven in the row.

Each end of a cross aisle shall terminate at an aisle, vomitory, foyer or doorway.

1004.3.2.5 Aisle steps.

1004.3.2.5.1 Where prohibited. Steps shall not be used in aisles having a slope of 1 unit vertical in 8 units horizontal (12.5% slope) or less.

1004.3.2.5.2 Where required. Aisles with a slope steeper than 1 unit vertical in 8 units horizontal (12.5% slope) shall consist of a series of risers and treads extending across the entire width of the aisle.

The height of risers shall not be more than 8 inches (203 mm) nor less than 4 inches (102 mm) and the tread run shall not be less than 11 inches (279 mm). The riser height shall be uniform within each flight and the tread run shall be uniform throughout the aisle. Variations in run or height between adjacent treads or risers shall not exceed $^3/_{16}$ inch (4.8 mm).

EXCEPTION: Where the slope of aisle steps and the adjoining seating area is the same, the riser heights may be increased to a maximum of 9 inches (229 mm) and may be nonuniform, but only to the extent necessitated by changes in the slope of the adjoining seating area to maintain adequate sight lines. Variations may exceed $^3/_{16}$ inch (4.8 mm) between adjacent risers, provided the exact location of such variations is identified with a marking stripe on each tread at the nosing or leading edge adjacent to the nonuniform riser. The marking stripe shall be distinctively different from the contrasting marking stripe.

A contrasting marking stripe or other approved marking shall be provided on each tread at the nosing or leading edge such that the location of each tread is readily apparent when viewed in descent. Such stripe shall be a minimum of 1 inch (25 mm) wide and a maximum of 2 inches (51 mm) wide.

EXCEPTION: The marking stripe may be omitted where tread surfaces are such that the location of each tread is readily apparent when viewed in descent.

1004.3.2.6 Ramp slope. The slope of ramped aisles shall not be more than 1 unit vertical in 8 units horizontal (12.5% slope). Ramped aisles shall have a slip-resistant surface.

1004.3.2.7 Handrails. Handrails shall comply with the height, size and shape dimensions set forth in Section 1003.3.3.6, and ends shall be returned or shall have rounded terminations or bends. Ramped aisles having a slope steeper than 1 unit vertical in 15 units horizontal (6.7% slope) and aisle stairs (two or more adjacent steps) shall have handrails located either at the side or within the aisle width. Handrails may project into the required aisle width a distance of $3^1/_2$ inches (89 mm).

EXCEPTIONS: 1. Handrails may be omitted on ramped aisles having a slope not steeper than 1 unit vertical in 8 units horizontal (12.5% slope) and having fixed seats on both sides of the aisle.

2. Handrails may be omitted where a guardrail is at the side of an aisle that conforms to the size and shape requirements for handrails.

Handrails located within the aisle width shall be discontinuous with gaps or breaks at intervals not to exceed five rows. These gaps or breaks shall have a clear width of not less than 22 inches (559 mm) nor more than 36 inches (914 mm) measured horizontally. Such handrails shall have an additional intermediate handrail located 12 inches (305 mm) below the main handrail.

1004.3.3 Hallways.

1004.3.3.1 General. Hallways serving as a portion of the exit access in the means of egress system shall comply with the requirements of Section 1004.3.3. Hallways may be used as an exit-access component unless specifically prohibited based on requirements specified elsewhere in this chapter. For exit-access design purposes, hallways shall be considered as intervening rooms.

1004.3.3.2 Width. The width of hallways shall be determined as specified in Section 1003.2.3, but such width shall not be less than 44 inches (1118 mm), except as specified herein. Hallways serving an occupant load of less than 50 shall not be less than 36 inches (914 mm) in width.

The required width of hallways shall be unobstructed.

EXCEPTION: Doors, when fully opened, and handrails shall not reduce the required width by more than 7 inches (178 mm). Doors in any position shall not reduce the required width by more than one half. Other nonstructural projections such as trim and similar decorative features may project into the required width $1^1/_2$ inches (38 mm) from each side.

1004.3.3.3 Construction. Hallways are not required to be of fire-resistive construction unless a building element of the hallway is required to be of fire-resistive construction by some other provision of this code.

Hallways in buildings of Types I or II construction shall be of noncombustible construction, except where combustible materials are permitted in applicable building elements by other provisions of this code. Hallways in buildings of Types III, IV or V construction may be of combustible or noncombustible construction.

Hallways may have walls of any height. Partitions, rails, counters and similar space dividers not over 6 feet (1829 mm) in height above the floor shall not be construed to form a hallway.

1004.3.3.4 Openings. There is no restriction as to the amount and type of openings permitted in hallways, unless protection of openings is required by some other provision of this code.

1004.3.3.5 Elevator lobbies. Elevators opening into hallways need not be provided with elevator lobbies unless smoke- and draft-control assemblies are required for the protection of elevator door openings by some other provision of this code.

1004.3.4 Corridors.

1004.3.4.1 General. Corridors serving as a portion of an exit access in the means of egress system shall comply with the requirements of Section 1004.3.4.

For restrictions on the use of corridors to convey air, see Chapter 6 of the Mechanical Code.

1004.3.4.2 Width. The width of corridors shall be determined as specified in Section 1003.2.3, but such width shall not be less than 44 inches (1118 mm), except as specified herein. Corridors serving an occupant load of less than 50 shall not be less than 36 inches (914 mm) in width.

The required width of corridors shall be unobstructed.

EXCEPTION: Doors, when fully opened, and handrails shall not reduce the required width by more than 7 inches (178 mm). Doors in any position shall not reduce the required width by more than one half. Other nonstructural projections such as trim and similar decorative features may project into the required width $1^1/_2$ inches (38 mm) from each side.

1004.3.4.3 Construction. Corridors shall be fully enclosed by walls, a floor, a ceiling and permitted protected openings. The walls and ceilings of corridors shall be constructed of fire-resistive materials as specified in Section 1004.3.4.3.1.

EXCEPTIONS: 1. One-story buildings housing Group F, Division 2 and Group S, Division 2 Occupancies.

2. Corridors more than 30 feet (9144 mm) in width where occupancies served by such corridors have at least one exit independent from the corridor. (See Chapter 4 for covered malls.)

3. In Group I, Division 3 Occupancies such as jails, prisons, reformatories and similar buildings with open-barred cells forming corridor walls, the corridors and cell doors need not be fire-resistive.

4. Corridor walls and ceilings need not be of fire-resistive construction within office spaces having an occupant load of 100 or less when the entire story in which the space is located is equipped with an automatic sprinkler system throughout and an automatic smoke-detection system installed within the corridor. The actuation of any detector shall activate alarms audible in all areas served by the corridor.

5. Corridor walls and ceilings need not be of fire-resistive construction within office spaces having an occupant load of 100 or less when the building in which the space is located is equipped with an automatic sprinkler system throughout.

6. In Group B office buildings of Type I, Type II-FR and Type II-one-hour construction, corridor walls and ceilings need not be of fire-resistive construction within office spaces of a single tenant when the entire story in which the space is located is equipped with an approved automatic sprinkler system and an automatic smoke-detection system is installed within the corridor. The actuation of any detector shall activate alarms audible in all areas served by the corridor.

Corridor floors are not required to be of fire-resistive construction unless specified by some other provision of this code.

Corridors in buildings of Type I or II construction shall be of noncombustible construction, except where combustible materials are permitted in applicable building elements by other provisions of this code. Corridors in buildings of Type III, IV or V construction may be of combustible or noncombustible construction.

1004.3.4.3.1 Fire-resistive materials. Corridor walls shall be constructed of materials approved for one-hour fire-resistive construction on each side. Corridor walls shall extend vertically to a floor-ceiling or roof-ceiling constructed in accordance with one of the following:

1. The corridor-side fire-resistive membrane of the corridor wall shall terminate at the corridor ceiling membrane constructed

of materials approved for a one-hour fire-resistive floor-ceiling or roof-ceiling assembly to include suspended ceilings, dropped ceilings and lay-in roof-ceiling panels, which are a portion of a fire-resistive assembly.

The room-side fire-resistive membrane of the corridor wall shall terminate at the underside of a floor or roof constructed of materials approved for a one-hour fire-resistive floor-ceiling or roof-ceiling assembly.

EXCEPTION: Where the corridor ceiling is an element of not less than a one-hour fire-resistive floor-ceiling or roof-ceiling assembly at the entire story, both sides of corridor walls may terminate at the ceiling membrane.

2. The corridor ceiling may be constructed of materials approved for a fire-resistive wall assembly. When this method is utilized, the corridor-side fire-resistive membrane of the corridor wall shall terminate at the lower ceiling membrane and the room-side fire-resistive membrane of the corridor wall shall terminate at the upper ceiling membrane.

Corridor ceilings of noncombustible construction may be suspended below the fire-resistive ceiling membrane.

For wall and ceiling finish requirements, see Table 8-B.

1004.3.4.3.2 Openings. Openings in corridors shall be protected in accordance with the requirements of this section.

EXCEPTIONS: 1. Corridors that are excepted from fire-resistive requirements by Section 1004.3.4.3.

2. Corridors on the exterior walls of buildings may have unprotected openings to the exterior when permitted by Table 5-A.

3. Corridors in multitheater complexes may have unprotected openings where each motion picture auditorium has at least one half of its required exit or exit-access doorways opening directly to the exterior or into an exit passageway.

1004.3.4.3.2.1 Doors. All exit-access doorways and doorways from unoccupied areas to a corridor shall be protected by tightfitting smoke- and draft-control assemblies having a fire-protection rating of not less than 20 minutes when tested in accordance with UBC Standard 7-2, Part II. Such doors shall not have louvers, mail slots or similar openings. The door and frame shall bear an approved label or other identification showing the rating thereof, followed by the letter "S," the name of the manufacturer and the identification of the service conducting the inspection of materials and workmanship at the factory during fabrication and assembly. Doors shall be maintained self-closing or shall be automatic closing by actuation of a smoke detector in accordance with Section 713.2. Smoke- and draft-control door assemblies shall be provided with a gasket installed so as to provide a seal where the door meets the stop on both sides and across the top.

EXCEPTION: View ports may be installed if they require a hole not larger than 1 inch (25 mm) in diameter through the door, have at least a $^1/_4$-inch-thick (6.4 mm) glass disc and the holder is of metal that will not melt out when subject to temperatures of 1,700°F (927°C).

Exit doors from a corridor shall comply with the requirements for the individual exit component being accessed as specified elsewhere in this chapter.

1004.3.4.3.2.2 Windows. Windows in corridor walls shall be protected by fixed glazing listed and labeled or marked for a fire-protection rating of at least three-fourths hour and complying with Sections 713.8 and 713.9. The total area of windows in a corridor shall not exceed 25 percent of the area of a common wall with any room.

1004.3.4.3.2.3 Duct openings. For duct openings in corridors, see Sections 713.10 and 713.11. Where both smoke dampers and fire dampers are required by Sections 713.10 and 713.11, combination fire/smoke dampers shall be used.

1004.3.4.4 Intervening rooms. Corridors shall not be interrupted by intervening rooms.

EXCEPTIONS: 1. Foyers, lobbies or reception rooms constructed as required for corridors shall not be construed as intervening rooms.

2. In fully sprinklered office buildings, corridors may lead through enclosed elevator lobbies if all areas of the building have access to at least one required exit without passing through the elevator lobby.

1004.3.4.5 Elevators. Elevators opening into a corridor shall be provided with an elevator lobby at each floor containing such a corridor. The lobby shall completely separate the elevators from the corridor by construction conforming to Section 1004.3.4.3.1 and all openings into the lobby wall contiguous with the corridor shall be protected as required by Section 1004.3.4.3.2.

EXCEPTIONS: 1. In office buildings, separations need not be provided from a street floor elevator lobby, provided the entire street floor is protected with an automatic sprinkler system.

2. Elevators not required to meet the shaft enclosure requirements of Section 711.

3. Where additional doors are provided in accordance with Section 3007.

Elevator lobbies shall comply with the requirements of Section 3002.

SECTION 1005 — THE EXIT

1005.1 General. The exit is that portion of the means of egress system between the exit access and the exit discharge or the public way. Components that may be selectively included in the exit include exterior exit doors, exit enclosures, exit passageways and horizontal exits, in addition to those common means of egress components described in Section 1003.3.

1005.2 Exit Design Requirements. The exit portion of the means of egress system shall comply with the applicable design requirements of this section.

1005.2.1 Separation of exits. Exits shall be separated in accordance with the requirements of Section 1004.2.4.

1005.2.2 Travel distance. Travel distance shall not be limited within an exit enclosure or exit passageway, which complies with the applicable requirements of Section 1005.3.

1005.2.3 Travel through intervening rooms. Exits shall not be interrupted by intervening rooms.

EXCEPTIONS: 1. Horizontal exits may lead to an exit-access element complying with the requirements of Section 1004.

2. In office buildings, and Group I, Division 1.1 hospitals and nursing homes, a maximum of 50 percent of the exits may pass through a street-floor lobby, provided the entire street floor is protected with an automatic sprinkler system.

1005.3 Exit Components.

1005.3.1 General. Exit components incorporated into the design of the exit portion of the means of egress system shall comply with the requirements of Section 1005.3.

Once a given level of fire-resistive protection is achieved in an exit component, the fire-resistive time-period of such component shall not be reduced until arrival at the exit discharge or the public way.

EXCEPTION: Horizontal exits may lead to an exit-access element complying with the requirements of Section 1004.

Doors of exit components that open directly to the exterior of a building shall not be located in areas where openings are not permitted due to location on property by Table 5-A.

1005.3.2 Exterior exit doors.

1005.3.2.1 General. Exterior exit doors serving as an exit in a means of egress system shall comply with the requirements of

Section 1005.3.2. Buildings or structures used for human occupancy shall have at least one exterior exit door that meets the requirements of Section 1003.3.1.3.

1005.3.2.2 Detailed requirements. Exterior exit doors shall comply with the applicable requirements of Section 1003.3.1.

1005.3.2.3 Arrangement. Exterior exit doors shall lead directly to the exit discharge or the public way.

1005.3.3 Exit enclosures.

1005.3.3.1 General. Exit enclosures serving as an exit in a means of egress system shall comply with the requirements of Section 1005.3.3. Exit enclosures shall not be used for any purpose other than as a means of egress.

Interior stairways, ramps or escalators shall be enclosed as specified in this section.

> **EXCEPTIONS:** 1. In other than Groups H and I Occupancies, an exit enclosure need not be provided for a stairway, ramp or escalator serving only one adjacent floor. Any two such atmospherically interconnected floors shall not communicate with other floors. For enclosure of escalators serving Groups B, F, M and S Occupancies, see Sections 304.6, 306.6, 309.6 and 311.6.
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> 2. Stairways in Group R, Division 3 Occupancies and stairways within individual dwelling units in Group R, Division 1 Occupancies need not be enclosed.
>
> 3. Stairs in open parking garages, as defined in Section 311.9, need not be enclosed.

1005.3.3.2 Construction. Exit enclosures shall be of fire-resistive construction as follows:

1. In buildings of other than Type I- or Type II-F.R. construction and less than four stories in height, exit enclosures shall not be of less than one-hour fire-resistive construction.

2. In buildings of Type I- or Type II-F.R. construction of any height, exit enclosures shall not be of less than two-hour fire-resistive construction.

3. In buildings of any type of construction and four or more stories in height, exit enclosures shall not be of less than two-hour fire-resistive construction.

> **EXCEPTION:** In sprinkler-protected parking garages restricted to the storage of private or pleasure-type motor vehicles, exit enclosures may be enclosed with glazing meeting the requirements of Sections 713.7, 713.8 and 713.9.

Exit enclosures in buildings of Type I or II construction shall be of noncombustible construction except where combustible materials are permitted in applicable building elements by other provisions of this code. Exit enclosures in buildings of Type III, IV or V construction may be of combustible or noncombustible construction.

1005.3.3.3 Extent of enclosure. Exit enclosures shall be continuous and fully enclose all portions of the stairway or ramp to include parts of floors connecting stairway flights. Exit enclosures shall exit directly to the exterior of the building or shall include an exit passageway on the ground floor leading from the exit enclosure directly to the exterior of the building. Openings into the exit passageway shall comply with the requirements of Section 1005.3.3.5.

> **EXCEPTIONS:** 1. Exit passageways are not required from unenclosed stairways or ramps.
>
> 2. In office buildings, and Group I, Division 1.1 hospitals and nursing homes, a maximum of 50 percent of the exits may pass through a street-floor lobby, provided the entire street floor is protected with an automatic sprinkler system.

1005.3.3.4 Barrier. A stairway in an exit enclosure shall not continue below the grade level exit unless an approved barrier is provided at the ground-floor level to prevent persons from accidentally continuing into the basement. Directional exit signs shall be provided as specified in Section 1003.2.8.

1005.3.3.5 Openings and penetrations. Openings in exit enclosures shall be limited to those necessary for egress from normally occupied spaces into the enclosure and those necessary for egress from the enclosure.

> **EXCEPTION:** Exit enclosures on the exterior walls of buildings may have unprotected openings to the exterior when permitted by Table 5-A.

All interior exit doors in an exit enclosure shall be protected by a fire assembly having a fire-protection rating of not less than one hour where one-hour enclosure construction is permitted in Section 1005.3.3.2 and one and one-half hours where two-hour enclosure construction is required by Section 1005.3.3.2. Such doors shall be maintained self-closing or shall be automatic closing by actuation of a smoke detector as specified in Section 713.2. All hold-open devices shall be listed for the intended purpose and shall close or release the fire assembly to the closed position in the event of a power failure. The maximum transmitted temperature end point for such doors shall not exceed 450°F (232°C) above ambient at the end of 30 minutes of the fire exposure specified in UBC Standard 7-2.

Penetrations into or through an exit enclosure are prohibited except for those serving the exit enclosure such as ductwork and equipment necessary for independent stairway pressurization, sprinkler piping, standpipes and electrical conduit terminating in a listed box not exceeding 16 square inches (10 323 mm^2) in area. Penetrations and communicating openings between exit enclosures in the same building are not permitted regardless of their protection.

1005.3.3.6 Use of space under stairway or ramp. There shall not be enclosed usable space under stairways or ramps in an exit enclosure. The open space under such stairways shall not be used for any purpose.

1005.3.3.7 Pressurized enclosure. In a building having a floor level used for human occupancy located more than 75 feet (22 860 mm) above the lowest level of fire department vehicle access, all required exit enclosures shall be pressurized in accordance with Section 905 and this section. Pressurization shall occur automatically upon activation of an approved fire alarm system.

> **EXCEPTION:** If the building is not equipped with a fire alarm system, pressurization shall be upon activation of a spot-type smoke detector listed for releasing service located within 5 feet (1524 mm) of each vestibule entry.

A controlled relief vent capable of discharging a minimum of 2,500 cubic feet per minute (1180 L/s) of air at the design pressure difference shall be located in the upper portion of such pressurized exit enclosures.

1005.3.3.7.1 Vestibules. Pressurized exit enclosures shall be provided with a pressurized entrance vestibule that complies with the requirements of this section.

1005.3.3.7.1.1 Vestibule size. Vestibules shall not be less than 44 inches (1118 mm) in width and not less than 72 inches (1829 mm) in the direction of travel.

1005.3.3.7.1.2 Vestibule construction. Vestibules shall have walls, floors and ceilings of not less than two-hour fire-resistive construction.

1005.3.3.7.1.3 Vestibule doors. The door assembly from the building into the vestibule shall not have less than a one and one-half hour fire-protection rating, and the door assembly from the vestibule to the exit enclosure shall be a smoke- and draft-control assembly having not less than a 20-minute fire-protection rating.

Doors shall be maintained self-closing or shall be automatic closing by activation of a smoke detector installed in accordance with Section 713. All hold-open devices shall be listed for the intended purpose and shall close or release the fire assembly to the closed position in the event of a power failure. The maximum transmitted temperature end point for the vestibule entry doors shall not exceed 450°F (232°C) above ambient at the end of 30 minutes of the fire exposure specified in UBC Standard 7-2.

1005.3.3.7.1.4 Pressure differences. The minimum pressure differences within the vestibule with the doors closed shall be 0.05-inch water gage (12.44 Pa) positive pressure relative to the fire floor and 0.05-inch water gage (12.44 Pa) negative pressure relative to the exit enclosure. No pressure difference is required relative to a nonfire floor.

1005.3.3.7.1.5 Standpipes. Fire department standpipe connections and valves serving the floor shall be within the vestibule and located in such a manner so as not to obstruct egress where hose lines are connected and charged.

1005.3.4 Exit passageways.

1005.3.4.1 General. Exit passageways serving as an exit in a means of egress system shall comply with the requirements of Section 1005.3.4. Exit passageways shall not be used for any purpose other than as a means of egress.

1005.3.4.2 Width. The width of exit passageways shall be determined as specified in Section 1003.2.3, but such width shall not be less than 44 inches (1118 mm), except as specified herein. Exit passageways serving an occupant load of less than 50 shall not be less than 36 inches (914 mm) in width.

The required width of exit passageways shall be unobstructed.

> **EXCEPTION:** Doors, when fully opened, and handrails shall not reduce the required width by more than 7 inches (178 mm). Doors in any position shall not reduce the required width by more than one half. Other nonstructural projections such as trim and similar decorative features may project into the required width $1^1/_2$ inches (38 mm) on each side.

1005.3.4.3 Construction. Exit passageways less than 400 feet (121 920 mm) in length shall have walls, floors and ceilings of not less than one-hour fire-resistive construction. Exit passageways 400 feet (121 920 mm) or more in length shall have walls, floors and ceilings of not less than two-hour fire-resistive construction.

Exit passageways in buildings of Type I or II construction shall be of noncombustible construction except where combustible materials are permitted in applicable building elements by other provisions of this code. Exit passageways in buildings of Type III, IV or V construction may be of combustible or noncombustible construction.

1005.3.4.4 Openings and penetrations. Openings into exit passageways shall be limited to those necessary for egress from normally occupied spaces into the exit passageway and those necessary for egress from the exit passageway. Elevators shall not open into an exit passageway.

All interior exit doors in an exit passageway shall be protected by a fire assembly having a fire-protection rating of not less than one hour where one-hour exit passageway construction is permitted in Section 1005.3.4.3 and not less than one and one-half hours where two-hour exit passageway construction is required by Section 1005.3.4.3. Such doors shall be maintained self-closing or shall be automatic closing by actuation of a smoke detector as specified in Section 713.2. All hold-open devices shall be listed for the intended purpose and shall close or release the fire assembly to the closed position in the event of a power failure. The maximum transmitted temperature end point for such doors shall not exceed 450°F (232°C) above ambient at the end of 30 minutes of the fire exposure specified in UBC Standard 7-2.

Penetrations into or through an exit passageway are prohibited except for those serving the exit passageway such as sprinkler piping, standpipes and electrical conduit terminating in a listed box not exceeding 16 square inches (10 323 mm^2) in area.

1005.3.4.5 Intervening rooms. Exit passageways shall not be interrupted by intervening rooms.

> **EXCEPTION:** In office buildings, a maximum of 50 percent of the exits may discharge through a street-floor lobby provided the entire street floor is protected with an automatic sprinkler system.

1005.3.4.6 Dead ends. Where an exit passageway is used and more than one exit is required, exit doors shall be arranged so that it is possible to go in either direction from any point in the exit passageway to a separate exit door, except for dead ends not exceeding 20 feet (6096 mm) in length.

1005.3.5 Horizontal exits.

1005.3.5.1 General. Horizontal exits serving as an exit in a means of egress system shall comply with the requirements of Section 1005.3.5. A horizontal exit is a wall that completely divides a floor of a building into two or more separate exit-access areas to afford safety from fire and smoke in the exit-access area of incident origin.

It is permissible for a horizontal exit to serve as an exit for each adjacent exit-access area (e.g., a two-way exit), providing that the exit-access design requirements for each exit-access area are independently satisfied.

A horizontal exit shall not serve as the only exit from the exit access. Where two or more exits are required from the exit access, not more than one half of the total number of exits or total exit width may be provided by horizontal exits.

1005.3.5.2 Construction. The wall containing a horizontal exit shall be constructed as required for an occupancy separation having a fire-resistive rating of not less than two hours. The horizontal exit wall shall be continuous from exterior wall to exterior wall and shall extend from the floor to the underside of the floor or roof directly above so as to completely divide the floor that is served by the horizontal exit. Structural members supporting a horizontal exit shall be protected by equivalent fire-resistive construction.

Horizontal exits in buildings of Type I, II or III construction shall be of noncombustible construction. Horizontal exits in buildings of Type IV or V construction may be of combustible or noncombustible construction.

1005.3.5.3 Openings and penetrations. Openings in a horizontal exit shall be protected by a fire assembly having a fire-protection rating of not less than one and one-half hours. Such fire assemblies shall be maintained self-closing or shall be automatic closing by actuation of a smoke detector as specified in Section 713.2. All hold-open devices shall be listed for the intended purpose and shall close or release the fire assembly to the closed position in the event of a power failure. The maximum transmitted temperature end point for such doors shall not exceed 450°F (232°C) above ambient at the end of 30 minutes of the fire exposure specified in UBC Standard 7-2.

1005.3.5.4 Refuge area. The floor area of the exit access to which a horizontal exit leads shall be of sufficient size to accommodate 100 percent of the occupant load of the exit access from which refuge is sought, plus 100 percent of the normal occupant load of the exit access serving as the refuge area. The capacity of such refuge floor area shall be determined by allowing 3 square feet (0.28 m^2) of net clear floor area of aisles, hallways and corridors per occupant. The area of stairs, elevators and other shafts shall not be used. In Group I, Division 1.1 Occupancies, the capacity of the refuge area shall be determined by allowing 15 square feet (1.4 m^2) of net clear floor area per ambulatory occupant and 30 square feet (2.8 m^2) of net clear floor area per nonambulatory occupant.

The design of the exit access serving as the refuge area shall comply with the requirements of Section 1004.2 based on the normal occupant load served and need not consider the increased occupant load imposed by persons entering such refuge area through horizontal exits.

SECTION 1006 — THE EXIT DISCHARGE

1006.1 General. The exit discharge is that portion of the means of egress system between the exit and the public way. Components that may be selectively included in the exit discharge include exterior exit balconies, exterior exit stairways, exterior exit ramps and exit courts, in addition to those common means of egress components described in Section 1003.3.

> **EXCEPTION:** When approved by the building official, the exit discharge may lead to a safe dispersal area on the same property as the building being exited. The proximity and size of such safe dispersal area shall be based on such factors as the occupant load served, the mobility of occupants, the type of construction of the building, the fire-protection features of the building, the height of the building and the degree of hazard of the occupancy. In any case, such safe dispersal areas shall not be located less than 50 feet (15 240 mm) from the building served. (See Section 1007 for means of egress from safe dispersal areas.)

Grade level areas designated as an exit discharge component for a building shall be permanently maintained. Such areas shall not be developed or otherwise altered in their capacity to provide for a continuous, unobstructed and undiminished means of egress for building occupants. If such areas are sold independent of the building they serve, an exit discharge complying with the requirements of Section 1006 shall be provided for such building.

1006.2 Exit Discharge Design Requirements. The exit discharge portion of the means of egress system shall comply with the applicable design requirements of this section.

1006.2.1 Location. The exit discharge shall be at grade or shall provide direct access to grade. The exit discharge shall not reenter the exit access. Exterior exit balconies, exterior exit stairways and exterior exit ramps shall not be located in areas where building openings are prohibited or openings are required to be protected by Table 5-A.

1006.2.2 Access to grade. Where the exit from a building discharges at other than grade level, there shall not be less than two separate paths of exit travel to grade level. Such paths of exit travel shall be arranged so that there are no dead ends more than 20 feet (6096 mm) in length.

> **EXCEPTIONS:** 1. Where the occupant load served by such exit is less than 10, only one path of exit travel to grade level need be provided.
>
> 2. Where exits discharge to an exterior exit stairway, such stairway may serve as a single path of exit travel directly to grade.

1006.2.3 Travel distance. Travel distance in the exit discharge at grade level shall not be limited.

Travel distance in the exit discharge at other than grade level shall not exceed the following:

1. In buildings not equipped with an automatic sprinkler system throughout, the travel distance to grade shall not exceed 200 feet (60 960 mm).

2. In buildings equipped with an automatic sprinkler system throughout, the travel distance to grade shall not exceed 250 feet (76 200 mm).

Where the path of exit travel includes unenclosed stairways or ramps within the exit discharge, the distance of travel on such means of egress components shall also be included in the travel distance measurement. The measurement along stairways shall be made on a plane parallel and tangent to the stair tread nosings in the center of the stairway.

1006.3 Exit Discharge Components.

1006.3.1 General. Exit discharge components incorporated into the design of the exit discharge portion of the means of egress system shall comply with the requirements of Section 1006.3. In all cases, components of the exit discharge shall be sufficiently open to the exterior to prevent the accumulation of smoke and toxic gases.

1006.3.2 Exterior exit balconies.

1006.3.2.1 General. Exterior exit balconies serving as a portion of the exit discharge in the means of egress system shall comply with the requirements of Section 1006.3.2. An exterior exit balcony is a balcony, landing or porch projecting from the wall of a building and serves as an exit discharge component in a means of egress system.

1006.3.2.2 Width. The width of exterior exit balconies shall be determined as specified in Section 1003.2.3, but such width shall not be less than 44 inches (1118 mm), except as specified herein. Exterior exit balconies serving an occupant load of less than 50 shall not be less than 36 inches (914 mm) in width.

The required width of exterior exit balconies shall be unobstructed.

> **EXCEPTION:** Doors, when fully opened, and handrails shall not reduce the required width by more than 7 inches (178 mm). Doors in any position shall not reduce the required width by more than one half. Other nonstructural projections such as trim and similar decorative features may project into the required width $1^1/_2$ inches (38 mm) from each side.

1006.3.2.3 Construction. Exterior exit balconies projecting from the walls of buildings of Type I or II construction shall be of noncombustible construction. Exterior exit balconies projecting from the walls of buildings of Type III, IV or V construction may be of combustible or noncombustible construction.

Walls of exterior exit balconies serving a Group R, Division 1 or Group I Occupancy having an occupant load of 10 or more shall not be less than one-hour fire-resistive construction and ceilings shall not be less than that required for a one-hour fire-resistive floor or roof system.

> **EXCEPTIONS:** 1. Exterior sides of exterior exit balconies.
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> 2. In other than Type I or II construction, exterior exit balcony roof assemblies may be of heavy-timber construction without concealed spaces.

1006.3.2.4 Openness. The long side of an exterior exit balcony shall be at least 50 percent open, and the open area above the guardrail shall be distributed to prevent the accumulation of smoke or toxic gases.

1006.3.3 Exterior exit stairways.

1006.3.3.1 General. Exterior exit stairways serving as a portion of the exit discharge in the means of egress system shall comply with the requirements of Section 1006.3.3. An exterior exit stairway serves as an exit discharge component in a means of egress system and is open on not less than two adjacent sides, except for required structural columns and open-type handrails and guardrails. The adjoining open areas shall be either yards, exit courts or public ways; the remaining sides may be enclosed by the exterior walls of the building. Any stairway not meeting the definition of an exterior stairway shall comply with the requirements for interior stairways.

1006.3.3.2 Construction. Exterior exit stairways shall be constructed based on type of construction requirements as specified in Sections 602.4, 603.4, 604.4, 605.4 and 606.4.

There shall be no enclosed usable space under exterior exit stairways. The open space under such stairways shall not be used for any purpose.

1006.3.3.3 Protection of exterior wall openings. All openings in the exterior wall below and within 10 feet (3048 mm), measured horizontally, of an exterior exit stairway serving a building over two stories in height or a floor level having such openings in two or more floors below shall be protected by fixed or self-closing fire assemblies having a three-fourths-hour fire-protection rating.

EXCEPTIONS: 1. Group R, Division 3 Occupancies.

2. Openings may be unprotected where two separated exterior stairways are served by a common exterior exit balcony.

3. Protection of openings is not required for open parking garages conforming to Section 311.9.

1006.3.3.4 Detailed requirements. Except for construction and opening protection as specified in Sections 1006.3.3.2 and 1006.3.3.3, exterior exit stairways shall comply with the applicable requirements for stairways as specified in Section 1003.3.3.

1006.3.4 Exterior exit ramps.

1006.3.4.1 General. Exterior exit ramps serving as a portion of the exit discharge in the means of egress system shall comply with the requirements of Section 1006.3.4. An exterior exit ramp serves as an exit discharge component in a means of egress system and is open on not less than two adjacent sides, except for required structural columns and open-type handrails and guardrails. The adjoining open areas shall be either yards, exit courts or public way; the remaining sides may be enclosed by the exterior walls of the building. Any ramp not meeting the definition of an exterior ramp shall comply with the requirements for interior ramps.

1006.3.4.2 Construction. Exterior exit ramps shall be constructed based on type of construction requirements as specified in Sections 602.4, 603.4, 604.4, 605.4 and 606.4.

There shall be no enclosed usable space under exterior exit ramps. The open space under such ramps shall not be used for any purpose.

1006.3.4.3 Protection of exterior wall openings. All openings in the exterior wall below and within 10 feet (3048 mm), measured horizontally, of an exterior exit ramp serving a building over two stories in height or a floor level having such openings in two or more floors below shall be protected by fixed or self-closing fire assemblies having a three-fourths-hour fire-protection rating.

EXCEPTIONS: 1. Group R, Division 3 Occupancies.

2. Openings may be unprotected where two separated exterior ramps are served by a common exterior exit balcony.

3. Protection of openings is not required for open parking garages conforming to Section 405.

1006.3.4.4 Detailed requirements. Except for construction and opening protection as specified in Sections 1006.3.4.2 and 1006.3.4.3, exterior exit ramps shall comply with the applicable requirements for ramps as specified in Section 1003.3.4.

1006.3.5 Exit courts.

1006.3.5.1 General. Exit courts serving as a portion of the exit discharge in the means of egress system shall comply with the requirements of Section 1006.3.5. An exit court is a court or yard that provides access to a public way for one or more required exits.

1006.3.5.2 Width. The width of exit courts shall be determined as specified in Section 1003.2.3, but such width shall not be less than 44 inches (1118 mm), except as specified herein. Exit courts serving Group R, Division 3 and Group U Occupancies shall not be less than 36 inches (914 mm) in width.

The required width of exit courts shall be unobstructed to a height of 7 feet (2134 mm).

EXCEPTION: Doors, when fully opened, and handrails shall not reduce the required width by more than 7 inches (178 mm). Doors in any position shall not reduce the required width by more than one half. Other nonstructural projections such as trim and similar decorative features may project into the required width $1^1/_2$ inches (38 mm) from each side.

Where an exit court exceeds the minimum required width and the width of such exit court is then reduced along the path of exit travel, the reduction in width shall be gradual. The transition in width shall be affected by a guardrail not less than 36 inches (914 mm) in height and shall not create an angle of more than 30 degrees with respect to the axis of the exit court along the path of exit travel. In no case shall the width of the exit court be less than the required minimum.

1006.3.5.3 Construction and openings. Where an exit court serving a building or portion thereof having an occupant load of 10 or more is less than 10 feet (3048 mm) in width, the exit court walls shall not be less than one-hour fire-resistive construction for a distance of 10 feet (3048 mm) above the floor of the court, and all openings therein shall be protected by fixed or self-closing fire assemblies having a three-fourths-hour fire-protection rating.

SECTION 1007 — MEANS OF EGRESS REQUIREMENTS BASED ON OCCUPANCY

1007.1 General. In addition to the general means of egress requirements specified elsewhere in this chapter, the detailed requirements of this section shall apply to those occupancies described herein.

1007.2 Group A Occupancies.

1007.2.1 Main exit. Group A, Division 1, 2 and 2.1 Occupancies shall be provided with a main exit. The main exit shall be of sufficient width to accommodate not less than one half of the total occupant load, but such width shall not be less than the total required width of all means of egress components leading thereto.

1007.2.2 Side exits. Auditoriums, theaters and similar assembly rooms of Group A, Division 1, 2 or 2.1 Occupancies shall be provided with exits on each side. The exits on each side of such assembly rooms shall be of sufficient width to accommodate not less than one third of the total occupant load served. Side exits shall open directly to a public way or into an exit or exit discharge leading to a public way. Side exits shall be accessible from a cross aisle.

1007.2.3 Balcony exits. Balconies, mezzanines and similar areas having an occupant load of 10 or more shall be provided with access to a minimum of two exits. Balconies shall directly access an exterior stairway or other approved stairway or ramp. Where there is more than one level of balconies, balconies shall directly access an exit enclosure or an exterior stairway or ramp. Balcony exits or exit access shall be accessible from a cross aisle. The number and distribution of exits and exit access shall be as specified elsewhere in this chapter.

1007.2.4 Multitheater complex. The main exit from a multitheater complex shall be of sufficient width to accommodate one half of the total occupant load of such complex.

1007.2.5 Panic hardware. Exit and exit-access doors serving Group A Occupancies shall not be provided with a latch or lock unless it is panic hardware.

> **EXCEPTIONS:** 1. In Group A, Division 3 Occupancies and in all churches, panic hardware may be omitted from the main exit where the main exit consists of a single door or pair of doors. A key-locking device may be used in place of the panic hardware, provided there is a readily visible durable sign adjacent to the doorway stating, "THIS DOOR MUST REMAIN UNLOCKED DURING BUSINESS HOURS." The sign shall be in letters not less than 1 inch (25 mm) high on a contrasting background. When unlocked, the single door or both leaves of a pair of doors must be free to swing without operation of any latching device. Manually operated edge- or surface-mounted flush bolts and surface bolts or any other type of device that may be used to close or restrain the door other than by operation of the locking device shall not be used. The use of this exception may be revoked by the building official for due cause.
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> 2. Panic hardware may be waived on gates surrounding stadiums where such gates are under constant immediate supervision while the public is present, and further provided that safe dispersal areas based on 3 square feet (0.28 m^2) per occupant are located between the stadium and the fence. Such required safe dispersal areas shall not be located less than 50 feet (15 240 mm) from the stadium. Gates may be of the horizontal sliding or swinging type and may exceed the 4-foot (1219 mm) maximum leaf width limitation.

1007.2.6 Posting of room capacity. Any room that is used for an assembly purpose where fixed seats are not installed shall have the capacity of the room posted in a conspicuous place on an approved sign near the main exit or exit-access doorway from the room. Such signs shall indicate the number of occupants permitted for each room use.

1007.2.7 Amusement building exit marking. Approved exit signs and directional exit marking that complies with the provisions of Section 1003.2.8 shall be provided in amusement buildings.

Additional approved low-level exit signs that are internally or externally illuminated, photoluminescent or self-luminous shall be provided. The bottom of such sign shall not be less than 6 inches (152 mm) nor more than 8 inches (203 mm) above the walking surface and shall indicate the path of exit travel. For exit and exit-access doors, the sign shall be on the door or adjacent to the door with the closest edge of the sign within 4 inches (102 mm) of the door frame.

1007.3 Group E Occupancies.

1007.3.1 Definitions. For the purpose of Section 1007.3, certain terms are defined as follows:

INTERIOR ROOM is a room whose only exit access is through an adjoining or intervening room and not a corridor.

ROOM is a space or area enclosed on more than 80 percent of the perimeter of such space or area. When determining the enclosed area, openings less than 3 feet (914 mm) in clear width and less than 6 feet 8 inches (2032 mm) high need not be considered.

SEPARATE MEANS OF EGRESS SYSTEM is not less than two paths of exit travel, which are separated in such a manner to provide an atmospheric separation that precludes contamination of both paths of exit travel by the same fire.

1007.3.2 Separate means of egress systems required. Every room with an occupant load of 300 or more shall have one of its exits or exit-access doorways lead directly into a separate means of egress system. Not more than two required exits or exit-access doorways shall enter into the same means of egress system.

1007.3.3 Travel distance.

1007.3.3.1 In rooms. The travel distance from any point in a room shall not exceed 75 feet (22 860 mm) to a corridor or an exit.

> **EXCEPTIONS:** 1. In buildings not more than two stories in height and protected throughout by smoke detectors, the travel distance may be increased to 90 feet (27 432 mm).
>
> 2. In buildings equipped with an automatic sprinkler system throughout, the travel distance may be increased to 110 feet (33 528 mm).

1007.3.3.2 From any location. In buildings not equipped with an automatic sprinkler system throughout, the travel distance shall not exceed 150 feet (45 720 mm).

> **EXCEPTIONS:** 1. In buildings not more than two stories in height and protected throughout by smoke detectors, the travel distance may be increased to 175 feet (53 340 mm).
>
> 2. In buildings equipped with an automatic sprinkler system throughout, the travel distance may be increased to 225 feet (68 580 mm).

The travel distances specified above may be increased up to an additional 100 feet (30 480 mm), provided that the last portion of travel leading to the exit occurs within a corridor. The length of such corridor shall not be less than the amount of the increase taken.

1007.3.4 Travel through intervening rooms. The path of exit travel shall not pass through laboratories using hazardous materials, industrial shops or other similar places.

Where only one exit access is required from an interior room and the path of exit travel is through an adjoining or intervening room, smoke detectors shall be installed throughout the common atmosphere of the exit access through which the path of exit travel passes. Such smoke detectors shall actuate alarms audible in the interior room and shall be connected to the school fire alarm system.

> **EXCEPTIONS:** 1. Where the aggregate occupant load of the interior room or rooms is 10 or less.
>
> 2. Where the enclosures forming interior rooms are less than two thirds of the floor-to-ceiling height and do not exceed 8 feet (2438 mm).
>
> 3. Rooms used exclusively for mechanical or public utility service to the buildings.

1007.3.5 Hallways, corridors and exterior exit balconies. The width of hallways and corridors in a Group E, Division 1 Occupancy shall be determined as specified in Section 1003.2.3, plus 2 feet (610 mm), but shall not be less than 6 feet (1829 mm).

> **EXCEPTION:** Where the total number of occupants served is less than 100, such hallway or corridor may be 44 inches (1118 mm) wide.

Any change in elevation of less than 2 feet (610 mm) in a hallway, corridor or exterior exit balcony shall be by means of a ramp.

1007.3.6 Stairways. The width of stairways shall be determined as specified in Section 1003.2.3, but stairways serving an occupant load of 100 or more shall not be less than 5 feet (1524 mm) in width.

1007.3.7 Exits serving auditoriums in Group E, Division 1 Occupancies. In determining the means of egress design requirements, an auditorium may be considered an accessory use area in accordance with the provisions of Section 1003.2.2.2.1 if the auditorium is not to be used simultaneously with other rooms.

1007.3.8 Laboratories. Laboratories having a floor area of 200 square feet (18.6 m^2) or more shall have access to not less than two separate exits or exit-access doorways. All portions of such laboratories shall be within 75 feet (22 860 mm) of an exit or exit-access door.

1007.3.9 Basement rooms. Exit stairways from a basement shall open directly to the exterior of the building without entering the first floor.

1007.3.10 Panic hardware. Exit and exit-access doors from rooms having an occupant load of 50 or more and from corridors shall not be provided with a latch or lock unless it is panic hardware.

1007.3.11 Fences and gates. School grounds may be fenced and gates therein may be equipped with locks, provided that safe dispersal areas based on 3 square feet (0.28 m^2) per occupant are located between the school and the fence. Such required safe dispersal areas shall not be located less than 50 feet (15 240 mm) from school buildings.

1007.4 Group H Occupancies.

1007.4.1 Access to exits. Every portion of a Group H Occupancy having a floor area of 200 square feet (18.6 m^2) or more shall have access to not less than two separate exits or exit-access doors.

> **EXCEPTION:** Group H, Division 4 Occupancies having a floor area of less than 1,000 square feet (92.9 m^2) may have one exit or exit-access door.

1007.4.2 Travel distance. The maximum travel distance shall be as specified in Section 1004.2.5 with the applicable additional limitations of Section 1007.4.2.1. The travel distance in Section 1004.2.5 is permitted to be increased as specified in Section 1004.2.5.2.3.

1007.4.2.1 Travel within rooms. Within Group H, Division 1, 2 and 3 Occupancies, all portions of any room shall be within 75 feet (22 850 mm) of an exit or exit access door from the room.

Within Group H, Division 7 and within fabrication areas of Group H, Division 6 Occupancies, the distance of travel to an exit corridor or to an exit shall not exceed 100 feet (30 480 mm).

1007.4.3 Corridor doors. Corridor doors shall be protected by a fire assembly having a fire-protection rating of not less than three-fourths-hour, shall not have more than 100 square inches (64 516 mm^2) of wired glass set in steel frames and shall be maintained self-closing or shall be automatic closing as specified in Section 713.2.

1007.4.4 Door swing. All exit and exit-access doors serving hazardous occupancies shall swing in the exit travel, regardless of the occupant load served.

1007.4.5 Panic hardware. Exit and exit-access doors from rooms in Group H, Divisions 1, 2, 3, 6 and 7 Occupancies shall not be provided with a latch or lock unless it is panic hardware.

1007.4.6 Incinerator rooms. Interior openings between a Group H Occupancy and an incinerator room are prohibited.

1007.5 Group I Occupancies.

1007.5.1 Minimum size of means of egress. The clear width of means of egress components in areas serving bed or litter patients shall be such to allow ready passage of beds, gurneys and similar equipment, but shall not be less than 44 inches (1118 mm). Other aisles shall have a clear width of not less than 32 inches (813 mm).

1007.5.2 Travel distance. All portions of Group I, Division 1.1 or 3 Occupancies shall be within 200 feet (60 960 mm) of an exit.

1007.5.3 Hallways. Hallways in Group I Occupancies that serve an occupant load of 10 or more shall comply with the requirements of Sections 1004.3.4 and 1007.5.4 for corridors.

1007.5.4 Corridors. Corridors serving any area caring for one or more nonambulatory persons shall not be less than 8 feet (2438 mm) in width.

> **EXCEPTION:** Corridors serving surgical areas of Group I, Division 1.2 Occupancies shall not be less than 6 feet (1829 mm) in width.

Any change in elevation in a corridor serving nonambulatory persons shall be by means of a ramp.

Corridors shall comply with the requirements of Section 1004.3.4, except that in hospitals and nursing homes classified as Group I, Division 1.1 Occupancies, the following exceptions apply:

1. Nurses' stations, including space for doctors' and nurses' charting and communications, constructed as required for corridors need not be separated from corridors.

2. Waiting areas and similar spaces constructed as required for corridors need not be separated from corridors, provided:

- 2.1 Where the aggregate of waiting areas in each smoke compartment does not exceed 600 square feet (55.7 m^2).
  - 2.1.1 Each area is located to permit direct visual supervision by the facility staff;
  - 2.1.2 Each area is equipped with an electrically supervised automatic smoke-detection system; and
  - 2.1.3 Each area is arranged not to obstruct access to required exits.
- 2.2 Where such spaces may be unlimited in size and open to the corridor.
  - 2.2.1 The spaces are not used for patient sleeping rooms, treatment rooms, hazardous areas or special use areas listed in Table 3-C;
  - 2.2.2 Each space is located to permit direct visual supervision by the facility staff;
  - 2.2.3 The space and corridors that the space open onto in the same smoke compartment are protected by an electrically supervised automatic smoke-detection system; and
  - 2.2.4 The space is arranged not to obstruct access to required exits.

3. In fully sprinklered buildings, door closers need not be installed on doors to sleeping or treatment rooms.

4. Fixed fully tempered or laminated glass in wood or metal frames may be used in corridor walls, provided the glazed area does not exceed 25 percent of the area of the corridor wall of the room.

5. The total area of glass in corridor walls is not limited when the glazing is fixed $^1/_4$-inch-thick (6.4 mm) wired glass in steel frames and the size of individual glazed panel does not exceed 1,296 square inches (0.836 m^2).

6. Corridor doors other than those required to be rated by Section 308.8 or for the enclosing of a vertical opening or an exit are not required to be fire-rated, provided the doors are tightfitting, smoke- and draft-control assemblies and are provided with positive latches. Roller latches are prohibited.

1007.5.5 Exterior exit doors. All required exterior exit doors shall open in the direction of exit travel regardless of the occupant load served.

1007.5.6 Basement exits. All rooms below grade shall have not less than one exit that leads directly to the exterior at grade level.

1007.5.7 Ramps. Where the first story of Group I, Divisions 1.1 and 1.2 Occupancies is at other than grade level, such occupancies housing nonambulatory patients shall have a ramp leading from the first story to the exterior of the building at grade level.

1007.5.8 Hardware. Exit and exit-access doors serving an area having an occupant load of 50 or more shall not be provided with a latch or lock unless it is panic hardware. Patient room doors shall be readily openable from either side without the use of keys.

> **EXCEPTIONS:** 1. In Group I, Division 1.1 hospitals and nursing homes, locking devices, when approved, may be installed on patient sleeping rooms, provided such devices are readily openable from the patient room side and are readily operable by the facility staff on the other side. Where key locks are used on patient room doors, keys shall be located on the floor involved at a prominent location accessible to the staff.
>
> 2. In Group I, Division 3 Occupancies, approved locks or safety devices may be used where it is necessary to forcibly restrain the personal liberties of inmates or patients.

1007.5.9 Suites.

1007.5.9.1 General. A group of rooms in a Group I, Division 1.1, Division 1.2 or Division 2 Occupancy may be considered a suite when it complies with the following:

1. **Size.** Suites or rooms, other than suites containing patient sleeping rooms, shall not exceed 10,000 square feet (929 m^2) in area. Suites containing patient sleeping rooms shall not exceed 5,000 square feet (464.5 m^2) in area.

2. **Occupancy separation.** Each suite of rooms shall be separated from the remainder of the building by not less than a one-hour fire-resistive occupancy separation.

3. **Visual supervision.** Each patient sleeping room in the suite shall be located to permit direct and constant visual supervision by the facility staff.

4. **Other exits.** Exiting for portions of the building outside a suite shall not require passage through the suite.

1007.5.9.2 Corridors. One-hour fire-resistive corridor construction is not required within a suite.

1007.5.9.3 Travel through adjoining rooms. Rooms within suites may have access to exits through one adjoining room if there is not more than 100 feet (30 480 mm) of travel distance within the suite to an exit or to a corridor that provides direct access to an exit. Rooms other than patient sleeping rooms may access exits through two adjoining rooms where there is not more than 50 feet (15 240 mm) of travel distance within the suite to an exit or to a corridor that provides direct access to an exit.

Other portions of the exit access shall not pass through suites.

1007.6 Group R Occupancies.

1007.6.1 Hallways. Hallways in Group R, Division 1 Occupancies which serve an occupant load of 10 or more shall comply with the requirements of Section 1004.3.4 for corridors.

1007.6.2 Floor-level exit signs. Where exit signs are required by Section 1003.2.8.2, additional approved low-level exit signs that are internally or externally illuminated, photoluminescent or self-luminous, shall be provided in all corridors serving guest rooms of hotels in Group R, Division 1 Occupancies.

The bottom of such sign shall not be less than 6 inches (152 mm) nor more than 8 inches (203 mm) above the floor level and shall indicate the path of exit travel. For exit and exit-access doors, the sign shall be on the door or adjacent to the door with the closest edge of the sign within 4 inches (102 mm) of the door frame.

1007.7 Special Hazards.

1007.7.1 Rooms containing fuel-fired equipment. All rooms containing a boiler, furnace, incinerator or other fuel-fired equipment shall be provided with access to two exits or exit-access doors when both of the following conditions exist:

1. The area of the room exceeds 500 square feet (46.45 m^2), and

2. The largest piece of fuel-fired equipment exceeds 400,000 Btu per hour (117 228 W) input capacity.

> **EXCEPTIONS:** 1. In Group R, Division 3 Occupancies.
>
> 2. If access to two exits or exit-access doors are required, one such access may be by a fixed ladder.

1007.7.2 Refrigeration machinery rooms.

1007.7.2.1 Access to exits. Machinery rooms larger than 1,000 square feet (92.9 m^2) shall have access to not less than two exits as required in Section 1007.7.1.

1007.7.2.2 Travel distance. Travel distance shall be determined as specified in Section 1004.2.5, but all portions of machinery rooms shall be within 150 feet (45 720 mm) of an exit or exit-access doorway. Travel distance may be increased in accordance with Section 1004.2.5.

1007.7.2.3 Doors. Doors shall swing in the direction of exit travel, regardless of the occupant load served. Doors shall be tight-fitting and self-closing.

1007.7.3 Refrigerated rooms or spaces.

1007.7.3.1 Access to exits. Rooms or spaces having a floor area of 1,000 square feet (92.9 m^2) or more, containing a refrigerant evaporator and maintained at a temperature below 68°F (20°C), shall have access to not less than two exits or exit-access doors.

1007.7.3.2 Travel distance. Travel distance shall be determined as specified in Section 1004.2.5, but all portions of the refrigerated room or space shall be within 150 feet (45 720 mm) of an exit or exit-access door where such rooms are not protected by an approved automatic sprinkler system. Travel distance may be increased in accordance with Section 1004.2.5. Egress is allowed through adjoining refrigerated rooms or spaces.

> **EXCEPTION:** Where using refrigerants in quantities limited to the amounts based on the volume set forth in the Mechanical Code.

1007.7.4 Cellulose nitrate film handling. Where cellulose nitrate film is handled in film laboratories, projection rooms and film processing rooms, access to not less than two exits or exit-access doors shall be provided. Doors to such rooms shall be protected by a fire assembly having a fire-protection rating of not less than one hour and shall be maintained self-closing.

SECTION 1008 — REVIEWING STANDS, GRANDSTANDS, BLEACHERS, AND FOLDING AND TELESCOPING SEATING

1008.1 Scope. The requirements of Section 1008 shall apply to reviewing stands, grandstands, bleachers, and folding and telescoping seating.

1008.2 Definitions. For the purpose of Section 1008, certain terms are defined as follows:

BLEACHERS are tiered or stepped seating facilities without backrests.

FOLDING AND TELESCOPING SEATING is a structure that is used for tiered seating of persons, and having an overall shape and size that may be reduced without being dismantled, for purposes of moving or storing.

FOOTBOARDS are that part of a raised seating facility other than an aisle or cross aisle upon which the occupant walks to reach a seat.

GRANDSTANDS are tiered or stepped seating facilities.

PERMANENT STANDS are those seating facilities that remain at a location for more than 90 days.

REVIEWING STANDS are elevated platforms accommodating not more than 50 persons. Seating facilities, if provided, are normally in the nature of loose chairs. Reviewing stands accommodating more than 50 persons shall be regulated as grandstands.

SAFE DISPERSAL AREA is an area that will accommodate a number of persons equal to the total capacity of the stand and building that it serves, such that a person within the area will not be closer than 50 feet (15 240 mm) from the stand or building. Safe dispersal area capacity shall be determined by allowing 3 square feet (0.28 m^2) of net clear area per person.

TEMPORARY SEATING FACILITIES are those that are intended for use at a location for not more than 90 days.

1008.3 Height of Reviewing Stands, Grandstands, Bleachers, and Folding and Telescoping Seating. See Section 303.2.

1008.4 Design Requirements. See Chapter 16 and Section 1806.10.

1008.5 General Requirements.

1008.5.1 Row spacing. There shall be a clear space of not less than 12 inches (305 mm) measured horizontally between the back or backrest of each seat and the front of the seat immediately behind it. The minimum spacing of rows of seats measured from back to back shall be:

1. Twenty-two inches (559 mm) for seats without backrests.
2. Thirty inches (762 mm) for seats with backrests.
3. Thirty-three inches (838 mm) for chair seating.

1008.5.2 Rise between rows. The maximum rise from one row of seats to the next shall not exceed 16 inches (406 mm) unless the seat spacing from back to back measured horizontally is 40 inches (1016 mm) or more.

> **EXCEPTION:** Where automatic- or self-rising seats are installed, the rise between rows may be increased to 24 inches (610 mm) with the horizontal spacing back to back of 33 inches (838 mm).

1008.5.3 Seating capacity determination. Where bench-type seating is used, the number of seats shall be based on one person for each 18 inches (457 mm) of length of the bench.

1008.5.4 Aisles.

1008.5.4.1 Aisles required. Aisles shall be provided in all seating facilities, except that aisles may be omitted when all the following conditions exist:

1. Seats are without backrests.
2. The rise from row to row does not exceed 6 inches (152 mm) per row.
3. The row spacing does not exceed 28 inches (711 mm) unless the seat boards and footboards are at the same elevation.
4. The number of rows does not exceed 16 in height.
5. The first seating board is not more than 12 inches (305 mm) above grade or floor below or a cross aisle.
6. Seat boards are continuous flat surfaces.
7. Seat boards provide a walking surface with a minimum width of 11 inches (279 mm).

1008.5.4.2 Obstructions. No obstruction shall be placed in the required width of any aisle or other means of egress component.

1008.5.4.3 Width. Aisles serving seats on both sides shall have a minimum width of 44 inches (1118 mm). Where serving seats on only one side, the aisle shall have a minimum width of 36 inches (914 mm). Except for temporary seating facilities, the required width for aisles shall equal the greater of the minimum required widths determined in accordance with Section 1004.3.2.3 and this section.

1008.5.5 Cross aisles and vomitories. Cross aisles and vomitories shall not be less than 54 inches (1372 mm) in clear width and shall extend to an exit or an exterior perimeter ramp. Except for temporary seating facilities, the required width for cross aisles shall equal the greatest of the minimum required widths determined as specified in Section 1004.3.2 and this section.

1008.5.6 Stairways and ramps. Except as otherwise provided in this section, grandstands, bleachers, and folding and telescoping seating shall comply with other applicable sections of this chapter. Stairways and ramps shall have a maximum rise and run as provided in Sections 1003.3.3.3 and 1003.3.4, except those within the seating facility that serve as aisles at right angles to the rows of seats where the rise shall not exceed 8 inches (203 mm). Where an aisle terminates at an elevation more than 8 inches (203 mm) above grade or floor below, the aisle shall be provided with a stairway or ramp with a width not less than the width of the aisle.

Stairways and ramps shall have handrails as provided in Sections 1003.3.3.6 and 1003.3.4.5, except stairways within the seating facility that serve as aisles at right angles where handrails shall be provided at one side or along the center line. A minimum clear width of 48 inches (1219 mm) between seats shall be provided for aisle stairways having center-aisle handrails. Where there is seating on both sides of the aisle, handrails shall be discontinuous with openings at intervals not exceeding five rows for access to seating. The opening shall have a clear width of at least 22 inches (559 mm) and not more than 36 inches (914 mm) measured horizontally, and the handrail shall have rounded terminations. Where handrails are provided in the middle of the aisle stairs, there shall be an additional intermediate rail located approximately 12 inches (305 mm) below the top of the handrail.

> **EXCEPTION:** Temporary seating facility stairways within the seating area that serve as aisles at right angles need not be provided with handrails.

1008.5.7 Guardrails. Perimeter guardrails, enclosing walls or fencing shall be provided for all portions of elevated seating facilities that are more than 30 inches (762 mm) above grade or the floor. Construction of guardrails shall comply with the requirements of Section 509 and Table 16-B. Guardrails shall be 42 inches (1067 mm) in height measured vertically above the leading edge of the tread adjacent walking surface, adjacent walking surface or adjacent seatboards.

> **EXCEPTION:** Guardrails at the front of the front row of seats, which are not located at the end of an aisle and where there is no cross aisle, may have a height of 26 inches (660 mm) and need not meet the 4-inch-maximum (102 mm) spacing specified in Section 509; however, a midrail shall be installed.

The open vertical space between footboards and seats shall not exceed 9 inches (229 mm) when footboards are more than 30 inches (762 mm) above grade.

1008.5.8 Toeboards. A 4-inch-high (102 mm), vertical barrier shall be installed along the edge of walking platforms whenever guardrails are required.

> **EXCEPTION:** Toeboards shall not be required at the ends of footboards.

1008.5.9 Footboards. Footboards shall be provided for all rows of seats above the third row or beginning at such a point where the seat is more than 2 feet (610 mm) above the grade or floor below. Where the same platform is used for both seating and footrests, footboards are not required, provided each level or platform is not less than 24 inches (610 mm) wide. When projected on a horizontal plane, there shall not be horizontal gaps exceeding $^1/_4$ inch (6.4 mm) between footboards and seatboards. At aisles, there shall not be horizontal gaps exceeding $^1/_4$ inch (6.4 mm) between footboards.

1008.6 Grandstands, Bleachers, and Folding and Telescoping Seating within Buildings. Except as otherwise provided in this section and Section 1008.7, grandstands, bleachers, and folding and telescoping seating within a building shall comply with the other applicable sections of this chapter.

EXCEPTIONS: 1. Where seats are without backrests, there may be nine seats between any seat and an aisle.

2. Where seats are without backrests, dead ends in vertical aisles shall not exceed a depth of 16 rows.

1008.7 Smoke-protected Assembly Seating.

1008.7.1 General. To be considered smoke protected, an assembly seating facility shall comply with the following requirements.

1008.7.2 Roof height. A smoke-protected assembly seating area with a roof shall have the lowest portion of the roof not less than 15 feet (4572 mm) above the level of the highest aisle or aisle accessway.

1008.7.3 Smoke control. All means of egress serving a smoke-protected assembly seating area shall be provided with completely automatic smoke control complying with Section 905.

EXCEPTION: Automatic smoke control is not required when a natural venting system design can be demonstrated to accomplish equivalent results.

1008.7.4 Travel distance. In a smoke-protected assembly seating area, the travel distance from each seat to the nearest entrance to an egress concourse shall not exceed 200 feet (60 960 mm). The travel distance from the entrance to vomitory portal or egress concourse to an approved egress stair, ramp or walk at the building exterior shall not exceed 200 feet (60 960 mm).

In outdoor assembly seating facilities where all portions of the means of egress are open to the outside, the distance of travel to an approved egress stair, ramp or walk at the building exterior shall not exceed 400 feet (121 920 mm). In outdoor assembly seating facilities of Type I or II construction where all portions of the means of egress are essentially open to the outside, the distance shall not be limited.

SECTION 1009 — BUILDING SECURITY

See Appendix Chapter 10 for requirements covering building security.

TABLE 10-A—MINIMUM EGRESS REQUIREMENTS[1]

USE[2]	MINIMUM OF TWO MEANS OF EGRESS ARE REQUIRED WHERE NUMBER OF OCCUPANTS IS AT LEAST	OCCUPANT LOAD FACTOR[3] (square feet) × 0.0929 for m^2
1. Aircraft hangars (no repair)	10	500
2. Auction rooms	30	7
3. Assembly areas, concentrated use (without fixed seats) Auditoriums, Churches and chapels, Dance floors, Lobby accessory to assembly occupancy, Lodge rooms, Reviewing stands, Stadiums	50	7
Waiting area	50	3
4. Assembly areas, less-concentrated use Conference rooms, Dining rooms, Drinking establishments, Exhibit rooms, Gymnasiums, Lounges, Stages	50	15
Gaming: keno, slot machine and live games area	50	11
5. Bowling alley (assume no occupant load for bowling lanes)	50	4
6. Children's homes and homes for the aged	6	80
7. Classrooms	50	20
8. Congregate residences	10	200
9. Courtrooms	50	40
10. Dormitories	10	50
11. Dwellings	10	300
12. Exercising rooms	50	50
13. Garage, parking	30	200
14. Health care facilities— Sleeping rooms	8	120
Treatment rooms	10	240
15. Hotels and apartments	10	200
16. Kitchen—commercial	30	200
17. Library— Reading rooms	50	50
Stack areas	30	100
18. Locker rooms	30	50
19. Malls (see Chapter 4)	—	—
20. Manufacturing areas	30	200
21. Mechanical equipment room	30	300
22. Nurseries for children (day care)	7	35
23. Offices	30	100
24. School shops and vocational rooms	50	50
25. Skating rinks	50	50 on the skating area; 15 on the deck
26. Storage and stock rooms	30	300
27. Stores—retail sales rooms Basements and ground floor	50	30
Upper floors	50	60
28. Swimming pools	50	50 for the pool area; 15 on the deck
29. Warehouses[5]	30	500
30. All others	50	100

[1]Access to, and egress from, buildings for persons with disabilities shall be provided as specified in Chapter 11.

[2]For additional provisions on number of exits from Groups H and I Occupancies and from rooms containing fuel-fired equipment or cellulose nitrate, see Sections 1007.4, 1007.5 and 1007.7, respectively.

[3]This table shall not be used to determine working space requirements per person.

[4]Occupant load based on five persons for each alley, including 15 feet (4572 mm) of runway.

[5]Occupant load for warehouses containing approved high rack storage systems designed for mechanical handling may be based on the floor area exclusive of the rack area rather than the gross floor area.

TABLE 10-B—EGRESS WIDTH PER PERSON SERVED

USE	STAIRWAYS (inches per person)	OTHER EGRESS COMPONENTS (inches per person)
		(× 25.4 for mm/person)
Hazardous: H-1, H-2, H-3 and H-7	0.7	0.4
Institutional: I-1	0.3	0.2
Institutional: I-2	0.4	0.2
All other uses	0.3	0.2

TABLE 10-C—CALCULATION FOR MINIMUM WIDTH IN BUILDINGS WITHOUT SMOKE-PROTECTED ASSEMBLY SEATING[1]

NUMBER OF SEATS	CLEAR WIDTH PER SEAT SERVED FOR STAIRS (inches)	CLEAR WIDTH PER SEAT SERVED FOR PASSAGEWAY, RAMPS AND DOORWAYS (inches)
	× 25.4 for mm	
Unlimited	0.300 AB	0.220 C

[1]See Section 1004.3.2.3.1 for determination of values A, B and C.

TABLE 10-D—CALCULATION FOR MINIMUM WIDTH IN BUILDINGS WITH SMOKE-PROTECTED ASSEMBLY SEATING[1]

NUMBER OF SEATS	CLEAR WIDTH PER SEAT SERVED FOR STAIRS (inches)	CLEAR WIDTH PER SEAT SERVED FOR PASSAGEWAYS, RAMPS AND DOORWAYS (inches)
	× 25.4 for mm	
2,000	0.300 AB	0.220 C
5,000	0.200 AB	0.150 C
10,000	0.130 AB	0.100 C
15,000	0.096 AB	0.070 C
20,000	0.076 AB	0.056 C
25,000 or more	0.060 AB	0.044 C

[1]See Section 1004.3.2.3.1 for determination of values A, B and C.

TABLE 10-E—MAXIMUM NUMBER OF SEATS ALLOWED TO HAVE THE MINIMUM 12 INCH (305 mm) CLEAR WIDTH

TOTAL NUMBER OF SEATS IN THE SPACE	NUMBER OF SEATS PER ROW PERMITTED TO HAVE A MINIMUM 12-INCH (305 mm) CLEAR WIDTH AISLE ACCESSWAY	
	Aisle or Doorway at Both Ends of Row	Aisle or Doorway at One End of Row
< 4,000	14	7
4,000-6,999	15	7
7,000-9,999	16	8
10,000-12,999	17	8
13,000-15,999	18	9
16,000-18,999	19	9
19,000-21,999	20	10
≥ 22,000	21	11

Chapter 11
ACCESSIBILITY

SECTION 1101 — SCOPE

1101.1 General. Buildings or portions of buildings shall be accessible to persons with disabilities as required by this chapter.

See also Appendix Chapter 11 for requirements governing the provision of accessible site facilities not regulated by this chapter. See Section 101.3 for applicability of appendix.

1101.2 Standards of Quality. The standard listed below labeled an "Adopted Standard" is also listed in Chapter 35, Part III, and is part of this code.

1. Accessible Design

Adopted Standard—CABO/ANSI A117.1-1992

1101.3 Design. The design and construction of accessible buildings and building elements shall be in accordance with this chapter and CABO/ANSI A117.1-1992. For a building to be considered accessible, it shall be designed and constructed to the minimum provisions of this chapter and CABO/ANSI A117.1.

EXCEPTION: Type B dwelling units shall comply with Section 1106.

SECTION 1102 — DEFINITIONS

For the purpose of this chapter, certain terms are defined as follows:

ACCESSIBLE describes a site, building, facility or portion thereof that complies with this chapter and that can be approached, entered and used by persons with physical disabilities.

ACCESSIBLE MEANS OF EGRESS is a path of travel, usable by a mobility-impaired person, that leads to a public way.

ACCESSIBLE ROUTE is a continuous path connecting accessible elements and spaces in a building or facility that is usable by persons with disabilities.

ADAPTABILITY is the capability of altering or adding to certain building spaces and elements, such as kitchen counters, sinks and grab bars, to accommodate the needs of persons with and without disabilities, or to accommodate the needs of persons with different types or degrees of disability.

AREA OF REFUGE is an area with direct access to an exit or an elevator where persons unable to use stairs can remain temporarily in safety to await instructions or assistance during emergency evacuation.

CABO/ANSI A117.1 is American National Standard A117.1-1992 published by the Council of American Building Officials.

COMMON-USE AREAS are rooms, spaces or elements that are made available for use by a specific group of people.

DWELLING UNIT—TYPE A is a dwelling unit that is designed and constructed for accessibility in accordance with CABO/ANSI A117.1.

DWELLING UNIT—TYPE B is a dwelling unit that is designed and constructed for accessibility in accordance with Section 1106.

ELEMENT is an architectural or mechanical component of a building, facility, space or site that is used in making spaces accessible.

FACILITY is all or any portion of a building, structure or area, including the site on which such building, structure or area is located, wherein specific services are provided or activities are performed.

GROUND FLOOR DWELLING UNIT is a dwelling unit with a primary entrance and habitable space at grade.

MULTISTORY DWELLING UNIT is a dwelling unit with habitable or bathroom space located on more than one story.

PERSON WITH DISABILITY is an individual who has an impairment, including a mobility, sensory or cognitive impairment, that results in a functional limitation in access to and use of a building or facility.

PUBLIC-USE AREAS are rooms or spaces that are made available to the general public.

SITE is a parcel of land bounded by a property line or a designated portion of a public right-of-way.

SECTION 1103 — BUILDING ACCESSIBILITY

1103.1 Where Required.

1103.1.1 General. Accessibility to temporary or permanent buildings, or portions thereof, shall be provided for all occupancy classifications except as modified by this chapter. See also Appendix Chapter 11.

EXCEPTIONS: 1. Floors or portions of floors not customarily occupied, including, but not limited to, elevator pits; observation galleries used primarily for security purposes; elevator penthouses; nonoccupiable spaces accessed only by ladders, catwalks, crawl spaces or freight elevators; piping and equipment catwalks; and machinery, mechanical and electrical equipment rooms.

2. Subject to the approval of the building official, areas where work cannot reasonably be performed by persons having a severe impairment (mobility, sight or hearing) need not have specific features which provide accessibility to such persons.

3. Temporary structures, sites and equipment directly associated with the construction process such as construction site trailers, scaffolding, bridging or material hoists are not required to be accessible. This exception does not include walkways or pedestrian protection required by Chapter 33.

1103.1.2 Group A Occupancies. Group A Occupancies shall be accessible as provided in this chapter.

EXCEPTION: In the assembly area of dining and drinking establishments that are located within nonelevator buildings, when the area of mezzanine seating is not more than 25 percent of the total seating, an accessible means of vertical access to the mezzanine is not required, provided the same services are provided in an accessible space.

1103.1.3 Group B Occupancies. Group B Occupancies shall be accessible as provided in this chapter.

1103.1.4 Group E Occupancies. Group E Occupancies shall be accessible as provided in this chapter.

1103.1.5 Group F Occupancies. Group F Occupancies shall be accessible as provided in this chapter.

1103.1.6 Group H Occupancies. Group H Occupancies shall be accessible as provided in this chapter.

1103.1.7 Group I Occupancies. Group I Occupancies shall be accessible in public-use, common-use and employee-use areas, and shall have accessible patient rooms, cells, and treatment or examination rooms as follows:

1. In Group I, Division 1.1 patient-care units within hospitals that specialize in treating conditions that affect mobility, all patient rooms, including associated toilet rooms and bathrooms.

2. In Group I, Division 1.1 patient-care units within hospitals that do not specialize in treating conditions that affect mobility, at least one in every 10 patient rooms, or fraction thereof, including associated toilet rooms and bathrooms.

3. In Group I, Divisions 1.1 and 2 nursing homes and long-term care facilities, at least one in every two patient rooms, or fraction thereof, including associated toilet rooms and bathrooms.

4. In Group I, Division 3 mental health occupancies, at least one in every 10 patient rooms, or fraction thereof, including associated toilet rooms and bathrooms.

5. In Group I, Division 3 jail, prison and similar occupancies, at least one in every 20 rooms or cells, or fraction thereof, including associated toilet rooms and bathrooms.

6. In Group I Occupancies, all treatment and examination rooms shall be accessible.

1103.1.8 Group M Occupancies. Group M Occupancies shall be accessible as provided in this chapter.

1103.1.9 Group R Occupancies.

1103.1.9.1 General. Group R Occupancies shall be accessible as provided in this chapter. Rooms and spaces available to the general public and spaces available for the use of residents that serve Group R, Division 1 Occupancy accessible dwelling units shall be accessible.

Where recreational facilities are provided serving accessible dwelling units, 25 percent, but not less than one of each type in each group of such facilities, shall be accessible. All recreational facilities of each type on a site shall be considered to determine the total number of each type that are required to be accessible.

1103.1.9.2 Hotels, lodging houses and congregate residences. In hotels, lodging houses and congregate residence occupancies containing six or more guest rooms, multibed rooms or spaces for more than six occupants, one for the first 30 guest rooms or spaces and one additional for each additional 100 guest rooms or spaces, or fraction thereof, shall be accessible. In hotels with more than 50 sleeping rooms or suites, roll-in-type showers shall be provided in one half, but not less than one, of the required accessible sleeping rooms or suites.

In addition to the accessible guest rooms required above, guest rooms for persons with hearing impairments shall be provided in accordance with Table 11-B. Guest rooms for persons with hearing impairments shall be provided with visible and audible alarm-indicating appliances, activated by both the in-room smoke detector and the building fire protective signaling system.

1103.1.9.3 Multi-unit dwellings. In Group R, Division 1 Occupancy apartments containing four or more dwelling units and Group R, Division 3 Occupancies where there are four or more dwelling units in a single structure, all dwelling units shall be Type B dwelling units. In Group R, Division 1 apartment occupancies containing more than 20 dwelling units, at least 2 percent, but not less than one, of the dwelling units shall be Type A dwelling units. All dwelling units on a site shall be considered to determine the total number of accessible dwelling units.

EXCEPTIONS: 1. Where no elevator service is provided in a building, Type B dwelling units need not be provided on floors other than the ground floor.

2. Where no elevator service is provided in a building and the ground floor does not contain dwelling units, only those dwelling units located on the first floor of either Group R, Division 1 apartment occupancies or Group R, Division 3 Occupancies need comply with the requirements of this section.

3. A multistory dwelling unit not provided with elevator service is not required to comply with requirements for Type B dwelling units. Where a multistory dwelling unit is provided with elevator service to only one floor, the floor provided with elevator service shall comply with the requirements for a Type B dwelling unit, and a toilet facility shall be provided on that floor.

4. The number of Type B dwelling units provided in multiple nonelevator buildings on a single site may be reduced to a percentage of the ground floor units that is equal to the percentage of the entire site having grades, prior to development, that are 10 percent or less; but in no case shall the number of Type B units be less than 20 percent of the ground floor dwelling units on the entire site.

5. The required number of Type A and Type B dwelling units shall not apply to a site where the lowest floor or the lowest structural building members is required to be at or above the base flood elevation resulting in:

5.1 A difference in elevation between the minimum required floor elevation at the primary entrances and all vehicular and pedestrian arrival points within 50 feet (15 240 mm) exceeding 30 inches (762 mm).

5.2 A slope exceeding 10 percent between the minimum required floor elevation at the primary entrances and all vehicular and pedestrian arrival points within 50 feet (15 240 mm).

Where no such arrival points are within 50 feet (15 240 mm) of the primary entrances, the closest arrival point shall be used.

1103.1.10 Group S Occupancies. Group S Occupancies shall be accessible as provided in this chapter.

1103.1.11 Group U Occupancies. Group U, Division 1 Occupancies shall be accessihle as follows:

1. Private garages and carports that contain accessible parking.

2. In Group U, Division 1 agricultural buildings, access need be provided only to paved work areas and areas open to the general public.

1103.2 Design and Construction.

1103.2.1 General. When accessibility is required by this chapter, it shall be designed and constructed in accordance with this chapter and CABO/ANSI A117.1.

EXCEPTION: Type B dwelling units shall comply with Section 1106.

1103.2.2 Accessible route. When a building, or portion of a building, is required to be accessible, an accessible route shall be provided to all portions of the building, to accessible building entrances, connecting accessible pedestrian walkways and the public way.

EXCEPTION: In other than the offices of health-care providers, transportation facilities, airports and Group M Occupancies with five or more tenants, floors above and below accessible levels that have an aggregate area of not more than 3,000 square feet (278.7 m^2) need not be served by an accessible route from an accessible level.

When floor levels are required to be connected by an accessible route, and an interior path of travel is provided between the levels, an interior accessible route between the levels shall be provided. When only one accessible route is provided, it shall not pass through kitchens, storage rooms, toilet rooms, bathrooms, closets or other similar spaces.

EXCEPTION: A single accessible route may pass through a kitchen or storage room in a Type A dwelling unit.

When more than one building or facility is located on a site, accessible routes shall be provided connecting accessible buildings and accessible site facilities.

EXCEPTION: For Group R, Division 1 apartment occupancies, when the slope of the finished grade between accessible buildings and facilities exceeds 1 unit vertical in 12 units horizontal (8.33% slope), or when physical barriers of the site prevent the installation of an accessible route, a vehicular route with parking at each accessible building or facility may be provided in place of an accessible route.

1103.2.3 Accessible entrances. Each building and structure, and each separate tenancy within a building or structure, shall be provided with at least one entrance that complies with the accessible route provisions of CABO/ANSI A117.1. At least 50 percent of all entrances shall be accessible.

EXCEPTIONS: 1. Entrances used exclusively for loading and service.

2. Entrances to spaces not required to be accessible as provided for in Section 1103.

When a building or facility has entrances that normally serve accessible parking facilities, transportation facilities, passenger loading zones, taxi stands, public streets and sidewalks, or accessible interior vertical access, at least one of the entrances serving each such function shall comply with the accessible route provisions of CABO/ANSI A117.1.

The primary entrance to either a Type A or Type B dwelling unit shall be located on an accessible route from public or common areas. The primary entrance to the dwelling unit shall not be to a bedroom.

1103.2.4 Signs.

1103.2.4.1 International symbol of accessibility. The following elements and spaces of accessible facilities shall be identified by the international symbol of accessibility:

1. Accessible parking spaces, except where the total parking spaces provided are five or less.
2. Accessible areas of refuge.
3. Accessible passenger loading zones.
4. Accessible toilet and bathing facilities.

1103.2.4.2 Other signs. Inaccessible building entrances, inaccessible public toilets and bathing facilities, and elevators not on an accessible route shall be provided with directional signage indicating the route to the nearest similar accessible element.

In assembly areas, a sign notifying the general public of the availability of assistive listening systems shall be provided at ticket offices or similar locations.

Each door to an exit stairway shall have a tactile sign, including raised letters and Braille, stating EXIT and shall comply with CABO/ANSI A117.1.

At exits and elevators serving a required accessible space, but not providing an approved accessible means of egress, signs shall be installed indicating the location of accessible means of egress.

In addition to the international symbol of accessibility, each unisex toilet or bathing room shall be identified by a tactile sign including raised letters and Braille. Directional signage shall be provided at all separate-sex toilet or bathing facilities indicating the location of the nearest unisex room.

SECTION 1104 — EGRESS AND AREAS OF REFUGE

1104.1 Means of Egress.

1104.1.1 General. All required accessible spaces shall be provided with not less than one accessible means of egress. When more than one exit or exit-access door is required from any accessible space, each accessible portion of the space shall be served by not less than two accessible means of egress. The maximum travel distance from any accessible space to an area of refuge shall not exceed the travel distance set forth in Chapter 10.

Each accessible means of egress shall be continuous from each required accessible occupied area to a public way and shall include accessible routes, ramps, exit stairs, elevators, horizontal exits or smoke barriers.

1104.1.2 Stairways. When an exit stairway is part of an accessible means of egress, the stairway shall have a clear width of not less than 48 inches (1219 mm) between handrails. The stairway shall either incorporate an area of refuge within an enlarged story-level landing or shall be accessed from an area of refuge complying with Section 1104.2 or a horizontal exit.

EXCEPTIONS: 1. Exit stairways serving a single dwelling unit or guest room.

2. Exit stairways serving buildings protected throughout by an approved automatic sprinkler system.

3. The clear width of 48 inches (1219 mm) between handrails is not required for exit stairways accessed from a horizontal exit.

4. Areas of refuge are not required in open parking garages.

1104.1.3 Elevators. When an accessible floor is four or more stories above or below the level of exit discharge serving that floor, at least one elevator shall serve as one required accessible means of egress.

EXCEPTION: In fully sprinklered buildings, the elevator need not be provided to floors provided with a horizontal exit and located at or above the level of exit discharge.

When an elevator is part of an accessible means of egress, standby power shall be provided. The elevator shall be accessed from either an area of refuge complying with Section 1104.2 or a horizontal exit.

EXCEPTIONS: 1. Elevators are not required to be accessed by an area of refuge or a horizontal exit in buildings protected throughout by an approved automatic sprinkler system.

2. Areas of refuge are not required in open parking garages.

1104.1.4 Platform lifts. Platform (wheelchair) lifts shall not serve as part of an accessible means of egress.

EXCEPTION: Within a dwelling unit.

1104.2 Areas of Refuge.

1104.2.1 Access. Required areas of refuge shall be accessible from the space served by an accessible means of egress. Required areas of refuge shall have direct access to a stairway or an elevator complying with Section 1104.1.

1104.2.2 Pressurization. When an elevator lobby is used as an area of refuge, the elevator shaft and lobby shall be pressurized in accordance with the requirements of Section 905.

EXCEPTION: When elevators are in an area of refuge formed by a horizontal exit or smoke barrier.

1104.2.3 Size. Each area of refuge shall be sized to accommodate one wheelchair space not less than 30 inches by 48 inches (762 mm by 1219 mm) for each 200 occupants, or portion thereof, based on the occupant load of the area of refuge and areas served by the area of refuge.

Wheelchair spaces shall not reduce the required exit width or interfere with access to or use of fire department hose connections and valves. Access to required wheelchair spaces in an area of refuge shall not be obstructed by more than one adjoining wheelchair space.

1104.2.4 Construction. Each area of refuge shall be separated from the remainder of the story by a smoke barrier having at least a one-hour fire-resistance rating. Smoke barriers shall extend to the roof or floor deck above. Doors in the smoke barrier shall be tightfitting smoke- and draft-control assemblies having a fire-protection rating of not less than 20 minutes. Doors shall be self-closing or automatic closing by smoke detection. An approved damper designed to resist the passage of smoke shall be provided at each point a duct penetrates the smoke barrier.

EXCEPTION: Areas of refuge located within a stairway enclosure.

1104.2.5 Two-way communication. Areas of refuge shall be provided with a two-way communication system between the area of refuge and a central control point. If the central control point is not constantly attended, the area of refuge shall also have controlled access to a public telephone system. Location of the central control point shall be approved by the fire department.

EXCEPTION: Buildings four stories or less in height.

1104.2.6 Instructions. In areas of refuge that have a two-way emergency communication system, instructions on the use of the area under emergency conditions shall be posted adjoining the communications system. The instructions shall include:

1. Directions to find other exits,
2. Advice that persons able to use the exit stairway do so as soon as possible, unless they are assisting others,
3. Information on planned availability of assistance in the use of stairs or supervised operation of elevators and how to summon such assistance, and
4. Directions for use of the emergency communications system.

1104.2.7 Identification. Each area of refuge shall be identified by a sign stating AREA OF REFUGE and the international symbol of accessibility. The sign shall be located at each door providing access to the area of refuge. The sign shall be illuminated as required for exit signs when exit sign illumination is required. Tactile signage shall be located at each door to an area of refuge.

SECTION 1105 — FACILITY ACCESSIBILITY

1105.1 General. When buildings or portions of buildings are required to be accessible, building facilities shall be accessible as provided in this section.

Building facilities or elements required by this section to be accessible shall be designed and constructed in accordance with CABO/ANSI A117.1.

EXCEPTION: Type B dwelling units shall comply with Section 1106.

1105.2 Bathing and Toilet Facilities.

1105.2.1 Bathing facilities. When bathing facilities are provided, at least one of each type of fixture or element shall be accessible.

EXCEPTION: A bathing facility for a single occupant and not for common or public use may be adaptable.

In recreational facilities, where separate-sex bathing facilities are provided, an accessible unisex bathing room shall be provided.

EXCEPTION: Where each separate-sex bathing facility has only one shower fixture, unisex bathing facilities need not be provided.

1105.2.2 Toilet facilities. Toilet facilities located within accessible dwelling units, guest rooms and congregate residences shall comply with CABO/ANSI A117.1.

In other occupancies, each toilet room shall be accessible. At least one of each type of fixture or element in each accessible toilet room shall be accessible. When toilet stalls are provided in a toilet room, at least one toilet stall shall be wheelchair accessible. When six or more toilet stalls are provided in a toilet room, at least one ambulatory accessible toilet stall shall be provided in addition to the wheelchair accessible toilet stall.

EXCEPTION: A toilet facility for a single occupant and not for common or public use may be adaptable.

In Groups A and M Occupancies, an accessible unisex toilet room shall be provided where an aggregate of six or more male and female water closets are required. In buildings of mixed occupancy, only those water closets required for the Group A or M Occupancy shall be used to determine the unisex toilet room requirement.

1105.2.3 Lavatories, mirrors and towel fixtures. At least one accessible lavatory shall be provided within toilet facilities. When mirrors, towel fixtures, and other toilet and bathroom accessories are provided, at least one of each shall be accessible.

1105.2.4 Unisex bathing and toilet rooms.

1105.2.4.1 General. Unisex bathing and toilet rooms shall comply with this section and CABO/ANSI A117.1.

1105.2.4.2 Location. Unisex toilet and bathing rooms shall be located on an accessible route. Unisex toilet rooms shall be located not more than one story above or below separate-sex toilet facilities. The accessible route from any separate-sex toilet room to a unisex toilet room shall not exceed 500 feet (152 400 mm).

Additionally, in passenger transportation facilities and airports, the accessible route from separate-sex toilet facilities to a unisex toilet room shall not pass through security checkpoints.

1105.2.4.3 Clear floor space. Where doors swing into a unisex toilet or bathing room, a clear floor space not less than 30 inches by 48 inches (762 mm by 1219 mm) shall be provided, within the room, beyond the area of the door swing.

1105.2.4.4 Privacy. Doors to unisex toilet and bathing rooms shall be securable from within the room.

1105.2.4.5 Required fixtures.

1105.2.4.5.1 Unisex toilet rooms. Unisex toilet rooms shall include only one water closet and only one lavatory. Where a bathing facility is provided within a unisex toilet room, only one shower shall be provided.

EXCEPTION: A separate-sex toilet room containing not more than two water closets without urinals, or containing only one water closet and one urinal may be considered a unisex toilet room.

1105.2.4.5.2 Unisex bathing rooms. Unisex bathing rooms shall include only one shower fixture. Unisex bathing rooms shall also include one water closet and one lavatory. Where storage facilities are provided for separate-sex bathing facilities, accessible storage facilities shall be provided for unisex bathing rooms.

1105.3 Elevators and Stairway and Platform Lifts. Elevators on an accessible route shall be accessible.

EXCEPTION: Private elevators serving only one dwelling unit.

Elevators required to be accessible shall be designed and constructed to comply with CABO/ANSI A117.1.

Stairways in buildings, or portions of buildings, required to be accessible shall be designed and constructed to comply with CABO/ANSI A117.1.

Platform lifts may be used in lieu of an elevator under one of the following conditions subject to approval by the building official:

1. To provide an accessible route of travel to a performing area in a Group A Occupancy.

2. To provide unobstructed sight lines and distribution for wheelchair viewing positions in Group A Occupancies.

3. To provide access to spaces with an occupant load of less than five.

4. To provide access where existing site constraints or other constraints make use of a ramp or elevator infeasible.

All platform lifts used in lieu of an elevator shall be capable of independent operation.

1105.4 Other Building Facilities.

1105.4.1 Drinking fountains. On any floor where drinking fountains are provided, at least 50 percent, but not less than one fountain, shall be accessible.

1105.4.2 Fixed or built-in seating or tables. When fixed or built-in seating or tables are provided, at least 5 percent, but not less than one, shall be accessible. In dining and drinking establishments, such seating or tables shall be distributed throughout the facility.

1105.4.3 Storage. When storage facilities such as cabinets, shelves, closets, lockers and drawers are provided in required accessible or adaptable spaces, at least one of each type provided shall contain storage space complying with CABO/ANSI A117.1.

1105.4.4 Customer service facilities.

1105.4.4.1 Dressing and fitting rooms. When dressing or fitting rooms are provided, at least 5 percent, but not less than one, in each group of rooms serving distinct and different functions shall be accessible.

1105.4.4.2 Counters and windows. Where customer sales and service counters or windows are provided, a portion of the counter or at least one window shall be accessible.

1105.4.4.3 Checkout aisles. Accessible checkout aisles shall be installed in accordance with Table 11-C. Traffic control devices, security devices and turnstiles located in accessible checkout aisles or lanes shall be accessible.

1105.4.5 Controls, operating mechanisms and hardware. Controls, operating mechanisms and hardware intended for operation by the occupant, including switches that control lighting and ventilation and electrical convenience outlets, in accessible spaces, along accessible routes or as parts of accessible elements shall be accessible.

1105.4.6 Alarms. Alarm systems, when provided, shall include both audible and visible alarms. The alarm devices shall be located in hotel guest rooms as required by Section 1103.1.9.2; accessible public- and common-use areas, including toilet rooms and bathing facilities; hallways; and lobbies.

1105.4.7 Rail transit platforms. Rail transit platform edges bordering a drop-off and not protected by platform screens or guardrails shall be provided with detectable warnings in accordance with CABO/ANSI A117.1.

1105.4.8 Assembly areas.

1105.4.8.1 Wheelchair spaces. Stadiums, theaters, auditoriums and similar occupancies shall be provided with wheelchair spaces in accordance with Table 11-A. Removable seats shall be permitted in the wheelchair positions.

When the seating capacity of an individual assembly area exceeds 300, wheelchair spaces shall be provided in more than one location and shall be on an accessible route of travel. Dispersion of wheelchair spaces shall be based on the availability of accessible routes to various seating areas, including seating at various levels in multilevel facilities. Services provided in inaccessible areas shall also be provided on an accessible level and shall be accessible.

1105.4.8.2 Assistive listening systems. Assistive listening systems complying with CABO/ANSI A117.1 shall be installed in stadiums, theaters, auditoriums, lecture halls and similar areas when these areas have fixed seats and where audible communications are integral to the use of the space as follows:

1. Areas with an occupant load of 50 or more.

2. Areas where an audio-amplification system is installed.

Receivers for assistive-listening systems shall be provided at a rate of 4 percent of the total number of seats, but in no case less than two receivers.

Stadiums, theaters, auditoriums, lecture halls and similar areas not equipped with an audio-amplification system or having an occupant load of less than 50 shall have a permanently installed assistive-listening system, or shall have electrical outlets or other supplementary wiring necessary to support a portable assistive-listening system.

Signage shall be installed to notify patrons of the availability of the listening system.

SECTION 1106 — TYPE B DWELLING UNITS

1106.1 General. Type B dwelling units, when required, shall comply with this section.

EXCEPTION: Type B dwelling units designed and constructed as Type A dwelling units.

1106.2 Type B Accessible Route.

1106.2.1 General. At least one accessible route complying with this section shall connect all spaces and elements that are a part of the dwelling unit. Where only one accessible route is provided, it shall not pass through bathrooms, closets or similar spaces.

EXCEPTION: One of the following is not required to be on an accessible route:

1. A raised floor area in a portion of a living, dining or sleeping room;

2. A sunken floor area in a portion of a living, dining or sleeping room; or

3. A mezzanine that does not have plumbing fixtures or an enclosed habitable space.

1106.2.2 Clear width. Clear width of the accessible route shall be 36 inches (914 mm) minimum, except at doors.

1106.2.3 Changes in level. Changes in level of not more than $^1/_2$ inch (12.7 mm) in height shall comply with CABO/ANSI A117.1. Changes in level greater than $^1/_2$ inch (12.7 mm) in height shall be accomplished by a ramp, elevator or wheelchair lift complying with CABO/ANSI A117.1.

EXCEPTION: Where exterior deck, patio or balcony surface materials are impervious, the finished exterior impervious surface shall be 4 inches (102 mm) maximum below the finished floor level of the adjacent interior spaces of the dwelling unit.

1106.3 Operating Controls.

1106.3.1 General. Lighting controls, electrical receptacles, environmental controls, and user controls for security or intercom systems shall comply with this section.

EXCEPTIONS: 1. Electrical receptacles serving a dedicated use.

2. Appliance-mounted controls or switches.

3. A single receptacle located above a portion of countertop uninterrupted by a sink or appliance need not be accessible, provided:

3.1 At least one receptacle complying with this section is provided for the portion of countertop and

3.2 All other receptacles provided for the portion of countertop comply with this section.

4. Floor electrical receptacles.

5. Plumbing fixture controls.

1106.3.2 Clear floor space. A 30-inch-by-48-inch (762 mm by 1219 mm) minimum clear floor space positioned for forward or parallel approach shall be provided at each accessible operating control. Where a parallel approach is provided to an operating control located above an obstruction, the offset between the center lines of the clear floor space and the operating control shall be 12 inches (305 mm) maximum.

1106.3.3 Height. Operable parts of operating controls shall be 48 inches (1219 mm) maximum and 15 inches (381 mm) minimum above the floor. Operable parts located above an obstruction shall comply with Section 4.2.5.2 or 4.2.6.2 of CABO/ANSI A117.1.

1106.4 Doors.

1106.4.1 Primary entrance door. The primary entrance door to the dwelling unit shall comply with Section 4.13 of CABO/ANSI A117.1.

> **EXCEPTION:** Maneuvering clearances required by Section 4.13.6 of CABO/ANSI A117.1 are not required on the dwelling unit side of the door.

1106.4.2 Other doorways. Doorways intended for user passage shall comply with this section.

1106.4.2.1 Clear width. Doorways shall have a clear opening of 32 inches (813 mm) minimum. The clear opening of swinging doors shall be measured between the face of the door and the stop, with the door open 90 degrees.

> **EXCEPTION:** A tolerance of minus $^1/_4$ inch (6.4 mm) is permitted.

1106.4.2.2 Double leaf doorways. Where an inactive leaf with operable parts of hardware located more than 48 inches (1219 mm) above the floor is provided, the active leaf shall provide the required clear width.

1106.4.2.3 Thresholds. Thresholds, if provided, shall be $^1/_2$ inch (12.7 mm) high maximum and shall comply with CABO/ANSI A117.1.

> **EXCEPTION:** Thresholds at exterior sliding doors may be $^3/_4$ inch (19 mm) high maximum, provided they are beveled with a slope of not greater than 1 unit vertical in 2 units horizontal (50% slope).

1106.5 Kitchens.

1106.5.1 Clearances. Clearances between all opposing base cabinets, counter tops, appliances or walls within kitchen work areas shall be 40 inches (1016 mm) minimum.

In kitchens with counters, appliances or cabinets located on three contiguous sides, clearance between all opposing base cabinets, counter tops, appliances or walls within kitchen work areas shall be 60 inches (1524 mm) minimum.

1106.5.2 Clear floor space. A 30-inch-by-48-inch (762 mm by 1219 mm) minimum clear floor space shall be provided at the sink and at each appliance.

1. The clear floor space at the sink shall be positioned for parallel approach. The clear floor space shall extend 15 inches (381 mm) minimum from each side of the sink center line.

> **EXCEPTION:** Sinks complying with Section 4.33.4.5 of CABO/ANSI A117.1.

2. Where provided, the dishwasher, range, cooktop, oven, refrigerator/freezer and trash compactor shall have a clear floor space positioned for either parallel or forward approach.

1106.6 Toilet and Bathing Facilities.

1106.6.1 General. Toilet and bathing facilities in Type B dwelling units shall comply with Sections 1106.2 through 1106.4 and this section.

> **EXCEPTION:** Facilities on levels not required to be accessible.

1106.6.2 Clear floor space. Doors shall not swing into the clear floor space or clearance required for any fixture.

> **EXCEPTION:** Where a 30-inch-by-48-inch (762 mm by 1219 mm) minimum clear floor space is provided within the room, beyond the arc of the door swing.

Clear floor space shall be permitted to include knee and toe clearances in accordance with Section 4.2.4.3 of CABO/ANSI A117.1.

Clear floor spaces and clearances may overlap.

1106.6.3 Grab bar and seat reinforcement. Where walls are located to permit installation of grab bars and seats complying with Section 4.17.4, 4.21.4, 4.22.3 or 4.22.4 of CABO/ANSI A117.1, reinforcement shall be provided for the installation of grab bars and seats meeting those requirements.

> **EXCEPTION:** Reinforcement is not required in a room containing only a lavatory and a water closet, provided that the room does not contain the only lavatory or water closet on the accessible level of the dwelling unit.

1106.6.4 Toilet and bathing fixtures. Toilet and bathing fixtures shall comply with either Section 1106.6.4.1 or 1106.6.4.2.

1106.6.4.1 Option A. Each fixture provided shall comply with this section.

> **EXCEPTION:** A lavatory and a water closet located in a room containing only a lavatory and water closet, provided that the room does not contain the only lavatory or water closet on the accessible level of the dwelling unit.

1106.6.4.1.1 Lavatory. A 30-inch-by-48-inch (762 mm by 1219 mm) minimum clear floor space positioned for parallel approach shall be provided.

> **EXCEPTION:** A lavatory complying with Section 4.20 of CABO/ANSI A117.1.

Clear floor space shall extend 15 inches (381 mm) minimum from each side of the lavatory center line.

1106.6.4.1.2 Water closet. The lateral distance from the center line of the water closet to a bathtub, lavatory or wall shall be 18 inches (457 mm) minimum on one side and 15 inches (381 mm) minimum on the other side. Where the water closet is located adjacent to a wall, the lateral distance from the center line of the water closet to the wall shall be 18 inches (457 mm) and 15 inches (381 mm) minimum to a lavatory or bathtub. Where the water closet is not located adjacent to a wall, the water closet shall be located to allow for the installation of a grab bar on the side with 18-inch (457 mm) clearance. Clearance areas around the water closet shall comply with one of the following:

1. **Parallel approach.**

   1.1 Fifty-six inches (1422 mm) minimum, measured from the wall behind the water closet.

   1.2 Forty-eight inches (1219 mm) minimum, measured from a point 18 inches (457 mm) from the center line of the water closet on the side designated for the installation of grab bars.

1.3 Vanities or lavatories located on the wall behind the water closet are permitted to overlap the clear floor space.

2. **Forward approach.**

2.1 Sixty-six inches (1676 mm) minimum, measured from the wall behind the water closet.

2.2 Forty-eight inches (1219 mm) minimum, measured from a point 18 inches (457 mm) from the center line of the water closet on the side designated for the installation of grab bars.

2.3 Vanities or lavatories located on the wall behind the water closet are permitted to overlap the clear floor space.

3. **Parallel or forward approach.**

3.1 Fifty-six inches (1422 mm) minimum, measured from the wall behind the water closet.

3.2 Sixty inches (1524 mm) minimum, measured from a point 18 inches (457 mm) from the center line of the water closet on the side designated for the installation of grab bars.

1106.6.4.1.3 Bathing fixtures. Where bathing fixtures are provided, at least one bathing fixture in each toilet/bathing area shall comply with the following:

1. **Parallel approach bathtubs.** Bathtubs with a parallel approach shall have a clearance 30 inches (762 mm) wide by 60 inches (1524 mm) long minimum adjacent to the bathtub. A lavatory may extend into the clearance at the control end of the tub if the 30-inch-by-48-inch (762 mm by 1219 mm) clearance remains.

EXCEPTION: Lavatories complying with Section 4.20 of CABO/ANSI A117.1 may be placed in the clearance.

2. **Forward approach bathtubs.** Bathtubs with a forward approach shall have a clearance 48 inches (1219 mm) wide by 60 inches (1524 mm) long minimum adjacent to the bathtub. A water closet may be placed in the clearance at the control end of the tub.

1106.6.4.1.4 Showers. If a stall shower is the only bathing fixture, the stall shower shall have minimum dimensions of 36 inches by 36 inches (914 mm by 914 mm). A clear floor space of not less than 30 inches (762 mm) measured perpendicular from the face of the shower stall by 48 inches (1219 mm) measured parallel from the shower head wall shall be provided.

1106.6.4.2 Option B. One of each type of fixture provided shall comply with Section 1106.6.4.2. The accessible fixtures shall be located in a single toilet/bathing area.

1106.6.4.2.1 Lavatory. A 30-inch-by-48-inch (762 mm by 1219 mm) minimum clear floor space positioned for parallel approach shall be provided.

EXCEPTION: A lavatory complying with Section 4.20 of CABO/ANSI A117.1.

The clear floor space shall extend 15 inches (381 mm) minimum from each side of the lavatory center line.

The fixture rim shall be 34 inches (864 mm) maximum above the finished floor.

1106.6.4.2.2 Water closet. The water closet shall comply with Section 1106.6.4.1.2.

1106.6.4.2.3 Bathing fixtures. Where bathing fixtures are provided, at least one bathing fixture shall comply with the following:

1. **Bathtub.** A 30-inch-by-48-inch (762 mm by 1219 mm) minimum clear floor space positioned for parallel approach shall be provided adjacent to the bathtub. The front edge of the clear floor space shall align with the control end of the bathtub.

2. **Stall showers.** If a stall shower is the only bathing fixture, the stall shower shall have minimum dimensions of 36 inches by 36 inches (914 mm by 914 mm). A clear floor space of not less than 30 inches (762 mm) measured perpendicular from the face of the shower stall by 48 inches (1219 mm) measured parallel from the shower head wall shall be provided.

TABLE 11-A—WHEELCHAIR SPACES REQUIRED IN ASSEMBLY AREAS

CAPACITY OF SEATING	NUMBER OF REQUIRED WHEELCHAIR SPACES
4 to 25	1
26 to 50	2
51 to 300	4
301 to 500	6
over 500	6 plus 1 for each 200 over 500

TABLE 11-B—NUMBER OF ROOMS FOR PERSONS WITH HEARING IMPAIRMENTS

TOTAL NUMBER OF ROOMS	MINIMUM REQUIRED NUMBER
6-25	1
26-50	2
51-75	3
76-100	4
101-150	5
151-200	6
201-300	7
301-400	8
401-500	9
501-1,000	2% of total rooms
Over 1,000	20 plus 1 for every 100 rooms, or fraction thereof, over 1,000

TABLE 11-C—REQUIRED CHECKOUT AISLES

TOTAL CHECKOUT AISLES	MINIMUM NUMBER OF ACCESSIBLE CHECKOUT AISLES
1-4	1
5-8	2
9-15	3
Over 15	3 plus 20% of additional aisles over 15

Chapter 12
INTERIOR ENVIRONMENT

SECTION 1201 — GENERAL

Buildings and portions thereof shall provide occupants with light and ventilation as set forth in this chapter. For ventilation of hazardous vapors or fumes, see Section 306.5 and the Mechanical Code.

SECTION 1202 — LIGHT AND VENTILATION IN GROUPS A, B, E, F, H, I, M AND S OCCUPANCIES

1202.1 Light. All enclosed portions of Groups A, B, E, F, H, I, M and S Occupancies customarily occupied by human beings shall be provided with natural light by means of exterior glazed openings with an area not less than one tenth of the total floor area, or shall be provided with artificial light. Such exterior openings shall open directly onto a public way or a yard or court as set forth in Section 1203.4. See Section 1003.2.9 for required means of egress illumination.

1202.2 Ventilation.

1202.2.1 General. All enclosed portions of Groups A, B, E, F, H, I, M and S Occupancies customarily occupied by human beings shall be provided with natural ventilation by means of openable exterior openings with an area not less than $^1/_{20}$ of the total floor area or shall be provided with a mechanically operated ventilation system. Such exterior openings shall open directly onto a public way or a yard or court as set forth in Section 1203.4. Such mechanically operated ventilation system shall be capable of supplying a minimum of 15 cubic feet per minute (7 L/s) of outside air per occupant in all portions of the building during such time as the building is occupied. If the velocity of the air at a register exceeds 10 feet per second (3 m/s), the register shall be placed more than 8 feet (2438 mm) above the floor directly beneath.

Toilet rooms shall be provided with a fully openable exterior window with an area not less than 3 square feet (0.279 m^2), or a vertical duct not less than 100 square inches (64 516 mm^2) in area for the first water closet plus 50 square inches (32 258 mm^2) additional of area for each additional water closet, or a mechanically operated exhaust system capable of providing a complete change of air every 15 minutes. Such mechanically operated exhaust systems shall be connected directly to the outside, and the point of discharge shall be at least 3 feet (914 mm) from any opening that allows air entry into occupied portions of the building.

For ventilation of hazardous vapors or fumes in Group H Occupancies, see Sections 307.5.2 and 1202.2.3. For Group S, Division 3 Occupancies, see Section 1202.2.7.

1202.2.2 Groups B, F, M and S Occupancies. In all buildings classified as Groups B, F, M and S Occupancies or portions thereof where Class I, II or III-A liquids are used, a mechanically operated exhaust ventilation shall be provided sufficient to produce six air changes per hour. Such exhaust ventilation shall be taken from a point at or near the floor level.

1202.2.3 Group H Occupancies. Rooms, areas or spaces of Group H Occupancies in which explosive, corrosive, combustible, flammable or highly toxic dusts, mists, fumes, vapors or gases are or may be emitted due to the processing, use, handling or storage of materials shall be mechanically ventilated as required by the Fire Code and the Mechanical Code.

Ducts conveying explosives or flammable vapors, fumes or dusts shall extend directly to the exterior of the building without entering other spaces. Exhaust ducts shall not extend into or through ducts and plenums.

EXCEPTION: Ducts conveying vapor or fumes having flammable constituents less than 25 percent of their lower flammability limit may pass through other spaces.

Emissions generated at work stations shall be confined to the area in which they are generated as specified in the Fire Code and the Mechanical Code.

The location of supply and exhaust openings shall be in accordance with the Mechanical Code. Exhaust air contaminated by highly toxic material shall be treated in accordance with the Fire Code.

A manual shutoff control shall be provided outside of the room in a position adjacent to the access door to the room or in a location approved by the chief. The switch shall be of the break-glass type and shall be labeled VENTILATION SYSTEM EMERGENCY SHUTOFF. F F F F F F F F

1202.2.4 Group H, Division 4 Occupancies. In all buildings classified as Group H, Division 4 Occupancies used for the repair or handling of motor vehicles operating under their own power, mechanical ventilation shall be provided capable of exhausting a minimum of 1 cubic foot per minute per square foot (0.044 L/s/m^2) of floor area. Each engine repair stall shall be equipped with an exhaust pipe extension duct, extending to the outside of the building, which, if over 10 feet (3048 mm) in length, shall mechanically exhaust 300 cubic feet per minute (141.6 L/s). Connecting offices and waiting rooms shall be supplied with conditioned air under positive pressure.

EXCEPTION: When approved, ventilating equipment may be omitted in repair garages, enclosed heliports and aircraft hangars when well-distributed unobstructed openings to the outer air of sufficient size to supply necessary ventilation are furnished.

1202.2.5 Group H, Division 6 Occupancies. In Group H, Division 6 Occupancies, mechanical exhaust ventilation shall be provided throughout the fabrication area at the rate of not less than 1 cubic foot per minute per square foot (0.044 L/s/m^2) of floor area. The exhaust air duct system of one fabrication area shall not connect to another duct system outside that fabrication area within the building.

Ventilation systems shall comply with the Mechanical Code except that the automatic shutoffs need not be installed on air-moving equipment. However, smoke detectors shall be installed in the circulating airstream and shall initiate a signal at the emergency control station.

Except for exhaust systems, at least one manually operated remote control switch that will shut down the fabrication area ventilation system shall be installed at an approved location outside the fabrication area.

A ventilation system shall be provided to capture and exhaust fumes and vapors at work stations. Two or more operations shall not be connected to the same exhaust system when either one or the combination of the substances removed could constitute a fire, explosion or hazardous chemical reaction within the exhaust duct system.

Exhaust ducts penetrating occupancy separations shall be contained in a shaft of equivalent fire-resistive construction. Exhaust ducts shall not penetrate area separation walls. Fire dampers shall not be installed in exhaust ducts.

1202.2.6 Group S repair and storage garages and aircraft hangars. In Group S, Division 3 repair garages and storage garages and in Division 5 aircraft hangars, the mechanical ventilating system required by Section 1202.2.1 may be omitted when, in the opinion of the building official, the building is supplied with unobstructed openings to the outer air that are sufficient to provide the necessary ventilation.

1202.2.7 Group S parking garages. In Group S, Division 3 parking garages, other than open parking garages, used for storing or handling automobiles operating under their own power and on loading platforms in bus terminals, ventilation shall be provided capable of exhausting a minimum of 1.5 cubic feet per minute (cfm) per square foot (0.761 L/s/m^2) of gross floor area. The building official may approve an alternate ventilation system designed to exhaust a minimum of 14,000 cfm (6608 L/s) for each operating vehicle. Such system shall be based on the anticipated instantaneous movement rate of vehicles, but not less than 2.5 percent (or one vehicle) of the garage capacity. Automatic carbon monoxide-sensing devices may be employed to modulate the ventilation system to maintain a maximum average concentration of carbon monoxide of 50 parts per million during any eight-hour period, with a maximum concentration not greater than 200 parts per million for a period not exceeding one hour. Connecting offices, waiting rooms, ticket booths and similar uses shall be supplied with conditioned air under positive pressure.

> **EXCEPTION:** Mechanical ventilation need not be provided within a Group S, Division 3 parking garage when openings complying with Section 311.9.2.2 are provided.

SECTION 1203 — LIGHT AND VENTILATION IN GROUP R OCCUPANCIES

1203.1 General. For the purpose of determining the light or ventilation for Group R Occupancies required by this section, any room may be considered as a portion of an adjoining room when one half of the area of the common wall is open and unobstructed and provides an opening of not less than one tenth of the floor area of the interior room or 25 square feet (2.3 m^2), whichever is greater.

Exterior openings for natural light or ventilation required by this section shall open directly onto a public way or a yard or court as set forth in Section 1203.4.

> **EXCEPTIONS:** 1. Required exterior openings may open into a roofed porch where the porch:
>
> 1.1 Abuts a public way, yard or court;
>
> 1.2 Has a ceiling height of not less than 7 feet (2134 mm); and
>
> 1.3 Has a longer side at least 65 percent open and unobstructed.
>
> 2. Skylights.

1203.2 Light. Guest rooms and habitable rooms within a dwelling unit or congregate residence shall be provided with natural light by means of exterior glazed openings with an area not less than one tenth of the floor area of such rooms with a minimum of 10 square feet (0.93 m^2).

> **EXCEPTION:** Kitchens in Group R Occupancies may be provided with artificial light.

1203.3 Ventilation. Guest rooms and habitable rooms within a dwelling unit or congregate residence shall be provided with natural ventilation by means of openable exterior openings with an area of not less than $^1/_{20}$ of the floor area of such rooms with a minimum of 5 square feet (0.46 m^2).

In lieu of required exterior openings for natural ventilation, a mechanical ventilating system may be provided. Such system shall be capable of providing two air changes per hour in guest rooms, dormitories, habitable rooms and in public corridors with a minimum of 15 cubic feet per minute (7 L/s) of outside air per occupant during such time as the building is occupied.

Bathrooms, water closet compartments, laundry rooms and similar rooms shall be provided with natural ventilation by means of openable exterior openings with an area not less than $^1/_{20}$ of the floor area of such rooms with a minimum of $1^1/_2$ square feet (0.14 m^2).

> **EXCEPTION:** Laundry rooms in Group R, Division 3 Occupancies.

In lieu of required exterior openings for natural ventilation in bathrooms containing a bathtub, shower or combination thereof; laundry rooms; and similar rooms, a mechanical ventilation system connected directly to the outside capable of providing five air changes per hour shall be provided. Such systems shall be connected directly to the outside, and the point of discharge shall be at least 3 feet (914 mm) from any opening that allows air entry into occupied portions of the building. Bathrooms that contain only a water closet, lavatory or combination thereof and similar rooms may be ventilated with an approved mechanical recirculating fan or similar device designed to remove odors from the air.

1203.4 Yards or Courts.

1203.4.1 General. This section shall apply to yards and courts adjacent to exterior openings that provide required natural light or ventilation. Such yards and courts shall be on the same property as the building.

1203.4.2 Yards. Yards shall not be less than 3 feet (914 mm) in width for one- and two-story buildings. For buildings more than two stories in height, the minimum width of the yard shall be increased at the rate of 1 foot (305 mm) for each additional story. For buildings exceeding 14 stories in height, the required width of the yard shall be computed on the basis of 14 stories.

1203.4.3 Courts. Courts shall not be less than 3 feet (914 mm) in width. Courts having windows opening on opposite sides shall not be less than 6 feet (1829 mm) in width. Courts bounded on three or more sides by the walls of the building shall not be less than 10 feet (3048 mm) in length unless bounded on one end by a public way or yard. For buildings more than two stories in height, the court shall be increased 1 foot (305 mm) in width and 2 feet (610 mm) in length for each additional story. For buildings exceeding 14 stories in height, the required dimensions shall be computed on the basis of 14 stories.

Adequate access shall be provided to the bottom of all courts for cleaning purposes. Every court more than two stories in height shall be provided with a horizontal air intake at the bottom not less than 10 square feet (0.93 m^2) in area and leading to the exterior of the building unless abutting a yard or public way. The construction of the air intake shall be as required for the court walls of the building, but in no case shall be less than one-hour fire resistive.

SECTION 1204 — EAVES

Where eaves extend over required windows, they shall project no closer than 30 inches (762 mm) to any side or rear property line. See also Sections 503.2 and 705.

SECTION 1205 — ALTERNATE VENTILATION WHEN APPLICABLE

1205.1 General. Requirements for ventilation are included in Appendix Chapter 12 of this code. When adopted (see Section

101.3) the appendix criteria shall take precedence over the ventilation requirements set forth in Sections 1202 and 1203 of this code.

1205.2 Standards. The standard listed below is a recognized standard (see Sections 3503 and 3504).

ANSI/ASHRAE 62-1989 including ANSI/ASHRAE Addendum 62a-1990, Ventilation for Acceptable Indoor Air Quality

Chapter 13
ENERGY CONSERVATION

SECTION 1301 — SOLAR ENERGY COLLECTORS

Collectors that function as building components shall comply with the applicable provisions of the code.

Collectors located above or upon a roof and not functioning as building components shall not reduce the required fire-resistance or fire-retardancy classification of the roof-covering materials.

EXCEPTIONS: 1. Collectors installed on one- and two-family dwellings.

2. Noncombustible collectors located on buildings not over three stories in height or 9,000 square feet (836 m^2) in total floor area.

3. Collectors that comply with the provisions of Section 2603.14.

A complete code for energy conservation in new buildings is contained in Appendix Chapter 13. When adopted, as set forth in Section 101.3, Appendix Chapter 13 applies.

Chapter 14
EXTERIOR WALL COVERINGS

SECTION 1401 — GENERAL

1401.1 Applicability. Exterior wall coverings for the building shall provide weather protection for the building at its exterior boundaries.

Exterior wall covering shall be in accordance with this chapter and as specified by the applicable provisions elsewhere in this code. For additional provisions, see Chapter 19 for concrete, Chapter 20 for lightweight metals, Chapter 21 for masonry, Chapter 22 for steel, Chapter 23 for wood, Chapter 25 for gypsum wallboard and plaster, and Chapter 26 for plastics. Also, see the following:

SECTION	SUBJECT
601.5.4	Walls fronting on streets
602.1	Materials in Type I construction
603.1	Materials in Type II construction
604.3.1	Exterior walls in Type III construction
605.3.1	Exterior walls in Type IV construction
606.1	Materials in Type V construction

1401.2 Standards. The standards listed below labeled a "UBC standard" are also listed in Chapter 35, Part II, and are part of this code.

1. UBC Standard 14-1, Kraft Waterproof Building Paper
2. UBC Standard 14-2, Vinyl Siding

SECTION 1402 — WEATHER PROTECTION

1402.1 Weather-resistive Barriers. All weather-exposed surfaces shall have a weather-resistive barrier to protect the interior wall covering. Such barrier shall be equal to that provided for in UBC Standard 14-1 for kraft waterproof building paper or asphalt-saturated rag felt. Building paper and felt shall be free from holes and breaks other than those created by fasteners and construction system due to attaching of the building paper, and shall be applied over studs or sheathing of all exterior walls. Such felt or paper shall be applied horizontally, with the upper layer lapped over the lower layer not less than 2 inches (51 mm). Where vertical joints occur, felt or paper shall be lapped not less than 6 inches (152 mm).

A weather-resistive barrier may be omitted in the following cases:

1. When exterior covering is of approved weatherproof panels.
2. In back-plastered construction.
3. When there is no human occupancy.
4. Over water-repellent panel sheathing.
5. Under approved paperbacked metal or wire fabric lath.
6. Behind lath and portland cement plaster applied to the underside of roof and eave projections.

1402.2 Flashing and Counterflashing. Exterior openings exposed to the weather shall be flashed in such a manner as to make them weatherproof.

All parapets shall be provided with coping of approved materials. All flashing, counterflashing and coping, when of metal, shall have a minimum thickness of 0.019-inch (0.48 mm) (No. 26 galvanized sheet metal gage) corrosion-resistant metal.

1402.3 Waterproofing Weather-exposed Areas. Balconies, landings, exterior stairways, occupied roofs and similar surfaces exposed to the weather and sealed underneath shall be waterproofed and sloped a minimum of $^1/_4$ unit vertical in 12 units horizontal (2% slope) for drainage.

1402.4 Dampproofing Foundation Walls. Unless otherwise approved by the building official, foundation walls enclosing a basement below finished grade shall be dampproofed outside by approved methods and materials.

1402.5 Window Wells. All window wells shall extend below the window sill height.

SECTION 1403 — VENEER

1403.1 Scope.

1403.1.1 General. All veneer and its application shall conform to the requirements of this code. Wainscots not exceeding 4 feet (1219 mm) in height measured above the adjacent ground elevation for exterior veneer or the finish floor elevation for interior veneer may be exempted from the provisions of this chapter if approved by the building official.

1403.1.2 Limitations. Exterior veneer shall not be attached to wood-frame construction at a point more than 30 feet (9144 mm) in height above the noncombustible foundation, except the 30-foot (9144 mm) limit may be increased when special construction is designed to provide for differential movement and when approved by the building official.

1403.2 Definitions. For the purpose of this chapter, certain terms are defined as follows:

BACKING as used in this chapter is the surface or assembly to which veneer is attached.

VENEER is nonstructural facing of brick, concrete, stone, tile, metal, plastic or other similar approved material attached to a backing for the purpose of ornamentation, protection or insulation.

Adhered Veneer is veneer secured and supported through adhesion to an approved bonding material applied over an approved backing.

Anchored Veneer is veneer secured to and supported by approved connectors attached to an approved backing.

Exterior Veneer is veneer applied to weather-exposed surfaces as defined in Section 224.

Interior Veneer is veneer applied to surfaces other than weather-exposed surfaces as defined in Section 224.

1403.3 Materials. Materials used in the application of veneer shall conform to the applicable requirements for such materials as set forth elsewhere in this code.

For masonry units and mortar, see Chapter 21.

For precast concrete units, see Chapter 19.

For portland cement plaster, see Chapter 25.

Anchors, supports and ties shall be noncombustible and corrosion resistant.

When the terms "corrosion resistant" or "noncorrosive" are used in this chapter, they shall mean having a corrosion resistance equal to or greater than a hot-dipped galvanized coating of 1.5 ounces of zinc per square foot (458 g/m^2) of surface area. When an element is required to be corrosion resistant or noncorrosive, all of its parts, such as screws, nails, wire, dowels, bolts, nuts, washers, shims, anchors, ties and attachments, shall be corrosion resistant.

1403.4 Design.

1403.4.1 General. The design of all veneer shall comply with the requirements of Chapter 16 and this section.

Veneer shall support no load other than its own weight and the vertical dead load of veneer above.

Surfaces to which veneer is attached shall be designed to support the additional vertical and lateral loads imposed by the veneer.

Consideration shall be given for differential movement of supports, including that caused by temperature changes, shrinkage, creep and deflection.

1403.4.2 Adhered veneer. With the exception of ceramic tile, adhered veneer and its backing shall be designed to have a bond to the supporting element sufficient to withstand a shearing stress of 50 psi (345 kPa).

1403.4.3 Anchored veneer. Anchored veneer and its attachments shall be designed to resist a horizontal force equal to at least twice the weight of the veneer.

1403.5 Adhered Veneer.

1403.5.1 Permitted backing. Backing shall be continuous and may be of any material permitted by this code. It shall have surfaces prepared to secure and support the imposed loads of veneer.

Exterior veneer, including its backing, shall provide a weatherproof covering.

For additional backing requirements, see Section 1402.

1403.5.2 Area limitations. The height and length of veneered areas shall be unlimited except as required to control expansion and contraction and as limited by Section 1403.1.2.

1403.5.3 Unit size limitations. Veneer units shall not exceed 36 inches (914 mm) in the greatest dimension or more than 720 square inches (0.46 m^2) in total area and shall not weigh more than 15 pounds per square foot (psf) (73.2 kg/m^2) unless approved by the building official.

> **EXCEPTION:** Veneer units weighing less than 3 psf (14.6 kg/m^2) shall not be limited in dimension or area.

1403.5.4 Application. In lieu of the design required by Sections 1403.4.1 and 1403.4.2, adhered veneer may be applied by one of the following application methods:

1. A paste of neat portland cement shall be brushed on the backing and the back of the veneer unit. Type S mortar then shall be applied to the backing and the veneer unit. Sufficient mortar shall be used to create a slight excess to be forced out the edges of the units. The units shall be tapped into place so as to completely fill the space between the units and the backing. The resulting thickness of mortar in back of the units shall not be less than $^1/_2$ inch (12.7 mm) or more than $1^1/_4$ inches (32 mm).

2. Units of tile, masonry, stone or terra cotta, not over 1 inch (25 mm) in thickness, shall be restricted to 81 square inches (52 258 mm^2) in area unless the back side of each unit is ground or box screeded to true up any deviations from plane. These units and glass mosaic units of tile not over 2 inches by 2 inches by $^3/_8$ inch (51 mm by 51 mm by 9.5 mm) in size may be adhered by means of portland cement. Backing may be of masonry, concrete or portland cement plaster on metal lath. Metal lath shall be fastened to the supports in accordance with the requirements of Chapter 25. Mortar as described in Table 14-A shall be applied to the backing as a setting bed. The setting bed shall be a minimum of $^3/_8$ inch (10 mm) thick and a maximum of $^3/_4$ inch (19 mm) thick. A paste of neat portland cement or one half portland cement and one half graded sand shall be applied to the back of the exterior veneer units and to the setting bed and the veneer pressed and tapped into place to provide complete coverage between the mortar bed and veneer unit. A cement mortar shall be used to point the veneer.

1403.5.5 Ceramic tile. Portland cement mortars for installing ceramic tile on walls, floors and ceilings shall be as set forth in Table 14-A.

1403.6 Anchored Veneer.

1403.6.1 Permitted backing. Backing may be of any material permitted by this code. Exterior veneer including its backing shall provide a weatherproof covering.

1403.6.2 Height and support limitations. Anchored veneers shall be supported on footings, foundations or other noncombustible support except as provided under Section 2307.

In Seismic Zones 2, 3 and 4, the weight of all anchored veneers installed on structures more than 30 feet (9144 mm) in height above the noncombustible foundation or support shall be supported by noncombustible, corrosion-resistant structural framing. The structural framing shall have horizontal supports spaced not more than 12 feet (3658 mm) vertically above the initial 30-foot (9144 mm) height. The vertical spacing between horizontal supports may be increased when special design techniques, approved by the building official, are used in the construction.

Noncombustible, noncorrosive lintels and noncombustible supports shall be provided over all openings where the veneer unit is not self-spanning. The deflections of all structural lintels and horizontal supports required by this subsection shall not exceed $^1/_{600}$ of the span under full load of the veneer.

1403.6.3 Area limitations. The area and length of anchored veneer walls shall be unlimited, except as required to control expansion and contraction and by Section 1403.1.2.

1403.6.4 Application.

1403.6.4.1 General. In lieu of the design required by Sections 1403.4.1 and 1403.4.3, anchored veneer may be applied in accordance with this section.

1403.6.4.2 Masonry and stone units [5 inches (127 mm) maximum in thickness]. Masonry and stone veneer not exceeding 5 inches (127 mm) in thickness may be anchored directly to structural masonry, concrete or studs in one of the following manners:

1. Wall ties shall be corrosion resistant, and if made of sheet metal, shall have a minimum thickness of 0.030 inch (0.76 mm) (No. 22 galvanized sheet gage) by $^3/_4$ inch (19.1 mm) or, if of wire, shall have a minimum diameter of 0.148 inch (3.76 mm) (No. 9 B.W. gage). Wall ties shall be spaced so as to support not more than 2 square feet (0.19 m^2) of wall area but shall not be more than 24 inches (610 mm) on center horizontally. In Seismic Zones 3 and 4, wall ties shall have a lip or hook on the extended leg that will engage or enclose a horizontal joint reinforcement wire having a diameter of 0.148 inch (3.76 mm) (No. 9 B.W. gage) or equivalent. The joint reinforcement shall be continuous with butt splices between ties permitted.

When applied over stud construction, 2-inch-by-4-inch (51 mm by 102 mm) stud spacing shall not exceed 16 inches (406 mm) on center and 2-inch-by-6-inch (51 mm by 152 mm) stud spacing shall not exceed 24 inches (610 mm) on center. Approved paper shall first be applied over the sheathing or wires between studs except as otherwise provided in Section 1402, and mortar shall be slushed into the 1-inch (25 mm) space between facing and paper.

As an alternate to approved paper with slush fill, an air space of at least 1 inch (25 mm) may be maintained between the backing and the veneer in which case spot bedding at all ties shall be of cement mortar.

2. Veneer may be applied with 1-inch-minimum (25 mm) grouted backing space reinforced by not less than 2-inch-by-2-inch (51 mm by 51 mm) 0.065-inch (1.65 mm) (No. 16 B.W. gage) galvanized wire mesh placed over waterproof paper backing and anchored directly to stud construction.

Two-inch-by-4-inch (51 mm by 102 mm) stud spacing shall not exceed 16 inches (406 mm) on center and 2-inch-by-6-inch (51 mm by 152 mm) stud spacing shall not exceed 24 inches (610 mm) on center. The galvanized wire mesh shall be anchored to wood studs by galvanized steel wire furring nails at 4 inches (102 mm) on center or by barbed galvanized nails at 6 inches (152 mm) on center with a $1^1/_8$-inch-minimum (29 mm) penetration. The galvanized wire mesh may be attached to steel studs by equivalent wire ties. If this method is applied over solid sheathing, the mesh must be furred for embedment in grout. The wire mesh must be attached at the top and bottom with not less than 8-penny (64 mm) common wire nails. The grout fill shall be placed to fill the space intimately around the mesh and veneer facing.

1403.6.4.3 Stone units [10 inches (254 mm) maximum in thickness]. Stone veneer units not exceeding 10 inches (254 mm) in thickness may be anchored directly to structural masonry, concrete or to studs:

1. **With concrete or masonry backing.** Anchor ties shall not be less than 0.109-inch (2.77 mm) (No. 12 B.W. gage) galvanized wire, or approved equal, formed as an exposed eye and extending not less than $^1/_2$ inch (12.7 mm) beyond the face of the backing. The legs of the loops shall not be less than 6 inches (152 mm) in length bent at right angles and laid in the masonry mortar joint and spaced so that the eyes or loops are 12 inches (254 mm) maximum on center in both directions. There shall be provided not less than a 0.109-inch (2.77 mm) (No. 12 B.W. gage) galvanized wire tie, or approved equal, threaded through the exposed loops for every 2 square feet (0.19 m^2) of stone veneer. This tie shall be a loop having legs not less than 15 inches (381 mm) in length bent so that it will lie in the stone veneer mortar joint. The last 2 inches (51 mm) of each wire leg shall have a right angle bend. One inch (25 mm) of cement grout shall be placed between the backing and the stone veneer.

2. **With stud backing.** A 2-inch-by-2-inch (51 mm by 51 mm) 0.065-inch (1.65 mm) (No. 16 B.W. gage) galvanized wire mesh with two layers of waterproof paper backing shall be applied directly to 2-inch-by-4-inch (51 mm by 102 mm) wood studs spaced a maximum of 16 inches (406 mm) on center or 2-inch-by-6-inch (51 mm by 152 mm) wood studs spaced a maximum of 24 inches (610 mm) on center. On studs, the mesh shall be attached with 2-inch-long (51 mm) galvanized steel wire furring nails at 4 inches (102 mm) on center providing a minimum $1^1/_8$-inch (29 mm) penetration into each stud and with 8-penny (64 mm) common nails at 8 inches (203 mm) on center into top and bottom plates. The galvanized wire mesh may be attached to steel studs with equivalent wire ties. There shall not be less than 0.109-inch (2.77 mm) (No. 12 B.W. gage) galvanized wire, or approved equal, looped through the mesh for every 2 square feet (0.19 m^2) of stone veneer. This tie shall be a loop having legs not less than 15 inches (381 mm) in length, bent so that it will lie in the stone veneer mortar joint. The last 2 inches (51 mm) of each wire leg shall have a right angle bend. One-inch-minimum (25 mm) thickness of cement grout shall be placed between the backing and the stone veneer.

1403.6.4.4 Slab-type units [2 inches (51 mm) maximum in thickness]. For veneer units of marble, travertine, granite or other stone units of slab form, ties of corrosion-resistant dowels shall engage drilled holes located in the middle third of the edge of the units spaced a maximum of 24 inches (610 mm) apart around the periphery of each unit with not less than four ties per veneer unit. Units shall not exceed 20 square feet (1.9 m^2) in area.

If the dowels are not tightfitting, the holes may be drilled not more than $^1/_{16}$ inch (1.6 mm) larger in diameter than the dowel with the hole countersunk to a diameter and depth equal to twice the diameter of the dowel in order to provide a tightfitting key of cement mortar at the dowel locations when the mortar in the joint has set.

All veneer ties shall be corrosion-resistant metal capable of resisting in tension or compression a force equal to two times the weight of the attached veneer.

If made of sheet metal, veneer ties shall not be smaller in area than 0.030 inch (0.76 mm) (No. 22 galvanized sheet gage) by 1 inch (25 mm) or, if made of wire, not smaller in diameter than 0.148-inch (3.76 mm) (No. 9 B.W. gage) wire.

1403.6.4.5 Terra cotta or ceramic units. Tied terra cotta or ceramic veneer units shall not be less than $1^1/_4$ inches (32 mm) in thickness with projecting dovetail webs on the back surface spaced approximately 8 inches (203 mm) on centers. The facing shall be tied to the backing wall with noncorrosive metal anchors of not less than 0.165-inch (4.19 mm) (No. 8 B.W. gage) wire installed at the top of each piece in horizontal bed joints not less than 12 inches (305 mm) or more than 18 inches (457 mm) on centers; these anchors shall be secured to $^1/_4$-inch (6.4 mm) galvanized pencil rods that pass through the vertical aligned loop anchors in the backing wall. The veneer ties shall have sufficient strength to support the full weight of the veneer in tension. The facing shall be set with not less than a 2-inch (51 mm) space from the backing wall and the space shall be filled solidly with portland cement grout and pea gravel. Immediately prior to setting, the backing wall and the facing shall be drenched with clean water and shall be distinctly damp when the grout is poured.

SECTION 1404 — VINYL SIDING

1404.1 General. Vinyl siding conforming to the requirements of this section and complying with UBC Standard 14-2 may be installed on exterior walls of buildings of Type V construction located in areas where the wind speed specified in Figure 16-1 does not exceed 80 miles per hour (129 km/h) and the building height is less than 40 feet (12 192 mm) in Exposure C. If construction is located in areas where wind speed exceeds 80 miles per hour (129 km/h) or building heights are in excess of 40 feet (12 192 mm), data indicating compliance with Chapter 16 must be submitted. Vinyl siding shall be secured to the building to provide weather protection for the exterior walls of the building.

1404.2 Application. The siding shall be applied over sheathing or materials listed in Section 2310. Siding shall be applied to conform with the weather-resistive barrier requirements in Section 1402.1. Siding and accessories shall be installed in accordance with approved manufacturer's instructions.

Nails used to fasten the siding and accessories shall have a minimum $^3/_8$-inch (9.5 mm) head diameter and 0.120-inch (3.05 mm) shank diameter. The nails shall be corrosion resistant and shall be long enough to penetrate the studs or nailing strip at least $^3/_4$ inch (19 mm). Where the siding is installed horizontally, the fastener spacing shall not exceed 16 inches (406 mm) horizontally and 12 inches (305 mm) vertically. Where the siding is installed vertically, the fastener spacing shall not exceed 12 inches (305 mm) horizontally and 12 inches (305 mm) vertically.

TABLE 14-A—CERAMIC TILE SETTING MORTARS

COAT		VOLUME TYPE 1 PORTLAND CEMENT	VOLUME TYPE S HYDRATED LIME	VOLUME SAND		MAXIMUM THICKNESS OF COAT (inches)	MINIMUM INTERVAL BETWEEN COATS (hours)
				Dry	Damp	× 25.4 for mm	
1. Walls and ceilings over 10 square feet (0.93 m^2)	Scratch	1	$^1/_2$	4	5	$^3/_8$	24
		1	0	3	4	$^3/_8$	24
		1	$^1/_2$	4	5	$^3/_4$	24
	Float or leveling	1	1	6	7	$^3/_4$	24
2. Walls and ceilings 10 square feet (0.93 m^2) or less	Scratch and float	1	$^1/_2$	$2^1/_2$	3	$^3/_8$ $^3/_4$	24
3. Floors	Setting bed	1	0	5	6	$1^1/_4$	—
		1	$^1/_{10}$	5	6	$1^1/_4$	—

Chapter 15
ROOFING AND ROOF STRUCTURES

SECTION 1501 — SCOPE

1501.1 General. Roofing assemblies, roof coverings and roof structures shall be as specified in this code and as otherwise required by this chapter.

Subject to the requirements of this chapter, combustible roofing and roof insulation may be used in any type of construction.

Skylights shall be constructed as required in Chapter 24.

For use of plastics in roofs, see Chapter 26.

For solar energy collectors located above or upon a roof, see Chapter 13.

1501.2 Standards of Quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards (see Sections 3503 and 3504).

1. **Roof coverings.**
   - 1.1 UL 55-A, Materials for Use in Construction of Built-up Roof Coverings
   - 1.2 UL 55-B, Class C Sheet Roofing and Shingles Made from Organic Felt
   - 1.3 ASTM A 570 and A 611, Sheet Metals
   - 1.4 UBC Standard 15-3, Wood Shakes
   - 1.5 ASTM C 222, Asbestos-Cement Shingles
   - 1.6 ASTM C 406, Slate Shingles
   - 1.7 UBC Standard 15-4, Wood Shingles
   - 1.8 UBC Standard 15-5, Roof Tile
   - 1.9 UBC Standard 15-6, Modified Bitumen, Thermoplastic and Thermoset Membranes Used for Roof Coverings
2. **Roofing materials.**
   - 2.1 ASTM D 312 and D 450, Roofing Asphalt and Coal Tar Bitumen
   - 2.2 UBC Standard 15-1, Roofing Aggregates
   - 2.3 ASTM A 219 and A 239, Corrosion-resistant Metals
   - 2.4 ASTM B 134, B 211 and B 250, Wire
   - 2.5 ASTM D 1970, Self-adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection
3. **Roofing test.**

   UBC Standard 15-2, Test Standard for Determining the Fire Retardancy of Roof Assemblies

SECTION 1502 — DEFINITIONS

For purposes of this chapter, certain terms are designated as follows:

BASE PLY is one layer of felt secured to the deck over which a built-up roof is applied.

BASE SHEET is a product used as the base ply in a built-up roofing membrane.

BUILT-UP ROOFING is two or more layers of felt cemented together and surfaced with a cap sheet, mineral aggregate, smooth coating or similar surfacing material.

BUILT-UP ROOFING PLY is a layer of felt in built-up roofing.

CAP SHEET is roof covering made of organic or inorganic fibers, saturated and coated on both sides with a bituminous compound, surfaced with mineral granules, mica, talc, ilmenite, inorganic fibers or similar materials.

CEMENTING is solidly mopped application of asphalt, cold liquid asphalt compound, coal tar pitch or other approved cementing material.

COMBINATION SHEET is a glass fiber felt integrally attached to kraft paper.

CORROSION-RESISTANT is any nonferrous metal or any metal having an unbroken surfacing of nonferrous metal, or steel with not less than 10 percent chromium or with not less than 0.20 percent copper.

EQUIVISCOUS TEMPERATURE (EVT) is the temperature determined by the manufacturer at which a bitumen attains the proper viscosity for built-up membrane applications.

FELT is matted organic or inorganic fibers, saturated or coated with bituminous compound.

FELT, NONBITUMINOUS SATURATED, is a felt for special-purpose roofing weighing no less than 12 pounds per 100 square feet (0.6 kg/m^2), not less than 0.022 inch (0.56 mm) in thickness, containing a fire- and water-retardant binder and reinforced with glass fibers running lengthwise of the sheet not more than $^1/_4$ inch (6.4 mm) apart.

INTERLAYMENT is a layer of felt or nonbituminous saturated felt not less than 18 inches (457 mm) wide, shingled between each course of roofing material.

INTERLOCKING ROOFING TILES are individual units, typically of clay or concrete, possessing matching riffed or interlocking vertical side joints that have been designed to restrict lateral movement and water penetration.

METAL ROOF COVERING is metal shingles or sheets for application on solid roof surfaces, and corrugated or otherwise shaped metal sheets or sections for application on roof frameworks or on solid roof surfaces.

MODIFIED BITUMEN MEMBRANE ROOF COVERING is one or more layers of polymer modified asphalt sheet membranes complying with UBC Standard 15-6. The sheet materials may be fully adhered or mechanically attached to the substrate or held in place with an appropriate ballast layer.

ROOF COVERING is a durable exterior surface material that provides weather protection for the building at the roof.

ROOFING ASSEMBLY includes the roof deck, substrate or thermal barrier, insulation, vapor retarder, underlayment, interlayment, base plies, roofing plies, and roof covering that is assigned a roofing classification.

ROOFING ASSEMBLY, FIRE RETARDANT, is a roofing assembly complying with UBC Standard 15-2 and listed as a Class A, Class B or Class C roofing assembly.

ROOFING CLASSIFICATION is the classification by Section 1504 assigned to a roof covering or roofing assembly.

ROOFING SQUARE is 100 square feet (9.3 m^2) of roof surface.

SPOT CEMENTING is discontinuous application of asphalt, cold liquid asphalt compound, coal tar pitch or other approved cementing material.

THERMOPLASTIC MEMBRANE ROOF COVERING is a sheet membrane composed of polymers and other proprietary ingredients, in compliance with UBC Standard 15-6, whose chemical composition allows the sheet to be welded together by either heat or solvent throughout its service life.

THERMOSET MEMBRANE ROOF COVERING is a sheet membrane composed of polymers and other proprietary ingredients, in compliance with UBC Standard 15-6, whose chemical composition vulcanizes or cross-links during manufacture or during its service life.

TILES are roof covering units, typically clay, concrete or cement-based material, that comply with UBC Standard 15-5.

UNDERLAYMENT is one or more layers of felt, sheathing paper, nonbituminous saturated felt or other approved material over which a roofing system is applied.

VAPOR RETARDER is a layer of material or a laminate used to appreciably reduce the flow of water vapor into the roofing system.

WOOD SHAKES are split or sawn tapered or nontapered pieces of approved durable wood or taper-sawn pieces of approved preservative treated wood complying with UBC Standard 15-3.

WOOD SHAKES AND SHINGLES, FIRE-RETARDANT (treated), are wood shakes and shingles complying with UBC Standard 15-3 or 15-4 impregnated by the full-cell vacuum-pressure process with fire-retardant chemicals, complying with UBC Standard 15-2 for use on Class A, B or C roofs.

WOOD SHINGLES are tapered pieces of approved durable wood sawn both sides complying with UBC Standard 15-4.

SECTION 1503 — ROOFING REQUIREMENTS

The roof covering or roofing assembly on any structure regulated by this code shall be as specified in Table 15-A and as classified in Section 1504. Noncombustible roof covering as defined in Section 1504.2 may be applied in accordance with the manufacturer's requirements in lieu of a fire-retardant roofing assembly.

Roofing shall be secured or fastened to the supporting roof construction and shall provide weather protection for the building at the roof.

SECTION 1504 — ROOFING CLASSIFICATION

1504.1 Fire-retardant Roofing. Fire-retardant roofs are roofing assemblies complying with UBC Standard 15-2 and listed as Class A, B or C roofs.

1504.2 Noncombustible Roof Covering. Noncombustible roof covering shall be one of the following:

1. Cement shingles or sheets.
2. Exposed concrete slab roof.
3. Ferrous or copper shingles or sheets.
4. Slate shingles.
5. Clay or concrete roofing tile.
6. Approved roof covering of noncombustible material.

1504.3 Nonrated Roofing. Nonrated roofing is approved material that is not listed as a Class A, B or C roofing assembly.

SECTION 1505 — ATTICS: ACCESS, DRAFT STOPS AND VENTILATION

1505.1 Access. An attic access opening shall be provided to attics of buildings with combustible ceiling or roof construction.

> **EXCEPTION:** Attics with a maximum vertical height of less than 30 inches (762 mm).

The opening shall not be less than 22 inches (559 mm) by 30 inches (762 mm) and shall be located in a corridor, hallway or other readily accessible location. Thirty-inch-minimum (762 mm) unobstructed headroom in the attic space shall be provided at or above the access opening.

1505.2 Draft Stops. Attics, mansards, overhangs and other concealed roof spaces formed of combustible construction shall be draft stopped as specified in Section 708.3.

1505.3 Ventilation. Where determined necessary by the building official due to atmospheric or climatic conditions, enclosed attics and enclosed rafter spaces formed where ceilings are applied directly to the underside of roof rafters shall have cross ventilation for each separate space by ventilating openings protected against the entrance of rain and snow. The net free ventilating area shall not be less than $^1/_{150}$ of the area of the space ventilated.

> **EXCEPTIONS:** 1. The opening area may be $^1/_{300}$ of the area of the space ventilated provided 50 percent of the required opening area is provided by ventilators located in the upper portion of the space to be ventilated at least 3 feet (914 mm) above eave or cornice vents with the balance of the required ventilation provided by eave or cornice vents.
>
> 2. The opening area may be $^1/_{300}$ of the area of the space ventilated provided a vapor barrier not exceeding 1 perm [5.7 $\times$ 10^{-11} kg/(Pa $\cdot$ s $\cdot$ m^2)] is installed on the warm side of the attic insulation.

Where eave or cornice vents are installed, insulation shall not block the free flow of air. A minimum of 1 inch (25 mm) of air space shall be provided between the insulation and roof sheathing.

Openings for ventilation shall be covered with corrosion-resistant metal mesh with mesh openings of $^1/_4$ inch (6.4 mm) in dimension.

Smoke and heat venting shall be in accordance with Section 906.

SECTION 1506 — ROOF DRAINAGE

1506.1 General. Roofs shall be sloped a minimum of 1 unit vertical in 48 units horizontal (2% slope) for drainage unless designed for water accumulation in accordance with Section 1611 and approved by the building official.

1506.2 Roof Drains. Unless roofs are sloped to drain over roof edges, roof drains shall be installed at each low point of the roof.

Roof drains shall be sized and discharged in accordance with the Plumbing Code.

1506.3 Overflow Drains and Scuppers. Where roof drains are required, overflow drains having the same size as the roof drains shall be installed with the inlet flow line located 2 inches (51 mm) above the low point of the roof, or overflow scuppers having three times the size of the roof drains and having a minimum opening height of 4 inches (102 mm) may be installed in the adjacent parapet walls with the inlet flow line located 2 inches (51 mm) above the low point of the adjacent roof.

Overflow drains shall discharge to an approved location and shall not be connected to roof drain lines.

1506.4 Concealed Piping. Roof drains and overflow drains, where concealed within the construction of the building, shall be installed in accordance with the Plumbing Code.

1506.5 Over Public Property. Roof drainage water from a building shall not be permitted to flow over public property.

EXCEPTION: Group R, Division 3 and Group U Occupancies.

SECTION 1507 — ROOF-COVERING MATERIALS AND APPLICATION

1507.1 Materials. The quality and design of roofing materials and their fastenings shall conform to the applicable standards listed in Chapter 35, Part II.

1507.2 Identification. All material shall be delivered in packages bearing the manufacturer's label or identifying mark.

Each package of asphalt shingles, mineral surfaced roll roofing, fire-retardant-treated wood shingles and shakes, modified bitumen, thermoplastic and thermoset membranes, and built-up roofing ply materials shall bear the label of an approved agency having a service for the inspection of material and finished products during manufacture.

Each bundle of wood shakes or shingles shall comply with UBC Standard 15-3 or 15-4, respectively. Each bundle of wood shakes or shingles and slate shingles shall bear the label or identification mark of an approved inspection bureau or agency showing the grade.

Asphalt shall be delivered in cartons indicating the name of the manufacturer, the flash point and the type of product. Bulk shipments shall be accompanied with the same information issued in the form of a certification or on the bill of lading by the manufacturer. Coal tar pitch shall bear the manufacturer's name and type. Additional information such as equiviscous temperature (EVT) may be furnished.

1507.3 Asbestos-cement Roofing. Corrugated asbestos-cement roofing shall be applied in an approved manner.

1507.4 Asbestos-cement Shingles. Asbestos-cement shingles shall be installed in an approved manner.

1507.5 Asphalt Shingles. Asphalt shingles shall be fastened according to the manufacturer's instructions and Table 15-B-1.

1507.6 Built-up Roofs. Built-up roofing shall be applied in accordance with the manufacturer's instructions and Tables 15-E through 15-G.

1507.7 Clay or Concrete Tile. Tile of clay or concrete shall comply with UBC Standard 15-5 and shall be installed in accordance with the manufacturer's instructions and Tables 15-D-1 and 15-D-2.

1507.8 Metal Roof Covering. Metal roof covering exposed to the weather shall be corrosion resistant.

Corrugated or ribbed steel shall not be less than 0.013 inch (0.33 mm) (No. 30 galvanized sheet gage).

Flat steel sheets shall not be less than 0.013 inch (0.33 mm) (No. 30 galvanized sheet gage). Other ferrous sections or shapes shall not be less than No. 26 galvanized sheet gage.

Flat nonferrous sheets shall not be less than 0.0159 inch (0.40 mm) (No. 28 B.&S. gage). Other nonferrous sections or shapes shall not be less than 0.0179 inch (0.45 mm) (No. 25 B.&S. gage).

Corrugated or otherwise shaped sheets or sections shall be designed to support the loads required by Chapter 16.

Ferrous sheets or sections shall comply with Chapter 22, Division V.

1507.9 Metal Shingles. Metal shingles shall be applied in an approved manner. Nonferrous shingles shall not be less than 0.0159 inch (0.40 mm) (No. 28 B.&S. gage).

1507.10 Sheet Roof Covering. Sheet roof covering shall be installed in an approved manner.

1507.11 Slate Shingles. Slate shingles shall be installed in an approved manner.

1507.12 Wood Shakes. Shakes shall comply with UBC Standard 15-3 and shall be installed in accordance with Table 15-B-2.

1507.13 Wood Shingles. Shingles shall comply with UBC Standard 15-4 and shall be installed in accordance with Table 15-B-2.

1507.14 Modified Bitumen, Thermoplastic and Thermoset Membranes. Modified bitumen, thermoplastic and thermoset roof membranes shall be applied in accordance with the manufacturer's instructions.

SECTION 1508 — VALLEY FLASHING

1508.1 Valleys. Roof valley flashings shall be as noted in this section. Shingle application shall be consistent with applicable Table 15-B-1, 15-B-2, 15-D-1 or 15-D-2.

1508.2 Asphalt Shingles. The roof valley flashing shall not be provided of less than 0.016-inch (0.41 mm) (No. 28 galvanized sheet gage) corrosion-resistant metal, and shall extend at least 8 inches (203 mm) from the center line each way. Sections of flashing shall have an end lap of not less than 4 inches (102 mm). Alternatively, the valley shall consist of woven asphalt shingles applied in accordance with the manufacturer's printed instructions.

In each case, the roof valley flashing shall have a 36-inch-wide (914 mm) underlayment directly under it consisting of one layer of Type 15 felt running the full length of the valley, in addition to the underlayment specified in Table 15-B-1. In severe climates, the metal valley flashing underlayment shall be solid cemented to the roof underlayment for slopes under 7 units vertical in 12 units horizontal (58.3% slope).

1508.3 Metal Shingles. The roof valley flashing shall not be provided of less than 0.016-inch (0.41 mm) (No. 28 galvanized sheet gage) corrosion-resistant metal, which shall extend at least 8 inches (203 mm) from the center line each way and shall have a splash diverter rib not less than $^3/_4$ inch (19 mm) high at the flow line formed as part of the flashing. Sections of flashing shall have an end lap of not less than 4 inches (102 mm). The metal valley flashing shall have a 36-inch-wide (914 mm) underlayment directly under it consisting of one layer of Type 15 felt running the full length of the valley, in addition to underlayment required for metal shingles. In severe climates, the metal valley flashing underlayment shall be solid cemented to the roofing underlayment for roof slopes under 7 units vertical in 12 units horizontal (58.3% slope).

1508.4 Asbestos-cement Shingles, Slate Shingles, and Clay and Concrete Tile. The roof valley flashing shall not be provided of less than 0.016-inch (0.41 mm) (No. 28 galvanized sheet gage) corrosion-resistant metal, which shall extend at least 11 inches (279 mm) from the center line each way and shall have a splash diverter rib not less than 1 inch (25 mm) high at the flow line formed as part of the flashing. Sections of flashing shall have an end lap of not less than 4 inches (102 mm). For roof slopes of 3 units vertical in 12 units horizontal (25% slope) and over, the metal valley flashing shall have a 36-inch-wide (914 mm) underlayment directly under it consisting of one layer of Type 15 felt running the full length of the valley, in addition to the underlayment specified in Tables 15-D-1 and 15-D-2. In severe climates, the metal valley flashing underlayment shall be solid cemented to the roofing underlayment for slopes under 7 units vertical in 12 units horizontal (58.3% slope).

1508.5 Wood Shingles and Wood Shakes. The roof valley flashing shall not be provided of less than 0.016-inch (0.41 mm) (No. 28 galvanized sheet gage) corrosion-resistant metal, which shall extend at least 8 inches (203 mm) from the center line each way for wood shingles and 11 inches (279 mm) from the center line each way for wood shakes. Sections of flashing shall have an overlap of not less than 4 inches (102 mm). The metal valley flashing shall have a 36-inch-wide (914 mm) underlayment directly under it consisting of one layer of Type 15 felt running the full length of the valley, in addition to underlayment specified in Table 15-B-2. In severe climates, the metal valley flashing underlayment shall be solid cemented to the roofing underlayment for roof slopes under 7 units vertical in 12 units horizontal (58.3% slope).

EXCEPTION: Where local practice indicates satisfactory performance, the building official may permit valley flashing without underlayment.

SECTION 1509 — OTHER FLASHING

At the juncture of the roof and vertical surfaces, flashing and counterflashing shall be provided per the roofing manufacturer's instructions and, when of metal, shall not be less than 0.019-inch (0.48 mm) (No. 26 galvanized sheet gage) corrosion-resistant metal.

SECTION 1510 — ROOF INSULATION

Roof insulation shall be of a rigid type suitable as a base for application of a roof covering. Foam plastic roof insulation shall conform to the requirements of Section 2602. The use of insulation in fire-resistive construction shall comply with Section 710.1.

The roof insulation, deck material and roof covering shall meet the fire-retardancy requirements of Section 1504 and Table 15-A.

Insulation for built-up roofs shall be applied in accordance with Table 15-E. Insulation for modified bitumen, thermoplastic and thermoset membrane roofs shall be applied in accordance with the roofing manufacturer's recommendations. For other roofing materials such as shingles or tile, the insulation shall be covered with a suitable nailing base secured to the structure.

SECTION 1511 — PENTHOUSES AND ROOF STRUCTURES

1511.1 Height. In buildings other than Type I construction, penthouses or other roof structures shall not exceed 28 feet (8534 mm) in height above the roof surface.

1511.2 Area. The aggregate area of all penthouses and other roof structures shall not exceed $33^1/_3$ percent of the area of the supporting roof.

1511.3 Prohibited Uses. No penthouse, bulkhead or any other similar projection above the roof shall be used for purposes other than shelter of mechanical equipment or shelter of vertical shaft openings in the roof. Penthouses or bulkheads used for purposes other than permitted by this section shall conform to the requirements of this code for an additional story.

1511.4 Construction. Roof structures shall be constructed with walls, floors and roof as required for the main portion of the building.

EXCEPTIONS: 1. On Types I and II-F.R. buildings, the exterior walls and roofs of penthouses that are 5 feet (1524 mm) or more from an adjacent property line may be of one-hour fire-resistive noncombustible construction.

2. On Types III and IV buildings, walls not less than 5 feet (1524 mm) from an adjacent property line may be of one-hour fire-resistive noncombustible construction.

3. Enclosures housing only mechanical equipment and located at least 20 feet (6096 mm) from adjacent property lines may be of unprotected noncombustible construction.

4. On one-story buildings, unroofed mechanical equipment screens, fences or similar enclosures may be of combustible construction when located at least 20 feet (6096 mm) from adjacent property lines and when not exceeding 4 feet (1219 mm) in height above the roof surface.

The restrictions of this section shall not prohibit the placing of wood flagpoles or similar structures on the roof of any building.

SECTION 1512 — TOWERS AND SPIRES

Towers or spires when enclosed shall have exterior walls as required for the building to which they are attached. Towers not enclosed and which extend more than 75 feet (22 860 mm) above grade shall have their framework constructed of iron, steel or reinforced concrete. No tower or spire shall occupy more than one fourth of the street frontage of any building to which it is attached and in no case shall the base area exceed 1,600 square feet (149 m^2) unless it conforms entirely to the type of construction requirements of the building to which it is attached and is limited in height as a main part of the building. If the area of the tower or spire exceeds 100 square feet (9.29 m^2) at any horizontal cross section, its supporting frame shall extend directly to the ground. The roof covering of spires shall be as required for the main roof of the rest of the structure.

Skeleton towers used as radio masts and placed on the roof of any building shall be constructed entirely of noncombustible materials when more than 25 feet (7620 mm) in height and shall be directly supported on a noncombustible framework to the ground. They shall be designed to withstand a wind load from any direction as specified in Chapter 16, Division III, in addition to any other loads.

SECTION 1513 — ACCESS TO ROOFTOP EQUIPMENT

Access shall be provided to all mechanical equipment located on the roof as required by the Mechanical Code.

TABLE 15-A—MINIMUM ROOF CLASSES

OCCUPANCY	TYPES OF CONSTRUCTION								
	I	II			III		IV	V	
	F.R.	F.R.	One-hour	N	One-hour	N	H.T.	One-hour	N
A-1	B	B	—	—	—	—	—	—	—
A) 2-2.1	B	B	B	—	B	—	B	B	—
A-3	B	B	B	B	B[1]	C	B[1]	B[1]	C
A-4	B	B	B	B	B	B	B	B	B[1]
B	B	B	B	B	B[1]	C	B[1]	B[1]	C
E	B	B	B	B	B	B	B	B	B[1]
F	B	B	B	B	B[1]	C	B[1]	B[1]	C
H-1	A	A	A	A	—	—	—	—	—
H) 2-3-4-5-6-7	A	B	B	B	B	B	B	B	B
I) 1.1-1.2-2	A	B	B	—	B	—	B	B	—
I-3	A	B	B[1]	—	B[2]	—	—	B[3]	—
M	B	B	B	B	B[1]	C	B[1]	B[1]	C
R-1	B	B	B	B	B[1,3]	C[3]	B[1,3]	B[1,3]	C[3]
R-3	B	B	B	B	NR	NR	NR	NR	NR
S-1, S-3	B	B	B	B	B[1]	C	B[1]	B[1]	C
S-2, S-5	B	B	B	B	B	B	B	B	B[1]
S-4	B	B	B	B	—	—	—	—	—
U	B	B	B	B	NR[4]	NR[4]	NR[4]	NR[4]	NR[4]

A—Class A roofing.
B—Class B roofing.
C—Class C roof covering.
F.R.—Fire resistive.
H.T.—Heavy timber.
N—No requirements for fire resistance.
NR—Nonrated roof coverings.

[1]Buildings that are not more than two stories in height and have not more than 6,000 square feet (557 m^2) of projected roof area and where there is a minimum of 10 feet (3048 mm) from the extremity of the roof to the property line or assumed property line on all sides except for street fronts may have Class C roof coverings that comply with UBC Standard 15-2.

[2]See Section 308.2.2.

[3]Nonrated roof coverings may be used on buildings that are not more than two stories in height and have not more than 3,000 square feet (279 m^2) of projected roof area and where there is a minimum of 10 feet (3048 mm) from the extremity of the roof to the property line on all sides except for street fronts.

[4]Unless otherwise required because of location, Group U, Division 1 roof coverings shall consist of not less than one layer of cap sheet, or built-up roofing consisting of two layers of felt and a surfacing material of 300 pounds per roofing square (14.6 kg/m^2) of gravel or other approved surfacing material, or 250 pounds (12.2 kg/m^2) of crushed slag.

TABLE 15-B-1—ASPHALT SHINGLE APPLICATION

ASPHALT SHINGLES		
	Not Permitted below 2 Units Vertical in 12 Units Horizontal (16.7% Slope)	
Roof Slope	2 Units Vertical in 12 Units Horizontal (16.7% Slope) to Less than 4 Units Vertical in 12 Units Horizontal (33.3% Slope)	4 Units Vertical in 12 Units Horizontal (33.3% Slope) and Over
1. Deck requirement	Asphalt shingles shall be fastened to solidly sheathed roofs. Sheathing shall conform to Sections 2312.2 and 2320.12.9.	
2. Underlayment Temperate climate	Asphalt strip shingles may be installed on slopes as low as 2 units vertical in 12 units horizontal (16.7% slope), provided the shingles are approved self-sealing or are hand sealed and are installed with an underlayment consisting of two layers of nonperforated Type 15 felt applied shingle fashion. Starting with an 18-inch-wide (457 mm) sheet and a 36-inch-wide (914 mm) sheet over it at the eaves, each subsequent sheet shall be lapped 19 inches (483 mm) horizontally.	One layer nonperforated Type 15 felt lapped 2 inches (51 mm) horizontally and 4 inches (102 mm) vertically to shed water.
Severe climate: In areas subject to wind-driven snow or roof ice buildup	Same as for temperate climate, and the two layers shall be solid cemented together with approved cementing material between the plies extending from the eave up the roof to a line 24 inches (610 mm) inside the exterior wall line of the building. As an alternative to the two layers of cemented Type 15 felt, an approved self-adhering, polymer modified, bituminous sheet may be used.	Same as for temperate climate, except that one layer No. 40 coated roofing or coated glass base shall be applied from the eaves to a line 12 inches (305 mm) inside the exterior wall line with all laps cemented together. As an alternative to the layer of No. 40 felt, a self-adhering, polymer modified, bituminous sheet may be used.
3. Attachment Combined systems, type of fasteners	Corrosion-resistant nails, minimum 12-gage $^3/_8$-inch (9.5 mm) head, or approved corrosion-resistant staples, minimum 16-gage $^{15}/_{16}$-inch (23.8 mm) crown width. Fasteners shall comply with the requirements of Chapter 23, Division III, Part III. Fasteners shall be long enough to penetrate into the sheathing $^3/_4$ inch (19 mm) or through the thickness of the sheathing, whichever is less.	
No. of fasteners[1]	4 per 36-inch to 40-inch (914 mm to 1016 mm) strip 2 per 9-inch to 18-inch (229 mm to 457 mm) shingle	
Exposure Field of roof Hips and ridges	Per manufacturer's instructions included with packages of shingles. Hip and ridge weather exposures shall not exceed those permitted for the field of the roof.	
Method	Per manufacturer's instructions included with packages of shingles.	
4. Flashing Valleys Other flashing	Per Section 1508.2 Per Section 1509	

[1]Figures shown are for normal application. For special conditions, such as mansard application and where roofs are in special wind regions, shingles shall be attached per the manufacturer's instructions.

TABLE 15-B-2—WOOD SHINGLE OR SHAKE APPLICATION

ROOF SLOPE	WOOD SHINGLES	WOOD SHAKES
	Not Permitted below 3 Units Vertical in 12 Units Horizontal (25% Slope)	Not Permitted below 4 Units Vertical in 12 Units Horizontal (33.3% Slope)[1]
	See Table 15-C	See Table 15-C
1. Deck requirement	Shingles and shakes shall be applied to roofs with solid or spaced sheathing. When spaced sheathing is used, sheathing boards shall not be less than 1 inch by 4 inches (25 mm by 102 mm) nominal dimensions and shall be spaced on centers equal to the weather exposure to coincide with the placement of fasteners. When 1-inch-by-4-inch (25 mm by 102 mm) spaced sheathing is installed at 10 inches (254 mm) on center, additional 1-inch-by-4-inch (25 mm by 102 mm) boards must be installed between the sheathing boards. Sheathing shall conform to Sections 2312.2 and 2320.12.9.	
2. Interlayment	No requirements.	One 18-inch-wide (457 mm) interlayment of Type 30 felt shingled between each course in such a manner that no felt is exposed to the weather below the shake butts and in the keyways (between the shakes).
3. Underlayment Temperate climate	No requirements.	No requirements.
Severe climate: In areas subject to wind-driven snow or roof ice buildup	Two layers of nonperforated Type 15 felt applied shingle fashion shall be installed and solid cemented together with approved cementing material between the plies extending from the eave up the roof to a line 36 inches (914 mm) inside the exterior wall line of the building.	Sheathing shall be solid and, in addition to the interlayment of felt shingled between each course in such a manner that no felt is exposed to the weather below the shake butts, the shakes shall be applied over a layer of nonperforated Type 15 felt applied shingle fashion. Two layers of nonperforated Type 15 felt applied shingle fashion shall be installed and solid cemented together with approved cementing material between the plies extending from the eave up the roof to a line 36 inches (914 mm) inside the exterior wall line of the building.
4. Attachment Type of fasteners	Corrosion-resistant nails, minimum No. $14^1/_2$-gage, $^7/_{32}$-inch (5.6 mm) head, or corrosion-resistant staples, when approved by the building official.	Corrosion-resistant nails, minimum No. 13-gage, $^7/_{32}$-inch (5.6 mm) head, or corrosion-resistant staples, when approved by the building official.
	Fasteners shall comply with the requirements of Chapter 23, Division III, Part III. Fasteners shall be long enough to penetrate into the sheathing $^3/_4$ inch (19 mm) or through the thickness of the sheathing, whichever is less.	
No. of fasteners	2 per shingle	2 per shake
Exposure Field of roof Hips and ridges	Weather exposures shall not exceed those set forth in Table 15-C. Hip and ridge weather exposure shall not exceed those permitted for the field of the roof.	
Method	Shingles shall be laid with a side lap of not less than $1^1/_2$ inches (38 mm) between joints in adjacent courses, and not in direct alignment in alternate courses. Spacing between shingles shall be approximately $^1/_4$ inch (6.4 mm). Each shingle shall be fastened with two nails only, positioned approximately $^3/_4$ inch (19 mm) from each edge and approximately 1 inch (25 mm) above the exposure line. Starter course at the eaves shall be doubled.	Shakes shall be laid with a side lap of not less than $1^1/_2$ inches (38 mm) between joints in adjacent courses. Spacing between shakes shall not be less than $^3/_8$ inch (9.5 mm) or more than $^5/_8$ inch (15.9 mm) except for preservative-treated wood shakes, which shall have a spacing not less than $^1/_4$ inch (6.4 mm) or more than $^3/_8$ inch (9.5 mm). Shakes shall be fastened to the sheathing with two nails only, positioned approximately 1 inch (25 mm) from each edge and approximately 2 inches (51 mm) above the exposure line. The starter course at the eaves shall be doubled. The bottom or first layer may be either shakes or shingles. Fifteen-inch or 18-inch (381 mm or 457 mm) shakes may be used for the starter course at the eaves and final course at the ridge.
5. Flashing Valleys Other flashing	Per Section 1508.5 Per Section 1509	

[1]When approved by the building official, wood shakes may be installed on a slope of not less than 3 units vertical in 12 units horizontal (25% slope) when an underlayment of not less than nonperforated Type 15 felt is installed.

TABLE 15-C—MAXIMUM WEATHER EXPOSURE

GRADE LENGTH	3 UNITS VERTICAL TO LESS THAN 4 UNITS VERTICAL IN 12 UNITS HORIZONTAL (25% ≤ 33.3% SLOPE)	4 UNITS VERTICAL IN 12 UNITS HORIZONTAL (33.3% SLOPE)
	× 25.4 for mm	
	Wood Shingles	
1. No. 1 16-inch	$3^3/_4$	5
2. No. 2[1] 16-inch	$3^1/_2$	4
3. No. 3[1] 16-inch	3	$3^1/_2$
4. No. 1 18-inch	$4^1/_4$	$5^1/_2$
5. No. 2[1] 18-inch	4	$4^1/_2$
6. No. 3[1] 18-inch	$3^1/_2$	4
7. No. 1 24-inch	$5^3/_4$	$7^1/_2$
8. No. 2[1] 24-inch	$5^1/_2$	$6^1/_2$
9. No. 3[1] 24-inch	5	$5^1/_2$
	Wood Shakes[2]	
10. No. 1 18-inch	$7^1/_2$	$7^1/_2$
11. No. 1 24-inch	10	10
12. No. 2 18-inch tapersawn shakes	—	$5^1/_2$
13. No. 2 24-inch tapersawn shakes	—	$7^1{}_2$

[1]To be used only when specifically permitted by the building official.
[2]Exposure of 24-inch by $^3/_8$-inch (610 mm by 9.5 mm) resawn handsplit shakes shall not exceed 5 inches (127 mm) regardless of the roof slope.

TABLE 15-D-1—ROOFING TILE APPLICATION[1] FOR ALL TILES

	ROOF SLOPE $2^1/_2$ UNITS VERTICAL IN 12 UNITS HORIZONTAL (21% Slope) TO LESS THAN 3 UNITS VERTICAL IN 12 UNITS HORIZONTAL (25% Slope)	ROOF SLOPE 3 UNITS VERTICAL IN 12 UNITS HORIZONTAL (25% Slope) AND OVER
1. Deck requirements	Solid sheathing per Sections 2312.2 and 2320.12.9	
2. Underlayment In climate areas subject to wind-driven snow, roof ice damming or special wind regions as shown in Chapter 16, Figure 16-1.	Built-up roofing membrane, three plies minimum, applied per Section 1507.6. Surfacing not required.	Same as for other climate areas, except that extending from the eaves up the roof to a line 24 inches (610 mm) inside the exterior wall line of the building, two layers of underlayment shall be applied shingle fashion and solidly cemented together with an approved cementing material.
Other climate areas		One layer heavy-duty felt or Type 30 felt side lapped 2 inches (51 mm) and end lapped 6 inches (153 mm).
3. Attachment[2] Type of fasteners	Corrosion-resistant nails not less than No. 11 gage, $^5/_{16}$-inch (7.9 mm) head. Fasteners shall comply with the requirements of Chapter 23, Division III, Part III. Fasteners shall be long enough to penetrate into the sheathing $^3/_4$ inch (19 mm) or through the thickness of the sheathing, whichever is less. Attaching wire for clay or concrete tile shall not be smaller than 0.083 inch (2.11 mm) (No. 14 B.W. gage).	
Number of fasteners[2,3]	One fastener per tile. Flat tile without vertical laps, two fasteners per tile.	Two fasteners per tile. Only one fastener on slopes of 7 units vertical in 12 units horizontal (58.3% slope) and less for tiles with installed weight exceeding 7.5 pounds per square foot (36.6 kg/m^2) having a width no greater than 16 inches (406 mm).[4]
4. Tile headlap	3 inches (76 mm) minimum.	
5. Flashing	Per Sections 1508.4 and 1509.	

[1]In snow areas, a minimum of two fasteners per tile are required.
[2]In areas designated by the building official as being subject to repeated wind velocities in excess of 80 miles per hour (129 km/h) or where the roof height exceeds 40 feet (12 192 mm) above grade, all tiles shall be attached as follows:
2.1 The heads of all tiles shall be nailed.
2.2 The noses of all eave course tiles shall be fastened with approved clips.
2.3 All rake tiles shall be nailed with two nails.
2.4 The noses of all ridge, hip and rake tiles shall be set in a bead of approved roofer's mastic.
[3]In snow areas, a minimum of two fasteners per tile are required, or battens and one fastener.
[4]On slopes over 24 units vertical in 12 units horizontal (200% slope), the nose end of all tiles shall be securely fastened.

TABLE 15-D-2—CLAY OR CONCRETE ROOFING TILE APPLICATION INTERLOCKING TILE WITH PROJECTING ANCHOR LUGS— MINIMUM ROOF SLOPE 4 UNITS VERTICAL IN 12 UNITS HORIZONTAL (33.3% Slope)

ROOF SLOPE	4 UNITS VERTICAL IN 12 UNITS HORIZONTAL (33.3% Slope) AND OVER
1. Deck requirements	Spaced structural sheathing boards or solid roof sheathing.
2. Underlayment In climate areas subject to wind-driven snow, roof ice or special wind regions as shown in Chapter 16, Figure 16-1.	Solid sheathing one layer of Type 30 felt lapped 2 inches (51 mm) horizontally and 6 inches (152 mm) vertically, except that extending from the eaves up the roof to line 24 inches (610 mm) inside the exterior wall line of the building, two layers of the underlayment shall be applied shingle fashion and solid cemented together with approved cementing material.
Other climates	For spaced sheathing, approved reinforced membrane. For solid sheathing, one layer heavy-duty felt or Type 30 felt lapped 2 inches (51 mm) horizontally and 6 inches (152 mm) vertically.
3. Attachment[1] Type of fasteners	Corrosion-resistant nails not less than No. 11 gage, $^5/_{16}$-inch (7.9 mm) head. Fasteners shall comply with the requirements of Chapter 23, Division III, Part III. Fasteners shall be long enough to penetrate into the battens[2] or sheathing $^3/_4$ inch (19 mm) or through the thickness of the sheathing, whichever is less. Attaching wire for clay or concrete tile shall not be smaller than 0.083 inch (2.11 mm) (No. 14 B.W. gage). Horizontal battens are required on solid sheathing for slopes 7 units vertical in 12 units horizontal (58.3% slope) and over.[2] Horizontal battens are required for slopes over 7 units vertical in 12 units horizontal (58.3% slope).[2]
No. of fasteners with: Spaced/solid sheathing with battens, or spaced sheathing[3]	Below 5 units vertical in 12 units horizontal (41.7% slope), fasteners not required. Five units vertical in 12 units horizontal (41.7% slope) to less than 12 units vertical in 12 units horizontal (100% slope), one fastener per tile every other row. Twelve units vertical in 12 units horizontal (100% slope) to 24 units vertical in 12 units horizontal (200% slope), one fastener every tile.[4] All perimeter tiles require one fastener.[5] Tiles with installed weight less than 9 pounds per square foot (4.4 kg/m^2) require a minimum of one fastener per tile regardless of roof slope.
Solid sheathing without battens[3]	One fastener per tile.
4. Tile headlap	3-inch (76 mm) minimum.
5. Flashing	Per Sections 1508.4 and 1509.

[1]In areas designated by the building official as being subject to repeated wind velocities in excess of 80 miles per hour (129 km/h), or where the roof height exceeds 40 feet (12 192 mm) above grade, all tiles shall be attached as set forth below:
1.1 The heads of all tiles shall be nailed.
1.2 The noses of all eave course tiles shall be fastened with a special clip.
1.3 All rake tiles shall be nailed with two nails.
1.4 The noses of all ridge, hip and rake tiles shall be set in a bead of approved roofer's mastic.

[2]Battens shall not be less than 1-inch-by-2-inch (25 mm by 51 mm) nominal. Provisions shall be made for drainage beneath battens by a minimum of $^1/_8$-inch (3.2 mm) risers at each nail or by 4-foot-long (1219 mm) battens with at least $^1/_2$-inch (12.7 mm) separation between battens. Battens shall be fastened with approved fasteners spaced at not more than 24 inches (610 mm) on center.

[3]In snow areas, a minimum of two fasteners per tile are required, or battens and one fastener.

[4]Slopes over 24 units vertical in 12 units horizontal (200% slope), nose ends of all tiles must be securely fastened.

[5]Perimeter fastening areas include three tile courses but not less than 36 inches (914 mm) from either side of hips or ridges and edges of eaves and gable rakes.

TABLE 15-E—BUILT-UP ROOF-COVERING APPLICATION

	MECHANICALLY FASTENED SYSTEMS	ADHESIVELY FASTENED SYSTEMS
1. Deck conditions	Decks shall be firm, broom-clean, smooth and dry. Insulated decks shall have wood insulation stops at all edges of the deck, unless an alternative suitable curbing is provided. Insulated decks with slopes greater than 2 units vertical in 12 units horizontal (16.7% slope) shall have wood insulation stops at not more than 8 feet (2438 mm) face to face. Wood nailers shall be provided where nailing is required for roofing plies.	
	Solid wood sheathing shall conform to Sections 2312.2 and 2320.12.9.	Provide wood nailers where nailing is required for roofing plies (see below).
2. Underlayment	One layer of sheathing paper, Type 15 felt or other approved underlayment nailed sufficiently to hold in place, is required over board decks where openings between boards would allow bitumen to drip through. No underlayment requirements for plywood decks. Underlayment on other decks shall be in accordance with deck manufacturer's recommendations.	Not required.
3. Base ply requirements Over noninsulated decks	Over approved decks, the base ply shall be nailed using not less than one fastener for each $1^1/_3$ square feet (0.124 m^2).	Decks shall be primed in accordance with the roofing manufacturer's instructions. The base ply shall be solidly cemented or spot mopped as required by the type of deck material using adhesive application rates shown in Table 15-F.
4. Mechanical fasteners	Fasteners shall be long enough to penetrate $^3/_4$ inch (19 mm) into the sheathing or through the thickness of the sheathing, whichever is less. Built-up roofing nails for wood board decks shall be minimum No. 12 gage, $^7/_{16}$-inch (11.1 mm) head driven through tin caps or approved nails with integral caps. For plywood, No. 11 gage ring-shank nails driven through tin caps or approved nails with integral caps shall be used. For gypsum, insulating concrete, cementitious wood fiber and other decks, fasteners recommended by the manufacturer shall be used.	When mechanical fasteners are required for attachment of roofing plies to wood nailers or insulation stops (see below), they shall be as required for wood board decks.
5. Vapor retarder Over insulated decks	A vapor retarder shall be installed where the average January temperature is below 45°F (7°C), or where excessive moisture conditions are anticipated within the building. It shall be applied as for a base ply.	
6. Insulation	When no vapor retarder is required, roof insulation shall be fastened in an approved manner. When a vapor retarder is required, roof insulation is to be solidly mopped to the vapor retarder using the adhesive application rate specified in Table 15-F. See manufacturer's instructions for the attachment of insulation over steel decks.	When no vapor retarder is required, roof insulation shall be solid mopped to the deck using the adhesive application rate specified in Table 15-F. When a vapor retarder is required, roof insulation is to be solidly mopped to the vapor retarder, using the adhesive application rate specified in Table 15-F. See manufacturer's installation instructions for attachment of insulation over steel decks.
7. Roofing plies	Successive layers shall be solidly cemented together and to the base ply or the insulation using the adhesive rates shown in Table 15-F. On slopes greater than 1 unit vertical in 12 units horizontal (8.3% slope) for aggregate-surfaced, or 2 units vertical in 12 units horizontal (16.7% slope) for smooth-surfaced or cap sheet surfaced roofs, mechanical fasteners are required. Roofing plies shall be blind-nailed to the deck, wood nailers or wood insulation stops in accordance with the roofing manufacturer's recommendations. On slopes exceeding 3 units vertical in 12 units horizontal (25% slope), plies shall be laid parallel to the slope of the deck (strapping method).	
8. Cementing materials	See Table 15-G.	
9. Curbs and walls	Suitable cant strips shall be used at all vertical intersections. Adequate attachment shall be provided for both base flashing and counterflashing on all vertical surfaces. Reglets shall be provided in wall or parapets receiving metal counterflashing.	
10. Surfacing	Mineral aggregate surfaced roofs shall comply with the requirements of UBC Standard 15-1 and Table 15-F. Cap sheets shall be cemented to the roofing plies as set forth in Table 15-F.	

TABLE 15-F—BUILT-UP ROOFING CEMENTING ADHESIVE AND SURFACING APPLICATION RATES

MATERIAL TO BE ADHERED	MINIMUM APPLICATION RATE, MATERIAL/100 FT.² (9.3 m²) ROOF AREA		
	Hot Asphalt (pounds)	Hot Coal-tar (pounds)	Cold-process Cement (gallons)
	× 0.45 for kg	× 0.45 for kg	× 3.785 for liters
Base ply or vapor retarder			
1. Spot mopping	15	15	1
2. Solid cementing	20	20	$1^1/_2$
Insulation			
1. Solid cementing	20	20	$1^1/_2$
Roofing plies (and between layers of vapor retarder)			
1. Felts	20	20	Not permitted
2. Coated felts	20	20	$1^1/_2$
Cap sheets			
1. Solid cementing	20	Not permitted	$1^1/_2$
Mineral aggregate[1,2]			
1. Fire-retardant roof coverings			
1.1 Gravel, 400 lb./sq. (20.1 kg/m²)	50	60	4
1.2 Slag, 300 lb./sq. (15.1 kg/m²)	50	60	4
1.3 Granules, 60 lb./sq. (3 kg/m²)	—	—	3
2. Nonrated roof coverings			
2.1 Gravel, 300 lb./sq. (15.1 kg/m²)	40	50	4
2.2 Slag, 250 lb./sq. (12.6 kg/m²)	40	50	4
2.3 Granules, 60 lb./sq. (3 kg/m²)	—	—	3

[1]Mineral aggregate shall not be used for built-up roofing membranes at roof slopes greater than 3 units vertical in 12 units horizontal (25% slope).
[2]A minimum of 50 percent of the required aggregate shall be embedded in the pour coat.

TABLE 15-G—APPLICATION OF CEMENTING MATERIALS

APPLICATION	MAXIMUM SLOPE, VERTICAL UNITS PER 12 UNITS HORIZONTAL				
	Asphalt Type				Coal-tar Pitch
	Type I	Type II	Type III	Type IV	
1. Insulation to deck	—	—	All	All	—
2. Felt or vapor retarder to deck	—	$^1/_2$ (4% slope) or less	3 (25% slope) or less	All	$^1/_2$ (4% slope) or less
3. Felt to felt	—	$^1/_2$ (4% slope) or less	$^1/_2$ -3 (4%-25% slope)	All	$^1/_2$ (4% slope) or less
4. Cap sheet to felt	—	—	3 (25% slope) or less	All	—
5. Gravel to felts	$^1/_2$ (4% slope) or less	$^1/_2$ (4% slope) or less	$^1/_2$ -3 (4%-25% slope)	N.P.	$^1/_2$ (4% slope) or less
6. Heating of cementing material,[1] °F Temperature at kettle[2] (maximum)	475 (246°C)	525 (274°C)	525 (274°C)	525 (274°C)	425 (218°C)
Application temperature,[3] °F	375-425 (190-218°C)	375-425 (190-218°C)	375-425 (190-218°C)	400-450 (204-232°C)	350-400 (177-204°C)

N.P.—Not permitted.

[1]Bulk tanker temperatures shall be reduced to 320°F to 350°F (160°C to 177°C) at night or during periods when no roofing will occur.
[2]Cementing material shall not be heated above a temperature that is 25°F (14°C) below its flash point.
[3]Bitumen identified with the equiviscous temperature (EVT) shall be applied at the EVT ± 25°F (14°C).

Chapter 16 is printed in its entirety in Volume 2 of the *Uniform Building Code*.
Excerpts from Chapter 16 are reprinted herein.

Excerpts from Chapter 16
STRUCTURAL DESIGN REQUIREMENTS

SECTION 1601 — SCOPE

This chapter prescribes general design requirements applicable to all structures regulated by this code.

SECTION 1602 — DEFINITIONS

The following terms are defined for use in this code:

ALLOWABLE STRESS DESIGN is a method of proportioning structural elements such that computed stresses produced in the elements by the allowable stress load combinations do not exceed specified allowable stress (also called working stress design).

BALCONY, EXTERIOR, is an exterior floor system projecting from a structure and supported by that structure, with no additional independent supports.

DEAD LOADS consist of the weight of all materials and fixed equipment incorporated into the building or other structure.

DECK is an exterior floor system supported on at least two opposing sides by an adjoining structure and/or posts, piers, or other independent supports.

FACTORED LOAD is the product of a load specified in Sections 1606 through 1611 and a load factor. See Section 1612.2 for combinations of factored loads.

LIMIT STATE is a condition in which a structure or component is judged either to be no longer useful for its intended function (serviceability limit state) or to be unsafe (strength limit state).

LIVE LOADS are those loads produced by the use and occupancy of the building or other structure and do not include dead load, construction load, or environmental loads such as wind load, snow load, rain load, earthquake load or flood load.

LOAD AND RESISTANCE FACTOR DESIGN (LRFD) is a method of proportioning structural elements using load and resistance factors such that no applicable limit state is reached when the structure is subjected to all appropriate load combinations. The term "LRFD" is used in the design of steel and wood structures.

STRENGTH DESIGN is a method of proportioning structural elements such that the computed forces produced in the elements by the factored load combinations do not exceed the factored element strength. The term "strength design" is used in the design of concrete and masonry structures.

SECTION 1604 — STANDARDS

The standards listed below are recognized standards (see Section 3504).

1. Wind Design.
   - 1.1 ASCE 7, Chapter 6, Minimum Design Loads for Buildings and Other Structures
   - 1.2 ANSI EIA/TIA 222-E, Structural Standards for Steel Antenna Towers and Antenna Supporting Structures
   - 1.3 ANSI/NAAMM FP1001, Guide Specifications for the Design Loads of Metal Flagpoles

SECTION 1605 — DESIGN

1605.1 General. Buildings and other structures and all portions thereof shall be designed and constructed to sustain, within the limitations specified in this code, all loads set forth in Chapter 16 and elsewhere in this code, combined in accordance with Section 1612. Design shall be in accordance with Strength Design, Load and Resistance Factor Design or Allowable Stress Design methods, as permitted by the applicable materials chapters.

> **EXCEPTION:** Unless otherwise required by the building official, buildings or portions thereof that are constructed in accordance with the conventional light-framing requirements specified in Chapter 23 of this code shall be deemed to meet the requirements of this section.

1605.2 Rationality. Any system or method of construction to be used shall be based on a rational analysis in accordance with well-established principles of mechanics. Such analysis shall result in a system that provides a complete load path capable of transferring all loads and forces from their point of origin to the load-resisting elements. The analysis shall include, but not be limited to, the provisions of Sections 1605.2.1 through 1605.2.3.

1605.2.1 Distribution of horizontal shear. The total lateral force shall be distributed to the various vertical elements of the lateral-force-resisting system in proportion to their rigidities considering the rigidity of the horizontal bracing system or diaphragm. Rigid elements that are assumed not to be part of the lateral-force-resisting system may be incorporated into buildings, provided that their effect on the action of the system is considered and provided for in the design.

Provision shall be made for the increased forces induced on resisting elements of the structural system resulting from torsion due to eccentricity between the center of application of the lateral forces and the center of rigidity of the lateral-force-resisting system. For accidental torsion requirements for seismic design, see Section 1630.6.

1605.2.2 Stability against overturning. Every structure shall be designed to resist the overturning effects caused by the lateral forces specified in this chapter. See Section 1611.6 for retaining walls, Section 1615 for wind and Section 1626 for seismic.

1605.2.3 Anchorage. Anchorage of the roof to walls and columns, and of walls and columns to foundations, shall be provided to resist the uplift and sliding forces that result from the application of the prescribed forces.

Concrete and masonry walls shall be anchored to all floors, roofs and other structural elements that provide lateral support for the wall. Such anchorage shall provide a positive direct connection capable of resisting the horizontal forces specified in this chapter but not less than the minimum forces in Section 1611.4. In addition, in Seismic Zones 3 and 4, diaphragm to wall anchorage using embedded straps shall have the straps attached to or hooked around the reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel. Walls shall be designed to resist bending between anchors where the anchor spacing exceeds 4 feet (1219 mm). Required anchors in masonry walls of hollow units or cavity walls shall be embedded in a reinforced grouted structural element of the wall. See Sections 1632, 1633.2.8 and 1633.2.9 for earthquake design requirements.

1605.3 Erection of Structural Framing. Walls and structural framing shall be erected true and plumb in accordance with the design.

SECTION 1606 — DEAD LOADS

1606.1 General. Dead loads shall be as defined in Section 1602 and this section.

1606.2 Partition Loads. Floors in office buildings and other buildings where partition locations are subject to change shall be designed to support, in addition to all other loads, a uniformly distributed dead load equal to 20 pounds per square foot (psf) (0.96 kN/m^2) of floor area.

> **EXCEPTION:** Access floor systems shall be designed to support, in addition to all other loads, a uniformly distributed dead load not less than 10 psf (0.48 kN/m^2) of floor area.

SECTION 1607 — LIVE LOADS

1607.1 General. Live loads shall be the maximum loads expected by the intended use or occupancy but in no case shall be less than the loads required by this section.

1607.2 Critical Distribution of Live Loads. Where structural members are arranged to create continuity, members shall be designed using the loading conditions, which would cause maximum shear and bending moments. This requirement may be satisfied in accordance with the provisions of Section 1607.3.2 or 1607.4.2, where applicable.

1607.3 Floor Live Loads.

1607.3.1 General. Floors shall be designed for the unit live loads as set forth in Table 16-A. These loads shall be taken as the minimum live loads in pounds per square foot of horizontal projection to be used in the design of buildings for the occupancies listed, and loads at least equal shall be assumed for uses not listed in this section but that create or accommodate similar loadings.

Where it can be determined in designing floors that the actual live load will be greater than the value shown in Table 16-A, the actual live load shall be used in the design of such buildings or portions thereof. Special provisions shall be made for machine and apparatus loads.

1607.3.2 Distribution of uniform floor loads. Where uniform floor loads are involved, consideration may be limited to full dead load on all spans in combination with full live load on adjacent spans and alternate spans.

1607.3.3 Concentrated loads. Provision shall be made in designing floors for a concentrated load, L, as set forth in Table 16-A placed upon any space $2^1/_2$ feet (762 mm) square, wherever this load upon an otherwise unloaded floor would produce stresses greater than those caused by the uniform load required therefor.

Provision shall be made in areas where vehicles are used or stored for concentrated loads, L, consisting of two or more loads spaced 5 feet (1524 mm) nominally on center without uniform live loads. Each load shall be 40 percent of the gross weight of the maximum-size vehicle to be accommodated. Parking garages for the storage of private or pleasure-type motor vehicles with no repair or refueling shall have a floor system designed for a concentrated load of not less than 2,000 pounds (8.9 kN) acting on an area of 20 square inches (12 903 mm^2) without uniform live loads. The condition of concentrated or uniform live load, combined in accordance with Section 1612.2 or 1612.3 as appropriate, producing the greatest stresses shall govern.

1607.3.4 Special loads. Provision shall be made for the special vertical and lateral loads as set forth in Table 16-B.

1607.3.5 Live loads posted. The live loads for which each floor or portion thereof of a commercial or industrial building is or has been designed shall have such design live loads conspicuously posted by the owner in that part of each story in which they apply, using durable metal signs, and it shall be unlawful to remove or deface such notices. The occupant of the building shall be responsible for keeping the actual load below the allowable limits.

1607.4 Roof Live Loads.

1607.4.1 General. Roofs shall be designed for the unit live loads, L_r, set forth in Table 16-C. The live loads shall be assumed to act vertically upon the area projected on a horizontal plane.

1607.4.2 Distribution of loads. Where uniform roof loads are involved in the design of structural members arranged to create continuity, consideration may be limited to full dead loads on all spans in combination with full roof live loads on adjacent spans and on alternate spans.

> **EXCEPTION:** Alternate span loading need not be considered where the uniform roof live load is 20 psf (0.96 kN/m^2) or more or where load combinations, including snow load, result in larger members or connections.

For those conditions where light-gage metal preformed structural sheets serve as the support and finish of roofs, roof structural members arranged to create continuity shall be considered adequate if designed for full dead loads on all spans in combination with the most critical one of the following superimposed loads:

1. Snow load in accordance with Section 1614.

2. The uniform roof live load, L_r, set forth in Table 16-C on all spans.

3. A concentrated gravity load, L_r, of 2,000 pounds (8.9 kN) placed on any span supporting a tributary area greater than 200 square feet (18.58 m^2) to create maximum stresses in the member, whenever this loading creates greater stresses than those caused by the uniform live load. The concentrated load shall be placed on the member over a length of $2^1/_2$ feet (762 mm) along the span. The concentrated load need not be applied to more than one span simultaneously.

4. Water accumulation as prescribed in Section 1611.7.

1607.4.3 Unbalanced loading. Unbalanced loads shall be used where such loading will result in larger members or connections. Trusses and arches shall be designed to resist the stresses caused by unit live loads on one half of the span if such loading results in reverse stresses, or stresses greater in any portion than the stresses produced by the required unit live load on the entire span. For roofs whose structures are composed of a stressed shell, framed or solid, wherein stresses caused by any point loading are distributed throughout the area of the shell, the requirements for unbalanced unit live load design may be reduced 50 percent.

1607.4.4 Special roof loads. Roofs to be used for special purposes shall be designed for appropriate loads as approved by the building official.

Greenhouse roof bars, purlins and rafters shall be designed to carry a 100-pound-minimum (444.8 N) concentrated load, L_r, in addition to the uniform live load.

1607.5 Reduction of Live Loads. The design live load determined using the unit live loads as set forth in Table 16-A for floors and Table 16-C, Method 2, for roofs may be reduced on any member supporting more than 150 square feet (13.94 m^2), including flat slabs, except for floors in places of public assembly and for live loads greater than 100 psf (4.79 kN/m^2), in accordance with the following formula:

$$R = r(A - 150) \qquad (7\text{-}1)$$

For **SI:**

$$R = r(A - 13.94)$$

The reduction shall not exceed 40 percent for members receiving load from one level only, 60 percent for other members or R, as determined by the following formula:

$$R = 23.1\ (1 + D/L) \qquad (7\text{-}2)$$

WHERE:

A = area of floor or roof supported by the member, square feet (m^2).

D = dead load per square foot (m^2) of area supported by the member.

L = unit live load per square foot (m^2) of area supported by the member.

R = reduction in percentage.

r = rate of reduction equal to 0.08 percent for floors. See Table 16-C for roofs.

For storage loads exceeding 100 psf (4.79 kN/m^2), no reduction shall be made, except that design live loads on columns may be reduced 20 percent.

The live load reduction shall not exceed 40 percent in garages for the storage of private pleasure cars having a capacity of not more than nine passengers per vehicle.

1607.6 Alternate Floor Live Load Reduction. As an alternate to Formula (7-1), the unit live loads set forth in Table 16-A may be reduced in accordance with Formula (7-3) on any member, including flat slabs, having an influence area of 400 square feet (37.2 m^2) or more.

$$L = L_o\left(0.25 + \frac{15}{\sqrt{A_I}}\right) \qquad (7\text{-}3)$$

For **SI:**

$$L = L_o\left[0.25 + 4.57\left(\frac{1}{\sqrt{A_I}}\right)\right]$$

WHERE:

A_I = influence area, in square feet (m^2). The influence area A_I is four times the tributary area for a column, two times the tributary area for a beam, equal to the panel area for a two-way slab, and equal to the product of the span and the full flange width for a precast T-beam.

L = reduced design live load per square foot (m^2) of area supported by the member.

L_o = unreduced design live load per square foot (m^2) of area supported by the member (Table 16-A).

The reduced live load shall not be less than 50 percent of the unit live load L_o for members receiving load from one level only, nor less than 40 percent of the unit live load L_o for other members.

SECTION 1608 — SNOW LOADS

Snow loads shall be determined in accordance with Chapter 16, Division II.

SECTION 1609 — WIND LOADS

Wind loads shall be determined in accordance with Chapter 16, Division III.

SECTION 1610 — EARTHQUAKE LOADS

Earthquake loads shall be determined in accordance with Chapter 16, Division IV.

SECTION 1611 — OTHER MINIMUM LOADS

1611.1 General. In addition to the other design loads specified in this chapter, structures shall be designed to resist the loads specified in this section and the special loads set forth in Table 16-B.

1611.2 Other Loads. Buildings and other structures and portions thereof shall be designed to resist all loads due to applicable fluid pressures, F, lateral soil pressures, H, ponding loads, P, and self-straining forces, T. See Section 1611.7 for ponding loads for roofs.

1611.3 Impact Loads. Impact loads shall be included in the design of any structure where impact loads occur.

1611.4 Anchorage of Concrete and Masonry Walls. Concrete and masonry walls shall be anchored as required by Section 1605.2.3. Such anchorage shall be capable of resisting the load combinations of Section 1612.2 or 1612.3 using the greater of the wind or earthquake loads required by this chapter or a minimum horizontal force of 280 pounds per linear foot (4.09 kN/m) of wall, substituted for E.

1611.5 Interior Wall Loads. Interior walls, permanent partitions and temporary partitions that exceed 6 feet (1829 mm) in height shall be designed to resist all loads to which they are subjected but not less than a load, L, of 5 psf (0.24 kN/m^2) applied perpendicular to the walls. The 5 psf (0.24 kN/m^2) load need not be applied simultaneously with wind or seismic loads. The deflection of such walls under a load of 5 psf (0.24 kN/m^2) shall not exceed $^1/_{240}$ of the span for walls with brittle finishes and $^1/_{120}$ of the span for walls with flexible finishes. See Table 16-O for earthquake design requirements where such requirements are more restrictive.

> **EXCEPTION:** Flexible, folding or portable partitions are not required to meet the load and deflection criteria but must be anchored to the supporting structure to meet the provisions of this code.

1611.6 Retaining Walls. Retaining walls shall be designed to resist loads due to the lateral pressure of retained material in accordance with accepted engineering practice. Walls retaining drained soil, where the surface of the retained soil is level, shall be designed for a load, H, equivalent to that exerted by a fluid weighing not less than 30 psf per foot of depth (4.71 $kN/m^2/m$) and having a depth equal to that of the retained soil. Any surcharge shall be in addition to the equivalent fluid pressure.

Retaining walls shall be designed to resist sliding by at least 1.5 times the lateral force and overturning by at least 1.5 times the overturning moment, using allowable stress design loads.

1611.7 Water Accumulation. All roofs shall be designed with sufficient slope or camber to ensure adequate drainage after the long-term deflection from dead load or shall be designed to resist ponding load, P, combined in accordance with Section 1612.2 or 1612.3. Ponding load shall include water accumulation from any source, including snow, due to deflection. See Section 1506 and Table 16-C, Footnote 3, for drainage slope. See Section 1613 for deflection criteria.

1611.8 Hydrostatic Uplift. All foundations, slabs and other footings subjected to water pressure shall be designed to resist a uniformly distributed uplift load, F, equal to the full hydrostatic pressure.

1611.9 Flood-resistant Construction. For flood-resistant construction requirements, where specifically adopted, see Appendix Chapter 31, Division I.

1611.10 Heliport and Helistop Landing Areas. In addition to other design requirements of this chapter, heliport and helistop landing or touchdown areas shall be designed for the following loads, combined in accordance with Section 1612.2 or 1612.3:

1. Dead load plus actual weight of the helicopter.

2. Dead load plus a single concentrated impact load, *L*, covering 1 square foot (0.093 m^2) of 0.75 times the fully loaded weight of the helicopter if it is equipped with hydraulic-type shock absorbers, or 1.5 times the fully loaded weight of the helicopter if it is equipped with a rigid or skid-type landing gear.

3. The dead load plus a uniform live load, *L*, of 100 psf (4.8 kN/m^2). The required live load may be reduced in accordance with Section 1607.5 or 1607.6.

1611.11 Prefabricated Construction.

1611.11.1 Connections. Every device used to connect prefabricated assemblies shall be designed as required by this code and shall be capable of developing the strength of the members connected, except in the case of members forming part of a structural frame designed as specified in this chapter. Connections shall be capable of withstanding uplift forces as specified in this chapter.

1611.11.2 Pipes and conduit. In structural design, due allowance shall be made for any material to be removed for the installation of pipes, conduits or other equipment.

1611.11.3 Tests and inspections. See Section 1704 for requirements for tests and inspections of prefabricated construction.

TABLE 16-A—UNIFORM AND CONCENTRATED LOADS

USE OR OCCUPANCY		UNIFORM LOAD[1] (psf)	CONCENTRATED LOAD (pounds)
Category	Description	× 0.0479 for kN/m²	× 0.004 48 for kN
1. Access floor systems	Office use	50	2,000[2]
	Computer use	100	2,000[2]
2. Armories		150	0
3. Assembly areas[3] and auditoriums and balconies therewith	Fixed seating areas	50	0
	Movable seating and other areas	100	0
	Stage areas and enclosed platforms	125	0
4. Cornices and marquees		60[4]	0
5. Exit facilities[5]		100	0[6]
6. Garages	General storage and/or repair	100	[7]
	Private or pleasure-type motor vehicle storage	50	[7]
7. Hospitals	Wards and rooms	40	1,000[2]
8. Libraries	Reading rooms	60	1,000[2]
	Stack rooms	125	1,500[2]
9. Manufacturing	Light	75	2,000[2]
	Heavy	125	3,000[2]
10. Offices		50	2,000[2]
11. Printing plants	Press rooms	150	2,500[2]
	Composing and linotype rooms	100	2,000[2]
12. Residential[8]	Basic floor area	40	0[6]
	Exterior balconies	60[4]	0
	Decks	40[4]	0
	Storage	40	0
13. Restrooms[9]			
14. Reviewing stands, grandstands, bleachers, and folding and telescoping seating		100	0
15. Roof decks	Same as area served or for the type of occupancy accommodated		
16. Schools	Classrooms	40	1,000[2]
17. Sidewalks and driveways	Public access	250	[7]
18. Storage	Light	125	
	Heavy	250	
19. Stores		100	3,000[2]
20. Pedestrian bridges and walkways		100	

[1]See Section 1607 for live load reductions.
[2]See Section 1607.3.3, first paragraph, for area of load application.
[3]Assembly areas include such occupancies as dance halls, drill rooms, gymnasiums, playgrounds, plazas, terraces and similar occupancies that are generally accessible to the public.
[4]When snow loads occur that are in excess of the design conditions, the structure shall be designed to support the loads due to the increased loads caused by drift buildup or a greater snow design as determined by the building official. See Section 1614. For special-purpose roofs, see Section 1607.4.4.
[5]Exit facilities shall include such uses as corridors serving an occupant load of 10 or more persons, exterior exit balconies, stairways, fire escapes and similar uses.
[6]Individual stair treads shall be designed to support a 300-pound (1.33 kN) concentrated load placed in a position that would cause maximum stress. Stair stringers may be designed for the uniform load set forth in the table.
[7]See Section 1607.3.3, second paragraph, for concentrated loads. See Table 16-B for vehicle barriers.
[8]Residential occupancies include private dwellings, apartments and hotel guest rooms.
[9]Restroom loads shall not be less than the load for the occupancy with which they are associated, but need not exceed 50 pounds per square foot (2.4 kN/m²).

TABLE 16-B—SPECIAL LOADS[1]

USE		VERTICAL LOAD	LATERAL LOAD
Category	Description	(pounds per square foot unless otherwise noted)	
		× 0.0479 for kN/m^2	
1. Construction, public access at site (live load)	Walkway, see Section 3303.6	150	
	Canopy, see Section 3303.7	150	
2. Grandstands, reviewing stands, bleachers, and folding and telescoping seating (live load)	Seats and footboards	120[2]	See Footnote 3
3. Stage accessories (live load)	Catwalks	40	
	Followspot, projection and control rooms	50	
4. Ceiling framing (live load)	Over stages	20	
	All uses except over stages	10[4]	
5. Partitions and interior walls, see Sec. 1611.5 (live load)			5
6. Elevators and dumbwaiters (dead and live loads)		2 × total loads[5]	
7. Mechanical and electrical equipment (dead load)		Total loads	
8. Cranes (dead and live loads)	Total load including impact increase	1.25 × total load[6]	0.10 × total load[7]
9. Balcony railings and guardrails	Exit facilities serving an occupant load greater than 50		50[8]
	Other than exit facilities		20[8]
	Components		25[9]
10. Vehicle barriers	See Section 311.2.3.5		6,000[10]
11. Handrails		See Footnote 11	See Footnote 11
12. Storage racks	Over 8 feet (2438 mm) high	Total loads[12]	See Table 16-O
13. Fire sprinkler structural support		250 pounds (1112 N) plus weight of water-filled pipe[13]	See Table 16-O
14. Explosion exposure	Hazardous occupancies, see Section 307.10		

[1]The tabulated loads are minimum loads. Where other vertical loads required by this code or required by the design would cause greater stresses, they shall be used.
[2]Pounds per lineal foot (× 14.6 for N/m).
[3]Lateral sway bracing loads of 24 pounds per foot (350 N/m) parallel and 10 pounds per foot (145.9 N/m) perpendicular to seat and footboards.
[4]Does not apply to ceilings that have sufficient total access from below, such that access is not required within the space above the ceiling. Does not apply to ceilings if the attic areas above the ceiling are not provided with access. This live load need not be considered as acting simultaneously with other live loads imposed upon the ceiling framing or its supporting structure.
[5]Where Appendix Chapter 30 has been adopted, see reference standard cited therein for additional design requirements.
[6]The impact factors included are for cranes with steel wheels riding on steel rails. They may be modified if substantiating technical data acceptable to the building official is submitted. Live loads on crane support girders and their connections shall be taken as the maximum crane wheel loads. For pendant-operated traveling crane support girders and their connections, the impact factors shall be 1.10.
[7]This applies in the direction parallel to the runway rails (longitudinal). The factor for forces perpendicular to the rail is 0.20 × the transverse traveling loads (trolley, cab, hooks and lifted loads). Forces shall be applied at top of rail and may be distributed among rails of multiple rail cranes and shall be distributed with due regard for lateral stiffness of the structures supporting these rails.
[8]A load per lineal foot (× 14.6 for N/m) to be applied horizontally at right angles to the top rail.
[9]Intermediate rails, panel fillers and their connections shall be capable of withstanding a load of 25 pounds per square foot (1.2 kN/m^2) applied horizontally at right angles over the entire tributary area, including openings and spaces between rails. Reactions due to this loading need not be combined with those of Footnote 8.
[10]A horizontal load in pounds (N) applied at right angles to the vehicle barrier at a height of 18 inches (457 mm) above the parking surface. The force may be distributed over a 1-foot-square (304.8-millimeter-square) area.
[11]The mounting of handrails shall be such that the completed handrail and supporting structure are capable of withstanding a load of at least 200 pounds (890 N) applied in any direction at any point on the rail. These loads shall not be assumed to act cumulatively with Item 9.
[12]Vertical members of storage racks shall be protected from impact forces of operating equipment, or racks shall be designed so that failure of one vertical member will not cause collapse of more than the bay or bays directly supported by that member.
[13]The 250-pound (1.11 kN) load is to be applied to any single fire sprinkler support point but not simultaneously to all support joints.

TABLE 16-C—MINIMUM ROOF LIVE LOADS[1]

ROOF SLOPE	METHOD 1			METHOD 2		
	Tributary Loaded Area in Square Feet for Any Structural Member					
	× 0.0929 for m²					
	0 to 200	201 to 600	Over 600			
	Uniform Load (psf)			Uniform Load[2] (psf)	Rate of Reduction *r* (percentage)	Maximum Reduction *R* (percentage)
	× 0.0479 for kN/m²					
1. Flat[3] or rise less than 4 units vertical in 12 units horizontal (33.3% slope). Arch or dome with rise less than one eighth of span	20	16	12	20	.08	40
2. Rise 4 units vertical to less than 12 units vertical in 12 units horizontal (33% to less than 100% slope). Arch or dome with rise one eighth of span to less than three eighths of span	16	14	12	16	.06	25
3. Rise 12 units vertical in 12 units horizontal (100% slope) and greater. Arch or dome with rise three eighths of span or greater	12	12	12	12	No reductions permitted	
4. Awnings except cloth covered[4]	5	5	5	5		
5. Greenhouses, lath houses and agricultural buildings[5]	10	10	10	10		

[1]Where snow loads occur, the roof structure shall be designed for such loads as determined by the building official. See Section 1614. For special-purpose roofs, see Section 1607.4.4.

[2]See Sections 1607.5 and 1607.6 for live load reductions. The rate of reduction *r* in Section 1607.5 Formula (7-1) shall be as indicated in the table. The maximum reduction *R* shall not exceed the value indicated in the table.

[3]A flat roof is any roof with a slope of less than $^1/_4$ unit vertical in 12 units horizontal (2% slope). The live load for flat roofs is in addition to the ponding load required by Section 1611.7.

[4]As defined in Section 3206.

[5]See Section 1607.4.4 for concentrated load requirements for greenhouse roof members.

Chapter 17 is printed in its entirety in Volume 2 of the *Uniform Building Code*. Excerpts from Chapter 17 are reprinted herein.

Excerpts from Chapter 17
STRUCTURAL TESTS AND INSPECTIONS

SECTION 1701 — SPECIAL INSPECTIONS

1701.1 General. In addition to the inspections required by Section 108, the owner or the engineer or architect of record acting as the owner's agent shall employ one or more special inspectors who shall provide inspections during construction on the types of work listed under Section 1701.5.

EXCEPTION: The building official may waive the requirement for the employment of a special inspector if the construction is of a minor nature.

1701.2 Special Inspector. The special inspector shall be a qualified person who shall demonstrate competence, to the satisfaction of the building official, for inspection of the particular type of construction or operation requiring special inspection.

1701.3 Duties and Responsibilities of the Special Inspector. The special inspector shall observe the work assigned for conformance to the approved design drawings and specifications.

The special inspector shall furnish inspection reports to the building official, the engineer or architect of record, and other designated persons. All discrepancies shall be brought to the immediate attention of the contractor for correction, then, if uncorrected, to the proper design authority and to the building official.

The special inspector shall submit a final signed report stating whether the work requiring special inspection was, to the best of the inspector's knowledge, in conformance to the approved plans and specifications and the applicable workmanship provisions of this code.

1701.4 Standards of Quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards. (See Sections 3503 and 3504.)

1. **Concrete.**

ASTM C 94, Ready-mixed Concrete

2. **Connections.**

Specification for Structural Joints Using ASTM A 325 or A 490 Bolts-Load and Resistance Factor Design, Research Council of Structural Connections, Section 1701.5, Item 6.

Specification for Structural Joints Using ASTM A 325 or A 490 Bolts-Allowable Stress Design, Research Council of Structural Connections, Section 1701.5, Item 6.

3. **Spray-applied Fire-resistive Materials.**

UBC Standard 7-6, Thickness and Density Determination for Spray-applied Fire-resistive Materials

1701.5 Types of Work. Except as provided in Section 1701.1, the types of work listed below shall be inspected by a special inspector.

1. **Concrete.** During the taking of test specimens and placing of reinforced concrete. See Item 12 for shotcrete.

EXCEPTIONS: 1. Concrete for foundations conforming to minimum requirements of Table 18-I-C or for Group R, Division 3 or Group U, Division 1 Occupancies, provided the building official finds that a special hazard does not exist.

2. For foundation concrete, other than cast-in-place drilled piles or caissons, where the structural design is based on an f'_c no greater than 2,500 pounds per square inch (psi) (17.2 MPa).

3. Nonstructural slabs on grade, including prestressed slabs on grade when effective prestress in concrete is less than 150 psi (1.03 MPa).

4. Site work concrete fully supported on earth and concrete where no special hazard exists.

2. **Bolts installed in concrete.** Prior to and during the placement of concrete around bolts when stress increases permitted by Footnote 5 of Table 19-D or Section 1923 are utilized.

3. **Special moment-resisting concrete frame.** For moment frames resisting design seismic load in structures within Seismic Zones 3 and 4, the special inspector shall provide reports to the person responsible for the structural design and shall provide continuous inspection of the placement of the reinforcement and concrete.

4. **Reinforcing steel and prestressing steel tendons.**

4.1 During all stressing and grouting of tendons in prestressed concrete.

4.2 During placing of reinforcing steel and prestressing tendons for all concrete required to have special inspection by Item 1.

EXCEPTION: The special inspector need not be present continuously during placing of reinforcing steel and prestressing tendons, provided the special inspector has inspected for conformance to the approved plans prior to the closing of forms or the delivery of concrete to the jobsite.

5. **Structural welding.**

5.1 **General.** During the welding of any member or connection that is designed to resist loads and forces required by this code.

EXCEPTIONS: 1. Welding done in an approved fabricator's shop in accordance with Section 1701.7.

2. The special inspector need not be continuously present during welding of the following items, provided the materials, qualifications of welding procedures and welders are verified prior to the start of work; periodic inspections are made of work in progress; and a visual inspection of all welds is made prior to completion or prior to shipment of shop welding:

2.1 Single-pass fillet welds not exceeding $^5/_{16}$ inch (7.9 mm) in size.

2.2 Floor and roof deck welding.

2.3 Welded studs when used for structural diaphragm or composite systems.

2.4 Welded sheet steel for cold-formed steel framing members such as studs and joists.

2.5 Welding of stairs and railing systems.

5.2 **Special moment-resisting steel frames.** During the welding of special moment-resisting steel frames. In addition to Item 5.1 requirements, nondestructive testing as required by Section 1703 of this code.

5.3 **Welding of reinforcing steel.** During the welding of reinforcing steel.

EXCEPTION: The special inspector need not be continuously present during the welding of ASTM A 706 reinforcing steel not larger than No. 5 bars used for embedments, provided the materials, qualifications of welding procedures and welders are verified prior to the start of work; periodic inspections are made of work in progress; and a visual inspection of all welds is made prior to completion or prior to shipment of shop welding.

6. **High-strength bolting.** The inspection of high-strength A 325 and A 490 bolts shall be in accordance with approved nationally recognized standards and the requirements of this section.

While the work is in progress, the special inspector shall determine that the requirements for bolts, nuts, washers and paint; bolted parts; and installation and tightening in such standards are met. Such inspections may be performed on a periodic basis in accordance with the requirements of Section 1701.6. The special inspector shall observe the calibration procedures when such procedures are required by the plans or specifications and shall monitor the installation of bolts to determine that all plies of connected materials have been drawn together and that the selected procedure is properly used to tighten all bolts.

7. **Structural masonry.**

7.1 For masonry, other than fully grouted open-end hollow-unit masonry, during preparation and taking of any required prisms or test specimens, placing of all masonry units, placement of reinforcement, inspection of grout space, immediately prior to closing of clean-outs, and during all grouting operations.

EXCEPTION: For hollow-unit masonry where the f'_m is no more than 1,500 psi (10.34 MPa) for concrete units or 2,600 psi (17.93 MPa) for clay units, special inspection may be performed as required for fully grouted open-end hollow-unit masonry specified in Item 7.2.

7.2 For fully grouted open-end hollow-unit masonry during preparation and taking of any required prisms or test specimens, at the start of laying units, after the placement of reinforcing steel, grout space prior to each grouting operation, and during all grouting operations.

EXCEPTION: Special inspection as required in Items 7.1 and 7.2 need not be provided when design stresses have been adjusted as specified in Chapter 21 to permit noncontinuous inspection.

8. **Reinforced gypsum concrete.** When cast-in-place Class B gypsum concrete is being mixed and placed.

9. **Insulating concrete fill.** During the application of insulating concrete fill when used as part of a structural system.

EXCEPTION: The special inspections may be limited to an initial inspection to check the deck surface and placement of reinforcing. The special inspector shall supervise the preparation of compression test specimens during this initial inspection.

10. **Spray-applied fire-resistive materials.** As required by UBC Standard 7-6.

11. **Piling, drilled piers and caissons.** During driving and testing of piles and construction of cast-in-place drilled piles or caissons. See Items 1 and 4 for concrete and reinforcing steel inspection.

12. **Shotcrete.** During the taking of test specimens and placing of all shotcrete and as required by Sections 1924.10 and 1924.11.

EXCEPTION: Shotcrete work fully supported on earth, minor repairs and when, in the opinion of the building official, no special hazard exists.

13. **Special grading, excavation and filling.** During earth-work excavations, grading and filling operations inspection to satisfy requirements of Chapter 18 and Appendix Chapter 33.

14. **Smoke-control system.**

14.1 During erection of ductwork and prior to concealment for the purposes of leakage testing and recording of device location.

14.2 Prior to occupancy and after sufficient completion for the purposes of pressure difference testing, flow measurements, and detection and control verification.

15. **Special cases.** Work that, in the opinion of the building official, involves unusual hazards or conditions.

1701.6 Continuous and Periodic Special Inspection.

1701.6.1 Continuous special inspection. Continuous special inspection means that the special inspector is on the site at all times observing the work requiring special inspection.

1701.6.2 Periodic special inspection. Some inspections may be made on a periodic basis and satisfy the requirements of continuous inspection, provided this periodic scheduled inspection is performed as outlined in the project plans and specifications and approved by the building official.

1701.7 Approved Fabricators. Special inspections required by this section and elsewhere in this code are not required where the work is done on the premises of a fabricator registered and approved by the building official to perform such work without special inspection. The certificate of registration shall be subject to revocation by the building official if it is found that any work done pursuant to the approval is in violation of this code. The approved fabricator shall submit a certificate of compliance that the work was performed in accordance with the approved plans and specifications to the building official and to the engineer or architect of record. The approved fabricator's qualifications shall be contingent on compliance with the following:

1. The fabricator has developed and submitted a detailed fabrication procedural manual reflecting key quality control procedures that will provide a basis for inspection control of workmanship and the fabricator plant.

2. Verification of the fabricator's quality control capabilities, plant and personnel as outlined in the fabrication procedural manual shall be by an approved inspection or quality control agency.

3. Periodic plant inspections shall be conducted by an approved inspection or quality control agency to monitor the effectiveness of the quality control program.

4. It shall be the responsibility of the inspection or quality control agency to notify the approving authority in writing of any change to the procedural manual. Any fabricator approval may be revoked for just cause. Reapproval of the fabricator shall be contingent on compliance with quality control procedures during the past year.

SECTION 1702 — STRUCTURAL OBSERVATION

Structural observation shall be provided in Seismic Zone 3 or 4 when one of the following conditions exists:

1. The structure is defined in Table 16-K as Occupancy Category 1, 2 or 3,

2. The structure is required to comply with Section 403,

3. The structure is in Seismic Zone 4, N_a as set forth in Table 16-S is greater than one, and a lateral design is required for the entire structure,

EXCEPTION: One- and two-story Group R, Division 3 and Group U Occupancies and one- and two-story Groups B, F, M and S Occupancies.

4. When so designated by the architect or engineer of record, or

5. When such observation is specifically required by the building official.

The owner shall employ the engineer or architect responsible for the structural design, or another engineer or architect designated by the engineer or architect responsible for the structural design, to perform structural observation as defined in Section 220. Observed deficiencies shall be reported in writing to the owner's representative, special inspector, contractor and the building official. The structural observer shall submit to the building official a written statement that the site visits have been made and identifying any reported deficiencies that, to the best of the structural observer's knowledge, have not been resolved.

SECTION 1703 — NONDESTRUCTIVE TESTING

In Seismic Zones 3 and 4, welded, fully restrained connections between the primary members of ordinary moment frames and special moment-resisting frames shall be tested by nondestructive methods for compliance with approved standards and job specifications. This testing shall be a part of the special inspection requirements of Section 1701.5. A program for this testing shall be established by the person responsible for structural design and as shown on plans and specifications.

As a minimum, this program shall include the following:

1. All complete penetration groove welds contained in joints and splices shall be tested 100 percent either by ultrasonic testing or by radiography.

EXCEPTIONS: 1. When approved, the nondestructive testing rate for an individual welder or welding operator may be reduced to 25 percent, provided the reject rate is demonstrated to be 5 percent or less of the welds tested for the welder or welding operator. A sampling of at least 40 completed welds for a job shall be made for such reduction evaluation. Reject rate is defined as the number of welds containing rejectable defects divided by the number of welds completed. For evaluating the reject rate of continuous welds over 3 feet (914 mm) in length where the effective throat thickness is 1 inch (25 mm) or less, each 12-inch increment (305 mm) or fraction thereof shall be considered as one weld. For evaluating the reject rate on continuous welds over 3 feet (914 mm) in length where the effective throat thickness is greater than 1 inch (25 mm), each 6 inches (152 mm) of length or fraction thereof shall be considered one weld.

2. For complete penetration groove welds on materials less than $^{5}/_{16}$ inch (7.9 mm) thick, nondestructive testing is not required; for this welding, continuous inspection is required.

3. When approved by the building official and outlined in the project plans and specifications, this nondestructive ultrasonic testing may be performed in the shop of an approved fabricator utilizing qualified test techniques in the employment of the fabricator.

2. Partial penetration groove welds when used in column splices shall be tested either by ultrasonic testing or radiography when required by the plans and specifications. For partial penetration groove welds when used in column splices, with an effective throat less than $^{3}/_{4}$ inch (19.1 mm) thick, nondestructive testing is not required; for this welding, continuous special inspection is required.

3. Base metal thicker than $1^{1}/_{2}$ inches (38 mm), when subjected to through-thickness weld shrinkage strains, shall be ultrasonically inspected for discontinuities directly behind such welds after joint completion.

Any material discontinuities shall be accepted or rejected on the basis of the defect rating in accordance with the (larger reflector) criteria of approved national standards.

SECTION 1704 — PREFABRICATED CONSTRUCTION

1704.1 General.

1704.1.1 Purpose. The purpose of this section is to regulate materials and establish methods of safe construction where any structure or portion thereof is wholly or partially prefabricated.

1704.1.2 Scope. Unless otherwise specifically stated in this section, all prefabricated construction and all materials used therein shall conform to all the requirements of this code. (See Section 104.2.8.)

1704.1.3 Definition.

PREFABRICATED ASSEMBLY is a structural unit, the integral parts of which have been built up or assembled prior to incorporation in the building.

1704.2 Tests of Materials. Every approval of a material not specifically mentioned in this code shall incorporate as a proviso the kind and number of tests to be made during prefabrication.

1704.3 Tests of Assemblies. The building official may require special tests to be made on assemblies to determine their durability and weather resistance.

1704.4 Connections. See Section 1611.11.1 for design requirements of connections for prefabricated assemblies.

1704.5 Pipes and Conduits. See Section 1611.11.2 for design requirements for removal of material for pipes, conduit and other equipment.

1704.6 Certificate and Inspection.

1704.6.1 Materials. Materials and the assembly thereof shall be inspected to determine compliance with this code. Every material shall be graded, marked or labeled where required elsewhere in this code.

1704.6.2 Certificate. A certificate of approval shall be furnished with every prefabricated assembly, except where the assembly is readily accessible to inspection at the site. The certificate of approval shall certify that the assembly in question has been inspected and meets all the requirements of this code. When mechanical equipment is installed so that it cannot be inspected at the site, the certificate of approval shall certify that such equipment complies with the laws applying thereto.

1704.6.3 Certifying agency. To be acceptable under this code, every certificate of approval shall be made by an approved agency.

1704.6.4 Field erection. Placement of prefabricated assemblies at the building site shall be inspected by the building official to determine compliance with this code.

1704.6.5 Continuous inspection. If continuous inspection is required for certain materials where construction takes place on the site, it shall also be required where the same materials are used in prefabricated construction.

EXCEPTION: Continuous inspection will not be required during prefabrication if the approved agency certifies to the construction and furnishes evidence of compliance.

Chapter 18 is printed in its entirety in Volume 2 of the *Uniform Building Code*. Excerpts from Chapter 18 are reprinted herein.

Excerpts from Chapter 18
FOUNDATIONS AND RETAINING WALLS
Division I—GENERAL

SECTION 1801 — SCOPE

1801.1 General. This chapter sets forth requirements for excavation and fills for any building or structure and for foundations and retaining structures.

Reference is made to Appendix Chapter 33 for requirements governing excavation, grading and earthwork construction, including fills and embankments.

1801.2 Standards of Quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code.

1. **Testing.**

   1.1 UBC Standard 18-1, Soils Classification

   1.2 UBC Standard 18-2, Expansion Index Test

SECTION 1802 — QUALITY AND DESIGN

The quality and design of materials used structurally in excavations, footings and foundations shall conform to the requirements specified in Chapters 16, 19, 21, 22 and 23.

Excavations and fills shall comply with Chapter 33.

Allowable bearing pressures, allowable stresses and design formulas provided in this chapter shall be used with the allowable stress design load combinations specified in Section 1612.3.

SECTION 1803 — SOIL CLASSIFICATION—EXPANSIVE SOIL

1803.1 General. For the purposes of this chapter, the definition and classification of soil materials for use in Table 18-I-A shall be according to UBC Standard 18-1.

1803.2 Expansive Soil. When the expansive characteristics of a soil are to be determined, the procedures shall be in accordance with UBC Standard 18-2 and the soil shall be classified according to Table 18-I-B. Foundations for structures resting on soils with an expansion index greater than 20, as determined by UBC Standard 18-2, shall require special design consideration. If the soil expansion index varies with depth, the variation is to be included in the engineering analysis of the expansive soil effect upon the structure.

SECTION 1804 — FOUNDATION INVESTIGATION

1804.1 General. The classification of the soil at each building site shall be determined when required by the building official. The building official may require that this determination be made by an engineer or architect licensed by the state to practice as such.

1804.2 Investigation. The classification shall be based on observation and any necessary tests of the materials disclosed by borings or excavations made in appropriate locations. Additional studies may be necessary to evaluate soil strength, the effect of moisture variation on soil-bearing capacity, compressibility, liquefaction and expansiveness.

In Seismic Zones 3 and 4, when required by the building official, the potential for seismically induced soil liquefaction and soil instability shall be evaluated as described in Section 1804.5.

> **EXCEPTIONS:** 1. The building official may waive this evaluation upon receipt of written opinion of a qualified geotechnical engineer or geologist that liquefaction is not probable.
>
> 2. A detached, single-story dwelling of Group R, Division 3 Occupancy with or without attached garages.
>
> 3. Group U, Division 1 Occupancies.
>
> 4. Fences.

1804.3 Reports. The soil classification and design-bearing capacity shall be shown on the plans, unless the foundation conforms to Table 18-I-C. The building official may require submission of a written report of the investigation, which shall include, but need not be limited to, the following information:

1. A plot showing the location of all test borings and/or excavations.
2. Descriptions and classifications of the materials encountered.
3. Elevation of the water table, if encountered.
4. Recommendations for foundation type and design criteria, including bearing capacity, provisions to mitigate the effects of expansive soils, provisions to mitigate the effects of liquefaction and soil strength, and the effects of adjacent loads.
5. Expected total and differential settlement.

1804.4 Expansive Soils. When expansive soils are present, the building official may require that special provisions be made in the foundation design and construction to safeguard against damage due to this expansiveness. The building official may require a special investigation and report to provide these design and construction criteria.

1804.5 Liquefaction Potential and Soil Strength Loss. When required by Section 1804.2, the potential for soil liquefaction and soil strength loss during earthquakes shall be evaluated during the geotechnical investigation. The geotechnical report shall assess potential consequences of any liquefaction and soil strength loss, including estimation of differential settlement, lateral movement or reduction in foundation soil-bearing capacity, and discuss mitigating measures. Such measures shall be given consideration in the design of the building and may include, but are not limited to, ground stabilization, selection of appropriate foundation type and depths, selection of appropriate structural systems to accommodate anticipated displacements, or any combination of these measures.

The potential for liquefaction and soil strength loss shall be evaluated for a site peak ground acceleration that, as a minimum, conforms to the probability of exceedance specified in Section 1631.2. Peak ground acceleration may be determined based on a site-specific study taking into account soil amplification effects. In the absence of such a study, peak ground acceleration may be assumed equal to the seismic zone factor in Table 16-I.

1804.6 Adjacent Loads. Where footings are placed at varying elevations, the effect of adjacent loads shall be included in the foundation design.

1804.7 Drainage. Provisions shall be made for the control and drainage of surface water around buildings. (See also Section 1806.5.5.)

SECTION 1805 — ALLOWABLE FOUNDATION AND LATERAL PRESSURES

The allowable foundation and lateral pressures shall not exceed the values set forth in Table 18-I-A unless data to substantiate the use of higher values are submitted. Table 18-I-A may be used for design of foundations on rock or nonexpansive soil for Type II One-hour, Type II-N and Type V buildings that do not exceed three stories in height or for structures that have continuous footings having a load of less than 2,000 pounds per lineal foot (29.2 kN/m) and isolated footings with loads of less than 50,000 pounds (222.4 kN).

Allowable bearing pressures provided in Table 18-I-A shall be used with the allowable stress design load combinations specified in Section 1612.3.

SECTION 1806 — FOOTINGS

1806.1 General. Footings and foundations shall be constructed of masonry, concrete or treated wood in conformance with Division II and shall extend below the frost line. Footings of concrete and masonry shall be of solid material. Foundations supporting wood shall extend at least 6 inches (152 mm) above the adjacent finish grade. Footings shall have a minimum depth as indicated in Table 18-I-C, unless another depth is recommended by a foundation investigation.

The provisions of this section do not apply to building and foundation systems in those areas subject to scour and water pressure by wind and wave action. Buildings and foundations subject to such loads shall be designed in accordance with approved national standards. See Section 3302 for subsoil preparation and wood form removal.

1806.2 Footing Design. Except for special provisions of Section 1808 covering the design of piles, all portions of footings shall be designed in accordance with the structural provisions of this code and shall be designed to minimize differential settlement when necessary and the effects of expansive soils when present.

Slab-on-grade and mat-type footings for buildings located on expansive soils may be designed in accordance with the provisions of Division III or such other engineering design based on geotechnical recommendation as approved by the building official.

1806.3 Bearing Walls. Bearing walls shall be supported on masonry or concrete foundations or piles or other approved foundation system that shall be of sufficient size to support all loads. Where a design is not provided, the minimum foundation requirements for stud bearing walls shall be as set forth in Table 18-I-C, unless expansive soils of a severity to cause differential movement are known to exist.

EXCEPTIONS: 1. A one-story wood- or metal-frame building not used for human occupancy and not over 400 square feet (37.2 m^2) in floor area may be constructed with walls supported on a wood foundation plate when approved by the building official.

2. The support of buildings by posts embedded in earth shall be designed as specified in Section 1806.8. Wood posts or poles embedded in earth shall be pressure treated with an approved preservative. Steel posts or poles shall be protected as specified in Section 1807.9.

1806.4 Stepped Foundations. Foundations for all buildings where the surface of the ground slopes more than 1 unit vertical in 10 units horizontal (10% slope) shall be level or shall be stepped so that both top and bottom of such foundation are level.

1806.5 Footings on or Adjacent to Slopes.

1806.5.1 Scope. The placement of buildings and structures on or adjacent to slopes steeper than 1 unit vertical in 3 units horizontal (33.3% slope) shall be in accordance with this section.

1806.5.2 Building clearance from ascending slopes. In general, buildings below slopes shall be set a sufficient distance from the slope to provide protection from slope drainage, erosion and shallow failures. Except as provided for in Section 1806.5.6 and Figure 18-I-1, the following criteria will be assumed to provide this protection. Where the existing slope is steeper than 1 unit vertical in 1 unit horizontal (100% slope), the toe of the slope shall be assumed to be at the intersection of a horizontal plane drawn from the top of the foundation and a plane drawn tangent to the slope at an angle of 45 degrees to the horizontal. Where a retaining wall is constructed at the toe of the slope, the height of the slope shall be measured from the top of the wall to the top of the slope.

1806.5.3 Footing setback from descending slope surface. Footing on or adjacent to slope surfaces shall be founded in firm material with an embedment and setback from the slope surface sufficient to provide vertical and lateral support for the footing without detrimental settlement. Except as provided for in Section 1806.5.6 and Figure 18-I-1, the following setback is deemed adequate to meet the criteria. Where the slope is steeper than 1 unit vertical in 1 unit horizontal (100% slope), the required setback shall be measured from an imaginary plane 45 degrees to the horizontal, projected upward from the toe of the slope.

1806.5.4 Pools. The setback between pools regulated by this code and slopes shall be equal to one half the building footing setback distance required by this section. That portion of the pool wall within a horizontal distance of 7 feet (2134 mm) from the top of the slope shall be capable of supporting the water in the pool without soil support.

1806.5.5 Foundation elevation. On graded sites, the top of any exterior foundation shall extend above the elevation of the street gutter at point of discharge or the inlet of an approved drainage device a minimum of 12 inches (305 mm) plus 2 percent. The building official may approve alternate elevations, provided it can be demonstrated that required drainage to the point of discharge and away from the structure is provided at all locations on the site.

1806.5.6 Alternate setback and clearance. The building official may approve alternate setbacks and clearances. The building official may require an investigation and recommendation of a qualified engineer to demonstrate that the intent of this section has been satisfied. Such an investigation shall include consideration of material, height of slope, slope gradient, load intensity and erosion characteristics of slope material.

1806.6 Foundation Plates or Sills. Wood plates or sills shall be bolted to the foundation or foundation wall. Steel bolts with a minimum nominal diameter of $^1/_2$ inch (12.7 mm) shall be used in Seismic Zones 0 through 3. Steel bolts with a minimum nomiaal diameter of $^5/_8$ inch (16 mm) shall be used in Seismic Zone 4. Bolts shall be embedded at least 7 inches (178 mm) into the concrete or masonry and shall be spaced not more than 6 feet (1829 mm) apart. There shall be a minimum of two bolts per piece with one bolt located not more than 12 inches (305 mm) or less than seven bolt diameters from each end of the piece. A properly sized nut and washer shall be tightened on each bolt to the plate. Foundation plates and sills shall be the kind of wood specified in Section 2306.4.

1806.6.1 Additional requirements in Seismic Zones 3 and 4. The following additional requirements shall apply in Seismic Zones 3 and 4.

1. Sill bolt diameter and spacing for three-story raised wood floor buildings shall be specifically designed.

2. Plate washers a minimum of 2 inch by 2 inch by $^3/_{16}$ inch (51 mm by 51 mm by 4.8 mm) thick shall be used on each bolt.

1806.7 Seismic Zones 3 and 4. In Seismic Zones 3 and 4, horizontal reinforcement in accordance with Sections 1806.7.1 and 1806.7.2 shall be placed in continuous foundations to minimize differential settlement. Foundation reinforcement shall be provided with cover in accordance with Section 1907.7.1.

1806.7.1 Foundations with stemwalls. Foundations with stemwalls shall be provided with a minimum of one No. 4 bar at the top of the wall and one No. 4 bar at the bottom of the footing.

1806.7.2 Slabs–on–ground with turned–down footings. Slabs–on–ground with turned-down footings shall have a minimum of one No. 4 bar at the top and bottom.

EXCEPTION: For slabs-on-ground cast monolithically with a footing, one No. 5 bar may be located at either the top or bottom.

1806.8 Designs Employing Lateral Bearing.

1806.8.1 General. Construction employing posts or poles as columns embedded in earth or embedded in concrete footings in the earth may be used to resist both axial and lateral loads. The depth to resist lateral loads shall be determined by means of the design criteria established herein or other methods approved by the building official.

1806.8.2 Design criteria.

1806.8.2.1 Nonconstrained. The following formula may be used in determining the depth of embedment required to resist lateral loads where no constraint is provided at the ground surface, such as rigid floor or rigid ground surface pavement.

$$d = \frac{A}{2}\left(1 + \sqrt{1 + \frac{4.36h}{A}}\right) \qquad (6\text{-}1)$$

WHERE:

$A = \frac{2.34P}{S_1 b}$

b = diameter of round post or footing or diagonal dimension of square post or footing, feet (m).

d = depth of embedment in earth in feet (m) but not over 12 feet (3658 mm) for purpose of computing lateral pressure.

h = distance in feet (m) from ground surface to point of application of "P."

P = applied lateral force in pounds (kN).

S_1 = allowable lateral soil-bearing pressure as set forth in Table 18-I-A based on a depth of one third the depth of embedment (kPa).

S_3 = allowable lateral soil-bearing pressure as set forth in Table 18-I-A based on a depth equal to the depth of embedment (kPa).

1806.8.2.2 Constrained. The following formula may be used to determine the depth of embedment required to resist lateral loads where constraint is provided at the ground surface, such as a rigid floor or pavement.

$$d^2 = 4.25\frac{Ph}{S_3 b} \qquad (6\text{-}2)$$

1806.8.2.3 Vertical load. The resistance to vertical loads is determined by the allowable soil-bearing pressure set forth in Table 18-I-A.

1806.8.3 Backfill. The backfill in the annular space around columns not embedded in poured footings shall be by one of the following methods:

1. Backfill shall be of concrete with an ultimate strength of 2,000 pounds per square inch (13.79 MPa) at 28 days. The hole shall not be less than 4 inches (102 mm) larger than the diameter of the column at its bottom or 4 inches (102 mm) larger than the diagonal dimension of a square or rectangular column.

2. Backfill shall be of clean sand. The sand shall be thoroughly compacted by tamping in layers not more than 8 inches (203 mm) in depth.

1806.8.4 Limitations. The design procedure outlined in this section shall be subject to the following limitations:

The frictional resistance for retaining walls and slabs on silts and clays shall be limited to one half of the normal force imposed on the soil by the weight of the footing or slab.

Posts embedded in earth shall not be used to provide lateral support for structural or nonstructural materials such as plaster, masonry or concrete unless bracing is provided that develops the limited deflection required.

1806.9 Grillage Footings. When grillage footings of structural steel shapes are used on soils, they shall be completely embedded in concrete with at least 6 inches (152 mm) on the bottom and at least 4 inches (102 mm) at all other points.

1806.10 Bleacher Footings. Footings for open-air seating facilities shall comply with Chapter 18.

EXCEPTIONS: Temporary open-air portable bleachers as defined in Section 1008.2 may be supported upon wood sills or steel plates placed directly upon the ground surface, provided soil pressure does not exceed 1,200 pounds per square foot (57.5 kPa).

SECTION 1807 — PILES — GENERAL REQUIREMENTS

1807.1 General. Pile foundations shall be designed and installed on the basis of a foundation investigation as defined in Section 1804 where required by the building official.

The investigation and report provisions of Section 1804 shall be expanded to include, but not be limited to, the following:

1. Recommended pile types and installed capacities.

2. Driving criteria.

3. Installation procedures.

4. Field inspection and reporting procedures (to include procedures for verification of the installed bearing capacity where required).

5. Pile load test requirements.

The use of piles not specifically mentioned in this chapter shall be permitted, subject to the approval of the building official upon submission of acceptable test data, calculations or other information relating to the properties and load-carrying capacities of such piles.

1807.2 Interconnection. Individual pile caps and caissons of every structure subjected to seismic forces shall be interconnected by ties. Such ties shall be capable of resisting, in tension or compression, a minimum horizontal force equal to 10 percent of the larger column vertical load.

EXCEPTION: Other approved methods may be used where it can be demonstrated that equivalent restraint can be provided.

1807.3 Determination of Allowable Loads. The allowable axial and lateral loads on piles shall be determined by an approved formula, by load tests or by a foundation investigation.

1807.4 Static Load Tests. When the allowable axial load of a single pile is determined by a load test, one of the following methods shall be used:

Method 1. It shall not exceed 50 percent of the yield point under test load. The yield point shall be defined as that point at which an increase in load produces a disproportionate increase in settlement.

Method 2. It shall not exceed one half of the load which causes a net settlement, after deducting rebound, of 0.01 inch per ton (0.000565 mm/N) of test load which has been applied for a period of at least 24 hours.

Method 3. It shall not exceed one half of that load under which, during a 40-hour period of continuous load application, no additional settlement takes place.

1807.5 Column Action. All piles standing unbraced in air, water or material not capable of lateral support, shall conform with the applicable column formula as specified in this code. Such piles driven into firm ground may be considered fixed and laterally supported at 5 feet (1524 mm) below the ground surface and in soft material at 10 feet (3048 mm) below the ground surface unless otherwise prescribed by the building official after a foundation investigation by an approved agency.

1807.6 Group Action. Consideration shall be given to the reduction of allowable pile load when piles are placed in groups. Where soil conditions make such load reductions advisable or necessary, the allowable axial load determined for a single pile shall be reduced by any rational method or formula approved by the building official.

1807.7 Piles in Subsiding Areas. Where piles are driven through subsiding fills or other subsiding strata and derive support from underlying firmer materials, consideration shall be given to the downward frictional forces which may be imposed on the piles by the subsiding upper strata.

Where the influence of subsiding fills is considered as imposing loads on the pile, the allowable stresses specified in this chapter may be increased if satisfactory substantiating data are submitted.

1807.8 Jetting. Jetting shall not be used except where and as specifically permitted by the building official. When used, jetting shall be carried out in such a manner that the carrying capacity of existing piles and structures shall not be impaired. After withdrawal of the jet, piles shall be driven down until the required resistance is obtained.

1807.9 Protection of Pile Materials. Where the boring records of site conditions indicate possible deleterious action on pile materials because of soil constituents, changing water levels or other factors, such materials shall be adequately protected by methods or processes approved by the building official. The effectiveness of such methods or processes for the particular purpose shall have been thoroughly established by satisfactory service records or other evidence which demonstrates the effectiveness of such protective measures.

1807.10 Allowable Loads. The allowable loads based on soil conditions shall be established in accordance with Section 1807.

EXCEPTION: Any uncased cast-in-place pile may be assumed to develop a frictional resistance equal to one sixth of the bearing value of the soil material at minimum depth as set forth in Table 18-I-A but not to exceed 500 pounds per square foot (24 kPa) unless a greater value is allowed by the building official after a soil investigation as specified in Section 1804 is submitted. Frictional resistance and bearing resistance shall not be assumed to act simultaneously unless recommended after a foundation investigation as specified in Section 1804.

1807.11 Use of Higher Allowable Pile Stresses. Allowable compressive stresses greater than those specified in Section 1808 shall be permitted when substantiating data justifying such higher stresses are submitted to and approved by the building official. Such substantiating data shall include a foundation investigation including a report in accordance with Section 1807.1 by a soils engineer defined as a civil engineer experienced and knowledgeable in the practice of soils engineering.

SECTION 1808 — SPECIFIC PILE REQUIREMENTS

1808.1 Round Wood Piles.

1808.1.1 Material. Except where untreated piles are permitted, wood piles shall be pressure treated. Untreated piles may be used only when it has been established that the cutoff will be below lowest groundwater level assumed to exist during the life of the structure.

1808.1.2 Allowable stresses. The allowable unit stresses for round wood piles shall not exceed those set forth in Chapter 23, Division III, Part I.

The allowable values listed in Chapter 23, Division III, Part I, for compression parallel to the grain at extreme fiber in bending are based on load sharing as occurs in a pile cluster. For piles which support their own specific load, a safety factor of 1.25 shall be applied to compression parallel to the grain values and 1.30 to extreme fiber in bending values.

1808.2 Uncased Cast-in-place Concrete Piles.

1808.2.1 Material. Concrete piles cast in place against earth in drilled or bored holes shall be made in such a manner as to ensure the exclusion of any foreign matter and to secure a full-sized shaft. The length of such pile shall be limited to not more than 30 times the average diameter. Concrete shall have a specified compressive strength f'_c of not less than 2,500 psi (17.24 MPa).

EXCEPTION: The length of pile may exceed 30 times the diameter provided the design and installation of the pile foundation is in accordance with an approved investigation report.

1808.2.2 Allowable stresses. The allowable compressive stress in the concrete shall not exceed $0.33f'_c$. The allowable compressive stress of reinforcement shall not exceed 34 percent of the yield strength of the steel or 25,500 psi (175.7 MPa).

1808.3 Metal-cased Concrete Piles.

1808.3.1 Material. Concrete used in metal-cased concrete piles shall have a specified compressive strength f'_c of not less than 2,500 psi (17.24 MPa).

1808.3.2 Installation. Every metal casing for a concrete pile shall have a sealed tip with a diameter of not less than 8 inches (203 mm).

Concrete piles cast in place in metal shells shall have shells driven for their full length in contact with the surrounding soil and left permanently in place. The shells shall be sufficiently strong to resist collapse and sufficiently watertight to exclude water and foreign material during the placing of concrete.

Piles shall be driven in such order and with such spacing as to ensure against distortion of or injury to piles already in place. No pile shall be driven within four and one-half average pile diameters of a pile filled with concrete less than 24 hours old unless approved by the building official.

1808.3.3 Allowable stresses. Allowable stresses shall not exceed the values specified in Section 1808.2.2, except that the allowable concrete stress may be increased to a maximum value of $0.40f'_c$ for that portion of the pile meeting the following conditions:

1. The thickness of the metal casing is not less than 0.068 inch (1.73 mm) (No. 14 carbon sheet steel gage).

2. The casing is seamless or is provided with seams of equal strength and is of a configuration that will provide confinement to the cast-in-place concrete.

3. The specified compressive strength f'_c shall not exceed 5,000 psi (34.47 MPa) and the ratio of steel minimum specified yield strength f_y to concrete specified compressive strength f'_c shall not be less than 6.

4. The pile diameter is not greater than 16 inches (406 mm).

1808.4 Precast Concrete Piles.

1808.4.1 Materials. Precast concrete piles shall have a specified compressive strength f'_c of not less than 3,000 psi (20.68 MPa), and shall develop a compressive strength of not less than 3,000 psi (20.68 MPa) before driving.

1808.4.2 Reinforcement ties. The longitudinal reinforcement in driven precast concrete piles shall be laterally tied with steel ties or wire spirals. Ties and spirals shall not be spaced more than 3 inches (76 mm) apart, center to center, for a distance of 2 feet (610 mm) from the ends and not more than 8 inches (203 mm) elsewhere. The gage of ties and spirals shall be as follows:

For piles having a diameter of 16 inches (406 mm) or less, wire shall not be smaller than 0.22 inch (5.6 mm) (No. 5 B.W. gage).

For piles having a diameter of more than 16 inches (406 mm) and less than 20 inches (508 mm), wire shall not be smaller than 0.238 inch (6.0 mm) (No. 4 B.W. gage).

For piles having a diameter of 20 inches (508 mm) and larger, wire shall not be smaller than $^1/_4$ inch (6.4 mm) round or 0.259 inch (6.6 mm) (No. 3 B.W. gage).

1808.4.3 Allowable stresses. Precast concrete piling shall be designed to resist stresses induced by handling and driving as well as by loads. The allowable stresses shall not exceed the values specified in Section 1808.2.2.

1808.5 Precast Prestressed Concrete Piles (Pretensioned).

1808.5.1 Materials. Precast prestressed concrete piles shall have a specified compressive strength f'_c of not less than 5,000 psi (34.48 MPa) and shall develop a compressive strength of not less than 4,000 psi (27.58 MPa) before driving.

1808.5.2 Reinforcement. The longitudinal reinforcement shall be high-tensile seven-wire strand. Longitudinal reinforcement shall be laterally tied with steel ties or wire spirals.

Ties or spiral reinforcement shall not be spaced more than 3 inches (76 mm) apart, center to center, for a distance of 2 feet (610 mm) from the ends and not more than 8 inches (203 mm) elsewhere.

At each end of the pile, the first five ties or spirals shall be spaced 1 inch (25 mm) center to center.

For piles having a diameter of 24 inches (610 mm) or less, wire shall not be smaller than 0.22 inch (5.6 mm) (No. 5 B.W. gage). For piles having a diameter greater than 24 inches (610 mm) but less than 36 inches (914 mm), wire shall not be smaller than 0.238 inch (6.0 mm) (No. 4 B.W. gage). For piles having a diameter greater than 36 inches (914 mm), wire shall not be smaller than $^1/_4$ inch (6.4 mm) round or 0.259 inch (6.6 mm) (No. 3 B.W. gage).

1808.5.3 Allowable stresses. Precast prestressed piling shall be designed to resist stresses induced by handling and driving as well as by loads. The effective prestress in the pile shall not be less than 400 psi (2.76 MPa) for piles up to 30 feet (9144 mm) in length, 550 psi (3.79 MPa) for piles up to 50 feet (15 240 mm) in length, and 700 psi (4.83 MPa) for piles greater than 50 feet (15 240 mm) in length.

The compressive stress in the concrete due to externally applied load shall not exceed:

$$f_c = 0.33f'_c - 0.27fp_c$$

WHERE:

fp_c = effective prestress stress on the gross section.

Effective prestress shall be based on an assumed loss of 30,000 psi (206.85 MPa) in the prestressing steel. The allowable stress in the prestressing steel shall not exceed the values specified in Section 1918.

1808.6 Structural Steel Piles.

1808.6.1 Material. Structural steel piles, steel pipe piles and fully welded steel piles fabricated from plates shall conform to UBC Standard 22-1 and be identified in accordance with Section 2202.2.

1808.6.2 Allowable stresses. The allowable axial stresses shall not exceed 0.35 of the minimum specified yield strength F_y or 12,600 psi (86.88 MPa), whichever is less.

> **EXCEPTION:** When justified in accordance with Section 1807.11, the allowable axial stress may be increased above 12,600 psi (86.88 MPa) and $0.35F_y$, but shall not exceed $0.5F_y$.

1808.6.3 Minimum dimensions. Sections of driven H-piles shall comply with the following:

1. The flange projection shall not exceed 14 times the minimum thickness of metal in either the flange or the web, and the flange widths shall not be less than 80 percent of the depth of the section.

2. The nominal depth in the direction of the web shall not be less than 8 inches (203 mm).

3. Flanges and webs shall have a minimum nominal thickness of $^3/_8$ inch (9.5 mm).

Sections of driven pipe piles shall have an outside diameter of not less than 10 inches (254 mm) and a minimum thickness of not less than $^1/_4$ inch (6.4 mm).

1808.7 Concrete-filled Steel Pipe Piles.

1808.7.1 Material. The concrete-filled steel pipe piles shall conform to UBC Standard 22-1 and shall be identified in accordance with Section 2202.2. The concrete-filled steel pipe piles shall have a specified compressive strength f'_c of not less than 2,500 psi (17.24 MPa).

1808.7.2 Allowable stresses. The allowable axial stresses shall not exceed 0.35 of the minimum specified yield strength F_y of the steel plus 0.33 of the specified compressive strength f'_c of concrete, provided F_y shall not be assumed greater than 36,000 psi (248.22 MPa) for computational purposes.

EXCEPTION: When justified in accordance with Section 2807.11, the allowable stresses may be increased to 0.50 F_y.

1808.7.3 Minimum dimensions. Driven piles of uniform section shall have a nominal outside diameter of not less than 8 inches (203 mm).

SECTION 1809 — FOUNDATION CONSTRUCTION—SEISMIC ZONES 3 AND 4

1809.1 General. In Seismic Zones 3 and 4 the further requirements of this section shall apply to the design and construction of foundations, foundation components and the connection of superstructure elements thereto.

1809.2 Soil Capacity. The foundation shall be capable of transmitting the design base shear and overturning forces prescribed in Section 1630 from the structure into the supporting soil. The short-term dynamic nature of the loads may be taken into account in establishing the soil properties.

1809.3 Superstructure-to-Foundation Connection. The connection of superstructure elements to the foundation shall be adequate to transmit to the foundation the forces for which the elements were required to be designed.

1809.4 Foundation-Soil Interface. For regular buildings, the force F_t as provided in Section 1630.5 may be omitted when determining the overturning moment to be resisted at the foundation-soil interface.

1809.5 Special Requirements for Piles and Caissons.

1809.5.1 General. Piles, caissons and caps shall be designed according to the provisions of Section 1605, including the effects of lateral displacements. Special detailing requirements as described in Section 1809.5.2 shall apply for a length of piles equal to 120 percent of the flexural length. Flexural length shall be considered as a length of pile from the first point of zero lateral deflection to the underside of the pile cap or grade beam.

1809.5.2 Steel piles, nonprestressed concrete piles and prestressed concrete piles.

1809.5.2.1 Steel piles. Piles shall conform to width-thickness ratios of stiffened, unstiffened and tubular compression elements as shown in Chapter 22, Division VIII.

1809.5.2.2 Nonprestressed concrete piles. Piles shall have transverse reinforcement meeting the requirements of Section 1921.4.

EXCEPTION: Transverse reinforcement need not exceed the amount determined by Formula (21-2) in Section 1921.4.4.1 for spiral or circular hoop reinforcement or by Formula (21-4) in Section 1921.4.4.1 for rectangular hoop reinforcement.

1809.5.2.3 Prestressed concrete piles. Piles shall have a minimum volumetric ratio of spiral reinforcement no less than 0.021 for 14-inch (356 mm) square and smaller piles, and 0.012 for 24-inch (610 mm) square and larger piles unless a smaller value can be justified by rational analysis. Interpolation may be used between the specified ratios for intermediate sizes.

TABLE 18-I-A—ALLOWABLE FOUNDATION AND LATERAL PRESSURE

CLASS OF MATERIALS[1]	ALLOWABLE FOUNDATION PRESSURE (psf)[2] × 0.0479 for kPa	LATERAL BEARING LBS./SQ. FT./FT. OF DEPTH BELOW NATURAL GRADE[3] × 0.157 for kPa per meter	LATERAL SLIDING[4] Coefficient[5]	LATERAL SLIDING[4] Resistance (psf)[6] × 0.0479 for kPa
1. Massive crystalline bedrock	4,000	1,200	0.70	
2. Sedimentary and foliated rock	2,000	400	0.35	
3. Sandy gravel and/or gravel (GW and GP)	2,000	200	0.35	
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	1,500	150	0.25	
5. Clay, sandy clay, silty clay and clayey silt (CL, ML, MH and CH)	1,000[7]	100		130

[1]For soil classifications OL, OH and PT (i.e., organic clays and peat), a foundation investigation shall be required.
[2]All values of allowable foundation pressure are for footings having a minimum width of 12 inches (305 mm) and a minimum depth of 12 inches (305 mm) into natural grade. Except as in Footnote 7, an increase of 20 percent shall be allowed for each additional foot (305 mm) of width or depth to a maximum value of three times the designated value. Additionally, an increase of one third shall be permitted when considering load combinations, including wind or earthquake loads, as permitted by Section 1612.3.2.
[3]May be increased the amount of the designated value for each additional foot (305 mm) of depth to a maximum of 15 times the designated value. Isolated poles for uses such as flagpoles or signs and poles used to support buildings that are not adversely affected by a $^1/_2$-inch (12.7 mm) motion at ground surface due to short-term lateral loads may be designed using lateral bearing values equal to two times the tabulated values.
[4]Lateral bearing and lateral sliding resistance may be combined.
[5]Coefficient to be multiplied by the dead load.
[6]Lateral sliding resistance value to be multiplied by the contact area. In no case shall the lateral sliding resistance exceed one half the dead load.
[7]No increase for width is allowed.

TABLE 18-I-B—CLASSIFICATION OF EXPANSIVE SOIL

EXPANSION INDEX	POTENTIAL EXPANSION
0-20	Very low
21-50	Low
51-90	Medium
91-130	High
Above 130	Very high

TABLE 18-I-C—FOUNDATIONS FOR STUD BEARING WALLS—MINIMUM REQUIREMENTS[1,2,3,4]

NUMBER OF FLOORS SUPPORTED BY THE FOUNDATION[5]	THICKNESS OF FOUNDATION WALL (inches) × 25.4 for mm: Concrete	THICKNESS OF FOUNDATION WALL (inches) × 25.4 for mm: Unit Masonry	WIDTH OF FOOTING (inches) × 25.4 for mm	THICKNESS OF FOOTING (inches) × 25.4 for mm	DEPTH BELOW UNDISTURBED GROUND SURFACE (inches) × 25.4 for mm
1	6	6	12	6	12
2	8	8	15	7	18
3	10	10	18	8	24

[1]Where unusual conditions or frost conditions are found, footings and foundations shall be as required in Section 1806.1.
[2]The ground under the floor may be excavated to the elevation of the top of the footing.
[3]Interior stud bearing walls may be supported by isolated footings. The footing width and length shall be twice the width shown in this table and the footings shall be spaced not more than 6 feet (1829 mm) on center.
[4]In Seismic Zone 4, continuous footings shall be provided with a minimum of one No. 4 bar top and bottom.
[5]Foundations may support a roof in addition to the stipulated number of floors. Foundations supporting roofs only shall be as required for supporting one floor.

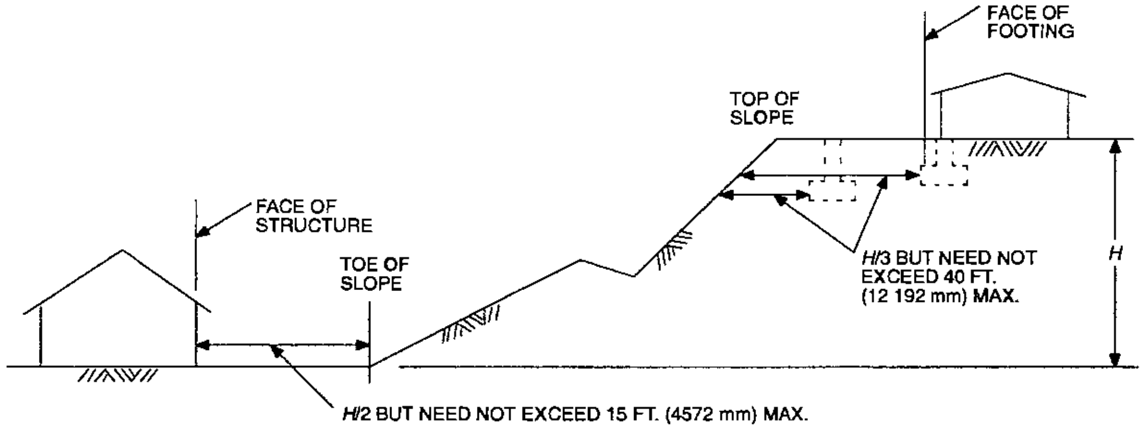


FIGURE 18-I-1—SETBACK DIMENSIONS

Chapter 19 is printed in its entirety in Volume 2 of the *Uniform Building Code*.
Excerpts from Chapter 19 are reprinted herein.

Excerpts from Chapter 19
CONCRETE

NOTE: This is a new division.

Division I — GENERAL

SECTION 1900 — GENERAL

1900.1 Scope. The design of concrete structures of cast-in-place or precast construction, plain, reinforced or prestressed shall conform to the rules and principles specified in this chapter.

1900.2 General Requirements. All concrete structures shall be designed and constructed in accordance with the requirements of Division II and the additional requirements contained in Section 1900.4 of this division.

1900.3 Design Methods. The design of concrete structures shall be in accordance with one of the following methods.

1900.3.1 Strength design (load and resistance factor design). The design of concrete structures using the strength design method shall be in accordance with the requirements of Division II.

1900.3.2 Allowable stress design. The design of concrete structures using the Allowable Stress Design Method shall be in accordance with the requirements of Division VI, Section 1926.

1900.4 Additional Design and Construction Requirements.

1900.4.1 Anchorage. Anchorage of bolts and headed stud anchors to concrete shall be in accordance with Division III.

1900.4.2 Shotcrete. In addition to the requirements of Division II, design and construction of shotcrete structures shall meet the requirements of Division IV.

1900.4.3 Reinforced gypsum concrete. Reinforced gypsum concrete shall be in accordance with Division V.

1900.4.4 Minimum slab thickness. The minimum thickness of concrete floor slabs supported directly on the ground shall not be less than $3^1/_2$ inches (89 mm).

1900.4.5 Unified design provisions for reinforced and prestressed concrete flexural and compression members. It shall be permitted to use the alternate flexural and axial load design provisions in accordance with Division VII, Section 1927.

1900.4.6 Alternative load-factor combination and strength-reduction factors. It shall be permitted to use the alternative load-factor and strength-reduction factors in accordance with Division VIII, Section 1928.

Division II

The contents of this division are patterned after, and in general conformity with, the provisions of Building Code Requirements for Reinforced Concrete (ACI 318-95) and commentary—ACI 318 R-95. For additional background information and research data, see the referenced American Concrete Institute (ACI) publication.

To make reference to the ACI commentary easier for users of the code, the section designations of this division have been made similar to those found in ACI 318. The first two digits of a section number indicates this chapter number and the balance matches the ACI chapter and section designation wherever possible. Italics are used in this chapter to indicate where the *Uniform Building Code* differs substantively from the ACI standard.

SECTION 1901 — SCOPE

The design of structures in concrete of cast-in-place or precast construction, plain, reinforced or prestressed, shall conform to the rules and principles specified in this chapter.

SECTION 1902 — DEFINITIONS

The following terms are defined for general use in this code. Specialized definitions appear in individual *sections.*

ADMIXTURE is material other than water, aggregate, or hydraulic cement used as an ingredient of concrete and added to concrete before or during its mixing to modify its properties.

AGGREGATE is granular material, such as sand, gravel, crushed stone and iron blast-furnace slag, and when used with a cementing medium forms a hydraulic cement concrete or mortar.

AGGREGATE, LIGHTWEIGHT, is aggregate with a dry, loose weight of 70 pounds per cubic foot (pcf) (1120 kg/m^3) or less.

AIR-DRY WEIGHT *is the unit weight of a lightweight concrete specimen cured for seven days with neither loss nor gain of moisture at 60°F to 80°F (15.6°C to 26.7°C) and dried for 21 days in 50 ± 7 percent relative humidity at 73.4°F ± 2°F (23.0°C ± 1.1°C).*

ANCHORAGE in posttensioning is a device used to anchor tendons to concrete member; in pretensioning, a device used to anchor tendons during hardening of concrete.

BONDED TENDON is a prestressing tendon that is bonded to concrete either directly or through grouting.

CEMENTITIOUS MATERIALS are materials as specified in Section 1903 which have cementing value when used in concrete either by themselves, such as portland cement, blended hydraulic cements and expansive cement, or such materials in combination with fly ash, raw or other calcined natural pozzolans, silica fume, or ground granulated blast-furnace slag.

COLUMN is a member with a ratio of height-to-least-lateral dimension of 3 or greater used primarily to support axial compressive load.

COMPOSITE CONCRETE FLEXURAL MEMBERS are concrete flexural members of precast and cast-in-place concrete elements or both constructed in separate placements but so interconnected that all elements respond to loads as a unit.

COMPRESSION-CONTROLLED SECTION is a cross section in which the net tensile strain in the extreme tension steel at nominal strength is less than or equal to the compression-controlled strain limit.

COMPRESSION-CONTROLLED STRAIN LIMIT is the net tensile strain at balanced strain conditions. (See *Section* B1910.3.2.)

CONCRETE is a mixture of portland cement or any other hydraulic cement, fine aggregate, coarse aggregate and water, with or without admixtures.

CONCRETE, SPECIFIED COMPRESSIVE STRENGTH OF (f'_c), is the compressive strength of concrete used in design and evaluated in accordance with provisions of Section 1905, expressed in pounds per square inch (psi) (MPa). Whenever the quantity f'_c is under a radical sign, square root of numerical value only is intended, and result has units of psi (MPa).

CONCRETE, STRUCTURAL LIGHTWEIGHT, is concrete containing lightweight aggregate having an air-dry unit weight as determined by definition above, not exceeding 115 pcf (1840 kg/m^3). In this code, a lightweight concrete without natural sand is termed "all-lightweight concrete" and lightweight concrete in which all fine aggregate consists of normal-weight sand is termed "sand-lightweight concrete."

CONTRACTION JOINT is a formed, sawed, or tooled groove in a concrete structure to create a weakened plane and regulate the location of cracking resulting from the dimensional change of different parts of the structure.

CURVATURE FRICTION is friction resulting from bends or curves in the specified prestressing tendon profile.

DEFORMED REINFORCEMENT is deformed reinforcing bars, bar and rod mats, deformed wire, welded smooth wire fabric and welded deformed wire fabric.

DEVELOPMENT LENGTH is the length of embedded reinforcement required to develop the design strength of reinforcement at a critical section. See Section 1909.3.3.

EFFECTIVE DEPTH OF SECTION (*d*) is the distance measured from extreme compression fiber to centroid of tension reinforcement.

EFFECTIVE PRESTRESS is the stress remaining in prestressing tendons after all losses have occurred, excluding effects of dead load and superimposed load.

EMBEDMENT LENGTH is the length of embedded reinforcement provided beyond a critical section.

EXTREME TENSION STEEL is the reinforcement (prestressed or nonprestressed) that is the farthest from the extreme compression fiber.

ISOLATION JOINT is a separation between adjoining parts of a concrete structure, usually a vertical plane, at a designed location such as to interfere least with performance of the structure, yet such as to allow relative movement in three directions and avoid formation of cracks elsewhere in the concrete and through which all or part of the bonded reinforcement is interrupted.

JACKING FORCE is the temporary force exerted by device that introduces tension into prestressing tendons in prestressed concrete.

LOAD, DEAD, is the dead weight supported by a member, as defined by *Section 1602* (without load factors).

LOAD, FACTORED, is the load, multiplied by appropriate load factors, used to proportion members by the strength design method of this code. See Sections 1908.1.1 and 1909.2.

LOAD, LIVE, *is the live load specified by Section 1602* (without load factors).

LOAD, SERVICE, *is the live and dead loads* (without load factors).

MODULUS OF ELASTICITY is the ratio of normal stress to corresponding strain for tensile or compressive stresses below proportional limit of material. See Section 1908.5.

NET TENSILE STRAIN is the tensile strain at nominal strength exclusive of strains due to effective prestress, creep, shrinkage and temperature.

PEDESTAL is an upright compression member with a ratio of unsupported height to average least lateral dimension of 3 or less.

PLAIN CONCRETE is structural concrete with no reinforcement or with less reinforcement than the minimum amount specified for reinforced concrete.

PLAIN REINFORCEMENT is reinforcement that does not conform to definition of deformed reinforcement.

POSTTENSIONING is a method of prestressing in which tendons are tensioned after concrete has hardened.

PRECAST CONCRETE is a structural concrete element cast in other than its final position in the structure.

PRESTRESSED CONCRETE is structural concrete in which internal stresses have been introduced to reduce potential tensile stresses in concrete resulting from loads.

PRETENSIONING is a method of prestressing in which tendons are tensioned before concrete is placed.

REINFORCED CONCRETE is structural concrete reinforced with no less than the minimum amounts of prestressing tendons or nonprestressed reinforcement specified in this code.

REINFORCEMENT is material that conforms to Section 1903.5.1, excluding prestressing tendons unless specifically included.

RESHORES are shores placed snugly under a concrete slab or other structural member after the original forms and shores have been removed from a larger area, thus requiring the new slab or structural member to deflect and support its own weight and existing construction loads applied prior to the installation of the reshores.

SHORES are vertical or inclined support members designed to carry the weight of the formwork, concrete and construction loads above.

SPAN LENGTH. See Section 1908.7.

SPIRAL REINFORCEMENT is continuously wound reinforcement in the form of a cylindrical helix.

SPLITTING TENSILE STRENGTH (f_{ct}) is the tensile strength of concrete. See Section 1905.1.4.

STIRRUP is reinforcement used to resist shear and torsion stresses in a structural member; typically bars, wires, or welded wire fabric (smooth or deformed) bent into L, U or rectangular shapes and located perpendicular to or at an angle to longitudinal reinforcement. (The term "stirrups" is usually applied to lateral reinforcement in flexural members and the term "ties" to those in compression members.) See "tie."

STRENGTH, DESIGN, is the nominal strength multiplied by a strength-reduction factor ϕ. See Section 1909.3.

STRENGTH, NOMINAL, is the strength of a member or cross section calculated in accordance with provisions and assumptions of the strength design method of this code before application of any strength-reduction factors. See Section 1909.3.1.

STRENGTH, REQUIRED, is the strength of a member or cross section required to resist factored loads or related internal moments and forces in such combinations as are stipulated in this code. See Section 1909.1.1.

STRESS is the intensity of force per unit area.

STRUCTURAL CONCRETE is all concrete used for structural purposes, including plain and reinforced concrete.

TENDON is a steel element such as wire, cable, bar, rod or strand, or a bundle of such elements, used to impart prestress to concrete.

TENSION-CONTROLLED SECTION is a cross section in which the net tensile strain in the extreme tension steel at nominal strength is greater than or equal to 0.005.

TIE is a loop of reinforcing bar or wire enclosing longitudinal reinforcement. A continuously wound bar or wire in the form of a circle, rectangle or other polygon shape without re-entrant corners is acceptable. See "stirrup."

TRANSFER is the act of transferring stress in prestressing tendons from jacks or pretensioning bed to concrete member.

WALL is a member, usually vertical, used to enclose or separate spaces.

WOBBLE FRICTION in prestressed concrete, is friction caused by unintended deviation of prestressing sheath or duct from its specified profile.

YIELD STRENGTH is the specified minimum yield strength or yield point of reinforcement in psi.

SECTION 1903 — SPECIFICATIONS FOR TESTS AND MATERIALS

1903.0 Notation.

f_y = specified yield strength of nonprestressed reinforcement, psi (MPa).

1903.1 Tests of Materials.

1903.1.1 The building official may require the testing of any materials used in concrete construction to determine if materials are of quality specified.

1903.1.2 Tests of materials and of concrete shall be made *by an approved agency and at no expense to the jurisdiction. Such tests shall be made in accordance with the standards listed in Section 1903.*

1903.1.3 A complete record of tests of materials and of concrete shall be available for inspection during progress of work and for two years after completion of the project, and shall be preserved by the inspecting engineer or architect for that purpose.

1903.1.4 Material and test standards. *The standards listed in this chapter labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed in this chapter are recognized standards. (See Sections 3503 and 3504.)*

1903.2 Cement.

1. ASTM C 845, Expansive Hydraulic Cement
2. ASTM C 150, Portland Cement
3. ASTM C 595 or ASTM C 1157, Blended Hydraulic Cements

1903.3 Aggregates.

1903.3.1 Recognized standards.

1. ASTM C 33, Concrete Aggregates

2. ASTM C 330, Lightweight Aggregates for Structural Concrete

3. ASTM C 332, Lightweight Aggregates for Insulating Concrete

4. ASTM C 144, Aggregate for Masonry Mortar

5. Aggregates failing to meet the above specifications but which have been shown by special test or actual service to produce concrete of adequate strength and durability may be used where authorized by the building official.

1903.3.2 The nominal maximum size of coarse aggregate shall not be larger than:

1. One fifth the narrowest dimension between sides of forms, or
2. One third the depth of slabs, or
3. Three fourths the minimum clear spacing between individual reinforcing bars or wires, bundles of bars, or prestressing tendons or ducts.

These limitations may be waived if, in the judgment of the *building official,* workability and methods of consolidation are such that concrete can be placed without honeycomb or voids.

1903.4 Water.

1903.4.1 Water used in mixing concrete shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials or other substances deleterious to concrete or reinforcement.

1903.4.2 Mixing water for prestressed concrete or for concrete that will contain aluminum embedments, including that portion of mixing water contributed in the form of free moisture on aggregates, shall not contain deleterious amounts of chloride ions. See Section 1904.4.1.

1903.4.3 Nonpotable water shall not be used in concrete unless the following are satisfied:

1903.4.3.1 Selection of concrete proportions shall be based on concrete mixes using water from the same source.

1903.4.3.2 Mortar test cubes made with nonpotable mixing water shall have seven-day and 28-day strengths equal to at least 90 percent of strengths of similar specimens made with potable water. Strength test comparison shall be made on mortars, identical except for the mixing water, prepared and tested in accordance with ASTM C 109 (Compressive Strength of Hydraulic Cement Mortars).

1903.5 Steel Reinforcement.

1903.5.1 Reinforcement shall be deformed reinforcement, except that plain reinforcement may be used for spirals or tendons, and reinforcement consisting of structural steel, steel pipe or steel tubing may be used as specified in this chapter.

1903.5.2 Welding of reinforcing bars shall conform to *approved nationally recognized standards.* Type and location of welded splices and other required welding of reinforcing bars shall be indicated on the design drawings or in the project specifications. ASTM reinforcing bar specifications, except for A 706, shall be supplemented to require a report of material properties necessary to conform to requirements in UBC Standard 19-1.

1903.5.3 Deformed reinforcements.

1903.5.3.1 ASTM A 615, A 616, A 617, A 706, A 767 and A 775, Reinforcing Bars for Concrete.

1903.5.3.2 Deformed reinforcing bars with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa) may be used, provided f_y shall be the stress corresponding to a strain of 0.35 percent and the bars otherwise conform to approved national standards, see *ASTM A 615, A 616, A 617, A 706, A 767 and A 775.* See Section 1909.4.

1903.5.3.3 ASTM A 184, Fabricated Deformed Steel Bar Mats. For reinforced bars used in bar mats, see ASTM A 615, A 616, A 617, A 706, A 767 or A 775.

1903.5.3.4 ASTM A 496, Steel Wire, Deformed, for Concrete Reinforcement.

For deformed wire for concrete reinforcement, see *ASTM A 496,* except that wire shall not be smaller than size D4, and for wire with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa), f_y shall be the stress corresponding to a strain of 0.35 percent, if the yield strength specified in design exceeds 60,000 psi (413.7 MPa).

1903.5.3.5 ASTM A 185, Steel Welded Wire, Fabric, Plain for Concrete Reinforcement.

For welded plain wire fabric for concrete reinforcement, see *ASTM 185,* except that for wire with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa), f_y shall be the stress corresponding to a strain of 0.35 percent, if the yield strength specified in design exceeds 60,000 psi (413.7 MPa). Welded intersections shall not be spaced farther apart than 12 inches (305 mm) in direction of calculated stress, except for wire fabric used as stirrups in accordance with Section 1912.14.

1903.5.3.6 ASTM A 497, Welded Deformed Steel Wire Fabric for Concrete Reinforcement.

For welded deformed wire fabric for concrete reinforcement, see *ASTM A 497,* except that for wire with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa), f_y shall be the stress corresponding to a strain of 0.35 percent, if the yield strength specified in design exceeds 60,000 psi (413.7 MPa). Welded intersections shall not be spaced farther apart than 16 inches (406 mm) in direction of calculated stress, except for wire fabric used as stirrups in accordance with Section 1912.13.2.

1903.5.3.7 Deformed reinforcing bars may be galvanized or epoxy coated. For zinc or epoxy-coated reinforcement, see ASTM A 615, A 616, A 617, A 706, A 767 and A 775 and ASTM A 934 *(Epoxy-Coated Steel Reinforcing Bars).*

1903.5.3.8 Epoxy-coated wires and welded wire fabric shall comply with ASTM A 884 *(Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Fabric for Reinforcement).* Epoxy-coated wires shall conform to Section 1903.5.3.4 and epoxy-coated welded wire fabric shall conform to Section 1903.5.3.5 or 1903.5.3.6.

1903.5.4 Plain reinforcement.

1903.5.4.1 Plain bars for spiral reinforcement shall conform to approved national standards, see ASTM *A 615, A 616 and A 617.*

1903.5.4.2 For plain wire for spiral reinforcement, see *ASTM A 82* except that for wire with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa), f_y shall be the stress corresponding to a strain of 0.35 percent, if the yield strength specified in design exceeds 60,000 psi (413.7 MPa).

1903.5.5 Prestressing tendons.

1903.5.5.1 1. ASTM A 416, Uncoated Seven-wire Stress-relieved Steel Strand for Prestressed Concrete

2. ASTM A 421, Uncoated Stress-relieved Wire for Prestressed Concrete

3. ASTM A 722. Uncoated High-strength Steel Bar for Prestressing Concrete

1903.5.5.2 Wire, strands and bars not specifically listed in *ASTM A 416, A 421 and A 722* may be used, provided they conform to minimum requirements of these specifications and do not have properties that make them less satisfactory than those listed.

1903.5.6 Structural steel, steel pipe or tubing.

1903.5.6.1 For structural steel used with reinforcing bars in composite compression members meeting requirements of Section 1910.16.7 or 1910.16.8, see *ASTM A 36, A 242, A 572 and A 588.*

1903.5.6.2 For steel pipe or tubing for composite compression members composed of a steel-encased concrete core meeting requirements of Section 1910.16.4, see *ASTM A 53, A 500 and A 501.*

1903.5.7 *UBC Standard 19-1, Welding Reinforcing Steel, Metal Inserts and Connections in Reinforced Concrete Construction*

1903.6 Admixtures.

1903.6.1 Admixtures to be used in concrete shall be subject to prior approval by the *building official.*

1903.6.2 An admixture shall be shown capable of maintaining essentially the same composition and performance throughout the work as the product used in establishing concrete proportions in accordance with Section 1905.2.

1903.6.3 Calcium chloride or admixtures containing chloride from other than impurities from admixture ingredients shall not be used in prestressed concrete, in concrete containing embedded aluminum, or in concrete cast against stay-in-place galvanized steel forms. See Sections 1904.3.2 and 1904.4.1.

1903.6.4 ASTM C 260, Air-entraining Admixtures for Concrete

1903.6.5 ASTM C 494 and C 1017, Chemical Admixtures for Concrete

1903.6.6 ASTM C 618, Fly Ash and Raw or Calcined Natural Pozzolans for Use as Admixtures in Portland Cement Concrete

1903.6.7 *ASTM C 989,* Ground-iron Blast-furnace Slag for Use in Concrete and Mortars

1903.6.8 Admixtures used in concrete containing ASTM C 845 expansive cements shall be compatible with the cement and produce no deleterious effects.

1903.6.9 Silica fume used as an admixture shall conform to ASTM C 1240 (*Silica Fume for Use in Hydraulic Cement Concrete and Mortar*).

1903.7 Storage of Materials.

1903.7.1 Cementitious materials and aggregate shall be stored in such manner as to prevent deterioration or intrusion of foreign matter.

1903.7.2 Any material that has deteriorated or has been contaminated shall not be used for concrete.

1903.8 Concrete Testing.

1. ASTM C 192, Making and Curing Concrete Test Specimens in the Laboratory

2. ASTM C 31, Making and Curing Concrete Test Specimens in the Field

3. ASTM C 42, Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

4. ASTM C 39, Compressive Strength of Cylindrical Concrete Specimens

5. ASTM C 172, Sampling Freshly Mixed Concrete

6. ASTM C 496, Splitting Tensile Strength of Cylindrical Concrete Specimens

7. ASTM C 1218, Water-Soluble Chloride in Mortar and Concrete

1903.9 Concrete Mix.

1. ASTM C 94, Ready-mixed Concrete

2. ASTM C 685, Concrete Made by Volumetric Batching and Continuous Mixing

3. UBC Standard 19-2, Mill-mixed Gypsum Concrete and Poured Gypsum Roof Diaphragms

4. ASTM C 109, Compressive Strength of Hydraulic Cement Mortars

5. ASTM C 567, Unit Weight of Structural Lightweight Concrete

1903.10 Welding. *The welding of reinforcing steel, metal inserts and connections in reinforced concrete construction shall conform to UBC Standard 19-1.*

1903.11 Glass Fiber Reinforced Concrete. Recommended Practice for Glass Fiber Reinforced Concrete Panels, P.C.I. Manual 128.

SECTION 1904 — DURABILITY REQUIREMENTS

1904.0 Notation.

f'_c = specified compressive strength of concrete, psi (MPa).

1904.1 Water-Cementitious Materials Ratio.

1904.1.1 The water-cementitious materials ratios specified in Tables 19-A-2 and 19-A-4 shall be calculated using the weight of cement meeting ASTM C 150, C 595 or C 845 plus the weight of fly ash and other pozzolans meeting ASTM C 618, slag meeting ASTM C 989, and silica fume meeting ASTM C 1240, if any, except that when concrete is exposed to deicing chemicals, Section 1904.2.3 further limits the amount of fly ash, pozzolans, silica fume, slag or the combination of these materials.

1904.2 Freezing and Thawing Exposures.

1904.2.1 Normal-weight and lightweight concrete exposed to freezing and thawing or deicing chemicals shall be air entrained with air content indicated in Table 19-A-1. Tolerance on air content as delivered shall be ± 1.5 percent. For specified compressive strength f'_c greater than 5,000 psi (34.47 MPa), reduction of air content indicated in Table 19-A-1 by 1.0 percent shall be permitted.

1904.2.2 Concrete that will be subjected to the exposures given in Table 19-A-2 shall conform to the corresponding maximum water-cementitious materials ratios and minimum specified concrete compressive strength requirements of that table. In addition, concrete that will be exposed to deicing chemicals shall conform to the limitations of Section 1904.2.3.

1904.2.3 For concrete exposed to deicing chemicals, the maximum weight of fly ash, other pozzolans, silica fume or slag that is included in the concrete shall not exceed the percentages of the total weight of cementitious materials given in Table 19-A-3.

1904.3 Sulfate Exposure.

1904.3.1 Concrete to be exposed to sulfate-containing solutions or soils shall conform to the requirements of Table 19-A-4 or shall be concrete made with a cement that provides sulfate resistance and that has a maximum water-cementitious materials ratio and minimum compressive strength set forth in Table 19-A-4.

1904.3.2 Calcium chloride as an admixture shall not be used in concrete to be exposed to severe or very severe sulfate-containing solutions, as defined in Table 19-A-4.

1904.4 Corrosion Protection of Reinforcement.

1904.4.1 For corrosion protection of reinforcement in concrete, maximum water soluble chloride ion concentrations in hardened concrete at ages from 28 to 42 days contributed from the ingredients, including water, aggregates, cementitious materials and admixtures shall not exceed the limits of Table 19-A-5. When testing is performed to determine water soluble chloride ion content, test procedures shall conform to ASTM C 1218.

1904.4.2 If concrete with reinforcement will be exposed to chlorides from deicing chemicals, salt, salt water, brackish water, sea water or spray from these sources, requirements of Table 19-A-2 for water-cementitious materials ratio and concrete strength and the minimum concrete cover requirements of Section 1907.7 shall be satisfied. In addition, see Section 1918.14 for unbonded prestressed tendons.

SECTION 1905 — CONCRETE QUALITY, MIXING AND PLACING

1905.0 Notations.

f'_c = specified compressive strength of concrete, psi (MPa).

f'_{cr} = required average compressive strength of concrete used as the basis for selection of concrete proportions, psi (MPa).

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, psi (MPa).

s = standard deviation, psi (MPa).

1905.1 General.

1905.1.1 Concrete shall be proportioned to provide an average compressive strength as prescribed in Section 1905.3.2, as well as satisfy the durability criteria of Section 1904. Concrete shall be produced to minimize frequency of strengths below f'_c as prescribed in Section 1905.6.2.3.

1905.1.2 Requirements for f'_c shall be based on tests of cylinders made and tested as prescribed in Section 1905.6.2.

1905.1.3 Unless otherwise specified, f'_c shall be based on 28-day tests. If other than 28 days, test age for f'_c shall be as indicated in design drawings or specifications.

Design drawings shall show specified compressive strength of concrete f'_c for which each part of structure is designed.

1905.1.4 Where design criteria in Sections 1909.5.2.3, 1911.2; and 1912.2.4, provide for use of a splitting tensile strength value of concrete, laboratory tests shall be made to establish value of f_{ct} corresponding to specified values of f'_c.

1905.1.5 Splitting tensile strength tests shall not be used as a basis for field acceptance of concrete.

1905.2 Selection of Concrete Proportions.

1905.2.1 Proportions of materials for concrete shall be established to provide:

1. Workability and consistency to permit concrete to be worked readily into forms and around reinforcement under conditions of placement to be employed without segregation or excessive bleeding.

2. Resistance to special exposures as required by Section 1904.

3. Conformance with strength test requirements of Section 1905.6.

1905.2.2 Where different materials are to be used for different portions of proposed work, each combination shall be evaluated.

1905.2.3 Concrete proportions, including water-cementitious materials ratio, shall be established on the basis of field experience and/or trial mixtures with materials to be employed (see Section 1905.3), except as permitted in Section 1905.4 or required by Section 1904.

1905.3 Proportioning on the Basis of Field Experience and Trial Mixtures.

1905.3.1 Standard deviation.

1905.3.1.1 Where a concrete production facility has test records, a standard deviation shall be established. Test records from which a standard deviation is calculated:

1. Must represent materials, quality control procedures and conditions similar to those expected, and changes in materials and proportions within the test records shall not have been more restricted than those for proposed work.

2. Must represent concrete produced to meet a specified strength or strengths f'_c within 1,000 psi (6.89 MPa) of that specified for proposed work.

3. Must consist of at least 30 consecutive tests or two groups of consecutive tests totaling at least 30 tests as defined in Section 1905.6.1.4, except as provided in Section 1905.3.1.2.

1905.3.1.2 Where a concrete production facility does not have test records meeting requirements of Section 1905.3.1.1, but does have a record based on 15 to 29 consecutive tests, a standard deviation may be established as the product of the calculated standard deviation and the modification factor of Table 19-A-6. To be acceptable, the test record must meet the requirements of Section 1905.3.1.1, Items 1 and 2, and represent only a single record of consecutive tests that span a period of not less than 45 calendar days.

1905.3.2 Required average strength.

1905.3.2.1 Required average compressive strength f'_{cr} used as the basis for selection of concrete proportions shall be the larger of Formula (5-1) or (5-2) using a standard deviation calculated in accordance with Section 1905.3.1.1 or 1905.3.1.2.

$$f'_{cr} = f'_c + 1.34s \qquad (5\text{-}1)$$

or

$$f'_{cr} = f'_c + 2.33s - 500 \qquad (5\text{-}2)$$

For SI: $$f'_{cr} = f'_c + 2.33s - 3.45$$

1905.3.2.2 When a concrete production facility does not have field strength test records for calculation of standard deviation meeting requirements of Section 1905.3.1.1 or 1905.3.1.2, required average strength f'_{cr} shall be determined from Table 19-B and documentation of average strength shall be in accordance with requirements of Section 1905.3.3.

1905.3.3 Documentation of average strength. Documentation that proposed concrete proportions will produce an average compressive strength equal to or greater than required average compressive strength (see Section 1905.3.2) shall consist of a field strength test record. several strength test records, or trial mixtures.

1905.3.3.1 When test records are used to demonstrate that proposed concrete proportions will produce the required average strength f'_{cr} (see Section 1905.3.2), such records shall represent materials and conditions similar to those expected. Changes in materials, conditions and proportions within the test records shall not have been more restricted than those for proposed work. For the purpose of documenting average strength potential, test records consisting of less than 30 but not less than 10 consecutive tests may be used, provided test records encompass a period of time not less than 45 days. Required concrete proportions may be established by interpolation between the strengths and proportions of two or more test records each of which meets other requirements of this section.

1905.3.3.2 When an acceptable record of field test results is not available, concrete proportions established from trial mixtures meeting the following restrictions shall be permitted:

1. Combination of materials shall be those for proposed work.
2. Trial mixtures having proportions and consistencies required for proposed work shall be made using at least three different water-cementitious materials ratios or cementitious materials contents that will produce a range of strengths encompassing the required average strength f'_{cr}.
3. Trial mixture shall be designed to produce a slump within ± 0.75 inch (± 19 mm) of maximum permitted, and for air-entrained concrete, within ± 0.5 percent of maximum allowable air content.
4. For each water-cementitious materials ratio or cementitious materials content, at least three test cylinders for each test age shall be made and cured. Cylinders shall be tested at 28 days or at test age designated for determination of f'_c.
5. From results of cylinder tests, a curve shall be plotted showing relationship between water-cementitious materials ratio or cementitious materials content and compressive strength at designated test age.
6. Maximum water-cementitious materials ratio or minimum cementitious materials content for concrete to be used in proposed work shall be that shown by the curve to produce the average strength required by Section 1905.3.2, unless a lower water-cementitious materials ratio or higher strength is required by Section 1904.

1905.4 Proportioning without Field Experience or Trial Mixtures.

1905.4.1 If data required by Section 1905.3 are not available, concrete proportions shall be based upon other experience or information, if approved by the building official. The required average compressive strength f'_{cr} of concrete produced with materials similar to those proposed for use shall be at least 1,200 psi (8.3 MPa) greater than the specified compressive strength, f'_c. This alternative shall not be used for specified compressive strength greater than 4,000 psi (27.58 MPa).

1905.4.2 Concrete proportioned by Section 1905.4 shall conform to the durability requirements of Section 1904 and to compressive strength test criteria of Section 1905.6.

1905.5 Average Strength Reduction. As data become available during construction, it shall be permitted to reduce the amount by which f'_{cr} must exceed the specified value of f'_c, provided:

1. Thirty or more test results are available and average of test results exceeds that required by Section 1905.3.2.1, using a standard deviation calculated in accordance with Section 1905.3.1.1, or
2. Fifteen to 29 test results are available and average of test results exceeds that required by Section 1905.3.2.1, using a standard deviation calculated in accordance with Section 1905.3.1.2, and
3. Special exposure requirements of Section 1904 are met.

1905.6 Evaluation and Acceptance of Concrete.

1905.6.1 Frequency of testing.

1905.6.1.1 Samples for strength tests of each class of concrete placed each day shall be taken not less than once a day, or not less than once for each 150 cubic yards (115 m^3) of concrete, or not less than once for each 5,000 square feet (465 m^2) of surface area for slabs or walls.

1905.6.1.2 On a given project, if the total volume of concrete is such that the frequency of testing required by Section 1905.6.1.1 would provide less than five strength tests for a given class of concrete, tests shall be made from at least five randomly selected batches or from each batch if fewer than five batches are used.

1905.6.1.3 When total quantity of a given class of concrete is less than 50 cubic yards (38 m^3), strength tests are not required when evidence of satisfactory strength is submitted to and approved by the building official.

1905.6.1.4 A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days or at test age designated for determination of f'_c.

1905.6.2 Laboratory-cured specimens.

1905.6.2.1 Samples for strength tests shall be taken.

1905.6.2.2 Cylinders for strength tests shall be molded and laboratory cured and tested.

1905.6.2.3 Strength level of an individual class of concrete shall be considered satisfactory if both the following requirements are met:

1. Every arithmetic average of any three consecutive strength tests equals or exceeds f'_c.
2. No individual strength test (average of two cylinders) falls below f'_c by more than 500 psi (3.45 MPa).

1905.6.2.4 If either of the requirements of Section 1905.6.2.3 are not met, steps shall be taken to increase the average of subsequent strength test results. Requirements of Section 1905.6.4 shall be observed if the requirement of Item 2 of Section 1905.6.2.3 is not met.

1905.6.3 Field-cured specimens.

1905.6.3.1 If required by the building official, results of strength tests of cylinders cured under field conditions shall be provided.

1905.6.3.2 Field-cured cylinders shall be cured under field conditions, in accordance with Section 1903.8.

1905.6.3.3 Field-cured test cylinders shall be molded at the same time and from the same samples as laboratory-cured test cylinders.

1905.6.3.4 Procedures for protecting and curing concrete shall be improved when strength of field-cured cylinders at test age designated for determination of f'_c is less than 85 percent of that of companion laboratory-cured cylinders. The 85 percent limitation shall not apply if field-cured strength exceeds f'_c by more than 500 psi (3.45 MPa).

1905.6.4 Investigation of low-strength test results.

1905.6.4.1 If any strength test (see Section 1905.6.1.4) of laboratory-cured cylinders falls below specified values of f'_c by more than 500 psi (3.45 MPa) (see Section 1905.6.2.3, Item 2) or if tests of field-cured cylinders indicate deficiencies in protection and curing (see Section 1905.6.3.4), steps shall be taken to ensure that load-carrying capacity of the structure is not jeopardized.

1905.6.4.2 If the likelihood of low-strength concrete is confirmed and calculations indicate that load-carrying capacity is significantly reduced, tests of cores drilled from the area in question shall be permitted. In such case, three cores shall be taken for each strength test more than 500 psi (3.45 MPa) below specified value of f'_c.

1905.6.4.3 If concrete in the structure will be dry under service conditions, cores shall be air dried [temperatures 60°F to 80°F (15.6°C to 26.7°C), relative humidity less than 60 percent] for seven days before test and shall be tested dry. If concrete in the structure will be more than superficially wet under service conditions, cores shall be immersed in water for at least 40 hours and be tested wet.

1905.6.4.4 Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equal to at least 85 percent of f'_c and if no single core is less than 75 percent of f'_c. Additional testing of cores extracted from locations represented by erratic core strength results shall be permitted.

1905.6.4.5 If criteria of Section 1905.6.4.4 are not met, and if structural adequacy remains in doubt, the responsible authority shall be permitted to order a strength evaluation in accordance with Section 1920 for the questionable portion of the structure, or take other appropriate action.

1905.7 Preparation of Equipment and Place of Deposit.

1905.7.1 Preparation before concrete placement shall include the following:

1. All equipment for mixing and transporting concrete shall be clean.

2. All debris and ice shall be removed from spaces to be occupied by concrete.

3. Forms shall be properly coated.

4. Masonry filler units that will be in contact with concrete shall be well drenched.

5. Reinforcement shall be thoroughly clean of ice or other deleterious coatings.

6. Water shall be removed from place of deposit before concrete is placed unless a tremie is to be used or unless otherwise permitted by the building official.

7. All laitance and other unsound material shall be removed before additional concrete is placed against hardened concrete.

1905.8 Mixing.

1905.8.1 All concrete shall be mixed until there is a uniform distribution of materials and shall be discharged completely before mixer is recharged.

1905.8.2 Ready-mixed concrete shall be mixed and delivered in accordance with requirements of *ASTM C 94 (Ready-Mixed Concrete) or ASTM C 685 (Concrete Made by Volumetric Batching and Continuous Mixing).*

1905.8.3 Job-mixed concrete shall be mixed in accordance with the following:

1. Mixing shall be done in a batch mixer of an approved type.

2. Mixer shall be rotated at a speed recommended by the manufacturer.

3. Mixing shall be continued for at least $1^1/_2$ minutes after all materials are in the drum, unless a shorter time is shown to be satisfactory by the mixing uniformity tests of *ASTM C 94 (Ready-Mixed Concrete).*

4. Materials handling, batching and mixing shall conform to applicable provisions of *ASTM C 94 (Ready-Mixed Concrete).*

5. A detailed record shall be kept to identify:

5.1 Number of batches produced;

5.2 Proportions of materials used;

5.3 Approximate location of final deposit in structure;

5.4 Time and date of mixing and placing.

1905.9 Conveying.

1905.9.1 Concrete shall be conveyed from mixer to place of final deposit by methods that will prevent separation or loss of materials.

1905.9.2 Conveying equipment shall be capable of providing a supply of concrete at site of placement without separation of ingredients and without interruptions sufficient to permit loss of plasticity between successive increments.

1905.10 Depositing.

1905.10.1 Concrete shall be deposited as nearly as practicable in its final position to avoid segregation due to rehandling or flowing.

1905.10.2 Concreting shall be carried on at such a rate that concrete is at all times plastic and flows readily into spaces between reinforcement.

1905.10.3 Concrete that has partially hardened or been contaminated by foreign materials shall not be deposited in the structure.

1905.10.4 Retempered concrete or concrete that has been remixed after initial set shall not be used unless approved by the *building official.*

1905.10.5 After concreting is started, it shall be carried on as a continuous operation until placing of a panel or section, as defined by its boundaries or predetermined joints, is completed, except as permitted or prohibited by Section 1906.4.

1905.10.6 Top surfaces of vertically formed lifts shall be generally level.

1905.10.7 When construction joints are required, joints shall be made in accordance with Section 1906.4.

1905.10.8 All concrete shall be thoroughly consolidated by suitable means during placement and shall be thoroughly worked around reinforcement and embedded fixtures and into corners of forms.

1905.11 Curing.

1905.11.1 Concrete (other than high-early-strength) shall be maintained above 50°F (10.0°C) and in a moist condition for at least the first seven days after placement, except when cured in accordance with Section 1905.11.3.

1905.11.2 High-early-strength concrete shall be maintained above 50°F (10.0°C) and in a moist condition for at least the first three days, except when cured in accordance with Section 1905.11.3.

1905.11.3 Accelerated curing.

1905.11.3.1 Curing by high-pressure steam, steam at atmospheric pressure, heat and moisture or other accepted processes, may be employed to accelerate strength gain and reduce time of curing.

1905.11.3.2 Accelerated curing shall provide a compressive strength of the concrete at the load stage considered at least equal to required design strength at that load stage.

1905.11.3.3 Curing process shall be such as to produce concrete with a durability at least equivalent to the curing method of Section 1905.11.1 or 1905.11.2.

1905.11.3.4 When required by the building official, supplementary strength tests in accordance with Section 1905.6.3 shall be performed to assure that curing is satisfactory.

1905.12 Cold Weather Requirements.

1905.12.1 Adequate equipment shall be provided for heating concrete materials and protecting concrete during freezing or near-freezing weather.

1905.12.2 All concrete materials and all reinforcement, forms, fillers and ground with which concrete is to come in contact shall be free from frost.

1905.12.3 Frozen materials or materials containing ice shall not be used.

1905.13 Hot Weather Requirements. During hot weather, proper attention shall be given to ingredients, production methods, handling, placing, protection and curing to prevent excessive concrete temperatures or water evaporation that may impair required strength or serviceability of the member or structure.

SECTION 1906 — FORMWORK, EMBEDDED PIPES AND CONSTRUCTION JOINTS

1906.1 Design of Formwork.

1906.1.1 Forms shall result in a final structure that conforms to shapes, lines and dimensions of the members as required by the design drawings and specifications.

1906.1.2 Forms shall be substantial and sufficiently tight to prevent leakage of mortar.

1906.1.3 Forms shall be properly braced or tied together to maintain position and shape.

1906.1.4 Forms and their supports shall be designed so as not to damage previously placed structure.

1906.1.5 Design of formwork shall include consideration of the following factors:

1. Rate and method of placing concrete.

2. Construction loads, including vertical, horizontal and impact loads.

3. Special form requirements for construction of shells, folded plates, domes, architectural concrete or similar types of elements.

1906.1.6 Forms for prestressed concrete members shall be designed and constructed to permit movement of the member without damage during application of prestressing force.

1906.2 Removal of Forms, Shores and Reshoring.

1906.2.1 Removal of forms. Forms shall be removed in such a manner as not to impair safety and serviceability of the structure. Concrete to be exposed by form removal shall have sufficient strength not to be damaged by removal operation.

1906.2.2 Removal of shores and resboring. The provisions of Section 1906.2.2.1 through 1906.2.2.3 shall apply to slabs and beams except where cast on the ground.

1906.2.2.1 Before starting construction, the contractor shall develop a procedure and schedule for removal of shores and installation of reshores and for calculating the loads transferred to the structure during the process.

1. The structural analysis and concrete strength data used in planning and implementing form removal and shoring shall be furnished by the contractor to the building official when so requested.

2. Construction loads shall *not* be supported on, or any shoring removed from, any part of the structure under construction except when that portion of the structure in combination with remaining forming and shoring system has sufficient strength to support safely its weight and loads placed thereon.

3. Sufficient strength shall be demonstrated by structural analysis considering proposed loads, strength of forming and shoring system and concrete strength data. Concrete strength data may be based on tests of field-cured cylinders or, when approved by the building official, on other procedures to evaluate concrete strength.

1906.2.2.2 Construction loads exceeding the combination of superimposed dead load plus specified live load shall *not* be supported on any unshored portion of the structure under construction, unless analysis indicates adequate strength to support such additional loads.

1906.2.2.3 Form supports for prestressed concrete members shall not be removed until sufficient prestressing has been applied to enable prestressed members to carry their dead load and anticipated construction loads.

1906.3 Conduits and Pipes Embedded in Concrete.

1906.3.1 Conduits, pipes and sleeves of any material not harmful to concrete and within limitations of this subsection may be embedded in concrete with approval of the *building official,* provided they are not considered to replace structurally the displaced concrete.

1906.3.2 Conduits and pipes of aluminum shall not be embedded in structural concrete unless effectively coated or covered to prevent aluminum-concrete reaction or electrolytic action between aluminum and steel.

1906.3.3 Conduits, pipes and sleeves passing through a slab, wall or beam shall not impair significantly the strength of the construction.

1906.3.4 Conduits and pipes, with their fittings, embedded within a column shall not displace more than 4 percent of the area of cross section on which strength is calculated or which is required for fire protection.

1906.3.5 Except when plans for conduits and pipes are approved by the *building official,* conduits and pipes embedded within a slab, wall or beam (other than those merely passing through) shall satisfy the following:

1906.3.5.1 They shall not be larger in outside dimension than one third the overall thickness of slab, wall or beam in which they are embedded.

1906.3.5.2 They shall be spaced not closer than three diameters or widths on center.

1906.3.5.3 They shall not impair significantly the strength of the construction.

1906.3.6 Conduits, pipes and sleeves may be considered as replacing structurally in compression the displaced concrete, provided:

1906.3.6.1 They are not exposed to rusting or other deterioration.

1906.3.6.2 They are of uncoated or galvanized iron or steel not thinner than standard Schedule 40 steel pipe.

1906.3.6.3 They have a nominal inside diameter not over 2 inches (51 mm) and are spaced not less than three diameters on centers.

1906.3.7 Pipes and fittings shall be designed to resist effects of the material, pressure and temperature to which they will be subjected.

1906.3.8 No liquid, gas or vapor, except water not exceeding 90°F (32.2°C) or 50 psi (0.34 MPa) pressure, shall be placed in the pipes until the concrete has attained its design strength.

1906.3.9 In solid slabs, piping, unless it is used for radiant heating or snow melting, shall be placed between top and bottom reinforcement.

1906.3.10 Concrete cover for pipes, conduit and fittings shall not be less than $1^1/_2$ inches (38 mm) for concrete exposed to earth or weather, or less than $^3/_4$ inch (19 mm) for concrete not exposed to weather or in contact with ground.

1906.3.11 Reinforcement with an area not less than 0.002 times the area of concrete section shall be provided normal to the piping.

1906.3.12 Piping and conduit shall be so fabricated and installed that cutting, bending or displacement of reinforcement from its proper location will not be required.

1906.4 Construction Joints.

1906.4.1 Surface of concrete construction joints shall be cleaned and laitance removed.

1906.4.2 Immediately before new concrete is placed, all construction joints shall be wetted and standing water removed.

1906.4.3 Construction joints shall be so made and located as not to impair the strength of the structure. Provision shall be made for transfer of shear and other forces through construction joints. See Section 1911.7.9.

1906.4.4 Construction joints in floors shall be located within the middle third of spans of slabs, beams and girders. Joints in girders shall be offset a minimum distance of two times the width of intersecting beams.

1906.4.5 Beams, girders or slabs supported by columns or walls shall not be cast or erected until concrete in the vertical support members is no longer plastic.

1906.4.6 Beams, girders, haunches, drop panels and capitals shall be placed monolithically as part of a slab system, unless otherwise shown in design drawings or specifications.

SECTION 1907 — DETAILS OF REINFORCEMENT

1907.0 Notations.

d = distance from extreme compression fiber to centroid of tension reinforcement, inches (mm).

d_b = nominal diameter of bar, wire or prestressing strand, inches (mm).

f_y = specified yield strength of nonprestressed reinforcement, psi (MPa).

l_d = development length, inches (mm). See Section 1912.

1907.1 Standard Hooks. "Standard hook" as used in this code is one of the following:

1907.1.1 One-hundred-eighty-degree bend plus $4d_b$ extension, but not less than $2^1/_2$ inches (64 mm) at free end of bar.

1907.1.2 Ninety-degree bend plus $12d_b$ extension at free end of bar.

1907.1.3 For stirrup and tie hooks:

1. No. 5 bar and smaller, 90-degree bend plus $6d_b$ extension at free end of bar, or
2. No. 6, No. 7 and No. 8 bar, 90-degree bend, plus $12d_b$ extension at free end of bar, or
3. No. 8 bar and smaller, 135-degree bend plus $6d_b$ extension at free end of bar.
4. *For stirrups and tie hooks in Seismic Zones 3 and 4, refer to the hoop and crosstie provisions of Section 1921.1.*

1907.2 Minimum Bend Diameters.

1907.2.1 Diameter of bend measured on the inside of the bar, other than for stirrups and ties in sizes No. 3 through No. 5, shall not be less than the values in Table 19-B.

1907.2.2 Inside diameter of bends for stirrups and ties shall not be less than $4d_b$ for No. 5 bar and smaller. For bars larger than No. 5, diameter of bend shall be in accordance with Table 19-B.

1907.2.3 Inside diameter of bends in welded wire fabric (plain or deformed) for stirrups and ties shall not be less than $4d_b$ for deformed wire larger than D6 and $2d_b$ for all other wires. Bends with inside diameter of less than $8d_b$ shall not be less than $4d_b$ from nearest welded intersection.

1907.3 Bending.

1907.3.1 All reinforcement shall be bent cold, unless otherwise permitted by the *building official.*

1907.3.2 Reinforcement partially embedded in concrete shall not be field bent, except as shown on the design drawings or permitted by the *building official.*

1907.4 Surface Conditions of Reinforcement.

1907.4.1 At the time concrete is placed, reinforcement shall be free from mud, oil or other nonmetallic coatings that decrease bond. Epoxy coatings of bars in accordance with Section 1903.5.3.7 shall be permitted.

1907.4.2 Reinforcement, except prestressing tendons, with rust, mill scale or a combination of both, shall be considered satisfactory, provided the minimum dimensions (including height of deformations) and weight of a hand-wire-brushed test specimen are not less than applicable specification requirements.

1907.4.3 Prestressing tendons shall be clean and free of oil, dirt, scale, pitting and excessive rust. A light oxide shall be permitted.

1907.5 Placing Reinforcement.

1907.5.1 Reinforcement, prestressing tendons and ducts shall be accurately placed and adequately supported before concrete is placed, and shall be secured against displacement within tolerances of this section.

1907.5.2 Unless otherwise *approved by the building official,* reinforcement, prestressing tendons and prestressing ducts shall be placed within the following tolerances:

1907.5.2.1 Tolerance for depth *d,* and minimum concrete cover in flexural members, walls and compression members shall be as follows:

	TOLERANCE ON d	TOLERANCE ON MINIMUM CONCRETE COVER
$d \leq$ 8 in. (203 mm)	$\pm$ $^3/_8$ in. (9.5 mm)	$-^3/_8$ in. (9.5 mm)
$d >$ 8 in. (203 mm)	$\pm$ $^1/_2$ in. (12.7 mm)	$-^1/_2$ in. (12.7 mm)

except that tolerance for the clear distance to formed soffits shall be minus $^1/_4$ inch (6.4 mm) and tolerance for cover shall not exceed minus one third the minimum concrete cover required by the approved plans or specifications.

1907.5.2.2 Tolerance for longitudinal location of bends and ends of reinforcement shall be $\pm$ 2 inches ($\pm$ 51 mm) except at discontinuous ends of members where tolerance shall be $\pm$ $^1/_2$ inch ($\pm$ 12.7 mm).

1907.5.3 Welded wire fabric (with wire size not greater than W5 or D5) used in slabs not exceeding 10 feet (3048 mm) in span shall be permitted to be curved from a point near the top of slab over the support to a point near the bottom of slab at midspan, provided such reinforcement is either continuous over, or securely anchored at, support.

1907.5.4 Welding of crossing bars shall not be permitted for assembly of reinforcement.

EXCEPTIONS: *1. Reinforcing steel not required by design.*

2. When specifically approved by the building official, welding of crossing bars for assembly purposes in Seismic Zones 0, 1 and 2 may be permitted, provided that data are submitted to the building official to show that there is no detrimental effect on the action of the structural member as a result of welding of the crossing bars.

1907.6 Spacing Limits for Reinforcement.

1907.6.1 The minimum clear spacing between parallel bars in a layer shall be d_b but not less than 1 inch (25 mm). See also Section 1903.3.2.

1907.6.2 Where parallel reinforcement is placed in two or more layers, bars in the upper layers shall be placed directly above bars in the bottom layer with clear distance between layers not less than 1 inch (25 mm).

1907.6.3 In spirally reinforced or tied reinforced compression members, clear distance between longitudinal bars shall not be less than $1.5d_b$ or less than $1^1/_2$ inches (38 mm). See also Section 1903.3.2.

1907.6.4 Clear distance limitation between bars shall apply also to the clear distance between a contact lap splice and adjacent splices or bars.

1907.6.5 In walls and slabs other than concrete joist construction, primary flexural reinforcement shall not be spaced farther apart than three times the wall or slab thickness, or 18 inches (457 mm).

1907.6.6 Bundled bars.

1907.6.6.1 Groups of parallel reinforcing bars bundled in contact to act as a unit shall be limited to four bars in one bundle.

1907.6.6.2 Bundled bars shall be enclosed within stirrups or ties.

1907.6.6.3 Bars larger than No. 11 shall not be bundled in beams.

1907.6.6.4 Individual bars within a bundle terminated within the span of flexural members shall terminate at different points with at least $40d_b$ stagger.

1907.6.6.5 Where spacing limitations and minimum concrete cover are based on bar diameter d_b, a unit of bundled bars shall be treated as a single bar of a diameter derived from the equivalent total area.

1907.6.7 Prestressing tendons and ducts.

1907.6.7.1 Clear distance between pretensioning tendons at each end of a member shall not be less than $4d_b$ for wire, or $3d_b$ for strands. See also Section 1903.3.2. Closer vertical spacing and bundling of tendons shall be permitted in the middle portion of a span.

1907.6.7.2 Bundling of posttensioning ducts shall be permitted if it is shown that concrete can be satisfactorily placed and if provision is made to prevent the tendons, when tensioned, from breaking through the duct.

1907.7 Concrete Protection for Reinforcement.

1907.7.1 Cast-in-place concrete (nonprestressed). The following minimum concrete cover shall be provided for reinforcement:

		MINIMUM COVER, Inches (mm)
1.	Concrete cast against and permanently exposed to earth	3 (76)
2.	Concrete exposed to earth or weather:	
	No. 6 through No. 18 bar	2 (51)
	No. 5 bar, W31 or D31 wire, and smaller	$1^1/_2$ (38)
3.	Concrete not exposed to weather or in contact with ground:	
	Slabs, walls, joists:	
	No. 14 and No. 18 bar	$1^1/_2$ (38)
	No. 11 bar and smaller	$^3/_4$ (19)
	Beams, columns:	
	Primary reinforcement, ties, stirrups, spirals	$1^1/_2$ (38)
	Shells, folded plate members:	
	No. 6 bar and larger	$^3/_4$ (19)
	No. 5 bar, W31 or D31 wire, and smaller	$^1/_2$ (12.7)
4.	*Concrete tilt-up panels cast against a rigid horizontal surface, such as a concrete slab, exposed to the weather:*	
	No. 8 and smaller	*1 (25)*
	No. 9 through No. 18	*2 (51)*

1907.7.2 Precast concrete (manufactured under plant control conditions). The following minimum concrete cover shall be provided for reinforcement:

	MINIMUM COVER, inches (mm)
1. Concrete exposed to earth or weather:	
Wall panels:	
No. 14 and No. 18 bar	$1^1/_2$ (38)
No. 11 bar and smaller	$^3/_4$ (19)
Other members:	
No. 14 and No. 18 bar	2 (51)
No. 6 through No. 11 bar	$1^1/_2$ (38)
No. 5 bar W31 or D31 wire, and smaller	$1^1/_4$ (32)
2. Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists:	
No. 14 and No. 18 bar	$1^1/_4$ (32)
No. 11 bar and smaller	$^5/_8$ (16)
Beams, columns:	
Primary reinforcement	d_b but not less than $^5/_8$ (16) and need not exceed $1^1/_2$ (38)
Ties, stirrups, spirals	$^3/_8$ (9.5)
Shells, folded plate members:	
No. 6 bar and larger	$^5/_8$ (16)
No. 5 bar, W31 or D31 wire, and smaller	$^3/_8$ (9.5)

1907.7.3 Prestressed concrete.

1907.7.3.1 The following minimum concrete cover shall be provided for prestressed and nonprestressed reinforcement, ducts and end fittings, except as provided in Sections 1907.7.3.2 and 1907.7.3.3.

	MINIMUM COVER, inches (mm)
1. Concrete cast against and permanently exposed to earth	3 (76)
2. Concrete exposed to earth or weather:	
Wall panels, slabs, joists	1 (25)
Other members	$1^1/_2$ (32)
3. Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists	$^3/_4$ (19)
Beams, columns:	
Primary reinforcement	$1^1/_2$ (38)
Ties, stirrups, spirals	1 (25)
Shells, folded plate members:	
No. 5 bars, W31 or D31 wire, and smaller	$^3/_8$ (9.5)
Other reinforcement	d_b but not less than $^3/_4$ (19)

1907.7.3.2 For prestressed concrete members exposed to earth, weather or corrosive environments, and in which permissible tensile stress of Section 1918.4.2, Item 3, is exceeded, minimum cover shall be increased 50 percent.

1907.7.3.3 For prestressed concrete members manufactured under plant control conditions, minimum concrete cover for nonprestressed reinforcement shall be as required in Section 1907.7.2.

1907.7.4 Bundled bars. For bundled bars, minimum concrete cover shall be equal to the equivalent diameter of the bundle, but need not be greater than 2 inches (51 mm); except for concrete cast against and permanently exposed to earth, minimum cover shall be 3 inches (76 mm).

1907.7.5 Corrosive environments. In corrosive environments or other severe exposure conditions, amount of concrete protection shall be suitably increased, and denseness and nonporosity of protecting concrete shall be considered, or other protection shall be provided.

1907.7.6 Future extensions. Exposed reinforcement, inserts and plates intended for bonding with future extensions shall be protected from corrosion.

1907.7.7 Fire protection. When a thickness of cover for fire protection greater than the minimum concrete cover specified in Section 1907.7 is required, such greater thickness shall be used.

1907.8 Special Reinforcement Details for Columns.

1907.8.1 Offset bars. Offset bent longitudinal bars shall conform to the following:

1907.8.1.1 Slope of inclined portion of an offset bar with axis of column shall not exceed 1 in 6.

1907.8.1.2 Portions of bar above and below an offset shall be parallel to axis of column.

1907.8.1.3 Horizontal support at offset bends shall be provided by lateral ties, spirals or parts of the floor construction. Horizontal support provided shall be designed to resist one and one-half times the horizontal component of the computed force in the inclined portion of an offset bar. Lateral ties or spirals, if used, shall be placed not more than 6 inches (152 mm) from points of bend.

1907.8.1.4 Offset bars shall be bent before placement in the forms. See Section 1907.3.

1907.8.1.5 Where a column face is offset 3 inches (76 mm) or greater, longitudinal bars shall not be offset bent. Separate dowels, lap spliced with the longitudinal bars adjacent to the offset column faces, shall be provided. Lap splices shall conform to Section 1912.17.

1907.8.2 Steel cores. Load transfer in structural steel cores of composite compression members shall be provided by the following:

1907.8.2.1 Ends of structural steel cores shall be accurately finished to bear at end-bearing splices, with positive provision for alignment of one core above the other in concentric contact.

1907.8.2.2 At end-bearing splices, bearing shall be considered effective to transfer not more than 50 percent of the total compressive stress in the steel core.

1907.8.2.3 Transfer of stress between column base and footing shall be designed in accordance with Section 1915.8.

1907.8.2.4 Base of structural steel section shall be designed to transfer the total load from the entire composite member to the footing; or, the base may be designed to transfer the load from the steel core only, provided ample concrete section is available for transfer of the portion of the total load carried by the reinforced concrete section to the footing by compression in the concrete and by reinforcement.

1907.9 Connections.

1907.9.1 At connections of principal framing elements (such as beams and columns), enclosure shall be provided for splices of continuing reinforcement and for anchorage of reinforcement terminating in such connections.

1907.9.2 Enclosure at connections may consist of external concrete or internal closed ties, spirals or stirrups.

1907.10 Lateral Reinforcement for Compression Members.

1907.10.1 Lateral reinforcement for compression members shall conform to the provisions of Sections 1907.10.4 and 1907.10.5

and, where shear or torsion reinforcement is required, shall also conform to provisions of Section 1911.

1907.10.2 Lateral reinforcement requirements for composite compression members shall conform to Section 1910.16. Lateral reinforcement requirements for prestressing tendons shall conform to Section 1918.11.

1907.10.3 It shall be permitted to waive the lateral reinforcement requirements of Sections 1907.10, 1910.16 and 1918.11 where tests and structural analyses show adequate strength and feasibility of construction.

1907.10.4 Spirals. Spiral reinforcement for compression members shall conform to Section 1910.9.3 and to the following:

1907.10.4.1 Spirals shall consist of evenly spaced continuous bar or wire of such size and so assembled as to permit handling and placing without distortion from designed dimensions.

1907.10.4.2 For cast-in-place construction, size of spirals shall not be less than $^3/_8$-inch (9.5 mm) diameter.

1907.10.4.3 Clear spacing between spirals shall not exceed 3 inches (76 mm) or be less than 1 inch (25 mm). See also Section 1903.3.2.

1907.10.4.4 Anchorage of spiral reinforcement shall be provided by one and one-half extra turns of spiral bar or wire at each end of a spiral unit.

1907.10.4.5 Splices in spiral reinforcement shall be lap splices of $48d_b$, but not less than 12 inches (305 mm) or welded.

1907.10.4.6 Spirals shall extend from top of footing or slab in any story to level of lowest horizontal reinforcement in members supported above.

1907.10.4.7 Where beams or brackets do not frame into all sides of a column, ties shall extend above termination of spiral to bottom of slab or drop panel.

1907.10.4.8 In columns with capitals, spirals shall extend to a level at which the diameter or width of capital is two times that of the column.

1907.10.4.9 Spirals shall be held firmly in place and true to line.

1907.10.5 Ties. Tie reinforcement for compression members shall conform to the following:

1907.10.5.1 All nonprestressed bars shall be enclosed by lateral ties, at least No. 3 in size for longitudinal bars No. 10 or smaller, and at least No. 4 in size for Nos. 11, 14 and 18 and bundled longitudinal bars. Deformed wire or welded wire fabric of equivalent area shall be permitted.

1907.10.5.2 Vertical spacing of ties shall not exceed 16 longitudinal bar diameters, 48 tie bar or wire diameters, or least dimension of the compression member.

1907.10.5.3 Ties shall be arranged such that every corner and alternate longitudinal bar shall have lateral support provided by the corner of a tie with an included angle of not more than 135 degrees and a bar shall be not farther than 6 inches (152 mm) clear on each side along the tie from such a laterally supported bar. Where longitudinal bars are located around the perimeter of a circle, a complete circular tie shall be permitted.

1907.10.5.4 Ties shall be located vertically not more than one half a tie spacing above the top of footing or slab in any story and shall be spaced as provided herein to not more than one half a tie spacing below the lowest horizontal reinforcement *in members supported above.*

1907.10.5.5 Where beams or brackets frame from four directions into a column, termination of ties not more than 3 inches (76 mm) below reinforcement in shallowest of such beams or brackets shall be permitted.

1907.10.5.6 Column ties shall have hooks as specified in Section 1907.1.3.

1907.11 Lateral Reinforcement for Flexural Members.

1907.11.1 Compression reinforcement in beams shall be enclosed by ties or stirrups satisfying the size and spacing limitations in Section 1907.10.5 or by welded wire fabric of equivalent area. Such ties or stirrups shall be provided throughout the distance where compression reinforcement is required.

1907.11.2 Lateral reinforcement for flexural framing members subject to stress reversals or to torsion at supports shall consist of closed ties, closed stirrups, or spirals extending around the flexural reinforcement.

1907.11.3 Closed ties or stirrups may be formed in one piece by overlapping standard stirrup or tie end hooks around a longitudinal bar, or formed in one or two pieces lap spliced with a Class B splice (lap of 1.3 l_d), or anchored in accordance with Section 1912.13.

1907.12 Shrinkage and Temperature Reinforcement.

1907.12.1 Reinforcement for shrinkage and temperature stresses normal to flexural reinforcement shall be provided in structural slabs where the flexural reinforcement extends in one direction only.

1907.12.1.1 Shrinkage and temperature reinforcement shall be provided in accordance with either Section 1907.12.2 or 1907.12.3 below.

1907.12.1.2 Where shrinkage and temperature movements are significantly restrained, the requirements of Sections 1908.2.4 and 1909.2.7 shall be considered.

1907.12.2 Deformed reinforcement conforming to Section 1903.5.3 used for shrinkage and temperature reinforcement shall be provided in accordance with the following:

1907.12.2.1 Area of shrinkage and temperature reinforcement shall provide at least the following ratios of reinforcement area to gross concrete area, but not less than 0.0014:

1. Slabs where Grade 40 or 50 deformed bars are used — 0.0020
2. Slabs where Grade 60 deformed bars or welded wire fabric (smooth or deformed) are used — 0.0018
3. Slabs where reinforcement with yield stress exceeding 60,000 psi (413.7 MPa) measured at a yield strain of 0.35 percent is used

$$\frac{0.0018 \times 60,000}{f_y}$$

For SI:

$$\frac{0.0018 \times 413.7}{f_y}$$

1907.12.2.2 Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness, or 18 inches (457 mm).

1907.12.2.3 At all sections where required, reinforcement for shrinkage and temperature stresses shall develop the specified yield strength f_y in tension in accordance with Section 1912.

1907.12.3 Prestressing tendons conforming to Section 1903.5.5 used for shrinkage and temperature reinforcement shall be provided in accordance with the following:

1907.12.3.1 Tendons shall be proportioned to provide a minimum average compressive stress of 100 psi (0.69 MPa) on gross concrete area using effective prestress, after losses, in accordance with Section 1918.6.

1907.12.3.2 Spacing of prestressed tendons shall not exceed 6 feet (1829 mm).

1907.12.3.3 When the spacing of prestressed tendons exceeds 54 inches (1372 mm), additional bonded shrinkage and temperature reinforcement conforming with Section 1907.12.2 shall be provided between the tendons at slab edges extending from the slab edge for a distance equal to the tendon spacing.

1907.13 Requirements for Structural Integrity.

1907.13.1 In the detailing of reinforcement and connections, members of a structure shall be effectively tied together to improve integrity of the overall structure.

1907.13.2 For cast-in-place construction, the following shall constitute minimum requirements:

1907.13.2.1 In joist construction, at least one bottom bar shall be continuous or shall be spliced over the support with a Class A tension splice and at noncontinuous supports be terminated with a standard hook.

1907.13.2.2 Beams at the perimeter of the structure shall have at least one sixth of the tension reinforcement required for negative moment at the support and one-quarter of the positive moment reinforcement required at midspan made continuous around the perimeter and tied with closed stirrups or stirrups anchored around the negative moment reinforcement with a hook having a bend of at least 135 degrees. Stirrups need not be extended through any joints. When splices are needed, the required continuity shall be provided with top reinforcement spliced at midspan and bottom reinforcement spliced at or near the support with Class A tension splices.

1907.13.2.3 In other than perimeter beams, when closed stirrups are not provided, at least one-quarter of the positive moment reinforcement required at midspan shall be continuous or shall be spliced over the support with a Class A tension splice and at noncontinuous supports be terminated with a standard hook.

1907.13.2.4 For two-way slab construction, see Section 1913.3.8.5.

1907.13.3 For precast concrete construction, tension ties shall be provided in the transverse, longitudinal, and vertical directions and around the perimeter of the structure to effectively tie elements together. The provisions of Section 1916.5 shall apply.

1907.13.4 For lift-slab construction, see Sections 1913.3.8.6 and 1918.12.6.

SECTION 1915 — FOOTINGS

1915.7 Minimum Footing Depth. Depth of footing above bottom reinforcement shall not be less than 6 inches (152 mm) for footings on soil, or not less than 12 inches (305 mm) for footings on piles.

SECTION 1922 — STRUCTURAL PLAIN CONCRETE

1922.1 Scope.

1922.1.1 This section provides minimum requirements for design and construction of structural plain concrete members (cast-in-place or precast) except as specified in Sections 1922.1.1.1 and 1922.1.1.2.

> ***EXCEPTION:*** *The design is not required when the minimum foundation for stud walls is in accordance with Table 18-I-C.*

1922.1.1.1 Structural plain concrete basement walls shall be exempted from the requirements for special exposure conditions of Section 1904.2.2.

1922.1.1.2 Design and construction of soil-supported slabs, such as sidewalks and slabs on grade shall not be regulated by this code unless they transmit vertical loads from other parts of the structure to the soil.

1922.1.2 For special structures, such as arches, underground utility structures, gravity walls, and shielding walls, provisions of this section shall govern where applicable.

1922.2 Limitations.

1922.2.1 Provisions of this section shall apply for design of structural plain concrete members defined as either unreinforced or containing less reinforcement than the minimum amount specified in this code for reinforced concrete.

1922.2.2 Use of structural plain concrete shall be limited to (1) members that are continuously supported by soil or supported by other structural members capable of providing continuous vertical support, (2) members for which arch action provides compression under all conditions of loading, or (3) walls and pedestals. See Sections 1922.6 and 1922.8. The use of structural plain concrete columns is not permitted.

1922.2.3 This section does not govern design and installation of cast-in-place concrete piles and piers embedded in ground.

1922.2.4 Minimum strength. Specified compressive strength of concrete, f'_c, used in structural plain concrete elements shall not be less than 2,500 psi (17.2 MPa).

1922.2.5 Seismic Zones 2, 3 and 4. *Plain concrete shall not be used in Seismic Zone 2, 3 or 4 except where specifically permitted by Section 1922.10.3.*

1922.3 Joints.

1922.3.1 Contraction or isolation joints shall be provided to divide structural plain concrete members into flexurally discontinuous elements. Size of each element shall be limited to control buildup of excessive internal stresses within each element caused by restraint to movements from creep, shrinkage and temperature effects.

1922.3.2 In determining the number and location of contraction or isolation joints, consideration shall be given to: influence of climatic conditions; selection and proportioning of materials; mixing, placing and curing of concrete; degree of restraint to movement; stresses due to loads to which an element is subject; and construction techniques.

TABLE 19-B—MINIMUM DIAMETERS OF BEND

BAR SIZE	MINIMUM DIAMETER
Nos. 3 through 8	$6d_b$
Nos. 9, 10 and 11	$8d_b$
Nos. 14 and 18	$10d_b$

Chapter 20

Chapter 20 is printed in Volume 2 of the *Uniform Building Code*.

Chapter 21 is printed in its entirety in Volume 2 of the *Uniform Building Code.*
Excerpts from Chapter 21 are reprinted herein.

Excerpts from Chapter 21
MASONRY

SECTION 2101 — GENERAL

2101.1 Scope. The materials, design, construction and quality assurance of masonry shall be in accordance with this chapter.

2101.2 Design Methods. Masonry shall comply with the provisions of one of the following design methods in this chapter as well as the requirements of Sections 2101 through 2105.

2101.2.1 Working stress design. Masonry designed by the working stress design method shall comply with the provisions of Sections 2106 and 2107.

2101.2.2 Strength design. Masonry designed by the strength design method shall comply with the provisions of Sections 2106 and 2108.

2101.2.3 Empirical design. Masonry designed by the empirical design method shall comply with the provisions of Sections 2106.1 and 2109.

2101.2.4 Glass masonry. Glass masonry shall comply with the provisions of Section 2110.

2101.3 Definitions. For the purpose of this chapter, certain terms are defined as follows:

AREAS:

Bedded Area is the area of the surface of a masonry unit which is in contact with mortar in the plane of the joint.

Effective Area of Reinforcement is the cross-sectional area of reinforcement multiplied by the cosine of the angle between the reinforcement and the direction for which effective area is to be determined.

Gross Area is the total cross-sectional area of a specified section.

Net Area is the gross cross-sectional area minus the area of ungrouted cores, notches, cells and unbedded areas. Net area is the actual surface area of a cross section of masonry.

Transformed Area is the equivalent area of one material to a second based on the ratio of moduli of elasticity of the first material to the second.

BOND:

Adhesion Bond is the adhesion between masonry units and mortar or grout.

Reinforcing Bond is the adhesion between steel reinforcement and mortar or grout.

BOND BEAM is a horizontal grouted element within masonry in which reinforcement is embedded.

CELL is a void space having a gross cross-sectional area greater than $1^1/_2$ square inches (967 mm^2).

CLEANOUT is an opening to the bottom of a grout space of sufficient size and spacing to allow the removal of debris.

COLLAR JOINT is the mortared or grouted space between wythes of masonry.

COLUMN, REINFORCED, is a vertical structural member in which both the reinforcement and masonry resist compression.

COLUMN, UNREINFORCED, is a vertical structural member whose horizontal dimension measured at right angles to the thickness does not exceed three times the thickness.

DIMENSIONS:

Actual Dimensions are the measured dimensions of a designated item. The actual dimension shall not vary from the specified dimension by more than the amount allowed in the appropriate standard of quality in Section 2102.

Nominal Dimensions of masonry units are equal to its specified dimensions plus the thickness of the joint with which the unit is laid.

Specified Dimensions are the dimensions specified for the manufacture or construction of masonry, masonry units, joints or any other component of a structure.

GROUT LIFT is an increment of grout height within the total grout pour.

GROUT POUR is the total height of masonry wall to be grouted prior to the erection of additional masonry. A grout pour will consist of one or more grout lifts.

GROUTED MASONRY:

Grouted Hollow-unit Masonry is that form of grouted masonry construction in which certain designated cells of hollow units are continuously filled with grout.

Grouted Multiwythe Masonry is that form of grouted masonry construction in which the space between the wythes is solidly or periodically filled with grout.

JOINTS:

Bed Joint is the mortar joint that is horizontal at the time the masonry units are placed.

Head Joint is the mortar joint having a vertical transverse plane.

MASONRY UNIT is brick, tile, stone, glass block or concrete block conforming to the requirements specified in Section 2102.

Hollow-masonry Unit is a masonry unit whose net cross-sectional areas (solid area) in any plane parallel to the surface containing cores, cells or deep frogs is less than 75 percent of its gross cross-sectional area measured in the same plane.

Solid-masonry Unit is a masonry unit whose net cross-sectional area in any plane parallel to the surface containing the cores or cells is at least 75 percent of the gross cross-sectional area measured in the same plane.

PRISM is an assemblage of masonry units and mortar with or without grout used as a test specimen for determining properties of the masonry.

REINFORCED MASONRY is that form of masonry construction in which reinforcement acting in conjunction with the masonry is used to resist forces.

SHELL is the outer portion of a hollow masonry unit as placed in masonry.

WALLS

Bonded Wall is a masonry wall in which two or more wythes are bonded to act as a structural unit.

Cavity Wall is a wall containing continuous air space with a minimum width of 2 inches (51 mm) and a maximum width of $4^1/_2$ inches (114 mm) between wythes which are tied with metal ties.

WALL TIE is a mechanical metal fastener which connects wythes of masonry to each other or to other materials.

WEB is an interior solid portion of a hollow-masonry unit as placed in masonry.

WYTHE is the portion of a wall which is one masonry unit in thickness. A collar joint is not considered a wythe.

SECTION 2102 — MATERIAL STANDARDS

2102.1 Quality. Materials used in masonry shall conform to the requirements stated herein. If no requirements are specified in this section for a material, quality shall be based on generally accepted good practice, subject to the approval of the building official.

Reclaimed or previously used masonry units shall meet the applicable requirements as for new masonry units of the same material for their intended use.

2102.2 Standards of Quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards. See Sections 3503 and 3504.

1. **Aggregates.**
   - 1.1 ASTM C 144, Aggregates for Masonry Mortar
   - 1.2 ASTM C 404, Aggregates for Grout
2. **Cement.**
   - 2.1 UBC Standard 21-11, Cement, Masonry. (Plastic cement conforming to the requirements of UBC Standard 25-1 may be used in lieu of masonry cement when it also conforms to UBC Standard 21-11.)
   - 2.2 ASTM C 150, Portland Cement
   - 2.3 UBC Standard 21-14, Mortar Cement
3. **Lime.**
   - 3.1 UBC Standard 21-12, Quicklime for Structural Purposes
   - 3.2 UBC Standard 21-13, Hydrated Lime for Masonry Purposes. When Types N and NA hydrated lime are used in masonry mortar, they shall comply with the provisions of UBC Standard 21-15, Section 21.1506.7, excluding the plasticity requirement.
4. **Masonry units of clay or shale.**
   - 4.1 ASTM C 34, Structural Clay Load-bearing Wall Tile
   - 4.2 ASTM C 56, Structural Clay Nonload-bearing Tile
   - 4.3 UBC Standard 21-1, Section 21.101, Building Brick (solid units)
   - 4.4 ASTM C 126, Ceramic Glazed Structural Clay Facing Tile, Facing Brick and Solid Masonry Units. Load-bearing glazed brick shall conform to the weathering and structural requirements of UBC Standard 21-1, Section 21.106, Facing Brick
   - 4.5 UBC Standard 21-1, Section 21.106, Facing Brick (solid units)
   - 4.6 UBC Standard 21-1, Section 21.107, Hollow Brick
   - 4.7 ASTM C 67, Sampling and Testing Brick and Structural Clay Tile
   - 4.8 ASTM C 212, Structural Clay Facing Tile
   - 4.9 ASTM C 530, Structural Clay Non-Loadbearing Screen Tile
5. **Masonry units of concrete.**
   - 5.1 UBC Standard 21-3, Concrete Building Brick
   - 5.2 UBC Standard 21-4, Hollow and Solid Load-bearing Concrete Masonry Units
   - 5.3 UBC Standard 21-5, Nonload-bearing Concrete Masonry Units
   - 5.4 ASTM C 140, Sampling and Testing Concrete Masonry Units
   - 5.5 ASTM C 426, Standard Test Method for Drying Shrinkage of Concrete Block
6. **Masonry units of other materials.**
   - 6.1 **Calcium silicate.**
     UBC Standard 21-2, Calcium Silicate Face Brick (Sand-lime Brick)
   - 6.2 UBC Standard 21-9, Unburned Clay Masonry Units and Standard Methods of Sampling and Testing Unburned Clay Masonry Units
   - 6.3 ACI-704, Cast Stone
   - 6.4 UBC Standard 21-17, Test Method for Compressive Strength of Masonry Prisms
7. **Connectors.**
   - 7.1 Wall ties and anchors made from steel wire shall conform to UBC Standard 21-10, Part II, and other steel wall ties and anchors shall conform to A 36 in accordance with UBC Standard 22-1. Wall ties and anchors made from copper, brass or other nonferrous metal shall have a minimum tensile yield strength of 30,000 psi (207 MPa).
   - 7.2 All such items not fully embedded in mortar or grout shall either be corrosion resistant or shall be coated after fabrication with copper, zinc or a metal having at least equivalent corrosion-resistant properties.
8. **Mortar.**
   - 8.1 UBC Standard 21-15, Mortar for Unit Masonry and Reinforced Masonry other than Gypsum
   - 8.2 UBC Standard 21-16, Field Tests Specimens for Mortar
   - 8.3 UBC Standard 21-20, Standard Test Method for Flexural Bond Strength of Mortar Cement
9. **Grout.**
   - 9.1 UBC Standard 21-18, Method of Sampling and Testing Grout
   - 9.2 UBC Standard 21-19, Grout for Masonry
10. **Reinforcement.**
    - 10.1 UBC Standard 21-10, Part I, Joint Reinforcement for Masonry
    - 10.2 ASTM A 615, A 616, A 617, A 706, A 767, and A 775, Deformed and Plain Billet-steel Bars, Rail-steel Deformed and Plain Bars, Axle-steel Deformed and Plain Bars, and Deformed Low-alloy Bars for Concrete Reinforcement

10.3 UBC Standard 21-10, Part II, Cold-drawn Steel Wire for Concrete Reinforcement

SECTION 2103 — MORTAR AND GROUT

2103.1 General. Mortar and grout shall comply with the provisions of this section. Special mortars, grouts or bonding systems may be used, subject to satisfactory evidence of their capabilities when approved by the building official.

2103.2 Materials. Materials used as ingredients in mortar and grout shall conform to the applicable requirements in Section 2102. Cementitious materials for grout shall be one or both of the following: lime and portland cement. Cementitious materials for mortar shall be one or more of the following: lime, masonry cement, portland cement and mortar cement. Cementitious materials or additives shall not contain epoxy resins and derivatives, phenols, asbestos fibers or fireclays.

Water used in mortar or grout shall be clean and free of deleterious amounts of acid, alkalies or organic material or other harmful substances.

2103.3 Mortar.

2103.3.1 General. Mortar shall consist of a mixture of cementitious materials and aggregate to which sufficient water and approved additives, if any, have been added to achieve a workable, plastic consistency.

2103.3.2 Selecting proportions. Mortar with specified proportions of ingredients that differ from the mortar proportions of Table 21-A may be approved for use when it is demonstrated by laboratory or field experience that this mortar with the specified proportions of ingredients, when combined with the masonry units to be used in the structure, will achieve the specified compressive strength f'_m. Water content shall be adjusted to provide proper workability under existing field conditions. When the proportion of ingredients is not specified, the proportions by mortar type shall be used as given in Table 21-A.

2103.4 Grout.

2103.4.1 General. Grout shall consist of a mixture of cementitious materials and aggregate to which water has been added such that the mixture will flow without segregation of the constituents. The specified compressive strength of grout, f'_g, shall not be less than 2,000 psi (13.8 MPa).

2103.4.2 Selecting proportions. Water content shall be adjusted to provide proper workability and to enable proper placement under existing field conditions, without segregation. Grout shall be specified by one of the following methods:

1. Proportions of ingredients and any additives shall be based on laboratory or field experience with the grout ingredients and the masonry units to be used. The grout shall be specified by the proportion of its constituents in terms of parts by volume, or

2. Minimum compressive strength which will produce the required prism strength, or

3. Proportions by grout type shall be used as given in Table 21-B.

2103.5 Additives and Admixtures.

2103.5.1 General. Additives and admixtures to mortar or grout shall not be used unless approved by the building official.

2103.5.2 Antifreeze compounds. Antifreeze liquids, chloride salts or other such substances shall not be used in mortar or grout.

2103.5.3 Air entrainment. Air-entraining substances shall not be used in mortar or grout unless tests are conducted to determine compliance with the requirements of this code.

2103.5.4 Colors. Only pure mineral oxide, carbon black or synthetic colors may be used. Carbon black shall be limited to a maximum of 3 percent of the weight of the cement.

SECTION 2104 — CONSTRUCTION

2104.1 General. Masonry shall be constructed according to the provisions of this section.

2104.2 Materials: Handling, Storage and Preparation. All materials shall comply with applicable requirements of Section 2102. Storage, handling and preparation at the site shall conform also to the following:

1. Masonry materials shall be stored so that at the time of use the materials are clean and structurally suitable for the intended use.

2. All metal reinforcement shall be free from loose rust and other coatings that would inhibit reinforcing bond.

3. At the time of laying, burned clay units and sand lime units shall have an initial rate of absorption not exceeding 0.035 ounce per square inch (1.6 L/m^2) during a period of one minute. In the absorption test, the surface of the unit shall be held $^1/_8$ inch (3 mm) below the surface of the water.

4. Concrete masonry units shall not be wetted unless otherwise approved.

5. Materials shall be stored in a manner such that deterioration or intrusion of foreign materials is prevented and that the material will be capable of meeting applicable requirements at the time of mixing or placement.

6. The method of measuring materials for mortar and grout shall be such that proportions of the materials can be controlled.

7. Mortar or grout mixed at the jobsite shall be mixed for a period of time not less than three minutes or more than 10 minutes in a mechanical mixer with the amount of water required to provide the desired workability. Hand mixing of small amounts of mortar is permitted. Mortar may be retempered. Mortar or grout which has hardened or stiffened due to hydration of the cement shall not be used. In no case shall mortar be used two and one-half hours, nor grout used one and one-half hours, after the initial mixing water has been added to the dry ingredients at the jobsite.

> **EXCEPTION:** Dry mixes for mortar and grout which are blended in the factory and mixed at the jobsite shall be mixed in mechanical mixers until workable, but not to exceed 10 minute

2104.3 Cold-weather Construction.

2104.3.1 General. All materials shall be delivered in a usable condition and stored to prevent wetting by capillary action, rain and snow.

The tops of all walls not enclosed or sheltered shall be covered with a strong weather-resistive material at the end of each day or shutdown.

Partially completed walls shall be covered at all times when work is not in progress. Covers shall be draped over the wall and extend a minimum of 2 feet (600 mm) down both sides and shall be securely held in place, except when additional protection is required in Section 2104.3.4.

2104.3.2 Preparation. If ice or snow has inadvertently formed on a masonry bed, it shall be thawed by application of heat carefully applied until top surface of the masonry is dry to the touch.

A section of masonry deemed frozen and damaged shall be removed before continuing construction of that section.

2104.3.3 Construction. Masonry units shall be dry at time of placement. Wet or frozen masonry units shall not be laid.

Special requirements for various temperature ranges are as follows:

1. Air temperature 40°F to 32°F (4.5°C to 0°C): Sand or mixing water shall be heated to produce mortar temperatures between 40°F and 120°F (4.5°C and 49°C).

2. Air temperature 32°F to 25°F (0°C to –4°C): Sand and mixing water shall be heated to produce mortar temperatures between 40°F and 120°F (4.5°C and 49°C). Maintain temperatures of mortar on boards above freezing.

3. Air temperature 25°F to 20°F (–4°C to –7°C): Sand and mixing water shall be heated to produce mortar temperatures between 40°F and 120°F (4.5°C and 49°C). Maintain mortar temperatures on boards above freezing. Salamanders or other sources of heat shall be used on both sides of walls under construction. Windbreaks shall be employed when wind is in excess of 15 miles per hour (24 km/h).

4. Air temperature 20°F (–7°C) and below: Sand and mixing water shall be heated to produce mortar temperatures between 40°F and 120°F (4.5°C and 49°C). Enclosure and auxiliary heat shall be provided to maintain air temperature above freezing. Temperature of units when laid shall not be less than 20°F (–7°C).

2104.3.4 Protection. When the mean daily air temperature is 40°F to 32°F (4.5°C to 0°C), masonry shall be protected from rain or snow for 24 hours by covering with a weather-resistive membrane.

When the mean daily air temperature is 32°F to 25°F (0°C to –4°C), masonry shall be completely covered with a weather-resistive membrane for 24 hours.

When the mean daily air temperature is 25°F to 20°F (–4°C to –7°C), masonry shall be completely covered with insulating blankets or equally protected for 24 hours.

When the mean daily air temperature is 20°F (–7°C) or below, masonry temperature shall be maintained above freezing for 24 hours by enclosure and supplementary heat, by electric heating blankets, infrared heat lamps or other approved methods.

2104.3.5 Placing grout and protection of grouted masonry. When air temperatures fall below 40°F (4.5°C), grout mixing water and aggregate shall be heated to produce grout temperatures between 40°F and 120°F (4.5°C and 49°C).

Masonry to be grouted shall be maintained above freezing during grout placement and for at least 24 hours after placement.

When atmospheric temperatures fall below 20°F (–7°C), enclosures shall be provided around the masonry during grout placement and for at least 24 hours after placement.

2104.4 Placing Masonry Units.

2104.4.1 Mortar. The mortar shall be sufficiently plastic and units shall be placed with sufficient pressure to extrude mortar from the joint and produce a tight joint. Deep furrowing which produces voids shall not be used.

The initial bed joint thickness shall not be less than $^{1}/_{4}$ inch (6 mm) or more than 1 inch (25 mm); subsequent bed joints shall not be less than $^{1}/_{4}$ inch (6 mm) or more than $^{5}/_{8}$ inch (16 mm) in thickness.

2104.4.2 Surfaces. Surfaces to be in contact with mortar or grout shall be clean and free of deleterious materials.

2104.4.3 Solid masonry units. Solid masonry units shall have full head and bed joints.

2104.4.4 Hollow-masonry units. All head and bed joints shall be filled solidly with mortar for a distance in from the face of the unit not less than the thickness of the shell.

Head joints of open-end units with beveled ends that are to be fully grouted need not be mortared. The beveled ends shall form a grout key which permits grout within $^{5}/_{8}$ inch (16 mm) of the face of the unit. The units shall be tightly butted to prevent leakage of grout.

2104.5 Reinforcement Placing. Reinforcement details shall conform to the requirements of this chapter. Metal reinforcement shall be located in accordance with the plans and specifications. Reinforcement shall be secured against displacement prior to grouting by wire positioners or other suitable devices at intervals not exceeding 200 bar diameters.

Tolerances for the placement of reinforcement in walls and flexural elements shall be plus or minus $^{1}/_{2}$ inch (12.7 mm) for d equal to 8 inches (200 mm) or less, ± 1 inch (± 25 mm) for d equal to 24 inches (600 mm) or less but greater than 8 inches (200 mm), and ± $1^{1}/_{4}$ inches (32 mm) for d greater than 24 inches (600 mm).

Tolerance for longitudinal location of reinforcement shall be ± 2 inches (51 mm).

2104.6 Grouted Masonry.

2104.6.1 General conditions. Grouted masonry shall be constructed in such a manner that all elements of the masonry act together as a structural element.

Prior to grouting, the grout space shall be clean so that all spaces to be filled with grout do not contain mortar projections greater than $^{1}/_{2}$ inch (12.7 mm), mortar droppings or other foreign material. Grout shall be placed so that all spaces designated to be grouted shall be filled with grout and the grout shall be confined to those specific spaces.

Grout materials and water content shall be controlled to provide adequate fluidity for placement without segregation of the constituents, and shall be mixed thoroughly.

The grouting of any section of wall shall be completed in one day with no interruptions greater than one hour.

Between grout pours, a horizontal construction joint shall be formed by stopping all wythes at the same elevation and with the grout stopping a minimum of $1^{1}/_{2}$ inches (38 mm) below a mortar joint, except at the top of the wall. Where bond beams occur, the grout pour shall be stopped a minimum of $^{1}/_{2}$ inch (12.7 mm) below the top of the masonry.

Size and height limitations of the grout space or cell shall not be less than shown in Table 21-C. Higher grout pours or smaller cavity widths or cell size than shown in Table 21-C may be used when approved, if it is demonstrated that grout spaces will be properly filled.

Cleanouts shall be provided for all grout pours over 5 feet (1524 mm) in height.

Where required, cleanouts shall be provided in the bottom course at every vertical bar but shall not be spaced more than 32 inches (813 mm) on center for solidly grouted masonry. When cleanouts are required, they shall be sealed after inspection and before grouting.

Where cleanouts are not provided, special provisions must be made to keep the bottom and sides of the grout spaces, as well as the minimum total clear area as required by Table 21-C, clean and clear prior to grouting.

Units may be laid to the full height of the grout pour and grout shall be placed in a continuous pour in grout lifts not exceeding 6 feet (1830 mm). When approved, grout lifts may be greater than 6 feet (1830 mm) if it can be demonstrated the grout spaces can be properly filled.

All cells and spaces containing reinforcement shall be filled with grout.

2104.6.2 Construction requirements. Reinforcement shall be placed prior to grouting. Bolts shall be accurately set with templates or by approved equivalent means and held in place to prevent dislocation during grouting.

Segregation of the grout materials and damage to the masonry shall be avoided during the grouting process.

Grout shall be consolidated by mechanical vibration during placement before loss of plasticity in a manner to fill the grout space. Grout pours greater than 12 inches (300 mm) in height shall be reconsolidated by mechanical vibration to minimize voids due to water loss. Grout pours 12 inches (300 mm) or less in height shall be mechanically vibrated or puddled.

In one-story buildings having wood-frame exterior walls, foundations not over 24 inches (600 mm) high measured from the top of the footing may be constructed of hollow-masonry units laid in running bond without mortared head joints. Any standard shape unit may be used, provided the masonry units permit horizontal flow of grout to adjacent units. Grout shall be solidly poured to the full height in one lift and shall be puddled or mechanically vibrated.

In nonstructural elements which do not exceed 8 feet (2440 mm) in height above the highest point of lateral support, including fireplaces and residential chimneys, mortar of pouring consistency may be substituted for grout when the masonry is constructed and grouted in pours of 12 inches (300 mm) or less in height.

In multiwythe grouted masonry, vertical barriers of masonry shall be built across the grout space the entire height of the grout pour and spaced not more than 30 feet (9144 mm) horizontally. The grouting of any section of wall between barriers shall be completed in one day with no interruption longer than one hour.

2104.7 Aluminum Equipment. Grout shall not be handled nor pumped utilizing aluminum equipment unless it can be demonstrated with the materials and equipment to be used that there will be no deleterious effect on the strength of the grout.

2104.8 Joint Reinforcement. Wire joint reinforcement used in the design as principal reinforcement in hollow-unit construction shall be continuous between supports unless splices are made by lapping:

1. Fifty-four wire diameters in a grouted cell, or

2. Seventy-five wire diameters in the mortared bed joint, or

3. In alternate bed joints of running bond masonry a distance not less than 54 diameters plus twice the spacing of the bed joints, or

4. As required by calculation and specific location in areas of minimum stress, such as points of inflection.

Side wires shall be deformed and shall conform to UBC Standard 21-10, Part I, Joint Reinforcement for Masonry.

SECTION 2105 — QUALITY ASSURANCE

2105.1 General. Quality assurance shall be provided to ensure that materials, construction and workmanship are in compliance with the plans and specifications, and the applicable requirements of this chapter. When required, inspection records shall be maintained and made available to the building official.

2105.2 Scope. Quality assurance shall include, but is not limited to, assurance that:

1. Masonry units, reinforcement, cement, lime, aggregate and all other materials meet the requirements of the applicable standards of quality and that they are properly stored and prepared for use.

2. Mortar and grout are properly mixed using specified proportions of ingredients. The method of measuring materials for mortar and grout shall be such that proportions of materials are controlled.

3. Construction details, procedures and workmanship are in accordance with the plans and specifications.

4. Placement, splices and reinforcement sizes are in accordance with the provisions of this chapter and the plans and specifications.

2105.3 Compliance with f'_m.

2105.3.1 General. Compliance with the requirements for the specified compressive strength of masonry f'_m shall be in accordance with one of the sections in this subsection.

2105.3.2 Masonry prism testing. The compressive strength of masonry determined in accordance with UBC Standard 21-17 for each set of prisms shall equal or exceed f'_m. Compressive strength of prisms shall be based on tests at 28 days. Compressive strength at seven days or three days may be used provided a relationship between seven-day and three-day and 28-day strength has been established for the project prior to the start of construction. Verification by masonry prism testing shall meet the following:

1. A set of five masonry prisms shall be built and tested in accordance with UBC Standard 21-17 prior to the start of construction. Materials used for the construction of the prisms shall be taken from those specified to be used in the project. Prisms shall be constructed under the observation of the engineer or special inspector or an approved agency and tested by an approved agency.

2. When full allowable stresses are used in design, a set of three prisms shall be built and tested during construction in accordance with UBC Standard 21-17 for each 5,000 square feet (465 m^2) of wall area, but not less than one set of three masonry prisms for the project.

3. When one half the allowable masonry stresses are used in design, testing during construction is not required. A letter of certification from the supplier of the materials used to verify the f'_m in accordance with Section 2105.3.2, Item 1, shall be provided at the time of, or prior to, delivery of the materials to the jobsite to ensure the materials used in construction are representative of the materials used to construct the prisms prior to construction.

2105.3.3 Masonry prism test record. Compressive strength verification by masonry prism test records shall meet the following:

1. A masonry prism test record approved by the building official of at least 30 masonry prisms which were built and tested in accordance with UBC Standard 21-17. Prisms shall have been constructed under the observation of an engineer or special inspector or an approved agency and shall have been tested by an approved agency.

2. Masonry prisms shall be representative of the corresponding construction.

3. The average compressive strength of the test record shall equal or exceed $1.33 f'_m$.

4. When full allowable stresses are used in design, a set of three masonry prisms shall be built during construction in accordance with UBC Standard 21-17 for each 5,000 square feet (465 m^2) of wall area, but not less than one set of three prisms for the project.

5. When one half the allowable masonry stresses are used in design, field testing during construction is not required. A letter of certification from the supplier of the materials to the jobsite shall be provided at the time of, or prior to, delivery of the materials to assure the materials used in construction are representative of the materials used to develop the prism test record in accordance with Section 2105.3.3, Item 1.

2105.3.4 Unit strength method. Verification by the unit strength method shall meet the following:

1. When full allowable stresses are used in design, units shall be tested prior to construction and test units during construction for each 5,000 square feet (465 m^2) of wall area for compressive strength to show compliance with the compressive strength required in Table 21-D; and

> **EXCEPTION:** Prior to the start of construction, prism testing may be used in lieu of testing the unit strength. During construction, prism testing may also be used in lieu of testing the unit strength and the grout as required by Section 2105.3.4, Item 4.

2. When one half the allowable masonry stresses are used in design, testing is not required for the units. A letter of certification from the manufacturer of the units shall be provided at the time of, or prior to, delivery of the units to the jobsite to assure the units comply with the compressive strength required in Table 21-D; and

3. Mortar shall comply with the mortar type required in Table 21-D; and

4. When full stresses are used in design for concrete masonry, grout shall be tested for each 5,000 square feet (465 m^2) of wall area, but not less than one test per project, to show compliance with the compressive strength required in Table 21-D, Footnote 4.

5. When one half the allowable stresses are used in design for concrete masonry, testing is not required for the grout. A letter of certification from the supplier of the grout shall be provided at the time of, or prior to, delivery of the grout to the jobsite to assure the grout complies with the compressive strength required in Table 21-D, Footnote 4; or

6. When full allowable stresses are used in design for clay masonry, grout proportions shall be verified by the engineer or special inspector or an approved agency to conform with Table 21-B.

7. When one half the allowable masonry stresses are used in design for clay masonry, a letter of certification from the supplier of the grout shall be provided at the time of, or prior to, delivery of the grout to the jobsite to assure the grout conforms to the proportions of Table 21-B.

2105.3.5 Testing prisms from constructed masonry. When approved by the building official, acceptance of masonry which does not meet the requirements of Section 2105.3.2, 2105.3.3 or 2105.3.4 shall be permitted to be based on tests of prisms cut from the masonry construction in accordance with the following:

1. A set of three masonry prisms that are at least 28 days old shall be saw cut from the masonry for each 5,000 square feet (465 m^2) of the wall area that is in question but not less than one set of three masonry prisms for the project. The length, width and height dimensions of the prisms shall comply with the requirements of UBC Standard 21-17. Transporting, preparation and testing of prisms shall be in accordance with UBC Standard 21-17.

2. The compressive strength of prisms shall be the value calculated in accordance with UBC Standard 21-17, Section 21.1707.2, except that the net cross-sectional area of the prism shall be based on the net mortar bedded area.

3. Compliance with the requirement for the specified compressive strength of masonry, f'_m, shall be considered satisfied provided the modified compressive strength equals or exceeds the specified f'_m. Additional testing of specimens cut from locations in question shall be permitted.

2105.4 Mortar Testing. When required, mortar shall be tested in accordance with UBC Standard 21-16.

2105.5 Grout Testing. When required, grout shall be tested in accordance with UBC Standard 21-18.

SECTION 2107 — WORKING STRESS DESIGN OF MASONRY

2107.2.2.1 Maximum reinforcement size. The maximum size of reinforcement shall be No. 11 bars. Maximum reinforcement area in cells shall be 6 percent of the cell area without splices and 12 percent of the cell area with splices.

2107.2.2.2 Cover. All reinforcing bars, except joint reinforcement, shall be completely embedded in mortar or grout and have a minimum cover, including the masonry unit, of at least $^3/_4$ inch (19 mm), $1^1/_2$ inches (38 mm) of cover when the masonry is exposed to weather and 2 inches (51 mm) of cover when the masonry is exposed to soil.

SECTION 2109 — EMPIRICAL DESIGN OF MASONRY

2109.1 General. The design of masonry structures using empirical design located in those portions of Seismic Zones 0 and 1 as defined in Part III of Chapter 16 where the basic wind speed is less than 80 miles per hour as defined in Part II of Chapter 16 shall comply with the provisions of Section 2106 and this section, subject to approval of the building official.

2109.2 Height. Buildings relying on masonry walls for lateral load resistance shall not exceed 35 feet (10 668 mm) in height.

2109.3 Lateral Stability. Where the structure depends on masonry walls for lateral stability, shear walls shall be provided parallel to the direction of the lateral forces resisted.

Minimum nominal thickness of masonry shear walls shall be 8 inches (203 mm).

In each direction in which shear walls are required for lateral stability, the minimum cumulative length of shear walls provided shall be 0.4 times the long dimension of the building. The cumulative length of shear walls shall not include openings.

The maximum spacing of shear walls shall not exceed the ratio listed in Table 21-L.

2109.4 Compressive Stresses.

2109.4.1 General. Compressive stresses in masonry due to vertical dead loads plus live loads, excluding wind or seismic loads, shall be determined in accordance with Section 2109.4.3. Dead and live loads shall be in accordance with this code with permitted live load reductions.

2109.4.2 Allowable stresses. The compressive stresses in masonry shall not exceed the values set forth in Table 21-M. The allowable stresses given in Table 21-M for the weakest combination of the units and mortar used in any load wythe shall be used for all loaded wythes of multiwythe walls.

2109.4.3 Stress calculations. Stresses shall be calculated based on specified rather than nominal dimensions. Calculated compressive stresses shall be determined by dividing the design load by the gross cross-sectional area of the member. The area of openings, chases or recesses in walls shall not be included in the gross cross-sectional area of the wall.

2109.4.4 Anchor bolts. Bolt values shall not exceed those set forth in Table 21-N.

2109.5 Lateral Support. Masonry walls shall be laterally supported in either the horizontal or vertical direction not exceeding the intervals set forth in Table 21-O.

Lateral support shall be provided by cross walls, pilasters, buttresses or structural framing members horizontally or by floors, roof or structural framing members vertically.

Except for parapet walls, the ratio of height to nominal thickness for cantilever walls shall not exceed 6 for solid masonry or 4 for hollow masonry.

In computing the ratio for cavity walls, the value of thickness shall be the sums of the nominal thickness of the inner and outer wythes of the masonry. In walls composed of different classes of units and mortars, the ratio of height or length to thickness shall not exceed that allowed for the weakest of the combinations of units and mortar of which the member is composed.

2109.6 Minimum Thickness.

2109.6.1 General. The nominal thickness of masonry bearing walls in buildings more than one story in height shall not be less than 8 inches (203 mm). Solid masonry walls in one-story buildings may be of 6-inch nominal thickness when not over 9 feet (2743 mm) in height, provided that when gable construction is used, an additional 6 feet (1829 mm) is permitted to the peak of the gable.

> **EXCEPTION:** The thickness of unreinforced grouted brick masonry walls may be 2 inches (51 mm) less than required by this section, but in no case less than 6 inches (152 mm).

2109.6.2 Variation in thickness. Where a change in thickness due to minimum thickness occurs between floor levels, the greater thickness shall be carried up to the higher floor level.

2109.6.3 Decrease in thickness. Where walls of masonry of hollow units or masonry-bonded hollow walls are decreased in thickness, a course or courses of solid masonry shall be constructed between the walls below and the thinner wall above, or special units or construction shall be used to transmit the loads from face shells or wythes to the walls below.

2109.6.4 Parapets. Parapet walls shall be at least 8 inches (203 mm) in thickness and their height shall not exceed three times their thickness. The parapet wall shall not be thinner than the wall below.

2109.6.5 Foundation walls. Mortar used in masonry foundation walls shall be either Type M or S.

Where the height of unbalanced fill (height of finished grade above basement floor or inside grade) and the height of the wall between lateral support does not exceed 8 feet (2438 mm), and when the equivalent fluid weight of unbalanced fill does not exceed 30 pounds per cubic foot (480 kg/m^2), the minimum thickness of foundation walls shall be as set forth in Table 21-P. Maximum depths of unbalanced fill permitted in Table 21-P may be increased with the approval of the building official when local soil conditions warrant such an increase.

Where the height of unbalanced fill, height between lateral supports or equivalent fluid weight of unbalanced fill exceeds that set forth above, foundation walls shall be designed in accordance with Chapter 18.

2109.7 Bond.

2109.7.1 General. The facing and backing of multiwythe masonry walls shall be bonded in accordance with this section.

2109.7.2 Masonry headers. Where the facing and backing of solid masonry construction are bonded by masonry headers, not less than 4 percent of the wall surface of each face shall be composed of headers extending not less than 3 inches (76 mm) into the backing. The distance between adjacent full-length headers shall not exceed 24 inches (610 mm) either vertically or horizontally. In walls in which a single header does not extend through the wall, headers from opposite sides shall overlap at least 3 inches (76 mm), or headers from opposite sides shall be covered with another header course overlapping the header below at least 3 inches (76 mm).

Where two or more hollow units are used to make up the thickness of the wall, the stretcher courses shall be bonded at vertical intervals not exceeding 34 inches (864 mm) by lapping at least 3 inches (76 mm) over the unit below, or by lapping at vertical intervals not exceeding 17 inches (432 mm) with units which are at least 50 percent greater in thickness than the units below.

2109.7.3 Wall ties. Where the facing and backing of masonry walls are bonded with $^3/_{16}$-inch-diameter (4.8 mm) wall ties or metal ties of equivalent stiffness embedded in the horizontal mortar joints, there shall be at least one metal tie for each $4^1/_2$ square feet (0.42 m^2) of wall area. Ties in alternate courses shall be staggered, the maximum vertical distance between ties shall not exceed 24 inches (610 mm), and the maximum horizontal distance shall not exceed 36 inches (914 mm). Rods bent to rectangular shape shall be used with hollow-masonry units laid with the cells vertical. In other walls, the ends of ties shall be bent to 90-degree angles to provide hooks not less than 2 inches (51 mm) long. Additional ties shall be provided at all openings, spaced not more than 3 feet (914 mm) apart around the perimeter and within 12 inches (305 mm) of the opening.

The facing and backing of masonry walls may be bonded with prefabricated joint reinforcement. There shall be at least one cross wire serving as a tie for each $2^2/_3$ square feet (0.25 m^2) of wall area. The vertical spacing of the joint reinforcement shall not exceed 16 inches (406 mm). Cross wires of prefabricated joint reinforcement shall be at least No. 9 gage wire. The longitudinal wire shall be embedded in mortar.

2109.7.4 Longitudinal bond. In each wythe of masonry, head joints in successive courses shall be offset at least one fourth of the unit length or the walls shall be reinforced longitudinally as required in Section 2106.1.12.3, Item 4.

2109.8 Anchorage.

2109.8.1 Intersecting walls. Masonry walls depending on one another for lateral support shall be anchored or bonded at locations where they meet or intersect by one of the following methods:

1. Fifty percent of the units at the intersection shall be laid in an overlapping pattern, with alternating units having a bearing of not less than 3 inches (76 mm) on the unit below.

2. Walls shall be anchored by steel connectors having a minimum section of $^1/_4$ inch by $1^1/_2$ inches (6.4 mm by 38 mm) with ends bent up at least 2 inches (51 mm), or with cross pins to form anchorage. Such anchors shall be at least 24 inches (610 mm) long and the maximum spacing shall be 4 feet (1219 mm) vertically.

3. Walls shall be anchored by joint reinforcement spaced at a maximum distance of 8 inches (203 mm) vertically. Longitudinal

rods of such reinforcement shall be at least No. 9 gage and shall extend at least 30 inches (762 mm) in each direction at the intersection.

4. Interior nonbearing walls may be anchored at their intersection, at vertical spacing of not more than 16 inches (406 mm) with joint reinforcement or $^1/_4$-inch (6.4 mm) mesh galvanized hardware cloth.

5. Other metal ties, joint reinforcement or anchors may be used, provided they are spaced to provide equivalent area of anchorage to that required by this section.

2109.8.2 Floor and roof anchorage. Floor and roof diaphragms providing lateral support to masonry walls shall be connected to the masonry walls by one of the following methods:

1. Wood floor joists bearing on masonry walls shall be anchored to the wall by approved metal strap anchors at intervals not exceeding 6 feet (1829 mm). Joists parallel to the wall shall be anchored with metal straps spaced not more than 6 feet (1829 mm) on center extending over and under and secured to at least three joists. Blocking shall be provided between joists at each strap anchor.

2. Steel floor joists shall be anchored to masonry walls with No. 3 bars, or their equivalent, spaced not more than 6 feet (1829 mm) on center. Where joists are parallel to the wall, anchors shall be located at joist cross bridging.

3. Roof structures shall be anchored to masonry walls with $^1/_2$-inch-diameter (12.7 mm) bolts at 6 feet (1829 mm) on center or their equivalent. Bolts shall extend and be embedded at least 15 inches (381 mm) into the masonry, or be hooked or welded to not less than 0.2 square inch (129 mm^2) of bond beam reinforcement placed not less than 6 inches (152 mm) from the top of the wall.

2109.8.3 Walls adjoining structural framing. Where walls are dependent on the structural frame for lateral support, they shall be anchored to the structural members with metal anchors or keyed to the structural members. Metal anchors shall consist of $^1/_2$-inch-diameter (12.7 mm) bolts spaced at a maximum of 4 feet (1219 mm) on center and embedded at least 4 inches (102 mm) into the masonry, or their equivalent area.

2109.9 Unburned Clay Masonry.

2109.9.1 General. Masonry of stabilized unburned clay units shall not be used in any building more than one story in height. The unsupported height of every wall of unburned clay units shall not be more than 10 times the thickness of such walls. Bearing walls shall in no case be less than 16 inches (406 mm) in thickness. All footing walls which support masonry of unburned clay units shall extend to an elevation not less than 6 inches (152 mm) above the adjacent ground at all points.

2109.9.2 Bolts. Bolt values shall not exceed those set forth in Table 21-Q.

2109.10 Stone Masonry.

2109.10.1 General. Stone masonry is that form of construction made with natural or cast stone in which the units are laid and set in mortar with all joints filled.

2109.10.2 Construction. In ashlar masonry, bond stones uniformly distributed shall be provided to the extent of not less than 10 percent of the area of exposed facets. Rubble stone masonry 24 inches (610 mm) or less in thickness shall have bond stones with a maximum spacing of 3 feet (914 mm) vertically and 3 feet (914 mm) horizontally and, if the masonry is of greater thickness than 24 inches (610 mm), shall have one bond stone for each 6 square feet (0.56 m^2) of wall surface on both sides.

2109.10.3 Minimum thickness. The thickness of stone masonry bearing walls shall not be less than 16 inches (406 mm).

SECTION 2110 — GLASS MASONRY

2110.1 General. Masonry of glass blocks may be used in nonload-bearing exterior or interior walls and in openings which might otherwise be filled with windows, either isolated or in continuous bands, provided the glass block panels have a minimum thickness of 3 inches (76 mm) at the mortar joint and the mortared surfaces of the blocks are treated for mortar bonding. Glass block may be solid or hollow and may contain inserts.

2110.2 Mortar Joints. Glass block shall be laid in Type S or N mortar. Both vertical and horizontal mortar joints shall be at least $^1/_4$ inch (6 mm) and not more than $^3/_8$ inch (9.5 mm) thick and shall be completely filled. All mortar contact surfaces shall be treated to ensure adhesion between mortar and glass.

2110.3 Lateral Support. Glass panels shall be laterally supported along each end of the panel.

Lateral support shall be provided by panel anchors spaced not more than 16 inches (406 mm) on center or by channels. The lateral support shall be capable of resisting the horizontal design forces determined in Chapter 16 or a minimum of 200 pounds per lineal foot (2920 N per linear meter) of wall, whichever is greater. The connection shall accommodate movement requirements of Section 2110.6.

2110.4 Reinforcement. Glass block panels shall have joint reinforcement spaced not more than 16 inches (406 mm) on center and located in the mortar bed joint extending the entire length of the panel. A lapping of longitudinal wires for a minimum of 6 inches (152 mm) is required for joint reinforcement splices. Joint reinforcement shall also be placed in the bed joint immediately below and above openings in the panel. Joint reinforcement shall conform to UBC Standard 21-10, Part I. Joint reinforcement in exterior panels shall be hot-dip galvanized in accordance with UBC Standard 21-10, Part I.

2110.5 Size of Panels. Glass block panels for exterior walls shall not exceed 144 square feet (13.4 m^2) of unsupported wall surface or 15 feet (4572 mm) in any dimension. For interior walls, glass block panels shall not exceed 250 square feet (23.2 m^2) of unsupported area or 25 feet (7620 mm) in any dimension.

2110.6 Expansion Joints. Glass block shall be provided with expansion joints along the sides and top, and these joints shall have sufficient thickness to accommodate displacements of the supporting structure, but not less than $^3/_8$ inch (9.5 mm). Expansion joints shall be entirely free of mortar and shall be filled with resilient material.

2110.7 Reuse of Units. Glass block units shall not be reused after being removed from an existing panel.

SECTION 2111 — CHIMNEYS, FIREPLACES AND BARBECUES

Chimneys, flues, fireplaces and barbecues and their connections carrying products of combustion shall be designed, anchored, supported and reinforced as set forth in Chapter 31 and any applicable provisions of this chapter.

TABLE 21-A—MORTAR PROPORTIONS FOR UNIT MASONRY

MORTAR	TYPE	PROPORTIONS BY VOLUME (CEMENTITIOUS MATERIALS)								AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
		Portland Cement or Blended Cement	Masonry Cement[1] M	Masonry Cement[1] S	Masonry Cement[1] N	Mortar Cement[2] M	Mortar Cement[2] S	Mortar Cement[2] N	Hydrated Lime or Lime Putty	
Cement-lime	M	1	—	—	—	—	—	—	$\frac{1}{4}$	Not less than $2\frac{1}{4}$ and not more than 3 times the sum of the separate volumes of cementitious materials.
	S	1	—	—	—	—	—	—	over $\frac{1}{4}$ to $\frac{1}{2}$	
	N	1	—	—	—	—	—	—	over $\frac{1}{2}$ to $1\frac{1}{4}$	
	O	1	—	—	—	—	—	—	over $1\frac{1}{4}$ to $2\frac{1}{2}$	
Mortar cement	M	1	—	—	—	—	—	1	—	
	M	—	—	—	—	1	—	—	—	
	S	$\frac{1}{2}$	—	—	—	—	—	1	—	
	S	—	—	—	—	—	1	—	—	
	N	—	—	—	—	—	—	1	—	
Masonry cement	M	1	—	—	1	—	—	—	—	
	M	—	1	—	—	—	—	—	—	
	S	$\frac{1}{2}$	—	—	1	—	—	—	—	
	S	—	—	1	—	—	—	—	—	
	N	—	—	—	1	—	—	—	—	
	O	—	—	—	1	—	—	—	—	

[1]Masonry cement conforming to the requirements of UBC Standard 21-11.

[2]Mortar cement conforming to the requirements of UBC Standard 21-14.

TABLE 21-B—GROUT PROPORTIONS BY VOLUME[1]

TYPE	PARTS BY VOLUME OF PORTLAND CEMENT OR BLENDED CEMENT	PARTS BY VOLUME OF HYDRATED LIME OR LIME PUTTY	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION	
			Fine	Coarse
Fine grout	1	0 to $\frac{1}{10}$	$2\frac{1}{4}$ to 3 times the sum of the volumes of the cementitious materials	
Coarse grout	1	0 to $\frac{1}{10}$	$2\frac{1}{4}$ to 3 times the sum of the volumes of the cementitious materials	1 to 2 times the sum of the volumes of the cementitious materials

[1]Grout shall attain a minimum compressive strength at 28 days of 2,000 psi (13.8 MPa). The building official may require a compressive field strength test of grout made in accordance with UBC Standard 21-18.

TABLE 21-C—GROUTING LIMITATIONS

GROUT TYPE	GROUT POUR MAXIMUM HEIGHT (feet)[1]	MINIMUM DIMENSIONS OF THE TOTAL CLEAR AREAS WITHIN GROUT SPACES AND CELLS[2,3] × 25.4 for mm	
	× 304.8 for mm	Multiwythe Masonry	Hollow-unit Masonry
Fine	1	$\frac{3}{4}$	$1\frac{1}{2} \times 2$
Fine	5	$1\frac{1}{2}$	$1\frac{1}{2} \times 2$
Fine	8	$1\frac{1}{2}$	$1\frac{1}{2} \times 3$
Fine	12	$1\frac{1}{2}$	$1\frac{3}{4} \times 3$
Fine	24	2	3×3
Coarse	1	$1\frac{1}{2}$	$1\frac{1}{2} \times 3$
Coarse	5	2	$2\frac{1}{2} \times 3$
Coarse	8	2	3×3
Coarse	12	$2\frac{1}{2}$	3×3
Coarse	24	3	3×4

[1]See also Section 2104.6.

[2]The actual grout space or grout cell dimensions must be larger than the sum of the following items: (1) The required minimum dimensions of total clear areas in Table 21-C; (2) The width of any mortar projections within the space; and (3) The horizontal projections of the diameters of the horizontal reinforcing bars within a cross section of the grout space or cell.

[3]The minimum dimensions of the total clear areas shall be made up of one or more open areas, with at least one area being $\frac{3}{4}$ inch (19 mm) or greater in width.

TABLE 21-G—MINIMUM DIAMETERS OF BEND

BAR SIZE	MINIMUM DIAMETER
No. 3 through No. 8	6 bar diameters
No. 9 through No. 11	8 bar diameters

TABLE 21-H-1—RADIUS OF GYRATION[1] FOR CONCRETE MASONRY UNITS[2]

GROUT SPACING (inches) × 25.4 for mm	NOMINAL WIDTH OF WALL (inches) × 25.4 for mm				
	4	6	8	10	12
Solid grouted	1.04	1.62	2.19	2.77	3.34
16	1.16	1.79	2.43	3.04	3.67
24	1.21	1.87	2.53	3.17	3.82
32	1.24	1.91	2.59	3.25	3.91
40	1.26	1.94	2.63	3.30	3.97
48	1.27	1.96	2.66	3.33	4.02
56	1.28	1.98	2.68	3.36	4.05
64	1.29	1.99	2.70	3.38	4.08
72	1.30	2.00	2.71	3.40	4.10
No grout	1.35	2.08	2.84	3.55	4.29

[1]For single-wythe masonry or for an individual wythe of a cavity wall.

$$r = \sqrt{I/A_e}$$

[2]The radius of gyration shall be based on the specified dimensions of the masonry units or shall be in accordance with the values shown which are based on the minimum dimensions of hollow concrete masonry unit face shells and webs in accordance with UBC Standard 21-4 for two cell units.

TABLE 21-L—SHEAR WALL SPACING REQUIREMENTS FOR EMPIRICAL DESIGN OF MASONRY

FLOOR OR ROOF CONSTRUCTION	MAXIMUM RATIO Shear Wall Spacing to Shear Wall Length
Cast-in-place concrete	5:1
Precast concrete	4:1
Metal deck with concrete fill	3:1
Metal deck with no fill	2:1
Wood diaphragm	2:1

Chapter 22 is printed in its entirety in Volume 2 of the *Uniform Building Code*. Excerpts from Chapter 22 are reprinted herein.

Excerpts from Chapter 22
STEEL

Division I—GENERAL

SECTION 2201 — SCOPE

The quality, testing and design of steel used structurally in buildings or structures shall conform to the requirements specified in this chapter.

SECTION 2202 — STANDARDS OF QUALITY

The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards. (See Sections 3503 and 3504.)

2202.1 Material Standards.

UBC Standard 22-1, Material Specifications for Structural Steel

2202.2 Design Standards.

ANSI/ASCE 8, Specification for the Design of Cold-formed Stainless Steel Structural Members, American Society of Civil Engineers

2202.3 Connectors.

ASTM A 502, Structural Rivet Steel

SECTION 2203 — MATERIAL IDENTIFICATION

2203.1 General. Steel furnished for structural load-carrying purposes shall be properly identified for conformity to the ordered grade in accordance with approved national standards, the provisions of this chapter and the appropriate UBC standards. Steel which is not readily identifiable as to grade from marking and test records shall be tested to determine conformity to such standards.

2203.2 Structural Steel. structural steel shall be identified by the mill in accordance with approved national standards. When such steel is furnished to a specified minimum yield point greater than 36,000 pounds per square inch (psi) (248 MPa), the American Society for Testing and Materials (ASTM) or other specification designation shall be so indicated.

The fabricator shall maintain identity of the material and shall maintain suitable procedures and records attesting that the specified grade has been furnished in conformity with the applicable standard. The fabricator's identification mark system shall be established and on record prior to fabrication.

When structural steel is furnished to a specified minimum yield point greater than 36,000 psi (248 MPa), the ASTM or other specification designation shall be included near the erection mark on each shipping assembly or important construction component over any shop coat of paint prior to shipment from the fabricator's plant. Pieces of such steel which are to be cut to smaller sizes shall, before cutting, be legibly marked with the fabricator's identification mark on each of the smaller-sized pieces to provide continuity of identification. When subject to fabrication operations, prior to assembling into members, which might obliterate paint marking, such as blast cleaning, galvanizing or heating for forming, such pieces of steel shall be marked by steel die stamping or by a substantial tag firmly attached.

Individual pieces of steel having a minimum specified yield point in excess of 36,000 psi (248 MPa), which are received by the fabricator in a tagged bundle or lift or which have only the top shape or plate in the bundle or lift marked by the mill shall be marked by the fabricator prior to use in accordance with the fabricator's established identification marking system.

2203.3 Cold-formed Carbon and Low-alloy Steel. Cold-formed carbon and low-alloy steel used for structural purposes shall be identified by the mill in accordance with approved national standards. When such steel is furnished to a specified minimum yield point greater than 33,000 psi (228 MPa), the fabricator shall indicate the ASTM or other specification designation, by painting, decal, tagging or other suitable means, on each lift or bundle of fabricated elements.

When cold-formed carbon and low-alloy steel used for structural purposes has a specified yield point equal to or greater than 33,000 psi (228 MPa), which was obtained through additional treatment, the resulting minimum yield point shall be identified in addition to the specification designation.

2203.4 Cold-formed Stainless Steel. Cold-formed stainless steel structural members designed in accordance with recognized standards shall be identified as to grade through mill test reports. (See reference to ANSI/ASCE 8 in Chapter 35.) A certification shall be furnished that the chemical and mechanical properties of the material supplied equals or exceeds that considered in the design. Each lift or bundle of fabricated elements shall be identified by painting, decal, tagging or other suitable means.

2203.5 Open-web Steel Joists. Open-web steel joists and similar fabricated light steel load-carrying members shall be identified in accordance with Division II as to type, size and manufacturer by tagging or other suitable means at the time of manufacture or fabrication. Such identification shall be maintained continuously to the point of their installation in a structure.

SECTION 2205 — DESIGN AND CONSTRUCTION PROVISIONS

2205.11 Bolts. The use of high-strength A 325 and A 490 bolts shall be in accordance with the requirements of Divisions II and III.

Anchor bolts shall be set accurately to the pattern and dimensions called for on the plans. The protrusion of the threaded ends through the connected material shall be sufficient to fully engage the threads of the nuts, but shall not be greater than the length of threads on the bolts. Base plate holes for anchor bolts may be oversized as follows:

Bolt Size, inches (mm)	Hole Size, inches (mm)
$^3/_4$ (19.1)	$^5/_{16}$ (7.9) oversized
$^7/_8$ (22.2)	$^5/_{16}$ (7.9) oversized
1 < 2 (25.4 < 50.8)	$^1/_2$ (12.7) oversized
> 2 (> 50.8)	1 (25.4) > bolt diameter

Chapter 23 is printed in its entirety in Volume 2 of the *Uniform Building Code*. Excerpts from Chapter 23 are reprinted herein.

Excerpts from Chapter 23
WOOD

NOTE: This chapter has been revised in its entirety.

Division I—GENERAL DESIGN REQUIREMENTS

SECTION 2301 — GENERAL

2301.1 Scope. The quality and design of wood members and their fastenings shall conform to the provisions of this chapter.

2301.2 Design Methods. Design shall be based on one of the following methods.

2301.2.1 Allowable stress design. Design using allowable stress design methods shall resist the load combinations of Section 1612.3, in accordance with the applicable requirements of Section 2305.

2301.2.2 Conventional light-frame construction. The design and construction of conventional light-frame wood structures shall be in accordance with the applicable requirements of Section 2305.

SECTION 2302 — DEFINITIONS

2302.1 Definitions. The following terms used in this chapter shall have the meanings indicated in this section:

AFPA is the American Forest and Paper Association, 1111 19th Street, N.W., Suite 800, Washington, D.C. 20036 (formerly NFoPA, National Forest Products Association).

AHA is the American Hardboard Association, Inc., 1210 W. Northwest Highway, Palatine, Illinois 60067.

AITC is the American Institute of Timber Construction, 7012 S. Revere Parkway, Suite 140, Englewood, Colorado 80112.

ALSC is the American Lumber Standard Committee, Post Office Box 210, Germantown, Maryland 20875-0210.

APA is the American Plywood Association, 7011 South 19th Street, Tacoma, Washington 98411.

AWPA is the American Wood Preservers Association, Post Office Box 286, Woodstock, Maryland 21163-0286.

BLOCKED DIAPHRAGM is a diaphragm in which all sheathing edges not occurring on framing members are supported on and connected to blocking.

BRACED WALL LINE is a series of braced wall panels in a single story that meets the requirements of Section 2320.11.3.

BRACED WALL PANEL is a section of wall braced in accordance with Section 2320.11.3.

CONVENTIONAL LIGHT-FRAME CONSTRUCTION is a type of construction whose primary structural elements are formed by a system of repetitive wood-framing members. Refer to Section 2320 for conventional light-frame construction provisions.

DIAPHRAGM is a horizontal or nearly horizontal system acting to transmit lateral forces to the vertical-resisting elements. When the term "diaphragm" is used, it includes horizontal bracing systems.

FIBERBOARD is a fibrous-felted, homogeneous panel made from lignocellulosic fibers (usually wood or cane) and having a density of less than 31 pounds per cubic foot (497 kg/m^3) but more than 10 pounds per cubic foot (160 kg/m^3).

GLUED BUILT-UP MEMBERS are structural elements, the sections of which are composed of built-up lumber, wood structural panels or wood structural panels in combination with lumber, all parts bonded together with adhesives.

GRADE (Lumber) is the classification of lumber in regard to strength and utility in accordance with UBC Standard 23-1 and the grading rules of an approved lumber grading agency.

HARDBOARD is a fibrous-felted, homogeneous panel made from lignocellulosic fibers consolidated under heat and pressure in a hot press to a density not less than 31 pounds per cubic foot (497 kg/m^3).

NELMA is the Northeastern Lumber Manufacturers Association, 272 Tuttle Road, Post Office Box 87 A, Cumberland Center, Maine 04021.

NLGA is the National Lumber Grades Authority, 103-4000 Dominion Street, Burnaby B.C., Canada V5G 4G3.

NSLB is the Northern Softwood Lumber Bureau (serviced by NELMA), 272 Tuttle Road, Post Office Box 87 A, Cumberland Center, Maine 04021.

NOMINAL LOADING is a design load that stresses a member of fastening to the full allowable stress tabulated in this chapter. This loading may be applied for approximately 10 years, either continuously or cumulatively, and 90 percent of this load may be applied for the remainder of the life of the member or fastening.

NOMINAL SIZE (Lumber) is the commercial size designation of width and depth, in standard sawn lumber and glued-laminated lumber grades; somewhat larger than the standard net size of dressed lumber, in accordance with UBC Standard 23-1 for sawn lumber.

PARTICLEBOARD is a manufactured panel product consisting of particles of wood or combinations of wood particles and wood fibers bonded together with synthetic resins or other suitable bonding system by a bonding process in accordance with approved nationally recognized standards.

PLYWOOD is a panel of laminated veneers conforming to UBC Standard 23-2 or 23-3.

RIS is the Redwood Inspection Service, 405 Enfrente Drive, Suite 200, Novato, California 94949.

ROTATION is the torsional movement of a diaphragm about a vertical axis.

SPIB is the Southern Pine Inspection Bureau, 4709 Scenic Highway, Pensacola, Florida 32504.

STRUCTURAL GLUED-LAMINATED TIMBER is any member comprising an assembly of laminations of lumber in which the grain of all laminations is approximately parallel longitudinally, in which the laminations are bonded with adhesives.

SUBDIAPHRAGM is a portion of a larger wood diaphragm designed to anchor and transfer local forces to primary diaphragm struts and the main diaphragm.

TREATED WOOD is wood treated with an approved preservative under treating and quality control procedures.

WCLIB is the West Coast Lumber Inspection Bureau, 6980 S.W. Varnes Road, Post Office Box 23145, Portland, Oregon 97223.

WOOD OF NATURAL RESISTANCE TO DECAY OR TERMITES is the heartwood of the species set forth below. Corner sapwood is permitted on 5 percent of the pieces provided 90 percent or more of the width of each side on which it occurs is heartwood. Recognized species are:

Decay resistant: Redwood, Cedars, Black Locust

Termite resistant: Redwood, Eastern Red Cedar

WOOD STRUCTURAL PANEL is a structural panel product composed primarily of wood and meeting tbe requirements of UBC Standard 23-2 or 23-3. Wood structural panels include all-veneer plywood, composite panels containing a combination of veneer and wood-based material, and matformed panels such as oriented strand board and waferboard.

WWPA is the Western Wood Products Association, Yeon Building, 522 S. W. Fifth Avenue, Portland, Oregon 97204-2122.

SECTION 2303 — STANDARDS OF QUALITY

The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards. (See Sections 3503 and 3504.)

1. **Grading rules.**

   1.1 UBC Standard 23-1, Classification, Definition; Methods of Grading and Development of Design values for All Species of Lumber

   1.2 Standard Grading Rules for Canadian Lumber, United States Edition, NLGA

   1.3 Standard Grading Rules No. 17, WCLIB

   1.4 Standard Grading Rules, WWPA

   1.5 Grading Rules, NHPMA

   1.6 Grading Rules, SPIB

   1.7 Standard Specifications for Grades of California Redwood Lumber, RIS

   1.8 Standard Grading Rules, NELMA

2. **Structural glued-laminated timber.**

   2.1 ANSI/AITC Standard A190.1 and ASTM D 3737, Design and Manufacture of Structural Glued-laminated Timber

   2.2 Standard Specifications for Structural Glued-laminated Timber of Softwood Species, AITC 117; Manufacturing, AITC 117; Design and Standard Specifications for Hardwood Glued-laminated Timber, AITC 119.

   2.3 Inspection Manual AITC 200 of the American Institute of Timber Construction, Tests for Structural Glued-laminated Timber.

   2.4 AITC 500, Determination of Design Values for Structural Glued-laminated Timber in accordance with ASTM D 3737, American Institute of Timber Construction.

3. **Preservative treatment by pressure process and quality control.**

   3.1 Standard Specifications C1, C2, C3, C4, C9, C14, C15, C16, C22, C23, C24, C28 and M4, AWPA

4. **Product standards.**

   4.1 UBC Standard 23-2, Construction and Industrial Plywood

   4.2 UBC Standard 23-3, Performance Standard for Wood-Based Structural-Use Panels

   4.3 ANSI A208.1, Particleboard

   4.4 ASTM D 1037, Evaluating the Properties of Wood-based Fiber and Particle Panel Materials

   4.5 ASTM D 1333, Determining Formaldehyde Levels from Wood-based Products Under Defined Test Conditions Using a Large Chamber

   4.6 ANSI 05.1, Wood Poles—Specifications and Dimensions

   4.7 ASTM D 25, Round Timber Piles

   4.8 ANSI/AHA A194.1, Cellulosic Fiber Insulating Board (Fiberboard)

   4.9 ANSI/AHA 135.6, Hardboard Siding

5. **Design standards.**

   5.1 ASTM D 5055, Structural Capacities of Prefabricated Wood I-Joists

   5.2 ANSI/TPI 1 National Design Standard for Metal Plate Connected Wood Truss Construction

   5.3 ANSI/TPI 2 Standard for Testing Performance for Metal Plate Connected Wood Trusses

   5.4 ASCE 16, Load and Resistance Factor Design Standard for Engineered Wood Construction

6. **Fire retardancy.**

   6.1 UBC Standard 23-4, Fire-retardant-treated Wood Tests on Durability and Hygroscopic Properties

   6.2 UBC Standard 23-5, Fire-retardant-treated Wood

7. **Adhesives and glues.**

   7.1 ASTM D 3024, Dry Use Adhesive with Protein Base, Casein Type

   7.2 ASTM D 2559, Wet Use Adhesives

   7.3 APA Specification AFG-01, Adhesives for Field Gluing Plywood to Wood Framing

   7.4 ASTM D 1101 and AITC 200 in Testing of Glue Joints in Laminated Wood Product

8. **Design values.**

   8.1 ASTM D 1990, Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens

   8.2 ASTM D 245, Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber

   8.3 ASTM D 2555, Standard Test Methods for Establishing Clear Wood Strength Values

SECTION 2304 — MINIMUM QUALITY

2304.1 Quality and Identification. All lumber, wood structural panels, particleboard, structural glued-laminated timber, end-jointed lumber, fiberboard sheathing (when used structurally), hardboard siding (when used structurally), piles and poles regulated by this chapter shall conform to the applicable standards and grading rules specified in this code and shall be so identified by the grade mark or certificate of inspection issued by an approved agency.

All preservatively treated wood required to be treated under Section 2306 shall be identified by the quality mark of an inspection agency which has been accredited by an accreditation body which complies with the requirements of the American Lumber Standard Committee Treated Wood Program, or equivalent.

2304.2 Minimum Capacity or Grade. Minimum capacity of structural framing members may be established by performance tests. When tests are not made, capacity shall be based on allowable stresses and design criteria specified in this code.

Studs, joists, rafters, foundation plates or sills, planking 2 inches (51 mm) or more in depth, beams, stringers, posts, structural sheathing and similar load-bearing members shall be of at least the minimum grades set forth in the tables in this chapter.

Approved end-jointed lumber may be used interchangeably with solid-sawn members of the same species and grade. Such use shall include, but not be limited to, light-framing joists, planks and decking.

Wood structural panels shall be of the grades specified in UBC Standard 23-2 or 23-3.

2304.3 Timber Connectors and Fasteners. Safe loads and design practices for types of connectors and fasteners not mentioned or fully covered in Division III, Part III, may be determined in a manner approved by the building official.

The number and size of nails connecting wood members shall not be less than that set forth in Tables 23-II-B-1 and 23-II-B-2. Other connections shall be fastened to provide equivalent strength. End and edge distances and nail penetrations shall be in accordance with the applicable provisions of Division III, Part III.

Fasteners for pressure-preservative treated and fire-retardant treated wood shall be of hot-dipped zinc coated galvanized, stainless steel, silicon bronze or copper. Fasteners for wood foundations shall be as required in Chapter 18, Division II. Fasteners required to be corrosion resistant shall be either zinc-coated fasteners, aluminum alloy wire fasteners or stainless steel fasteners.

Connections depending on joist hangers or framing anchors, ties, and other mechanical fastenings not otherwise covered may be used where approved.

2304.4 Fabrication, Installation and Manufacture.

2304.4.1 General. Preparation, fabrication and installation of wood members and their fastenings shall conform to accepted engineering practices and to the requirements of this code. All members shall be framed, anchored, tied and braced to develop the strength and rigidity necessary for the purposes for which they are used.

2304.4.2 Timber connectors and fasteners. The installation of timber connectors and fasteners shall be in accordance with the provisions set forth in Division III, Part III.

2304.4.3 Structural glued-laminated timber. The manufacture and fabrication of structural glued-laminated timber shall be under the supervision of qualified personnel.

2304.4.4 Metal-plate-connected wood trusses. Metal-plate-connected wood trusses shall conform to the provisions of Division V. Each manufacturer of trusses using metal plate connectors shall retain an approved agency having no financial interest in the plant being inspected to make nonscheduled inspections of truss fabrication, delivery, and operations. The inspection shall cover all phases of truss operation, including lumber storage, handling, cutting, fixtures, presses or rollers, fabrication, bundling and banding, handling and delivery.

2304.5 Dried Fire-retardant-treated Wood. Approved fire-retardant-treated wood shall be dried, following treatment, to a maximum moisture content as follows: solid-sawn lumber 2 inches (51 mm) in thickness or less to 19 percent, and plywood to 15 percent.

2304.6 Size of Structural Members. Sizes of lumber and structural glued-laminated timber referred to in this code are nominal sizes. Computations to determine the required sizes of members shall be based on the net dimensions (actual sizes) and not the nominal sizes.

2304.7 Shrinkage. Consideration shall be given in design to the possible effect of cross-grain dimensional changes considered vertically which may occur in lumber fabricated in a green condition.

2304.8 Rejection. The building official may deny permission for the use of a wood member where permissible grade characteristics or defects are present in such a combination that they affect the serviceability of the member.

SECTION 2305 — DESIGN AND CONSTRUCTION REQUIREMENTS

2305.1 General. The following design requirements apply.

2305.2 All wood structures shall be designed and constructed in accordance with the requirements of Division I and Division II, Part I.

2305.3 Wind and earthquake load-resisting systems for all engineered wood structures shall be designed and constructed in accordance with the requirements of Division II, Part II.

2305.4 The design and construction of wood structures using allowable stress design methods shall be in accordance with Division III.

2305.5 The design and construction of conventional light-frame wood structures shall be in accordance with Division IV.

2305.6 The design and installation of timber connectors and fasteners shall be in accordance with Division III, Part III.

2305.7 Metal-plate-connected wood trusses shall conform to the provisions of Division V.

2305.8 Design of structural glued built-up members with plywood components shall be in accordance with Division VI.

2305.9 Design of joists and rafters shall be permitted to be in accordance with Division VII.

2305.10 Design of plank and beam flooring shall be permitted to be in accordance with Division VIII.

Division II—GENERAL REQUIREMENTS

Part I—REQUIREMENTS APPLICABLE TO ALL DESIGN METHODS

SECTION 2306 — DECAY AND TERMITE PROTECTION

2306.1 Preparation of Building Site. Site preparation shall be in accordance with Section 3302.

2306.2 Wood Support Embedded in Ground. Wood embedded in the ground or in direct contact with the earth and used for the support of permanent structures shall be treated wood unless continuously below the groundwater line or continuously submerged in fresh water. Round or rectangular posts, poles and sawn timber columns supporting permanent structures that are embedded in concrete or masonry in direct contact with earth or embedded in concrete or masonry exposed to the weather shall be treated wood. The wood shall be treated for ground contact.

2306.3 Under-floor Clearance. When wood joists or the bottom of wood structural floors without joists are located closer than 18 inches (457 mm) or wood girders are located closer than 12 inches (305 mm) to exposed ground in crawl spaces or unexcavated areas located within the periphery of the building foundation, the floor assembly, including posts, girders, joists and subfloor, shall be approved wood of natural resistance to decay as listed in Section 2306.4 or treated wood.

When the above under-floor clearances are required, the under-floor area shall be accessible. Accessible under-floor areas shall be provided with a minimum 18-inch-by-24-inch (457 mm by 610 mm) opening unobstructed by pipes, ducts and similar construction. All under-floor access openings shall be effectively screened or covered. Pipes, ducts and other construction shall not interfere with the accessibility to or within under-floor areas.

2306.4 Plates, Sills and Sleepers. All foundation plates or sills and sleepers on a concrete or masonry slab, which is in direct contact with earth, and sills that rest on concrete or masonry foundations, shall be treated wood or Foundation redwood, all marked or branded by an approved agency. Foundation cedar or No. 2 Foundation redwood marked or branded by an approved agency may be used for sills in territories subject to moderate hazard, where termite damage is not frequent and when specifically approved by the building official. In territories where hazard of termite damage is slight, any species of wood permitted by this code may be used for sills when specifically approved by the building official.

2306.5 Columns and Posts. Columns and posts located on concrete or masonry floors or decks exposed to the weather or to water splash or in basements and that support permanent structures shall be supported by concrete piers or metal pedestals projecting above floors unless approved wood of natural resistance to decay or treated wood is used. The pedestals shall project at least 6 inches (152 mm) above exposed earth and at least 1 inch (25 mm) above such floors.

Individual concrete or masonry piers shall project at least 8 inches (203 mm) above exposed ground unless the columns or posts that they support are of approved wood of natural resistance to decay or treated wood is used.

2306.6 Girders Entering Masonry or Concrete Walls. Ends of wood girders entering masonry or concrete walls shall be provided with a $^1/_2$-inch (12.7 mm) air space on tops, sides and ends unless approved wood of natural resistance to decay or treated wood is used.

2306.7 Under-floor Ventilation. Under-floor areas shall be ventilated by an approved mechanical means or by openings into the under-floor area walls. Such openings shall have a net area of not less than 1 square foot for each 150 square feet (0.067 m^2 for each 10 m^2) of under-floor area. Openings shall be located as close to corners as practical and shall provide cross ventilation. The required area of such openings shall be approximately equally distributed along the length of at least two opposite sides. They shall be covered with corrosion-resistant wire mesh with mesh openings of $^1/_4$ inch (6.4 mm) in dimension. Where moisture due to climate and groundwater conditions is not considered excessive, the building official may allow operable louvers and may allow the required net area of vent openings to be reduced to 10 percent of the above, provided the under-floor ground surface area is covered with an approved vapor retarder.

2306.8 Wood and Earth Separation. Protection of wood against deterioration as set forth in the previous sections for specified applications is required. In addition, wood used in construction of permanent structures and located nearer than 6 inches (152 mm) to earth shall be treated wood or wood of natural resistance to decay, as defined in Section 2302.1. Where located on concrete slabs placed on earth, wood shall be treated wood or wood of natural resistance to decay. Where not subject to water splash or to exterior moisture and located on concrete having a minimum thickness of 3 inches (76 mm) with an impervious membrane installed between concrete and earth, the wood may be untreated and of any species.

Where planter boxes are installed adjacent to wood frame walls, a 2-inch-wide (51 mm) air space shall be provided between the planter and the wall. Flashings shall be installed when the air space is less than 6 inches (152 mm) in width. Where flashing is used, provisions shall be made to permit circulation of air in the air space. The wood-frame wall shall be provided with an exterior wall covering conforming to the provisions of Section 2310.

2306.9 Wood Supporting Roofs and Floors. Wood structural members supporting moisture-permeable floors or roofs that are exposed to the weather, such as concrete or masonry slabs, shall be approved wood of natural resistance to decay or treated wood unless separated from such floors or roofs by an impervious moisture barrier.

2306.10 Moisture Content of Treated Wood. When wood pressure treated with a water-borne preservative is used in enclosed locations where drying in service cannot readily occur, such wood shall be at a moisture content of 19 percent or less before being covered with insulation, interior wall finish, floor covering or other material.

2306.11 Retaining Walls. Wood used in retaining or crib walls shall be treated wood.

2306.12 Weather Exposure. Those portions of glued-laminated timbers that form the structural supports of a building or other structure and are exposed to weather and not properly protected by a roof, eave overhangs of similar covering shall be pressure treated with an approved preservative or be manufactured from wood of natural resistance to decay.

All wood structural panels, when designed to be exposed in outdoor applications, shall be of exterior type, except as provided in Section 2306.2. In geographical areas where experience has demonstrated a specific need, approved wood of natural resistance to decay or treated wood shall be used for those portions of wood members which form the structural supports of buildings, balconies, porches or similar permanent building appurtenances when such members are exposed to the weather without adequate protection from a roof, eave, overhang or other covering to prevent moisture or water accumulation on the surface or at joints between members. Depending on local experience, such members may include horizontal members such as girders, joists and decking; or vertical members such as posts, poles and columns; or both horizontal and vertical members.

2306.13 Water Splash. Where wood-frame walls and partitions are covered on the interior with plaster, tile or similar materials and are subject to water splash, the framing shall be protected with approved waterproof paper conforming to Section 1402.1.

SECTION 2307 — WOOD SUPPORTING MASONRY OR CONCRETE

Wood members shall not be used to permanently support the dead load of any masonry or concrete.

EXCEPTIONS: 1. Masonry or concrete nonstructural floor or roof surfacing not more than 4 inches (102 mm) thick may be supported by wood members.

2. Any structure may rest upon wood piles constructed in accordance with the requirements of Chapter 18.

3. Veneer of brick, concrete or stone applied as specified in Section 1403.6.2 may be supported by approved treated wood foundations when the maximum height of veneer does not exceed 30 feet (9144 mm) above the foundations. Such veneer used as an interior wall finish may also be supported on wood floors that are designed to support the additional load and designed to limit the deflection and shrinkage to $^1/_{600}$ of the span of the supporting members.

4. Glass block masonry having an installed weight of 20 pounds per square foot (97.6 kg/m^2) or less and installed with the provisions of Section 2109.5. When glass block is supported on wood floors, the floors shall be designed to limit deflection and shrinkage to $^1/_{600}$ of the span of the supporting members and the allowable stresses for the framing members shall be reduced in accordance with Division III, Part I.

See Division II, Part II for wood members resisting horizontal forces contributed by masonry or concrete.

SECTION 2308 — WALL FRAMING

The framing of exterior and interior walls shall be in accordance with provisions specified in Division IV unless a specific design is furnished.

Wood stud walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the building official shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems, or other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternate, such systems shall be designed to accommodate the differential shrinkage or movements.

SECTION 2309 — FLOOR FRAMING

Wood-joisted floors shall be framed and constructed and anchored to supporting wood stud or masonry walls as specified in Chapter 16.

Fire block and draft stops shall be in accordance with Section 708.

SECTION 2310 — EXTERIOR WALL COVERINGS

2310.1 General. Exterior wood stud walls shall be covered on the outside with the materials and in the manner specified in this section or elsewhere in this code. Studs or sheathing shall be covered on the outside face with a weather-resistive barrier when required by Section 1402.1. Exterior wall coverings of the minimum thickness specified in this section are based on a maximum stud spacing of 16 inches (406 mm) unless otherwise specified.

2310.2 Siding. Solid wood siding shall have an average thickness of $^3/_8$ inch (9.5 mm) unless placed over sheathing permitted by this code.

Siding patterns known as rustic, drop siding or shiplap shall have an average thickness in place of not less than $^{19}/_{32}$ inch (15 mm) and shall have a minimum thickness of not less than $^3/_8$ inch (9.5 mm). Bevel siding shall have a minimum thickness measured at the butt section of not less than $^7/_{16}$ inch (11 mm) and a tip thickness of not less than $^3/_{16}$ inch (4.8 mm). Siding of lesser dimensions may be used, provided such wall covering is placed over sheathing which conforms to the provisions specified elsewhere in this code.

All weatherboarding or siding shall be securely nailed to each stud with not less than one nail, or to solid 1-inch (25 mm) nominal wood sheathing or $^{15}/_{32}$-inch (12 mm) wood structural panel sheathing or $^1/_2$-inch (13 mm) particleboard sheathing with not less than one line of nails spaced not more than 24 inches (610 mm) on center in each piece of the weatherboarding or siding.

Wood board sidings applied horizontally, diagonally or vertically shall be fastened to studs, nailing strips or blocking set at a maximum 24 inches (610 mm) on center. Fasteners shall be nails or screws with a penetration of not less than $1^1/_2$ inches (38 mm) into studs, studs and wood sheathing combined, or blocking. Distance between such fastenings shall not exceed 24 inches (610 mm) for horizontally or vertically applied sidings and 32 inches (813 mm) for diagonally applied sidings.

2310.3 Plywood. When plywood is used for covering the exterior of outside walls, it shall be of the exterior type not less than $^3/_8$ inch (9.5 mm) thick. Plywood panel siding shall be installed in accordance with Table 23-II-A-1. Unless applied over 1-inch (25 mm) wood sheathing or $^{15}/_{32}$-inch (12 mm) wood structural panel sheathing or $^1/_2$-inch (13 mm) particleboard sheathing, joints shall occur over framing members and shall be protected with a continuous wood batten, approved caulking, flashing, vertical or horizontal shiplaps; or joints shall be lapped horizontally or otherwise made waterproof.

2310.4 Shingles or Shakes. Wood shingles or shakes and asbestos cement shingles may be used for exterior wall covering, provided the frame of the structure is covered with building paper as specified in Section 1402.1. All shingles or shakes attached to sheathing other than wood sheathing shall be secured with approved corrosion-resistant fasteners or on furring strips attached to the studs. Wood shingles or shakes may be applied over fiberboard shingle backer and sheathing with annular grooved nails. The thickness of wood shingles or shakes between wood nailing boards shall not be less than $^3/_8$ inch (9.5 mm). Wood shingles or shakes and asbestos shingles or siding may be nailed directly to approved fiberboard nailbase sheathing not less than $^1/_2$-inch (13 mm) nominal thickness with annular grooved nails.

The weather exposure of wood shingle or shake siding used on exterior walls shall not exceed maximums set forth in Table 23-II-K.

2310.5 Particleboard. When particleboard is used for covering the exterior of outside walls, it shall be of the M-1, M-S and M-2 Exterior Glue grades. Particleboard panel siding shall be installed in accordance with Tables 23-II-A-2 and 23-II-B-1. Panels shall be gapped $^1/_8$ inch (3.2 mm) and nails shall be spaced not less than $^3/_8$ inch (9.5 mm) from edges and ends of sheathing. Unless applied over $^5/_8$-inch (16 mm) net wood sheathing or $^1/_2$-inch (13 mm) plywood sheathing or $^1/_2$-inch (13 mm) particleboard sheathing, joints shall occur over framing members and shall be covered with a continuous wood batt; or joints shall be lapped horizontally or otherwise made waterproof to the satisfaction of the building official. Particleboard shall be sealed and protected with exterior quality finishes.

2310.6 Hardboard. When hardboard siding is used for covering the outside of exterior walls, it shall conform to Table 23-II-C. Lap siding shall be installed horizontally and applied to sheathed or unsheathed walls. Corner bracing shall be installed in conformance with Division IV. A weather-resistive barrier shall be installed under the lap siding as required by Section 1402.1.

Square-edged nongrooved panels and shiplap grooved or nongrooved siding shall be applied vertically to sheathed or unsheathed walls. Siding that is grooved shall not be less than $^1/_4$ inch (6.4 mm) thick in the groove.

Nail size and spacing shall follow Table 23-II-C and shall penetrate framing $1^1/_2$ inches (38 mm). Lap siding shall overlap 1 inch (25 mm) minimum and be nailed through both courses and into framing members with nails located $^1/_2$ inch (13 mm) from bottom of the overlapped course. Square-edged nongrooved panels shall be nailed $^3/_8$ inch (9.5 mm) from the perimeter of the panel and intermediately into studs. Shiplap edge panel siding with $^3/_8$-inch (9.5 mm) shiplap shall be nailed $^3/_8$ inch (9.5 mm) from the edges on both sides of the shiplap. The $^3/_4$-inch (19 mm) shiplap shall be nailed $^3/_8$ inch (9.5 mm) from the edge and penetrate through both the overlap and underlap. Top and bottom edges of the panel shall be nailed $^3/_8$ inch (9.5 mm) from the edge. Shiplap and lap siding shall not be force fit. Square-edged panels shall maintain a $^1/_{16}$-inch (1.6 mm) gap at joints. All joints and edges of siding shall be over framing members, and shall be made resistant to weather penetration with battens, horizontal overlaps or shiplaps to the satisfaction of the building official. A $^1/_8$-inch (3.2 mm) gap shall be provided around all openings.

2310.7 Nailing. All fasteners used for the attachment of siding shall be of a corrosion-resistant type.

SECTION 2311 — INTERIOR PANELING

All softwood wood structural panels shall conform with the provisions of Chapter 8 and shall be installed in accordance with Table 23-II-B-1. Panels shall comply with UBC Standard 23-3.

SECTION 2312 — SHEATHING

2312.1 Structural Floor Sheathing. Structural floor sheathing shall be designed in accordance with the general provisions of this code and the special provisions in this section.

Sheathing used as subflooring shall be designed to support all loads specified in this code and shall be capable of supporting concentrated loads of not less than 300 pounds (1334 N) without failure. The concentrated lóad shall be applied by a loaded disc, 3 inches (76 mm) or smaller in diameter.

Flooring, including the finish floor, underlayment and subfloor, where used, shall meet the following requirements:

1. Deflection under uniform design load limited to $^1/_{360}$ of the span between supporting joists or beams.

2. Deflection of flooring relative to joists under a 1-inch-diameter (25 mm) concentrated load of 200 pounds (890 N) limited to 0.125 inch (3.2 mm) or less when loaded midway between supporting joists or beams not over 24 inches (610 mm) on center and $^1/_{360}$ of the span for spans over 24 inches (610 mm).

Floor sheathing conforming to the provisions of Table 23-II-D-1, 23-II-D-2, 23-II-E-1, 23-II-F-1 or 23-II-F-2 shall be deemed to meet the requirements of this section.

2312.2 Structural Roof Sheathing. Structural roof sheathing shall be designed in accordance with the general provisions of this code and the special provisions in this section. Structural roof sheathing shall be designed to support all loads specified in this code and shall be capable of supporting concentrated loads of not less than 300 pounds (1334 N) without failure. The concentrated load shall be applied by a loaded disc, 3 inches (76 mm) or smaller in diameter. Structural roof sheathing shall meet the following requirement:

1. Deflection under uniform design live and dead load limited to $^1/_{180}$ of the span between supporting rafters or beams and $^1/_{240}$ under live load only.

Roof sheathing conforming to the provisions of Tables 23-II-D-1 and 23-II-D-2 or 23-II-E-1 and 23-II-E-2 shall be deemed to meet the requirements of this section.

Wood structural panel roof sheathing shall be bonded by intermediate or exterior glue. Wood structural panel roof sheathing exposed on the underside shall be bonded with exterior glue.

SECTION 2313 — MECHANICALLY LAMINATED FLOORS AND DECKS

A laminated lumber floor or deck built up of wood members set on edge, when meeting the following requirements, may be designed as a solid floor or roof deck of the same thickness, and continuous spans may be designed on the basis of the full cross section using the simple span moment coefficient.

Nail length shall not be less than two and one-half times the net thickness of each lamination. When deck supports are 4 feet (1219 mm) on center or less, side nails shall be spaced not more than 30 inches (762 mm) on center and staggered one third of the spacing in adjacent laminations. When supports are spaced more than 4 feet (1219 mm) on center, side nails shall be spaced not more than 18 inches (457 mm) on center alternately near top and bottom edges, and also staggered one third of the spacing in adjacent laminations. Two side nails shall be used at each end of butt-jointed pieces.

Laminations shall be toenailed to supports with 20d or larger common nails. When the supports are 4 feet (1219 mm) on center or less, alternate laminations shall be toenailed to alternate supports; when supports are spaced more than 4 feet (1219 mm) on center, alternate laminations shall be toenailed to every support.

A single-span deck shall have all laminations full length.

A continuous deck of two spans shall not have more than every fourth lamination spliced within quarter points adjoining supports.

Joints shall be closely butted over supports or staggered across the deck but within the adjoining quarter spans.

No lamination shall be spliced more than twice in any span.

SECTION 2314 — POST-BEAM CONNECTIONS

Where post and beam or girder construction is used, the design shall be in accordance with the provisions of this code. Positive connection shall be provided to ensure against uplift and lateral displacement.

TABLE 23-II-A-1—EXPOSED PLYWOOD PANEL SIDING

MINIMUM THICKNESS[1] (inch)	MINIMUM NUMBER OF PLIES	STUD SPACING (inches) PLYWOOD SIDING APPLIED DIRECTLY TO STUDS OR OVER SHEATHING
× 25.4 for mm		× 25.4 for mm
$^3/_8$	3	16[2]
$^1/_2$	4	24

[1]Thickness of grooved panels is measured at bottom of grooves.
[2]May be 24 inches (610 mm) if plywood siding applied with face grain perpendicular to studs or over one of the following: (1) 1-inch (25 mm) board sheathing, (2) $^7/_{16}$-inch (11 mm) wood structural panel sheathing or (3) $^3/_8$-inch (9.5 mm) wood structural panel sheathing with strength axis (which is the long direction of the panel unless otherwise marked) of sheathing perpendicular to studs.

TABLE 23-II-A-2—ALLOWABLE SPANS FOR EXPOSED PARTICLEBOARD PANEL SIDING

GRADE	STUD SPACING (inches)	MINIMUM THICKNESS (inches)		
		× 25.4 for mm		
		Siding		Exterior Ceilings and Soffits
	× 25.4 for mm	Direct to Studs	Continuous Support	Direct to Supports
M-1 M-S	16	$^5/_8$	$^3/_8$	$^3/_8$
M-2 "Exterior Glue"	24	$^5/_8$	$^3/_8$	$^3/_8$

TABLE 23-II-B-1—NAILING SCHEDULE

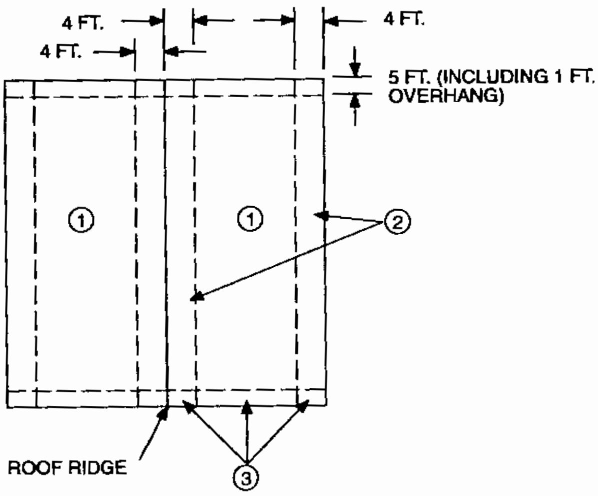
CONNECTION	NAILING[1]
1. Joist to sill or girder, toenail	3-8d
2. Bridging to joist, toenail each end	2-8d
3. 1″ × 6″ (25 mm × 152 mm) subfloor or less to each joist, face nail	2-8d
4. Wider than 1″ × 6″ (25 mm × 152 mm) subfloor to each joist, face nail	3-8d
5. 2″ (51 mm) subfloor to joist or girder, blind and face nail	2-16d
6. Sole plate to joist or blocking, typical face nail Sole plate to joist or blocking, at braced wall panels	16d at 16″ (406 mm) o.c. 3-16d per 16″ (406 mm)
7. Top plate to stud, end nail	2-16d
8. Stud to sole plate	4-8d, toenail or 2-16d, end nail
9. Double studs, face nail	16d at 24″ (610 mm) o.c.
10. Doubled top plates, typical face nail Double top plates, lap splice	16d at 16″ (406 mm) o.c. 8-16d
11. Blocking between joists or rafters to top plate, toenail	3-8d
12. Rim joist to top plate, toenail	8d at 6″ (152 mm) o.c.
13. Top plates, laps and intersections, face nail	2-16d
14. Continuous header, two pieces	16d at 16″ (406 mm) o.c. along each edge
15. Ceiling joists to plate, toenail	3-8d
16. Continuous header to stud, toenail	4-8d
17. Ceiling joists, laps over partitions, face nail	3-16d
18. Ceiling joists to parallel rafters, face nail	3-16d
19. Rafter to plate, toenail	3-8d
20. 1″ (25 mm) brace to each stud and plate, face nail	2-8d
21. 1″ × 8″ (25 mm × 203 mm) sheathing or less to each bearing, face nail	2-8d
22. Wider than 1″ × 8″ (25 mm × 203 mm) sheathing to each bearing, face nail	3-8d
23. Built-up corner studs	16d at 24″ (610 mm) o.c.
24. Built-up girder and beams	20d at 32″ (813 mm) o.c. at top and bottom and staggered 2-20d at ends and at each splice
25. 2″ (51 mm) planks	2-16d at each bearing
26. Wood structural panels and particleboard[2]: Subfloor and wall sheathing (to framing): $^1/_2$″ (12.7 mm) and less $^{19}/_{32}$″-$^3/_4$″ (15 mm-19 mm) $^7/_8$″-1″ (22 mm-25 mm) $1^1/_8$″-$1^1/_4$″ (29 mm-32 mm) Combination subfloor-underlayment (to framing): $^3/_4$″ (19 mm) and less $^7/_8$″-1″ (22 mm-25 mm) $1^1/_8$″-$1^1/_4$″ (29 mm-32 mm)	 6d[3] 8d[4] or 6d[5] 8d[3] 10d[4] or 8d[5] 6d[5] 8d[5] 10d[4] or 8d[5]
27. Panel siding (to framing):[2] $^1/_2$″ (12.7 mm) or less $^5/_8$″ (16 mm)	 6d[6] 8d[6]
28. Fiberboard sheathing:[7] $^1/_2$″ (12.7 mm) $^{25}/_{32}$″ (20 mm)	 No. 11 ga.[8] 6d[4] No. 16 ga.[9] No. 11 ga.[8] 8d[4] No. 16 ga.[9]
29. Interior paneling $^1/_4$″ (6.4 mm) $^3/_8$″ (9.5 mm)	 4d[10] 6d[11]

[1]Common or box nails may be used except where otherwise stated.
[2]Nails spaced at 6 inches (152 mm) on center at edges, 12 inches (305 mm) at intermediate supports except 6 inches (152 mm) at all supports where spans are 48 inches (1219 mm) or more. For nailing of wood structural panel and particleboard diaphragms and shear walls, refer to Sections 2315.3.3 and 2315.4. Nails for wall sheathing may be common, box or casing.
[3]Common or deformed shank.
[4]Common.
[5]Deformed shank.
[6]Corrosion-resistant siding or casing nails conforming to the requirements of Section 2304.3.
[7]Fasteners spaced 3 inches (76 mm) on center at exterior edges and 6 inches (152 mm) on center at intermediate supports.
[8]Corrosion-resistant roofing nails with $^7/_{16}$-inch-diameter (11 mm) head and $1^1/_2$-inch (38 mm) length for $^1/_2$-inch (12.7 mm) sheathing and $1^3/_4$-inch (44 mm) length for $^{25}/_{32}$-inch (20 mm) sheathing conforming to the requirements of Section 2304.3.
[9]Corrosion-resistant staples with nominal $^7/_{16}$-inch (11 mm) crown and $1^1/_8$-inch (29 mm) length for $^1/_2$-inch (12.7 mm) sheathing and $1^1/_2$-inch (38 mm) length for $^{25}/_{32}$-inch (20 mm) sheathing conforming to the requirements of Section 2304.3.
[10]Panel supports at 16 inches (406 mm) [20 inches (508 mm) if strength axis in the long direction of the panel, unless otherwise marked]. Casing or finish nails spaced 6 inches (152 mm) on panel edges, 12 inches (305 mm) at intermediate supports.
[11]Panel supports at 24 inches (610 mm). Casing or finish nails spaced 6 inches (152 mm) on panel edges, 12 inches (305 mm) at intermediate supports.

TABLE 23-II-B-2—WOOD STRUCTURAL PANEL ROOF SHEATHING NAILING SCHEDULE[1]

WIND REGION	NAILS	PANEL LOCATION	ROOF FASTENING ZONE[2]		
			1	2	3
			Fastening Schedule (inches on center) × 25.4 for mm		
Greater than 90 mph (145 km/h)	8d common	Panel edges[3]	6	6	4[4]
		Panel field	6	6	6[4]
Greater than 80 mph (129 km/h) to 90 mph (145 km/h)	8d common	Panel edges[3]	6	6	4
		Panel field	12	6	6
80 mph (129 km/h) or less	8d common	Panel edges[3]	6	6	6
		Panel field	12	12	12

[1]Applies only to mean roof heights up to 35 feet (10 700 mm). For mean roof heights over 35 feet (10 700 mm), the nailing shall be designed.
[2]The roof fastening zones are shown below:



ROOF FASTENING ZONES

For SI: 1 foot = 304.8 mm.

[3]Edge spacing also applies over roof framing at gable-end walls.
[4]Use 8d ring-shank nails in this zone if mean roof height is greater than 25 feet (7600 mm).

TABLE 23-II-C—HARDBOARD SIDING

SIDING	MINIMAL NOMINAL THICKNESS (inch)	FRAMING (2" x 4") MAXIMUM SPACING	NAIL SIZE[1, 2]	NAIL SPACING: General	NAIL SPACING: Bracing Panels[3]
	× 25.4 for mm				
1. LAP SIDING					
Direct to studs	$^3/_8$	16" o.c.	8d	16" o.c.	Not applicable
Over sheathing	$^3/_8$	16" o.c.	10d	16" o.c.	Not applicable
2. SQUARE EDGE PANEL SIDING					
Direct to studs	$^3/_8$	24" o.c.	6d	6" o.c. edges; 12" o.c. at intermed. supports	4" o.c. edges; 8" o.c. intermed. supports
Over sheathing	$^3/_8$	24" o.c.	8d	6" o.c. edges; 12" o.c. at intermed. supports	4" o.c. edges; 8" o.c. intermed. supports
3. SHIPLAP EDGE PANEL SIDING					
Direct to studs	$^3/_8$	16" o.c.	6d	6" o.c. edges; 12" o.c. at intermed. supports	4" o.c. edges; 8" o.c. intermed. supports
Over sheathing	$^3/_8$	16" o.c.	8d	6" o.c. edges; 12" o.c. at intermed. supports	4" o.c. edges; 8" o.c. intermed. supports

[1]Nails shall be corrosion resistant in accordance with Division III, Part III.
[2]Minimum acceptable nail dimensions (inches).

	Panel Siding (inch)	Lap Siding (inch)
	× 25.4 for mm	
Shank diameter	0.092	0.099
Head diameter	0.225	0.240

[3]When used to comply with Division IV, Section 2320.11.3.

TABLE 23-II-D-1—ALLOWABLE SPANS FOR LUMBER FLOOR AND ROOF SHEATHING[1, 2]

SPAN (inches)	MINIMUM NET THICKNESS (inches) OF LUMBER PLACED: Perpendicular to Supports: Surfaced Dry[3]	Perpendicular to Supports: Surfaced Unseasoned	Diagonally to Supports: Surfaced Dry[3]	Diagonally to Supports: Surfaced Unseasoned
× 25.4 for mm	× 25.4 for mm			
	Floors			
1. 24	$^3/_4$	$^{25}/_{32}$	$^3/_4$	$^{25}/_{32}$
2. 16	$^5/_8$	$^{11}/_{16}$	$^5/_8$	$^{11}/_{16}$
	Roofs			
3. 24	$^5/_8$	$^{11}/_{16}$	$^3/_4$	$^{25}/_{32}$

[1]Installation details shall conform to Sections 2320.9.1 and 2320.12.8 for floor and roof sheathing, respectively.
[2]Floor or roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2312.
[3]Maximum 19 percent moisture content.

TABLE 23-II-D-2—SHEATHING LUMBER SHALL MEET THE FOLLOWING MINIMUM GRADE REQUIREMENTS: BOARD GRADE

SOLID FLOOR OR ROOF SHEATHING	SPACED ROOF SHEATHING	GRADING RULES
1. Utility	Standard	NLGA, WCLIB, WWPA
2. 4 common or utility	3 common or standard	NLGA, WCLIB, WWPA, NHPMA or NELMA
3. No. 3	No. 2	SPIB
4. Merchantable	Construction common	RIS

TABLE 23-II-E-1—ALLOWABLE SPANS AND LOADS FOR WOOD STRUCTURAL PANEL SHEATHING AND SINGLE-FLOOR GRADES CONTINUOUS OVER TWO OR MORE SPANS WITH STRENGTH AXIS PERPENDICULAR TO SUPPORTS[1,2]

SHEATHING GRADES		ROOF[3]				FLOOR[4]
		Maximum Span (inches)		Load[5] (pounds per square foot)		
Panel Span Rating	Panel Thickness (inches)	× 25.4 for mm		× 0.0479 for kN/m²		Maximum Span (inches)
Roof/Floor Span	× 25.4 for mm	With Edge Support[6]	Without Edge Support	Total Load	Live Load	× 25.4 for mm
12/0	5/16	12	12	40	30	0
16/0	5/16, 3/8	16	16	40	30	0
20/0	5/16, 3/8	20	20	40	30	0
24/0	3/8, 7/16, 1/2	24	20[7]	40	30	0
24/16	7/16, 1/2	24	24	50	40	16
32/16	15/32, 1/2, 5/8	32	28	40	30	16[8]
40/20	19/32, 5/8, 3/4, 7/8	40	32	40	30	20[8,9]
48/24	23/32, 3/4, 7/8	48	36	45	35	24
54/32	7/8, 1	54	40	45	35	32
60/48	7/8, 1, 1 1/8	60	48	45	35	48
SINGLE-FLOOR GRADES		ROOF[3]				FLOOR[4]
		Maximum Span (inches)		Load[5] (pounds per square foot)		
Panel Span Rating (inches)	Panel Thickness (inches)	× 25.4 for mm		× 0.0479 for kN/m²		Maximum Span (inches)
× 25.4 for mm		With Edge Support[6]	Without Edge Support	Total Load	Live Load	× 25.4 for mm
16 oc	1/2, 19/32, 5/8	24	24	50	40	16[8]
20 oc	19/32, 5/8, 3/4	32	32	40	30	20[8,9]
24 oc	23/32, 3/4	48	36	35	25	24
32 oc	7/8, 1	48	40	50	40	32
48 oc	1 3/32, 1 1/8	60	48	50	50	48

[1]Applies to panels 24 inches (610 mm) or wider.
[2]Floor and roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2312.
[3]Uniform load deflection limitations 1/180 of span under live load plus dead load, 1/240 under live load only.
[4]Panel edges shall have approved tongue-and-groove joints or shall be supported with blocking unless 1/4-inch (6.4 mm) minimum thickness underlayment or 1 1/2 inches (38 mm) of approved cellular or lightweight concrete is placed over the subfloor, or finish floor is 3/4-inch (19 mm) wood strip. Allowable uniform load based on deflection of 1/360 of span is 100 pounds per square foot (psf) (4.79 kN/m²) except the span rating of 48 inches on center is based on a total load of 65 psf (3.11 kN/m).
[5]Allowable load at maximum span.
[6]Tongue-and-groove edges, panel edge clips [one midway between each support, except two equally spaced between supports 48 inches (1219 mm) on center], lumber blocking, or other. Only lumber blocking shall satisfy blocked diaphgrams requirements.
[7]For 1/2-inch (12.7 mm) panel, maximum span shall be 24 inches (610 mm).
[8]May be 24 inches (610 mm) on center where 3/4-inch (19 mm) wood strip flooring is installed at right angles to joist.
[9]May be 24 inches (610 mm) on center for floors where 1 1/2 inches (38 mm) of cellular or lightweight concrete is applied over the panels.

TABLE 23-II-E-2—ALLOWABLE LOAD (PSF) FOR WOOD STRUCTURAL PANEL ROOF SHEATHING CONTINUOUS OVER TWO OR MORE SPANS AND STRENGTH AXIS PARALLEL TO SUPPORTS (Plywood structural panels are five-ply, five-layer unless otherwise noted.)[1,2]

			LOAD AT MAXIMUM SPAN (psf)	
	THICKNESS (inch)	MAXIMUM SPAN (inches)	× 0.0479 for kN/m²	
PANEL GRADE	× 25.4 for mm		Live	Total
Structural I	7/16	24	20	30
	15/32	24	35[3]	45[3]
	1/2	24	40[3]	50[3]
	19/32, 5/8	24	70	80
	23/32, 3/4	24	90	100
Other grades covered in UBC Standard 23-2 or 23-3	7/16	16	40	50
	15/32	24	20	25
	1/2	24	25	30
	19/32	24	40[3]	50[3]
	5/8	24	45[3]	55[3]
	23/32, 3/4	24	60[3]	65[3]

[1]Roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2312.
[2]Uniform load deflection limitations: 1/180 of span under live load plus dead load, 1/240 under live load only. Edges shall be blocked with lumber or other approved type of edge supports.
[3]For composite and four-ply plywood structural panel, load shall be reduced by 15 pounds per square foot (0.72 kN/m²).

TABLE 23-II-F-1—ALLOWABLE SPAN FOR WOOD STRUCTURAL PANEL COMBINATION SUBFLOOR-UNDERLAYMENT (SINGLE FLOOR)[1,2] Panels Continuous over Two or More Spans and Strength Axis Perpendicular to Supports

IDENTIFICATION	MAXIMUM SPACING OF JOISTS (inches) × 25.4 for mm				
	16	20	24	32	48
Species Group[3]	Thickness (inches) × 25.4 for mm				
1	$^{1}/_{2}$	$^{5}/_{8}$	$^{3}/_{4}$	—	—
2, 3	$^{5}/_{8}$	$^{3}/_{4}$	$^{7}/_{8}$	—	—
4	$^{3}/_{4}$	$^{7}/_{8}$	1	—	—
Span rating[4]	16 o.c.	20 o.c.	24 o.c.	32 o.c.	48 o.c.

[1]Spans limited to value shown because of possible effects of concentrated loads. Allowable uniform loads based on deflection of $^{1}/_{360}$ of span is 100 pounds per square foot (psf) (4.79 kN/m^2), except allowable total uniform load for $1^{1}/_{8}$-inch (29 mm) wood structural panels over joists spaced 48 inches (1219 mm) on center is 65 psf (3.11 kN/m^2). Panel edges shall have approved tongue-and-groove joints or shall be supported with blocking, unless $^{1}/_{4}$-inch (6.4 mm) minimum thickness underlayment or $1^{1}/_{2}$ inches (38 mm) of approved cellular or lightweight concrete is placed over the subfloor, or finish floor is $^{3}/_{4}$-inch (19 mm) wood strip.

[2]Floor panels conforming with this table shall be deemed to meet the design criteria of Section 2312.

[3]Applicable to all grades of sanded exterior-type plywood. See UBC Standard 23-2 for plywood species groups.

[4]Applicable to underlayment grade and C-C (plugged) plywood, and single floor grade wood structural panels.

TABLE 23-II-F-2—ALLOWABLE SPANS FOR PARTICLEBOARD SUBFLOOR AND COMBINED SUBFLOOR-UNDERLAYMENT[1,2]

GRADE	THICKNESS (inches) × 25.4 for mm	MAXIMUM SPACING OF SUPPORTS (inches)[3] × 25.4 for mm	
		Subfloor	Combined Subfloor-Underlayment[4,5]
2-M-W	$^{1}/_{2}$	16	—
	$^{5}/_{8}$	20	16
	$^{3}/_{4}$	24	24
2-M-3	$^{3}/_{4}$	20	20

[1]All panels are continuous over two or more spans.
[2]Floor sheathing conforming with this table shall be deemed to meet the design criteria of Section 2312.
[3]Uniform deflection limitation: $^{1}/_{360}$ of the span under 100 pounds per square foot (4.79 kN/m^2) minimum load.
[4]Edges shall have tongue-and-groove joints or shall be supported with blocking. The tongue-and-groove panels are installed with the long dimension perpendicular to supports.
[5]A finish wearing surface is to be applied to the top of the panel.

TABLE 23-II-G—MAXIMUM DIAPHRAGM DIMENSION RATIOS

MATERIAL	HORIZONTAL DIAPHRAGMS Maximum Span-Width Ratios	SHEAR WALLS Maximum Height-Width Ratios
1. Diagonal sheathing, conventional	3:1	1:1[1]
2. Diagonal sheathing, special	4:1	2:1[2]
3. Wood structural panels and particleboard, nailed all edges	4:1	2:1[2,3]
4. Wood structural panels and particleboard, blocking omitted at intermediate joints.	4:1	[4]

[1]In Seismic Zones 0, 1, 2 and 3, the maximum ratio may be 2:1.

[2]In Seismic Zones 0, 1, 2 and 3, the maximum ratio may be $3^{1}/_{2}$:1.

[3]In Seismic Zone 4, the maximum ratio may be $3^{1}/_{2}$:1 for walls not exceeding 10 feet (3048 mm) in height on each side of the door to a one-story Group U Occupancy.

[4]Not permitted.

TABLE 23-II-K—WOOD SHINGLE AND SHAKE SIDE WALL EXPOSURES

SHINGLE OR SHAKE	MAXIMUM WEATHER EXPOSURES (inches) × 25.4 for mm			
	Single-Coursing		Double-Coursing	
Length and Type	No. 1	No. 2	No. 1	No. 2
16-inch (405 mm) shingles	$7^{1}/_{2}$	$7^{1}/_{2}$	12	10
18-inch (455 mm) shingles	$8^{1}/_{2}$	$8^{1}/_{2}$	14	11
24-inch (610 mm) shingles	$11^{1}/_{2}$	$11^{1}/_{2}$	16	14
18-inch (455 mm) resawn shakes	$8^{1}/_{2}$	—	14	—
18-inch (455 mm) straight-split shakes	$8^{1}/_{2}$	—	16	—
24-inch (610 mm) resawn shakes	$11^{1}/_{2}$	—	20	—

Division IV—CONVENTIONAL LIGHT-FRAME CONSTRUCTION

SECTION 2320 — CONVENTIONAL LIGHT-FRAME CONSTRUCTION DESIGN PROVISIONS

2320.1 General. The requirements in this section are intended for conventional light-frame construction. Other methods may be used provided a satisfactory design is submitted showing compliance with other provisions of this code.

Only the following occupancies may be constructed in accordance with this division:

1. One-, two- or three-story buildings housing Group R Occupancies.

2. One-story Occupancy Category 4 buildings, as defined in Table 16-K, when constructed on a slab-on-grade floor.

3. Group U Occupancies.

4. Top-story walls and roofs of Occupancy Category 4 buildings not exceeding two stories of wood framing.

5. Interior nonload-bearing partitions, ceilings and curtain walls in all occupancies.

When total loads exceed those specified in Tables 23-IV-J-1, 23-IV-J-3, and 23-IV-R-1, 23-IV-R-2, 23-IV-R-3, 23-IV-R-4, 23-IV-R-7, 23-IV-R-8, 23-IV-R-9, 23-IV-R-10, 23-IV-R-11 and 23-IV-R-12; 23-VII-R-1, 23-VII-R-3, 23-VII-R-7, 23-VII-R-9, 23-VIII-A, 23-VIII-B, 23-VIII-C, 23-VIII-D, an engineering design shall be provided for the gravity load system.

Other approved repetitive wood members may be used in lieu of solid-sawn lumber in conventional construction provided these members comply with the provisions of this code.

2320.2 Design of Portions. When a building of otherwise conventional construction contains nonconventional structural elements, those elements shall be designed in accordance with Section 1605.2.

2320.3 Additional Requirements for Conventional Construction in High-wind Areas. Appendix Chapter 23 provisions for conventional construction in high-wind areas shall apply when specifically adopted.

2320.4 Additional Requirements for Conventional Construction in Seismic Zones 0, 1, 2 and 3.

2320.4.1 Braced wall lines. Where the basic wind speed is not greater than 80 miles per hour (mph) (129 km/h), buildings shall be provided with exterior and interior braced wall lines. Spacing shall not exceed 34 feet (10 363 mm) on center in both the longitudinal and transverse directions in each story.

2320.4.2 Braced wall lines for high wind. Where the basic wind speed exceeds 80 mph (129 km/h), buildings shall be provided with exterior and interior braced wall lines. Spacing shall not exceed 25 feet (7620 mm) on center in both the longitudinal and transverse directions in each story.

> **EXCEPTION:** In one- and two-story Group R, Division 3 buildings, interior braced wall line spacing may be increased to not more than 34 feet (10 363 mm) on center in order to accommodate one single room per dwelling unit not exceeding 900 square feet (83.6 m^2). The building official may require additional walls to contain braced panels when this exception is used.

2320.4.3 Veneer. Anchored masonry and stone wall veneer shall not exceed 5 inches (127 mm) in thickness and shall conform to the requirements of Chapter 14.

2320.4.4 Lateral force-resisting system. Buildings in Seismic Zone 3 that are not provided with braced wall lines in accordance with Section 2320.4 or that are of unusual shape as described in Section 2320.5.4 shall have a lateral-force-resisting system designed to resist the forces specified in Chapter 16.

2320.5 Additional Requirements for Conventional Construction in Seismic Zone 4.

2320.5.1 Braced wall lines. Buildings shall be provided with exterior and interior braced wall lines. Spacing shall not exceed 25 feet (7620 mm) on center in both the longitudinal and transverse directions in each story.

> **EXCEPTION:** In one- and two-story Group R, Division 3 buildings, interior braced wall line spacing may be increased to not more than 34 feet (10 363 mm) on center in order to accommodate one single room per dwelling unit not exceeding 900 square feet (83.61 m^2). The building official may require additional walls to contain braced panels when this exception is used.

2320.5.2 Lateral-force-resisting system. When total loads supported on wood framing exceed those specified in Tables 23-IV-J-1, 23-IV-J-3, 23-IV-R-1, 23-IV-R-2, 23-IV-R-3, 23-IV-R-4, 23-IV-R-7, 23-IV-R-8, 23-IV-R-9 and 23-IV-R-10, 23-VII-R-1. 23-VII-R-3, 23-VII-R-7, 23-VII-R-9, 23-VIII-A, 23-VIII-B, 23-VIII-C and 23-VIII-D, an engineering design shall be provided for the lateral-force-resisting system.

2320.5.3 Veneer. Anchored masonry and stone wall veneer shall not exceed 5 inches (127 mm) in thickness, shall conform to the requirements of Chapter 14 and shall not extend above the first story.

2320.5.4 Unusually shaped buildings. When of unusual shape, buildings of light-frame construction shall have a lateral-force-resisting system designed to resist the forces specified in Chapter 16. Buildings shall be considered to be of unusual shape when the building official determines that the structure has framing irregularities, offsets, split levels or any configuration that creates discontinuities in the seismic load path and may include one or more of the following.

2320.5.4.1 When exterior braced wall panels, as required by Section 2320.11.3, are not in one plane vertically from the foundation to the uppermost story in which they are required.

> **EXCEPTION:** Floors with cantilevers or setbacks not exceeding four times the nominal depth of the floor joists may support braced wall panels provided:
>
> 1. Floor joists are 2 inches by 10 inches (51 mm by 254 mm) or larger and spaced at not more than 16 inches (406 mm) on center.
> 2. The ratio of the back span to the cantilever is at least 2 to 1.
> 3. Floor joists at ends of braced wall panels are doubled.
> 4. A continuous rim joist is connected to ends of all cantilevered joists. The rim joist may be spliced using a metal tie not less than 0.058 inch (1.47 mm) (16 galvanized gage) and $1^1/_2$ inches (38 mm) wide fastened with six 16d nails.
> 5. Gravity loads carried at the end of cantilevered joists are limited to uniform wall and roof load and the reactions from headers having a span of 8 feet (2438 mm) or less.

2320.5.4.2 When a section of floor or roof is not laterally supported by braced wall lines on all edges.

> **EXCEPTION:** Portions of roofs or floors which do not support braced wall panels above may extend up to 6 feet (1829 mm) beyond a braced wall line.

2320.5.4.3 When the end of a required braced wall panel extends more than 1 foot (305 mm) over an opening in the wall below. This provision is applicable to braced wall panels offset in plane and to braced wall panels offset out of plane as permitted by Section 2320.5.4.1, exception.

> **EXCEPTION:** Braced wall panels may extend over an opening not more than 8 feet (2438 mm) in width when the header is a 4-inch by 12-inch (102 mm by 305 mm) or larger member.

2320.5.4.4 When an opening in a floor or roof exceeds the lesser of 12 feet (3657 mm) or 50 percent of the least floor or roof dimension.

2320.5.4.5 Construction where portions of a floor level are vertically offset such that the framing members on either side of the offset cannot be lapped or tied together in an approved manner as required by Section 2320.8.3.

> **EXCEPTION:** Framing supported directly by foundations.

2320.5.4.6 When braced wall lines do not occur in two perpendicular directions.

2320.5.5 Lumber roof decks. Lumber roof decks shall have solid sheathing.

2320.5.6 Interior braced wall support. In one-story buildings, interior braced wall lines shall be supported on continuous foundations at intervals not exceeding 50 feet (15 240 mm). In buildings more than one story in height, all interior braced wall panels shall be supported on continuous foundations.

> **EXCEPTION:** Two-story buildings may have interior braced wall lines supported on continuous foundations at intervals not exceeding 50 feet (15 240 mm) provided:
>
> 1. Cripple wall height does not exceed 4 feet (1219 mm).
> 2. First-floor braced wall panels are supported on doubled floor joists, continuous blocking or floor beams.
> 3. Distance between bracing lines does not exceed twice the building width parallel to the braced wall line.

2320.6 Foundation Plates or Sills. Foundations and footings shall be as specified in Chapter 18. Foundation plates or sills resting on concrete or masonry foundations shall be bolted as required by Section 1806.6.

2320.7 Girders. Girders for single-story construction or girders supporting loads from a single floor shall not be less than 4 inches by 6 inches (102 mm by 153 mm) for spans 6 feet (1829 mm) or less, provided that girders are spaced not more than 8 feet (2438 mm) on center. Other girders shall be designed to support the loads specified in this code. Girder end joints shall occur over supports. When a girder is spliced over a support, an adequate tie shall be provided. The end of beams or girders supported on masonry or concrete shall not have less than 3 inches (76 mm) of bearing.

2320.8 Floor Joists.

2320.8.1 General. Spans for joists shall be in accordance with Tables 23-IV-J-1 and 23-IV-J-2.

2320.8.2 Bearing. Except where supported on a 1-inch by 4-inch (25 mm by 102 mm) ribbon strip and nailed to the adjoining stud, the ends of each joist shall not have less than $1^1/_2$ inches (38 mm) of bearing on wood or metal, or less than 3 inches (76 mm) on masonry.

2320.8.3 Framing details. Joists shall be supported laterally at the ends and at each support by solid blocking except where the ends of joists are nailed to a header, band or rim joist or to an adjoining stud or by other approved means. Solid blocking shall not be less than 2 inches (51 mm) in thickness and the full depth of joist.

Notches on the ends of joists shall not exceed one fourth the joist depth. Holes bored in joists shall not be within 2 inches (51 mm) of the top or bottom of the joist, and the diameter of any such hole shall not exceed one third the depth of the joist. Notches in the top or bottom of joists shall not exceed one sixth the depth and shall not be located in the middle third of the span.

Joist framing from opposite sides of a beam, girder or partition shall be lapped at least 3 inches (76 mm) or the opposing joists shall be tied together in an approved manner.

Joists framing into the side of a wood girder shall be supported by framing anchors or on ledger strips not less than 2 inches by 2 inches (51 mm by 51 mm).

2320.8.4 Framing around openings. Trimmer and header joists shall be doubled, or of lumber of equivalent cross section, when the span of the header exceeds 4 feet (1219 mm). The ends of header joists more than 6 feet (1829 mm) long shall be supported by framing anchors or joist hangers unless bearing on a beam, partition or wall. Tail joists over 12 feet (3658 mm) long shall be supported at header by framing anchors or on ledger strips not less than 2 inches by 2 inches (51 mm by 51 mm).

2320.8.5 Supporting bearing partitions. Bearing partitions perpendicular to joists shall not be offset from supporting girders, walls or partitions more than the joist depth.

Joists under and parallel to bearing partitions shall be doubled.

2320.8.6 Blocking. Floor joists shall be blocked when required by the provisions of Division III, Part I (Sec. 4.4.1.2 of NDS-91) or Section 2320.8.3.

2320.9 Subflooring.

2320.9.1 Lumber subfloor. Sheathing used as a structural subfloor shall conform to the limitations set forth in Tables 23-II-D-1 and 23-II-D-2.

Joints in subflooring shall occur over supports unless end-matched lumber is used, in which case each piece shall bear on at least two joists.

Subflooring may be omitted when joist spacing does not exceed 16 inches (406 mm) and 1-inch (25 mm) nominal tongue-and-groove wood strip flooring is applied perpendicular to the joists.

2320.9.2 Wood structural panels. Where used as structural subflooring, wood structural panels shall be as set forth in Tables 23-II-E-1 and 23-II-E-2. Wood structural panel combination subfloor underlayment shall have maximum spans as set forth in Table 23-II-F-1.

When wood structural panel floors are glued to joists with an adhesive in accordance with the adhesive manufacturer's directions, fasteners may be spaced a maximum of 12 inches (305 mm) on center at all supports.

2320.9.3 Plank flooring. Plank flooring shall be designed in accordance with the general provisions of this code.

In lieu of such design, 2-inch (51 mm) tongue-and-groove planking may be used in accordance with Table 23-IV-A. Joints in such planking may be randomly spaced, provided the system is applied to not less than three continuous spans, planks are center-matched and end-matched or splined, each plank bears on at least one support and joints are separated by at least 24 inches (610 mm) in adjacent pieces. One-inch (25 mm) nominal strip square-edged flooring, $^1/_2$-inch (12.7 mm) tongue-and-groove flooring or $^3/_8$-inch (9.5 mm) wood structural panel shall be applied over random-length decking used as a floor. The strip and tongue-and-groove flooring shall be applied at right angles to the span of the planks. The $^3/_8$-inch (9.5 mm) plywood shall be applied with the face grain at right angles to the span of the planks.

2320.9.4 Particleboard. Where used as structural subflooring or as combined subfloor underlayment, particleboard shall be as set forth in Table 23-II-F-2.

2320.10 Particleboard Underlayment. In accordance with approved recognized standards, particleboard floor underlayment shall conform to Type PBU. Underlayment shall not be less than $^1/_4$ inch (6.4 mm) in thickness and shall be identified by the grade mark of an approved inspection agency. Underlayment shall be installed in accordance with this code and as recommended by the manufacturer.

2320.11 Wall Framing.

2320.11.1 Size, height and spacing. The size, height and spacing of studs shall be in accordance with Table 23-IV-B except that Utility grade studs shall not be spaced more than 16 inches (406 mm) on center, or support more than a roof and ceiling, or exceed 8 feet (2438 mm) in height for exterior walls and load-bearing walls or 10 feet (3048 mm) for interior nonload-bearing walls.

2320.11.2 Framing details. Studs shall be placed with their wide dimension perpendicular to the wall. Not less than three studs shall be installed at each corner of an exterior wall.

> **EXCEPTION:** At corners, a third stud may be omitted through the use of wood spacers or backup cleats of $^3/_8$-inch-thick (9.5 mm) wood structural panel, $^3/_8$-inch (9.5 mm) Type M "Exterior Glue" particleboard, 1-inch-thick (25 mm) lumber or other approved devices that will serve as an adequate backing for the attachment of facing materials. Where fire-resistance ratings or shear values are involved, wood spacers, backup cleats or other devices shall not be used unless specifically approved for such use.

Bearing and exterior wall studs shall be capped with double top plates installed to provide overlapping at corners and at intersections with other partitions. End joints in double top plates shall be offset at least 48 inches (2438 mm).

> **EXCEPTION:** A single top plate may be used, provided the plate is adequately tied at joints, corners and intersecting walls by at least the equivalent of 3-inch by 6-inch (76 mm by 152 mm) by 0.036-inch-thick (0.9 mm) galvanized steel that is nailed to each wall or segment of wall by six 8d nails or equivalent, provided the rafters, joists or trusses are centered over the studs with a tolerance of no more than 1 inch (25 mm).

When bearing studs are spaced at 24-inch (610 mm) intervals and top plates are less than two 2-inch by 6-inch (51 mm by 152 mm) or two 3-inch by 4-inch (76 mm by 102 mm) members and when the floor joists, floor trusses or roof trusses which they support are spaced at more than 16-inch (406 mm) intervals, such joists or trusses shall bear within 5 inches (127 mm) of the studs beneath or a third plate shall be installed.

Interior nonbearing partitions may be capped with a single top plate installed to provide overlapping at corners and at intersections with other walls and partitions. The plate shall be continuously tied at joints by solid blocking at least 16 inches (406 mm) in length and equal in size to the plate or by $^1/_8$-inch by $1^1/_2$-inch (3.2 mm by 38 mm) metal ties with spliced sections fastened with two 16d nails on each side of the joint.

Studs shall have full bearing on a plate or sill not less than 2 inches (51 mm) in thickness having a width not less than that of the wall studs.

2320.11.3 Bracing. Braced wall lines shall consist of braced wall panels which meet the requirements for location, type and amount of bracing specified in Table 23-IV-C-1 and are in line or offset from each other by not more than 4 feet (1219 mm). Braced wall panels shall start at not more than 8 feet (2438 mm) from each end of a braced wall line. All braced wall panels shall be clearly indicated on the plans. Construction of braced wall panels shall be by one of the following methods:

1. Nominal 1-inch by 4-inch (25 mm by 102 mm) continuous diagonal braces let into top and bottom plates and intervening studs, placed at an angle not more than 60 degrees or less than 45 degrees from the horizontal, and attached to the framing in conformance with Table 23-II-B-1.

2. Wood boards of $^5/_8$-inch (16 mm) net minimum thickness applied diagonally on studs spaced not over 24 inches (610 mm) on center.

3. Wood structural panel sheathing with a thickness not less than $^5/_{16}$ inch (7.9 mm) for 16-inch (406 mm) stud spacing and not less than $^3/_8$ inch (9.5 mm) for 24-inch (610 mm) stud spacing in accordance with Tables 23-II-A-1 and 23-IV-D-1.

4. Fiberboard sheathing 4-foot by 8-foot (1219 mm by 2438 mm) panels not less than $^1/_2$ inch (13 mm) thick applied vertically on studs spaced not over 16 inches (406 mm) on center when installed in accordance with Section 2315.6 and Table 23-II-J.

5. Gypsum board [sheathing $^1/_2$ inch (13 mm) thick by 4 feet (1219 mm) wide, wallboard or veneer base] on studs spaced not over 24 inches (610 mm) on center and nailed at 7 inches (178 mm) on center with nails as required by Table 25-I.

6. Particleboard wall sheathing panels where installed in accordance with Table 23-IV-D-2.

7. Portland cement plaster on studs spaced 16 inches (406 mm) on center installed in accordance with Table 25-I.

8. Hardboard panel siding when installed in accordance with Section 2310.6 and Table 23-II-C.

Method 1 is not permitted in Seismic Zones 2B, 3 and 4. For cripple wall bracing, see Section 2320.11.5. For Methods 2, 3, 4, 6, 7 and 8, each braced panel must be at least 48 inches (1219 mm) in length, covering three stud spaces where studs are spaced 16 inches (406 mm) apart and covering two stud spaces where studs are spaced 24 inches (610 mm) apart.

For Method 5, each braced wall panel must be at least 96 inches (2438 mm) in length when applied to one face of a braced wall panel and 48 inches (1219 mm) when applied to both faces.

All vertical joints of panel sheathing shall occur over studs. Horizontal joints shall occur over blocking equal in size to the studding except where waived by the installation requirements for the specific sheathing materials.

Braced wall panel sole plates shall be nailed to the floor framing and top plates shall be connected to the framing above in accordance with Table 23-II-B-1. Sills shall be bolted to the foundation or slab in accordance with Section 1806.6. Where joists are perpendicular to braced wall lines above, blocking shall be provided under and in line with the braced wall panels.

2320.11.4 Alternate braced wall panels. Any braced wall panel required by Section 2320.11.3 may be replaced by an alternate braced wall panel constructed in accordance with the following:

1. In one-story buildings, each panel shall have a length of not less than 2 feet 8 inches (813 mm) and a height of not more than 10 feet (3048 mm). Each panel shall be sheathed on one face with $^3/_8$-inch-minimum-thickness (9.5 mm) plywood sheathing nailed with 8d common or galvanized box nails in accordance with Table 23-II-B-1 and blocked at all plywood edges. Two anchor bolts installed in accordance with Section 1806.6, shall be provided in each panel. Anchor bolts shall be placed at panel quarter points. Each panel end stud shall have a tie-down device fastened to the foundation, capable of providing an approved uplift capacity of not less than 1,800 pounds (816.5 kg). The tie-down device shall

be installed in accordance with the manufacturer's recommendations. The panels shall be supported directly on a foundation or on floor framing supported directly on a foundation which is continuous across the entire length of the braced wall line. This foundation shall be reinforced with not less than one No. 4 bar top and bottom.

2. In the first story of two-story buildings, each braced wall panel shall be in accordance with Section 2320.11.4, Item 1, except that the plywood sheathing shall be provided on both faces, three anchor bolts shall be placed at one-fifth points, and tie-down device uplift capacity shall not be less than 3,000 pounds (1360.8 kg).

2320.11.5 Cripple walls. Foundation cripple walls shall be framed of studs not less in size than the studding above with a minimum length of 14 inches (356 mm), or shall be framed of solid blocking. When exceeding 4 feet (1219 mm) in height, such walls shall be framed of studs having the size required for an additional story.

Cripple walls having a stud height exceeding 14 inches (356 mm) shall be braced in accordance with Table 23-IV-C-2. Solid blocking or wood structural panel sheathing may be used to brace cripple walls having a stud height of 14 inches (356 mm) or less. In Seismic Zone 4, Method 7 is not permitted for bracing any cripple wall studs.

Spacing of boundary nailing for required wall bracing shall not exceed 6 inches (152 mm) on center along the foundation plate and the top plate of the cripple wall. Nail size, nail spacing for field nailing and more restrictive boundary nailing requirements shall be as required elsewhere in the code for the specific bracing material used.

2320.11.6 Headers. Headers and lintels shall conform to the requirements set forth in this paragraph and together with their supporting systems shall be designed to support the loads specified in this code. All openings 4 feet (1219 mm) wide or less in bearing walls shall be provided with headers consisting of either two pieces of 2-inch (51 mm) framing lumber placed on edge and securely fastened together or 4-inch (102 mm) lumber of equivalent cross section. All openings more than 4 feet (1219 mm) wide shall be provided with headers or lintels. Each end of a lintel or header shall have a length of bearing of not less than $1^1/_2$ inches (38 mm) for the full width of the lintel.

2320.11.7 Pipes in walls. Stud partitions containing plumbing, heating, or other pipes shall be so framed and the joists underneath so spaced as to give proper clearance for the piping. Where a partition containing such piping runs parallel to the floor joists, the joists underneath such partitions shall be doubled and spaced to permit the passage of such pipes and shall be bridged. Where plumbing, heating or other pipes are placed in or partly in a partition, necessitating the cutting of the soles or plates, a metal tie not less than 0.058 inch (1.47 mm) (16 galvanized gage) and $1^1/_2$ inches (38 mm) wide shall be fastened to each plate across and to each side of the opening with not less than six 16d nails.

2320.11.8 Bridging. Unless covered by interior or exterior wall coverings or sheathing meeting the minimum requirements of this code, all stud partitions or walls with studs having a height-to-least-thickness ratio exceeding 50 shall have bridging not less than 2 inches (51 mm) in thickness and of the same width as the studs fitted snugly and nailed thereto to provide adequate lateral support.

2320.11.9 Cutting and notching. In exterior walls and bearing partitions, any wood stud may be cut or notched to a depth not exceeding 25 percent of its width. Cutting or notching of studs to a depth not greater than 40 percent of the width of the stud is permitted in nonbearing partitions supporting no loads other than the weight of the partition.

2320.11.10 Bored holes. A hole not greater in diameter than 40 percent of the stud width may be bored in any wood stud. Bored holes not greater than 60 percent of the width of the stud are permitted in nonbearing partitions or in any wall where each bored stud is doubled, provided not more than two such successive doubled studs are so bored.

In no case shall the edge of the bored hole be nearer than $^5/_8$ inch (16 mm) to the edge of the stud. Bored holes shall not be located at the same section of stud as a cut or notch.

2320.12 Roof and Ceiling Framing.

2320.12.1 General. The framing details required in this section apply to roofs having a minimum slope of 3 units vertical in 12 units horizontal (25% slope) or greater. When the roof slope is less than 3 units vertical in 12 units horizontal (25% slope), members supporting rafters and ceiling joists such as ridge board, hips and valleys shall be designed as beams.

2320.12.2 Spans. Allowable spans for ceiling joists shall be in accordance with Tables 23-IV-J-3 and 23-IV-J-4. Allowable spans for rafters shall be in accordance with Tables 23-IV-R-1 through 23-IV-R-12, where applicable.

2320.12.3 Framing. Rafters shall be framed directly opposite each other at the ridge. There shall be a ridge board at least 1-inch (25 mm) nominal thickness at all ridges and not less in depth than the cut end of the rafter. At all valleys and hips there shall be a single valley or hip rafter not less than 2-inch (51 mm) nominal thickness and not less in depth than the cut end of the rafter.

2320.12.4 Notches and holes. Notching at the ends of rafters or ceiling joists shall not exceed one fourth the depth. Notches in the top or bottom of the rafter or ceiling joist shall not exceed one sixth the depth and shall not be located in the middle one third of the span, except that a notch not exceeding one third of the depth is permitted in the top of the rafter or ceiling joist not further from the face of the support than the depth of the member.

Holes bored in rafters or ceiling joists shall not be within 2 inches (51 mm) of the top and bottom and their diameter shall not exceed one third the depth of the member.

2320.12.5 Framing around openings. Trimmer and header rafters shall be doubled, or of lumber of equivalent cross section, when the span of the header exceeds 4 feet (1219 mm). The ends of header rafters more than 6 feet (1829 mm) long shall be supported by framing anchors or rafter hangers unless bearing on a beam, partition or wall.

2320.12.6 Rafter ties. Rafters shall be nailed to adjacent ceiling joists to form a continuous tie between exterior walls when such joists are parallel to the rafters. Where not parallel, rafters shall be tied to 1-inch by 4-inch (25 mm by 102 mm) (nominal) minimum-size crossties. Rafter ties shall be spaced not more than 4 feet (1219 mm) on center.

2320.12.7 Purlins. Purlins to support roof loads may be installed to reduce the span of rafters within allowable limits and shall be supported by struts to bearing walls. The maximum span of 2-inch by 4-inch (51 mm by 102 mm) purlins shall be 4 feet (1219 mm). The maximum span of the 2-inch by 6-inch (51 mm by 152 mm) purlin shall be 6 feet (1829 mm) but in no case shall the purlin be smaller than the supported rafter. Struts shall not be smaller than 2-inch by 4-inch (51 mm by 102 mm) members. The unbraced length of struts shall not exceed 8 feet (2438 mm) and the minimum slope of the struts shall not be less than 45 degrees from the horizontal.

2320.12.8 Blocking. Roof rafters and ceiling joists shall be supported laterally to prevent rotation and lateral displacement when required by Division III, Part I, Section 4.4.1.2. Roof trusses shall be supported laterally at points of bearing by solid blocking to prevent rotation and lateral displacement.

2320.12.9 Roof sheathing. Roof sheathing shall be in accordance with Tables 23-II-E-1 and 23-II-E-2 for wood structural panels, and Tables 23-II-D-1 and 23-II-D-2 for lumber.

Joints in lumber sheathing shall occur over supports unless approved end-matched lumber is used, in which case each piece shall bear on at least two supports.

Wood structural panels used for roof sheathing shall be bonded by intermediate or exterior glue. Wood structural panel roof sheathing exposed on the underside shall be bonded with exterior glue.

2320.12.10 Roof planking. Planking shall be designed in accordance with the general provisions of this code.

In lieu of such design, 2-inch (51 mm) tongue-and-groove planking may be used in accordance with Table 23-IV-A. Joints in such planking may be randomly spaced, provided the system is applied to not less than three continuous spans, planks are center-matched and end-matched or splined, each plank bears on at least one support, and joints are separated by at least 24 inches (610 mm) in adjacent pieces.

2320.13 Exit Facilities. In Seismic Zones 3 and 4, exterior exit balconies, stairs and similar exit facilities shall be positively anchored to the primary structure at not over 8 feet (2438 mm) on center or shall be designed for lateral forces. Such attachment shall not be accomplished by use of toenails or nails subject to withdrawal.

TABLE 23-IV-A—ALLOWABLE SPANS FOR 2-INCH (51 mm) TONGUE-AND-GROOVE DECKING

SPAN[1] (feet)	LIVE LOAD	DEFLECTION LIMIT	f (psi)	E (psi)
× 304.8 for mm	× 0.0479 for kN/m²		× 0.00689 for N/mm²	
		Roofs		
4	20	1/240	160	170,000
		1/360		256,000
	30	1/240	210	256,000
		1/360		384,000
	40	1/240	270	340,000
		1/360		512,000
4.5	20	1/240	200	242,000
		1/360		305,000
	30	1/240	270	363,000
		1/360		405,000
	40	1/240	350	484,000
		1/360		725,000
5.0	20	1/240	250	332,000
		1/360		500,000
	30	1/240	330	495,000
		1/360		742,000
	40	1/240	420	660,000
		1/360		1,000,000
5.5	20	1/240	300	442,000
		1/360		660,000
	30	1/240	400	662,000
		1/360		998,000
	40	1/240	500	884,000
		1/360		1,330,000
6.0	20	1/240	360	575,000
		1/360		862,000
	30	1/240	480	862,000
		1/360		1,295,000
	40	1/240	600	1,150,000
		1/360		1,730,000
6.5	20	1/240	420	595,000
		1/360		892,000
	30	1/240	560	892,000
		1/360		1,340,000
	40	1/240	700	1,190,000
		1/360		1,730,000
7.0	20	1/240	490	910,000
		1/360		1,360,000
	30	1/240	650	1,370,000
		1/360		2,000,000
	40	1/240	810	1,820,000
		1/360		2,725,000
7.5	20	1/240	560	1,125,000
		1/360		1,685,000
	30	1/240	750	1,685,000
		1/360		2,530,000
	40	1/240	930	2,250,000
		1/360		3,380,000
8.0	20	1/240	640	1,360,000
		1/360		2,040,000
	30	1/240	850	2,040,000
		1/360		3,060,000
		Floors		
4	40	1/360	840	1,000,000
4.5			950	1,300,000
5.0			1060	1,600,000

[1]Spans are based on simple beam action with 10 pounds per square foot (0.48 kN/m²) dead load and provisions for a 300-pound (1334 N) concentrated load on a 12-inch (305 mm) width of floor decking. Random lay-up permitted in accordance with the provisions of Section 2320.9.3 or 2320.12.9. Lumber thickness assumed at $1^1/_2$ inches (38 mm), net.

TABLE 23-IV-B—SIZE, HEIGHT AND SPACING OF WOOD STUDS

STUD SIZE (inches)	BEARING WALLS				NONBEARING WALLS	
	Laterally Unsupported Stud Height[1] (feet)	Supporting Roof and Ceiling Only	Supporting One Floor, Roof and Ceiling	Supporting Two Floors, Roof and Ceiling	Laterally Unsupported Stud Height[1] (feet)	Spacing (inches)
		Spacing (inches)				
× 25.4 for mm	× 304.8 for mm	× 25.4 for mm			× 304.8 for mm	× 25.4 for mm
1. 2 × 3[2]	—	—	—	—	10	16
2. 2 × 4	10	24	16	—	14	24
3. 3 × 4	10	24	24	16	14	24
4. 2 × 5	10	24	24	—	16	24
5. 2 × 6	10	24	24	16	20	24

[1]Listed heights are distances between points of lateral support placed perpendicular to the plane of the wall. Increases in unsupported height are permitted where justified by an analysis.
[2]Shall not be used in exterior walls.

TABLE 23-IV-C-1—BRACED WALL PANELS[1]

SEISMIC ZONE	CONDITION	CONSTRUCTION METHOD[2,3]								BRACED PANEL LOCATION AND LENGTH[4]
		1	2	3	4	5	6	7	8	
0, 1 and 2A	One story, top of two or three story	X	X	X	X	X	X	X	X	Each end and not more than 25 feet (7620 mm) on center
	First story of two story or second story of three story	X	X	X	X	X	X	X	X	
	First story of three story		X	X	X	X[5]	X	X	X	
2B, 3 and 4	One story, top of two story or three story		X	X	X	X	X	X[6]	X	Each end and not more than 25 feet (7620 mm) on center
	First story of two story or second of three story		X	X	X	X[5]	X	X[6]	X	Each end and not more than 25 feet (7620 mm) on center but not less than 25% of building length[7]
	First story of three story		X	X	X	X[5]	X	X[6]	X	Each end and not more than 25 feet (7620 mm) on center but not less than 40% of building length[7]

[1]This table specifies minimum requirements for braced panels which form interior or exterior braced wall lines.
[2]See Section 2320.11.3 for full description.
[3]See Section 2320.11.4 for alternate braced panel requirement.
[4]Building length is the dimension parallel to the braced wall length.
[5]Gypsum wallboard applied to supports at 16 inches (406 mm) on center.
[6]Not permitted for bracing cripple walls in Seismic Zone 4. See Section 2320.11.5.
[7]The required lengths shall be doubled for gypsum board applied to only one face of a braced wall panel.

TABLE 23-IV-C-2—CRIPPLE WALL BRACING

SEISMIC ZONE	CONDITION	AMOUNT OF CRIPPLE WALL BRACING[1,2]
		× 25.4 for mm
4	One story above cripple wall	$^3/_8$" wood structural panel with 8d at 6"/12" nailing on 60 percent of wall length minimum
	Two story above cripple wall	$^3/_8$" wood structural panel with 8d at 4"/12" nailing on 50 percent of wall length minimum or $^3/_8$" wood structural panel with 8d at 6"/12" nailing on 75 percent of wall length minimum
3	One story above cripple wall	$^3/_8$" wood structural panel with 8d at 6"/12" nailing on 40 percent of wall length minimum
0, 1 and 2	One story above cripple wall	$^3/_8$" wood structural panel with 8d at 6"/12" nailing on 30 percent of wall length minimum
0, 1, 2 and 3	Two story above cripple wall	$^3/_8$" wood structural panel with 8d at 4"/12" nailing on 40 percent of wall length minimum or $^3/_8$" wood structural panel with 8d at 6"/12" nailing on 60 percent of wall length minimum

[1]Braced panel length shall be at least two times the height of the cripple wall, but not less than 48 inches (1219 mm).
[2]All panels along a wall shall be nearly equal in length and shall be nearly equally spaced along the length of the wall.

TABLE 23-IV-D-1—WOOD STRUCTURAL PANEL WALL SHEATHING[1]
(Not exposed to the weather, strength axis parallel or perpendicular to studs)

MINIMUM THICKNESS (inch)	PANEL SPAN RATING	STUD SPACING (inches) × 25.4 for mm		
			Sheathing under Coverings Specified in Section 2310.4	
× 25.4 for mm		Siding Nailed to Studs	Sheathing Parallel to Studs	Sheathing Perpendicular to Studs
5/16	12/0, 16/0, 20/0 Wall—16 o.c.	16	—	16
3/8, 15/32, 1/2	16/0, 20/0, 24/0, 32/16 Wall—24 o.c.	24	16	24
7/16, 15/32, 1/2	24/0, 24/16, 32/16 Wall—24 o.c.	24	24[2]	24

[1]In reference to Section 2320.11.3, blocking of horizontal joints is not required.

[2]Plywood shall consist of four or more plies.

TABLE 23-IV-D-2—ALLOWABLE SPANS FOR PARTICLEBOARD WALL SHEATHING[1]
(Not exposed to the weather, long dimension of the panel parallel or perpendicular to studs)

GRADE	THICKNESS (inch)	STUD SPACING (inches) × 25.4 for mm	
		Siding Nailed to Studs	Sheathing under Coverings Specified in Section 2310.4 Parallel or Perpendicular to Studs
	× 25.4 for mm		
M-1 M-S	3/8	16	16
M-2 "Exterior Glue"	1/2	16	16

[1]In reference to Section 2320.11.3, blocking of horizontal joints is not required.

TABLE 23-IV-J-1—FLOOR JOISTS WITH $L/360$ DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 40 psf (1.92 kN/m²) live load.
Limited to span in inches (mm) divided by 360.
Strength — Live load of 40 psf (1.92 kN/m²) plus dead load of 10 psf (0.48 kN/m²) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, E, in 1,000,000 psi × 0.00689 for N/mm²																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 6	12.0	8-6	8-10	9-2	9-6	9-9	10-0	10-3	10-6	10-9	10-11	11-2	11-4	11-7	11-9	11-11	12-1	12-3
	16.0	7-9	8-0	8-4	8-7	8-10	9-1	9-4	9-6	9-9	9-11	10-2	10-4	10-6	10-8	10-10	11-0	11-2
	19.2	7-3	7-7	7-10	8-1	8-4	8-7	8-9	9-0	9-2	9-4	9-6	9-8	9-10	10-0	10-2	10-4	10-6
	24.0	6-9	7-0	7-3	7-6	7-9	7-11	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4	9-6	9-7	9-9
2 × 8	12.0	11-3	11-8	12-1	12-6	12-10	13-2	13-6	13-10	14-2	14-5	14-8	15-0	15-3	15-6	15-9	15-11	16-2
	16.0	10-2	10-7	11-0	11-4	11-8	12-0	12-3	12-7	12-10	13-1	13-4	13-7	13-10	14-1	14-3	14-6	14-8
	19.2	9-7	10-0	10-4	10-8	11-0	11-3	11-7	11-10	12-1	12-4	12-7	12-10	13-0	13-3	13-5	13-8	13-10
	24.0	8-11	9-3	9-7	9-11	10-2	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-3	12-6	12-8	12-10
2 × 10	12.0	14-4	14-11	15-5	15-11	16-5	16-10	17-3	17-8	18-0	18-5	18-9	19-1	19-5	19-9	20-1	20-4	20-8
	16.0	13-0	13-6	14-0	14-6	14-11	15-3	15-8	16-0	16-5	16-9	17-0	17-4	17-8	17-11	18-3	18-6	18-9
	19.2	12-3	12-9	13-2	13-7	14-0	14-5	14-9	15-1	15-5	15-9	16-0	16-4	16-7	16-11	17-2	17-5	17-8
	24.0	11-4	11-10	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-7	14-11	15-2	15-5	15-8	15-11	16-2	16-5
2 × 12	12.0	17-5	18-1	18-9	19-4	19-11	20-6	21-0	21-6	21-11	22-5	22-10	23-3	23-7	24-0	24-5	24-9	25-1
	16.0	15-10	16-5	17-0	17-7	18-1	18-7	19-1	19-6	19-11	20-4	20-9	21-1	21-6	21-10	22-2	22-6	22-10
	19.2	14-11	15-6	16-0	16-7	17-0	17-6	17-11	18-4	18-9	19-2	19-6	19-10	20-2	20-6	20-10	21-2	21-6
	24.0	13-10	14-4	14-11	15-4	15-10	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-4	19-8	19-11
F_b	12.0	718	777	833	888	941	993	1,043	1,092	1,140	1,187	1,233	1,278	1,323	1,367	1,410	1,452	1,494
	16.0	790	855	917	977	1,036	1,093	1,148	1,202	1,255	1,306	1,357	1,407	1,456	1,504	1,551	1,598	1,644
	19.2	840	909	975	1,039	1,101	1,161	1,220	1,277	1,333	1,388	1,442	1,495	1,547	1,598	1,649	1,698	1,747
	24.0	905	979	1,050	1,119	1,186	1,251	1,314	1,376	1,436	1,496	1,554	1,611	1,667	1,722	1,776	1,829	1,882

NOTE: The required bending design value, F_b, in pounds per square inch (× 0.00689 for N/mm²) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-J-2—FLOOR JOISTS WITH L/360 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity (*E*) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 40 psf (1.92 kN/m^2) live load.
Limited to span in inches (mm) divided by 360.
Strength — Live load of 40 psf (1.92 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi × 0.00689 for N/mm^2																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 6	12.0	8-6	8-10	9-2	9-6	9-9	10-0	10-3	10-6	10-9	10-11	11-2	11-4	11-7	11-9	11-11	12-1	12-3
	16.0	7-9	8-0	8-4	8-7	8-10	9-1	9-4	9-6	9-9	9-11	10-2	10-4	10-6	10-8	10-10	11-0	11-2
	19.2	7-3	7-7	7-10	8-1	8-4	8-7	8-9	9-0	9-2	9-4	9-6	9-8	9-10	10-0	10-2	10-4	10-6
	24.0	6-9	7-0	7-3	7-6	7-9	7-11	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4	9-6	9-7	9-9
2 × 8	12.0	11-3	11-8	12-1	12-6	12-10	13-2	13-6	13-10	14-2	14-5	14-8	15-0	15-3	15-6	15-9	15-11	16-2
	16.0	10-2	10-7	11-0	11-4	11-8	12-0	12-3	12-7	12-10	13-1	13-4	13-7	13-10	14-1	14-3	14-6	14-8
	19.2	9-7	10-0	10-4	10-8	11-0	11-3	11-7	11-10	12-1	12-4	12-7	12-10	13-0	13-3	13-5	13-8	13-10
	24.0	8-11	9-3	9-7	9-11	10-2	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-3	12-6	12-8	12-10
2 × 10	12.0	14-4	14-11	15-5	15-11	16-5	16-10	17-3	17-8	18-0	18-5	18-9	19-1	19-5	19-9	20-1	20-4	20-8
	16.0	13-0	13-6	14-0	14-6	14-11	15-3	15-8	16-0	16-5	16-9	17-0	17-4	17-8	17-11	18-3	18-6	18-9
	19.2	12-3	12-9	13-2	13-7	14-0	14-5	14-9	15-1	15-5	15-9	16-0	16-4	16-7	16-11	17-2	17-5	17-8
	24.0	11-4	11-10	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-7	14-11	15-2	15-5	15-8	15-11	16-2	16-5
2 × 12	12.0	17-5	18-1	18-9	19-4	19-11	20-6	21-0	21-6	21-11	22-5	22-10	23-3	23-7	24-0	24-5	24-9	25-1
	16.0	15-10	16-5	17-0	17-7	18-1	18-7	19-1	19-6	19-11	20-4	20-9	21-1	21-6	21-10	22-2	22-6	22-10
	19.2	14-11	15-6	16-0	16-7	17-0	17-6	17-11	18-4	18-9	19-2	19-6	19-10	20-2	20-6	20-10	21-2	21-6
	24.0	13-10	14-4	14-11	15-4	15-10	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-4	19-8	19-11
F_b	12.0	862	932	1,000	1,066	1,129	1,191	1,251	1,310	1,368	1,424	1,480	1,534	1,587	1,640	1,692	1,742	1,793
	16.0	949	1,026	1,101	1,173	1,243	1,311	1,377	1,442	1,506	1,568	1,629	1,688	1,747	1,805	1,862	1,918	1,973
	19.2	1,008	1,090	1,170	1,246	1,321	1,393	1,464	1,533	1,600	1,666	1,731	1,794	1,857	1,918	1,978	2,038	2,097
	24.0	1,086	1,174	1,260	1,343	1,423	1,501	1,577	1,651	1,724	1,795	1,864	1,933	2,000	2,066	2,131	2,195	2,258

NOTE: The required bending design value, F_b, in pounds per square inch (× 0.00689 for N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-J-3—CEILING JOISTS WITH L/240 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity (*E*) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 10 psf (0.48 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.
Strength — Live load of 10 psf (0.48 kN/mm^2) plus dead load of 5 psf (0.24 kN/m^2) determines the required fiber stress value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi × 0.00689 for N/mm²																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 4	12.0	9-10	10-3	10-7	10-11	11-3	11-7	11-10	12-2	12-5	12-8	12-11	13-2	13-4	13-7	13-9	14-0	14-2
	16.0	8-11	9-4	9-8	9-11	10-3	10-6	10-9	11-0	11-3	11-6	11-9	11-11	12-2	12-4	12-6	12-9	12-11
	19.2	8-5	8-9	9-1	9-4	9-8	9-11	10-2	10-4	10-7	10-10	11-0	11-3	11-5	11-7	11-9	12-0	12-2
	24.0	7-10	8-1	8-5	8-8	8-11	9-2	9-5	9-8	9-10	10-0	10-3	10-5	10-7	10-9	10-11	11-1	11-3
2 × 6	12.0	15-6	16-1	16-8	17-2	17-8	18-2	18-8	19-1	19-6	19-11	20-3	20-8	21-0	21-4	21-8	22-0	22-4
	16.0	14-1	14-7	15-2	15-7	16-1	16-6	16-11	17-4	17-8	18-1	18-5	18-9	19-1	19-5	19-8	20-0	20-3
	19.2	13-3	13-9	14-3	14-8	15-2	15-7	15-11	16-4	16-8	17-0	17-4	17-8	17-11	18-3	18-6	18-10	19-1
	24.0	12-3	12-9	13-3	13-8	14-1	14-5	14-9	15-2	15-6	15-9	16-1	16-4	16-8	16-11	17-2	17-5	17-8
2 × 8	12.0	20-5	21-2	21-11	22-8	23-4	24-0	24-7	25-2	25-8								
	16.0	18-6	19-3	19-11	20-7	21-2	21-9	22-4	22-10	23-4	23-10	24-3	24-8	25-2	25-7	25-11		
	19.2	17-5	18-1	18-9	19-5	19-11	20-6	21-0	21-6	21-11	22-5	22-10	23-3	23-8	24-0	24-5	24-9	25-2
	24.0	16-2	16-10	17-5	18-0	18-6	19-0	19-6	19-11	20-5	20-10	21-2	21-7	21-11	22-4	22-8	23-0	23-4
2 × 10	12.0	26-0																
	16.0	23-8	24-7	25-5														
	19.2	22-3	23-1	23-11	24-9	25-5												
	24.0	20-8	21-6	22-3	22-11	23-8	24-3	24-10	25-5	26-0								
F_b	12.0	711	769	825	880	932	983	1,033	1,082	1,129	1,176	1,221	1,266	1,310	1,354	1,396	1,438	1,480
	16.0	783	847	909	968	1,026	1,082	1,137	1,191	1,243	1,294	1,344	1,394	1,442	1,490	1,537	1,583	1,629
	19.2	832	900	965	1,029	1,090	1,150	1,208	1,265	1,321	1,375	1,429	1,481	1,533	1,583	1,633	1,682	1,731
	24.0	896	969	1,040	1,108	1,174	1,239	1,302	1,363	1,423	1,481	1,539	1,595	1,651	1,706	1,759	1,812	1,864

NOTE: The required bending design value, F_b, in pounds per square inch (× 0.00689 for N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-J-4—CEILING JOISTS WITH $L/240$ DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, E, in 1,000,000 psi × 0.00689 for N/mm^2																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 4	12.0	7-10	8-1	8-5	8-8	8-11	9-2	9-5	9-8	9-10	10-0	10-3	10-5	10-7	10-9	10-11	11-1	11-3
	16.0	7-1	7-5	7-8	7-11	8-1	8-4	8-7	8-9	8-11	9-1	9-4	9-6	9-8	9-9	9-11	10-1	10-3
	19.2	6-8	6-11	7-2	7-5	7-8	7-10	8-1	8-3	8-5	8-7	8-9	8-11	9-1	9-3	9-4	9-6	9-8
	24.0	6-2	6-5	6-8	6-11	7-1	7-3	7-6	7-8	7-10	8-0	8-1	8-3	8-5	8-7	8-8	8-10	8-11
2 × 6	12.0	12-3	12-9	13-3	13-8	14-1	14-5	14-9	15-2	15-6	15-9	16-1	16-4	16-8	16-11	17-2	17-5	17-8
	16.0	11-2	11-7	12-0	12-5	12-9	13-1	13-5	13-9	14-1	14-4	14-7	14-11	15-2	15-5	15-7	15-10	16-1
	19.2	10-6	10-11	11-4	11-8	12-0	12-4	12-8	12-11	13-3	13-6	13-9	14-0	14-3	14-6	14-8	14-11	15-2
	24.0	9-9	10-2	10-6	10-10	11-2	11-5	11-9	12-0	12-3	12-6	12-9	13-0	13-3	13-5	13-8	13-10	14-1
2 × 8	12.0	16-2	16-10	17-5	18-0	18-6	19-0	19-6	19-11	20-5	20-10	21-2	21-7	21-11	22-4	22-8	23-0	23-4
	16.0	14-8	15-3	15-10	16-4	16-10	17-3	17-9	18-1	18-6	18-11	19-3	19-7	19-11	20-3	20-7	20-11	21-2
	19.2	13-10	14-5	14-11	15-5	15-10	16-3	16-8	17-1	17-5	17-9	18-1	18-5	18-9	19-1	19-5	19-8	19-11
	24.0	12-10	13-4	13-10	14-3	14-8	15-1	15-6	15-10	16-2	16-6	16-10	17-2	17-5	17-9	18-0	18-3	18-6
2 × 10	12.0	20-8	21-6	22-3	22-11	23-8	24-3	24-10	25-5	26-0								
	16.0	18-9	19-6	20-2	20-10	21-6	22-1	22-7	23-1	23-8	24-1	24-7	25-0	25-5	25-10			
	19.2	17-8	18-4	19-0	19-7	20-2	20-9	21-3	21-9	22-3	22-8	23-1	23-7	23-11	24-4	24-9	25-1	25-5
	24.0	16-5	17-0	17-8	18-3	18-9	19-3	19-9	20-2	20-8	21-1	21-6	21-10	22-3	22-7	22-11	23-4	23-8
F_b	12.0	896	969	1,040	1,108	1,174	1,239	1,302	1,363	1,423	1,481	1,539	1,595	1,651	1,706	1,759	1,812	1,864
	16.0	986	1,067	1,145	1,220	1,293	1,364	1,433	1,500	1,566	1,631	1,694	1,756	1,817	1,877	1,936	1,995	2,052
	19.2	1,048	1,134	1,216	1,296	1,374	1,449	1,522	1,594	1,664	1,733	1,800	1,866	1,931	1,995	2,058	2,120	2,181
	24.0	1,129	1,221	1,310	1,396	1,480	1,561	1,640	1,717	1,793	1,866	1,939	2,010	2,080	2,149	2,217	2,283	2,349

NOTE: The required bending design value, F_b, in pounds per square inch (× 0.00689 for N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-1—RAFTERS WITH L/240 DEFLECTION LIMITATION
The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m²) plus dead load of 10 psf (0.48 kN/m²) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m²) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²										
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300
2 × 6	12.0	7-1	8-2	9-2	10-0	10-10	11-7	12-4	13-0	13-7	14-2	14-9
	16.0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10
	19.2	5-7	6-6	7-3	7-11	8-7	9-2	9-9	10-3	10-9	11-3	11-8
	24.0	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5
2 × 8	12.0	9-4	10-10	12-1	13-3	14-4	15-3	16-3	17-1	17-11	18-9	19-6
	16.0	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10
	19.2	7-5	8-7	9-7	10-6	11-4	12-1	12-10	13-6	14-2	14-10	15-5
	24.0	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9
2 × 10	12.0	11-11	13-9	15-5	16-11	18-3	19-6	20-8	21-10	22-10	23-11	24-10
	16.0	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6
	19.2	9-5	10-11	12-2	13-4	14-5	15-5	16-4	17-3	18-1	18-11	19-8
	24.0	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7
2 × 12	12.0	14-6	16-9	18-9	20-6	22-2	23-9	25-2				
	16.0	12-7	14-6	16-3	17-9	19-3	20-6	21-9	23-0	24-1	25-2	
	19.2	11-6	13-3	14-10	16-3	17-6	18-9	19-11	21-0	22-0	23-0	23-11
	24.0	10-3	11-10	13-3	14-6	15-8	16-9	17-9	18-9	19-8	20-6	21-5
E	12.0	0.15	0.24	0.33	0.44	0.55	0.67	0.80	0.94	1.09	1.24	1.40
	16.0	0.13	0.21	0.29	0.38	0.48	0.58	0.70	0.82	0.94	1.07	1.21
	19.2	0.12	0.19	0.26	0.35	0.44	0.53	0.64	0.75	0.86	0.98	1.10
	24.0	0.11	0.17	0.24	0.31	0.39	0.48	0.57	0.67	0.77	0.88	0.99

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²										
× 25.4 for mm		1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
2 × 6	12.0	15-4	15-11	16-5	16-11	17-5	17-10					
	16.0	13-3	13-9	14-2	14-8	15-1	15-6	15-11	16-3			
	19.2	12-2	12-7	13-0	13-4	13-9	14-2	14-6	14-10	15-2	15-7	
	24.0	10-10	11-3	11-7	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2
2 × 8	12.0	20-3	20-11	21-7	22-3	22-11	23-7					
	16.0	17-6	18-1	18-9	19-4	19-10	20-5	20-11	21-5			
	19.2	16-0	16-7	17-1	17-7	18-1	18-7	19-1	19-7	20-0	20-6	
	24.0	14-4	14-10	15-3	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9
2 × 10	12.0	25-10										
	16.0	22-4	23-1	23-11	24-7	25-4	26-0					
	19.2	20-5	21-1	21-10	22-6	23-1	23-9	24-5	25-0	25-7		
	24.0	18-3	18-11	19-6	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11
2 × 12	12.0											
	16.0											
	19.2	24-10	25-8									
	24.0	22-2	23-0	23-9	24-5	25-2	25-10					
E	12.0	1.56	1.73	1.91	2.09	2.28	2.47					
	16.0	1.35	1.50	1.65	1.81	1.97	2.14	2.31	2.48			
	19.2	1.23	1.37	1.51	1.65	1.80	1.95	2.11	2.27	2.43	2.60	
	24.0	1.10	1.22	1.35	1.48	1.61	1.75	1.89	2.03	2.18	2.33	2.48

NOTE: The required modulus of elasticity, E, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm²) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm²) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-2—RAFTERS WITH L/240 DEFLECTION LIMITATION
The allowable bending stress (F_b) and modulus of elasticity (*E*) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m²) plus dead load of 10 psf (0.48 kN/m²) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m²) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²										
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300
2 × 6	12.0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10
	16.0	5-4	6-2	6-10	7-6	8-2	8-8	9-3	9-9	10-2	10-8	11-1
	19.2	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-11	9-4	9-9	10-1
	24.0	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1
2 × 8	12.0	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10
	16.0	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-0	14-7
	19.2	6-5	7-5	8-3	9-1	9-9	10-6	11-1	11-8	12-3	12-10	13-4
	24.0	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11
2 × 10	12.0	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6
	16.0	8-11	10-4	11-7	12-8	13-8	14-8	15-6	16-4	17-2	17-11	18-8
	19.2	8-2	9-5	10-7	11-7	12-6	13-4	14-2	14-11	15-8	16-4	17-0
	24.0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3
2 × 12	12.0	12-7	14-6	16-3	17-9	19-3	20-6	21-9	23-0	24-1	25-2	
	16.0	10-11	12-7	14-1	15-5	16-8	17-9	18-10	19-11	20-10	21-9	22-8
	19.2	9-11	11-6	12-10	14-1	15-2	16-3	17-3	18-2	19-0	19-11	20-8
	24.0	8-11	10-3	11-6	12-7	13-7	14-6	15-5	16-3	17-0	17-9	18-6
E	12.0	0.15	0.23	0.32	0.43	0.54	0.66	0.78	0.92	1.06	1.21	1.36
	16.0	0.13	0.20	0.28	0.37	0.47	0.57	0.68	0.80	0.92	1.05	1.18
	19.2	0.12	0.18	0.26	0.34	0.43	0.52	0.62	0.73	0.84	0.95	1.08
	24.0	0.11	0.16	0.23	0.30	0.38	0.46	0.55	0.65	0.75	0.85	0.96

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²										
× 25.4 for mm		1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
2 × 6	12.0	13-3	13-9	14-2	14-8	15-1	15-6	15-11				
	16.0	11-6	11-11	12-4	12-8	13-1	13-5	13-9	14-1	14-5		
	19.2	10-6	10-10	11-3	11-7	11-11	12-3	12-7	12-10	13-2	13-6	
	24.0	9-5	9-9	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4
2 × 8	12.0	17-6	18-1	18-9	19-4	19-10	20-5	20-11				
	16.0	15-2	15-8	16-3	16-9	17-2	17-8	18-1	18-7	19-0		
	19.2	13-10	14-4	14-10	15-3	15-8	16-2	16-7	16-11	17-4	17-9	
	24.0	12-5	12-10	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3
2 × 10	12.0	22-4	23-1	23-11	24-7	25-4	26-0					
	16.0	19-4	20-0	20-8	21-4	21-11	22-6	23-1	23-8	24-3		
	19.2	17-8	18-3	18-11	19-6	20-0	20-7	21-1	21-8	22-2	22-8	
	24.0	15-10	16-4	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8
2 × 12	12.0											
	16.0	23-6	24-4	25-2	25-11							
	19.2	21-6	22-3	23-0	23-8	24-4	25-0	25-8				
	24.0	19-3	19-11	20-6	21-2	21-9	22-5	23-0	23-6	24-1	24-8	25-2
E	12.0	1.52	1.69	1.86	2.04	2.22	2.41	2.60				
	16.0	1.32	1.46	1.61	1.76	1.92	2.08	2.25	2.42	2.60		
	19.2	1.20	1.33	1.47	1.61	1.75	1.90	2.05	2.21	2.37	2.53	
	24.0	1.08	1.19	1.31	1.44	1.57	1.70	1.84	1.98	2.12	2.27	2.41

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm²) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm²) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-3—RAFTERS WITH L/240 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	6-7	7-7	8-6	9-4	10-0	10-9	11-5	12-0	12-7	13-2	13-8	14-2	14-8
	16.0	5-8	6-7	7-4	8-1	8-8	9-4	9-10	10-5	10-11	11-5	11-10	12-4	12-9
	19.2	5-2	6-0	6-9	7-4	7-11	8-6	9-0	9-6	9-11	10-5	10-10	11-3	11-7
	24.0	4-8	5-4	6-0	6-7	7-1	7-7	8-1	8-6	8-11	9-4	9-8	10-0	10-5
2 × 8	12.0	8-8	10-0	11-2	12-3	13-3	14-2	15-0	15-10	16-7	17-4	18-0	18-9	19-5
	16.0	7-6	8-8	9-8	10-7	11-6	12-3	13-0	13-8	14-4	15-0	15-7	16-3	16-9
	19.2	6-10	7-11	8-10	9-8	10-6	11-2	11-10	12-6	13-1	13-8	14-3	14-10	15-4
	24.0	6-2	7-1	7-11	8-8	9-4	10-0	10-7	11-2	11-9	12-3	12-9	13-3	13-8
2 × 10	12.0	11-1	12-9	14-3	15-8	16-11	18-1	19-2	20-2	21-2	22-1	23-0	23-11	24-9
	16.0	9-7	11-1	12-4	13-6	14-8	15-8	16-7	17-6	18-4	19-2	19-11	20-8	21-5
	19.2	8-9	10-1	11-3	12-4	13-4	14-3	15-2	15-11	16-9	17-6	18-2	18-11	19-7
	24.0	7-10	9-0	10-1	11-1	11-11	12-9	13-6	14-3	15-0	15-8	16-3	16-11	17-6
2 × 12	12.0	13-5	15-6	17-4	19-0	20-6	21-11	23-3	24-7	25-9				
	16.0	11-8	13-5	15-0	16-6	17-9	19-0	20-2	21-3	22-4	23-3	24-3	25-2	26-0
	19.2	10-8	12-3	13-9	15-0	16-3	17-4	18-5	19-5	20-4	21-3	22-2	23-0	23-9
	24.0	9-6	11-0	12-3	13-5	14-6	15-6	16-6	17-4	18-2	19-0	19-10	20-6	21-3
E	12.0	0.12	0.19	0.26	0.35	0.44	0.54	0.64	0.75	0.86	0.98	1.11	1.24	1.37
	16.0	0.11	0.16	0.23	0.30	0.38	0.46	0.55	0.65	0.75	0.85	0.96	1.07	1.19
	19.2	0.10	0.15	0.21	0.27	0.35	0.42	0.51	0.59	0.68	0.78	0.88	0.98	1.09
	24.0	0.09	0.13	0.19	0.25	0.31	0.38	0.45	0.53	0.61	0.70	0.78	0.88	0.97

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	15-2	15-8	16-1	16-7	17-0	17-5	17-10					
	16.0	13-2	13-7	13-11	14-4	14-8	15-1	15-5	15-9	16-1	16-5		
	19.2	12-0	12-4	12-9	13-1	13-5	13-9	14-1	14-5	14-8	15-0	15-4	
	24.0	10-9	11-1	11-5	11-8	12-0	12-4	12-7	12-10	13-2	13-5	13-8	13-11
2 × 8	12.0	20-0	20-8	21-3	21-10	22-4	22-11	23-6					
	16.0	17-4	17-10	18-5	18-11	19-5	19-10	20-4	20-9	21-3	21-8		
	19.2	15-10	16-4	16-9	17-3	17-8	18-1	18-7	19-0	19-5	19-9	20-2	
	24.0	14-2	14-7	15-0	15-5	15-10	16-3	16-7	17-0	17-4	17-8	18-0	18-5
2 × 10	12.0	25-6											
	16.0	22-1	22-10	23-5	24-1	24-9	25-4	25-11					
	19.2	20-2	20-10	21-5	22-0	22-7	23-1	23-8	24-2	24-9	25-3	25-9	
	24.0	18-1	18-7	19-2	19-8	20-2	20-8	21-2	21-8	22-1	22-7	23-0	23-5
2 × 12	12.0												
	16.0												
	19.2	24-7	25-4	26-0									
	24.0	21-11	22-8	23-3	23-11	24-7	25-2	25-9					
E	12.0	1.51	1.66	1.81	1.96	2.12	2.28	2.44					
	16.0	1.31	1.44	1.56	1.70	1.83	1.97	2.11	2.26	2.41	2.56		
	19.2	1.20	1.31	1.43	1.55	1.67	1.80	1.93	2.06	2.20	2.34	2.48	
	24.0	1.07	1.17	1.28	1.39	1.50	1.61	1.73	1.85	1.97	2.09	2.22	2.35

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-4—RAFTERS WITH L/240 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (*E*) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m²) plus dead load of 15 psf (0.72 kN/m²) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m²) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	5-10	6-8	7-6	8-2	8-10	9-6	10-0	10-7	11-1	11-7	12-1	12-6	13-0
	16.0	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5	10-10	11-3
	19.2	4-7	5-4	5-11	6-6	7-0	7-6	7-11	8-4	8-9	9-2	9-6	9-11	10-3
	24.0	4-1	4-9	5-4	5-10	6-3	6-8	7-1	7-6	7-10	8-2	8-6	8-10	9-2
2 × 8	12.0	7-8	8-10	9-10	10-10	11-8	12-6	13-3	13-11	14-8	15-3	15-11	16-6	17-1
	16.0	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9	14-4	14-10
	19.2	6-0	7-0	7-10	8-7	9-3	9-10	10-6	11-0	11-7	12-1	12-7	13-1	13-6
	24.0	5-5	6-3	7-0	7-8	8-3	8-10	9-4	9-10	10-4	10-10	11-3	11-8	12-1
2 × 10	12.0	9-9	11-3	12-7	13-9	14-11	15-11	16-11	17-10	18-8	19-6	20-4	21-1	21-10
	16.0	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7	18-3	18-11
	19.2	7-8	8-11	9-11	10-11	11-9	12-7	13-4	14-1	14-9	15-5	16-1	16-8	17-3
	24.0	6-11	8-0	8-11	9-9	10-6	11-3	11-11	12-7	13-2	13-9	14-4	14-11	15-5
2 × 12	12.0	11-10	13-8	15-4	16-9	18-1	19-4	20-6	21-8	22-8	23-9	24-8	25-7	
	16.0	10-3	11-10	13-3	14-6	15-8	16-9	17-9	18-9	19-8	20-6	21-5	22-2	23-0
	19.2	9-4	10-10	12-1	13-3	14-4	15-4	16-3	17-1	17-11	18-9	19-6	20-3	21-0
	24.0	8-5	9-8	10-10	11-10	12-10	13-8	14-6	15-4	16-1	16-9	17-5	18-1	18-9
E	12.0	0.13	0.19	0.27	0.36	0.45	0.55	0.66	0.77	0.89	1.01	1.14	1.28	1.41
	16.0	0.11	0.17	0.24	0.31	0.39	0.48	0.57	0.67	0.77	0.88	0.99	1.10	1.22
	19.2	0.10	0.15	0.22	0.28	0.36	0.44	0.52	0.61	0.70	0.80	0.90	1.01	1.12
	24.0	0.09	0.14	0.19	0.25	0.32	0.39	0.46	0.54	0.63	0.72	0.81	0.90	1.00

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	13-5	13-10	14-2	14-7	15-0	15-4	15-8					
	16.0	11-7	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2			
	19.2	10-7	10-11	11-3	11-6	11-10	12-2	12-5	12-8	13-0	13-3	13-6	
	24.0	9-6	9-9	10-0	10-4	10-7	10-10	11-1	11-4	11-7	11-10	12-1	12-4
2 × 8	12.0	17-8	18-2	18-9	19-3	19-9	20-3	20-8					
	16.0	15-3	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9			
	19.2	13-11	14-5	14-10	15-2	15-7	16-0	16-4	16-9	17-1	17-5	17-9	
	24.0	12-6	12-10	13-3	13-7	13-11	14-4	14-8	15-0	15-3	15-7	15-11	16-3
2 × 10	12.0	22-6	23-3	23-11	24-6	25-2	25-10						
	16.0	19-6	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11			
	19.2	17-10	18-4	18-11	19-5	19-11	20-5	20-10	21-4	21-10	22-3	22-8	
	24.0	15-11	16-5	16-11	17-4	17-10	18-3	18-8	19-1	19-6	19-11	20-4	20-8
2 × 12	12.0												
	16.0	23-9	24-5	25-2	25-10								
	19.2	21-8	22-4	23-0	23-7	24-2	24-10	25-5	25-11				
	24.0	19-4	20-0	20-6	21-1	21-8	22-2	22-8	23-3	23-9	24-2	24-8	25-2
E	12.0	1.56	1.71	1.86	2.02	2.18	2.34	2.51					
	16.0	1.35	1.48	1.61	1.75	1.89	2.03	2.18	2.33	2.48			
	19.2	1.23	1.35	1.47	1.59	1.72	1.85	1.99	2.12	2.26	2.41	2.55	
	24.0	1.10	1.21	1.31	1.43	1.54	1.66	1.78	1.90	2.02	2.15	2.28	2.41

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm²) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm²) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-5—RAFTERS WITH L/240 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10	13-3	13-9
	16.0	5-4	6-2	6-10	7-6	8-2	8-8	9-3	9-9	10-2	10-8	11-1	11-6	11-11
	19.2	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-11	9-4	9-9	10-1	10-6	10-10
	24.0	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9
2 × 8	12.0	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10	17-6	18-1
	16.0	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-0	14-7	15-2	15-8
	19.2	6-5	7-5	8-3	9-1	9-9	10-6	11-1	11-8	12-3	12-10	13-4	13-10	14-4
	24.0	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10
2 × 10	12.0	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6	22-4	23-1
	16.0	8-11	10-4	11-7	12-8	13-8	14-8	15-6	16-4	17-2	17-11	18-8	19-4	20-0
	19.2	8-2	9-5	10-7	11-7	12-6	13-4	14-2	14-11	15-8	16-4	17-0	17-8	18-3
	24.0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4
2 × 12	12.0	12-7	14-6	16-3	17-9	19-3	20-6	21-9	23-0	24-1	25-2			
	16.0	10-11	12-7	14-1	15-5	16-8	17-9	18-10	19-11	20-10	21-9	22-8	23-6	24-4
	19.2	9-11	11-6	12-10	14-1	15-2	16-3	17-3	18-2	19-0	19-11	20-8	21-6	22-3
	24.0	8-11	10-3	11-6	12-7	13-7	14-6	15-5	16-3	17-0	17-9	18-6	19-3	19-11
E	12.0	0.10	0.15	0.22	0.28	0.36	0.44	0.52	0.61	0.71	0.80	0.91	1.01	1.13
	16.0	0.09	0.13	0.19	0.25	0.31	0.38	0.45	0.53	0.61	0.70	0.79	0.88	0.97
	19.2	0.08	0.12	0.17	0.23	0.28	0.35	0.41	0.48	0.56	0.64	0.72	0.80	0.89
	24.0	0.07	0.11	0.15	0.20	0.25	0.31	0.37	0.43	0.50	0.57	0.64	0.72	0.80

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	14-2	14-8	15-1	15-6	15-11	16-3	16-8	17-0	17-5	17-9	18-1	
	16.0	12-4	12-8	13-1	13-5	13-9	14-1	14-5	14-9	15-1	15-4	15-8	16-0
	19.2	11-3	11-7	11-11	12-3	12-7	12-10	13-2	13-6	13-9	14-0	14-4	14-7
	24.0	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1
2 × 8	12.0	18-9	19-4	19-10	20-5	20-11	21-5	21-11	22-5	22-11	23-5	23-10	
	16.0	16-3	16-9	17-2	17-8	18-1	18-7	19-0	19-5	19-10	20-3	20-8	21-1
	19.2	14-10	15-3	15-8	16-2	16-7	16-11	17-4	17-9	18-1	18-6	18-10	19-3
	24.0	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2
2 × 10	12.0	23-11	24-7	25-4	26-0								
	16.0	20-8	21-4	21-11	22-6	23-1	23-8	24-3	24-10	25-4	25-10		
	19.2	18-11	19-6	20-0	20-7	21-1	21-8	22-2	22-8	23-1	23-7	24-1	24-6
	24.0	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11
2 × 12	12.0												
	16.0	25-2	25-11										
	19.2	23-0	23-8	24-4	25-0	25-8							
	24.0	20-6	21-2	21-9	22-5	23-0	23-6	24-1	24-8	25-2	25-8		
E	12.0	1.24	1.36	1.48	1.60	1.73	1.86	2.00	2.14	2.28	2.42	2.57	
	16.0	1.07	1.18	1.28	1.39	1.50	1.61	1.73	1.85	1.97	2.10	2.22	2.35
	19.2	0.98	1.07	1.17	1.27	1.37	1.47	1.58	1.69	1.80	1.91	2.03	2.15
	24.0	0.88	0.96	1.05	1.13	1.22	1.32	1.41	1.51	1.61	1.71	1.82	1.92

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-6—RAFTERS WITH L/240 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	5-6	6-4	7-1	7-9	8-5	9-0	9-6	10-0	10-6	11-0	11-5	11-11	12-4
	16.0	4-9	5-6	6-2	6-9	7-3	7-9	8-3	8-8	9-1	9-6	9-11	10-3	10-8
	19.2	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9
	24.0	3-11	4-6	5-0	5-6	5-11	6-4	6-9	7-1	7-5	7-9	8-1	8-5	8-8
2 × 8	12.0	7-3	8-4	9-4	10-3	11-1	11-10	12-7	13-3	13-11	14-6	15-1	15-8	16-3
	16.0	6-3	7-3	8-1	8-11	9-7	10-3	10-10	11-6	12-0	12-7	13-1	13-7	14-0
	19.2	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10
	24.0	5-2	5-11	6-7	7-3	7-10	8-4	8-11	9-4	9-10	10-3	10-8	11-1	11-6
2 × 10	12.0	9-3	10-8	11-11	13-1	14-2	15-1	16-0	16-11	17-9	18-6	19-3	20-0	20-8
	16.0	8-0	9-3	10-4	11-4	12-3	13-1	13-10	14-8	15-4	16-0	16-8	17-4	17-11
	19.2	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4
	24.0	6-6	7-7	8-5	9-3	10-0	10-8	11-4	11-11	12-6	13-1	13-7	14-2	14-8
2 × 12	12.0	11-3	13-0	14-6	15-11	17-2	18-4	19-6	20-6	21-7	22-6	23-5	24-4	25-2
	16.0	9-9	11-3	12-7	13-9	14-11	15-11	16-10	17-9	18-8	19-6	20-3	21-1	21-9
	19.2	8-11	10-3	11-6	12-7	13-7	14-6	15-5	16-3	17-0	17-9	18-6	19-3	19-11
	24.0	7-11	9-2	10-3	11-3	12-2	13-0	13-9	14-6	15-3	15-11	16-7	17-2	17-9
E	12.0	0.11	0.17	0.23	0.31	0.38	0.47	0.56	0.66	0.76	0.86	0.97	1.09	1.21
	16.0	0.09	0.14	0.20	0.26	0.33	0.41	0.49	0.57	0.66	0.75	0.84	0.94	1.05
	19.2	0.09	0.13	0.18	0.24	0.30	0.37	0.44	0.52	0.60	0.68	0.77	0.86	0.95
	24.0	0.08	0.12	0.16	0.22	0.27	0.33	0.40	0.46	0.54	0.61	0.69	0.77	0.85

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	12-8	13-1	13-6	13-10	14-2	14-7	14-11	15-3	15-7	15-11		
	16.0	11-0	11-4	11-8	12-0	12-4	12-7	12-11	13-2	13-6	13-9	14-0	14-3
	19.2	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1
	24.0	9-0	9-3	9-6	9-9	10-0	10-3	10-6	10-9	11-0	11-3	11-5	11-8
2 × 8	12.0	16-9	17-3	17-9	18-3	18-9	19-2	19-8	20-1	20-6	20-11		
	16.0	14-6	14-11	15-5	15-10	16-3	16-7	17-0	17-5	17-9	18-1	18-6	18-10
	19.2	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2
	24.0	11-10	12-2	12-7	12-11	13-3	13-7	13-11	14-2	14-6	14-10	15-1	15-5
2 × 10	12.0	21-4	22-0	22-8	23-3	23-11	24-6	25-1	25-7				
	16.0	18-6	19-1	19-7	20-2	20-8	21-2	21-8	22-2	22-8	23-1	23-7	24-0
	19.2	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11
	24.0	15-1	15-7	16-0	16-6	16-11	17-4	17-9	18-1	18-6	18-11	19-3	19-7
2 × 12	12.0	26-0											
	16.0	22-6	23-2	23-10	24-6	25-2	25-9						
	19.2	20-6	21-2	21-9	22-5	23-0	23-6	24-1	24-8	25-2	25-8		
	24.0	18-4	18-11	19-6	20-0	20-6	21-1	21-7	22-0	22-6	23-0	23-5	23-10
E	12.0	1.33	1.46	1.59	1.72	1.86	2.00	2.14	2.29	2.44	2.60		
	16.0	1.15	1.26	1.37	1.49	1.61	1.73	1.86	1.99	2.12	2.25	2.39	2.53
	19.2	1.05	1.15	1.25	1.36	1.47	1.58	1.70	1.81	1.93	2.05	2.18	2.31
	24.0	0.94	1.03	1.12	1.22	1.31	1.41	1.52	1.62	1.73	1.84	1.95	2.06

NOTE: The required modulus of elasticity, E, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-7—RAFTERS WITH L/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m²) plus dead load of 10 psf (0.48 kN/m²) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m²) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-8	4-6	5-3	5-10	6-5	6-11	7-5	7-10	8-3	8-8	9-0	9-5	9-9	10-1	10-5
	16.0	3-2	3-11	4-6	5-1	5-6	6-0	6-5	6-9	7-2	7-6	7-10	8-2	8-5	8-9	9-0
	19.2	2-11	3-7	4-1	4-7	5-1	5-5	5-10	6-2	6-6	6-10	7-2	7-5	7-9	8-0	8-3
	24.0	2-7	3-2	3-8	4-1	4-6	4-11	5-3	5-6	5-10	6-1	6-5	6-8	6-11	7-2	7-5
2 × 6	12.0	5-10	7-1	8-2	9-2	10-0	10-10	11-7	12-4	13-0	13-7	14-2	14-9	15-4	15-11	16-5
	16.0	5-0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10	13-3	13-9	14-2
	19.2	4-7	5-7	6-6	7-3	7-11	8-7	9-2	9-9	10-3	10-9	11-3	11-8	12-2	12-7	13-0
	24.0	4-1	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5	10-10	11-3	11-7
2 × 8	12.0	7-8	9-4	10-10	12-1	13-3	14-4	15-3	16-3	17-1	17-11	18-9	19-6	20-3	20-11	21-7
	16.0	6-7	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10	17-6	18-1	18-9
	19.2	6-0	7-5	8-7	9-7	10-6	11-4	12-1	12-10	13-6	14-2	14-10	15-5	16-0	16-7	17-1
	24.0	5-5	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9	14-4	14-10	15-3
2 × 10	12.0	9-9	11-11	13-9	15-5	16-11	18-3	19-6	20-8	21-10	22-10	23-11	24-10	25-10		
	16.0	8-5	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6	22-4	23-1	23-11
	19.2	7-8	9-5	10-11	12-2	13-4	14-5	15-5	16-4	17-3	18-1	18-11	19-8	20-5	21-1	21-10
	24.0	6-11	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7	18-3	18-11	19-6
E	12.0	0.06	0.12	0.18	0.25	0.33	0.41	0.51	0.60	0.71	0.82	0.93	1.05	1.17	1.30	1.43
	16.0	0.05	0.10	0.15	0.22	0.28	0.36	0.44	0.52	0.61	0.71	0.80	0.91	1.01	1.13	1.24
	19.2	0.05	0.09	0.14	0.20	0.26	0.33	0.40	0.48	0.56	0.64	0.73	0.83	0.93	1.03	1.13
	24.0	0.04	0.08	0.13	0.18	0.23	0.29	0.36	0.43	0.50	0.58	0.66	0.74	0.83	0.92	1.01

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	10-9	11-1	11-4	11-8	11-11	12-3	12-6							
	16.0	9-4	9-7	9-10	10-1	10-4	10-7	10-10	11-1	11-4	11-6				
	19.2	8-6	8-9	9-0	9-3	9-5	9-8	9-11	10-1	10-4	10-6	10-9			
	24.0	7-7	7-10	8-0	8-3	8-5	8-8	8-10	9-0	9-3	9-5	9-7	9-9	9-11	10-1
2 × 6	12.0	16-11	17-5	17-10	18-4	18-9	19-3	19-8							
	16.0	14-8	15-1	15-6	15-11	16-3	16-8	17-0	17-5	17-9	18-1				
	19.2	13-4	13-9	14-2	14-6	14-10	15-2	15-7	15-11	16-2	16-6	16-10			
	24.0	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2	14-6	14-9	15-1	15-4	15-7	15-11
2 × 8	12.0	22-3	22-11	23-7	24-2	24-9	25-4	25-11							
	16.0	19-4	19-10	20-5	20-11	21-5	21-11	22-5	22-11	23-5	23-10				
	19.2	17-7	18-1	18-7	19-1	19-7	20-0	20-6	20-11	21-4	21-9	22-2			
	24.0	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9	19-1	19-6	19-10	20-3	20-7	20-11
2 × 10	12.0														
	16.0	24-7	25-4	26-0											
	19.2	22-6	23-1	23-9	24-5	25-0	25-7								
	24.0	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11	24-5	24-10	25-4	25-10		
E	12.0	1.57	1.71	1.85	2.00	2.15	2.31	2.47							
	16.0	1.36	1.48	1.60	1.73	1.86	2.00	2.14	2.28	2.42	2.57				
	19.2	1.24	1.35	1.46	1.58	1.70	1.82	1.95	2.08	2.21	2.34	2.48			
	24.0	1.11	1.21	1.31	1.41	1.52	1.63	1.74	1.86	1.98	2.10	2.22	2.34	2.47	2.60

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm²) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm²) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-8—RAFTERS WITH L/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-2	3-11	4-6	5-1	5-6	6-0	6-5	6-9	7-2	7-6	7-10	8-2	8-5	8-9	9-0
	16.0	2-9	3-5	3-11	4-4	4-10	5-2	5-6	5-10	6-2	6-6	6-9	7-1	7-4	7-7	7-10
	19.2	2-6	3-1	3-7	4-0	4-4	4-9	5-1	5-4	5-8	5-11	6-2	6-5	6-8	6-11	7-2
	24.0	2-3	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5
2 × 6	12.0	5-0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10	13-3	13-9	14-2
	16.0	4-4	5-4	6-2	6-10	7-6	8-2	8-8	9-3	9-9	10-2	10-8	11-1	11-6	11-11	12-4
	19.2	4-0	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-11	9-4	9-9	10-1	10-6	10-10	11-3
	24.0	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0
2 × 8	12.0	6-7	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10	17-6	18-1	18-9
	16.0	5-9	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-0	14-7	15-2	15-8	16-3
	19.2	5-3	6-5	7-5	8-3	9-1	9-9	10-6	11-1	11-8	12-3	12-10	13-4	13-10	14-4	14-10
	24.0	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
2 × 10	12.0	8-5	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6	22-4	23-1	23-11
	16.0	7-4	8-11	10-4	11-7	12-8	13-8	14-8	15-6	16-4	17-2	17-11	18-8	19-4	20-0	20-8
	19.2	6-8	8-2	9-5	10-7	11-7	12-6	13-4	14-2	14-11	15-8	16-4	17-0	17-8	18-3	18-11
	24.0	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11
E	12.0	0.06	0.11	0.17	0.24	0.32	0.40	0.49	0.59	0.69	0.79	0.91	1.02	1.14	1.27	1.39
	16.0	0.05	0.10	0.15	0.21	0.28	0.35	0.43	0.51	0.60	0.69	0.78	0.88	0.99	1.10	1.21
	19.2	0.05	0.09	0.14	0.19	0.25	0.32	0.39	0.47	0.54	0.63	0.72	0.81	0.90	1.00	1.10
	24.0	0.04	0.08	0.12	0.17	0.23	0.29	0.35	0.42	0.49	0.56	0.64	0.72	0.81	0.89	0.99

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	9-4	9-7	9-10	10-1	10-4	10-7	10-10	11-1						
	16.0	8-1	8-4	8-6	8-9	9-0	9-2	9-5	9-7	9-9	10-0				
	19.2	7-4	7-7	7-9	8-0	8-2	8-5	8-7	8-9	8-11	9-1	9-3	9-5		
	24.0	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5	8-7	8-9
2 × 6	12.0	14-8	15-1	15-6	15-11	16-3	16-8	17-0	17-5						
	16.0	12-8	13-1	13-5	13-9	14-1	14-5	14-9	15-1	15-4	15-8				
	19.2	11-7	11-11	12-3	12-7	12-10	13-2	13-6	13-9	14-0	14-4	14-7	14-10		
	24.0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3	13-6	13-9
2 × 8	12.0	19-4	19-10	20-5	20-11	21-5	21-11	22-5	22-11						
	16.0	16-9	17-2	17-8	18-1	18-7	19-0	19-5	19-10	20-3	20-8				
	19.2	15-3	15-8	16-2	16-7	16-11	17-4	17-9	18-1	18-6	18-10	19-3	19-7		
	24.0	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6	17-10	18-1
2 × 10	12.0	24-7	25-4	26-0											
	16.0	21-4	21-11	22-6	23-1	23-8	24-3	24-10	25-4	25-10					
	19.2	19-6	20-0	20-7	21-1	21-8	22-2	22-8	23-1	23-7	24-1	24-6	25-0		
	24.0	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4	22-9	23-1
E	12.0	1.53	1.66	1.80	1.95	2.10	2.25	2.40	2.56						
	16.0	1.32	1.44	1.56	1.69	1.82	1.95	2.08	2.22	2.36	2.50				
	19.2	1.21	1.32	1.43	1.54	1.66	1.78	1.90	2.03	2.15	2.28	2.42	2.55		
	24.0	1.08	1.18	1.28	1.38	1.48	1.59	1.70	1.81	1.93	2.04	2.16	2.28	2.41	2.53

NOTE: The required modulus of elasticity, E, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-9—RAFTERS WITH L/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (*E*) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m²) plus dead load of 15 psf (0.72 kN/m²) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m²) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-5	4-2	4-10	5-5	5-11	6-5	6-10	7-3	7-8	8-0	8-4	8-8	9-0	9-4	9-8
	16.0	2-11	3-7	4-2	4-8	5-1	5-6	5-11	6-3	6-7	6-11	7-3	7-6	7-10	8-1	8-4
	19.2	2-8	3-4	3-10	4-3	4-8	5-1	5-5	5-9	6-0	6-4	6-7	6-11	7-2	7-5	7-8
	24.0	2-5	2-11	3-5	3-10	4-2	4-6	4-10	5-1	5-5	5-8	5-11	6-2	6-5	6-7	6-10
2 × 6	12.0	5-4	6-7	7-7	8-6	9-4	10-0	10-9	11-5	12-0	12-7	13-2	13-8	14-2	14-8	15-2
	16.0	4-8	5-8	6-7	7-4	8-1	8-8	9-4	9-10	10-5	10-11	11-5	11-10	12-4	12-9	13-2
	19.2	4-3	5-2	6-0	6-9	7-4	7-11	8-6	9-0	9-6	9-11	10-5	10-10	11-3	11-7	12-0
	24.0	3-10	4-8	5-4	6-0	6-7	7-1	7-7	8-1	8-6	8-11	9-4	9-8	10-0	10-5	10-9
2 × 8	12.0	7-1	8-8	10-0	11-2	12-3	13-3	14-2	15-0	15-10	16-7	17-4	18-0	18-9	19-5	20-0
	16.0	6-2	7-6	8-8	9-8	10-7	11-6	12-3	13-0	13-8	14-4	15-0	15-7	16-3	16-9	17-4
	19.2	5-7	6-10	7-11	8-10	9-8	10-6	11-2	11-10	12-6	13-1	13-8	14-3	14-10	15-4	15-10
	24.0	5-0	6-2	7-1	7-11	8-8	9-4	10-0	10-7	11-2	11-9	12-3	12-9	13-3	13-8	14-2
2 × 10	12.0	9-0	11-1	12-9	14-3	15-8	16-11	18-1	19-2	20-2	21-2	22-1	23-0	23-11	24-9	25-6
	16.0	7-10	9-7	11-1	12-4	13-6	14-8	15-8	16-7	17-6	18-4	19-2	19-11	20-8	21-5	22-1
	19.2	7-2	8-9	10-1	11-3	12-4	13-4	14-3	15-2	15-11	16-9	17-6	18-2	18-11	19-7	20-2
	24.0	6-5	7-10	9-0	10-1	11-1	11-11	12-9	13-6	14-3	15-0	15-8	16-3	16-11	17-6	18-1
E	12.0	0.05	0.09	0.14	0.20	0.26	0.33	0.40	0.48	0.56	0.65	0.74	0.83	0.93	1.03	1.14
	16.0	0.04	0.08	0.12	0.17	0.23	0.28	0.35	0.41	0.49	0.56	0.64	0.72	0.80	0.89	0.98
	19.2	0.04	0.07	0.11	0.16	0.21	0.26	0.32	0.38	0.44	0.51	0.58	0.66	0.73	0.81	0.90
	24.0	0.04	0.07	0.10	0.14	0.18	0.23	0.28	0.34	0.40	0.46	0.52	0.59	0.66	0.73	0.80

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	9-11	10-3	10-6	10-10	11-1	11-4	11-7	11-10	12-1	12-4	12-7			
	16.0	8-7	8-10	9-1	9-4	9-7	9-10	10-0	10-3	10-5	10-8	10-10	11-1	11-3	11-5
	19.2	7-10	8-1	8-4	8-6	8-9	8-11	9-2	9-4	9-7	9-9	9-11	10-1	10-3	10-5
	24.0	7-0	7-3	7-5	7-8	7-10	8-0	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4
2 × 6	12.0	15-8	16-1	16-7	17-0	17-5	17-10	18-2	18-7	19-0	19-4	19-9			
	16.0	13-7	13-11	14-4	14-8	15-1	15-5	15-9	16-1	16-5	16-9	17-1	17-5	17-8	18-0
	19.2	12-4	12-9	13-1	13-5	13-9	14-1	14-5	14-8	15-0	15-4	15-7	15-11	16-2	16-5
	24.0	11-1	11-5	11-8	12-0	12-4	12-7	12-10	13-2	13-5	13-8	13-11	14-2	14-5	14-8
2 × 8	12.0	20-8	21-3	21-10	22-4	22-11	23-6	24-0	24-6	25-0	25-6	26-0			
	16.0	17-10	18-5	18-11	19-5	19-10	20-4	20-9	21-3	21-8	22-1	22-6	22-11	23-4	23-9
	19.2	16-4	16-9	17-3	17-8	18-1	18-7	19-0	19-5	19-9	20-2	20-7	20-11	21-4	21-8
	24.0	14-7	15-0	15-5	15-10	16-3	16-7	17-0	17-4	17-8	18-0	18-5	18-9	19-1	19-5
2 × 10	12.0														
	16.0	22-10	23-5	24-1	24-9	25-4	25-11								
	19.2	20-10	21-5	22-0	22-7	23-1	23-8	24-2	24-9	25-3	25-9				
	24.0	18-7	19-2	19-8	20-2	20-8	21-2	21-8	22-1	22-7	23-0	23-5	23-11	24-4	24-9
E	12.0	1.24	1.36	1.47	1.59	1.71	1.83	1.96	2.09	2.22	2.35	2.49			
	16.0	1.08	1.17	1.27	1.37	1.48	1.59	1.70	1.81	1.92	2.04	2.16	2.28	2.40	2.53
	19.2	0.98	1.07	1.16	1.25	1.35	1.45	1.55	1.65	1.75	1.86	1.97	2.08	2.19	2.31
	24.0	0.88	0.96	1.04	1.12	1.21	1.29	1.38	1.48	1.57	1.66	1.76	1.86	1.96	2.06

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm²) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm²) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-10—RAFTERS WITH *L*/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (*E*) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-0	3-8	4-3	4-9	5-3	5-8	6-0	6-5	6-9	7-1	7-5	7-8	8-0	8-3	8-6
	16.0	2-7	3-2	3-8	4-1	4-6	4-11	5-3	5-6	5-10	6-1	6-5	6-8	6-11	7-2	7-5
	19.2	2-5	2-11	3-4	3-9	4-1	4-5	4-9	5-1	5-4	5-7	5-10	6-1	6-4	6-6	6-9
	24.0	2-2	2-7	3-0	3-4	3-8	4-0	4-3	4-6	4-9	5-0	5-3	5-5	5-8	5-10	6-0
2 × 6	12.0	4-9	5-10	6-8	7-6	8-2	8-10	9-6	10-0	10-7	11-1	11-7	12-1	12-6	13-0	13-5
	16.0	4-1	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5	10-10	11-3	11-7
	19.2	3-9	4-7	5-4	5-11	6-6	7-0	7-6	7-11	8-4	8-9	9-2	9-6	9-11	10-3	10-7
	24.0	3-4	4-1	4-9	5-4	5-10	6-3	6-8	7-1	7-6	7-10	8-2	8-6	8-10	9-2	9-6
2 × 8	12.0	6-3	7-8	8-10	9-10	10-10	11-8	12-6	13-3	13-11	14-8	15-3	15-11	16-6	17-1	17-8
	16.0	5-5	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9	14-4	14-10	15-3
	19.2	4-11	6-0	7-0	7-10	8-7	9-3	9-10	10-6	11-0	11-7	12-1	12-7	13-1	13-6	13-11
	24.0	4-5	5-5	6-3	7-0	7-8	8-3	8-10	9-4	9-10	10-4	10-10	11-3	11-8	12-1	12-6
2 × 10	12.0	8-0	9-9	11-3	12-7	13-9	14-11	15-11	16-11	17-10	18-8	19-6	20-4	21-1	21-10	22-6
	16.0	6-11	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7	18-3	18-11	19-6
	19.2	6-4	7-8	8-11	9-11	10-11	11-9	12-7	13-4	14-1	14-9	15-5	16-1	16-8	17-3	17-10
	24.0	5-8	6-11	8-0	8-11	9-9	10-6	11-3	11-11	12-7	13-2	13-9	14-4	14-11	15-5	15-11
E	12.0	0.05	0.09	0.15	0.20	0.27	0.34	0.41	0.49	0.58	0.67	0.76	0.86	0.96	1.06	1.17
	16.0	0.04	0.08	0.13	0.18	0.23	0.29	0.36	0.43	0.50	0.58	0.66	0.74	0.83	0.92	1.01
	19.2	0.04	0.08	0.12	0.16	0.21	0.27	0.33	0.39	0.46	0.53	0.60	0.68	0.76	0.84	0.92
	24.0	0.04	0.07	0.10	0.14	0.19	0.24	0.29	0.35	0.41	0.47	0.54	0.61	0.68	0.75	0.83

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	8-9	9-0	9-3	9-6	9-9	10-0	10-3	10-5	10-8	10-10	11-1			
	16.0	7-7	7-10	8-0	8-3	8-5	8-8	8-10	9-0	9-3	9-5	9-7	9-9	9-11	10-1
	19.2	6-11	7-2	7-4	7-6	7-9	7-11	8-1	8-3	8-5	8-7	8-9	8-11	9-1	9-3
	24.0	6-3	6-5	6-7	6-9	6-11	7-1	7-3	7-5	7-6	7-8	7-10	8-0	8-1	8-3
2 × 6	12.0	13-10	14-2	14-7	15-0	15-4	15-8	16-1	16-5	16-9	17-1	17-5			
	16.0	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2	14-6	14-9	15-1	15-4	15-7	15-11
	19.2	10-11	11-3	11-6	11-10	12-2	12-5	12-8	13-0	13-3	13-6	13-9	14-0	14-3	14-6
	24.0	9-9	10-0	10-4	10-7	10-10	11-1	11-4	11-7	11-10	12-1	12-4	12-6	12-9	13-0
2 × 8	12.0	18-2	18-9	19-3	19-9	20-3	20-8	21-2	21-7	22-1	22-6	22-11			
	16.0	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9	19-1	19-6	19-10	20-3	20-7	20-11
	19.2	14-5	14-10	15-2	15-7	16-0	16-4	16-9	17-1	17-5	17-9	18-1	18-5	18-9	19-1
	24.0	12-10	13-3	13-7	13-11	14-4	14-8	15-0	15-3	15-7	15-11	16-3	16-6	16-10	17-1
2 × 10	12.0	23-3	23-11	24-6	25-2	25-10									
	16.0	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11	24-5	24-10	25-4	25-10		
	19.2	18-4	18-11	19-5	19-11	20-5	20-10	21-4	21-10	22-3	22-8	23-1	23-7	24-0	24-5
	24.0	16-5	16-11	17-4	17-10	18-3	18-8	19-1	19-6	19-11	20-4	20-8	21-1	21-5	21-10
E	12.0	1.28	1.39	1.51	1.63	1.76	1.88	2.01	2.15	2.28	2.42	2.56			
	16.0	1.11	1.21	1.31	1.41	1.52	1.63	1.74	1.86	1.98	2.10	2.22	2.34	2.47	2.60
	19.2	1.01	1.10	1.20	1.29	1.39	1.49	1.59	1.70	1.80	1.91	2.03	2.14	2.25	2.37
	24.0	0.90	0.99	1.07	1.15	1.24	1.33	1.42	1.52	1.61	1.71	1.81	1.91	2.02	2.12

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-11—RAFTERS WITH $L/180$ DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-2	3-11	4-6	5-1	5-6	6-0	6-5	6-9	7-2	7-6	7-10	8-2	8-5	8-9	9-0
	16.0	2-9	3-5	3-11	4-4	4-10	5-2	5-6	5-10	6-2	6-6	6-9	7-1	7-4	7-7	7-10
	19.2	2-6	3-1	3-7	4-0	4-4	4-9	5-1	5-4	5-8	5-11	6-2	6-5	6-8	6-11	7-2
	24.0	2-3	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5
2 × 6	12.0	5-0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10	13-3	13-9	14-2
	16.0	4-4	5-4	6-2	6-10	7-6	8-2	8-8	9-3	9-9	10-2	10-8	11-1	11-6	11-11	12-4
	19.2	4-0	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-11	9-4	9-9	10-1	10-6	10-10	11-3
	24.0	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0
2 × 8	12.0	6-7	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10	17-6	18-1	18-9
	16.0	5-9	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-0	14-7	15-2	15-8	16-3
	19.2	5-3	6-5	7-5	8-3	9-1	9-9	10-6	11-1	11-8	12-3	12-10	13-4	13-10	14-4	14-10
	24.0	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
2 × 10	12.0	8-5	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6	22-4	23-1	23-11
	16.0	7-4	8-11	10-4	11-7	12-8	13-8	14-8	15-6	16-4	17-2	17-11	18-8	19-4	20-0	20-8
	19.2	6-8	8-2	9-5	10-7	11-7	12-6	13-4	14-2	14-11	15-8	16-4	17-0	17-8	18-3	18-11
	24.0	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11
E	12.0	0.04	0.08	0.12	0.16	0.21	0.27	0.33	0.39	0.46	0.53	0.60	0.68	0.76	0.84	0.93
	16.0	0.04	0.07	0.10	0.14	0.18	0.23	0.28	0.34	0.40	0.46	0.52	0.59	0.66	0.73	0.80
	19.2	0.03	0.06	0.09	0.13	0.17	0.21	0.26	0.31	0.36	0.42	0.48	0.54	0.60	0.67	0.73
	24.0	0.03	0.05	0.08	0.11	0.15	0.19	0.23	0.28	0.32	0.37	0.43	0.48	0.54	0.60	0.66

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	9-4	9-7	9-10	10-1	10-4	10-7	10-10	11-1	11-4	11-6	11-9	11-11	12-2	12-4
	16.0	8-1	8-4	8-6	8-9	9-0	9-2	9-5	9-7	9-9	10-0	10-2	10-4	10-6	10-9
	19.2	7-4	7-7	7-9	8-0	8-2	8-5	8-7	8-9	8-11	9-1	9-3	9-5	9-7	9-9
	24.0	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5	8-7	8-9
2 × 6	12.0	14-8	15-1	15-6	15-11	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-5
	16.0	12-8	13-1	13-5	13-9	14-1	14-5	14-9	15-1	15-4	15-8	16-0	16-3	16-7	16-10
	19.2	11-7	11-11	12-3	12-7	12-10	13-2	13-6	13-9	14-0	14-4	14-7	14-10	15-1	15-4
	24.0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3	13-6	13-9
2 × 8	12.0	19-4	19-10	20-5	20-11	21-5	21-11	22-5	22-11	23-5	23-10	24-4	24-9	25-2	25-8
	16.0	16-9	17-2	17-8	18-1	18-7	19-0	19-5	19-10	20-3	20-8	21-1	21-5	21-10	22-2
	19.2	15-3	15-8	16-2	16-7	16-11	17-4	17-9	18-1	18-6	18-10	19-3	19-7	19-11	20-3
	24.0	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6	17-10	18-1
2 × 10	12.0	24-7	25-4	26-0											
	16.0	21-4	21-11	22-6	23-1	23-8	24-3	24-10	25-4	25-10					
	19.2	19-6	20-0	20-7	21-1	21-8	22-2	22-8	23-1	23-7	24-1	24-6	25-0	25-5	25-10
	24.0	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4	22-9	23-1
E	12.0	1.02	1.11	1.20	1.30	1.40	1.50	1.60	1.71	1.82	1.93	2.04	2.15	2.27	2.39
	16.0	0.88	0.96	1.04	1.13	1.21	1.30	1.39	1.48	1.57	1.67	1.76	1.86	1.96	2.07
	19.2	0.80	0.88	0.95	1.03	1.10	1.18	1.27	1.35	1.44	1.52	1.61	1.70	1.79	1.89
	24.0	0.72	0.78	0.85	0.92	0.99	1.06	1.13	1.21	1.28	1.36	1.44	1.52	1.60	1.69

NOTE: The required modulus of elasticity, E, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-12—RAFTERS WITH L/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity (E) used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m²) plus dead load of 20 psf (0.96 kN/m²) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m²) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	2-10	3-6	4-0	4-6	4-11	5-4	5-9	6-1	6-5	6-8	7-0	7-3	7-7	7-10	8-1
	16.0	2-6	3-0	3-6	3-11	4-3	4-8	4-11	5-3	5-6	5-10	6-1	6-4	6-7	6-9	7-0
	19.2	2-3	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5
	24.0	2-0	2-6	2-10	3-2	3-6	3-9	4-0	4-3	4-6	4-9	4-11	5-2	5-4	5-6	5-9
2 × 6	12.0	4-6	5-6	6-4	7-1	7-9	8-5	9-0	9-6	10-0	10-6	11-0	11-5	11-11	12-4	12-8
	16.0	3-11	4-9	5-6	6-2	6-9	7-3	7-9	8-3	8-8	9-1	9-6	9-11	10-3	10-8	11-0
	19.2	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0
	24.0	3-2	3-11	4-6	5-0	5-6	5-11	6-4	6-9	7-1	7-5	7-9	8-1	8-5	8-8	9-0
2 × 8	12.0	5-11	7-3	8-4	9-4	10-3	11-1	11-10	12-7	13-3	13-11	14-6	15-1	15-8	16-3	16-9
	16.0	5-2	6-3	7-3	8-1	8-11	9-7	10-3	10-10	11-6	12-0	12-7	13-1	13-7	14-0	14-6
	19.2	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
	24.0	4-2	5-2	5-11	6-7	7-3	7-10	8-4	8-11	9-4	9-10	10-3	10-8	11-1	11-6	11-10
2 × 10	12.0	7-7	9-3	10-8	11-11	13-1	14-2	15-1	16-0	16-11	17-9	18-6	19-3	20-0	20-8	21-4
	16.0	6-6	8-0	9-3	10-4	11-4	12-3	13-1	13-10	14-8	15-4	16-0	16-8	17-4	17-11	18-6
	19.2	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11
	24.0	5-4	6-6	7-7	8-5	9-3	10-0	10-8	11-4	11-11	12-6	13-1	13-7	14-2	14-8	15-1
E	12.0	0.04	0.08	0.12	0.17	0.23	0.29	0.35	0.42	0.49	0.57	0.65	0.73	0.82	0.91	1.00
	16.0	0.04	0.07	0.11	0.15	0.20	0.25	0.31	0.36	0.43	0.49	0.56	0.63	0.71	0.78	0.86
	19.2	0.03	0.06	0.10	0.14	0.18	0.23	0.28	0.33	0.39	0.45	0.51	0.58	0.65	0.72	0.79
	24.0	0.03	0.06	0.09	0.12	0.16	0.20	0.25	0.30	0.35	0.40	0.46	0.52	0.58	0.64	0.71

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm²														
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	8-4	8-7	8-10	9-0	9-3	9-6	9-8	9-11	10-1	10-4	10-6	10-8	10-11	11-1
	16.0	7-3	7-5	7-8	7-10	8-0	8-2	8-5	8-7	8-9	8-11	9-1	9-3	9-5	9-7
	19.2	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5	8-7	8-9
	24.0	5-11	6-1	6-3	6-5	6-7	6-8	6-10	7-0	7-2	7-3	7-5	7-7	7-8	7-10
2 × 6	12.0	13-1	13-6	13-10	14-2	14-7	14-11	15-3	15-7	15-11	16-2	16-6	16-10	17-1	17-5
	16.0	11-4	11-8	12-0	12-4	12-7	12-11	13-2	13-6	13-9	14-0	14-3	14-7	14-10	15-1
	19.2	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3	13-6	13-9
	24.0	9-3	9-6	9-9	10-0	10-3	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-4
2 × 8	12.0	17-3	17-9	18-3	18-9	19-2	19-8	20-1	20-6	20-11	21-4	21-9	22-2	22-6	22-11
	16.0	14-11	15-5	15-10	16-3	16-7	17-0	17-5	17-9	18-1	18-6	18-10	19-2	19-6	19-10
	19.2	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6	17-10	18-1
	24.0	12-2	12-7	12-11	13-3	13-7	13-11	14-2	14-6	14-10	15-1	15-5	15-8	15-11	16-3
2 × 10	12.0	22-0	22-8	23-3	23-11	24-6	25-1	25-7							
	16.0	19-1	19-7	20-2	20-8	21-2	21-8	22-2	22-8	23-1	23-7	24-0	24-6	24-11	25-4
	19.2	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4	22-9	23-1
	24.0	15-7	16-0	16-6	16-11	17-4	17-9	18-1	18-6	18-11	19-3	19-7	20-0	20-4	20-8
E	12.0	1.09	1.19	1.29	1.39	1.50	1.61	1.72	1.83	1.95	2.07	2.19	2.31	2.43	2.56
	16.0	0.95	1.03	1.12	1.21	1.30	1.39	1.49	1.59	1.69	1.79	1.89	2.00	2.11	2.22
	19.2	0.86	0.94	1.02	1.10	1.19	1.27	1.36	1.45	1.54	1.63	1.73	1.83	1.92	2.03
	24.0	0.77	0.84	0.91	0.99	1.06	1.14	1.22	1.30	1.38	1.46	1.55	1.63	1.72	1.81

NOTE: The required modulus of elasticity, E, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm²) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm²) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER
For Use in Tables 23-IV-J-1 through 23-IV-R-12 and Chapter 23, Division VII only.

These "F_b" values are for use where repetitive members are spaced not more than 24 inches (610 mm). For wider spacing, the "F_b" values shall be reduced 13 percent.
Values for surfaced dry or surfaced green lumber apply at 19 percent maximum moisture content in use.

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi — Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
ASPEN						
Select Structural	2 × 4	1,510	1,735	1,885	1,100,000	NELMA NSLB WWPA
No. 1		1,080	1,240	1,350	1,100,000	
No. 2		1,035	1,190	1,295	1,000,000	
No. 3		605	695	755	900,000	
Stud		600	690	750	900,000	
Construction		805	925	1,005	900,000	
Standard		430	495	540	900,000	
Utility		200	230	250	800,000	
Select Structural	2 × 6	1,310	1,505	1,635	1,100,000	
No. 1		935	1,075	1,170	1,100,000	
No. 2		895	1,030	1,120	1,000,000	
No. 3		525	600	655	900,000	
Stud		545	630	685	900,000	
Select Structural	2 × 8	1,210	1,390	1,510	1,100,000	
No. 1		865	990	1,080	1,100,000	
No. 2		830	950	1,035	1,000,000	
No. 3		485	555	605	900,000	
Select Structural	2 × 10	1,105	1,275	1,385	1,100,000	
No. 1		790	910	990	1,100,000	
No. 2		760	875	950	1,000,000	
No. 3		445	510	555	900,000	
Select Structural	2 × 12	1,005	1,155	1,260	1,100,000	
No. 1		720	825	900	1,100,000	
No. 2		690	795	865	1,000,000	
No. 3		405	465	505	900,000	
BEECH-BIRCH-HICKORY						
Select Structural	2 × 4	2,500	2,875	3,125	1,700,000	NELMA
No. 1		1,810	2,085	2,265	1,600,000	
No. 2		1,725	1,985	2,155	1,500,000	
No. 3		990	1,140	1,240	1,300,000	
Stud		980	1,125	1,225	1,300,000	
Construction		1,325	1,520	1,655	1,400,000	
Standard		750	860	935	1,300,000	
Utility		345	395	430	1,200,000	
Select Structural	2 × 6	2,170	2,495	2,710	1,700,000	
No. 1		1,570	1,805	1,960	1,600,000	
No. 2		1,495	1,720	1,870	1,500,000	
No. 3		860	990	1,075	1,300,000	
Stud		890	1,025	1,115	1,300,000	
Select Structural	2 × 8	2,000	2,300	2,500	1,700,000	
No. 1		1,450	1,665	1,810	1,600,000	
No. 2		1,380	1,585	1,725	1,500,000	
No. 3		795	915	990	1,300,000	
Select Structural	2 × 10	1,835	2,110	2,295	1,700,000	
No. 1		1,330	1,525	1,660	1,600,000	
No. 2		1,265	1,455	1,580	1,500,000	
No. 3		725	835	910	1,300,000	
Select Structural	2 × 12	1,670	1,920	2,085	1,700,000	
No. 1		1,210	1,390	1,510	1,600,000	
No. 2		1,150	1,325	1,440	1,500,000	
No. 3		660	760	825	1,300,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi × 0.00689 for N/mm^2			MODULUS OF ELASTICITY "E" psi × 0.00689 for N/mm^2	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
COTTONWOOD						
Select Structural	2 × 4	1,510	1,735	1,885	1,200,000	NSLB
No. 1		1,080	1,240	1,350	1,200,000	
No. 2		1,080	1,240	1,350	1,100,000	
No. 3		605	695	755	1,000,000	
Stud		600	690	750	1,000,000	
Construction		805	925	1,005	1,000,000	
Standard		460	530	575	900,000	
Utility		200	230	250	900,000	
Select Structural	2 × 6	1,310	1,505	1,635	1,200,000	
No. 1		935	1,075	1,170	1,200,000	
No. 2		935	1,075	1,170	1,100,000	
No. 3		525	600	655	1,000,000	
Stud		545	630	685	1,000,000	
Select Structural	2 × 8	1,210	1,390	1,510	1,200,000	
No. 1		865	990	1,080	1,200,000	
No. 2		865	990	1,080	1,100,000	
No. 3		485	555	605	1,000,000	
Select Structural	2 × 10	1,105	1,275	1,385	1,200,000	
No. 1		790	910	990	1,200,000	
No. 2		790	910	990	1,100,000	
No. 3		445	510	555	1,000,000	
Select Structural	2 × 12	1,005	1,155	1,260	1,200,000	
No. 1		720	825	900	1,200,000	
No. 2		720	825	900	1,100,000	
No. 3		405	465	505	1,000,000	
DOUGLAS FIR-LARCH						
Select Structural	2 × 4	2,500	2,875	3,125	1,900,000	WCLIB WWPA
No. 1 and better		1,985	2,280	2,480	1,800,000	
No. 1		1,725	1,985	2,155	1,700,000	
No. 2		1,510	1,735	1,885	1,600,000	
No. 3		865	990	1,080	1,400,000	
Stud		855	980	1,065	1,400,000	
Construction		1,150	1,325	1,440	1,500,000	
Standard		635	725	790	1,400,000	
Utility		315	365	395	1,300,000	
Select Structural	2 × 6	2,170	2,495	2,710	1,900,000	
No. 1 and better		1,720	1,975	2,150	1,800,000	
No. 1		1,495	1,720	1,870	1,700,000	
No. 2		1,310	1,505	1,635	1,600,000	
No. 3		750	860	935	1,400,000	
Stud		775	895	970	1,400,000	
Select Structural	2 × 8	2,000	2,300	2,500	1,900,000	
No. 1 and better		1,585	1,825	1,985	1,800,000	
No. 1		1,380	1,585	1,725	1,700,000	
No. 2		1,210	1,390	1,510	1,600,000	
No. 3		690	795	865	1,400,000	
Select Structural	2 × 10	1,835	2,110	2,295	1,900,000	
No. 1 and better		1,455	1,675	1,820	1,800,000	
No. 1		1,265	1,455	1,580	1,700,000	
No. 2		1,105	1,275	1,385	1,600,000	
No. 3		635	725	790	1,400,000	
Select Structural	2 × 12	1,670	1,920	2,085	1,900,000	
No. 1 and better		1,325	1,520	1,655	1,800,000	
No. 1		1,150	1,325	1,440	1,700,000	
No. 2		1,005	1,155	1,260	1,600,000	
No. 3		575	660	720	1,400,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi: Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
	× 25.4 for mm	× 0.00689 for N/mm²				
DOUGLAS FIR-LARCH (North)						
Select Structural	2 × 4	2,245	2,580	2,805	1,900,000	NLGA
No. 1/No. 2	2 × 4	1,425	1,635	1,780	1,600,000	NLGA
No. 3	2 × 4	820	940	1,025	1,400,000	NLGA
Stud	2 × 4	820	945	1,030	1,400,000	NLGA
Construction	2 × 4	1,095	1,255	1,365	1,500,000	NLGA
Standard	2 × 4	605	695	755	1,400,000	NLGA
Utility	2 × 4	290	330	360	1,300,000	NLGA
Select Structural	2 × 6	1,945	2,235	2,430	1,900,000	NLGA
No. 1/No. 2	2 × 6	1,235	1,420	1,540	1,600,000	NLGA
No. 3	2 × 6	710	815	890	1,400,000	NLGA
Stud	2 × 6	750	860	935	1,400,000	NLGA
Select Structural	2 × 8	1,795	2,065	2,245	1,900,000	NLGA
No. 1/No. 2	2 × 8	1,140	1,310	1,425	1,600,000	NLGA
No. 3	2 × 8	655	755	820	1,400,000	NLGA
Select Structural	2 × 10	1,645	1,890	2,055	1,900,000	NLGA
No. 1/No. 2	2 × 10	1,045	1,200	1,305	1,600,000	NLGA
No. 3	2 × 10	600	690	750	1,400,000	NLGA
Select Structural	2 × 12	1,495	1,720	1,870	1,900,000	NLGA
No. 1/No. 2	2 × 12	950	1,090	1,185	1,600,000	NLGA
No. 3	2 × 12	545	630	685	1,400,000	NLGA
DOUGLAS FIR (South)						
Select Structural	2 × 4	2,245	2,580	2,805	1,400,000	WWPA
No. 1	2 × 4	1,555	1,785	1,940	1,300,000	WWPA
No. 2	2 × 4	1,425	1,635	1,780	1,200,000	WWPA
No. 3	2 × 4	820	940	1,025	1,100,000	WWPA
Stud	2 × 4	820	945	1,030	1,100,000	WWPA
Construction	2 × 4	1,065	1,225	1,330	1,200,000	WWPA
Standard	2 × 4	605	695	755	1,100,000	WWPA
Utility	2 × 4	290	330	360	1,000,000	WWPA
Select Structural	2 × 6	1,945	2,235	2,430	1,400,000	WWPA
No. 1	2 × 6	1,345	1,545	1,680	1,300,000	WWPA
No. 2	2 × 6	1,235	1,420	1,540	1,200,000	WWPA
No. 3	2 × 6	710	815	890	1,100,000	WWPA
Stud	2 × 6	750	860	935	1,100,000	WWPA
Select Structural	2 × 8	1,795	2,065	2,245	1,400,000	WWPA
No. 1	2 × 8	1,240	1,430	1,555	1,300,000	WWPA
No. 2	2 × 8	1,140	1,310	1,425	1,200,000	WWPA
No. 3	2 × 8	655	755	820	1,100,000	WWPA
Select Structural	2 × 10	1,645	1,890	2,055	1,400,000	WWPA
No. 1	2 × 10	1,140	1,310	1,425	1,300,000	WWPA
No. 2	2 × 10	1,045	1,200	1,305	1,200,000	WWPA
No. 3	2 × 10	600	690	750	1,100,000	WWPA
Select Structural	2 × 12	1,495	1,720	1,870	1,400,000	WWPA
No. 1	2 × 12	1,035	1,190	1,295	1,300,000	WWPA
No. 2	2 × 12	950	1,090	1,185	1,200,000	WWPA
No. 3	2 × 12	545	630	685	1,100,000	WWPA

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi — Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
EASTERN HEMLOCK—TAMARACK						
Select Structural	2 × 4	2,155	2,480	2,695	1,200,000	NELMA NSLB
No. 1		1,335	1,535	1,670	1,100,000	
No. 2		990	1,140	1,240	1,100,000	
No. 3		605	695	755	900,000	
Stud		570	655	710	900,000	
Construction		775	895	970	1,000,000	
Standard		430	495	540	900,000	
Utility		200	230	250	800,000	
Select Structural	2 × 6	1,870	2,150	2,335	1,200,000	
No. 1		1,160	1,330	1,450	1,100,000	
No. 2		860	990	1,075	1,100,000	
No. 3		525	600	655	900,000	
Stud		520	595	645	900,000	
Select Structural	2 × 8	1,725	1,985	2,155	1,200,000	
No. 1		1,070	1,230	1,335	1,100,000	
No. 2		795	915	990	1,100,000	
No. 3		485	555	605	900,000	
Select Structural	2 × 10	1,580	1,820	1,975	1,200,000	
No. 1		980	1,125	1,225	1,100,000	
No. 2		725	835	910	1,100,000	
No. 3		445	510	555	900,000	
Select Structural	2 × 12	1,440	1,655	1,795	1,200,000	
No. 1		890	1,025	1,115	1,100,000	
No. 2		660	760	825	1,100,000	
No. 3		405	465	505	900,000	
EASTERN SOFTWOODS						
Select Structural	2 × 4	2,155	2,480	2,695	1,200,000	NELMA NSLB
No. 1		1,335	1,535	1,670	1,100,000	
No. 2		990	1,140	1,240	1,100,000	
No. 3		605	695	755	900,000	
Stud		570	655	710	900,000	
Construction		775	895	970	1,000,000	
Standard		430	495	540	900,000	
Utility		200	230	250	800,000	
Select Structural	2 × 6	1,870	2,150	2,335	1,200,000	
No. 1		1,160	1,330	1,450	1,100,000	
No. 2		860	990	1,075	1,100,000	
No. 3		525	600	655	900,000	
Stud		520	595	645	900,000	
Select Structural	2 × 8	1,725	1,985	2,155	1,200,000	
No. 1		1,070	1,230	1,335	1,100,000	
No. 2		795	915	990	1,100,000	
No. 3		485	555	605	900,000	
Select Structural	2 × 10	1,580	1,820	1,975	1,200,000	
No. 1		980	1,125	1,225	1,100,000	
No. 2		725	835	910	1,100,000	
No. 3		445	510	555	900,000	
Select Structural	2 × 12	1,440	1,655	1,795	1,200,000	
No. 1		890	1,025	1,115	1,100,000	
No. 2		660	760	825	1,100,000	
No. 3		405	465	505	900,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi: Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
EASTERN WHITE PINE						
Select Structural	2 × 4	2,155	2,480	2,695	1,200,000	NELMA NSLB
No. 1	2 × 4	1,335	1,535	1,670	1,100,000	
No. 2	2 × 4	990	1,140	1,240	1,100,000	
No. 3	2 × 4	605	695	755	900,000	
Stud	2 × 4	570	655	710	900,000	
Construction	2 × 4	775	895	970	1,000,000	
Standard	2 × 4	430	495	540	900,000	
Utility	2 × 4	200	230	250	800,000	
Select Structural	2 × 6	1,870	2,150	2,335	1,200,000	
No. 1	2 × 6	1,160	1,330	1,450	1,100,000	
No. 2	2 × 6	860	990	1,075	1,100,000	
No. 3	2 × 6	525	600	655	900,000	
Stud	2 × 6	520	595	645	900,000	
Select Structural	2 × 8	1,725	1,985	2,155	1,200,000	
No. 1	2 × 8	1,070	1,230	1,335	1,100,000	
No. 2	2 × 8	795	915	990	1,100,000	
No. 3	2 × 8	485	555	605	900,000	
Select Structural	2 × 10	1,580	1,820	1,975	1,200,000	
No. 1	2 × 10	980	1,125	1,225	1,100,000	
No. 2	2 × 10	725	835	910	1,100,000	
No. 3	2 × 10	445	510	555	900,000	
Select Structural	2 × 12	1,440	1,655	1,795	1,200,000	
No. 1	2 × 12	890	1,025	1,115	1,100,000	
No. 2	2 × 12	660	760	825	1,100,000	
No. 3	2 × 12	405	465	505	900,000	
HEM-FIR						
Select Structural	2 × 4	2,415	2,775	3,020	1,600,000	WCLIB WWPA
No. 1 and better	2 × 4	1,810	2,085	2,265	1,500,000	
No. 1	2 × 4	1,640	1,885	2,050	1,500,000	
No. 2	2 × 4	1,465	1,685	1,835	1,300,000	
No. 3	2 × 4	865	990	1,080	1,200,000	
Stud	2 × 4	855	980	1,065	1,200,000	
Construction	2 × 4	1,120	1,290	1,400	1,300,000	
Standard	2 × 4	635	725	790	1,200,000	
Utility	2 × 4	290	330	360	1,100,000	
Select Structural	2 × 6	2,095	2,405	2,615	1,600,000	
No. 1 and better	2 × 6	1,570	1,805	1,960	1,500,000	
No. 1	2 × 6	1,420	1,635	1,775	1,500,000	
No. 2	2 × 6	1,270	1,460	1,590	1,300,000	
No. 3	2 × 6	750	860	935	1,200,000	
Stud	2 × 6	775	895	970	1,200,000	
Select Structural	2 × 8	1,930	2,220	2,415	1,600,000	
No. 1 and better	2 × 8	1,450	1,665	1,810	1,500,000	
No. 1	2 × 8	1,310	1,510	1,640	1,500,000	
No. 2	2 × 8	1,175	1,350	1,465	1,300,000	
No. 3	2 × 8	690	795	865	1,200,000	
Select Structural	2 × 10	1,770	2,035	2,215	1,600,000	
No. 1 and better	2 × 10	1,330	1,525	1,660	1,500,000	
No. 1	2 × 10	1,200	1,380	1,500	1,500,000	
No. 2	2 × 10	1,075	1,235	1,345	1,300,000	
No. 3	2 × 10	635	725	790	1,200,000	
Select Structural	2 × 12	1,610	1,850	2,015	1,600,000	
No. 1 and better	2 × 12	1,210	1,390	1,510	1,500,000	
No. 1	2 × 12	1,095	1,255	1,365	1,500,000	
No. 2	2 × 12	980	1,125	1,220	1,300,000	
No. 3	2 × 12	575	660	720	1,200,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
HEM-FIR (North)						
Select Structural	2 × 4	2,245	2,580	2,805	1,700,000	NLGA
No. 1/No. 2		1,725	1,985	2,155	1,600,000	
No. 3		990	1,140	1,240	1,400,000	
Stud		980	1,125	1,225	1,400,000	
Construction		1,325	1,520	1,655	1,500,000	
Standard		720	825	900	1,400,000	
Utility		345	395	430	1,300,000	
Select Structural	2 × 6	1,945	2,235	2,430	1,700,000	
No. 1/No. 2		1,495	1,720	1,870	1,600,000	
No. 3		860	990	1,075	1,400,000	
Stud		890	1,025	1,115	1,400,000	
Select Structural	2 × 8	1,795	2,065	2,245	1,700,000	
No. 1/No. 2		1,380	1,585	1,725	1,600,000	
No. 3		795	915	990	1,400,000	
Select Structural	2 × 10	1,645	1,890	2,055	1,700,000	
No. 1/No. 2		1,265	1,455	1,580	1,600,000	
No. 3		725	835	910	1,400,000	
Select Structural	2 × 12	1,495	1,720	1,870	1,700,000	
No. 1/No. 2		1,150	1,325	1,440	1,600,000	
No. 3		660	760	825	1,400,000	
MIXED MAPLE						
Select Structural	2 × 4	1,725	1,985	2,155	1,300,000	NELMA
No. 1		1,250	1,440	1,565	1,200,000	
No. 2		1,210	1,390	1,510	1,100,000	
No. 3		690	795	865	1,000,000	
Stud		695	800	870	1,000,000	
Construction		920	1,060	1,150	1,100,000	
Standard		520	595	645	1,000,000	
Utility		260	300	325	900,000	
Select Structural	2 × 6	1,495	1,720	1,870	1,300,000	
No. 1		1,085	1,245	1,355	1,200,000	
No. 2		1,045	1,205	1,310	1,100,000	
No. 3		600	690	750	1,000,000	
Stud		635	725	790	1,000,000	
Select Structural	2 × 8	1,380	1,585	1,725	1,300,000	
No. 1		1,000	1,150	1,250	1,200,000	
No. 2		965	1,110	1,210	1,100,000	
No. 3		550	635	690	1,000,000	
Select Structural	2 × 10	1,265	1,455	1,580	1,300,000	
No. 1		915	1,055	1,145	1,200,000	
No. 2		885	1,020	1,105	1,100,000	
No. 3		505	580	635	1,000,000	
Select Structural	2 × 12	1,150	1,325	1,440	1,300,000	
No. 1		835	960	1,040	1,200,000	
No. 2		805	925	1,005	1,100,000	
No. 3		460	530	575	1,000,000	
MIXED OAK						
Select Structural	2 × 4	1,985	2,280	2,480	1,100,000	NELMA
No. 1		1,425	1,635	1,780	1,000,000	
No. 2		1,380	1,585	1,725	900,000	
No. 3		820	940	1,025	800,000	
Stud		790	910	990	800,000	
Construction		1,065	1,225	1,330	900,000	
Standard		605	695	755	800,000	
Utility		290	330	360	800,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi: Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
	× 25.4 for mm	× 0.00689 for N/mm²				
MIXED OAK—(continued)						
Select Structural	2 × 6	1,720	1,975	2,150	1,100,000	NELMA
No. 1		1,235	1,420	1,540	1,000,000	
No. 2		1,195	1,375	1,495	900,000	
No. 3		710	815	890	800,000	
Stud		720	825	900	800,000	
Select Structural	2 × 8	1,585	1,825	1,985	1,100,000	
No. 1		1,140	1,310	1,425	1,000,000	
No. 2		1,105	1,270	1,380	900,000	
No. 3		655	755	820	800,000	
Select Structural	2 × 10	1,455	1,675	1,820	1,100,000	
No. 1		1,045	1,200	1,305	1,000,000	
No. 2		1,010	1,165	1,265	900,000	
No. 3		600	690	750	800,000	
Select Structural	2 × 12	1,325	1,520	1,655	1,100,000	
No. 1		950	1,090	1,185	1,000,000	
No. 2		920	1,060	1,150	900,000	
No. 3		545	630	685	800,000	
MIXED SOUTHERN PINE						
Select Structural	2 × 4	2,360	2,710	2,950	1,600,000	SPIB
No. 1		1,670	1,920	2,080	1,500,000	
No. 2		1,500	1,720	1,870	1,400,000	
No. 3		865	990	1,080	1,200,000	
Stud		890	1,020	1,110	1,200,000	
Construction		1,150	1,320	1,440	1,300,000	
Standard		635	725	790	1,200,000	
Utility		315	365	395	1,100,000	
Select Structural	2 × 6	2,130	2,450	2,660	1,600,000	
No. 1		1,490	1,720	1,870	1,500,000	
No. 2		1,320	1,520	1,650	1,400,000	
No. 3		775	895	970	1,200,000	
Stud		775	895	970	1,200,000	
Select Structural	2 × 8	2,010	2,310	2,520	1,600,000	
No. 1		1,380	1,590	1,720	1,500,000	
No. 2		1,210	1,390	1,510	1,400,000	
No. 3		720	825	900	1,200,000	
Select Structural	2 × 10	1,730	1,980	2,160	1,600,000	
No. 1		1,210	1,390	1,510	1,500,000	
No. 2		1,060	1,220	1,330	1,400,000	
No. 3		605	695	755	1,200,000	
Select Structural	2 × 12	1,610	1,850	2,010	1,600,000	
No. 1		1,120	1,290	1,400	1,500,000	
No. 2		1,010	1,160	1,260	1,400,000	
No. 3		575	660	720	1,200,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi: Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
	× 25.4 for mm	× 0.00689 for N/mm²				
NORTHERN RED OAK						
Select Structural	2 × 4	2,415	2,775	3,020	1,400,000	NELMA
No. 1		1,725	1,985	2,155	1,400,000	
No. 2		1,680	1,935	2,100	1,300,000	
No. 3		950	1,090	1,185	1,200,000	
Stud		950	1,090	1,185	1,200,000	
Construction		1,265	1,455	1,580	1,200,000	
Standard		720	825	900	1,100,000	
Utility		345	395	430	1,000,000	
Select Structural	2 × 6	2,095	2,405	2,615	1,400,000	
No. 1		1,495	1,720	1,870	1,400,000	
No. 2		1,460	1,675	1,820	1,300,000	
No. 3		820	945	1,030	1,200,000	
Stud		865	990	1,080	1,200,000	
Select Structural	2 × 8	1,930	2,220	2,415	1,400,000	
No. 1		1,380	1,585	1,725	1,400,000	
No. 2		1,345	1,545	1,680	1,300,000	
No. 3		760	875	950	1,200,000	
Select Structural	2 × 10	1,770	2,035	2,215	1,400,000	
No. 1		1,265	1,455	1,580	1,400,000	
No. 2		1,235	1,420	1,540	1,300,000	
No. 3		695	800	870	1,200,000	
Select Structural	2 × 12	1,610	1,850	2,015	1,400,000	
No. 1		1,150	1,325	1,440	1,400,000	
No. 2		1,120	1,290	1,400	1,300,000	
No. 3		635	725	790	1,200,000	
NORTHERN SPECIES						
Select Structural	2 × 4	1,640	1,885	2,050	1,100,000	NLGA
No. 1/No. 2		990	1,140	1,240	1,100,000	
No. 3		605	695	755	1,000,000	
Stud		570	655	710	1,000,000	
Construction		775	895	970	1,000,000	
Standard		430	495	540	900,000	
Utility		200	230	250	900,000	
Select Structural	2 × 6	1,420	1,635	1,775	1,100,000	
No. 1/No. 2		860	990	1,075	1,100,000	
No. 3		525	600	655	1,000,000	
Stud		520	595	645	1,000,000	
Select Structural	2 × 8	1,310	1,510	1,640	1,100,000	
No. 1/No. 2		795	915	990	1,100,000	
No. 3		485	555	605	1,000,000	
Select Structural	2 × 10	1,200	1,380	1,500	1,100,000	
No. 1/No. 2		725	835	910	1,100,000	
No. 3		445	510	555	1,000,000	
Select Structural	2 × 12	1,095	1,255	1,365	1,100,000	
No. 1/No. 2		660	760	825	1,100,000	
No. 3		405	465	505	1,000,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm²				
NORTHERN WHITE CEDAR						
Select Structural	2 × 4	1,335	1,535	1,670	800,000	NELMA
No. 1	2 × 4	990	1,140	1,240	700,000	NELMA
No. 2	2 × 4	950	1,090	1,185	700,000	NELMA
No. 3	2 × 4	560	645	700	600,000	NELMA
Stud	2 × 4	540	620	670	600,000	NELMA
Construction	2 × 4	720	825	900	700,000	NELMA
Standard	2 × 4	405	465	505	600,000	NELMA
Utility	2 × 4	200	230	250	600,000	NELMA
Select Structural	2 × 6	1,160	1,330	1,450	800,000	NELMA
No. 1	2 × 6	860	990	1,075	700,000	NELMA
No. 2	2 × 6	820	945	1,030	700,000	NELMA
No. 3	2 × 6	485	560	605	600,000	NELMA
Stud	2 × 6	490	560	610	600,000	NELMA
Select Structural	2 × 8	1,070	1,230	1,335	800,000	NELMA
No. 1	2 × 8	795	915	990	700,000	NELMA
No. 2	2 × 8	760	875	950	700,000	NELMA
No. 3	2 × 8	450	515	560	600,000	NELMA
Select Structural	2 × 10	980	1,125	1,225	800,000	NELMA
No. 1	2 × 10	725	835	910	700,000	NELMA
No. 2	2 × 10	695	800	870	700,000	NELMA
No. 3	2 × 10	410	475	515	600,000	NELMA
Select Structural	2 × 12	890	1,025	1,115	800,000	NELMA
No. 1	2 × 12	660	760	825	700,000	NELMA
No. 2	2 × 12	635	725	790	700,000	NELMA
No. 3	2 × 12	375	430	465	600,000	NELMA
RED MAPLE						
Select Structural	2 × 4	2,245	2,580	2,805	1,700,000	NELMA
No. 1	2 × 4	1,595	1,835	1,995	1,600,000	NELMA
No. 2	2 × 4	1,555	1,785	1,940	1,500,000	NELMA
No. 3	2 × 4	905	1,040	1,130	1,300,000	NELMA
Stud	2 × 4	885	1,020	1,105	1,300,000	NELMA
Construction	2 × 4	1,210	1,390	1,510	1,400,000	NELMA
Standard	2 × 4	660	760	825	1,300,000	NELMA
Utility	2 × 4	315	365	395	1,200,000	NELMA
Select Structural	2 × 6	1,945	2,235	2,430	1,700,000	NELMA
No. 1	2 × 6	1,385	1,590	1,730	1,600,000	NELMA
No. 2	2 × 6	1,345	1,545	1,680	1,500,000	NELMA
No. 3	2 × 6	785	905	980	1,300,000	NELMA
Stud	2 × 6	805	925	1,005	1,300,000	NELMA
Select Structural	2 × 8	1,795	2,065	2,245	1,700,000	NELMA
No. 1	2 × 8	1,275	1,470	1,595	1,600,000	NELMA
No. 2	2 × 8	1,240	1,430	1,555	1,500,000	NELMA
No. 3	2 × 8	725	835	905	1,300,000	NELMA
Select Structural	2 × 10	1,645	1,890	2,055	1,700,000	NELMA
No. 1	2 × 10	1,170	1,345	1,465	1,600,000	NELMA
No. 2	2 × 10	1,140	1,310	1,425	1,500,000	NELMA
No. 3	2 × 10	665	765	830	1,300,000	NELMA
Select Structural	2 × 12	1,495	1,720	1,870	1,700,000	NELMA
No. 1	2 × 12	1,065	1,225	1,330	1,600,000	NELMA
No. 2	2 × 12	1,035	1,190	1,295	1,500,000	NELMA
No. 3	2 × 12	605	695	755	1,300,000	NELMA

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
	× 25.4 for mm	× 0.00689 for N/mm²				
RED OAK						
Select Structural	2 × 4	1,985	2,280	2,480	1,400,000	NELMA
No. 1		1,425	1,635	1,780	1,300,000	
No. 2		1,380	1,585	1,725	1,200,000	
No. 3		820	940	1,025	1,100,000	
Stud		790	910	990	1,100,006	
Construction		1,065	1,225	1,330	1,200,000	
Standard		605	695	755	1,100,000	
Utility		290	330	360	1,000,000	
Select Structural	2 × 6	1,720	1,975	2,150	1,400,000	
No. 1		1,235	1,420	1,540	1,300,000	
No. 2		1,195	1,375	1,495	1,200,000	
No. 3		710	815	890	1,100,000	
Stud		720	825	900	1,100,000	
Select Structural	2 × 8	1,585	1,825	1,985	1,400,000	
No. 1		1,140	1,310	1,425	1,300,000	
No. 2		1,105	1,270	1,380	1,200,000	
No. 3		655	755	820	1,100,000	
Select Structural	2 × 10	1,455	1,675	1,820	1,400,000	
No. 1		1,045	1,200	1,305	1,300,000	
No. 2		1,010	1,165	1,265	1,200,000	
No. 3		600	690	750	1,100,000	
Select Structural	2 × 12	1,325	1,520	1,655	1,400,000	
No. 1		950	1,090	1,185	1,300,000	
No. 2		920	1,060	1,150	1,200,000	
No. 3		545	630	685	1,100,000	
REDWOOD						
Clear Structural	2 × 4	3,020	3,470	3,775	1,400,000	RIS
Select Structural		2,330	2,680	2,910	1,400,000	
Select Structural, open grain		1,900	2,180	2,370	1,100,000	
No. 1		1,680	1,935	2,100	1,300,000	
No. 1, open grain		1,335	1,535	1,670	1,100,000	
No. 2		1,595	1,835	1,995	1,200,000	
No. 2, open grain		1,250	1,440	1,565	1,000,000	
No. 3		905	1,040	1,130	1,100,000	
No. 3, open grain		735	845	915	900,000	
Stud		725	835	910	900,000	
Construction		950	1,090	1,185	900,000	
Standard		520	595	645	900,000	
Utility		260	300	325	800,000	
Clear Structural	2 × 6	2,615	3,010	3,270	1,400,000	
Select Structural		2,020	2,320	2,525	1,400,000	
Select Structural, open grain		1,645	1,890	2,055	1,100,000	
No. 1		1,460	1,675	1,820	1,300,000	
No. 1, open grain		1,160	1,330	1,450	1,100,000	
No. 2		1,385	1,590	1,730	1,200,000	
No. 2, open grain		1,085	1,245	1,355	1,000,000	
No. 3		785	905	980	1,100,000	
No. 3, open grain		635	730	795	900,000	
Stud		660	760	825	900,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm²				
REDWOOD—(continued)						
Clear Structural	2 × 8	2,415	2,775	3,020	1,400,000	RIS
Select Structural	2 × 8	1,865	2,140	2,330	1,400,000	RIS
Select Structural, open grain	2 × 8	1,520	1,745	1,900	1,100,000	RIS
No. 1	2 × 8	1,345	1,545	1,680	1,300,000	RIS
No. 1, open grain	2 × 8	1,070	1,230	1,335	1,100,000	RIS
No. 2	2 × 8	1,275	1,470	1,595	1,200,000	RIS
No. 2, open grain	2 × 8	1,000	1,150	1,250	1,000,000	RIS
No. 3	2 × 8	725	835	905	1,100,000	RIS
No. 3, open grain	2 × 8	585	675	735	900,000	RIS
Clear Structural	2 × 10	2,215	2,545	2,765	1,400,000	RIS
Select Structural	2 × 10	1,710	1,965	2,135	1,400,000	RIS
Select Structural, open grain	2 × 10	1,390	1,600	1,740	1,100,000	RIS
No. 1	2 × 10	1,235	1,420	1,540	1,300,000	RIS
No. 1, open grain	2 × 10	980	1,125	1,225	1,100,000	RIS
No. 2	2 × 10	1,170	1,345	1,465	1,200,000	RIS
No. 2, open grain	2 × 10	915	1,055	1,145	1,000,000	RIS
No. 3	2 × 10	665	765	830	1,100,000	RIS
No. 3, open grain	2 × 10	540	620	670	900,000	RIS
Clear Structural	2 × 12	2,015	2,315	2,515	1,400,000	RIS
Select Structural	2 × 12	1,555	1,785	1,940	1,400,000	RIS
Select Structural, open grain	2 × 12	1,265	1,455	1,580	1,100,000	RIS
No. 1	2 × 12	1,120	1,290	1,400	1,300,000	RIS
No. 1, open grain	2 × 12	890	1,025	1,115	1,100,000	RIS
No. 2	2 × 12	1,065	1,225	1,330	1,200,000	RIS
No. 2, open grain	2 × 12	835	960	1,040	1,000,000	RIS
No. 3	2 × 12	605	695	755	1,100,000	RIS
No. 3, open grain	2 × 12	490	560	610	900,000	RIS
SOUTHERN PINE						
Dense Select Structural	2 × 4	3,510	4,030	4,380	1,900,000	SPIB
Select Structural	2 × 4	3,280	3,770	4,100	1,800,000	SPIB
Non-Dense Select Structural	2 × 4	3,050	3,500	3,810	1,700,000	SPIB
No. 1 Dense	2 × 4	2,300	2,650	2,880	1,800,000	SPIB
No. 1	2 × 4	2,130	2,450	2,660	1,700,000	SPIB
No. 1 Non-Dense	2 × 4	1,950	2,250	2,440	1,600,000	SPIB
No. 2 Dense	2 × 4	1,960	2,250	2,440	1,700,000	SPIB
No. 2	2 × 4	1,720	1,980	2,160	1,600,000	SPIB
No. 2 Non-Dense	2 × 4	1,550	1,790	1,940	1,400,000	SPIB
No. 3	2 × 4	980	1,120	1,220	1,400,000	SPIB
Stud	2 × 4	1,010	1,160	1,260	1,400,000	SPIB
Construction	2 × 4	1,270	1,450	1,580	1,500,000	SPIB
Standard	2 × 4	720	825	900	1,300,000	SPIB
Utility	2 × 4	345	395	430	1,300,000	SPIB

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm²				
SOUTHERN PINE—(continued)						
Dense Select Structural	2 × 6	3,100	3,570	3,880	1,900,000	SPIB
Select Structural		2,930	3,370	3,670	1,800,000	
Non-Dense Select Structural		2,700	3,110	3,380	1,700,000	
No. 1 Dense		2,010	2,310	2,520	1,800,000	
No. 1		1,900	2,180	2,370	1,700,000	
No. 1 Non-Dense		1,720	1,980	2,160	1,600,000	
No. 2 Dense		1,670	1,920	2,080	1,700,000	
No. 2		1,440	1,650	1,800	1,600,000	
No. 2 Non-Dense		1,320	1,520	1,650	1,400,000	
No. 3		865	990	1,080	1,400,000	
Stud		890	1,020	1,110	1,400,000	
Dense Select Structural	2 × 8	2,820	3,240	3,520	1,900,000	
Select Structural		2,650	3,040	3,310	1,800,000	
Non-Dense Select Structural		2,420	2,780	3,020	1,700,000	
No. 1 Dense		1,900	2,180	2,370	1,800,000	
No. 1		1,730	1,980	2,160	1,700,000	
No. 1 Non-Dense		1,550	1,790	1,940	1,600,000	
No. 2 Dense		1,610	1,850	2,010	1,700,000	
No. 2		1,380	1,590	1,720	1,600,000	
No. 2 Non-Dense		1,260	1,450	1,580	1,400,000	
No. 3		805	925	1,010	1,400,000	
Dense Select Structural	2 × 10	2,470	2,840	3,090	1,900,000	
Select Structural		2,360	2,710	2,9500	1,800,000	
Non-Dense Select Structural		2,130	2,450	2,660	1,700,000	
No. 1 Dense		1,670	1,920	2,080	1,800,000	
No. 1		1,500	1,720	1,870	1,700,000	
No. 1 Non-Dense		1,380	1,590	1,730	1,600,000	
No. 2 Dense		1,380	1,590	1,730	1,700,000	
No. 2		1,210	1,390	1,510	1,600,000	
No. 2 Non-Dense		1,090	1,260	1,370	1,400,000	
No. 3		690	795	865	1,400,000	
Dense Select Structural	2 × 12	2,360	2,710	2,950	1,900,000	
Select Structural		2,190	2,510	2,730	1,800,000	
Non-Dense Select Structural		2,010	2,310	2,520	1,700,000	
No. 1 Dense		1,550	1,790	1,940	1,800,000	
No. 1		1,440	1,650	1,800	1,700,000	
No. 1 Non-Dense		1,320	1,520	1,650	1,600,000	
No. 2 Dense		1,320	1,520	1,650	1,700,000	
No. 2		1,120	1,290	1,400	1,600,000	
No. 2 Non-Dense		1,040	1,190	1,290	1,400,000	
No. 3		660	760	825	1,400,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi — Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
SPRUCE-PINE-FIR						
Select Structural	2 × 4	2,155	2,480	2,695	1,500,000	NLGA
No. 1/No. 2		1,510	1,735	1,885	1,400,000	
No. 3		865	990	1,080	1,200,000	
Stud		855	980	1,065	1,200,000	
Construction		1,120	1,290	1,400	1,300,000	
Standard		635	725	790	1,200,000	
Utility		290	330	360	1,100,000	
Select Structural	2 × 6	1,870	2,150	2,335	1,500,000	
No. 1/No. 2		1,310	1,505	1,635	1,400,000	
No. 3		750	860	935	1,200,000	
Stud		775	895	970	1,200,000	
Select Structural	2 × 8	1,725	1,985	2,155	1,500,000	
No. 1/No. 2		1,210	1,390	1,510	1,400,000	
No. 3		690	795	865	1,200,000	
Select Structural	2 × 10	1,580	1,820	1,975	1,500,000	
No. 1/No. 2		1,105	1,275	1,385	1,400,000	
No. 3		635	725	790	1,200,000	
Select Structural	2 × 12	1,440	1,655	1,795	1,500,000	
No. 1/No. 2		1,005	1,155	1,260	1,400,000	
No. 3		575	660	720	1,200,000	
SPRUCE-PINE-FIR (South)						
Select Structural	2 × 4	2,245	2,580	2,805	1,300,000	NELMA NSLB WCLIB WWPA
No. 1		1,465	1,685	1,835	1,200,000	
No. 2		1,295	1,490	1,615	1,100,000	
No. 3		735	845	915	1,000,000	
Stud		725	835	910	1,000,000	
Construction		980	1,125	1,220	1,000,000	
Standard		545	630	685	900,000	
Utility		260	300	325	900,000	
Select Structural	2 × 6	1,945	2,235	2,430	1,300,000	
No. 1		1,270	1,460	1,590	1,200,000	
No. 2		1,120	1,290	1,400	1,100,000	
No. 3		635	730	795	1,000,000	
Stud		660	760	825	1,000,000	
Select Structural	2 × 8	1,795	2,065	2,245	1,300,000	
No. 1		1,175	1,350	1,465	1,200,000	
No. 2		1,035	1,190	1,295	1,100,000	
No. 3		585	675	735	1,000,000	
Select Structural	2 × 10	1,645	1,890	2,055	1,300,000	
No. 1		1,075	1,235	1,345	1,200,000	
No. 2		950	1,090	1,185	1,100,000	
No. 3		540	620	670	1,000,000	
Select Structural	2 × 12	1,495	1,720	1,870	1,300,000	
No. 1		980	1,125	1,220	1,200,000	
No. 2		865	990	1,080	1,100,000	
No. 3		490	560	610	1,000,000	
WESTERN CEDARS						
Select Structural	2 × 4	1,725	1,985	2,155	1,100,000	WCLIB WWPA
No. 1		1,250	1,440	1,565	1,000,000	
No. 2		1,210	1,390	1,510	1,000,000	
No. 3		690	795	865	900,000	
Stud		695	800	870	900,000	
Construction		920	1,060	1,150	900,000	
Standard		520	595	645	800,000	
Utility		260	300	325	800,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm²				
WESTERN CEDARS—(continued)						
Select Structural	2 × 6	1,495	1,720	1,870	1,100,000	WCLIB WWPA
No. 1	2 × 6	1,085	1,245	1,355	1,000,000	WCLIB WWPA
No. 2	2 × 6	1,045	1,205	1,310	1,000,000	WCLIB WWPA
No. 3	2 × 6	600	690	750	900,000	WCLIB WWPA
Stud	2 × 6	635	725	790	900,000	WCLIB WWPA
Select Structural	2 × 8	1,380	1,585	1,725	1,100,000	WCLIB WWPA
No. 1	2 × 8	1,000	1,150	1,250	1,000,000	WCLIB WWPA
No. 2	2 × 8	965	1,110	1,210	1,000,000	WCLIB WWPA
No. 3	2 × 8	550	635	690	900,000	WCLIB WWPA
Select Structural	2 × 10	1,265	1,455	1,580	1,100,000	WCLIB WWPA
No. 1	2 × 10	915	1,055	1,145	1,000,000	WCLIB WWPA
No. 2	2 × 10	885	1,020	1,105	1,000,000	WCLIB WWPA
No. 3	2 × 10	505	580	635	900,000	WCLIB WWPA
Select Structural	2 × 12	1,150	1,325	1,440	1,100,000	WCLIB WWPA
No. 1	2 × 12	835	960	1,040	1,000,000	WCLIB WWPA
No. 2	2 × 12	805	925	1,005	1,000,000	WCLIB WWPA
No. 3	2 × 12	460	530	575	900,000	WCLIB WWPA
WESTERN WOODS						
Select Structural	2 × 4	1,510	1,735	1,885	1,200,000	WCLIB WWPA
No. 1	2 × 4	1,120	1,290	1,400	1,100,000	WCLIB WWPA
No. 2	2 × 4	1,120	1,290	1,400	1,000,000	WCLIB WWPA
No. 3	2 × 4	645	745	810	900,000	WCLIB WWPA
Stud	2 × 4	635	725	790	900,000	WCLIB WWPA
Construction	2 × 4	835	960	1,040	1,000,000	WCLIB WWPA
Standard	2 × 4	460	530	575	900,000	WCLIB WWPA
Utility	2 × 4	230	265	290	800,000	WCLIB WWPA
Select Structural	2 × 6	1,310	1,505	1,635	1,200,000	WCLIB WWPA
No. 1	2 × 6	970	1,120	1,215	1,100,000	WCLIB WWPA
No. 2	2 × 6	970	1,120	1,215	1,000,000	WCLIB WWPA
No. 3	2 × 6	560	645	700	900,000	WCLIB WWPA
Stud	2 × 6	575	660	720	900,000	WCLIB WWPA
Select Structural	2 × 8	1,210	1,390	1,510	1,200,000	WCLIB WWPA
No. 1	2 × 8	895	1,030	1,120	1,100,000	WCLIB WWPA
No. 2	2 × 8	895	1,030	1,120	1,000,000	WCLIB WWPA
No. 3	2 × 8	520	595	645	900,000	WCLIB WWPA
Select Structural	2 × 10	1,105	1,275	1,385	1,200,000	WCLIB WWPA
No. 1	2 × 10	820	945	1,030	1,100,000	WCLIB WWPA
No. 2	2 × 10	820	945	1,030	1,000,000	WCLIB WWPA
No. 3	2 × 10	475	545	595	900,000	WCLIB WWPA
Select Structural	2 × 12	1,005	1,155	1,260	1,200,000	WCLIB WWPA
No. 1	2 × 12	750	860	935	1,100,000	WCLIB WWPA
No. 2	2 × 12	750	860	935	1,000,000	WCLIB WWPA
No. 3	2 × 12	430	495	540	900,000	WCLIB WWPA
WHITE OAK						
Select Structural	2 × 4	2,070	2,380	2,590	1,100,000	NELMA
No. 1	2 × 4	1,510	1,735	1,885	1,000,000	NELMA
No. 2	2 × 4	1,465	1,685	1,835	900,000	NELMA
No. 3	2 × 4	820	940	1,025	800,000	NELMA
Stud	2 × 4	820	945	1,030	800,000	NELMA
Construction	2 × 4	1,095	1,255	1,365	900,000	NELMA
Standard	2 × 4	605	695	755	800,000	NELMA
Utility	2 × 4	290	330	360	800,000	NELMA

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi — Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
WHITE OAK—(continued)						
Select Structural	2 × 6	1,795	2,065	2,245	1,100,000	NELMA
No. 1	2 × 6	1,310	1,505	1,635	1,000,000	NELMA
No. 2	2 × 6	1,270	1,460	1,590	900,000	NELMA
No. 3	2 × 6	710	815	890	800,000	NELMA
Stud	2 × 6	750	860	935	800,000	NELMA
Select Structural	2 × 8	1,655	1,905	2,070	1,100,000	NELMA
No. 1	2 × 8	1,210	1,390	1,510	1,000,000	NELMA
No. 2	2 × 8	1,175	1,350	1,465	900,000	NELMA
No. 3	2 × 8	655	755	820	800,000	NELMA
Select Structural	2 × 10	1,520	1,745	1,900	1,100,000	NELMA
No. 1	2 × 10	1,105	1,275	1,385	1,000,000	NELMA
No. 2	2 × 10	1,075	1,235	1,345	900,000	NELMA
No. 3	2 × 10	600	690	750	800,000	NELMA
Select Structural	2 × 12	1,380	1,585	1,725	1,100,000	NELMA
No. 1	2 × 12	1,005	1,155	1,260	1,000,000	NELMA
No. 2	2 × 12	980	1,125	1,220	900,000	NELMA
No. 3	2 × 12	545	630	685	800,000	NELMA
YELLOW POPLAR						
Select Structural	2 × 4	1,725	1,985	2,155	1,500,000	NSLB
No. 1	2 × 4	1,250	1,440	1,565	1,400,000	NSLB
No. 2	2 × 4	1,210	1,390	1,510	1,300,000	NSLB
No. 3	2 × 4	690	795	865	1,200,000	NSLB
Stud	2 × 4	695	800	870	1,200,000	NSLB
Construction	2 × 4	920	1,060	1,150	1,300,000	NSLB
Standard	2 × 4	520	595	645	1,100,000	NSLB
Utility	2 × 4	230	265	290	1,100,000	NSLB
Select Structural	2 × 6	1,495	1,720	1,870	1,500,000	NSLB
No. 1	2 × 6	1,085	1,245	1,355	1,400,000	NSLB
No. 2	2 × 6	1,045	1,205	1,310	1,300,000	NSLB
No. 3	2 × 6	600	690	750	1,200,000	NSLB
Stud	2 × 6	635	725	790	1,200,000	NSLB
Select Structural	2 × 8	1,380	1,585	1,725	1,500,000	NSLB
No. 1	2 × 8	1,000	1,150	1,250	1,400,000	NSLB
No. 2	2 × 8	965	1,110	1,210	1,300,000	NSLB
No. 3	2 × 8	550	635	690	1,200,000	NSLB
Select Structural	2 × 10	1,265	1,455	1,580	1,500,000	NSLB
No. 1	2 × 10	915	1,055	1,145	1,400,000	NSLB
No. 2	2 × 10	885	1,020	1,105	1,300,000	NSLB
No. 3	2 × 10	505	580	635	1,200,000	NSLB
Select Structural	2 × 12	1,150	1,325	1,440	1,500,000	NSLB
No. 1	2 × 12	835	960	1,040	1,400,000	NSLB
No. 2	2 × 12	805	925	1,005	1,300,000	NSLB
No. 3	2 × 12	460	530	575	1,200,000	NSLB

TABLE 23-IV-V-2—VALUES FOR JOISTS AND RAFTERS—MECHANICALLY GRADED LUMBER
For use in Tables 23-V-J-1 through 23-V-R-12 and Division V only.

GRADE DESIGNATION	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCIES
		× 0.00689 for N/mm²				
MACHINE STRESS RATED (MSR) LUMBER						
900f-1.0E	2 × 4 and wider	1,040	1,190	1,290	1,000,000	WCLIB,WWPA
1200f-1.2E		1,380	1,590	1,730	1,200,000	NLGA,SPIB,WCLIB,WWPA
1350f-1.3E		1,550	1,790	1,940	1,300,000	SPIB,WCLIB,WWPA
1450f-1.3E		1,670	1,920	2,080	1,300,000	NLGA,WCLIB,WWPA
1500f-1.3E		1,730	1,980	2,160	1,300,000	SPIB
1500f-1.4E		1,730	1,980	2,160	1,400,000	NLGA,SPIB,WCLIB,WWPA
1650f-1.4E		1,900	2,180	2,370	1,400,000	SPIB
1650f-1.5E		1,900	2,180	2,370	1,500,000	NLGA,SPIB,WCLIB,WWPA
1800f-1.6E		2,070	2,380	2,590	1,600,000	NLGA,SPIB,WCLIB,WWPA
1950f-1.5E		2,240	2,580	2,800	1,500,000	SPIB
1950f-1.7E		2,240	2,580	2,800	1,700,000	NLGA,SPIB,WWPA
2100f-1.8E		2,420	2,780	3,020	1,800,000	NLGA,SPIB,WCLIB,WWPA
2250f-1.6E		2,590	2,980	3,230	1,600,000	SPIB
2250f-1.9E		2,590	2,980	3,230	1,900,000	NLGA,SPIB,WWPA
2400f-1.7E		2,760	3,170	3,450	1,700,000	SPIB
2400f-2.0E		2,760	3,170	3,450	2,000,000	NLGA,SPIB,WCLIB,WWPA
2550f-2.1E		2,930	3,370	3,670	2,100,000	NLGA,SPIB,WWPA
2700f-2.2E		3,110	3,570	3,880	2,200,000	NLGA,SPIB,WCLIB,WWPA
2850f-2.3E		3,280	3,770	4,100	2,300,000	SPIB,WWPA
3000f-2.4E		3,450	3,970	4,310	2,400,000	NLGA,SPIB
3150f-2.5E		3,620	4,170	4,530	2,500,000	SPIB
3300f-2.6E		3,800	4,360	4,740	2,600,000	SPIB
900f-1.2E	2 × 6 and wider	1,040	1,190	1,290	1,200,000	NLGA,WCLIB
1200f-1.5E		1,380	1,590	1,730	1,500,000	NLGA,WCLIB
1350f-1.8E		1,550	1,790	1,940	1,800,000	NLGA
1500f-1.8E		1,730	1,980	2,160	1,800,000	WCLIB
1800f-2.1E		2,070	2,380	2,590	2,100,000	NLGA,WCLIB
MACHINE EVALUATED LUMBER (MEL)						
M-10	2 × 4 and wider	1,610	1,850	2,010	1,200,000	SPIB
M-11		1,780	2,050	2,230	1,500,000	
M-12		1,840	2,120	2,300	1,600,000	
M-13		1,840	2,120	2,300	1,400,000	
M-14		2,070	2,380	2,590	1,700,000	
M-15		2,070	2,380	2,590	1,500,000	
M-16		2,070	2,380	2,590	1,500,000	
M-17		2,240	2,580	2,800	1,700,000	
M-18		2,300	2,650	2,880	1,800,000	
M-19		2,300	2,650	2,880	1,600,000	
M-20		2,300	2,650	2,880	1,900,000	
M-21		2,650	3,040	3,310	1,900,000	
M-22		2,700	3,110	3,380	1,700,000	
M-23		2,760	3,170	3,450	1,800,000	
M-24		3,110	3,570	3,880	1,900,000	
M-25		3,160	3,640	3,950	2,200,000	
M-26	2 × 4 and wider	3,220	3,700	4,030	2,000,000	SPIB
M-27		3,450	3,970	4,310	2,100,000	

The note to Table 23-IV-V-1 applies also to mechanically graded lumber.

Chapter 24
GLASS AND GLAZING

SECTION 2401 — SCOPE

2401.1 General. The provisions of this chapter apply to:

1. Exterior glass and glazing in all occupancies.

EXCEPTION: Groups R and U Occupancies not over three stories in height and located in areas with a minimum basic wind speed less than 80 miles per hour (129 km/h).

2. Interior and exterior glass and glazing in all occupancies subject to human impact as specified in Section 2406 and hinged shower doors in all occupancies as specified in Section 2407.

3. Interior glass and glazing shall comply with Section 2404.1.

EXCEPTION: Groups R and U Occupancies.

4. Skylights and sloped glazing.

2401.2 Standards. Standards for material shall be as specified in this chapter and UBC Standard 24-1.

Standards for glazing subject to human impact (hazardous location) as specified in Section 2406 shall be as specified in UBC Standard 24-2.

2401.3 Other Provisions. See Chapter 6 of this code for additional glass requirements where openings are required to be fire protected, and Section 2603.4 for openings glazed with plastics.

2401.4 Standards of Quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code.

1. UBC Standard 24-1, Flat Glass

2. UBC Standard 24-2, Safety Glazing

SECTION 2402 — IDENTIFICATION

Each light shall bear the manufacturer's label designating the type and thickness of glass. When approved by the building official, labels may be omitted, provided an affidavit is furnished by the glazing contractor certifying that each light is glazed in accordance with approved plans and specifications. Identification of glazing in hazardous locations shall be in accordance with Section 2406.

SECTION 2403 — AREA LIMITATIONS

Glass in windows, curtain and window walls, skylights, doors, and other exterior applications shall be chosen to withstand the loads for cladding as set forth in Chapter 16, Division III.

The area of individual lights shall not be more than as set forth in Graph 24-1, as adjusted by Table 24-A. Glass sizing for skylight applications shall be adjusted per Section 2409.5.

Graph 24-1 is applicable to rectangular glass firmly supported on all four edges.

When approved by the building official, alternate means for selecting glass may be used in place of Graph 24-1 and Table 24-A.

Glass and glazing subject to ice or snow loads shall be designed in accordance with Chapter 16.

SECTION 2404 — GLAZING SUPPORT AND FRAMING

2404.1 Support. Glass shall be firmly supported on all four edges.

EXCEPTION: The building official may allow the use of glass that is not firmly supported on all four edges when justified by an approved design.

2404.2 Framing. The framing members for each individual glass pane shall be designed so the deflection perpendicular to the glass plane shall not exceed $^{1}/_{175}$ of the glass edge length or $^{3}/_{4}$ inch (19 mm), whichever is less, when subjected to the larger of the positive or negative load when loads are combined as specified in Section 1612.3.

SECTION 2405 — LOUVERED WINDOWS AND JALOUSIES

Regular float, wired and patterned glass in jalousies and louvered windows shall be no thinner than nominal $^{3}/_{16}$ inch (4.76 mm) and no longer than 48 inches (1219 mm). Exposed glass edges shall be smooth.

Wired glass with wire exposed on longitudinal edges shall not be used in jalousies or louvered windows.

SECTION 2406 — SAFETY GLAZING

2406.1 General. Glazing subject to human impact shall comply with this section.

2406.2 Identification. Each light of safety glazing material installed in hazardous locations as defined in Section 2406.4 shall be identified by a permanent label that specifies the labeler, whether the manufacturer or installer, and state that safety glazing material has been utilized in such installation. For additional identification requirements and for limitation on size and use by category classification, see UBC Standard 24-2, Part I.

Each unit of tempered glass shall be permanently identified by the manufacturer. The identification shall be etched or ceramic fired on the glass and be visible when the unit is glazed. Tempered spandrel glass is exempted from permanent labeling but such glass shall be identified by the manufacturer with a removable paper label.

2406.3 Human Impact Loads. Individual glazed areas in hazardous locations such as those indicated in Section 2406.4, including glazing used in fire assemblies in accordance with Section 713, shall pass the test requirements of UBC Standard 24-2, Part I.

EXCEPTIONS: 1. Louvered windows and jalousies complying with Section 2405 need not comply with Section 2406.3.

2. Polished wired glass complying with UBC Standard 24-2, Part II, may be used in smoke and draft control and fire assemblies.

Plastic glazing used in exterior applications also shall comply with the weathering requirements in UBC Standard 24-2, Part II.

2406.4 Hazardous Locations. The following shall be considered specific hazardous locations for the purposes of glazing:

1. Glazing in ingress and egress doors except jalousies.

2. Glazing in fixed and sliding panels of sliding door assemblies and panels in swinging doors other than wardrobe doors.

3. Glazing in storm doors.

4. Glazing in all unframed swinging doors.

5. Glazing in doors and enclosures for hot tubs, whirlpools, saunas, steam rooms, bathtubs and showers. Glazing in any portion of a building wall enclosing these compartments where the bottom exposed edge of the glazing is less than 60 inches (1525 mm) above a standing surface and drain inlet.

6. Glazing in fixed or operable panels adjacent to a door where the nearest exposed edge of the glazing is within a 24-inch (610 mm) arc of either vertical edge of the door in a closed position and where the bottom exposed edge of the glazing is less than 60 inches (1525 mm) above the walking surface.

7. Glazing in an individual fixed or operable panel, other than those locations described in Items 5 and 6, that meets all of the following conditions:

7.1 Exposed area of an individual pane greater than 9 square feet (0.84 m^2).

7.2 Exposed bottom edge less than 18 inches (457 mm) above the floor.

7.3 Exposed top edge greater than 36 inches (914 mm) above the floor.

7.4 One or more walking surfaces within 36 inches (914 mm) horizontally of the plane of the glazing.

8. Glazing in railings regardless of height above a walking surface. Included are structural baluster panels and nonstructural in-fill panels.

EXCEPTION: The following products and applications are exempt from the requirements for hazardous locations as listed in Items 1 through 8:

1. Glazing in Item 6 when there is an intervening wall or other permanent barrier between the door and the glazing.

2. Glazing in Item 7 when a protective bar is installed on the accessible sides of the glazing 34 inches (864 mm) to 38 inches (965 mm) above the floor. The bar shall be capable of withstanding a horizontal load of 50 pounds per linear foot (729 N/m) without contacting the glass and be a minimum of $1^1/_2$ inches (38 mm) in height.

3. Outboard pane in insulating glass units and in other multiple glazed panels in Item 7 when the bottom exposed edge of the glass is 25 feet (7620 mm) or more above any grade, roof, walking surface, or other horizontal or sloped (within 45 degrees of horizontal) surface adjacent to the glass exterior.

4. Openings in door through which a 3-inch-diameter (76.2 mm) sphere will not pass.

5. Assemblies of leaded, faceted or carved glass in Items 1, 2, 6 and 7 when used for decorative purposes.

6. Curved panels in revolving door assemblies.

7. Doors in commercial refrigerated cabinets.

8. Glass block panels complying with Section 2110.

9. Glazing in walls and fences used as the barrier for indoor and outdoor swimming pools and spas when all of the following conditions are present:

9.1 The bottom edge of the glazing is less than 60 inches (1525 mm) above the pool side of the glazing.

9.2 The glazing is within 5 feet (1525 mm) of a swimming pool or spa water's edge.

10. Glazing in walls enclosing stairway landings or within 5 feet (1525 mm) of the bottom and top of stairways where the bottom edge of the glass is less than 60 inches (1525 mm) above a walking surface.

2406.5 Wardrobe Doors. Glazing in wardrobe doors shall meet the impact test requirements for safety glazing as set forth in UBC Standard 24-2, Part II. Laminated glass must also meet the boil test requirements of UBC Standard 24-2, Part II.

EXCEPTION: The impact test shall be modified so that if no breakage occurs when the impacting object is dropped from the height of 18 inches (457 mm), the test shall progress in height increments of 6 inches (152.5 mm) until the maximum of 48 inches (1219 mm) is reached.

2406.6 Glass Railings. Glass used as structural balustrade panels in railings shall be one of the following types:

1. Single fully tempered glass.
2. Laminated fully tempered glass.
3. Laminated heat-strengthened glass.

The panels and their support system shall be designed to withstand the load specified in Table 16-B. A safety factor of 4 shall be used.

Each handrail or guardrail section shall be supported by a minimum of three glass balusters or otherwise supported so that it remains in place should one baluster panel fail.

Glass balusters shall not be installed without a handrail or guardrail attached.

For all glazing types, the minimum nominal thickness shall be $^1/_4$ inch (6.35 mm).

Glazing materials shall not be installed in railings in parking garages except for those locations where the railing is not exposed to impact from vehicles.

SECTION 2407 — HINGED SHOWER DOORS

Hinged shower doors shall open outward.

SECTION 2408 — RACQUETBALL AND SQUASH COURTS

2408.1 Test Method. Each panel of glass (including doors) in an actual installation or test mockup shall be impacted from the playing side at a point 59 inches (1499 mm) from the playing surface and its horizontal midpoint. The impactor and test procedure shall be as described in UBC Standard 24-2, Part I, Category II, using a drop height of 48 inches (1219 mm). Results from a test mockup shall apply only to actual installations in which the glass is no greater in either dimension and is at least as thick. Fittings and attachments for a mockup shall be identical to those used in actual installations. The conditions of Section 2408.2 shall be met.

2408.2 End Point Conditions. The following conditions shall be met when the glass is impacted as described in Section 2408.1:

1. The glass shall not break.

2. Deflection at the point of impact shall not exceed $1^1/_2$ inches (38 mm).

3. Door hardware shall remain intact and operable.

4. The deflection of the door edges shall be no greater than the following for the listed drop heights. The impactor and procedures shall be as indicated in Section 2408.1.

Drop Height	Deflection, inches (mm)
24 (610)	Thickness of adjacent glass + $^1/_8$ (+ 3.2)
36 (914)	Thickness of adjacent glass + $^1/_4$ (+ 6.4)
48 (1219)	Thickness of adjacent glass + $^1/_2$ (+ 12.7)

SECTION 2409 — SLOPED GLAZING AND SKYLIGHTS

2409.1 Scope. This section applies to the installation of glass or other transparent, translucent or opaque glazing material installed at a slope of 15 degrees or more from the vertical plane, including glazing materials in skylights, roofs and sloped walls.

2409.2 Allowable Glazing Materials. Sloped glazing shall be any of the following materials, subject to the limitations in this section:

1. Laminated glass with a minimum 0.015-inch (0.38 mm) polyvinyl butyral interlayer for glass panes 16 square feet (1.5 m^2) or less in area and with the highest point of the glass no more than 12 feet (3658 mm) above a walking surface; for larger or higher panes, the minimum interlayer thickness shall be 0.030 inch (0.76 mm).

2. Fully tempered glass.

3. Heat-strengthened glass.

4. Wired glass.

5. Approved rigid plastics meeting the requirements of Section 2603.7.

For multiple-layer glazing systems, each light or layer shall consist of any of the glazing materials specified above.

Annealed glass may be used as specified within Exceptions 2 and 3 of Section 2409.3.

2409.3 Screening. Heat-strengthened glass and fully tempered glass, when used in single-layer glazing systems, shall have screens installed below glazing. The screens shall be capable of supporting the weight of the glass and shall be substantially supported below and installed within 4 inches (102 mm) of the glass. They shall be constructed of a noncombustible material not thinner than 0.08 inch (2.03 mm) with a mesh not larger than 1 inch by 1 inch (25 mm by 25 mm). In a corrosive atmosphere, structurally equivalent noncorrosive screening materials shall be used. Heat-strengthened glass, fully tempered glass and wired glass, when used in multiple-layer glazing systems as the bottom glass layer over the walking surface, shall be equipped with screening that complies with the requirements for monolithic glazing systems.

EXCEPTIONS: 1. Fully tempered glass may be installed without required protective screens when located between intervening floors at a slope of 30 degrees or less from the vertical plane if the highest point of the glass is 10 feet (3048 mm) or less above the walking surface.

2. Allowable glazing material, including annealed glass, may be installed without required screens if the walking surface or any other accessible area below the glazing material is permanently protected from falling glass for a minimum horizontal distance equal to twice the height.

3. Allowable glazing material, including annealed glass, may be installed without screens in the sloped glazing systems of commercial or detached greenhouses used exclusively for growing plants and not intended for use by the public, provided the height of the greenhouse at the ridge does not exceed 20 feet (6096 mm) above grade.

4. Screens need not be provided within individual dwelling units when fully tempered glass is used as single glazing or in both panes of an insulating glass unit when all the following conditions are met:

4.1 The area of each pane (single glass) or unit (insulating glass) shall not exceed 16 square feet (1.49 m^2).

4.2 The highest point of the glass shall not be more than 12 feet (3658 mm) above any walking surface or other accessible area.

4.3 The nominal thickness of each pane shall not exceed $^3/_{16}$ inch (4.76 mm).

2409.4 Framing. In Types I and II construction, skylight frames shall be constructed of noncombustible materials.

EXCEPTION: In foundries or buildings where acid fumes deleterious to metal are incidental to the use of the buildings, approved pressure-treated woods or other approved noncorrosive materials may be used for sash and frames.

Skylights set at an angle of less than 45 degrees from the horizontal plane shall be mounted at least 4 inches (102 mm) above the plane of the roof on a curb constructed of materials as required for the frame. Skylights may be installed in the plane of the roof when the roof slope is 45 degrees or greater from horizontal.

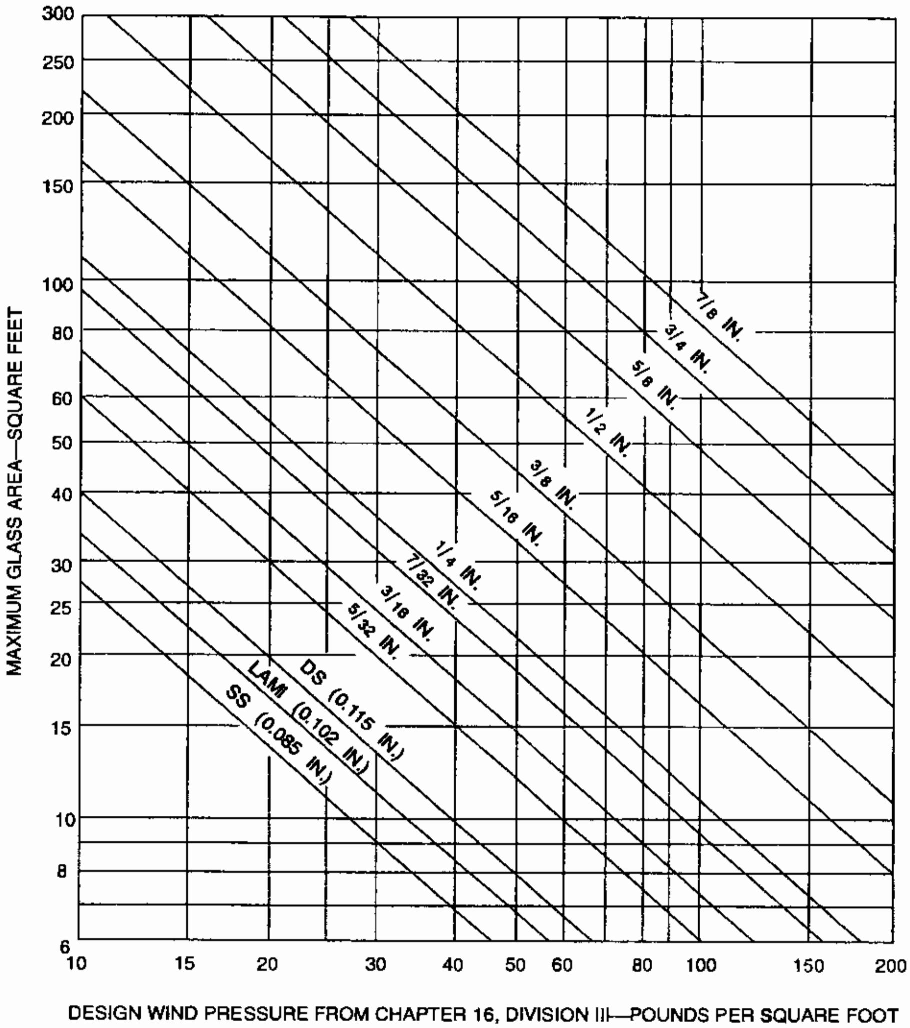
2409.5 Design Loads. Sloped glazing and skylights shall be designed to withstand the tributary loads specified in Section 1605. Sizing limitations specified within Graph 24-1 and Table 24-A may be utilized for glazing materials set forth in Section 2409.2, provided the design loads are increased by a factor of 2.67.

2409.6 Floors and Sidewalks. Glass used for the transmission of light, if placed in floors or sidewalks, shall be supported by metal or reinforced concrete frames, and such glass shall not be less than $^1/_2$ inch (12.7 mm) in thickness. Any such glass over 16 square inches (0.1 m^2) in area shall have wire mesh embedded in the same or shall be provided a wire screen underneath, as specified for skylights in this section. All portions of the floor lights or sidewalk lights shall be of the same strength as is required by this code for floor or sidewalk construction, except in cases where the floor is surrounded by a railing not less than 3 feet 6 inches (1067 mm) in height, in which case the construction shall be calculated for not less than roof loads.

TABLE 24-A—ADJUSTMENT FACTORS—RELATIVE RESISTANCE TO WIND LOADS

GLASS TYPE	ADJUSTMENT FACTOR[1]
Laminated[2]	0.75
Fully tempered	4.00
Heat strengthened	2.00
Wired	0.50
Insulating glass[3]—2 panes —3 panes	1.70 2.55
Patterned[4]	1.00
Regular (annealed)	1.00
Sandblasted	0.40[5]

[1]Loads determined from Chapter 16, Division III, shall be divided by this adjustment factor for use with Graph 24-1.
[2]Applies when two plies are identical in thickness and type; use total glass thickness, not thickness of one ply.
[3]Applies when each glass panel is the same thickness and type; use thickness of one panel.
[4]Use minimum glass thickness, i.e., measured at the thinnest part of the pattern; if necessary, interpolation of curves in Graph 24-1 may be required.
[5]Factor varies depending on depth and severity of sandblasting; value shown is minimum.



For SI: 1 inch = 25.4 mm, 1 square foot = 0.0929 m^2, 1 pound per square foot = 0.479 kN/m^2.

GRAPH 24-1—MAXIMUM ALLOWABLE AREA OF GLASS[1]

[1]Applicable for ratios of width to length of 1:1 to 5:1. Design safety factor = 2.5.

Chapter 25
GYPSUM BOARD AND PLASTER

SECTION 2501 — SCOPE

2501.1 General. The installation of lath, plaster and gypsum board shall be done in a manner and with materials as specified in this chapter and, when required for fire-resistive construction, also shall conform to the provisions of Chapter 7.

Other approved wall or ceiling coverings may be installed in accordance with the recommendations of the manufacturer and the conditions of approval.

2501.2 Inspection. No lath or gypsum board or their attachments shall be covered or finished until it has been inspected and approved by the building official in accordance with Section 108.5.

2501.3 Tests. The building official may require tests to be made in accordance with approved standards to determine compliance with the provisions of this chapter, provided the permit holder has been notified 24 hours in advance of the time of making such tests.

2501.4 Definitions. For purposes of this chapter, certain terms are defined as follows:

CEMENT PLASTER is a mixture of portland cement, portland cement and lime, masonry cement, or plastic cement and aggregate and other approved materials as specified in the code.

CORNER BEAD is a rigid formed unit or shape used at projecting or external angles to define and reinforce the corners of interior surfaces.

CORNERITE is a shaped reinforcing unit of expanded metal or wire fabric used for angle reinforcing and having minimum outstanding legs of not less than 2 inches (51 mm).

CORROSION-RESISTANT MATERIALS are materials that are inherently rust resistant or materials to which an approved rust-resistive coating has been applied either before or after forming or fabrication.

EXTERIOR SURFACES are weather-exposed surfaces as defined in Section 224.

EXTERNAL CORNER REINFORCEMENT is a shaped reinforcing unit for external corner reinforcement of cement plaster formed to ensure mechanical bond and a solid plaster corner.

INTERIOR SURFACES are surfaces other than weather-exposed surfaces.

MOIST CURING is any method employed to retain sufficient moisture for hydration of portland cement plaster.

PORTLAND CEMENT PLASTER is a mixture of portland cement or portland cement and lime and aggregate and other approved materials as specified in this code.

STEEL STUDS, LOAD-BEARING AND NONLOAD-BEARING, are prefabricated channel shapes, welded wire, or combination wire and steel angle types, galvanized or coated with rust-resistive material.

STRIPPING is flat reinforcing units of expanded metal or wire fabric or other materials not less than 3 inches (76 mm) wide to be installed as required over joints of gypsum lath.

TIE WIRE is wire for securing together metal framing or supports, for tying metal and wire fabric lath and gypsum lath and wallboard together, and for securing accessories.

WIRE BACKING is horizontal strands of tautened wire attached to surfaces of vertical wood supports that, when covered with building paper, provide a backing of cement plaster.

SECTION 2502 — MATERIALS

Lathing, plastering, wallboard materials and ceiling suspension systems shall conform to the applicable standards listed in Chapter 35.

The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards (see Sections 3503 and 3504).

1. UBC Standard 21-11, Cement, Masonry
2. ASTM C 150, Portland Cement
3. UBC Standard 25-1, Plastic Cement
4. UBC Standard 25-2, Metal Suspension Systems for Acoustical Tile and for Lay-in Panel Ceilings
5. United States Government Military Specification MIL-B-19235 (Docks), Plaster Bonding Agents
6. ASTM C 557, Adhesives for Fastening Gypsum Wallboard to Wood Framing
7. ASTM C 35, Perlite, Vermiculite and Sand Aggregates for Gypsum Plaster
8. ASTM C 1002, Drill Screws
9. ASTM C 475 and C 474, Gypsum Wallboard Tape and Joint Compound
10. ASTM C 442, Gypsum Backing Board
11. ASTM C 37, Gypsum Lath
12. ASTM C 28, Gypsum Plasters
13. ASTM C 79, Gypsum Sheathing Board
14. ASTM C 36, Gypsum Wallboard
15. ASTM C 61, Keene's Cement
16. ASTM C 630, Water-resistant Gypsum Backing Board
17. ASTM C 588 and C 587, Gypsum Base for Veneer Plaster and Gypsum Veneer Plaster
18. ASTM C 6 and C 206, Lime
19. ASTM C 144 and C 897, Aggregate for Masonry Mortar and Aggregate for Job-mixed Portland Cement-based Plaster
20. ASTM C 22, C 472 and C 473, Testing Gypsum and Gypsum Products
21. ASTM C 843 and C 844, Application of Gypsum Base for Veneer Plaster and Gypsum Veneer Plaster
22. ASTM C 514, Nails for the Application of Gypsum Wallboard, Gypsum Backing Board and Gypsum Veneer Base
23. ASTM C 931, Exterior Gypsum Soffit Board
24. ANSI A42.4-1955 and Specification 2.6.73 of the California Lathing and Plastering Contractors Association, Metal Lath, Wire Lath, Wire Fabric Lath and Metal Accessories

SECTION 2503 — VERTICAL ASSEMBLIES

2503.1 General. In addition to the requirements of this section, vertical assemblies of plaster or gypsum board shall be designed to resist the loads specified in Chapter 16 of this code. For wood framing, see Chapter 23. For metal framing, see Chapter 22.

> **EXCEPTION:** Wood-framed assemblies meeting the requirements of Section 2320 need not be designed.

2503.2 Wood Framing. Wood supports for lath or gypsum board shall not be less than 2 inches (51 mm) nominal in least dimension. Wood stripping or furring shall not be less than 2 inches (51 mm) nominal thickness in the least dimension except that furring strips not less than 1-inch-by-2-inch (25 mm by 51 mm) nominal dimension may be used over solid backing.

2503.3 Studless Partitions. The minimum thickness of vertically erected studless solid plaster partitions of $^3/_8$-inch (9.5 mm) and $^3/_4$-inch (19.1 mm) rib metal lath or $^1/_2$-inch-thick (12.7 mm) long-length gypsum lath and gypsum board partitions shall be 2 inches (51 mm).

SECTION 2504 — HORIZONTAL ASSEMBLIES

2504.1 General. In addition to the requirements of this section, supports for horizontal assemblies of plaster or gypsum board shall be designed to support all loads as specified in Chapter 16 of this code.

> **EXCEPTION:** Wood-framed assemblies meeting the requirements of Section 2320 need not be designed.

2504.2 Wood Framing. Wood stripping or suspended wood systems, where used, shall not be less than 2 inches (51 mm) nominal thickness in the least dimension, except that furring strips not less than 1-inch-by-2-inch (25 mm by 51 mm) nominal dimension may be used over solid backing.

2504.3 Hangers. Hangers for suspended ceilings shall not be less than the sizes set forth in Table 25-A, fastened to or embedded in the structural framing, masonry or concrete.

Hangers shall be saddle-tied around main runners to develop the full strength of the hangers. Lower ends of flat hangers shall be bolted with $^3/_8$-inch (9.5 mm) bolts to runner channels or bent tightly around runners and bolted to the main part of the hanger.

2504.4 Runners and Furring. The main runner and cross-furring shall not be less than the sizes set forth in Table 25-A, except that other steel sections of equivalent strength may be substituted for those set forth in this table. Cross-furring shall be securely attached to the main runner by saddle-tying with not less than one strand of 0.051-inch (1.30 mm) (No. 16 A.W. gage) or two strands of 0.040-inch (1.02 mm) (No. 18 A.W. gage) tie wire or approved equivalent attachments.

SECTION 2505 — INTERIOR LATH

2505.1 General. Gypsum lath shall not be installed until weather protection for the installation is provided. Where wood-frame walls and partitions are covered on the interior with cement plaster or tile of similar material and are subject to water splash, the framing shall be protected with an approved moisture barrier.

Showers and public toilet walls shall conform to Section 807.1.

2505.2 Application of Gypsum Lath. The thickness, spacing of supports and the method of attachment of gypsum lath shall be as set forth in Tables 25-B and 25-C. Approved wire and sheet metal attachment clips may be used.

Gypsum lath shall be applied with the long dimension perpendicular to supports and with end joints staggered in successive courses. End joints may occur on one support when stripping is applied the full length of the joints.

Where electrical radiant heat cables are installed on ceilings, the stripping, if conductive, may be omitted a distance not to exceed 12 inches (305 mm) from the walls.

Where lath edges are not in moderate contact and have joint gaps exceeding $^3/_8$ inch (9.5 mm), the joint gaps shall be covered with stripping or cornerite. Stripping or cornerite may be omitted when the entire surface is reinforced with not less than 1-inch (25 mm) 0.035-inch (0.89 mm) (No. 20 B.W. gage) woven wire. When lath is secured to horizontal or vertical supports not used as structural diaphragms, end joints may occur between supports when lath ends are secured together with approved fasteners. Vertical assemblies also shall conform to Section 1611.5.

Cornerite shall be installed so as to retain position during plastering at all internal corners. Cornerite may be omitted when plaster is not continuous from one plane to an adjacent plane.

2505.3 Application of Metal Plaster Bases. The type and weight of metal lath, and the gage and spacing of wire in welded or woven lath, the spacing of supports, and the methods of attachment to wood supports shall be as set forth in Tables 25-B and 25-C.

Metal lath shall be attached to metal supports with not less than 0.049-inch (1.2 mm) (No. 18 B.W. gage) tie wire spaced not more than 6 inches (152 mm) apart or with approved equivalent attachments.

Metal lath or wire fabric lath shall be applied with the long dimension of the sheets perpendicular to supports.

Metal lath shall be lapped not less than $^1/_2$ inch (12.7 mm) at sides and 1 inch (25 mm) at ends. Wire fabric lath shall be lapped not less than one mesh at sides and ends, but not less than 1 inch (25 mm). Rib metal lath with edge ribs greater than $^1/_8$ inch (3.2 mm) shall be lapped at sides by nesting outside ribs. When edge ribs are $^1/_8$ inch (3.2 mm) or less, rib metal lath may be lapped $^1/_2$ inch (12.7 mm) at sides, or outside ribs may be nested. Where end laps of sheets do not occur over supports, they shall be securely tied together with not less than 0.049-inch (1.2 mm) (No. 18 B.W. gage) wire.

Cornerite shall be installed in all internal corners to retain position during plastering. Cornerite may be omitted when lath is continuous or when plaster is not continuous from one plane to an adjacent plane.

SECTION 2506 — EXTERIOR LATH

2506.1 General. Exterior surfaces are weather-exposed surfaces as defined in Section 224. For eave overhangs required to be fire resistive, see Section 705.

2506.2 Corrosion Resistance. All lath and lath attachments shall be of corrosion-resistant material. See Section 2501.4.

2506.3 Backing. Backing or a lath shall provide sufficient rigidity to permit plaster application.

Where lath on vertical surfaces extends between rafters or other similar projecting members, solid backing shall be installed to provide support for lath and attachments.

Gypsum lath or gypsum board shall not be used, except that on horizontal supports of ceilings or roof soffits it may be used as backing for metal lath or wire fabric lath and cement plaster.

Backing is not required under metal lath or paperbacked wire fabric lath.

2506.4 Weather-resistive Barriers. Weather-resistive barriers shall be installed as required in Section 1402.1 and, when applied over wood base sheathing, shall include two layers of Grade D paper.

2506.5 Application of Metal Plaster Bases. The application of metal lath or wire fabric lath shall be as specified in Section 2505.3 and they shall be furred out from vertical supports or backing not less than $^1/_4$ inch (6.4 mm) except as set forth in Table 25-B, Footnote 2.

Where no external corner reinforcement is used, lath shall be furred out and carried around corners at least one support on frame construction.

A minimum 0.019-inch (0.48 mm) (No. 26 galvanized sheet gage) corrosion-resistant weep screed with a minimum vertical attachment flange of $3^1/_2$ inches (89 mm) shall be provided at or below the foundation plate line on all exterior stud walls. The screed shall be placed a minimum of 4 inches (102 mm) above the earth or 2 inches (51 mm) above paved areas and shall be of a type that will allow trapped water to drain to the exterior of the building. The weather-resistive barrier shall lap the attachment flange, and the exterior lath shall cover and terminate on the attachment flange of the screed.

SECTION 2507 — INTERIOR PLASTER

2507.1 General. Plastering with gypsum plaster or cement plaster shall not be less than three coats when applied over metal lath or wire fabric lath and shall not be less than two coats when applied over other bases permitted by this chapter. Showers and public toilet walls shall conform to Section 807.1.

Plaster shall not be applied directly to fiber insulation board. Cement plaster shall not be applied directly to gypsum lath, gypsum masonry or gypsum plaster except as specified in Section 2506.3.

When installed, grounds shall ensure the minimum thickness of plaster as set forth in Table 25-D. Plaster thickness shall be measured from the face of lath and other bases.

2507.2 Base Coat Proportions. Proportions of aggregate to cementitious materials shall not exceed the volume set forth in Table 25-E for gypsum plaster and Table 25-F for cement plaster.

2507.3 Base Coat Application.

2507.3.1 General. Base coats shall be applied with sufficient material and pressure to form a complete key or bond.

2507.3.2 Gypsum plaster. For two-coat work, the first coat shall be brought out to grounds and straightened to a true surface, leaving the surface rough to receive the finish coat. For three-coat work, the surface of the first coat shall be scored sufficiently to provide adequate bond for the second coat and shall be permitted to harden and set before the second coat is applied. The second coat shall be brought out to grounds and straightened to a true surface, leaving the surface rough to receive the finish coat.

2507.3.3 Cement plaster. The first two coats shall be as required for the first coats of exterior plaster, except that the moist-curing time period between the first and second coats shall not be less than 24 hours and the thickness shall be as set forth in Table 25-D. Moist curing shall not be required where job and weather conditions are favorable to the retention of moisture in the cement plaster for the required time period.

2507.4 Finish Coat Application. Finish coats shall be applied with sufficient material and pressure to form a complete bond. Finish coats shall be proportioned and mixed in an approved manner. Gypsum and lime and other interior finish coats shall be applied over gypsum base coats that have hardened and set. Thicknesses shall not be less than $^1/_{16}$ inch (1.6 mm).

Cement plaster finish coats may be applied over interior cement plaster base coats that have been in place not less than 24 hours.

Approved acoustical finish plaster may be applied over any base coat plaster, over clean masonry or concrete, or other approved surfaces.

2507.5 Interior Masonry or Concrete. Condition of surfaces shall be as specified in Section 2508.8. Approved specially prepared gypsum plaster designed for application to concrete surfaces or approved acoustical plaster may be used. The total thickness of base coat plaster applied to concrete ceilings shall be as set forth in Table 25-D. Should ceiling surfaces require more than the maximum thickness permitted in Table 25-D, metal lath or wire fabric lath shall be installed on such surfaces before plastering.

SECTION 2508 — EXTERIOR PLASTER

2508.1 General. Plastering with cement plaster shall not be less than three coats when applied over metal lath or wire fabric lath and shall not be less than two coats when applied over masonry, concrete or gypsum backing as specified in Section 2506.3. If plaster surface is completely covered by veneer or other facing material, or is completely concealed by another wall, plaster application need be only two coats, provided the total thickness is as set forth in Table 25-F.

On wood-frame or metal stud construction with an on-grade concrete floor slab system, exterior plaster shall be applied in such a manner as to cover, but not extend below, lath and paper. See Section 2506.5 for the application of paper and lath, and flashing or weep screeds.

Only approved plasticity agents and approved amounts thereof may be added to portland cement. When plastic cement is used, no additional lime or plasticizers shall be added. Hydrated lime or the equivalent amount of lime putty used as a plasticizer may be added to cement plaster or cement and lime plaster in an amount not to exceed that set forth in Table 25-F.

Gypsum plaster shall not be used on exterior surfaces. See Section 224.

2508.2 Base Coat Proportions. The proportion of aggregate to cementitious materials shall be as set forth in Table 25-F.

2508.3 Base Coat Application. The first coat shall be applied with sufficient material and pressure to fill solidly all openings in the lath. The surface shall be scored horizontally sufficiently rough to provide adequate bond to receive the second coat.

The second coat shall be brought out to proper thickness, rodded and floated sufficiently rough to provide adequate bond for the finish coat. The second coat shall have no variation greater than $^1/_4$ inch (6.4 mm) in any direction under a 5-foot (1524 mm) straight edge.

2508.4 Environmental Conditions. Portland cement-based plaster shall not be applied to frozen base or those bases containing frost. Plaster mixes shall not contain frozen ingredients. Plaster coats shall be protected from freezing for a period of not less than 24 hours after set has occurred.

2508.5 Curing and Interval. First and second coats of plaster shall be applied and moist cured as set forth in Table 25-F.

When applied over gypsum backing as specified in Section 2506.3 or directly to unit masonry surfaces, the second coat may be applied as soon as the first coat has attained sufficient hardness.

2508.6 Alternate Method of Application. As an alternate method of application, the second coat may be applied as soon as the first coat has attained sufficient rigidity to receive the second coat.

When using this method of application, calcium aluminate cement up to 15 percent of the weight of the portland cement may be added to the mix.

Curing of the first coat may be omitted and the second coat shall be cured as set forth in Table 25-F.

2508.7 Finish Coats. Finish coats shall be proportioned and mixed in an approved manner and in accordance with Table 25-F.

Cement plaster finish coats shall be applied over base coats that have been in place for the time periods set forth in Table 25-F. The third or finish coat shall be applied with sufficient material and pressure to bond to and to cover the brown coat and shall be of sufficient thickness to conceal the brown coat.

2508.8 Preparation of Masonry and Concrete. Surfaces shall be clean, free from efflorescence, sufficiently damp and rough to ensure proper bond. If surface is insufficiently rough, approved bonding agents or a portland cement dash bond coat mixed in proportions of one and one half parts volume of sand to one part volume of portland cement or plastic cement shall be applied. Dash bond coat shall be left undisturbed and shall be moist cured not less than 24 hours. When dash bond is applied, first coat of base coat plaster may be omitted. See Table 25-D for thickness.

SECTION 2509 — EXPOSED AGGREGATE PLASTER

2509.1 General. Exposed natural or integrally colored aggregate may be partially embedded in a natural or colored bedding coat of cement plaster or gypsum plaster, subject to the provisions of this section.

2509.2 Aggregate. The aggregate may be applied manually or mechanically and shall consist of marble chips, pebbles or similar durable, nonreactive materials, moderately hard (three or more on the Mohs scale).

2509.3 Bedding Coat Proportions. The exterior bedding coat shall be composed of one part portland cement, one part Type S lime, and a maximum three parts of graded white or natural sand by volume. The interior bedding coat shall be composed of 100 pounds (45.4 kg) neat gypsum plaster and a maximum 200 pounds (90.7 kg) of graded white sand, or exterior or interior may be a factory-prepared bedding coat. The exterior bedding coat shall have a minimum compressive strength of 1,000 pounds per square inch (6894.8 kPa).

2509.4 Application. The bedding coat may be applied directly over the first (scratch) coat of plaster, provided the ultimate overall thickness is a minimum of $^{7}/_{8}$ inch (22.2 mm), including lath. Over concrete or masonry surfaces, the overall thickness shall be a minimum of $^{1}/_{2}$ inch (12.7 mm).

2509.5 Bases. Exposed aggregate plaster may be applied over concrete, masonry, cement plaster base coats or gypsum plaster base coats.

2509.6 Preparation of Masonry and Concrete. Masonry and concrete surfaces shall be prepared in accordance with the provisions of Section 2508.8.

2509.7 Curing. Cement plaster base coats shall be cured in accordance with Table 25-F. Cement plaster bedding coat shall retain sufficient moisture for hydration (hardening) for 24 hours minimum or, where necessary, shall be kept damp for 24 hours by light water spraying.

SECTION 2510 — PNEUMATICALLY PLACED PLASTER (GUNITE)

Pneumatically placed portland cement plaster shall be a mixture of portland cement and sand, mixed dry, conveyed by air through a pipe or flexible tube, hydrated at the nozzle at the end of the conveyor, and deposited by air pressure in its final position.

Rebound material may be screened and reused as sand in an amount not greater than 25 percent of the total sand in any batch.

Pneumatically placed portland cement plaster shall consist of a mixture of one part cement to not more than five parts sand. Plasticity agents may be used as specified in Section 2508.1. Except when applied to concrete or masonry, such plaster shall be applied in not less than two coats to a minimum total thickness of $^{7}/_{8}$ inch (22.2 mm). The first coat shall be rodded as specified in Section 2508.3 for the second coat. The curing period and time interval shall be as set forth in Table 25-F.

SECTION 2511 — GYPSUM WALLBOARD

2511.1 General. Gypsum wallboard shall not be installed on exterior surfaces. See Section 224. For use as backing under stucco, see Section 2506.3.

Gypsum wallboard shall not be installed until weather protection for the installation is provided.

2511.2 Supports. Supports shall be spaced not to exceed the spacing set forth in Table 25-G for single-ply application and Table 25-H for two-ply application. Vertical assemblies shall comply with Section 2503. Horizontal assemblies shall comply with Section 2504.

2511.3 Single-ply Application. All edges and ends of gypsum wallboard shall occur on the framing members, except those edges and ends that are perpendicular to the framing members. All edges and ends of gypsum wallboard shall be in moderate contact except in concealed spaces where fire-resistive construction or diaphragm action is not required.

The size and spacing of fasteners shall comply with Table 25-G except where modified by fire-resistive construction meeting the requirements of Section 703.2. Fasteners shall not be spaced less than $^{3}/_{8}$ inch (9.5 mm) from edges and ends of gypsum wallboard. Fasteners at the top and bottom plates of vertical assemblies, or the edges and ends of horizontal assemblies perpendicular to supports, and at the wall line may be omitted except on shear-resisting elements or fire-resistive assemblies. Fasteners shall be applied in such a manner as not to fracture the face paper with the fastener head.

Gypsum wallboard may be applied to wood-framing members with an approved adhesive. A continuous bead of the adhesive shall be applied to the face of all framing members, except top and bottom plates, of sufficient size as to spread to an average width of 1 inch (25 mm) and thickness of $^{1}/_{16}$ inch (1.6 mm) when the gypsum wallboard is applied. Where the edges or ends of two pieces of gypsum wallboard occur on the same framing member, two continuous parallel beads of adhesive shall be applied to the framing member. Fasteners shall be used with adhesive application in accordance with Table 25-G.

2511.4 Two-ply Application. The base of gypsum wallboard shall be applied with fasteners of the type and size as required for the nonadhesive application of single-ply gypsum wallboard. Fastener spacings shall be in accordance with Table 25-H except where modified by fire-resistive construction meeting the requirements of Section 703.2.

The face ply of gypsum wallboard may be applied with gypsum wallboard joint compound or approved adhesive furnishing full coverage between the plies or with fasteners in accordance with Table 25-H. When the face ply is installed with joint compound or adhesive, the joints of the face ply need not occur on supports. Temporary nails or shoring shall be used to hold face ply in position until the joint compound or adhesive develops adequate bond.

2511.5 Joint Treatment. Gypsum wallboard single-layer fire-rated assemblies shall have joints treated.

EXCEPTION: Joint treatment need not be provided when any of the following conditions occur:

1. Where the wallboard is to receive a decorative finish such as wood paneling, battens, acoustical finishes or any similar application that would be equivalent to joint treatment.
2. Joints occur over wood-framing members.
3. Assemblies tested without joint treatment.

SECTION 2512 — USE OF GYPSUM IN SHOWERS AND WATER CLOSETS

When gypsum is used as a base for tile or wall panels for tub, shower or water closet compartment walls (see Sections 807.1.2 and 807.1.3), water-resistant gypsum backing board shall be used. Regular gypsum wallboard is permitted under tile or wall panels in other wall and ceiling areas when installed in accordance with Table 25-G. Water-resistant gypsum board shall not be used in the following locations:

1. Over a vapor retarder.
2. In areas subject to continuous high humidity, such as saunas, steam rooms or gang shower rooms.
3. On ceilings where frame spacing exceeds 12 inches (305 mm) on center.

SECTION 2513 — SHEAR-RESISTING CONSTRUCTION WITH WOOD FRAME

2513.1 General. Cement plaster, gypsum lath and plaster, gypsum veneer base, gypsum sheathing board, and gypsum wallboard may be used on wood studs for vertical diaphragms if applied in accordance with this section. Shear-resisting values shall not exceed those set forth in Table 25-I. The effects of overturning on vertical diaphragms shall be investigated in accordance with Section 1605.2.2.

The shear values tabulated shall not be cumulative with the shear value of other materials applied to the same wall. The shear values may be additive when the identical materials applied as specified in this section are applied to both sides of the wall.

2513.2 Masonry and Concrete Construction. Cement plaster, gypsum lath and plaster, gypsum veneer base, gypsum sheathing board, and gypsum wallboard shall not be used in vertical diaphragms to resist forces imposed by masonry or concrete construction.

2513.3 Wall Framing. Framing for vertical diaphragms shall comply with Section 2320.11 for bearing walls, and studs shall not be spaced farther apart than 16 inches (406 mm) center to center. Sills, plates and marginal studs shall be adequately connected to framing elements located above and below to resist all design forces.

2513.4 Height-to-length Ratio. The maximum allowable height-to-length ratio for the construction in this section shall be 2 to 1. Wall sections having height-to-length ratios in excess of $1^1/_2$ to 1 shall be blocked.

2513.5 Application. End joints of adjacent courses of gypsum lath, gypsum veneer base, gypsum sheathing board or gypsum wallboard sheets shall not occur over the same stud.

Where required in Table 25-I, blocking having the same cross-sectional dimensions as the studs shall be provided at all joints that are perpendicular to the studs.

The size and spacing of nails shall be as set forth in Table 25-I. Nails shall not be spaced less than $^3/_8$ inch (9.5 mm) from edges and ends of gypsum lath, gypsum veneer base, gypsum sheathing board and gypsum wallboard, or from sides of studs, blocking, and top and bottom plates.

2513.5.1 Gypsum lath. Gypsum lath shall be applied perpendicular to the studs. Maximum allowable shear values shall be as set forth in Table 25-I.

2513.5.2 Gypsum sheathing board. Four-foot-wide (1219 mm) pieces may be applied parallel or perpendicular to studs. Two-foot-wide (610 mm) pieces shall be applied perpendicular to the studs. Maximum allowable shear values shall be as set forth in Table 25-I.

2513.5.3 Gypsum wallboard or veneer base. Gypsum wallboard or veneer base may be applied parallel or perpendicular to studs. Maximum allowable shear values shall be as set forth in Table 25-I.

TABLE 25-A—SUSPENDED AND FURRED CEILINGS[1]
[For support of ceilings weighing not more than 10 pounds per square foot (4.89 kg/m^2)]

MINIMUM SIZES FOR WIRE AND RIGID HANGERS

Size and Type			Maximum Area Supported (square feet)	Size
			× 0.09 for m^2	× 25.4 for mm
Hangers for suspended ceilings			12.5	0.148-inch (3.76 mm) (No. 9 B.W. gage) wire
			16	0.145-inch (4.19 mm) (No. 8 B.W. gage) wire
			18	$^3/_{16}$" diameter, mild steel rod[2]
			20	$^7/_{32}$" diameter, mild steel rod[2]
			22.5	$^1/_4$" diameter, mild steel rod[2]
			22.0	1" × $^3/_{16}$" mild steel flats[3]
Hangers for attaching runners and furring directly to beams and joists	For supporting runners	Single hangers between beams[4]	8	0.109-inch (2.77 mm) (No. 12 B.W. gage) wire
			12	0.134-inch (3.40 mm) (No. 10 B.W. gage) wire
			16	0.165-inch (4.19 mm) (No. 8 B.W. gage) wire
		Double wire loops at beams or joists[3]	8	0.083-inch (2.11 mm) (No. 14 B.W. gage) wire
			12	0.109-inch (2.77 mm) (No. 12 B.W. gage) wire
			16	0.120-inch (3.05 mm) (No. 11 B.W. gage) wire
	For supporting furring without runners[4] (wire loops at supports)	Type of support:		
		Concrete	8	0.083-inch (2.11 mm) (No. 14 B.W. gage) wire
		Steel		0.065-inch (1.65 mm) (No. 16 B.W. gage) wire (2 loops)[5]
		Wood		0.065-inch (1.65 mm) (No. 16 B.W. gage) wire (2 loops)[5]

MINIMUM SIZES AND MAXIMUM SPANS FOR MAIN RUNNERS[6,7]

Size and Type	Maximum Spacing of Hangers or Supports (Along Runners)	Maximum Spacing of Runners (Transverse)
× 25.4 for mm × 1.49 for kg/m	× 304.8 for mm	
$^3/_4$" — 0.3 pound per foot, cold- or hot-rolled channel	2′	3′
$1^1/_2$" — 0.475 pound per foot, cold-rolled channel	3′	4′
$1^1/_2$" — 0.475 pound per foot, cold-rolled channel	3.5′	3.5′
$1^1/_2$" — 0.475 pound per foot, cold-rolled channel	4′	3′
$1^1/_2$" — 1.12 pounds per foot, hot-rolled channel	4′	5′
2" — 1.26 pounds per foot, hot-rolled channel	5′	5′
2" — 0.59 pounds per foot, cold-rolled channel	5′	3.5′
$1^1/_2$" × $1^1/_2$" × $^3/_{16}$" angle	5′	3.5′

MINIMUM SIZES AND MAXIMUM SPANS FOR CROSS FURRING[6,7]

Size and Type of Cross-furring	Maximum Spacing of Runners or Supports	Maximum Spacing of Cross-furring Members (Transverse)
× 25.4 for mm × 1.49 for kg/m	× 304.8 for mm	× 25.4 for mm
$^1/_4$" diameter pencil rods	2′	12"
$^3/_8$" diameter pencil rods	2′	19"
$^3/_8$" diameter pencil rods	2.5′	12"
$^3/_4$" — 0.3 pound per foot, cold- or hot-rolled channel	3′	24"
	3.5′	16"
	4′	12"
1" — 0.410 pound per foot, hot-rolled channel	4′	24"
	4.5′	19"
	5′	12"

[1]Metal suspension systems for acoustical tile and lay-in panel ceiling systems weighing not more than 4 pounds per square foot (19.5 kg/m^2), including light fixtures and all ceiling-supported equipment and conforming to UBC Standard 25-2, are exempt from Table 25-A.

[2]All rod hangers shall be protected with a zinc or cadmium coating or with a rust-inhibitive paint.

[3]All flat hangers shall be protected with a zinc or cadmium coating or with a rust-inhibitive paint.

[4]Inserts, special clips or other devices of equal strength may be substituted for those specified.

[5]Two loops of 0.049-inch (1.24 mm) (No. 18 B.W. gage) wire may be substituted for each loop of 0.065-inch (1.65 mm) (No. 16 B.W. gage) wire for attaching steel furring to steel or wood joists.

[6]Spans are based on webs of channels being erected vertically.

[7]Other sections of hot- or cold-rolled members of equivalent strength may be substituted for those specified.

TABLE 25-B[1]—TYPES OF LATH—MAXIMUM SPACING OF SUPPORTS

TYPE OF LATH[2]		MINIMUM WEIGHT (per square yard) (× 0.38 for kg/m²) GAGE AND MESH SIZE (× 25.4 for mm)	VERTICAL (inches) × 25.4 for mm: Wood	Metal: Solid Plaster Partitions	Metal: Other	HORIZONTAL (inches) × 25.4 for mm: Wood or Concrete	Metal
1. Expanded metal lath (diamond mesh)		2.5	16[3]	16[3]	12	12	12
		3.4	16[3]	16[3]	16	16	16
2. Flat rib expanded metal lath		2.75	16	16	16	16	16
		3.4	19	24	19	19	19
3. Stucco mesh expanded metal lath		1.8 and 3.6	16[4]	—	—	—	—
4. 3/8" (9.5 mm) rib expanded metal lath		3.4	24	24[5]	24	24	24
		4.0	24	24[5]	24	24	24
5. Sheet lath		4.5	24	[5]	24	24	24
6. Wire fabric lath	Welded	1.95 pounds, 0.120 inch (No. 11 B.W. gage), 2" x 2"	24	24	24	24	24
		1.16 pounds, 0.065 inch (No. 16 B.W. gage), 2" x 2"	16	16	16	16	16
		1.4 pounds, 0.049 inch (No. 18 B.W. gage), 1" x 1"[6]	16[4]	—	—	—	—
	Woven	1.1 pounds, 0.049 inch (No. 18 B.W. gage), 1 1/2" hexagonal[6]	24	16	16	24	16
		1.4 pounds, 0.058 inch (No. 17 B.W. gage), 1 1/2" hexagonal[6]	24	16	16	24	16
		1.4 pounds, 0.049 inch (No. 18 B.W. gage), 1" hexagonal[6]	24	16	16	24	16
7. 3/8" (9.5 mm) gypsum lath (plain)			16	—	16[7]	16	16
8. 1/2" (12.7 mm) gypsum lath (plain)			24	—	24	24	24

[1]For fire-resistive construction, see Tables 7-A, 7-B and 7-C. For shear-resisting elements, see Table 25-I.

[2]Metal lath and wire fabric lath used as reinforcement for cement plaster shall be furred out away from vertical supports at least 1/4 inch (6.4 mm). Self-furring lath meets furring requirements.

EXCEPTION: Furring of expanded metal lath is not required on supports having a bearing surface width of 1 5/8 inches (41 mm) or less.

[3]Span may be increased to 24 inches (610 mm) with self-furred metal lath over solid sheathing assemblies approved for this use.

[4]Wire backing required on open vertical frame construction except under expanded metal lath and paperbacked wire fabric lath.

[5]May be used for studless solid partitions.

[6]Woven wire or welded wire fabric lath not to be used as base for gypsum plaster without absorbent paperbacking or slot-perforated separator.

[7]Span may be increased to 24 inches (610 mm) on vertical screw or approved nailable assemblies.

TABLE 25-C—TYPES OF LATH—ATTACHMENT TO WOOD AND METAL[1] SUPPORTS

TYPE OF LATH	NAILS[2,3] Type and Size	NAILS Maximum Spacing[6] Vertical (inches) × 25.4 for mm	NAILS Maximum Spacing[6] Horizontal	SCREWS[3,4] Maximum Spacing[6] Vertical	SCREWS[3,4] Maximum Spacing[6] Horizontal	STAPLES[3,5] Round or Flattened Wire: Wire Gage No.	Crown (inches) × 25.4 for mm	Leg	Maximum Spacing[6] Vertical	Maximum Spacing[6] Horizontal
1. Diamond mesh expanded metal lath and flat rib metal lath	4d blued smooth box 1 1/2″[7] No. 14 gage 7/32″ head (clinched)[8] 1″ No. 11 gage 7/16″ head, barbed 1 1/2″ No. 11 gage 7/16″ head, barbed	6 6 6	— — 6	6	6	16	3/4	7/8	6	6
2. 3/8″ (9.5 mm) rib metal lath and sheet lath	1 1/2″ No. 11 gage 7/16″ head, barbed	6	6	6	6	16	3/4	1 1/4	At ribs	At ribs
3. 3/4″ (19.1 mm) rib metal lath	4d common 1 1/2″ No. 12 1/2 gage 1/4″ head 2″ No. 11 gage 7/16″ head, barbed	At ribs	— At ribs	At ribs	At ribs	16	3/4	1 5/8	At ribs	At ribs
4. Wire fabric lath[9]	4d blued smooth box (clinched)[8] 1″ No. 11 gage 7/16″ head, barbed	6 6	— —	6	6	16	3/4	7/8	6	6
	1 1/2″ No. 11 gage 7/16″ head, barbed 1 1/4″ No. 12 gage 3/8″ head, furring 1″ No. 12 gage 3/8″ head	6 6 6	6 6			16	7/16[9]	7/8	6	6
5. 3/8″ (9.5 mm) gypsum lath	1 1/8″ No. 13 gage 19/64″ head, blued	8[10]	8[10]	8[10]	8[10]	16	3/4	7/8[11]	8[10]	8[10]
6. 1/2″ (12.7 mm) gypsum lath	1 1/4″ No. 13 gage 19/64″ head, blued	8	8[10] 6[7]	8[10]	8[10] 6[7]	16	3/4	1 1/8[11]	8[10]	8[10] 6[7]

[1]Metal lath, wire lath, wire fabric lath and metal accessories shall conform to approved standards.
[2]For nailable nonload-bearing metal supports, use annular threaded nails or approved staples.
[3]For fire-resistive construction, see Tables 7-B and 7-C. For shear-resisting elements, see Table 25-I. Approved wire and sheet metal attachment clips may be used.
[4]Screws shall be an approved type long enough to penetrate into wood framing not less than 5/8 inch (15.9 mm) and through metal supports adaptable for screw attachment not less than 1/4 inch (6.4 mm).
[5]With chisel or divergent points.
[6]Maximum spacing of attachments from longitudinal edges shall not exceed 2 inches (51 mm).
[7]Supports spaced 24 inches (610 mm) on center. Four attachments per 16-inch-wide (406 mm) lath per bearing. Five attachments per 24-inch-wide (610 mm) lath per bearing.
[8]For interiors only.
[9]Attach self-furring wire fabric lath to supports at furring device.
[10]Three attachments per 16-inch-wide (406.4 mm) lath per bearing. Four attachments per 24-inch-wide (610 mm) lath per bearing.
[11]When lath and stripping are stapled simultaneously, increase leg length of staple 1/8 inch (3.2 mm).

TABLE 25-D—THICKNESS OF PLASTER[1]

PLASTER BASE	FINISHED THICKNESS OF PLASTER FROM FACE OF LATH, MASONRY, CONCRETE (× 25.4 for mm): Gypsum Plaster	Portland Cement Plaster
1. Expanded metal lath	5/8″ minimum[2]	5/8″ minimum[2]
2. Wire fabric lath	5/8″ minimum[2]	3/4″ minimum (interior)[3] 7/8″ minimum (exterior)[3]
3. Gypsum lath	1/2″ minimum	
4. Masonry walls[4]	1/2″ minimum	1/2″ minimum
5. Monolithic concrete walls[4,5]	5/8″ maximum[6]	7/8″ maximum[6]
6. Monolithic concrete ceilings[4,5]	3/8″ maximum[6,7,8]	1/2″ maximum[7,8]

[1]For fire-resistive construction, see Tables 7-A, 7-B and 7-C.
[2]When measured from back plane of expanded metal lath, exclusive of ribs, or self-furring lath, plaster thickness shall be 3/4 inch (19 mm) minimum.
[3]When measured from face of support or backing.
[4]Because masonry and concrete surfaces may vary in plane, thickness of plaster need not be uniform.
[5]When applied over a liquid bonding agent, finish coat may be applied directly to concrete surface.
[6]An approved skim-coat plaster 1/16 inch (1.6 mm) thick may be applied directly to concrete.
[7]On concrete ceilings, where the base coat plaster thickness exceeds the maximum thickness shown, metal lath or wire fabric lath shall be attached to the concrete.
[8]Approved acoustical plaster may be applied directly to concrete, or over base coat plaster, beyond the maximum plaster thickness shown.

TABLE 25-E—GYPSUM PLASTER PROPORTIONS[1]

NUMBER	COAT	PLASTER BASE OR LATH	MAXIMUM VOLUME AGGREGATE PER 100 POUNDS (45.4 kg) NEAT PLASTER[2,3] (cubic feet) × 0.028 for m³	
			Damp Loose Sand[4]	Perlite or Vermiculite[4]
1. Two-coat work	Base coat	Gypsum lath	$2^1/_2$	2
	Base coat	Masonry	3	3
2. Three-coat work	First coat	Lath	2[5]	2
	Second coat	Lath	3[5]	2[6]
	First and second coats	Masonry	3	3

[1]Wood-fibered gypsum plaster may be mixed in the proportions of 100 pounds (45.4 kg) of gypsum to not more than 1 cubic foot (0.028 m³) of sand where applied on masonry or concrete.
[2]For fire-resistive construction, see Tables 7-A, 7-B and 7-C.
[3]When determining the amount of aggregate in set plaster, a tolerance of 10 percent shall be allowed.
[4]Combinations of sand and lightweight aggregate may be used, provided the volume and weight relationship of the combined aggregate to gypsum plaster is maintained.
[5]If used for both first and second coats, the volume of aggregate may be $2^1/_2$ cubic feet (0.07 m³).
[6]Where plaster is 1 inch (25 mm) or more in total thickness, the proportions for the second coat may be increased to 3 cubic feet (0.08 m³).

TABLE 25-F—CEMENT PLASTERS[1]

PORTLAND CEMENT PLASTER						
Coat	Volume Cement	Maximum Weight (or Volume) Lime per Volume Cement	Maximum Volume Sand per Combined Volumes Cement and Lime[2]	Approximate Minimum Thickness[3] × 25.4 for mm	Minimum Period Moist Curing	Minimum Interval between Coats
First	1	20 lbs. (9.07 kg)	4	$^3/_8$″[4]	48 hours[5]	48 hours[6]
Second	1	20 lbs. (9.07 kg)	5	1st and 2nd coats total $^3/_4$″	48 hours	7 days[7]
Finish	1	1[8]	3	1st, 2nd and finish coats $^7/_8$″	—	7
PORTLAND CEMENT-LIME PLASTER[9]						
Coat	Volume Cement	Maximum Volume Lime per Volume Cement	Maximum Volume Sand per Combined Volumes Cement and Lime[3]	Approximate Minimum Thickness[3] × 25.4 for mm	Minimum Period Moist Curing	Minimum Interval between Coats
First	1	1	4	$^3/_8$″[4]	48 hours[5]	48 hours[6]
Second	1	1	$4^1/_2$	1st and 2nd coats total $^3/_4$″	48 hours	7 days[7]
Finish	1	1[8]	3	1st, 2nd and finish coats $^7/_8$″	—	7
PLASTIC CEMENT PLASTER[9]						
Coat	Volume Cement	Maximum Weight (or Volume) Lime per Volume Cement	Maximum Volume Sand per Volume Cement[2]	Approximate Minimum Thickness[3] × 25.4 for mm	Minimum Period Moist Curing	Minimum Interval between Coats
First	1	—	4	$^3/_8$″[4]	48 hours[5]	48 hours[6]
Second	1	—	5	1st and 2nd coats total $^3/_4$″	48 hours	7 days[7]
Finish	1	—	3	1st, 2nd and finish coats $^7/_8$″	—	7

[1]Exposed aggregate plaster shall be applied in accordance with Section 2509. Minimum overall thickness shall be $^3/_4$ inch (19 mm).
[2]When determining the amount of sand in set plaster, a tolerance of 10 percent may be allowed.
[3]See Table 25-D.
[4]Measured from face of support or backing to crest of scored plaster.
[5]See Section 2507.3.3.
[6]Twenty-four-hour minimum interval between coats of interior cement plaster. For alternate method of application, see Section 2508.6.
[7]Finish coat plaster may be applied to interior portland cement base coats after a 48-hour period.
[8]For finish coat plaster, up to an equal part of dry hydrated lime by weight (or an equivalent volume of lime putty) may be added to Types I, II and III standard portland cement.
[9]No additions of plasticizing agents shall be made.

TABLE 25-G—SINGLE-PLY GYPSUM WALLBOARD APPLIED PARALLEL (‖) OR PERPENDICULAR (⊥) TO FRAMING MEMBERS

<table>
<tr><th>THICKNESS OF GYPSUM WALLBOARD (inch)</th><th rowspan="2">PLANE OF FRAMING SURFACE</th><th>MAXIMUM SPACING OF FRAMING MEMBER[1] (Center to Center) (inches)</th><th colspan="2">LONG DIMENSION OF GYPSUM WALLBOARD SHEETS IN RELATION TO DIRECTION OF FRAMING MEMBERS</th><th colspan="2">MAXIMUM SPACING OF FASTENERS[1] (Center to Center) (inches)
× 25.4 for mm</th><th>NAILS[2]—TO WOOD</th></tr>
<tr><th>× 25.4 for mm</th><th>× 25.4 for mm</th><th>‖</th><th>⊥</th><th>Nails[3]</th><th>Screws[4]</th><th>× 25.4 for mm</th></tr>
<tr><td rowspan="4">$^1/_2$</td><td rowspan="2">Horizontal</td><td>16</td><td>P</td><td>P</td><td rowspan="2">7</td><td rowspan="2">12</td><td rowspan="4">No. 13 gage, $1^3/_8$″ long, $^{19}/_{64}$″ head; 0.098″ diameter, $1^1/_4$″ long, annular ringed; 5d, cooler (0.086″ dia., $1^5/_8$″ long, $^{15}/_{64}$″ head) or wallboard (0.086″ dia., $1^5/_8$″ long, $^9/_{32}$″ head) nail.</td></tr>
<tr><td>24</td><td>NP</td><td>P</td></tr>
<tr><td rowspan="2">Vertical</td><td>16</td><td>P</td><td>P</td><td rowspan="2">8</td><td>16</td></tr>
<tr><td>24</td><td>P</td><td>P</td><td>12</td></tr>
<tr><td rowspan="4">$^5/_8$</td><td rowspan="2">Horizontal</td><td>16</td><td>P</td><td>P</td><td rowspan="2">7</td><td rowspan="2">12</td><td rowspan="4">No. 13 gage, $1^5/_8$″ long, $^{19}/_{64}$″ head; 0.098″ diameter, $1^3/_8$″ long, annular ringed; 6d, cooler (0.092″ dia., $1^7/_8$″ long, $^1/_4$″ head) or wallboard (0.0915″ dia., $1^7/_8$″ long, $^{19}/_{64}$″ head) nail.</td></tr>
<tr><td>24</td><td>NP</td><td>P</td></tr>
<tr><td rowspan="2">Vertical</td><td>16</td><td>P</td><td>P</td><td rowspan="2">8</td><td>16</td></tr>
<tr><td>24</td><td>P</td><td>P</td><td>12</td></tr>
<tr><th colspan="8">Nail or Screw Fastenings with Adhesives (Maximum Center to Center in Inches)</th></tr>
<tr><th colspan="8">× 25.4 for mm</th></tr>
</table>

<table>
<tr><th colspan="5">(Column headings as above)</th><th>End</th><th>Edges</th><th>Field</th><th></th></tr>
<tr><td rowspan="3">$^1/_2$ or $^5/_8$</td><td rowspan="2">Horizontal</td><td>16</td><td>P</td><td>P</td><td>16</td><td>16</td><td>24</td><td rowspan="3">As required for $^1/_2$″ and $^5/_8$″ gypsum wallboard, see above.</td></tr>
<tr><td>24</td><td>NP</td><td>P</td><td>16</td><td>24</td><td>24</td></tr>
<tr><td>Vertical</td><td>24</td><td>P</td><td>P</td><td>16</td><td>24</td><td>NR</td></tr>
</table>

NOTES: Horizontal refers to applications such as ceilings. Vertical refers to applications such as walls.
‖ denotes parallel.
⊥ denotes perpendicular. P—Permitted. NP—Not permitted. NR—Not required.

[1] A combination of fasteners consisting of nails along the perimeter and screws in the field of the gypsum board may be used with the spacing of the fasteners shown in the table.
For fire-resistive construction, see Tables 7-B and 7-C. For shear-resisting elements, see Table 25-I.

[2] Where the metal framing has a clinching design formed to receive the nails by two edges of metal, the nails shall not be less than $^5/_8$ inch (15.9 mm) longer than the wallboard thickness, and shall have ringed shanks. Where the metal framing has a nailing groove formed to receive the nails, the nails shall have barbed shanks or be 5d, No. $13^1/_2$ gage, $1^5/_8$ inches (41 mm) long, $^{15}/_{64}$-inch (6.0 mm) head for $^1/_2$-inch (12.7 mm) gypsum wallboard; 6d, No. 13 gage, $1^7/_8$ (48 mm) inches long, $^{15}/_{64}$-inch (6.0 mm) head for $^5/_8$-inch (15.9 mm) gypsum wallboard.

[3] Two nails spaced 2 inches to $2^1/_2$ inches (51 mm to 64 mm) apart may be used where the pairs are spaced 12 inches (305 mm) on center except around the perimeter of the sheets.

[4] Screws shall be long enough to penetrate into wood framing not less than $^5/_8$ inch (15.9 mm) and through metal framing not less than $^1/_4$ inch (6.4 mm).

TABLE 25-H—APPLICATION OF TWO-PLY GYPSUM WALLBOARD[1]

FASTENERS ONLY								
Thickness of Gypsum Wallboard (Each Ply) (inch)	Plane of Framing Surface	Long Dimension of Gypsum Wallboard Sheets	Maximum Spacing of Framing Members (Center to Center) (inches)	Maximum Spacing of Fasteners (Center to Center) (inches) × 25.4 for mm				
				Base Ply			Face Ply	
× 25.4 for mm			× 25.4 for mm	Nails[2]	Screws[3]	Staples[4]	Nails[2]	Screws[3]
$^3/_8$	Horizontal	Perpendicular only	16				7	
	Vertical	Either direction	16				8	
$^1/_2$	Horizontal	Perpendicular only	24	16	24	16	7	12
	Vertical	Either direction	24				8	
$^5/_8$	Horizontal	Perpendicular only	24				7	
	Vertical	Either direction	24				8	
FASTENERS AND ADHESIVES								
$^3/_8$	Horizontal	Perpendicular only	16	7		5		
Base ply	Vertical	Either direction	24	8		7		
$^1/_2$	Horizontal	Perpendicular only	24	7	12	5	Temporary nailing or shoring to comply with Section 2511.4	
Base ply	Vertical	Either direction	24	8		7		
$^5/_8$	Horizontal	Perpendicular only	24	7		5		
Base ply	Vertical	Either direction	24	8		7		

[1] For fire-resistive construction, see Tables 7-B and 7-C. For shear-resisting elements, see Table 25-I.

[2] Nails for wood framing shall be long enough to penetrate into wood members not less than $^3/_4$ inch (19.1 mm), and the sizes shall comply with the provisions of Table 25-G. For nails not included in Table 25-G, use the appropriate size cooler or wallboard nails. Nails for metal framing shall comply with the provisions of Table 25-G.

[3] Screws shall comply with the provisions of Table 25-G.

[4] Staples shall not be less than No. 16 gage by $^3/_4$-inch (19.1 mm) crown width with leg length of $^7/_8$ inch (22.2 mm), $1^1/_8$ inches (28.6 mm) and $1^3/_8$ inches (34.9 mm) for gypsum wallboard thicknesses of $^3/_8$ inch (9.5 mm), $^1/_2$ inch (12.7 mm) and $^5/_8$ inch (15.9 mm), respectively.

TABLE 25-I—ALLOWABLE SHEAR FOR WIND OR SEISMIC FORCES IN POUNDS PER FOOT FOR VERTICAL DIAPHRAGMS OF LATH AND PLASTER OR GYPSUM BOARD FRAME WALL ASSEMBLIES[1]

TYPE OF MATERIAL	THICKNESS OF MATERIAL	WALL CONSTRUCTION	NAIL SPACING[2] MAXIMUM (Inches)	SHEAR VALUE	MINIMUM NAIL SIZE[3]
	× 25.4 for mm × 304.8 for mm		× 25.4 for mm	× 14.6 for N/m	× 25.4 for mm
1. Expanded metal, or woven wire lath and portland cement plaster	7/8″	Unblocked	6	180	No. 11 gage, 1 1/2″ long, 7/16″ head No. 16 gage staple, 7/8″ legs
2. Gypsum lath	3/8″ lath and 1/2″ plaster	Unblocked	5	100	No. 13 gage, 1 1/8″ long, 19/64″ head, plasterboard blued nail
3. Gypsum sheathing board	1/2″ × 2′ × 8′	Unblocked	4	75	No. 11 gage, 1 3/4″ long, 7/16″ head, diamond-point, galvanized
	1/2″ × 4′ 1/2″ × 4′	Blocked Unblocked	4 7	175 100	
4. Gypsum wallboard or veneer base	1/2″	Unblocked	7	100	5d cooler (0.086″ dia., 1 5/8″ long, 15/64″ head) or wallboard (0.086″ dia., 1 5/8″ long, 9/32″ head)
			4	125	
		Blocked	7	125	
			4	150	
	5/8″	Unblocked	7	115	6d cooler (0.092″ dia., 1 7/8″ long, 1/4″ head) or wallboard (0.0915″ dia., 1 7/8″ long, 19/64″ head)
			4	145	
		Blocked	7	145	
			4	175	
		Blocked Two ply	Base ply: 9 Face ply: 7	250	Base ply—6d cooler (0.092″ dia., 1 7/8″ long, 1/4″ head) or wallboard (0.0915″ dia., 1 7/8″ long, 19/64″ head) Face ply—8d cooler (0.113″ dia., 2 3/8″ long, 9/32″ head) or wallboard (0.113″ dia., 2 3/8″ long, 3/8″ head)

[1]These vertical diaphragms shall not be used to resist loads imposed by masonry or concrete construction. See Section 2513.2. Values shown are for short-term loading due to wind or due to seismic loading. Values shown must be reduced 25 percent for normal loading. The values shown in Items 2, 3 and 4 shall be reduced 50 percent for loading due to earthquake in Seismic Zones 3 and 4.

[2]Applies to nailing at all studs, top and bottom plates, and blocking.

[3]Alternate nails may be used if their dimensions are not less than the specified dimensions.

Chapter 26
PLASTIC

SECTION 2601 — SCOPE

Foam plastics, light-transmitting plastics and plastic veneers shall comply with this chapter.

See Section 1404 for requirements for vinyl siding.

SECTION 2602 — FOAM PLASTIC INSULATION

2602.1 General. The provisions of this section shall govern the requirements and uses of foam plastic insulation in buildings and structures. For trim, see Section 601.5.5.

2602.2 Labeling and Identification. Packages and containers of foam plastic insulation and foam plastic insulation components delivered to the jobsite shall bear the label of an approved agency showing the manufacturer's name, the product listing, product identification and information to show that the end use will comply with the code requirements.

2602.3 Surface-burning Characteristics. Foam plastic insulation used in building construction shall have a flame-spread rating of not more than 75 and a smoke-developed rating of not more than 450 when tested in accordance with UBC Standard 8-1 in the maximum thickness intended for use.

EXCEPTION: Foam plastic insulation when tested in a minimum thickness of 4 inches (102 mm) may be used in a greater thickness in cold-storage buildings, ice plants, food-processing rooms and similar areas. For rooms within a building, the foam plastic insulation shall be protected by a thermal barrier on both sides having an index of 15.

2602.4 Thermal Barrier. The interior of the building shall be separated from the foam plastic insulation by an approved thermal barrier having an index of 15 when tested in accordance with UBC Standard 26-2. The thermal barrier shall be installed in such a manner that it will remain in place for the time of its index classification based on approved diversified tests.

EXCEPTION: The thermal barrier is not required:

1. For siding backer board, provided the foam plastic insulation is not of more than 2,000 Btu per square foot (22.7 MJ/m^2) as determined by UBC Standard 26-1 and when it is separated from the interior of the building by not less than 2 inches (51 mm) of mineral fiber insulation or equivalent, or applied as re-siding over existing wall construction.

2. For walk-in coolers and freezer units having an aggregate floor area less than 400 square feet (37.2 m^2).

3. In a masonry or concrete wall, floor or roof system when the foam plastic insulation is covered by a minimum of 1-inch (25 mm) thickness of masonry or concrete. Loose-fill-type foam plastic insulation shall be tested as board stock for flame spread and smoke development as described above.

4. Within an attic or crawl space where entry is made only for service of utilities, and when foam plastic insulation is covered with a material such as $1^1/_2$-inch-thick (38 mm) mineral fiber insulation; $^1/_4$-inch-thick (6.4 mm) plywood, hardboard or gypsum wallboard; corrosion-resistant sheet metal having a base metal thickness not less than 0.0160 inch (0.4 mm) at any point; or other approved material installed in such a manner that the foam plastic insulation is not exposed.

5. In cooler and freezer walls when:

5.1 The foam plastic insulation has a flame-spread rating of 25 or less when tested in a minimum 4-inch (102 mm) thickness;

5.2 Has flash and self-ignition temperatures of not less than 600°F and 800°F (316°C and 427°C), respectively;

5.3 Is covered by not less than 0.032-inch (0.8 mm) aluminum or corrosion-resistant steel having a base metal thickness not less than 0.0160 inch (0.4 mm) at any point; and

5.4 Is protected by an automatic sprinkler system. When the cooler or freezer is within a building, both the cooler or freezer and that part of the building in which it is located shall be sprinklered.

6. Exterior garage doors in Group U, Division 1 Occupancies.

2602.5 Special Provisions.

2602.5.1 General. Foam plastic insulation may be used in the applications set forth in this section.

2602.5.2 Noncombustible exterior walls.

2602.5.2.1 One-story buildings. Foam plastic insulation may be used in exterior walls of one-story buildings where exterior walls are required to be of noncombustible construction subject to the following:

1. The building is protected throughout with automatic sprinklers.

2. Foam plastic insulation, tested in the maximum thickness and density intended for use, has a flame-spread rating of 25 or less and a smoke-developed rating of 450 or less in accordance with UBC Standard 8-1.

3. The foam plastic insulation has a maximum 4-inch (102 mm) thickness.

4. The thermal barrier may be omitted when the foam plastic insulation is covered by not less than 0.032-inch-thick (0.8 mm) aluminum or corrosion-resistant sheet steel, having a base metal thickness of 0.0160 (0.4 mm) inch.

5. When the wall is required to have a fire-resistive rating, data based on tests conducted in accordance with UBC Standard 7-1 are provided to substantiate that the required fire-resistive rating is maintained.

2602.5.2.2 Buildings of any height. Except for foam plastic insulation in masonry or concrete construction complying with Section 2602.4, Exception 3, assemblies employing foam plastic insulation in or on exterior walls of buildings where the exterior walls are required to be of noncombustible construction shall comply with the following:

1. When the wall is required to have a fire-resistive rating, data based on tests conducted in accordance with UBC Standard 7-1 are provided to substantiate that the fire-resistive rating is maintained.

2. The foam plastic insulation is separated from the interior of the building by a thermal barrier having an index of 15 unless specifically approved under Section 2602.6.

3. Combustible content of foam plastic insulation in any portion of the wall or panel does not exceed 6,000 Btu per square foot (68.2 MJ/m^2) of wall area as determined by tests in accordance with UBC Standard 26-1.

4. Foam plastic insulation, exterior coatings and facings tested separately shall each have a flame-spread rating of 25 or less and a smoke-developed rating of 450 or less in accordance with UBC Standard 8-1. The foam plastic shall be tested in the thickness intended for use.

5. The wall assembly passes the conditions of acceptance of UBC Standard 26-4 or 26-9.

6. Foam plastic insulation is listed and the edge or face of each piece is labeled with the following information:

6.1 Inspection agency name.

6.2 Product for which the insulation is listed.

6.3 Identification of the insulation manufacturer.

6.4 Flame-spread and smoke-development classifications.

2602.5.3 Roofing. Foam plastic insulation meeting the requirements of Sections 2602.2, 2602.3 and 2602.4 may be used as part of a roof-covering assembly, provided the assembly with the foam plastic insulation is a Class A, B or C roofing assembly when tested in accordance with UBC Standard 15-2. Foam plastic insulation, which is a part of a Class A, B or C roof-covering assembly, need not meet the requirements of Sections 2602.2, 2602.3 and 2602.4, provided the assembly with the foam plastic insulation satisfactorily passes a test for insulated roof decks.

Any roofing assembly or roof covering installed in accordance with this code and the manufacturer's instructions may be applied over foam plastic insulation when the foam is separated from the interior of the building by wood structural panel sheathing not less than $^1/_2$ inch (12.7 mm) in thickness bonded with exterior glue, with edges supported by blocking, tongue-and-groove joints or other approved type of edge support, or an equivalent material. The thermal barrier requirement is waived.

For all roof applications, the smoke-developed rating shall not be limited.

2602.5.4 Doors. Where pivoted or side-hinged swinging doors are permitted without a fire-resistive rating, foam plastic insulation having a flame-spread rating of 75 or less may be used as a core material when the door facing is metal having a minimum thickness of 0.032-inch (0.8 mm) aluminum or steel having a base metal thickness not less than 0.0160 inch (0.4 mm) at any point. The thermal barrier is not required for this condition.

2602.5.5 Garage doors. In other than Group U Occupancies and where garage doors are permitted without a fire-resistive rating, foam plastic insulation may be used without thermal barrier in such garage doors subject to the following:

1. The foam plastic insulation shall have a flame-spread index of 75 or less and smoke-developed rating of 450 or less, and

2. The facing on the side of the garage door located inside a building shall be minimum 0.010-inch (0.3 mm) steel or minimum $^1/_8$-inch (3.2 mm) wood or the garage door shall be tested in accordance with, and shall meet the acceptance criteria of, UBC Standard 26-8.

2602.6 Specific Approval. Foam plastic insulation or assemblies using foam plastic insulation may be used based on approved tests such as, but not limited to, tunnel tests in accordance with UBC Standard 8-1, fire tests related to actual end use such as UBC Standard 26-3 and an ignition temperature test establishing a minimum self-ignition temperature of 650°F (343°C). In lieu of testing, the specific approval may be based on the end use, quantity, location and similar considerations where such tests would not be applicable or practical.

Foam plastic insulation in a thickness greater than 4 inches (102 mm) may be used if it has been tested for flame spread and smoke development at a minimum thickness of 4 inches (102 mm) provided the end use has been specifically approved in accordance with this section with the thickness and density intended for use.

SECTION 2603 — LIGHT-TRANSMITTING PLASTICS

2603.1 General.

2603.1.1 Scope. The provisions of this section shall govern the quality and methods of application of plastics for use as light-transmitting materials in buildings and structures. For foam plastics, see Sections 601.5.5 and 2602. Light-transmitting plastic materials that meet the other code requirements for walls and roofs may be used in accordance with the other applicable chapters of the code.

2603.1.2 Approval for use. The building official shall require that sufficient technical data be submitted to substantiate the proposed use of any light-transmitting material and, if it is determined that the evidence submitted is satisfactory for the use intended, the building official may approve its use subject to the requirements of this section.

2603.1.3 Identification. Each unit or package of plastic shall be identified with a mark or decal satisfactory to the building official, which includes identification as to the material classification.

2603.1.4 Combination of glazing and exterior wall panels. Combinations of plastic glazing and plastic exterior wall panels shall be subject to the area, height, percentage and separation requirements applicable to the class of plastics as prescribed for wall panel installation.

2603.1.5 Combination of roof panels and skylights. Combinations of plastic roof panels and plastic skylights shall be subject to the area percentage and separation requirements applicable to roof panel installation.

2603.1.6 Standards of quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code.

1. UBC Standard 15-2, Test Standard for Determining the Fire Retardancy of Roof Assemblies

2. UBC Standard 26-5, Chamber Method of Test for Measuring the Density of Smoke from the Burning or Decomposition of Plastic Materials

3. UBC Standard 26-6, Ignition Properties of Plastics

4. UBC Standard 26-7, Method of Test for Determining Classification of Approved Light-transmitting Plastics

2603.2 Definitions. For the purpose of this section, certain terms are defined as follows:

EXTERIOR WALL PANELS are materials that are not classified as plastic glazing and are used as light-transmitting media in exterior walls.

GLASS FIBER REINFORCED PLASTIC is plastic reinforced with glass fiber having not less than 20 percent of glass fibers by weight.

GLAZING is material that has all edges set in a frame or sash and is not held by mechanical fasteners that pass through the material.

LIGHT-DIFFUSING SYSTEM is construction consisting in whole or in part of lenses, panels, grids or baffles made with approved plastics positioned below independently mounted electrical light sources. Lenses, panels, grids and baffles that are part of an electrical fixture shall not be considered as a light-diffusing system.

PLASTIC MATERIALS, APPROVED. See Chapter 2.

ROOF PANELS are structural panels other than skylights that are fastened to structural members or structural panels or sheathing and are used as light-transmitting media in the plane of the roof.

THERMOPLASTIC MATERIAL is a plastic material capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.

THERMOSETTING MATERIAL is a plastic material capable of being changed into a substantially nonreformable product when cured.

2603.3 Design and Installation.

2603.3.1 Structural requirements. Plastic materials in their assembly shall be of adequate strength and durability to withstand the design loads as prescribed elsewhere in this code. Technical data shall be submitted to establish stresses, maximum unsupported spans and such other information for the various thicknesses and forms used as may be deemed necessary by the building official.

2603.3.2 Fastening. Fastening shall be adequate to withstand design loads as prescribed elsewhere in this code. Proper allowance shall be made for expansion and contraction of plastic materials in accordance with accepted data on coefficient of expansion of the material and other material in conjunction with which it is employed.

2603.4 Glazing of Unprotected Openings. In Type V-N construction, doors, sash and framed openings not required to be fire protected may be glazed or equipped with approved plastic material.

In types of construction other than Type V-N, openings not required to be fire protected may be glazed or equipped with approved plastic, subject to the following requirements:

1. The aggregate area of plastic glazing shall not exceed 25 percent of the area of any wall face of the story in which it is installed. The area of a single pane of glazing installed above the first story shall not exceed 16 square feet (1.5 m^2) and the vertical dimension of a single pane shall not exceed 4 feet (1219 mm).

> **EXCEPTION:** When an approved automatic sprinkler system is provided throughout, the area of glazing may be increased to a maximum of 50 percent of the wall face of the story in which it is installed with no limit on the maximum dimension or area of a single pane of glazing.

2. Approved flame barriers extending 30 inches (762 mm) beyond the exterior wall in the plane of the floor, or vertical panels not less than 4 feet (1219 mm) in height, shall be installed between glazed units located in adjacent stories.

3. Plastics shall not be installed more than 65 feet (19 812 mm) above grade level.

2603.5 Light-transmitting Exterior Wall Panels. In Type V-N construction, approved plastics may be installed in exterior walls provided the walls are not required to have a fire-resistive rating.

In types of construction other than Type V-N, approved plastics may be installed in exterior walls, provided the walls are not required to have a fire-resistive rating, subject to the following requirements:

1. Approved exterior wall panels shall not be installed more than 40 feet (12 192 mm) above grade level.

2. Approved exterior wall panels shall not be installed in exterior walls located less than 10 feet (3048 mm) from the property line determined in accordance with Section 503.

3. The area and size shall be limited to that set forth in Table 26-A.

> **EXCEPTIONS:** 1. In structures provided with approved flame barriers extending 30 inches (762 mm) beyond the exterior wall in the plane of the floor, there need be no vertical separation at the floor except that provided by the vertical thickness of the flame-barrier projection.
>
> 2. When an approved automatic sprinkler system is provided throughout the building, the maximum percentage area of plastic panels in the exterior wall and the maximum square feet of any individual panel may he increased 50 percent above that set forth in Table 26-A, and the separation requirements, both vertical and horizontal, as set forth in Table 26-A may be reduced by 50 percent.

2603.6 Roof Panels. Approved plastic roof panels may be installed in roofs of buildings not required to have a fire-resistive rating, subject to the following limitations:

1. Individual roof panels or units shall be separated from each other by distances of not less than 4 feet (1219 mm) measured in a horizontal plane.

2. Roof panels or units shall not be installed within that portion of a roof located within a distance to property line or public way where openings in exterior walls are prohibited or required to be protected, whichever is most restrictive.

3. Roof panels of Class CC1 plastics shall be limited to a maximum individual panel area of 150 square feet (13.9 m^2), and the total maximum aggregate area of all panels shall not exceed $33^1/_3$ percent of the floor area of the room or space sheltered. Roof panels of Class CC2 plastics shall be limited to a maximum individual panel area of 100 square feet (9.3 m^2), and the total maximum aggregate area of all panels shall not exceed 25 percent of the floor area of the room or space sheltered.

> **EXCEPTION:** Swimming pool shelters are exempt from the area limitations of Section 2603.6, provided such shelters do not exceed 5,000 square feet (464.5 m^2) in area and are not closer than 10 feet (3048 mm) to the property line or adjacent building.

2603.7 Skylights.

2603.7.1 General. Skylight assemblies may be glazed with approved plastic materials in accordance with the following provisions:

1. The plastics shall be mounted at least 4 inches (102 mm) above the plane of the roof by a curb constructed consistent with the requirements for the type of construction classification.

> **EXCEPTION:** Curbs may be omitted on roofs of Group R, Division 3 Occupancies with a minimum slope of 3 units vertical in 12 units horizontal (25% slope) when self-flashing skylights are used.

2. Flat or corrugated plastic skylights shall slope at least 4 units vertical in 12 units horizontal (33.3% slope). Dome-shaped skylights shall rise above the mounting flange a minimum distance equal to 10 percent of the maximum span of the dome but not less than 5 inches (127 mm).

> **EXCEPTION:** Skylights that pass the Class B Burning Brand Test specified in UBC Standard 15-2.

3. The edges of the plastic lights or domes shall be protected by metal or other noncombustible materials or shall be tested to show that equivalent fire protection is provided.

> **EXCEPTION:** The metal or noncombustible edge is not required where nonrated roof coverings are permitted.

4. Each skylight unit may have a maximum area within the curb of 100 square feet (9.3 m^2) for CC2 material and 200 square feet (18.6 m^2) for CC1 material.

> **EXCEPTIONS:** 1. The maximum area within the curb need not be limited if the building on which the skylights are located is not more than one story in height, the building has an exterior separation from other buildings of at least 30 feet (9144 mm), and the room or space sheltered by the roof is not classified in a Group I, Division 1.1, 1.2 or 3 Occupancy or as a required means of egress.
>
> 2. Except for Groups A, Divisions 1 and 2; I, Divisions 1.1, 1.2 and 2; and H, Divisions 1 and 2 Occupancies, the maximum area within the curb need not be limited where skylights are:

2.1 Serving as a fire venting system complying with this code, or

2.2 Used in a building completely equipped with an approved automatic sprinkler system complying with UBC Standard 9-1 or 9-3.

5. The aggregate area of skylights installed in the roof shall not exceed $33^{1}/_{3}$ percent of the floor area of the room or space sheltered by the roof when CC1 materials are used and 25 percent when CC2 materials are used.

6. Skylight units shall be separated from each other by a distance of not less than 4 feet (1219 mm) measured in a horizontal plane.

EXCEPTIONS: 1. Except for Groups A, Divisions 1 and 2; I, Divisions 1.1, 1.2 and 2; and H, Divisions 1 and 2 Occupancies, the separation is not required where the skylights are:

1.1 Serving as a fire venting system complying with this code, or

1.2 Used in a building completely equipped with an approved automatic sprinkler system complying with UBC Standard 9-1 or 9-3.

2. Multiple skylights located above the same room or space with a combined area not exceeding the limits set forth in Section 2603.7.1, Item 4.

7. Skylights shall not be installed within that portion of a roof located within a distance to property line or public way where openings in exterior walls are prohibited or required to be protected, whichever is most restrictive.

2603.7.2 Plastics over stair shafts. Approved plastic materials that will not automatically vent but are able to be vented may be used over stairways and shafts, provided the installation conforms to the requirements of Section 2603.7.1.

2603.8 Light-diffusing Systems.

2603.8.1 General. Plastic diffusers in light-diffusing systems shall be supported directly or indirectly by the use of noncombustible hangers.

Light-transmitting plastic materials in light-diffusing systems shall comply with Chapter 8 unless the approved plastic used in the light-diffusing system meets the following requirements:

1. Diffusers shall fall from their mounting at an ambient temperature of at least 200°F (93°C) below the ignition temperature of the plastic material.

2. Diffusers shall remain in place at an ambient room temperature of 175°F (79°C) for a period of not less than 15 minutes.

3. The maximum length of any single plastic panel shall not exceed 10 feet (3048 mm), and the maximum area of any single plastic panel shall not exceed 30 square feet (2.8 m^2).

4. The area of approved plastic materials when used in required means of egress as defined in Chapter 10 shall not exceed 30 percent of the aggregate area of the ceiling in which they are installed.

EXCEPTION: The aggregate area need not be limited in a building equipped with an approved automatic sprinkler system complying with UBC Standard 9-1 or 9-3.

2603.8.2 Limitations. A plastic light-diffusing system shall not be installed in the areas to be equipped with automatic sprinklers unless appropriate tests have shown that the system does not prevent effective operation of the sprinklers or unless sprinklers are located both above and below the light-diffusing system to give effective sprinkler protection.

2603.9 Diffusers in Electrical Fixtures. Use of approved plastics as light-diffuser panels installed in approved electrical lighting fixtures in or on walls or ceilings shall comply with Chapter 8 unless the plastic panels meet the requirements of Section 2603.8.1.

2603.10 Partitions. Approved light-transmitting plastics may be used in or as partitions, in accordance with the requirements of this code.

2603.11 Awnings and Patio Covers. Approved plastics may be used in awnings and patio covers. All such awnings shall be constructed in accordance with provisions specified in Section 3206 for projections and appendages. For patio covers, see Appendix Chapter 31.

2603.12 Greenhouses. Approved plastics may be used in lieu of plain glass in greenhouses.

2603.13 Canopies. Plastic panels constructed of approved plastic materials may be installed in canopies erected over motor vehicle fuel-dispensing station fuel dispensers, provided the panels are located at least 10 feet (3048 mm) from any building on the same property and face yards or streets not less than 40 feet (12 192 mm) in width on the other sides. The aggregate area of plastics shall not exceed 1,000 square feet (92.9 m^2). The maximum area of any individual panel shall not exceed 100 square feet (9.3 m^2).

2603.14 Solar Collectors. Solar collectors having noncombustible sides and bottoms may be equipped with plastic covers on buildings not over three stories in height or 9,000 square feet (836.1 m^2) in total floor area, provided the plastic cover when exceeding a thickness of 0.010 inch (0.3 mm) shall be of approved plastic and the total area shall not exceed $33^{1}/_{3}$ percent of the roof area for CC1 materials or 25 percent of the roof area for CC2 materials.

EXCEPTION: Plastic covers having a thickness of 0.010 inch (0.3 mm) or less may be of any plastic, provided the total area of the collectors does not exceed $33^{1}/_{3}$ percent of the roof area.

SECTION 2604 — PLASTIC VENEER

2604.1 Interior Use. When used within a building, plastic veneer shall comply with the interior finish requirements of Chapter 8.

2604.2 Exterior Use. Exterior plastic veneer may be installed on the exterior walls of buildings of any type of construction in accordance with the following requirements:

1. Plastic veneer shall be of approved plastics materials as defined in Chapter 2.

2. Plastic veneer shall not be attached to any exterior wall to a height greater than 50 feet (15 240 mm) above grade.

3. Sections of plastic veneer shall not exceed 300 square feet (27.9 m^2) in area and shall be separated by a minimum of 4 feet (1219 mm) vertically.

EXCEPTION: The area and separation requirements and the smoke-density limitation are not applicable to plastic veneer applied to Type V-N buildings, provided the walls are not required to have a fire-resistive rating.

TABLE 26-A—AREA LIMITATION AND SEPARATION REQUIREMENTS FOR EXTERIOR WALL PANELS[1]

CLASS OF PLASTIC	MAXIMUM PERCENT AREA OF EXTERIOR WALLS IN PLASTIC PANELS	MAXIMUM SQUARE FEET SINGLE INDIVIDUAL PANELS	MAXIMUM PANEL HEIGHT (feet)	MINIMUM SEPARATION OF PANELS (feet)	
				× 304.8 for mm	
		× 0.093 for m^2	× 304.8 for mm	Vertical	Horizontal
CC1	25	100	16	6	4
CC2	15	75	8	8	4

[1]The maximum percent area of exterior walls limitation shall be based on the individual story wall area.

Chapter 27
ELECTRICAL SYSTEMS

SECTION 2701 — ELECTRICAL CODE

Electrical systems shall be in accordance with the Electrical Code. (See Section 206, Electrical Code.)

Chapter 28
MECHANICAL SYSTEMS

SECTION 2801 — MECHANICAL CODE

The installation and maintenance of heating, ventilating, product removal, cooling and refrigerating systems shall be in accordance with the Mechanical Code.

SECTION 2802 — REFRIGERATION SYSTEM MACHINERY ROOM

Refrigeration systems shall comply with the Mechanical Code. When a refrigeration machinery room is required, it shall be separated from the remainder of the building or located on the property as required for a Group H, Division 7 Occupancy, regardless of area. A horizontal occupancy separation may be limited to the actual floor area of the machinery room. Structural supporting elements shall be protected only for the type of construction and not the occupancy separation. Means of egress from the machinery room shall comply with Section 1007.7.2. Nothing contained herein shall be used to limit the height or area of the building or the machinery room. The refrigeration system, its refrigerant and its safety devices shall be maintained in accordance with the Fire Code.

Chapter 29
PLUMBING SYSTEMS

SECTION 2901 — PLUMBING CODE

Plumbing systems shall comply with the Plumbing Code.

SECTION 2902 — NUMBER OF FIXTURES

2902.1 General. The number of plumbing fixtures within a building shall not be less than set forth in Section 2902. Fixtures located within unisex toilet and bathing rooms shall be included in determining the number of fixtures provided in an occupancy.

2902.2 Group A Occupancies. In Group A Occupancies, at least one lavatory for each two water closets for each sex shall be provided at an approved location. At least one drinking fountain shall be provided at each floor level in an approved location.

EXCEPTION: A drinking fountain need not be provided in a drinking or dining establishment.

For other requirements on water closets, see Sections 807 and 2903. See Chapter 11 for access to water closets and drinking fountains.

2902.3 Groups B, F, H, M and S Occupancies. In Groups B, F, H, M and S Occupancies, buildings or portions thereof where persons are employed shall be provided with at least one water closet. Separate facilities shall be provided for each sex when the number of employees exceeds four. Such toilet facilities shall be located either in such building or conveniently in a building adjacent thereto on the same property.

Such water closet rooms in connection with food establishments where food is prepared, stored or served shall have a nonabsorbent interior finish as specified in Section 807.1, shall have hand-washing facilities therein or adjacent thereto, and shall be separated from food preparation or storage rooms as specified in Section 302.6.

For other requirements on water closets, see Section 2903.

2902.4 Group E Occupancies. Water closets shall be provided on the basis of the following ratio of water closets to the number of students:

	Boys	Girls
Elementary Schools	1:100	1:35
Secondary Schools	1:100	1:45

In addition, urinals shall be provided for boys on the basis of 1:30 in elementary and secondary schools.

There shall be provided at least one lavatory for each two water closets or urinals, and at least one drinking fountain on each floor for elementary and secondary schools.

For other requirements on water closets, see Sections 807 and 2903.

2902.5 Group I Occupancies. In Group I Occupancies, sanitation facilities for employees shall be provided as specified in Section 2902.3. Additional sanitation facilities shall be provided for other occupants when the facilities for employees are not accessible to such other occupants.

For other requirements on water closets, see Sections 807 and 2903.

2902.6 Group R Occupancies. Buildings classified as Group R Occupancies shall be provided with at least one water closet. Hotels or subdivisions thereof where both sexes are accommodated shall contain at least two separate toilet facilities that are conspicuously identified for male or female use, each of which contains at least one water closet.

EXCEPTION: Hotel guest rooms may have one unidentified toilet facility.

Additional water closets shall be provided on each floor for each sex at the rate of one for every additional 10 guests, or fractional part thereof, in excess of 10.

Dwelling units shall be provided with a kitchen equipped with a kitchen sink. Dwelling units, congregate residences and lodging houses shall be provided with a bathroom equipped with facilities consisting of a water closet, lavatory, and either a bathtub or shower. Each sink, lavatory, and either a bathtub or shower shall be equipped with hot and cold running water necessary for its normal operation.

For other requirements on water closets, see Sections 807 and 2903.

SECTION 2903 — ALTERNATE NUMBER OF FIXTURES

As an alternate to the minimum number of plumbing fixtures required by this chapter, see Appendix Chapter 29. When adopted, as set forth in Section 101.3, it will take precedence over the requirements of this chapter.

SECTION 2904 — ACCESS TO WATER CLOSET STOOL

The water closet stool in all occupancies shall be located in a clear space not less than 30 inches (762 mm) in width. The clear space in front of the water closet stool shall not be less than 24 inches (610 mm).

See Chapter 11 for requirements for water closets on floors required to be accessible to persons with disabilities.

Chapter 30
ELEVATORS, DUMBWAITERS, ESCALATORS AND MOVING WALKS

SECTION 3001 — SCOPE

The provisions of this chapter shall apply to the design, construction, installation, operation, alteration and repair of elevators, dumbwaiters, escalators and moving walks and their hoistways.

SECTION 3002 — ELEVATOR AND ELEVATOR LOBBY ENCLOSURES

Walls and partitions enclosing elevator and dumbwaiter hoistway shafts and escalator shafts shall not be of less than the fire-resistive construction required under Types of Construction in Chapter 6 of this code.

Elevator hoistway shaft enclosure walls not required to have a fire-resistive rating may be constructed with glass. Such glass shall be laminated glass that passes the test requirements of UBC Standard 24-2, Part I.

Elevator lobbies shall have at least one means of egress. The use of exit or exit-access doors shall not require keys, tools, or special knowledge or effort.

SECTION 3003 — SPECIAL PROVISIONS

3003.1 Number of Cars in Hoistway. When there are three or fewer elevator cars in a building, they may be located within the same hoistway enclosure. When there are four elevator cars, they shall be divided in such a manner that at least two separate hoistway enclosures are provided. When there are more than four elevators, not more than four elevator cars may be located within a single hoistway enclosure.

3003.2 Smoke-detection Recall. When the elevator vertical travel is 25 feet (7620 mm) or more, each associated elevator lobby or entrance area and associated machine rooms shall be provided with an approved, listed smoke detector for elevator recall purposes only. The detector may serve to close the elevator lobby door and additional doors at the hoistway opening allowed in Section 3006.

When the lobby or entrance area smoke detector, or machine room smoke detector, is activated, elevator doors shall be prevented from opening and all cars serving that lobby or entrance area, or served by equipment in that machine room, shall return to the main floor where they shall be under manual control only. If the main floor or transfer floor lobby or entrance-area smoke detector is activated, all cars serving the main floor or transfer floor shall return to a location approved by the chief of the fire department and building official where they shall be under manual control only.

3003.3 Standby Power. Standby power when required by Section 403 shall be provided to at least one elevator in each bank. Standby power shall be manually transferable to all elevators in each bank. Standby power shall be provided by an approved self-contained generator set to operate automatically whenever there is a loss of electrical power to the building. The generator set shall be located in a separate room enclosed by at least a one-hour fire-resistive occupancy separation. The generator shall have a fuel supply adequate to operate the equipment connected to it for a minimum of two hours.

EXCEPTIONS: 1. Where a single elevator serves all floor levels in the building and is located so that all areas of the building can be reached within a travel distance of 300 feet (91 440 mm) from the elevator, then only that elevator need be provided with standby power.

2. Standby power shall be capable of operating one elevator at a time in any bank or group of banks having a common lobby.

NOTE: A bank of elevators is a group of elevators or a single elevator controlled by a common operating system; that is, all those elevators that respond to a single call button constitute a bank of elevators. There is no limit on the number of cars that may be in a bank or group, but there may not be more than four cars within a common hoistway.

3003.4 Size of Cab and Control Locations.

3003.4.1 General. In buildings three or more stories in height served by an elevator or a building served by an elevator required by Chapter 11, at least one elevator serving all floors shall accommodate a wheelchair, in accordance with this section.

3003.4.2 Operation and leveling. The elevator shall be automatic and be provided with a self-leveling feature that will automatically bring the car to the floor landings within a tolerance of plus or minus $^1/_2$ inch (12.7 mm) under normal loading and unloading conditions. This self-leveling shall, within its zone, be entirely automatic and independent of the operating device and shall correct the overtravel or undertravel. The car shall also be maintained approximately level with the landing, irrespective of load.

3003.4.3 Door operation. Power-operated horizontally sliding car and hoistway doors opened and closed by automatic means shall be provided.

3003.4.4 Door size. Minimum clear width for elevator doors shall be 36 inches (914 mm).

EXCEPTION: When approved by the building official, the minimum door width may be reduced to 32 inches (813 mm) for a car with dimensions as permitted by the exception to Section 3003.4.7.

3003.4.5 Door protective and reopening device. Doors closed by automatic means shall be provided with a door-reopening device that will function to stop and reopen a car door and adjacent hoistway door in case the car door is obstructed while closing. This reopening device shall also be capable of sensing an object or person in the path of a closing door without requiring contact for activation at a nominal 5 inches and 29 inches (127 mm and 737 mm) above the floor.

Door-reopening devices shall remain effective for a period of not less than 20 seconds.

3003.4.6 Door delay (passenger service time).

3003.4.6.1 Hall call. The minimum acceptable time from notification that a car is answering a call (lantern and audible signal) until the doors of that car start to close shall be as indicated in the following table:

DISTANCE, feet (mm)	TIME (seconds)
0 to 5 (0 to 1524)	4
10 (3048)	7
15 (4572)	10
20 (6096)	13

The distance shall be established from a point in the center of the corridor or lobby [maximum 5 feet (1524 mm)] directly opposite the farthest hall button to the center line of the hoistway entrance.

3003.4.6.2 Car call. The minimum acceptable time for doors to remain fully open shall not be less than three seconds.

3003.4.7 Car inside. The car inside shall allow for the turning of a wheelchair. The minimum clear distance between walls or between wall and door, excluding return panels, shall not be less than 68 inches by 54 inches (1727 mm by 1372 mm). Minimum distance from wall to return panel shall not be less than 51 inches (1295 mm).

> **EXCEPTION:** When approved by the building official, elevators provided in schools, institutions or other buildings may have a minimum clear distance between walls or between wall and door, excluding return panels, of not less than 54 inches by 54 inches (1372 mm by 1372 mm). Minimum distance from wall to return panel shall not be less than 51 inches (1295 mm).

3003.4.8 Car controls. Controls shall be readily accessible from a wheelchair upon entering an elevator.

The center line of the alarm button and emergency stop switch shall be at a nominal 35 inches (889 mm), and the highest floor button no higher than 54 inches (1372 mm) from the floor. Floor registration buttons, exclusive of border, shall be a minimum $^3/_4$ inch (19.1 mm) in size, raised, flush or recessed. Visual indication shall be provided to show each call registered and extinguished when call is answered. Depth of flush or recessed buttons when operated shall not exceed $^3/_8$ inch (9.5 mm).

Markings shall be adjacent to the controls on a contrasting color background to the left of the controls. Letters or numbers shall be a minimum of $^5/_8$ inch (15.9 mm) high and raised or recessed 0.030 inch (0.8 mm).

Applied plates permanently attached shall be acceptable.

Emergency controls shall be grouped together at the bottom of the control panel.

Controls not essential to the automatic operation of the elevator may be located as convenient.

3003.4.9 Car position indicator and signal. A car position indicator shall be provided above the car operating panel or over the opening of each car to show the position of the car in the hoistway by illumination of the indication corresponding to the landing at which the car is stopped or passing.

Indications shall be on a contrasting color background and a minimum of $^1/_2$ inch (12.7 mm) in height.

In addition, an audible signal shall sound to tell a passenger that the car is stopping or passing a floor served by the elevator.

A special button located with emergency controls may be provided. Operation of the button will activate an audible signal only for the desired trip.

3003.4.10 Telephone or intercommunicating system. A means of two-way communication shall be provided between the elevator and a point outside the hoistway.

If a telephone is provided, it shall be located a maximum of 54 inches (1372 mm) from the floor with a minimum cord length of 29 inches (737 mm). Markings or the international symbol for telephones shall be adjacent to the control on a contrasting color background. Letters or numbers shall be a minimum of $^5/_8$ inch (15.9 mm) high and raised or recessed 0.030 inch (0.8 mm).

Applied plates permanently attached shall be acceptable.

3003.4.11 Floor covering. Floor covering shall have a nonslip hard surface that permits easy movement of wheelchairs.

If carpeting is used, it shall be securely attached, heavy duty, with a tight weave and low pile, installed without padding.

3003.4.12 Handrails. A handrail shall be provided on one wall of the car, preferably the rear. The rails shall be smooth and the inside surface at least $1^1/_2$ inches (38 mm) clear of the walls at a nominal height of 32 inches (813 mm) from the floor.

Nominal = ± 1 inch (25 mm).

> **NOTE:** Thirty-two inches (813 mm) required to reduce interference with car controls where lowest button is centered at 35 inches (889 mm) above floor.

3003.4.13 Minimum illumination. The minimum illumination at the car controls and the landing when the car and landing doors are open shall not be less than 5 footcandles (54 lx).

3003.4.14 Hall buttons. The center line of the hall call buttons shall be a nominal 42 inches (1067 mm) above the floor.

Direction buttons, exclusive of border, shall be a minimum of $^3/_4$ inch (19.1 mm) in size, raised, flush or recessed. Visual indication shall be provided to show each call registered and extinguished when the call is answered. Depth of flush or recessed button when operated shall not exceed $^3/_8$ inch (9.5 mm).

3003.4.15 Hall lantern. A visual and audible signal shall be provided at each hoistway entrance indicating to the prospective passenger the car answering the call and its direction of travel.

The visual signal for each direction shall be a minimum of $2^1/_2$ inches (64 mm) in size and visible from the proximity of the hall call button.

The audible signal shall sound once for the up direction and twice for the down direction.

The center line of the fixture shall be located a minimum of 6 feet (1829 mm) from the floor.

The use of in-car lanterns conforming to the above and located in jamb shall be acceptable.

3003.4.16 Doorjamb marking. The floor designation shall be provided at each hoistway entrance on both sides of jamb visible from within the car and the elevator lobby at a height of 60 inches (1524 mm) above the floor. Designations shall be on a contrasting background 2 inches (51 mm) high and raised 0.030 inch (0.8 mm).

Applied plates permanently attached shall be acceptable.

3003.5 Stretcher Requirements. In all structures four or more stories in height, at least one elevator shall be provided with a minimum clear distance between walls or between walls and door excluding return panels, of not less than 80 inches by 54 inches (2032 mm by 1372 mm), and a minimum distance from wall to return panel of not less than 51 inches (1295 mm) with a 42-inch (1067 mm) side slide door, unless otherwise designed to accommodate an ambulance-type stretcher 76 inches (1930 mm) by 24 inches (610 mm) in the horizontal position.

In buildings where one elevator does not serve all floors, two or more elevators may be used. The elevators shall be identified by the international symbol for emergency medical services (Star of Life). The symbol shall not be less than 3 inches (76 mm) and placed inside on both sides of the hoistway door frame. The symbol shall be placed no lower than 78 inches (1981 mm) from the floor level or higher than 84 inches (2134 mm) from floor level.

3003.6 Emergency Signs. Except at the main entrance level, an approved pictorial sign of a standardized design shall be posted adjacent to each elevator call station to indicate that, in case of fire, the elevator will not operate and that exit stairways should be used.

3003.7 Restricted or Limited-use Elevators. The building official may waive the requirements of this section for any elevator designed for limited or restricted use serving only specific floors or a specific function.

SECTION 3004 — HOISTWAY VENTING

Shafts (hoistways) housing elevators extending through more than two floor levels shall be vented to the outside. The area of the vent shall not be less than $3^1/_2$ percent of the area of the elevator shaft, provided a minimum of 3 square feet (0.279 m^2) per elevator is provided. Vents shall be capable of manual operation only.

The venting of each individual hoistway shall be independent from any other hoistway venting, and the interconnection of separate hoistways for the purpose of venting is prohibited.

SECTION 3005 — ELEVATOR MACHINE ROOM

3005.1 Operation of Solid-state Equipment. When solid-state equipment is used to operate the elevators, the elevator equipment room shall be provided with an independent ventilation or air-conditioning system to prevent overheating of the electrical equipment. The operating temperature shall be established by the elevator equipment manufacturer's specification. When standby power is connected to elevators, the machine room ventilation or air conditioning shall be connected to standby.

3005.2 Detection. The elevator machine room serving a pressurized elevator hoistway shall be pressurized upon activation of a heat or smoke detector located in the elevator machine room. See Section 905, Smoke Control.

SECTION 3006 — CHANGE IN USE

Any change in use of an elevator, freight to passenger, passenger to freight, or from one freight class to another, shall not be made without the approval of the building official. Said approval shall be granted only after it is demonstrated that the installation conforms to the requirements in the Elevator Code.

SECTION 3007 — ADDITIONAL DOORS

Doors other than the hoistway door and the elevator car door shall be prohibited at the point of access to an elevator car.

EXCEPTION: Doors that are readily openable from the car side without a key, tool, or special knowledge or effort.

Chapter 31
SPECIAL CONSTRUCTION

SECTION 3101 — SCOPE

The provisions of this chapter shall apply to special construction described herein.

SECTION 3102 — CHIMNEYS, FIREPLACES AND BARBECUES

3102.1 Scope. Chimneys, flues, fireplaces and barbecues, and their connections, carrying products of combustion shall conform to the requirements of this section.

3102.2 Definitions.

BARBECUE is a stationary open hearth or brazier, either fuel fired or electric, used for food preparation.

CHIMNEY is a hollow shaft containing one or more passageways, vertical or nearly so, for conveying products of combustion to the outside atmosphere.

CHIMNEY CLASSIFICATIONS:

Chimney, High-heat Industrial Appliance-type, is a factory-built, masonry or metal chimney suitable for removing the products of combustion from fuel-burning high-heat appliances producing combustion gases in excess of 2,000°F (1093°C) measured at the appliance flue outlet.

Chimney, Low-heat Industrial Appliance-type, is a factory-built, masonry or metal chimney suitable for removing the products of combustion from fuel-burning low-heat appliances producing combustion gases not in excess of 1,000°F (538°C) under normal operating conditions but capable of producing combustion gases of 1,400°F (760°C) during intermittent forced firing for periods up to one hour. All temperatures are measured at the appliance flue outlet.

Chimney, Medium-heat Industrial Appliance-type, is a factory-built, masonry or metal chimney suitable for removing the products of combustion from fuel-burning medium-heat appliances producing combustion gases not in excess of 2,000°F (1093°C) measured at the appliance flue outlet.

Chimney, Residential Appliance-type, is a factory-built or masonry chimney suitable for removing products of combustion from residential-type appliances producing combustion gases not in excess of 1,000°F (538°C) measured at the appliance flue outlet.

CHIMNEY CONNECTOR is the pipe or breeching that connects a fuel-burning appliance to a chimney. (See Mechanical Code, Chapter 9.)

CHIMNEY, FACTORY-BUILT, is a chimney manufactured at a location other than the building site and composed of listed factory-built components assembled in accordance with the terms of the listing to form the completed chimney.

CHIMNEY LINER is a lining material of fireclay or approved refractory brick. For recognized standards on fireclay refractory brick see Sections 3503 and 3504; ASTM C 27, Fireclay and High-Alumina Refractory Brick; or ASTM C 1261, Firebox Brick for Residential Fireplaces.

FIREBRICK is a refractory brick.

FIREPLACE is a hearth and fire chamber or similar prepared place in which a fire may be made and which is built in conjunction with a chimney.

Factory-built Fireplace is a listed assembly of a fire chamber, its chimney and related factory-made parts designed for unit assembly without requiring field construction. Factory-built fireplaces are not dependent on mortar-filled joints for continued safe use.

Masonry Fireplace is a hearth and fire chamber of solid masonry units such as bricks, stones, masonry units or reinforced concrete provided with a suitable chimney.

MASONRY CHIMNEY is a chimney of masonry units, bricks, stones or listed masonry chimney units lined with approved flue liners. For the purpose of this chapter, masonry chimneys shall include reinforced concrete chimneys.

3102.3 Chimneys, General.

3102.3.1 Chimney support. Chimneys shall be designed, anchored, supported and reinforced as required in this chapter and applicable provisions of Chapters 16, 18, 19, 21 and 22 of this code. A chimney shall not support any structural load other than its own weight unless designed as a supporting member.

3102.3.2 Construction. Each chimney shall be so constructed as to safely convey flue gases not exceeding the maximum temperatures for the type of construction as set forth in Table 31-B and shall be capable of producing a draft at the appliance not less than that required for safe operation.

3102.3.3 Clearance. Clearance to combustible material shall be as required by Table 31-B.

3102.3.4 Lining. When required by Table 31-B, chimneys shall be lined with clay flue tile, firebrick, molded refractory units or other approved lining not less than $^5/_8$ inch (15.9 mm) thick as set forth in Table 31-B. Chimney liners shall be carefully bedded in approved medium-duty refractory mortar with close-fitting joints left smooth on the inside. Medium-duty fractory motor shall be in accordance with Sections 3503, 3504 and ASTM C 199.

3102.3.5 Area. The minimum net cross-sectional area of the chimney flue for fireplaces shall be determined in accordance with Figure 31-1. The minimum cross-sectional area shown or a flue size providing equivalent net cross-sectional area shall be used. The height of the chimney shall be measured from the firebox floor to the top of the last chimney flue tile. Chimney passageways for low-heat chimneys and incinerators shall not be smaller in area than the vent connection on the appliance attached thereto or not less than that set forth in Table 31-A.

> **EXCEPTION:** Chimney passageways designed by engineering methods approved by the building official.

3102.3.6 Height and termination. Every chimney shall extend above the roof and the highest elevation of any part of a building as shown in Table 31-B. For altitudes over 2,000 feet (610 m), the building official shall be consulted in determining the height of the chimney.

3102.3.7 Cleanouts. Cleanout openings shall be provided within 6 inches (152 mm) of the base of every masonry chimney.

3102.3.8 Spark arrester. Where determined necessary by the building official due to local climatic conditions or where sparks escaping from the chimney would create a hazard, chimneys attached to any appliance or fireplace that burns solid fuel shall be equipped with an approved spark arrester. The net free area of the spark arrester shall not be less than four times the net free area of the outlet of the chimney. The spark arrester screen shall have heat and corrosion resistance equivalent to 0.109-inch (2.77 mm) (No. 12 B.W. gage) wire, 0.042-inch (1.07 mm) (No. 19 B.W. gage) galvanized wire or 0.022-inch (0.56 mm) (No. 24 B.W. gage) stainless steel. Openings shall not permit the passage of spheres having a diameter larger than $^1/_2$ inch (12.7 mm) and shall not block the passage of spheres having a diameter of less than $^3/_8$ inch (9.5 mm).

Chimneys used with fireplaces or heating appliances in which solid or liquid fuel is used shall be provided with a spark arrester as required in the Fire Code.

EXCEPTION: Chimneys that are located more than 200 feet (60 960 mm) from any mountainous, brush-covered or forest-covered land or land covered with flammable material and that are not attached to a structure having less than a Class C roof covering, as set forth in Chapter 15.

3102.4 Masonry Chimneys.

3102.4.1 Design. Masonry chimneys shall be designed and constructed to comply with Sections 3102.3.2 and 3102.4.2.

3102.4.2 Walls. Walls of masonry chimneys shall be constructed as set forth in Table 31-B.

3102.4.3 Reinforcing and seismic anchorage. Unless a specific design is provided, every masonry or concrete chimney in Seismic Zones 2, 3 and 4 shall be reinforced with not less than four No. 4 steel reinforcing bars conforming to the provisions of Chapter 19 or 21 of this code. The bars shall extend the full height of the chimney and shall be spliced in accordance with the applicable requirements of Chapter 19 or 21. In masonry chimneys, the vertical bars shall have a minimum cover of $^1/_2$ inch (12.7 mm) of grout or mortar tempered to a pouring consistency. The bars shall be tied horizontally at 18-inch (457 mm) intervals with not less than $^1/_4$-inch-diameter (6.4 mm) steel ties. The slope of the inclined portion of the offset in vertical bars shall not exceed 2 units vertical in 1 unit horizontal (200% slope). Two ties shall also be placed at each bend in vertical bars. Where the width of the chimney exceeds 40 inches (1016 mm), two additional No. 4 vertical bars shall be provided for each additional flue incorporated in the chimney or for each additional 40 inches (1016 mm) in width or fraction thereof.

In Seismic Zones 2, 3 and 4, all masonry and concrete chimneys shall be anchored at each floor or ceiling line more than 6 feet (1829 mm) above grade, except when constructed completely within the exterior walls of the building. Anchorage shall consist of two $^3/_{16}$-inch-by-1-inch (4.8 mm by 25 mm) steel straps cast at least 12 inches (305 mm) into the chimney with a 180-degree bend with a 6-inch (152 mm) extension around the vertical reinforcing bars in the outer face of the chimney.

Each strap shall be fastened to the structural framework of the building with two $^1/_2$-inch-diameter (12.7 mm) bolts per strap. Where the joists do not head into the chimney, the anchor strap shall be connected to 2-inch-by-4-inch (51 mm by 102 mm) ties crossing a minimum of four joists. The ties shall be connected to each joist with two 16d nails. As an alternative to the 2-inch-by-4-inch (51 mm by 102 mm) ties, each anchor strap shall be connected to the structural framework by two $^1/_2$-inch-diameter (12.7 mm) bolts in an approved manner.

3102.4.4 Chimney offset. Masonry chimneys may be offset at a slope of not more than 4 units vertical in 24 units horizontal (16.7% slope), but not more than one third of the dimension of the chimney, in the direction of the offset. The slope of the transition from the fireplace to the chimney shall not exceed 2 units vertical in 1 unit horizontal (200% slope).

3102.4.5 Change in size or shape. Masonry chimneys shall not change in size or shape within 6 inches (152 mm) above or below any combustible floor, ceiling or roof component penetrated by the chimney.

3102.4.6 Separation of masonry chimney passageways. Two or more flues in a chimney shall be separated by masonry not less than 4 inches (102 mm) thick bonded into the masonry wall of the chimney.

3102.4.7 Inlets. Every inlet to any masonry chimney shall enter the side thereof and shall not be of less than $^1/_8$-inch-thick (3.2 mm) metal or $^5/_8$-inch-thick (15.9 mm) refractory material. Where there is no other opening below the inlet other than the cleanout, a masonry plug shall be constructed in the chimney not more than 16 inches (406 mm) below the inlet and the cleanout shall be located where it is accessible above the plug. If the plug is located less than 6 inches (152 mm) below the inlet, the inlet may serve as the cleanout.

3102.5 Factory-built Chimneys and Fireplaces.

3102.5.1 General. Factory-built chimneys and factory-built fireplaces shall be listed and shall be installed in accordance with the terms of their listings and the manufacturer's instructions as specified in the Mechanical Code.

3102.5.2 Hearth extensions. Hearth extensions of listed factory-built fireplaces shall conform to the conditions of listing and the manufacturer's installation instructions.

3102.5.3 Multiple venting in vertical shafts. Factory-built chimneys utilized with listed factory-built fireplaces may be used in a common vertical shaft having the required fire-resistance rating.

3102.6 Metal Chimneys. Metal chimneys shall be constructed and installed to meet the requirements of the Mechanical Code.

Metal chimneys shall be anchored at each floor and roof with two $1^1/_2$-inch-by-$^1/_8$-inch (38 mm by 3.2 mm) metal straps looped around the outside of the chimney installation and nailed with not less than six 8d nails per strap at each joist.

3102.7 Masonry and Concrete Fireplaces and Barbecues.

3102.7.1 General. Masonry fireplaces, barbecues, smoke chambers and fireplace chimneys shall be of masonry or reinforced concrete and shall conform to the requirements of this section.

3102.7.2 Support. Masonry fireplaces shall be supported on foundations designed as specified in Chapters 16, 18 and 21.

When an approved design is not provided, foundations for masonry and concrete fireplaces shall not be less than 12 inches (305 mm) thick, extend not less than 6 inches (152 mm) outside the fireplace wall and project below the natural ground surface in accordance with the depth of foundations set forth in Table 18-I-C.

3102.7.3 Fireplace walls. Masonry walls of fireplaces shall not be less than 8 inches (203 mm) in thickness. Walls of fireboxes shall not be less than 10 inches (254 mm) in thickness, except that where a lining of firebrick is used, such walls shall not be less than a total of 8 inches (203 mm) in thickness. The firebox shall not be less than 20 inches (508 mm) in depth. Joints in firebrick shall not exceed $^1/_4$ inch (6.4 mm).

EXCEPTION: For Rumford fireplaces, the depth may be reduced to 12 inches (305 mm) when

1. The depth is at least one third the width of the fireplace opening.

2. The throat is at least 12 inches (305 mm) above the lintel and is at least $^1/_{20}$ of the cross-sectional area of the fireplace opening.

3102.7.4 Hoods. Metal hoods used as part of a fireplace or barbecue shall not be less than 0.036-inch (0.92 mm) (No. 19 carbon sheet steel gage) copper, galvanized steel or other equivalent corrosion-resistant ferrous metal with all seams and connections of smokeproof unsoldered constructions. The hoods shall be sloped at an angle of 45 degrees or less from the vertical and shall extend horizontally at least 6 inches (152 mm) beyond the limits of the firebox. Metal hoods shall be kept a minimum of 18 inches (457 mm) from combustible materials unless approved for reduced clearances.

3102.7.5 Metal heat circulators. Approved metal heat circulators may be installed in fireplaces.

3102.7.6 Smoke chamber. Front and side walls shall not be less than 8 inches (203 mm) in thickness. Smoke chamber back walls shall not be less than 6 inches (152 mm) in thickness. A minimum $^5/_8$-inch-thick (16 mm) clay flue lining, complying with Sections 3503, 3504 and ASTM C 315, shall be permitted to form the inside surface of the 8-inch (203 mm) and 6-inch (152 mm) smoke chamber walls.

3102.7.7 Chimneys. Chimneys for fireplaces shall be constructed as specified in Sections 3102.3, 3102.4 and 3102.5 for residential-type appliances.

3102.7.8 Clearance to combustible material. Combustible materials shall not be placed within 2 inches (51 mm) of fireplace, smoke chamber or chimney walls. Combustible material shall not be placed within 6 inches (152 mm) of the fireplace opening. No such combustible material within 12 inches (305 mm) of the fireplace opening shall project more than $^1/_8$ inch (3.2 mm) for each 1-inch (25 mm) clearance from such opening.

No part of metal hoods used as part of a fireplace or barbecue shall be less than 18 inches (457 mm) from combustible material. This clearance may be reduced to the minimum requirements specified in the Mechanical Code.

3102.7.9 Areas of flues, throats and dampers. The throat shall be at least 8 inches (203 mm) above the fireplace opening and shall be at least 4 inches (102 mm) in depth. The net cross-sectional area of the flue and of the throat between the firebox and the smoke chamber of a fireplace shall not be less than that set forth in Figure 31-1 or Table 31-A. Metal dampers equivalent to not less than 0.097-inch (2.46 mm) (No. 12 carbon sheet metal gage) steel shall be installed. When fully opened, damper openings shall not be less than 90 percent of the required flue area.

3102.7.10 Lintel. Masonry over the fireplace opening shall be supported by a noncombustible lintel unless the masonry is self-supporting.

3102.7.11 Hearth. Masonry fireplaces shall be provided with a brick, concrete, stone or other approved noncombustible hearth slab. This slab shall not be less than 4 inches (102 mm) thick and shall be supported by noncombustible materials or reinforced to carry its own weight and all imposed loads. Combustible forms and centering shall be removed.

3102.7.12 Hearth extensions. Hearths shall extend at least 16 inches (406 mm) from the front of, and at least 8 inches (203 mm) beyond each side of, the fireplace opening. Where the fireplace opening is 6 square feet (0.56 m^2) or larger, the hearth extension shall extend at least 20 inches (508 mm) in front of, and at least 12 inches (305 mm) beyond each side of, the fireplace opening.

Except for fireplaces that open to the exterior of the building, the hearth slab shall be readily distinguishable from the surrounding or adjacent floor.

3102.7.13 Fire blocking. Fire blocking between chimneys and combustible construction shall meet the requirements specified in Section 708.

SECTION 3103 — TEMPORARY BUILDINGS OR STRUCTURES

Temporary buildings or structures such as reviewing stands and other miscellaneous structures, sheds, canopies or fences used for the protection of the public around and in conjunction with construction work may be erected by special permit from the building official for a limited period of time. Such buildings or structures need not comply with the type of construction or fire-resistive time periods required by this code. Temporary buildings or structures shall be completely removed upon the expiration of the time limit stated in the permit.

TABLE 31-A—MINIMUM PASSAGEWAY AREAS FOR MASONRY CHIMNEYS[1]

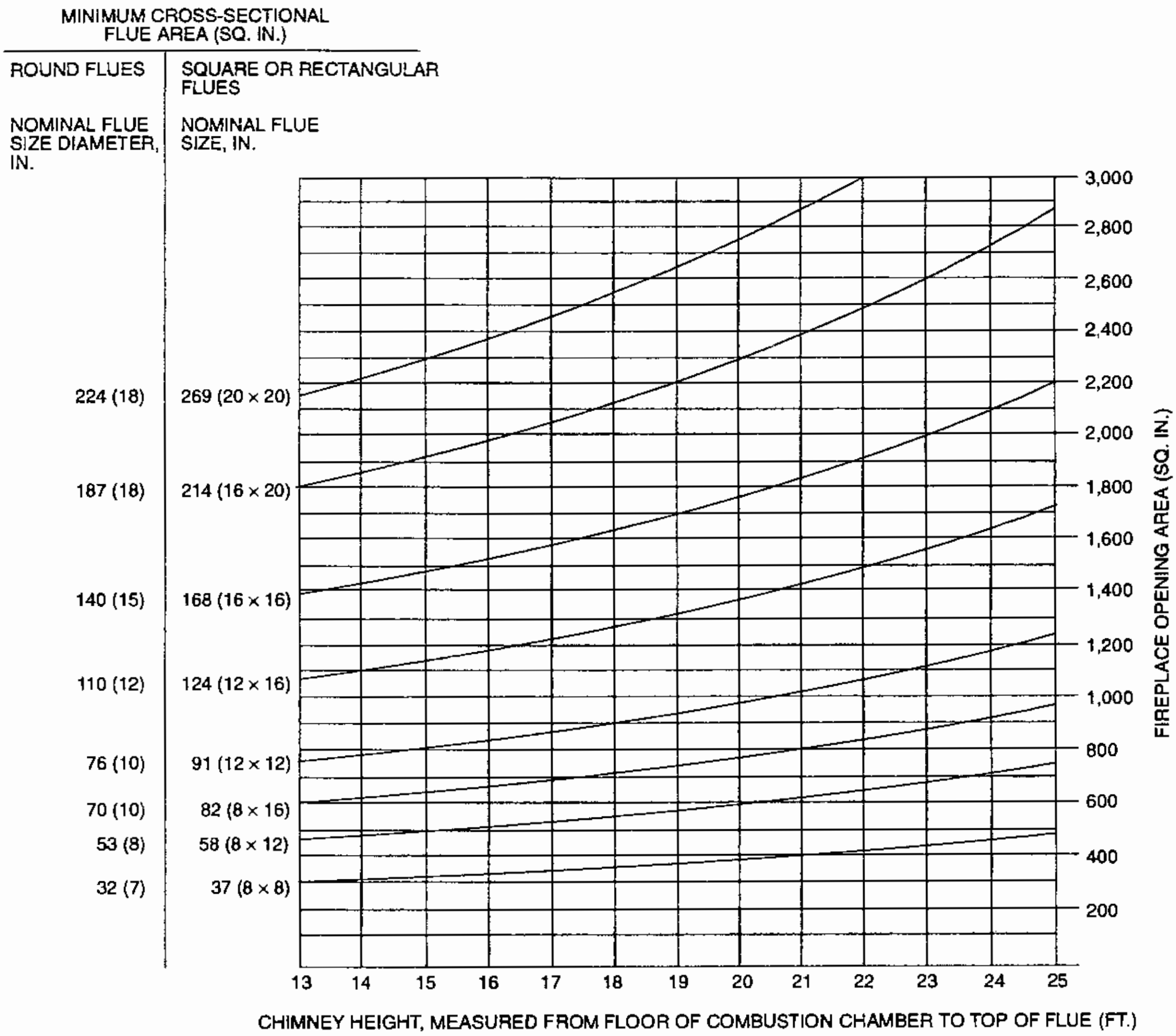
Type of Masonry Chimney	MINIMUM CROSS-SECTIONAL AREA × 645 for mm² — Tile Lined: Round	Tile Lined: Square or Rectangle	Lined with Firebrick or Unlined
1. Residential (other than fireplaces)	50 square inches	50 square inches	85 square inches
2. Fireplace	See Figure 31-1	See Figure 31-1	$^1/_8$ of opening minimum 100 square inches
3. Low heat	50 square inches	57 square inches	135 square inches
4. Incinerator Apartment type			Not applicable
1 opening	196 square inches		
2 to 6 openings	324 square inches		
7 to 14 openings	484 square inches		
15 or more openings	484 square inches plus 10 square inches for each additional opening		

NOTE: For altitudes over 2,000 feet (610 m) above sea level, the building official shall be consulted in determining the area of the passageway.
[1]Areas for medium- and high-heat chimneys shall be determined using accepted engineering methods and as approved by the building official.

TABLE 31-B—CONSTRUCTION, CLEARANCE AND TERMINATION REQUIREMENTS FOR MASONRY AND CONCRETE CHIMNEYS

CHIMNEYS SERVING	THICKNESS (min. inches) × 25.4 for mm		HEIGHT ABOVE ROOF OPENING (feet)	HEIGHT ABOVE ANY PART OF BUILDING WITHIN (feet) × 304.8 for mm			CLEARANCE TO COMBUSTIBLE CONSTRUCTION (inches) × 25.4 for mm	
	Walls	Lining	× 304.8 for mm	10	25	50	Int. inst.	Ext. inst.
1. **RESIDENTIAL-TYPE APPLIANCES**[1,2] (Low Btu input) Clay, shale or concrete brick Reinforced concrete Hollow masonry units Stone Unburned clay units	 4[3] 4[3] 4[4] 12 8	 5/8 fire-clay tile or 2 firebrick 4 1/2 firebrick	2	2			2	1 or 1/2 gypsum[5]
2. **BUILDING HEATING AND INDUSTRIAL-TYPE LOW-HEAT APPLIANCES**[1,2] [1,000°F (538°C) operating temp.—1,400°F (760°C) maximum] Clay, shale or concrete brick Hollow masonry units Reinforced concrete Stone	8 8[4] 8 12	5/8 fire-clay tile or 2 firebrick	3	2			2	2
3. **MEDIUM-HEAT INDUSTRIAL-TYPE APPLIANCES**[1,6] [2,000°F (1093°C) maximum] Clay, shale or concrete brick Hollow masonry units (Grouted solid) Reinforced concrete Stone	 8 8 8 12	4 1/2 medium-duty firebrick	10		10		4	4
4. **HIGH-HEAT INDUSTRIAL-TYPE APPLIANCES**[1,6] [Over 2,000°F (1093°C)] Clay, shale or concrete brick Hollow masonry units (Grouted solid) Reinforced concrete	 16[7] 16[7] 16[7]	4 1/2 high-duty firebrick	20			20	8	8
5. **RESIDENTIAL-TYPE INCINERATORS**	Same as for residential-type appliances as shown above.							
6. **CHUTE-FED AND FLUE-FED INCINERATORS WITH COMBINED HEARTH AND GRATE AREA 7 SQ. FT. (0.65 m²) OR LESS** Clay, shale or concrete brick or hollow units Portion extending to 10 ft. (3048 mm) above combustion chamber roof Portion more than 10 ft. (3048 mm) above combustion chamber roof	 4 8	4 1/2 medium-duty firebrick 5/8 fire-clay tile liner	3	2			2	2
7. **CHUTE-FED AND FLUE-FED INCINERATORS—COMBINED HEARTH AND GRATE AREAS LARGER THAN 7 SQ. FT.** (0.65 m²) Clay, shale or concrete brick or hollow units grouted solid or reinforced concrete Portion extending to 40 ft. (12 192 mm) above combustion chamber roof Portion more than 40 ft. (12 192 mm) above combustion chamber roof Reinforced concrete	 4 8 8	4 1/2 medium-duty firebrick 5/8 fire-clay tile liner 4 1/2 medium-duty firebrick laid in medium-duty refract mortar		10			2	2
8. **COMMERCIAL OR INDUSTRIAL-TYPE INCINERATORS**[2] Clay or shale solid brick Reinforced concrete	 8 8	4 1/2 medium-duty firebrick laid in medium-duty refract mortar		10			4	4

[1]See Table 8-B of the Mechanical Code for types of appliances allowed with each type of chimney.
[2]Lining shall extend from bottom to top of chimney.
[3]Chimneys having walls 8 inches (203 mm) or more in thickness may be unlined.
[4]Equivalent thickness including grouted cells when grouted solid. The equivalent thickness may also include the grout thickness between the liner and masonry unit.
[5]Chimneys for residential-type appliances installed entirely on the exterior of the building. For fireplace and barbecue chimneys, see Section 3102.7.8.
[6]Lining to extend from 24 inches (610 mm) below connector to 25 feet (7620 mm) above.
[7]Two 8-inch (203 mm) walls with 2-inch (51 mm) airspace between walls. Outer and inner walls may be of solid masonry units or reinforced concrete or any combination thereof.
[8]Clearance shall be approved by the building official and shall be such that the temperature of combustible materials will not exceed 160°F (710°C).



For SI: 1 inch = 25.4 mm, 1 square inch = 654.16 mm^2, 1 foot = 304.8 mm.

FIGURE 31-1—FLUE SIZES FOR MASONRY CHIMNEYS[1]

[1]The smaller flue area shall be utilized where the fireplace opening area and the chimney height selected intersect between flue area curves.

Chapter 32
CONSTRUCTION IN THE PUBLIC RIGHT OF WAY

SECTION 3201 — GENERAL

No part of any structure or any appendage thereto, except signs, shall project beyond the property line of the building site, except as specified in this chapter.

Structures or appendages regulated by this code shall be constructed of materials as specified in Section 705.

The projection of any structure or appendage shall be the distance measured horizontally from the property line to the outermost point of the projection.

Nothing in this code shall prohibit the construction and use of a structure between buildings and over or under a public way, provided the structure complies with all requirements of this code.

No provisions of this chapter shall be construed to permit the violation of other laws or ordinances regulating the use and occupancy of public property.

SECTION 3202 — PROJECTION INTO ALLEYS

No part of any structure or any appendage thereto shall project into any alley.

EXCEPTIONS: 1. A curb or buffer block may project not more than 9 inches (229 mm) and not exceed a height of 9 inches (229 mm) above grade.

2. Footings located at least 8 feet (2438 mm) below grade may project not more than 12 inches (305 mm).

SECTION 3203 — SPACE BELOW SIDEWALK

The space adjoining a building below a sidewalk on public property may be used and occupied in connection with the building for any purpose not inconsistent with this code or other laws or ordinances regulating the use and occupancy of such spaces on condition that the right to so use and occupy may be revoked by the city at any time and that the owner of the building will construct the necessary walls and footings to separate such space from the building and pay all costs and expenses attendant therewith.

Footings located at least 8 feet (2438 mm) below grade may project not more than 12 inches (305 mm).

SECTION 3204 — BALCONIES, SUN-CONTROL DEVICES AND APPENDAGES

Oriel windows, balconies, sun-control devices, unroofed porches, cornices, belt courses and appendages such as water tables, sills, capitals, bases and architectural projections may project over the public property of the building site a distance as determined by the clearance of the lowest point of the projection above the grade immediately below, as follows:

Clearance above grade less than 8 feet (2438 mm)—no projection is permitted.

Clearance above grade over 8 feet (2438 mm)—1 inch (25 mm) of projection is permitted for each additional inch of clearance, provided that no such projection shall exceed a distance of 4 feet (1219 mm).

SECTION 3205 — MARQUEES

3205.1 General. For the purpose of this section, a marquee shall include any object or decoration attached to or a part of said marquee.

3205.2 Projection and Clearance. The horizontal clearance between a marquee and the curb line shall not be less than 2 feet (610 mm).

A marquee projecting more than two thirds of the distance from the property line to the curb line shall not be less than 12 feet (3658 mm) above the ground or pavement below.

A marquee projecting less than two thirds of the distance from the property line to the curb line shall not be less than 8 feet (2438 mm) above the ground or pavement below.

3205.3 Length. A marquee projecting more than two thirds of the distance from the property line to the curb line shall not exceed 25 feet (7620 mm) in length along the direction of the street.

3205.4 Thickness. The maximum height or thickness of a marquee measured vertically from its lowest to its highest point shall not exceed 3 feet (914 mm) when the marquee projects more than two thirds of the distance from the property line to the curb line and shall not exceed 9 feet (2743 mm) when the marquee is less than two thirds of the distance from the property line to the curb line.

3205.5 Construction. A marquee shall be supported entirely by the building and constructed of noncombustible material or, when supported by a building of Type V construction, may be of one-hour fire-resistive construction.

3205.6 Roof Construction. The roof or any part thereof may be a skylight, provided glass skylights are of laminated or wired glass complying with Section 2409. Plastic skylights shall comply with Section 2603.7.

Every roof and skylight of a marquee shall be sloped to downspouts that shall conduct any drainage from the marquee under the sidewalk to the curb.

3205.7 Location Prohibited. Every marquee shall be so located as not to interfere with the operation of any exterior standpipe or to obstruct the clear passage of a means of egress from the building or the installation or maintenance of electroliers.

SECTION 3206 — AWNINGS

3206.1 Definition. For the purpose of this section:

AWNING is a shelter supported entirely from the exterior wall of a building.

3206.2 Construction. Awnings shall have noncombustible frames but may have combustible coverings. Awnings shall be either fixed, retractable, folding or collapsible. Awnings in any configuration shall not obstruct the use of a required means of egress.

3206.3 Projection. Awnings may extend over public property not more than 7 feet (2134 mm) from the face of a supporting building, but no portion shall extend nearer than 2 feet (610 mm) to the face of the nearest curb line measured horizontally. In no case shall the awning extend over public property greater than two thirds of the distance from the property line to the nearest curb in front of the building site.

3206.4 Clearances. All portions of any awning shall be at least 8 feet (2438 mm) above any public walkway.

> **EXCEPTION:** Any valance attached to an awning shall not project above the roof of the awning at the point of attachment and shall not extend more than 12 inches (305 mm) below the roof of the awning at the point of attachment, but in no case shall any portion of a valance be less than 7 feet (2134 mm) in height above a public way.

SECTION 3207 — DOORS

Power-operated doors and their guide rails shall not project over public property. Other doors, either fully opened or when opening, shall not project more than 1 foot (305 mm) beyond the property line, except that in alleys no projection beyond the property line is permitted.

Chapter 33
SITE WORK, DEMOLITION AND CONSTRUCTION

SECTION 3301 — EXCAVATIONS AND FILLS

3301.1 General. Excavation or fills for buildings or structures shall be so constructed or protected that they do not endanger life or property.

Slopes for permanent fills shall not be steeper than 1 unit vertical in 2 units horizontal (50% slope). Cut slopes for permanent excavations shall not be steeper than 1 unit vertical in 2 units horizontal (50% slope) unless substantiating data justifying steeper cut slopes are submitted. Deviation from the foregoing limitations for cut slopes shall be permitted only upon the presentation of a soil investigation report acceptable to the building official.

No fill or other surcharge loads shall be placed adjacent to any building or structure unless such building or structure is capable of withstanding the additional loads caused by the fill or surcharge.

Existing footings or foundations that may be affected by any excavation shall be underpinned adequately or otherwise protected against settlement and shall be protected against lateral movement.

For footings on adjacent slopes, see Section 1806.5.

Fills to be used to support the foundations of any building or structure shall be placed in accordance with accepted engineering practice. A soil investigation report and a report of satisfactory placement of fill, both acceptable to the building official, shall be submitted.

Where applicable (see Section 101.3), see Appendix Chapter 33 for excavation and grading.

3301.2 Protection of Adjoining Property. The requirements for protection of adjacent property and depth to which protection is required shall be as defined by prevailing law. Where not defined by law, the following shall apply: Any person making or causing an excavation to be made to a depth of 12 feet (3658 mm) or less below the grade shall protect the excavation so that the soil of adjoining property will not cave in or settle, but shall not be liable for the expense of underpinning or extending the foundation of buildings on adjoining properties when the excavation is not in excess of 12 feet (3658 mm) in depth. Before commencing the excavation, the person making or causing the excavation to be made shall notify in writing the owners of adjoining buildings not less than 10 days before such excavation is to be made that the excavation is to be made and that the adjoining buildings should be protected.

The owners of the adjoining properties shall be given access to the excavation for the purpose of protecting such adjoining buildings.

Any person making or causing an excavation to be made exceeding 12 feet (3658 mm) in depth below the grade shall protect the excavation so that the adjoining soil will not cave in or settle and shall extend the foundation of any adjoining buildings below the depth of 12 feet (3658 mm) below grade at the expense of the person causing or making the excavation. The owner of the adjoining buildings shall extend the foundation of these buildings to a depth of 12 feet (3658 mm) below grade at such owner's expense, as provided in the preceding paragraph.

SECTION 3302 — PREPARATION OF BUILDING SITE

All stumps and roots shall be removed from the soil to a depth of at least 12 inches (305 mm) below the surface of the ground in the area to be occupied by the building.

All wood forms that have been used in placing concrete, if within the ground or between foundation sills and the ground, shall be removed before a building is occupied or used for any purpose. Before completion, loose or casual wood shall be removed from direct contact with the ground under the building.

SECTION 3303 — PROTECTION OF PEDESTRIANS DURING CONSTRUCTION OR DEMOLITION

3303.1 General. No person shall use or occupy a street, alley or public sidewalk for the performance of work under a building permit except in accordance with the provisions of this chapter.

No person shall perform any work on any building or structure adjacent to a public way in general use by the public for pedestrian travel unless the pedestrians are protected as specified in this chapter.

Any material or structure temporarily occupying public property, including fences and walkways, shall be adequately lighted between sunset and sunrise.

For additional requirements for temporary buildings or structures, see Section 3103.

3303.2 Temporary Use of Streets and Alleys. The use of public property shall meet the requirements of the public agency having jurisdiction. Whenever requested, plot plans and construction details shall be submitted for review by the agencies concerned.

3303.3 Storage on Public Property. Material and equipment necessary for work to be done under a permit shall not be placed or stored on public property so as to obstruct free and convenient approach to and use of any fire hydrant, fire or police alarm box, utility box, catch basin, or manhole or so as to interfere with the free flow of water in any street or alley gutter.

3303.4 Mixing Mortar on Public Property. The mixing or handling of mortar, concrete or other material on public property shall be done in a manner that will not deface public property or create a nuisance.

3303.5 Protection of Utilities. A substantial protective frame and boarding shall be built around and over every street lamp, utility box, fire or police alarm box, fire hydrant, catch basin, and manhole that may be damaged by any work being done under the permit. This protection shall be maintained while such work is being done and shall not obstruct the normal functioning of the device.

3303.6 Walkway. A walkway not less than 4 feet (1219 mm) wide shall be maintained on the sidewalk in front of the building site during construction, alteration or demolition unless the public agency having jurisdiction authorizes the sidewalk to be fenced and closed. Adequate signs and railings shall be provided to direct pedestrian traffic. Railings shall be provided when required by Section 3303.7.

The walkway shall be capable of supporting a uniform live load of 150 pounds per square foot (psf) (7.18 kN/m^2). A durable wearing surface shall be provided.

3303.7 Pedestrian Protection.

3303.7.1 Protection required. Pedestrian traffic shall be protected by a railing on the street side when the walkway extends into the roadway, by a railing adjacent to excavations and by such other protection as set forth in Table 33-A. The construction of such protective devices shall be in accordance with the provisions of this chapter.

3303.7.2 Railings. Railings shall be substantially built and, when of wood, shall be constructed of new material having a nominal size of at least 2 inches by 4 inches (51 mm by 102 mm). Railings shall be at least 3 feet 6 inches (1067 mm) in height and, when adjacent to excavations, shall be provided with a midrail.

3303.7.3 Fences. Fences shall be solid and substantially built, be not less than 8 feet (2438 mm) in height above grade and be placed on the side of the walkway nearest to the building site. Fences shall extend the entire length of the building site and each end shall be returned to the building line.

Openings in such fences shall be protected by doors that are normally kept closed.

All fences shall be provided with 2-inch-by-4-inch (51 mm by 102 mm) plates, top and bottom, and shall be well braced. The fence material shall be a minimum of $^3/_4$-inch (19.1 mm) boards or $^1/_4$-inch (6.4 mm) plywood. Plywood fences shall conform to the following requirements:

1. Plywood panels shall be bonded with an adhesive identical to that for exterior plywood.

2. Plywood $^1/_4$ inch (6.4 mm) or $^5/_{16}$ inch (7.9 mm) in thickness shall have studs spaced not more than 2 feet (610 mm) on center.

3. Plywood $^3/_8$ inch (9.5 mm) or $^1/_2$ inch (12.7 mm) in thickness shall have studs spaced not more than 4 feet (1219 mm) on center, provided a 2-inch-by-4-inch (51 mm by 102 mm) stiffener is placed horizontally at the midheight when the stud spacing exceeds 2 feet (610 mm) on center.

4. Plywood $^5/_8$ inch (15.9 mm) or thicker shall not span over 8 feet (2438 mm).

3303.7.4 Canopies. The protective canopy shall have a clear height of 8 feet (2438 mm) above the walkway. The roof shall be tightly sheathed. The sheathing shall be 2-inch (51 mm) nominal wood planking or equal. Every canopy shall have a solid fence built along its entire length on the construction side.

If materials are stored or work is done on the roof of the canopy, the street sides and ends of the canopy roof shall be protected by a tight curb board not less than 1 foot (305 mm) high and a railing not less than 3 feet 6 inches (1067 mm) high.

The entire structure shall be designed to carry the loads to be imposed on it, provided the live load shall not be less than 150 psf (7.18 kN/m^2). In lieu of such design, a protection canopy supporting not more than 150 psf (7.18 kN/m^2) may be constructed as follows:

1. Footings shall be continuous 2-inch-by-6-inch (51 mm by 152 mm) members with scabbed joints.

2. Posts not less than 4 inches by 6 inches (102 mm by 152 mm) in size shall be provided on both sides of the canopy and spaced not more than 12 feet (3658 mm), center to center.

3. Stringers not less than 4 inches by 12 inches (102 mm by 305 mm) in size shall be placed on edge upon the posts.

4. Joists resting upon the stringers shall be at least 2 inches by 8 inches (51 mm by 305 mm) in size and shall be spaced not more than 2 feet (610 m), center to center.

5. The deck shall be of planks at least 2 inches (51 mm) thick nailed to the joists.

6. Each post shall be knee-braced to joists and stringers by members 4 feet (1219 mm) long, not less than 2 inches by 4 inches (51 mm by 102 mm) in size.

7. A curb not less than 2 inches by 12 inches (51 mm by 305 mm) in size shall be set on edge along the outside edge of the deck.

EXCEPTION: Protection canopies for new, light-frame construction not exceeding two stories in height may be designed for a live load of 75 psf (3.59 kN/m^2) or the loads to be imposed on it, whichever is the greater.

3303.8 Maintenance and Removal of Protective Devices.

3303.8.1 Maintenance. Pedestrian protection required by Section 3303.7 shall be maintained in place and kept in good order for the entire length of time pedestrians may be endangered.

3303.8.2 Removal. Every protection fence or canopy shall be removed within 30 days after such protection is no longer required by this chapter for protection of pedestrians.

3303.9 Demolition. The work of demolishing any building shall not commence until the required pedestrian protection structures are in place.

The building official may require the permittee to submit plans and a complete schedule for demolition. Where such are required, no work shall be done until such plans or schedule, or both, are approved by the building official.

TABLE 33-A—TYPE OF PROTECTION REQUIRED FOR PEDESTRIANS

HEIGHT OF CONSTRUCTION	DISTANCE FROM CONSTRUCTION	PROTECTION REQUIRED
× 304.8 for mm		
8 feet or less	Less than 6 feet	Railing
	6 feet or more	None
More than 8 feet	Less than 6 feet	Fence and canopy
	6 feet or more, but not more than one fourth the height of construction	Fence and canopy
	6 feet or more, but between one fourth to one half the height of construction	Fence
	6 feet or more, but exceeding one half the construction height	None

Chapter 34
EXISTING STRUCTURES

SECTION 3401 — GENERAL

Buildings in existence at the time of the adoption of this code may have their existing use or occupancy continued, if such use or occupancy was legal at the time of the adoption of this code, provided such continued use is not dangerous to life.

Any change in the use or occupancy of any existing building or structure shall comply with the provisions of Sections 109 and 3405 of this code.

For existing buildings, see Appendix Chapter 34. See also Section 101.3.

For a comprehensive code and guidelines on the treatment of existing buildings, see the *Uniform Code for Building Conservation.*

SECTION 3402 — MAINTENANCE

All buildings and structures, both existing and new, and all parts thereof, shall be maintained in a safe and sanitary condition. All devices or safeguards required by this code shall be maintained in conformance with the code edition under which installed. The owner or the owner's designated agent shall be responsible for the maintenance of buildings and structures. To determine compliance with this subsection, the building official may cause a structure to be reinspected.

SECTION 3403 — ADDITIONS, ALTERATIONS OR REPAIRS

3403.1 General. Buildings and structures to which additions, alterations or repairs are made shall comply with all the requirements of this code for new facilities except as specifically provided in this section. See Section 310.9 for provisions requiring installation of smoke detectors in existing Group R, Division 3 Occupancies.

3403.2 When Allowed. Additions, alterations or repairs may be made to any building or structure without requiring the existing building or structure to comply with all the requirements of this code, provided the addition, alteration or repair conforms to that required for a new building or structure.

Additions or alterations shall not be made to an existing building or structure that will cause the existing building or structure to be in violation of any of the provisions of this code and such additions or alterations shall not cause the existing building or structure to become unsafe. An unsafe condition shall be deemed to have been created if an addition or alteration will cause the existing building or structure to become structurally unsafe or overloaded, will not provide adequate egress in compliance with the provisions of this code or will obstruct existing exits, will create a fire hazard, will reduce required fire resistance, or will otherwise create conditions dangerous to human life. Any building so altered, which involves a change in use or occupancy, shall not exceed the height, number of stories and area permitted for new buildings. Any building plus new additions shall not exceed the height, number of stories and area specified for new buildings.

Additions or alterations shall not be made to an existing building or structure when such existing building or structure is not in full compliance with the provisions of this code except when such addition or alteration will result in the existing building or structure being no more hazardous based on life safety, firesafety and sanitation, than before such additions or alterations are undertaken. (See also Section 307.11.3 for Group H, Division 6 Occupancies.)

EXCEPTION: Alterations of existing structural elements, or additions of new structural elements, which are not required by Section 3401 and are initiated for the purpose of increasing the lateral-force-resisting strength or stiffness of an existing structure, need not be designed for forces conforming to these regulations provided that an engineering analysis is submitted to show that

1. The capacity of existing structural elements required to resist forces is not reduced,
2. The lateral loading to required existing structural eletuents is not increased beyond their capacity,
3. New structural elements are detailed and connected to the existing structural elements as required by these regulations,
4. New or relocated nonstructural elements are detailed and connected to existing or new structural elements as required by these regulations, and
5. An unsafe condition as defined above is not created.

3403.3 Nonstructural. Alterations or repairs to an existing building or structure that are nonstructural and do not adversely affect any structural member or any part of the building or structure having required fire resistance may be made with the same materials of which the building or structure is constructed.

3403.4 Glass Replacement. The installation or replacement of glass shall be as required for new installations.

3403.5 Historic Buildings. Repairs, alterations and additions necessary for the preservation, restoration, rehabilitation or continued use of a building or structure may be made without conformance to all the requirements of this code when authorized by the building official, provided

1. The building or structure has been designated by official action of the legally constituted authority of this jurisdiction as having special historical or architectural significance.
2. Any unsafe conditions as described in this code are corrected.
3. The restored building or structure will be no more hazardous based on life safety, firesafety and sanitation than the existing building.

SECTION 3404 — MOVED BUILDINGS

Buildings or structures moved into or within the jurisdiction shall comply with the provisions of this code for new buildings or structures.

SECTION 3405 — CHANGE IN USE

No change shall be made in the character of occupancies or use of any building that would place the building in a different division of the same group of occupancy or in a different group of occupancies, unless such building is made to comply with the requirements of this code for such division or group of occupancy.

EXCEPTION: The character of the occupancy of existing buildings may be changed subject to the approval of the building official, and the building may be occupied for purposes in other groups without conforming to all the requirements of this code for those groups, provided the new or proposed use is less hazardous, based on life and fire risk, than the existing use.

No change in the character of occupancy of a building shall be made without a certificate of occupancy, as required in Section 109 of this code. The building official may issue a certificate of occupancy pursuant to the intent of the above exception without certifying that the building complies with all provisions of this code.

Chapter 35
UNIFORM BUILDING CODE STANDARDS

Part I—General

SECTION 3501 — UBC STANDARDS

The Uniform Building Code standards referred to in various parts of this code, which are also listed in Part II of this chapter, are hereby declared to be part of this code and are referred to in this code as a "UBC standard."

SECTION 3502 — ADOPTED STANDARDS

The standards referred to in various parts of the code, which are listed in Part III of this chapter, are hereby declared to be part of this code.

SECTION 3503 — STANDARD OF DUTY

The standard of duty established for the recognized standards listed in Part IV of this chapter is that the design, construction and quality of materials of buildings and structures be reasonably safe for life, limb, health, property and public welfare.

SECTION 3504 — RECOGNIZED STANDARDS

The standards listed in Part IV of this chapter are recognized standards. Compliance with these recognized standards shall be prima facie evidence of compliance with the standard of duty set forth in Section 3503.

Part II—UBC Standards

UBC STD. AND SEC. — TITLE AND SOURCE

CHAPTER 2

2-1; 201.2, 215
Noncombustible Material—Tests. Standard Method of Test E 136-79 of the ASTM.*

CHAPTER 4

4-1; 303.8, 405.1.1, 405.3.4
Proscenium Firesafety Curtains. Installation Standard of the International Conference of Building Officials.

CHAPTER 7

7-1; 405.1.1, 601.3, 703.2, 703.4, 706, 709.3.2.2, 709.5, 709.6, 710.2, Table 7-A, 2602.5.2
Fire Tests of Building Construction and Materials. Standard Methods E 119-83 of the ASTM.

7-2; 302.4, 703.4, 713.5, 713.9, 1004.3.4.3.2, 1005.3.3.5
Fire Tests of Door Assemblies. Standard 10B-1988 of Underwriters Laboratories Inc. and International Conference of Building Officials Test Standard for Smoke- and Draft-Control Door Assemblies.

7-3; 703.4, 713.5
Tinclad Fire Doors. Specification of the American National Standards Institute/Underwriters Laboratories Inc. 10A-1979 (R 1985).

7-4; 703.4, 713.5, 713.9
Fire Tests of Window Assemblies. Standard Methods E 163-76 of the ASTM.

7-5; 703.4, 714
Fire Tests of Through-penetration Fire Stops. Standard Method E 814-83 of the ASTM.

7-6; 703.4; 704.6; 1701.4; 1701.5, Item 10
Thickness and Density Determination for Spray-applied Fireproofing. Test Standard of the International Conference of Building Officials.

7-7; 703.3, 703.4
Methods for Calculating Fire Resistance of Steel, Concrete, Wood, Concrete Masonry and Clay Masonry Construction. Standard of the International Conference of Building Officials.

7-8; 308.2.2.1, 1001.2, 1003.3.1.2
Horizontal Sliding Fire Doors Used in an Exit. Test Standard of the International Conference of Building Officials.

CHAPTER 8

8-1; 201.2; 207; 215; 217; 405.1.1; 601.3; 707.2; 707.3; 801.2; 802.1, Item 1; 802.2; 2602.3; 2602.5.2; 2602.6
Test Method for Surface-burning Characteristics of Building Materials. Standard Test Method E 84-84 of the ASTM.

8-2; 801.2, 805
Standard Test Method for Evaluating Room Fire Growth Contribution of Textile Wall Covering. Test Method of the International Conference of Building Officials.

CHAPTER 9

9-1; 307.11.3, 321.1, 403.2, 404.3.1, 405.1.1, 804.1, 902, 904.1.2, 904.1.3, 904.2.6.3, 904.2.7, 904.3.2, 2603.7.1, 2603.8.1
Installation of Sprinkler Systems. Standard for the Installation of Sprinkler Systems, NFPA 13-1991, National Fire Protection Association.

9-2; 902, 904.1.2, 904.5.1
Standpipe Systems. The Standard for Installation of Standpipe Systems and Hose Systems, NFPA 14-1993, National Fire Protection Association.

9-3; 804.1, 805, 902, 904.1.2, 904.1.3, 2603.7.1, 2603.8.1
Installation of Sprinkler Systems in Group R Occupancies Four Stories or Less. Standard for the Installation of Sprinkler Systems in Residential Occupancies up to Four Stories in Height, NFPA 13R-1989, National Fire Protection Association.

CHAPTER 10

10-1; 1001.2, 1003.3.1.2
Power-operated Exit Doors. Test Standard of the International Conference of Building Officials.

10-2; 1001.2, 1003.3.3.13
Stairway Identification. Specification Standard of the International Conference of Building Officials.

10-3; Appendix 3407.1
Exit Ladder Device. Test Standard of the International Conference of Building Officials.

10-4; 1001.2, 1003.3.1.9
Panic Hardware. Standard 305, July 30, 1979, of Underwriters Laboratories Inc.

*ASTM refers to the American Society for Testing and Materials.

CHAPTER 14

14-1; 601.3, 1401.2, 1402.1
Kraft Waterproof Building Paper. Federal Specification UU-B-790a (February 5, 1968).

14-2; 1401.2, 1404
Vinyl Siding. Standard Specification D 3679-91 for Rigid Polyvinyl Chloride (PVC) of the ASTM.

CHAPTER 15

15-1; 1501.2, Table 15-E
Roofing Aggregates. Material Standard of the International Conference of Building Officials.

15-2; 601.3, 1501.2, 1502, Table 15-A, 2602.5.3
Test Standard for Determining the Fire Retardancy of Roof-covering Materials. Standard Specification 790 (October 5, 1983) of Underwriters Laboratories Inc.

15-3; 1501.2, 1502, 1507.2, 1507.12
Wood Shakes. Part I—Wood Shakes (nonpreservative treated). Grading and Packing Rules for Red Cedar Shakes. Grading Rules of the Red Cedar Shingle & Handsplit Shake Bureau, 1975. Part II—Wood Shake Hip and Ridge Units (nonpreservative). Shake and Shingle Council and Material Standard of the International Conference of Building Officials. Part III—Wood Shakes (preservative treated). Grading and Packing Rules for Treated Southern Pine and Red Pine, Black Gum/Sweet Gum Taper-sawn Shakes. Grading Rules of the Red Cedar Shingle & Handsplit Shake Bureau, 1982, and Material Standard of the International Conference of Building Officials. Part IV—Southern Yellow Pine, Red Pine, Black Gum/Sweet Gum Taper-sawn Shake Hip and Ridge Units. Material Standard of the International Conference of Building Officials.

15-4; 1501.2, 1502, 1507.2, 1507.13
Wood Shingles. Standard of the Red Cedar Shingle & Handsplit Shake Bureau and Material Standard of the International Conference of Building Officials.

15-5; 1501.2, 1502, 1507.7
Roof Tile. Test Standard of the International Conference of Building Officials.

15-6; 1501.2, 1502
Modified Bitumen, Thermoplastic and Thermoset Membranes Used for Roof Coverings. Standard Specifications D 412-87, D 471-79, D 570-81, D 624-86, D 638-84, D 751-79, D 816-82, D 1004-66 (1981), D 1204-84, D 2136-84 and D 2137-83 of the ASTM.

15-7; 906.1, 906.4, 1501.2
Automatic Smoke and Heat Vents. Material Standard of the International Conference of Building Officials.

CHAPTER 18

18-1; 1801.2, 1803.1
Soils Classification. Standard Method D 2487-69 of the ASTM.

18-2; 1801.2, 1803.2
Expansion Index Test. Recommendation of the Los Angeles Section of the ASCE Soil Committee.

CHAPTER 19

19-1; 1903.5.2, 1912.14.3
Welding Reinforcing Steel, Metal Inserts and Connections in Reinforced Concrete Construction. Structural Welding Code—Reinforcing Steel ANSI/AWS D1.4-92 of the American Welding Society, Inc.

19-2; 1903.9, 1925.1, 1925.3
Mill-Mixed Gypsum Concrete and Poured Gypsum Roof Diaphragms. Standard Specification C 317-70 of the ASTM. Poured Gypsum Roof Diaphragm, based on reports of test programs by S. B. Barnes and Associates, dated February 1955, November 1956, January 1958 and February 1962.

CHAPTER 21

21-1; 2102.2, Item 4
Building Brick, Facing Brick and Hollow Brick. (Made from Clay or Shale.) Standard Specifications C 62-92c, C 216-94a and C 652-94a of the ASTM.

21-2; 2102.2, Item 6
Calcium Silicate Face Brick (Sand-lime Brick). Standard Specification C 73-95 of the ASTM.

21-3; 2102.2, Item 5
Concrete Building Brick. Standard Specification C 55-95 of the ASTM.

21-4; 2102.2, Item 5
Hollow and Solid Load-bearing Concrete Masonry Units. Standard Specification C 90-95 of the ASTM.

21-5; 2102.2, Item 5
Nonload-bearing Concrete Masonry Units. Standard Specification C 129-95 of the ASTM.

21-6; See *Uniform Code for Building Conservation.*
In-Place Masonry Shear Tests. Test Standard of the International Conference of Building Officials.

21-7; See *Uniform Code for Building Conservation.*
Tests of Anchors in Unreinforced Masonry Walls. Test Standard of the International Conference of Building Officials.

21-8; See *Uniform Code for Building Conservation.*
Pointing of Unreinforced Masonry Walls. Construction Specification of the International Conference of Building Officials.

21-9; 2102.2, Item 6
Unburned Clay Masonry Units and Standard Methods of Sampling and Testing Unburned Clay Masonry Units. Test Standard of the International Conference of Building Officials.

21-10; 2102.2, 2104.8
Part I—Joint Reinforcement for Masonry. Specification Standard of the International Conference of Building Officials. Part II—Cold-drawn Steel Wire for Concrete Reinforcement. Standard Specification A 82-90a of the ASTM.

21-11; 2102.2, Item 2; Table 21-A
Cement, Masonry. Standard Specification C 91-93a of the ASTM.

21-12; 2102.2, Item 3
Quicklime for Structural Purposes. Standard Specification C 5-79 (Reapproved 1992) of the ASTM.

21-13; 2102.2, Item 3
Hydrated Lime for Masonry Purposes. Standard Specification C 207-91 (Reapproved 1992) of the ASTM.

21-14; 2102.2, Item 2; Table 21-A
Mortar Cement. Test Standard of the International Conference of Building Officials.

21-15; 2102.2, Item 8
Mortar for Unit Masonry and Reinforced Masonry Other Than Gypsum. Standard Specification C 270-95T of the ASTM.

21-16; 2102.2, Item 8
Field Tests Specimens for Mortar. Test Standard of the International Conference of Building Officials.

21-17; 2102.2, Item 6; 2105.3.2, 2105.3.3
Test Method for Compressive Strength of Masonry Prisms. Standard Test Method E 447-80 of the ASTM.

21-18; 2102.2, Item 9; Table 21-B
Method of Sampling and Testing Grout. Standard Method C 1019-89a (93) of the ASTM.

21-19; 2102.2, Item 9
Grout for Masonry. Standard Specification C 476-91 of the ASTM.

21-20; 2102.2, Item 8
Standard Test Method for Flexural Bond Strength of Mortar Cement. Test Standard of the International Conference of Building Officials.

CHAPTER 22

22-1; 1808.6.1, 1808.7.1, 2202.2
Material Specifications for Structural Steel. Standard Specifications A 27, A 36, A 48, A 53, A 148, A 242, A 252, A 283, A 307, A 325, A 336, A 441, A 446, A 449, A 490, A 500, A 501, A 514, A 529, A 563, A 569, A 570, A 572, A 588, A 606, A 607, A 611, A 618, A 666, A 668, A 690, A 715 and A 852 of the ASTM.

CHAPTER 23

23-1; 2302.1, 2303
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Appendix

Appendix Chapter 3
USE OR OCCUPANCY
Division I—DETENTION AND CORRECTIONAL FACILITIES

SECTION 313 — SCOPE

The provisions of this chapter apply to the design and construction of Group I, Division 3 Occupancies housing detention or correctional facilities (prisons, jails and reformatories).

SECTION 314 — APPLICATION

This appendix chapter may be used as alternative provisions to requirements found in Chapter 3 of this code. If this appendix chapter is used for design or construction purposes, all requirements in this appendix chapter shall be used. Chapter 3 provisions may be used if not specifically noted in this appendix chapter.

SECTION 315 — DEFINITIONS

For the purpose of this chapter, certain terms are defined as follows:

CELL is a housing unit in a detention or correctional facility for the confinement of not more than two inmates or prisoners.

CELL COMPLEX is a cluster or group of cells in a jail, prison or similar detention facility, together with rooms used for accessory purposes, all of which open into the cell complex, and are used for functions such as dining, counseling, exercise, classrooms, sick call, visiting, storage, staff offices, control rooms or similar functions, and interconnecting corridors all within the cell complex.

CELL, MULTIPLE-OCCUPANCY, is a housing area in a detention or correctional facility designed to house no less than three or no more than 16 inmates.

CELL TIER are cells located one level above the other, not exceeding two levels per floor.

DAY ROOM is a room adjacent to a cell, cell complex or cell tier and is used as a dining, exercise or other activity room for inmates.

SECTION 316 — CONSTRUCTION, REQUIREMENT EXCEPTIONS

316.1 General. Except as provided in this appendix chapter, buildings shall be constructed in accordance with the provisions of this code.

316.2 Exceptions to Table 6-A. Regardless of the provisions of Table 6-A, nonbearing cell walls within cell complexes may be of nonfire-rated, noncombustible construction, provided the cell complex is separated from all other areas of the building, including corridors that connect to the cell complex by construction and opening protection as required for corridors.

The open space in front of a cell tier not exceeding two tiers in height in detention or correctional facilities shall not be considered a vertical shaft whether extending from the floor to ceiling above or from floor to underside of roof.

SECTION 317 — COMPARTMENTATION

Every story having an occupant load of more than 50 inmates in a detention or correctional facility shall be divided into not less than two approximately equal compartments by a smoke-stop partition, constructed pursuant to the provisions of Section 308.2.

> **EXCEPTIONS:** 1. Protection may be accomplished with horizontal exits. (See Section 1005.3.5.)
>
> 2. In restraint areas, there are no restrictions on the total area of glazed openings in a smoke barrier, provided vision panels are of glazing material as specified in Section 713.9.

SECTION 318 — OCCUPANCY SEPARATIONS

Regardless of the provisions of Table 3-B, a three-hour fire-resistive occupancy separation as set forth in Section 302.3 may be used between a Group I, Division 3 Occupancy and a Group S, Division 3 Occupancy used only for the parking of vehicles used to transport inmates or prisoners provided no repair work or fueling is performed.

> **EXCEPTION:** Such occupancy separations need not be provided unless the Group S, Division 3 Occupancy area is enclosed with both surrounding walls and a solid roof.

SECTION 319 — GLAZING

In restraint areas of fully sprinklered detention and correctional facilities, the area of glazing in one-hour corridor walls is not restricted, provided:

1. All glazing is approved $^{1}/_{4}$-inch-thick (6.4 mm) wired glass or other approved and fire-tested glazing material set in steel frames.

2. In lieu of the sizes set forth in Section 1004.3.4.3.2, the size and area of wired glass assemblies shall conform to Sections 713.7 and 713.8. Other glazing material shall not exceed the sizes and areas as specified in the fire test.

SECTION 320 — ELECTRICAL

Approved special electrical systems, exit illumination, power installations and alternate on-site electrical supplies shall be provided for every building or portion of a building housing 10 or more inmates in a detention or correctional facility.

SECTION 321 — AUTOMATIC SPRINKLER AND STANDPIPE SYSTEMS

321.1 General. Every building, or portion thereof, housing more than six inmates in a detention or correctional facility or similar occupancy shall be protected by an automatic sprinkler system conforming to the provisions of UBC Standard 9-1. The main sprinkler control valve or valves and all other control valves in the system shall be electrically supervised so that at least a local alarm will sound at a constantly attended location when valves are closed.

> **EXCEPTION:** The sprinkler and piping serving single cells may be imbedded in the concrete construction. Protection for sprinklers and piping shall meet the provisions of UBC Standard 9-1.

When a complete approved automatic sprinkler system conforming to this section is installed in a building or buildings of a detention or correctional facility, pressurized enclosures need not be provided. However all required stairways shall be pressurized to a minimum of 0.15 inch of water column (37.3 Pa) upon actuation of the smoke-detection system.

321.2 Wet Standpipes. Every building in a detention or correctional facility, housing 50 or more inmates, shall be provided with Class II standpipes with hoses, conforming to the provisions of Chapter 9. Wet standpipes shall be located in cell complexes and in other cell areas of the building. In addition, Class II standpipes shall be located so that it will not be necessary to extend hose lines through interlocking security doors or any exit doors in smoke-stop partitions or horizontal exit walls.

321.3 Dry Standpipes. Regardless of the height of the building or number of stories, every detention or correctional facility shall be provided with a Class I standpipe.

EXCEPTION: In lieu of dry standpipes, combined systems meeting the provisions of UBC Standard 9-2 may be used.

When acceptable to the fire authority having jurisdiction, fire department connections may be located inside all security walls or fences on the property.

Standpipes shall be located in accordance with Chapter 9 and, when located in cell complexes, may be placed in secured pipe chases.

SECTION 322 — FIRE ALARM SYSTEMS

Fire alarm systems shall be provided in accordance with the Fire Code.

SECTION 323 — SMOKE MANAGEMENT

323.1 Smoke Management System. A mechanically operated smoke management system or systems shall be provided in every detention or correctional facility.

323.2 Design and Installation. Every smoke management system shall be designed with zones that shall not exceed one smoke compartment per zone, except cell zones. Upon activation, the system shall operate at 100 percent exhaust from any zone of smoke generation and at 100 percent supply to all floors with returns closed in all zones adjacent to zone of smoke generation at not less than eight air changes per hour.

323.3 Automatic Initiation. Operation of the smoke-management system shall be initiated automatically upon the actuation of appropriately zoned automatic sprinkler flow indicators or smoke detectors, or both. Smoke detectors shall be installed in accordance with Section 608 of the Mechanical Code and their listing.

323.4 Manual Controls. Zone operation status indicators and manual controls capable of overriding the automatic controls shall be provided in a location approved by the fire department.

323.5 Location of Intakes. Exhaust discharges and fresh air supply intakes shall be so located as to prevent the reintroduction of smoke into the building.

323.6 Plans. The location of required fire dampers or combination smoke-fire dampers shall be clearly indicated on plans.

323.7 Omission of Fire Dampers. Fire dampers required by other provisions of this code are not required if such dampers interfere with the operation of the smoke management system.

EXCEPTION: Those required to maintain the integrity of a floor-ceiling assembly.

323.8 Duct Materials. Duct materials shall be capable of safely conveying heat, smoke and toxic gases, to withstand both positive and negative pressures that may be imposed during the smoke-control mode, and to maintain their structural integrity under fire exposure conditions.

SECTION 324 — MEANS OF EGRESS

324.1 Number of Means of Egress. Multiple-occupancy rooms and day rooms in buildings or portions thereof in correctional or detention facilities constructed of not less than one-hour fire-resistive construction shall be provided with a minimum of two means of egress when the occupant load is more than 20.

The occupant load of any restraint area shall be determined by Table 10-A and classified as to the occupancy group it most nearly resembles, and means of egress shall be provided as required by Section 1003.1.

A minimum of two means of egress shall be provided in all areas of restraint (cells, day rooms, cell tiers and cell complexes) within a detention or correctional facility when the occupant load is more than 20.

324.2 Adjoining or Accessory Areas. Means of egress from a room may open into an adjoining or intervening room or area, provided such adjoining room is accessory to the area served and provides a direct means of egress to a corridor, exit or exterior exit balcony.

EXCEPTIONS: 1. Means of egress are not to pass through kitchens, storerooms, restrooms, closets or spaces used for similar purposes.

2. The space in front of cells normally called a day room and used as means of egress in a detention or correctional facility shall not be considered an adjoining or accessory area if individual cells open directly into the space.

324.3 Cell Door Width. Cell doors shall not be less than 2 feet (610 mm) in width and 6 feet (1829 mm) in height.

324.4 Sliding Doors in Detention or Correctional Facilities. Electrically controlled and operated sliding doors may be used as exit doors regardless of occupant load served. Electrically controlled doors shall be designed to allow for manual operation by staff in the event of power failure.

324.5 Dead-end Balconies. Exit-access balconies serving cell tiers shall not extend more than 50 feet (15 240 mm) beyond an exit stairway.

NOTE: For number of means of egress, see Section 1004.2.3.

324.6 Electrically Operable Doors. All doors (except those opening directly to the exterior of the building) and doors from cells and holding rooms in detention and correctional occupancies shall be electrically operable from the facility control center. Electric operation shall override any manual device.

SECTION 325 — FENCED ENCLOSURES

Exterior fenced enclosures into which a means of egress from a building or buildings terminate shall be provided with a safe dispersal area located not less than 50 feet (15 240 mm) from any building. Dispersal areas shall be based on an area of not less than 3 square feet (0.28 m^2) per occupant. A gate shall be provided from the safe dispersal area to allow for necessary relocation of occupants.

Exterior fenced enclosures used for exit discharge and which do not provide a safe dispersal area shall have not less than two means of egress.

Fenced enclosures located on roofs of buildings one or more stories in height shall be provided with not less than two means of egress regardless of occupant load.

Fenced enclosures used for recreational or activity purposes only shall be provided with exits in accordance with Chapter 10.

Division II—AGRICULTURAL BUILDINGS

SECTION 326 — SCOPE

The provisions of this appendix shall apply exclusively to agricultural buildings. Such buildings shall be classified as Group U, Division 3 Occupancies and shall include the following uses:

1. Storage, livestock and poultry.
2. Milking barns.
3. Shade structures.
4. Horticultural structures (greenhouse and crop protection).

SECTION 327 — CONSTRUCTION, HEIGHT AND ALLOWABLE AREA

327.1 General. Buildings classed as Group U, Division 3 Occupancies shall be of one of the types of construction specified in this code and shall not exceed the area or height limits specified in Sections 504, 505 and 506 and Table A-3-A.

327.2 Special Provisions. The area of a Group U, Division 3 Occupancy in a one-story building shall not be limited if the building is entirely surrounded and adjoined by public ways or yards not less than 60 feet (18 288 mm) in width, regardless of the type of construction.

The area of a two-story Group U, Division 3 Occupancy shall not be limited if the building is entirely surrounded and adjoined by public ways or yards not less than 60 feet (18 288 mm) in width and is provided with an approved automatic sprinkler system throughout conforming to UBC Standard 9-1.

Buildings using plastics shall comply with Type V-N construction. Plastics shall be approved plastics as defined in Chapter 2 and regulated by Chapter 26. For foam plastic, see Section 2602.

EXCEPTIONS: 1. When used as skylights or roofs, the areas of plastic skylights shall not be limited.

2. Except where designs must consider snow loads, plastics less than 20 mil (0.51 mm) thick may be used without regard to structural considerations. The structural frame of the building, however, shall comply.

SECTION 328 — OCCUPANCY SEPARATIONS

Occupancy separations shall be as specified in Section 302 and Table A-3-B.

SECTION 329 — EXTERIOR WALLS AND OPENINGS

Except where Table 6-A requires greater protection, exterior walls of agricultural buildings shall not be less than one-hour fire-resistive construction when less than 20 feet (6096 mm) from property line.

Openings in exterior walls of agricultural buildings that are less than 20 feet (6096 mm) from property lines shall be protected by fire assemblies having a fire-protection rating of not less than three-fourths hour.

SECTION 330 — MEANS OF EGRESS

Means of egress shall be as specified in Chapter 10.

EXCEPTIONS: 1. The maximum travel distance shall not exceed 300 feet (91 440 mm).

2. One means of egress is required for each 15,000 square feet (1394 m^2) of floor area and fraction thereof.

3. Exit and exit-access openings shall not be less than 2 feet 6 inches by 6 feet 8 inches (762 mm by 2032 mm).

TABLE A-3-A—BASIC ALLOWABLE AREA FOR A GROUP U, DIVISION 3 OCCUPANCY, ONE STORY IN HEIGHT AND MAXIMUM HEIGHT OF SUCH OCCUPANCY

I	II			III and IV		V	
	F.R.	One-hour	N	One-hour or Type IV	N	One-hour	N
ALLOWABLE AREA[1] (square feet) × 0.093 for m^2							
Unlimited	60,000	27,100	18,000	27,100	18,000	21,100	12,000[1]
MAXIMUM HEIGHT IN STORIES[2]							
Unlimited	12	4	2	4	2	3	2

[1]See Section 327 for unlimited area under certain conditions.
[2]For maximum height in feet, see Chapter 5, Table 5-B.

TABLE A-3-B—REQUIRED SEPARATIONS BETWEEN GROUP U, DIVISION 3 AND OTHER OCCUPANCIES (In Hours)

Occupancy	A	E	I	H[1]	S-3	B	S-1, 2, 4 and 5	F and M	R-1	R-3	U
Rating	4	4	4	4	4	1	1	1	1	1	N

[1]See Chapter 3 for Group H, Division 1 Occupancies.

Division III—REQUIREMENTS FOR GROUP R, DIVISION 3 OCCUPANCIES

SECTION 331 — GENERAL

331.1 Purpose. The purpose of this division is to provide minimum standards for the protection of life, limb, health, property and environment and for the safety and welfare of the consumer, general public, and the owners and occupants of Group R, Division 3 Occupancies regulated by this code.

331.2 Scope. The provisions of this division apply to the construction, prefabrication, alteration, repair, use, occupancy and maintenance of detached one- or two-family dwellings not more than three stories in height and their accessory structures.

SECTION 332 — ONE AND TWO FAMILY DWELLING CODE ADOPTED

Buildings regulated by this division shall be designed and constructed to comply with the requirements of the Council of American Building Officials *One and Two Family Dwelling Code,* 1995 edition (as it applies to detached one- and two-family dwellings), promulgated jointly by the International Conference of Building Officials, Building Officials and Code Administrators International, and the Southern Building Code Congress International.

Division IV—REQUIREMENTS FOR GROUP R, DIVISION 4 OCCUPANCIES

SECTION 333 — GENERAL

333.1 Purpose. The purpose of this division is to provide minimum standards of safety for group care facilities.

333.2 Scope.

333.2.1 General. The provisions of this division shall apply to buildings or portions thereof that are to be used for Group R, Division 4 Occupancies.

333.2.2 Applicability of other provisions. Except as specifically required by this division, Group R, Division 4 Occupancies shall meet all applicable provisions of this code. Group R, Division 4 Occupancies need not be accessible to persons with disabilities.

333.3 Definitions. For the purpose of this division, certain terms are defined as follows:

AMBULATORY PERSONS are those capable of achieving mobility sufficient to exit without the assistance of another person.

GROUP R, DIVISION 4 OCCUPANCIES shall be residential group care facilities for ambulatory, nonrestrained persons who may have a mental or physical impairment (each accommodating more than five and not more than 16 clients or residents, excluding staff).

SECTION 334 — CONSTRUCTION, HEIGHT AND ALLOWABLE AREA

334.1 General. Buildings or portions of buildings classified as Group R, Division 4 may be constructed of any materials allowed by this code, shall not exceed two stories in height or be located above the second story in any building, and shall not exceed 3,000 square feet (278.7 m^2) in floor area per story except as provided in Sections 504, 505 and 506.

334.2 Special Provisions. Group R, Division 4 Occupancies having more than 3,000 square feet (278.7 m^2) of floor area above the first story shall not be of less than one-hour fire-resistive construction throughout.

334.3 Mixed Occupancies. Group R, Division 4 Occupancies shall be separated from Group H Occupancies by a four-hour fire-resistive occupancy separation and shall be separated from all other occupancies by a one-hour fire-resistive occupancy separation.

EXCEPTIONS: 1. An occupancy separation need not be provided between a Group R, Division 4 Occupancy and a carport having no enclosed uses above, provided the carport is entirely open on two or more sides.

2. In the one-hour occupancy separation between a Group R, Division 4 and Group U, Division 1 Occupancy, the separation may be limited to the installation of materials approved for one-hour fire-resistive construction on the garage side, and a self-closing, tightfitting, solid-wood door $1^3/_8$ inches (35 mm) in thickness will be permitted in lieu of a one-hour fire assembly. Fire dampers need not be installed in air ducts passing through the wall, floor or ceiling separating a Group R, Division 4 Occupancy from a Group U, Division 1 Occupancy, provided such ducts within the Group U Occupancy are constructed of steel having a thickness not less than 0.019 inch (0.48 mm) (No. 26 galvanized sheet gage) and have no openings into the Group U Occupancy.

SECTION 335 — LOCATION ON PROPERTY

Exterior walls located less than 3 feet (914 mm) from property lines shall be of one-hour fire-resistive construction. Openings shall not be permitted in exterior walls located less than 3 feet (914 mm) from property lines. For other requirements, see Section 503 and Chapter 6.

SECTION 336 — MEANS OF EGRESS AND EMERGENCY ESCAPES

336.1 General. Group R, Division 4 Occupancies shall be provided with means of egress as required by this section and Chapter 10 of this code.

336.2 Exits Required.

336.2.1 Number of exits. Every story, basement or portion thereof housing a Group R, Division 4 Occupancy shall not have less than two exit or exit-access doors.

EXCEPTIONS: 1. Basements used exclusively for the service of the building may have one exit or exit-access door. For the purpose of this exception, storage rooms, laundry rooms, maintenance offices and similar uses shall not be considered as providing service to the building.

2. Storage rooms, laundry rooms and maintenance offices not exceeding 300 square feet (27.9 m^2) in floor area may be provided with only one exit or exit-access door.

336.2.2 Distance to exits. The maximum travel distance specified in Chapter 10 shall be reduced by 50 percent.

336.3 Corridor Width. Corridors shall not be less than 36 inches (914 mm) in width.

336.4 Stairways. Stairways shall be constructed as required by Section 1003.3.3 of this code.

EXCEPTION: In buildings that are converted to a Group R, Division 4 Occupancy, existing stairways may have an 8-inch-maximum (203 mm) rise, 9-inch-minimum (229 mm) run and may be 30 inches (762 mm) in width.

336.5 Emergency Means of Egress Illumination. In the event of power failure, means of egress illumination shall be automatically provided from an emergency system. Emergency systems shall be supplied from storage batteries or an on-site generator set and the system shall be installed in accordance with the requirements of the Electrical Code.

336.6 Emergency Escape. Every sleeping room shall be provided with emergency escape or rescue facilities as required by Section 310.4 of this code.

SECTION 337 — LIGHT, VENTILATION AND SANITATION

Light and ventilation shall be as specified in Section 1203.

Sanitation shall be as specified in Section 2902.6.

SECTION 338 — YARDS AND COURTS

Yards and courts shall be as specified in Section 1203.4.

SECTION 339 — ROOM DIMENSIONS

Room dimensions shall be as specified in Section 310.6.

SECTION 340 — SHAFT ENCLOSURES

Exits shall be enclosed as specified in Chapter 10.

Elevator shafts, vent shafts, dumbwaiter shafts, clothes chutes and other vertical openings shall be enclosed and the enclosure shall be as specified in Section 711.

SECTION 341 — FIRE ALARM SYSTEMS

An approved automatic and manual fire alarm system shall be provided in Group R, Division 4 Occupancies.

SECTION 342 — HEATING

All habitable rooms shall be provided with heating facilities capable of maintaining a room temperature of 70°F (21°C) at a point 3 feet (914 mm) above the floor.

SECTION 343 — SPECIAL HAZARDS

343.1 Heating Equipment. All heating equipment shall be permanently installed. Chimneys and heating apparatus shall conform to the requirements of Chapter 31 of this code and the Mechanical Code.

343.2 Flammable Liquids. The storage and handling of gasoline, fuel oil or other flammable liquids shall be in accordance with the Fire Code.

Appendix Chapter 4
SPECIAL USE AND OCCUPANCY
Division I— BARRIERS FOR SWIMMING POOLS, SPAS AND HOT TUBS

SECTION 419 — GENERAL

419.1 Scope. The provisions of this section apply to the design and construction of barriers for swimming pools located on the premises of Group R, Division 3 Occupancies.

419.2 Standards of Quality. In addition to the other requirements of this code, safety covers for pools and spas shall meet the requirements for pool and spa safety covers as listed below. The standard listed below is a recognized standard. (See Section 3504.)

1. ASTM F 1346, Standard Performance Specification for Safety Covers and Labeling Requirement for All Covers for Swimming Pools, Spas and Hot Tubs

SECTION 420 — DEFINITIONS

For the purpose of this section, certain terms, words and phrases are defined as follows:

ABOVEGROUND/ON-GROUND POOL. See definition of "swimming pool."

BARRIER is a fence, wall, building wall or combination thereof that completely surrounds the swimming pool and obstructs access to the swimming pool.

GRADE is the underlying surface, such as earth or a walking surface.

HOT TUB. See definition of "spa, nonself-contained" and "spa, self-contained."

IN-GROUND POOL. See definition of "swimming pool."

SEPARATION FENCE is a barrier that separates all doors of a dwelling unit with direct access to a swimming pool from the swimming pool.

SPA, NONSELF-CONTAINED, is a hydromassage pool or tub for recreational or therapeutic use, not located in health-care facilities, designed for immersion of users and usually having a filter, heater and motor-driven blower. It may be installed indoors or outdoors, on the ground or on a supporting structure, or in the ground or in a supporting structure. A nonself-contained spa is intended for recreational bathing and contains water over 24 inches (610 mm) deep.

SPA, SELF-CONTAINED, is a continuous-duty appliance in which all control, water-heating and water-circulating equipment is an integral part of the product, located entirely under the spa skirt. A self-contained spa is intended for recreational bathing and contains water over 24 inches (610 mm) deep.

SWIMMING POOL is any structure intended for swimming or recreational bathing that contains water over 24 inches (610 mm) deep. This includes in-ground, aboveground and on-ground swimming pools, and fixed-in-place wading pools.

SWIMMING POOL, INDOOR, is a swimming pool that is totally contained within a residential structure and surrounded on all four sides by walls of said structure.

SWIMMING POOL, OUTDOOR, is any swimming pool that is not an indoor pool.

SECTION 421 — REQUIREMENTS

421.1 Outdoor Swimming Pool. An outdoor swimming pool shall be provided with a barrier that shall be installed, inspected and approved prior to plastering or filling with water. The barrier shall comply with the following:

1. The top of the barrier shall be at least 48 inches (1219 mm) above grade measured on the side of the barrier that faces away from the swimming pool. The maximum vertical clearance between grade and the bottom of the barrier shall be 2 inches (51 mm) measured on the side of the barrier that faces away from the swimming pool. The maximum vertical clearance at the bottom of the barrier may be increased to 4 inches (102 mm) when grade is a solid surface such as a concrete deck, or when the barrier is mounted on the top of the aboveground pool structure. When barriers have horizontal members spaced less than 45 inches (1143 mm) apart, the horizontal members shall be placed on the pool side of the barrier. Any decorative design work on the side away from the swimming pool, such as protrusions, indentations or cutouts, which render the barrier easily climbable, is prohibited.

2. Openings in the barrier shall not allow passage of a $1^{3}/_{4}$-inch-diameter (44.5 mm) sphere.

EXCEPTIONS: 1. When vertical spacing between such openings is 45 inches (1143 mm) or more, the opening size may be increased such that the passage of a 4-inch-diameter (102 mm) sphere is not allowed.

2. For fencing composed of vertical and horizontal members, the spacing between vertical members may be increased up to 4 inches (102 mm) when the distance between the tops of horizontal members is 45 inches (1143 mm) or more.

3. Chain link fences used as the barrier shall not be less than 11 gage.

4. Access gates shall comply with the requirements of Items 1 through 3. Pedestrian access gates shall be self-closing and have a self-latching device. Where the release mechanism of the self-latching device is located less than 54 inches (1372 mm) from the bottom of the gate, (1) the release mechanism shall be located on the pool side of the barrier at least 3 inches (76 mm) below the top of the gate, and (2) the gate and barrier shall have no opening greater than $^{1}/_{2}$ inch (12.7 mm) within 18 inches (457 mm) of the release mechanism. Pedestrian gates shall swing away from the pool. Any gates other than pedestrian access gates shall be equipped with lockable hardware or padlocks and shall remain locked at all times when not in use.

5. Where a wall of a Group R, Division 3 Occupancy dwelling unit serves as part of the barrier and contains door openings between the dwelling unit and the outdoor swimming pool that provide direct access to the pool, a separation fence meeting the requirements of Items 1, 2, 3 and 4 of Section 421.1 shall be provided.

EXCEPTION: When approved by the building official, one of the following may be used:

1. Self-closing and self-latching devices installed on all doors with direct access to the pool with the release mechanism located a minimum of 54 inches (1372 mm) above the floor.
2. An alarm installed on all doors with direct access to the pool. The alarm shall sound continuously for a minimum of 30 seconds within seven seconds after the door and its screen, if present, are opened, and be capable of providing a sound pressure level of not less than 85 dBA when measured indoors at 10 feet (3048 mm). The alarm shall automatically reset under all condi-

tions. The alarm system shall be equipped with a manual means, such as a touchpad or switch, to temporarily deactivate the alarm for a single opening. Such deactivation shall last no longer than 15 seconds. The deactivation switch shall be located at least 54 inches (1372 mm) above the threshold of the door.

3. Other means of protection may be acceptable so long as the degree of protection afforded is not less than that afforded by any of the devices described above.

6. Where an aboveground pool structure is used as a barrier or where the barrier is mounted on top of the pool structure, and the means of access is a ladder or steps, then (1) the ladder or steps shall be capable of being secured, locked or removed to prevent access or (2) the ladder or steps shall be surrounded by a barrier that meets the requirements of Items 1 through 5. When the ladder or steps are secured, locked or removed, any opening created shall be protected by a barrier complying with Items 1 through 5.

421.2 Indoor Swimming Pool. For an indoor swimming pool, protection shall comply with the requirements of Section 421.1, Item 5.

421.3 Spas and Hot Tubs. For a nonself-contained and self-contained spa or hot tub, protection shall comply with the requirements of Section 421.1.

EXCEPTION: A self-contained spa or hot tub equipped with a listed safety cover shall be exempt from the requirements of Section 421.1.

Division II—AVIATION CONTROL TOWERS

SECTION 422 — GENERAL

The provisions of this appendix apply exclusively to aviation control towers not exceeding 1,500 square feet (139.35 m^2) per floor. Such buildings shall be classified as Group B Occupancies and shall be used only for the following uses:

1. Airport traffic control cab.
2. Electrical and mechanical equipment rooms.
3. Airport terminal radar and electronics rooms.
4. Office spaces incidental to the tower operation.
5. Lounges for employees, including sanitary facilities.

SECTION 423 — CONSTRUCTION, HEIGHT AND ALLOWABLE AREA

Buildings or portions of buildings constructed under the provisions of this chapter shall be either Type I-F.R., Type II-F.R., Type II One-hour, Type II-N or Type III One-hour construction. The height of the building or parts thereof shall not exceed the limitations specified in Table A-4-A and the area of such buildings shall not exceed 1,500 square feet (139.35 m^2) on any floor.

SECTION 424 — MEANS OF EGRESS

A single stairway may be used for means of egress in towers of any height, provided the occupant load per floor does not exceed 15. Access to the stairway and the elevator shall be separated from each other a distance apart equal to no less than one half of the length of the maximum overall diagonal dimension of the area served measured in a straight line. The exit stairway and elevator hoistway may be located in a common shaft enclosure, provided they are separated from each other by a four-hour separation having no openings. Such stairway shall be constructed to comply with the requirements for pressurized enclosures as specified in Section 1005.3.3. Stairways, however, need not extend to the roof as specified in Section 1003.3.3.11. The provisions of Section 403 do not apply.

SECTION 425 — FIRE ALARMS

Smoke detectors shall be installed in all occupied levels. These devices shall be part of an approved fire alarm system having audible alarms mounted in all occupied levels.

SECTION 426 — ACCESSIBILITY

Aviation control towers need not be accessible to the handicapped as specified in the provisions of Chapter 11 and Section 2903.

SECTION 427 — STANDBY POWER AND EMERGENCY GENERATION SYSTEMS

A standby power-generation system conforming to the Electrical Code shall be installed in aviation control towers over 65 feet (19 812 mm) in height and shall provide power to the following equipment:

1. Pressurized enclosure, mechanical equipment and lighting.
2. Elevator operational power.
3. Smoke-detection systems.

TABLE A-4-A—MAXIMUM HEIGHT OF AVIATION CONTROL TOWERS (feet)

TYPES OF CONSTRUCTION				
I-F.R.	II-F.R.	II One-hour	III One-hour	II-N
× 0.3048 for m				
Unlimited	240	100	65	85

Appendix Chapter 9
BASEMENT PIPE INLETS

SECTION 907 — BASEMENT PIPE INLETS

907.1 General. All basement pipe inlets shall be installed in accordance with the requirements of this section.

907.2 Where Required. Basement pipe inlets shall be installed in the first floor of every store, warehouse or factory having basements.

> **EXCEPTIONS:** 1. Where the basement is equipped with an automatic sprinkler system as specified in Section 904.2.
>
> 2. Where the basement is used for the storage of permanent archives or valuables such as safe deposit vaults or similar uses adversely affected by water.

907.3 Location. The location of basement pipe inlets shall be as required by the fire department.

907.4 Detailed Requirements. All basement pipe inlets shall be of cast iron, steel, brass or bronze with lids of cast brass or bronze.

The basement pipe inlet shall consist of a sleeve not less than 8 inches (203 mm) inside diameter extending through the floor and terminating flush with or through the basement ceiling and shall have a top flange recessed with an inside shoulder to receive the lid. The top flange shall be installed flush with finish floor surface. The lid shall be a solid casting and have a lift recessed in the top. This lid shall be provided with a cast-in sign reading: FIRE DEPARTMENT ONLY, DO NOT COVER. The lid shall be installed in such a manner to permit its easy removal from the flange shoulder.

Appendix Chapter 10
BUILDING SECURITY

SECTION 1010 — BUILDING SECURITY

Building security shall be in accordance with the *Uniform Building Security Code.*

Appendix Chapter 11
ACCESSIBILITY
Division I—SITE ACCESSIBILITY

SECTION 1107 — ACCESSIBLE EXTERIOR ROUTES

1107.1 General. Accessible exterior routes shall be provided from public transportation stops, accessible parking and accessible passenger loading zones and public sidewalks to the accessible building entrance they serve.

When more than one building or facility is located on a site, at least one accessible route shall connect accessible elements, facilities and buildings that are on the same site. The accessible route between accessible parking and accessible building entrances shall be the most practical direct route.

1107.2 Definition. CABO/ANSI A117.1 is American National Standard A117.1-1992 published by the Council of American Building Officials.

1107.3 Design and Construction. When accessibility is required by this section, it shall be designed and constructed in accordance with CABO/ANSI A117.1.

SECTION 1108 — PARKING FACILITIES

1108.1 Accessible Parking Required. When parking lots or garage facilities are provided, accessible parking spaces shall be provided in accordance with Table A-11-A except for the following occupancies:

1. For Group I, Divisions 1.1 and 2 medical care occupancies specializing in the treatment of persons with mobility impairments, 20 percent of the parking spaces provided shall be accessible.

2. For Group I, Divisions 1.1 and 1.2 and Group B Occupancies providing outpatient medical care facilities, 10 percent of the parking spaces provided shall be accessible.

3. For Group R, Division 1 apartment building containing accessible or adaptable dwelling units where parking is provided, 2 percent of the parking spaces shall be accessible. Where parking is provided within or beneath a building, accessible parking spaces shall also be provided within or beneath the building.

One van accessible parking space shall be provided for every eight accessible parking spaces, or fraction thereof.

Accessible parking spaces shall be located on the shortest possible accessible route from adjacent parking to an accessible building entrance. In facilities with multiple accessible building entrances with adjacent parking, accessible parking spaces shall be dispersed and located near the accessible entrances.

EXCEPTION: In multilevel parking structures, accessible van parking spaces may be located on one level.

Where a parking facility is not accessory to a particular building, accessible parking spaces shall be located on the shortest accessible route to an accessible pedestrian entrance to the parking facility.

1108.2 Design and Construction. When accessible and van accessible parking spaces are required by this section, they shall be designed and constructed in accordance with CABO/ANSI A117.1.

1108.3 Signs. Accessible parking spaces required by this section shall be identified by a sign complying with CABO/ANSI A117.1.

EXCEPTION: Accessible parking space signs need not be provided in parking garages or parking facilities that have five or less total parking spaces.

SECTION 1109 — PASSENGER LOADING ZONES

1109.1 Location. When provided, passenger loading zones shall be located on an accessible route.

1109.2 Design and Construction. Passenger loading zones shall be designed and constructed in accordance with CABO/ANSI A117.1.

TABLE A-11-A—NUMBER OF ACCESSIBLE PARKING SPACES

TOTAL PARKING SPACES IN LOT OR GARAGE	MINIMUM REQUIRED NUMBER OF ACCESSIBLE SPACES
1-25	1
26-50	2
51-75	3
76-100	4
101-150	5
151-200	6
201-300	7
301-400	8
401-500	9
501-1,000	2% of total spaces
Over 1,000	20 spaces plus 1 space for every 100 spaces, or fraction thereof, over 1,000

Division II—ACCESSIBILITY FOR EXISTING BUILDINGS

SECTION 1110 — SCOPE

The provisions of this division apply to renovations, alterations and additions to existing buildings, including those identified as historic buildings. This division includes minimum standards for removing architectural barriers, and providing and maintaining access to existing buildings and facilities for persons with disabilities.

SECTION 1111 — DEFINITIONS

For the purpose of this division, certain terms are defined as follows:

ALTERATION is any change, addition or modification in construction or occupancy.

TECHNICALLY INFEASIBLE is an alteration of a building or facility that has little likelihood of being accomplished because existing structural conditions would require removing or altering a load-bearing member that is an essential part of the structural frame, or because existing physical or site constraints prohibit modification or addition of elements, spaces or features that are in full and strict compliance with the minimum requirements for new construction and which are necessary to provide accessibility.

SECTION 1112 — ALTERATIONS

1112.1 General.

1112.1.1 Compliance. Alterations to existing buildings or facilities shall comply with this section. Alterations shall not reduce or have the effect of reducing accessibility or usability of a building, portion of a building, or facility. If compliance with this section is technically infeasible, the alteration shall provide access to the maximum extent technically feasible.

> **EXCEPTION:** Alterations to Group R, Division 1 apartment occupancies need not comply with this section.

1112.1.2 Existing elements. If existing elements, spaces, essential features or common areas are altered, each such altered element, space, feature or area shall comply with the applicable provisions in Division I of this appendix chapter and CABO/ANSI A117.1.

> **EXCEPTION:** Accessible means of egress required by Section 1104 need not be provided in alterations of existing buildings and facilities.

When an alteration is to an area of primary function, the accessible route to the altered area shall be made accessible. The accessible route to the primary function area shall include toilet facilities or drinking fountains serving the area of primary function.

> **EXCEPTIONS:** 1. The costs of providing the accessible route need not exceed 20 percent of the costs of the alterations affecting the area of primary function.
>
> 2. Alterations to windows, hardware, operating controls, electrical outlets and signs.
>
> 3. Alterations to mechanical systems or electrical systems, installation or alteration of fire-protection systems, and abatement of hazardous materials.
>
> 4. Alterations undertaken for the primary purpose of increasing the accessibility of an existing building, facility or element.

1112.2 Modifications.

1112.2.1 General. Modifications set forth in this section may be used for compliance when the required standard is technically infeasible.

1112.2.2 Hotel guest rooms. When guest rooms of a hotel are being altered, at least one of every 25 guest rooms being altered shall be accessible, and at least one additional guest room for every 25 guest rooms being altered shall be provided with visible and audible alarm-indicating appliances for persons with hearing impairments. The total number of accessible guest rooms and guest rooms accessible to persons with hearing impairments need not exceed the number required by Section 1103.1.9.2.

1112.2.3 Performance areas. When it is technically infeasible to alter performance areas to be on an accessible route, at least one of each type of performance area shall be made accessible.

1112.2.4 Platform lifts. Platform lifts may be used when installation of an elevator is technically infeasible.

1112.2.5 Toilet rooms. The addition of one accessible unisex toilet facility accessible to occupants on the floor may be provided in lieu of making existing toilet facilities accessible when it is technically infeasible to alter existing toilet and bathing facilities to be accessible. The unisex facility shall be located on the same floor and in the same area as the existing toilet facilities. Each unisex toilet facility shall contain one accessible water closet and lavatory, and the door shall be lockable from within the room.

When existing toilet facilities are being altered and are not made accessible, directional signs shall be provided indicating the location of the nearest accessible toilet or bathing facility within the building.

1112.2.6 Assembly areas. Seating shall adjoin an accessible route that also serves as a means of egress. When it is technically infeasible to disperse accessible seating throughout an altered assembly area, accessible seating areas may be clustered. Each accessible seating area shall have provisions for companion seating.

1112.2.7 Dressing rooms. When it is technically infeasible to provide accessible dressing rooms in each group of rooms, one dressing room for each sex, or a unisex dressing room, on each level shall be accessible.

SECTION 1113 — CHANGE OF OCCUPANCY

Requirements for new construction provided in Chapter 11 shall apply to existing buildings that undergo a change of occupancy group, unless technically infeasible.

SECTION 1114 — HISTORIC PRESERVATION

Accessibility provisions of this division shall be applied to historic buildings and facilities as defined in Section 3403.5 of this code.

The building official, after consulting with the appropriate historic preservation officer, shall determine whether provisions required by this division for accessible routes, ramps, entrances, toilets, parking or signage would threaten or destroy the historic significance of the building or facility.

If it is determined that any of the accessibility requirements listed above would threaten or destroy the historic significance of a building or facility, the modifications of Section 1112.2 for that feature may be utilized.

Appendix Chapter 12
INTERIOR ENVIRONMENT
Division I—VENTILATION

SECTION 1206 — SCOPE

Buildings and structures enclosing spaces intended for human occupancy shall be provided with ventilation in accordance with this appendix chapter.

SECTION 1207 — VENTILATION

1207.1 General. Enclosed portions of buildings and structures in occupancies, other than the locations specified in Sections 1207.3 through 1207.7, shall be provided with natural ventilation by means of openable exterior openings with an area of not less than $^1/_{20}$ of the total floor area of such portions, or shall be provided with a mechanically operated ventilating system. The mechanically operated ventilating system shall be capable of supplying ventilation air in accordance with Table A-12-A during such time as the building or space is occupied.

1207.2 Register Velocity. In assembly, educational and institutional occupancies when the velocity of the air at the register exceeds 10 feet per second (3.048 m/s), the register shall be placed more than 8 feet (2438 mm) above the floor directly beneath.

1207.3 Toilet Rooms. Toilet rooms shall be provided with a fully openable exterior window at least 3 square feet (0.27 m^2) in area; a vertical duct not less than 100 square inches (0.064 516 m^2) in area for the first toilet facility, with 50 additional square inches (0.032 m^2) for each additional facility; or a mechanically operated exhaust system capable of exhausting 50 cubic feet of air per minute (23.6 L/s) for each water closet or urinal installed in the toilet room. Such systems shall be connected directly to the outside, and the point of discharge shall be at least 3 feet (914 mm) from any openable window.

1207.4 Ventilation in Hazardous Locations. Rooms, areas or spaces in which explosive, corrosive, combustible, flammable or highly toxic dusts, mists, fumes, vapors or gases are or may be emitted due to the processing, use, handling or storage of materials shall be mechanically ventilated as required by the Fire Code and the Mechanical Code.

Emissions generated at work stations shall be confined to the area in which they are generated as specified in the Fire Code and the Mechanical Code.

Supply and exhaust openings shall be in accordance with the Mechanical Code. Exhaust air contaminated by highly toxic material shall be treated in accordance with the Fire Code.

A manual shutoff control for ventilation equipment shall be provided outside the room adjacent to the principal access door to the room. The switch shall be of the break-glass type and shall be labeled "Ventilation System Emergency Shutoff."

1207.5 Groups B, F, M and S Occupancies. In Groups B, F, M and S Occupancies, or portions thereof, where Class I, II or III-A liquids are used, mechanical exhaust shall be provided sufficient to produce six air changes per hour. Such mechanical exhaust shall be taken from a point at or near the floor level.

1207.6 Group S Parking Garages. In parking garages, other than open parking garages as defined in Section 405.2, used for storing or handling of automobiles operating under their own power and on loading platforms in bus terminals, ventilation shall be provided capable of exhausting a minimum of 1.5 cubic feet per minute (cfm) per square foot (0.761 L/s/m^2) of gross floor area. The building official may approve an alternate ventilation system designed to exhaust a minimum of 14,000 cfm (6608 L/s) for each operating vehicle. Such system shall be based on the anticipated instantaneous movement rate of vehicles, but not less than 2.5 percent (or one vehicle) of the garage capacity. Automatic carbon monoxide-sensing devices may be employed to modulate the ventilation system to maintain a maximum average concentration of carbon monoxide of 50 parts per million during any eight-hour period, with a maximum concentration not greater than 200 parts per million for a period not exceeding one hour.

> **EXCEPTION:** In Group S, Division 3 repair garages and motor vehicle fuel-dispensing stations without lubrication pits; storage garages; and in Group S, Division 5 aircraft hangars, such ventilating system may be omitted when, in the building official's opinion, the building is supplied with unobstructed openings to the outer air that are sufficient to provide the necessary ventilation.

Connecting offices, waiting rooms, ticket booths and similar uses shall be supplied with conditioned air under positive pressure.

1207.7 Group H, Division 4 Occupancies. In buildings used for the repair or handling of motor vehicles operating under their own power, mechanical ventilation shall be provided capable of exhausting a minimum of 1.5 cfm per square foot (7.62 L/s/m^2) of floor area. Each engine repair stall shall be equipped with an exhaust pipe extension duct, extending to the outside of the building, that, if over 10 feet (3048 mm) in length, shall mechanically exhaust 300 cfm (141.6 L/s). Connecting offices and waiting rooms shall be supplied with conditioned air under positive pressure.

> **EXCEPTION:** In repair garages and aircraft hangars, the building official may authorize the omission of such ventilating equipment when, in his or her opinion, the building is supplied with unobstructed openings to the outer air that are well distributed and sufficient in size to provide the necessary ventilation.

TABLE A-12-A—OUTDOOR AIR REQUIREMENTS FOR VENTILATION

OCCUPANCY [1]	OUTDOOR VENTILATION AIR (cfm per square foot of area unless noted) [2] × 0.472 for L/s per m^2
Group A Occupancies	
Applications similar to:	
Food and Beverage Service	
Bars, cocktail lounges	3.00
Cafeteria, fast food	2.00
Dining rooms	1.40
Kitchens (cooking) [3]	0.30
Sports and Amusement	
Assembly rooms	1.80
Ballrooms and discos	2.50
Bowling alleys (seating areas)	1.75
Conference rooms	1.00
Gambling casinos	3.60
Game rooms	1.75
Ice arenas	0.50 (playing areas)
Playing floors (gymnasium)	0.60
Spectator areas	2.25
Swimming pools (pool and deck area)	0.50
Theaters	
Auditorium	2.25
Lobbies	3.00
Stages, studios	1.05
Ticket booths	1.20
Transportation	
Platforms	1.50
Waiting rooms	1.50
Group B Occupancies	
Applications similar to:	
Offices	
Bank vaults	0.08
Conference rooms	1.00
Corridors and utilities	0.05
Darkrooms	0.50
Duplicating, printing areas	0.50
Elevators	1.00[4]
Locker and dressing rooms	0.50
Meat-processing areas	0.15
Office spaces	0.14
Pharmacies	0.30
Photo studios	0.15
Public restrooms (per water closet or urinal)	50 cfm/water closet or urinal[4]
Reception areas	0.90
Smoking lounges	4.20[4]
Telecommunication centers and data entry spaces	1.20
Group E Occupancies	
Applications similar to:	
Education	
Auditoriums	2.25
Classrooms	0.75
Corridors	0.00
Laboratories	0.60
Libraries	0.30
Locker rooms	0.50
Music rooms	0.75
Smoking lounges	4.20[4]
Training shop	0.60

TABLE A-12-A—OUTDOOR AIR REQUIREMENTS FOR VENTILATION—(Continued)

OCCUPANCY[1]	OUTDOOR VENTILATION AIR (cfm per square foot of area unless noted)[2] × 0.472 for L/s per m^2
Group F Occupancies	
Applications similar to:	
Dry Cleaners, Laundries	
Coin-operated dry cleaners	0.30
Coin-operated laundries	0.30
Commercial dry cleaners	0.90
Commercial laundries	0.25
Storage, pick-up areas	1.05
Group I Occupancies	
Applications similar to:	
Hospitals, Nursing and Convalescent Homes	
Autopsy rooms	0.50[4]
Medical procedure rooms	0.30
Operating rooms	0.60
Patient rooms	0.25
Physical therapy rooms	0.30
Recovery and ICU rooms	0.30
Correctional facilities	
Cells	0.40
Dining halls	1.50
Guard stations	0.60
Public restrooms	50 cfm/water closet or urinal[4]
Group M Occupancies	
Applications similar to:	
Stores, Sales Floors and Showroom Floors	
Basement and street levels	0.30
Dressing rooms	0.20
Malls and arcades	0.20
Shipping and receiving areas	0.15
Smoking lounges	4.20[4]
Storage rooms	0.15
Upper levels	0.20
Warehouse	0.05
Specialty Shops	
Barber shops	0.38
Beauty shops	0.63
Clothiers	0.30
Drug stores	0.12
Fabric stores	0.12
Florists	0.12
Food stores	0.12
Furniture stores	0.30
Hardware stores	0.12
Pet shops	1.00
Reducing salons	0.30

(continued)

TABLE A-12-A—OUTDOOR AIR REQUIREMENTS FOR VENTILATION—(Continued)

OCCUPANCY [1]	OUTDOOR VENTILATION AIR (cfm per square foot of area unless noted) [2] × 0.472 for L/s per m^2
Group R Occupancies	
Division 1	
Hotels, motels, resorts, dormitories	
Assembly rooms	1.80
Bedrooms	30 cfm/room[5]
Conference rooms	1.00
Dormitory sleeping rooms	0.30
Living rooms	30 cfm/room[5]
Lobbies	0.45
Private bathrooms (intermittent exhaust)	35 cfm/room[5]
Division 1 Apartment Houses and Division 3 Dwellings and Lodging Houses	
Individual Dwelling Units, Lodging Houses	
Bathrooms (intermittent exhaust) or (continuous exhaust)	50 cfm/room[4,5] 20 cfm/room[4,5]
Kitchens (intermittent exhaust) or (continuous exhaust)	100 cfm/room[4,5] 25 cfm/room[4,5]
Living areas	0.35 ACH[6]
Group S Occupancies	
Applications similar to:	
Division 3	
Enclosed parking garages	1.50

[1]Applications may not be unique to a single occupancy group. Where specific use is not listed, judgment as to similarity shall be by the building official.

[2]Based on net occupiable space. The minimum amount of outdoor air supplied during occupancy shall be permitted to be based on the rate per square foot (m^2) of floor area indicated in Table A-12-A or cubic feet per minute (L/s) per person in accordance with nationally recognized standards. See Chapter 35. Controls shall be permitted to adjust outdoor air ventilation rates to provide equivalent rates per person under different conditions of occupancy.

[3]The sum of the outdoor and transfer air from adjacent spaces shall be sufficient to provide an exhaust rate of not less than 1.5 cubic feet per minute per square foot (0.708 L/s per m^2).

[4]Normally supplied by transfer air with local mechanical exhaust with no recirculation.

[5]Independent of room size.

[6]Air changes per hour, but not less than 15 cubic feet per minute (7.08 L/s) per person. Occupancy shall be based on the number of bedrooms; first bedroom, two persons each additional bedroom, one person.

Division II—SOUND TRANSMISSION CONTROL

SECTION 1208 — SOUND TRANSMISSION CONTROL

1208.1 General. In Group R Occupancies, wall and floor-ceiling assemblies separating dwelling units or guest rooms from each other and from public space such as interior corridors and service areas shall provide airborne sound insulation for walls, and both airborne and impact sound insulation for floor-ceiling assemblies.

The standards listed below are recognized standards (see Sections 3503 and 3504).

1. ASTM E 90 and E 413, Laboratory Determination of Airborne Sound Transmission Class (STC)
2. ASTM E 492, Impact Sound Insulation
3. ASTM E 336, Airborne Sound Insulation Field Test

1208.2 Airborne Sound Insulation. All such separating walls and floor-ceiling assemblies shall provide an airborne sound insulation equal to that required to meet a sound transmission class (STC) of 50 (45 if field tested).

Penetrations or openings in construction assemblies for piping; electrical devices; recessed cabinets; bathtubs; soffits; or heating, ventilating or exhaust ducts shall be sealed, lined, insulated or otherwise treated to maintain the required ratings.

Entrance doors from interior corridors together with their perimeter seals shall have a laboratory-tested STC rating of not less than 26 and such perimeter seals shall be maintained in good operating condition.

1208.3 Impact Sound Insulation. All separating floor-ceiling assemblies between separate units or guest rooms shall provide impact sound insulation equal to that required to meet an impact insulation class (IIC) of 50 (45 if field tested). Floor coverings may be included in the assembly to obtain the required ratings and must be retained as a permanent part of the assembly and may be replaced only by other floor covering that provides the same sound insulation required above.

1208.4 Tested Assemblies. Field or laboratory tested wall or floor-ceiling designs having an STC or IIC of 50 or more may be used without additional field testing when, in the opinion of the building official, the tested design has not been compromised by flanking paths. Tests may be required by the building official when evidence of compromised separations is noted.

1208.5 Field Testing and Certification. Field testing, when required, shall be done under the supervision of a professional acoustician who shall be experienced in the field of acoustical testing and engineering and who shall forward certified test results to the building official that minimum sound insulation requirements stated above have been met.

1208.6 Airborne Sound Insulation Field Tests. When required, airborne sound insulation shall be determined according to the applicable Field Airborne Sound Transmission Loss Test procedures. All sound transmitted from the source room to the receiving room shall be considered to be transmitted through the test partition.

1208.7 Impact Sound Insulation Field Test. When required, impact sound insulation shall be determined.

SECTION 1209 — SOUND TRANSMISSION CONTROL SYSTEMS

Generic systems as listed in the *Fire Resistance Design Manual,* Fourteenth Edition, dated April 1994, as published by the Gypsum Association, may be accepted where a laboratory test indicates that the requirements of Section 1208 are met by the system.

Appendix Chapter 13
ENERGY CONSERVATION IN NEW BUILDING CONSTRUCTION

SECTION 1302 — GENERAL

1302.1 Purpose. The purpose of this appendix is to regulate the design and construction of the exterior envelopes and selection of heating, ventilating and air-conditioning, service water heating, electrical distribution, and illuminating systems and equipment required for the purpose of effective conservation of energy within a building or structure governed by this code.

1302.2 *Model Energy Code* Adopted. To comply with the purpose of this appendix, buildings shall be designed to comply with the requirements of the *Model Energy Code* promulgated jointly by the International Conference of Building Officials, the Southern Building Code Congress International, Building Officials and Code Administrators International, and the National Conference of States on Building Codes and Standards, dated 1995.

Appendix Chapter 15
REROOFING

NOTE: This appendix chapter has been revised in its entirety.

SECTION 1514 — GENERAL

All reroofing shall conform to the applicable provisions of Chapter 15 of this code and as otherwise required in this chapter.

Roofing materials and methods of application shall comply with the UBC standards or shall follow manufacturer's installation requirements when approved by the building official.

SECTION 1515 — INSPECTION AND WRITTEN APPROVAL

1515.1 Written Approval Required. New roofing shall not be applied without first obtaining written approval from the building official.

The building official may allow existing roof coverings to remain when inspection or other evidence reveals all of the following:

1. The roof structure is sufficient to sustain the weight of the additional dead load of the new roofing.
2. The roof deck is structurally sound.
3. Roof drains and drainage are sufficient to prevent extensive accumulation of water.
4. The existing roofing is securely attached to the deck.
5. Existing insulation is not water soaked.
6. Fire-retardant requirements are maintained.

1515.2 Required Inspections.

1515.2.1 Preroofing inspection. Inspection prior to the installation of new roofing must be obtained from the building official to verify the existing roofing meets all the conditions in Section 1515.1. The building official may accept an inspection report of above-listed conditions prepared by a special inspector.

1515.2.2 Final inspection. A final inspection and approval shall be obtained from the building official when the reroofing is complete.

SECTION 1516 — REROOFING OVERLAYS ALLOWED

1516.1 General. No roof shall have in any combination more than that allowed in Table A-15-A. Roofing conforming to Section 1503 overlaid on existing roofing shall comply with the provisions of this section and manufacturer's installation requirements as an overlay when approved by the building official.

1516.2 Overlay on Existing Built-up Roofs. The building official may allow reroofing over existing built-up roofing when the conditions specified in Section 1515.1 have been met. When an existing built-up roof has been removed and prior to application of new roofing on a nailable deck that has residual bitumen, rosin-sized or other dry sheet shall be installed. Prior to the application of any reroofing, the existing surface shall be prepared as follows:

1. **Gravel-surfaced roofing.** Not more than one overlay shall be approved over an existing built-up roof. The existing built-up roof shall be cleaned of all loose gravel and debris. All blisters, buckles and other irregularities shall be cut and made smooth and secure. On nonnailable decks, minimum $^3/_8$-inch (9.5 mm) insulation board shall be securely cemented to the existing roofing with hot bitumen after the existing surface has been adequately primed. On nailable decks, a rosin-sized or other dry sheet shall be installed and a base sheet shall be mechanically fastened in place.

2. **Smooth or cap-sheet surface.** Not more than one overlay shall be applied over an existing built-up roof. All blisters, buckles and other irregularities of existing built-up roof shall be cut and made smooth and secure. On nonnailable decks, a base sheet shall be spot cemented to the existing roof. On nailable decks, a base sheet shall be mechanically fastened in place and where residual materials on the existing surface may cause the new base sheet to adhere to the old roof, a rosin-sized or other dry sheet shall be installed under the new hase sheet.

3. **Intersecting walls.** All concrete and masonry walls shall be completely cleaned and primed to receive new flashing. All other walls shall have the surface finish material removed to a minimum height of 6 inches (152 mm) above the new roof deck surface to receive new roofing and flashing. All rotted wood shall be replaced with new material. Surface finish material shall be replaced or reinstalled.

4. **Parapets.** Parapets of area separation walls shall have noncombustible faces, including counterflashing and coping materials.

   EXCEPTION: Combustible roofing may extend 7 inches (178 mm) above the roof surface.

5. **Cant strips.** Where space permits, cant strips shall be installed at all angles. All angles shall be flashed with at least two more layers than in the new roof with an exposed finish layer of inorganic felt or mineral surfaced cap sheet.

6. **Asphalt and wood shingle application.** Not more than one overlay of asphalt shingles shall be applied over one existing built-up roof on structures with a slope of 2 units vertical in 12 units horizontal (16.7% slope) or greater. Not more than one overlay of wood shingles shall be applied over one existing built-up roof on structures with a slope of 3 units vertical in 12 units horizontal (25% slope) or greater. The existing built-up roof shall have all surfaces cleaned of gravel and debris, all blisters and irregularities cut and made smooth and secure, and an underlayment of not less than Type 30 nonperforated felt shall be installed prior to reroofing.

7. **Spray-applied polyurethane foam application.** Spray-applied polyurethane foam may be applied directly to existing built-up roofing systems when the completed assembly is a Class A, B or C fire-retardant roofing assembly and complies with Section 2602.5.3. When applied on a fire-resistive roof-ceiling assembly, the completed assembly shall also comply with Section 710.1.

Base sheets or dry sheets are not required over existing surfaces when applying spray polyurethane foam roofing systems.

Miscellaneous materials such as adhesives, elastomeric caulking compounds, metal, vents and drains shall be a composite part of the roof system.

1516.3 Overlay on Existing Wood Roofs or Asphalt Shingle Roofs. The building official may allow reroofing over existing wood shingle roofing or asphalt shingle roofing. Only fire-retardant roofing assemblies or noncombustible roof covering may be applied over existing wood shake roofs in accordance with the listing or manufacturer's installation requirements when approved by the building official.

When the application of new roofing over existing wood shingle or wood shake roofs creates a combustible concealed space, the entire existing surface shall be covered with gypsum board, mineral fiber, glass fiber or other approved materials securely fastened in place.

Hip and ridge cover on existing shake or shingle roofing shall be removed prior to reroofing application. Roofing overlays may be installed in accordance with the following:

1. **Asphalt shingles.** Not more than two overlays of asphalt shingles shall be applied over an existing asphalt or wood shingle roof. Asphalt shingles applied over wood shingles shall not have less than Type 30 nonperforated felt underlayment installed prior to reroofing.

2. **Wood shakes.** Not more than one overlay of wood shakes shall be applied over an existing asphalt shingle or wood shingle roofing on structures with a slope of 4 units vertical in 12 units horizontal (33% slope) or greater. One layer of 18-inch (457 mm), Type 30 nonperforated felt shall be shingled between each course in such a manner that no felt is exposed to the weather below the shake butts.

3. **Wood shingles.** Not more than one overlay of wood shingles shall be applied over existing wood or asphalt shingles. Wood shingles applied over asphalt shingles shall not have less than Type 30 nonperforated felt underlayment installed prior to reroofing.

SECTION 1517 — TILE

Tile may be applied to roofs with a slope of 4 units vertical in 12 units horizontal (33% slope) or greater over existing roof coverings in accordance with Table A-15-A. Such installations shall be substantiated by a report prepared by an engineer or architect licensed by the state to practice as such, indicating that the existing or modified framing system is adequate to support the additional tile roof covering.

Tile shall be applied in accordance with the original manufacturer's specifications or when the original manufacturer's specifications are no longer available, in accordance with Section 1507.7.

Tile may be repaired to match the prior installation except that clay and terra-cotta hips and ridge tile shall be reinstalled with portland cement mortar.

SECTION 1518 — METAL ROOF COVERING

Metal roof covering may be applied over existing roofing in accordance with Table A-15-A. Reroofing with metal roof covering shall be in accordance with the original manufacturer's specifications or when the original manufacturer's specifications are no longer available as required by Section 1507.8.

SECTION 1519 — OTHER ROOFING

Reroofing with systems not covered elsewhere in Chapter 15 or this appendix, such as, but not limited to, those that are fluid applied or applied as nonasphaltic sheets, shall be done with materials and procedures approved by the building official.

SECTION 1520 — FLASHING AND EDGING

Missing, rusted or damaged flashing and counterflashing, vent caps, and metal edging shall be installed or replaced with new materials. When existing built-up roofs remain, vent flashing, metal edging, drain outlets, metal counterflashing and collars shall be removed and cleaned. All metal allowed to be reinstalled shall be primed prior to reroofing installation. Collars and flanges shall be flashed per the roofing manufacturer's instructions.

TABLE A-15-A—ALLOWABLE REROOFS OVER EXISTING ROOFING
(Inspection and Written Approval Required Prior to Application)

	NEW OVERLAY ROOFING							
EXISTING ROOFING	Built Up	Wood Shake	Wood Shingle	Asphalt Shingle	Tile Roof	Metal Roof	Modified Bitumen	Spray Polyurethane Foam
Built Up	Yes	NP	Yes (3:12)	Yes (2:12)	Yes (2.5:12)	Yes	Yes	Yes
Wood Shake[1]	NP	NP	NP	NP	Yes[2]	Yes[2]	NP	NP
Wood Shingle[1]	NP	Yes[3] (4:12)	Yes[4]	Yes[4]	Yes[2]	Yes[2]	NP	NP
Asphalt Shingle[1]	NP	Yes[3] (4:12)	Yes[4] (3:12)	Yes	Yes (2.5:12)	Yes	Yes	NP
Asphalt over Wood	NP	NP	NP	Yes	Yes[2]	Yes[2]	Yes	NP
Asphalt over Asphalt	NP	NP	NP	Yes	Yes	Yes	Yes	NP
Tile Roof	NP	NP	NP	NP	NP	NP	NP	NP
Metal Roof	NP	NP	NP	NP	NP	Yes	NP	NP
Modified Bitumen	Yes	NP	Yes (3:12)	Yes	Yes (2.5:12)	Yes	Yes	NP

NP = Not Permitted.
Note: (Minimum Roof Slope)
[1]See Section 1515.2 for specific requirements.
[2]Board and batten leveling system must be firestopped in accordance with Section 1516.3.
[3]One layer 18-inch (457 mm) Type 30 nonperforated felt interlaced between shake courses required.
[4]Type 30 nonperforated felt underlayment required for reroofing.

Appendix Chapter 16 is printed in its entirety in Volume 2 of the *Uniform Building Code.* Excerpts from Appendix Chapter 16 are reprinted herein.

Excerpts from Appendix Chapter 16

STRUCTURAL FORCES

Division II—EARTHQUAKE RECORDING INSTRUMENTATION

SECTION 1649 — GENERAL

In Seismic Zones 3 and 4 every building over six stories in height with an aggregate floor area of 60,000 square feet (5574 m^2) or more, and every building over 10 stories in height regardless of floor area, shall be provided with not less than three approved recording accelerographs.

The accelerographs shall be interconnected for common start and common timing.

SECTION 1650 — LOCATION

The instruments shall be located in the basement, midportion, and near the top of the building. Each instrument shall be located so that access is maintained at all times and is unobstructed by room contents. A sign stating MAINTAIN CLEAR ACCESS TO THIS INSTRUMENT shall be posted in a conspicuous location.

SECTION 1651 — MAINTENANCE

Maintenance and service of the instruments shall be provided by the owner of the building, subject to the approval of the building official. Data produced by the instruments shall be made available to the building official on request.

SECTION 1652 — INSTRUMENTATION OF EXISTING BUILDINGS

All owners of existing structures selected by the jurisdiction authorities shall provide accessible space for the installation of appropriate earthquake-recording instruments. Location of said instruments shall be determined by the jurisdiction authorities. The jurisdiction authorities shall make arrangements to provide, maintain and service the instruments. Data shall be the property of the jurisdiction, but copies of individual records shall be made available to the public on request and the payment of an appropriate fee.

Division III—SEISMIC ZONE TABULATION

NOTE: This division has been revised in its entirety.

SECTION 1653 — FOR AREAS OUTSIDE THE UNITED STATES

Location	Seismic Zone
AFRICA	
Algeria	
Alger	3
Oran	3
Angola	
Luanda	0
Benin	
Cotonou	0
Botswana	
Gaborone	0
Burundi	
Bujumbura	3
Cameroon	
Douala	0
Yaounde	0
Cape Verde	
Praia	0
Central African Republic	
Bangui	0
Chad	
Ndjamena	0
Congo	
Brazzaville	0
Djibouti	3
Egypt	
Alexandria	2A
Cairo	2A
Port Said	2A
Equatorial Guinea	
Malabo	0
Ethiopia	
Addis Ababa	3
Asmara	3
Gabon	
Libreville	0
Gambia	
Banjul	0
Ghana	
Accra	3
Guinea	
Bissau	1
Conakry	0
Ivory Coast	
Abidjan	0
Kenya	
Nairobi	2A
Lesotho	
Maseru	2A
Liberia	
Monrovia	1
Libya	
Tripoli	2A
Wheelus AFB	2A
Malagasy Republic	
Tananarive	0
Malawi	
Blantyre	3
Lilongwe	3
Zomba	3
Mali	
Bamako	0
Mauritania	
Nouakchott	0
Mauritius	
Port Louis	0
Morocco	
Casablanca	2A
Port Lyautcy	1
Rabat	2A
Tangier	3
Mozambique	
Maputo	2A
Niger	
Niamey	0
Nigeria	
Ibadan	0
Kaduna	0
Lagos	0
Republic of Rwanda	
Kigali	3
Senegal	
Dakar	0
Seychelles	
Victoria	0
Sierra Leone	
Freetown	0
Somalia	
Mogadishu	0
South Africa	
Cape Town	3
Durban	2A
Johannesburg	2A
Natal	1
Pretoria	2A
Swaziland	
Mbabane	2A
Tanzania	
Dar es Salaam	2A
Zanzibar	2A
Togo	
Lome	1
Tunisia	
Tunis	3
Uganda	
Kampala	2A
Upper Volta	
Ougadougou	0
Zaire	
Bukavu	3
Kinshasa	0
Lubumbashi	2A
Zambia	
Lukasa	2A
Zimbabwe	
Harare (Salisbury)	3
ASIA	
Afghanistan	
Kabul	4

Location	Seismic Zone
Bahrain	
Manama	0
Bangladesh	
Dacca	3
Brunei	
Bandar Seri Begawan	1
Burma	
Mandalay	3
Rangoon	3
China	
Beijing	4
Chengdu	3
Guangzhou	2A
Nanjing	2A
Qingdao	3
Shanghai	2A
Shengyang	4
Taiwan	
All	4
Tihwa	4
Wuhan	2A
Xianggang	2A
Cyprus	
Nicosia	3
India	
Bombay	3
Calcutta	2A
Madras	1
New Delhi	3
Indonesia	
Bandung	4
Jakarta	4
Medan	3
Surabaya	4
Iran	
Isfahan	3
Shiraz	3
Tabriz	4
Tehran	4
Iraq	
Baghdad	3
Basra	1
Israel	
Haifa	3
Jerusalem	3
Tel Aviv	3
Japan	
Fukuoka	3
Itazuke AFB	3
Misawa AFB	3
Naha, Okinawa	4
Osaka/Kobe	4
Sapporo	3
Tokyo	4
Wakkami	3
Yokohama	4
Yokota	4
Jordan	
Amman	3
Korea	
Kimhae	1
Kwangju	1
Pusan	1
Seoul	0
Kuwait	
Kuwait	1

Location	Seismic Zone
Laos	
Vientiane	1
Lebanon	
Beirut	3
Malaysia	
Kuala Lumpur	1
Nepal	
Kathmandu	4
Oman	
Muscat	2A
Pakistan	
Islamabad	4
Karachi	4
Lahore	2A
Peshawar	4
Qatar	
Doha	0
Saudi Arabia	
Al Batin	1
Dharan	1
Jiddah	2A
Khamis Mushayf	1
Riyadh	0
Singapore	
All	1
South Yemen	
Aden City	3
Sri Lanka	
Colombo	0
Syria	
Aleppo	3
Damascus	3
Thailand	
Bangkok	1
Chiang Mai	2A
Songkhla	0
Udorn	1
Turkey	
Adana	2A
Ankara	2A
Ismir	4
Istanbul	4
Karamursel	3
United Arab Emirates	
Abu Dhabi	0
Dubai	0
Viet Nam	
Ho Chi Minh (Saigon)	0
Yemen Aran Republic	
Sanaa	3
ATLANTIC OCEAN AREA	
Azores	
All	2A
Bermuda	
All	1
CARIBBEAN SEA	
Bahama Islands	
All	1
Cuba	
All	2A
Dominican Republic	
Santo Domingo	3
French West Indies	
Martinique	3
Grenada	
Saint Georges	3

Location	Seismic Zone
Haiti	
Port au Prince	3
Jamaica	
Kingston	3
Leeward Islands	
All	3
Trinidad & Tobago	
All	3
CENTRAL AMERICA	
Belize	
Belmopan	2A
Canal Zone	
All	2A
Costa Rica	
San Jose	3
El Salvador	
San Salvador	4
Guatemala	
Guatemala	4
Honduras	
Tegucigalpa	3
Mexico	
Ciudad Juarez	2A
Guadalajara	3
Hermosillo	3
Matamoros	0
Mazatlan	2A
Merida	0
Mexico City	3
Monterrey	0
Nuevo Laredo	0
Tijuana	3
Nicaragua	
Managua	4
Panama	
Colon	3
Galeta	2B
Panama	3
EUROPE	
Albania	
Tirana	3
Austria	
Salzburg	2A
Vienna	2A
Belgium	
Antwerp	1
Brussels	2A
Bosnia-Herzegovina	
Belgrade	2A
Bulgaria	
Sofia	3
Croatia	
Zagreb	3
Czechoslovakia	
Bratislava	2A
Prague	1
Denmark	
Copenhagen	1
Finland	
Helsinki	1
France	
Bordeaux	2A
Lyon	1
Marseille	3
Nice	3
Paris	0
Strasbourg	2A
Germany, Federal Republic	
Berlin	0
Bonn	2A
Bremen	0
Dusseldorf	1
Frankfurt	2A
Hamburg	0
Munich	1
Stuttgart	2A
Vaihigen	2A
Greece	
Athens	3
Kavalla	4
Makri	4
Rhodes	3
Sauda Bay	4
Thessaloniki	4
Hungary	
Budapest	2A
Iceland	
Keflavick	3
Reykjavik	4
Ireland	
Dublin	0
Italy	
Aviano AFB	3
Brindisi	0
Florence	3
Genoa	3
Milan	2A
Naples	3
Palermo	3
Rome	2A
Sicily	3
Trieste	3
Turin	2A
Luxembourg	
Luxembourg	1
Malta	
Valleta	2A
Netherlands	
All	0
Norway	
Oslo	2A
Poland	
Krakow	2A
Poznan	1
Warszawa	1
Portugal	
Lisbon	4
Opporto	3
Romania	
Bucharest	3
Russia	
Moscow	0
St. Petersburg	0
Spain	
Barcelona	2A
Bilbao	2A
Madrid	0
Rota	2A
Seville	2A
Sweden	
Goteborg	2A
Stockholm	1

Location	Seismic Zone
Switzerland	
Bern	2A
Geneva	1
Zurich	2A
Ukraine	
Kiev	0
United Kingdom	
Belfast	0
Edinburgh	1
Edzell	1
Glasgow/Renfrew	1
Hamilton	1
Liverpool	1
London	2A
Londonderry	1
Thurso	1
NORTH AMERICA	
Greenland	
All	1
Canada	
Argentia NAS	2A
Calgary, Alb	1
Churchill, Man	0
Cold Lake, Alb	1
Edmonton, Alb	1
E. Harmon AFB	2A
Fort Williams, Ont	0
Frobisher N.W. Ter.	0
Goose Airport	1
Halifax	1
Montreal, Quebec	3
Ottawa, Ont	2A
St. John's Nfd	3
Toronto, Ont	1
Vancouver	3
Winnepeg, Man	1
SOUTH AMERICA	
Argentina	
Buenos Aires	0
Bolivia	
La Paz	3
Santa Cruz	1
Brazil	
Belem	0
Belo Horizonte	0
Brasilia	0
Manaus	0
Porto Allegre	0
Recife	0
Rio de Janeiro	0
Salvador	0
Sao Paulo	1
Chile	
Santiago	4
Valparaiso	4
Colombia	
Bogota	3
Ecuador	
Guayaquil	3
Quito	4
Paraguay	
Asuncion	0

Location	Seismic Zone
Peru	
Lima	4
Piura	4
Uruguay	
Montevideo	0
Venezuela	
Caracas	4
Maracaibo	2A
PACIFIC OCEAN AREA	
Australia	
Brisbane	1
Canberra	1
Melbourne	1
Perth	1
Sydney	1
Caroline Islands	
Koror, Palau Is.	2A
Ponape	0
Fiji	
Suva	3
Johnson Island	
All	1
Mariana Islands	
Guam	3
Saipan	3
Tinian	3
Marshall Islands	
All	1
New Zealand	
Auckland	3
Wellington	4
Papau New Guinea	
Port Moresby	3
Phillipine Islands	
Baguio	3
Cebu	4
Manila	4
Samoa	
All	3
Wake Island	
All	0

The above compilation is a partial listing of seismic zones for cities and countries outside of the United States. It has been provided in this code primarily as a source of information, and may not, in all cases, reflect local ordinances or current scientific information.

When an authority having jurisdiction requires seismic design forces that are higher than would be indicated by the above zones, the local requirements shall govern. When an authority having jurisdiction requires seismic design forces that are lower than would be indicated by the above zones, and these forces have been developed with consideration of regional tectonics and up-to-date geologic and seismologic information, the local requirements may be used.

When no local seismic design requirements exist, properly determined information on site-specific ground motions may be used to justify a lower seismic zone. Such site-specific ground motions shall have been developed with proper consideration of regional tectonics and local geologic and seismologic information, and shall have no more than a 10 percent chance of being exceeded in a 50-year period.

Appendix Chapter 18 is printed in its entirety in Volume 2 of the *Uniform Building Code*. Excerpts from Appendix Chapter 18 are reprinted herein.

Excerpts from Appendix Chapter 18
WATERPROOFING AND DAMPPROOFING FOUNDATIONS

SECTION 1820 — SCOPE

Walls, or portions thereof, retaining earth and enclosing interior spaces and floors below grade shall be waterproofed or dampproofed according to this appendix chapter.

EXCEPTION: Walls enclosing crawl spaces.

SECTION 1821 — GROUNDWATER TABLE INVESTIGATION

A subsurface soils investigation shall be made in accordance with Section 1804.3, Item 3, to determine the possibility of the groundwater table rising above the proposed elevation of the floor or floors below grade. The building official may require that this determination be made by an engineer or architect licensed by the state to practice as such.

EXCEPTIONS: 1. When foundation waterproofing is provided.

2. When dampproofing is provided and the building official finds that there is satisfactory data from adjacent areas to demonstrate that groundwater has not been a problem.

SECTION 1822 — DAMPPROOFING REQUIRED

Where the groundwater investigation required by Section 1821 indicates that a hydrostatic pressure caused by the water table will not occur, floors and walls shall be dampproofed and a subsoil drainage system shall be installed in accordance with this appendix chapter.

EXCEPTION: Wood foundation systems shall be constructed in accordance with Chapter 18, Division II.

SECTION 1823 — FLOOR DAMPPROOFING

1823.1 General. Dampproofing materials shall be installed between the floor and base materials required by Section 1825.2.

EXCEPTION: Where a separate floor is provided above a concrete slab, the dampproofing may be installed on top of the slab.

1823.2 Dampproofing Materials. Dampproofing installed beneath the slab shall consist of not less than 6-mil (0.152 mm) polyethylene, or other approved methods or materials. When permitted to be installed on top of the slab, dampproofing shall consist of not less than 4-mil (0.1 mm) polyethylene, mopped-on bitumen or other approved methods or materials. Joints in membranes shall be lapped and sealed in an approved manner.

SECTION 1824 — WALL DAMPPROOFING

1824.1 General. Dampproofing materials shall be installed on the exterior surface of walls, and shall extend from a point 6 inches (152 mm) above grade, down to the top of the spread portion of the footing.

1824.2 Surface Preparation. Prior to application of dampproofing materials on concrete walls, fins or sharp projections that may pierce the membrane shall be removed and all holes and recesses resulting from the removal of form ties shall be sealed with a dry-pack mortar, bituminous material, or other approved methods or materials.

1824.3 Dampproofing Materials. Wall dampproofing shall consist of a bituminous material, acrylic modified cement base coating, any of the materials permitted for waterproofing in Section 1828.4, or other approved methods or materials. When such materials are not approved for direct application to unit masonry, the wall shall be parged on the exterior surface below grade with not less than $^3/_8$ inch (9.5 mm) of portland cement mortar.

SECTION 1825 — OTHER DAMPPROOFING REQUIREMENTS

1825.1 Subsoil Drainage System. When dampproofing is required, a base material shall be installed under the floor and a drain shall be installed around the foundation perimeter in accordance with this subsection.

EXCEPTION: When the finished ground level is below the floor level for more than 25 percent of the perimeter of the building, the base material required by Section 1825.2 need not be provided and the foundation drain required by Section 1825.3 need be provided only around that portion of the building where the ground level is above the floor level.

1825.2 Base Material. Floors shall be placed over base material not less than 4 inches (102 mm) in thickness consisting of gravel or crushed stone containing not more than 10 percent material that passes a No. 4 sieve (4.75 mm).

1825.3 Foundation Drain. The drain shall consist of gravel, crushed stone or drain tile.

Gravel or crushed stone drains shall contain not more than 10 percent material that passes a No. 4 sieve (4.75 mm). The drain shall extend a minimum of 12 inches (305 mm) beyond the outside edge of the footing. The depth shall be such that the bottom of the drain is not higher than the bottom of the base material under the floor, and the top of the drain is not less than 6 inches (152 mm) above the spread portion of the footing. The top of the drain shall be covered with an approved filter membrane material.

When drain tile or perforated pipe is used, the invert of the pipe or tile shall be not higher than the floor elevation. The top of joints or the top of perforations shall be protected with an approved filter membrane material. The pipe or tile shall be placed on not less than 2 inches (51 mm) of gravel or crushed stone complying with this section and covered with not less than 6 inches (152 mm) of the same material.

1825.4 Drainage Disposal. The floor base and foundation perimeter drain shall discharge by gravity or mechanical means into an approved drainage system.

EXCEPTION: Where a site is located in well-drained gravel or sand-gravel mixture soils, a dedicated drainage system need not be provided.

SECTION 1826 — WATERPROOFING REQUIRED

Where the groundwater investigation required by Section 1821 indicates that a hydrostatic pressure caused by the water table does exist, walls and floors shall be waterproofed in accordance with this appendix chapter.

EXCEPTIONS: 1. When the groundwater table can be lowered and maintained at an elevation not less than 6 inches (152 mm) below the bottom of the lowest floor, dampproofing provisions in accordance with Section 1822 may be used in lieu of waterproofing.

The design of the system to lower the groundwater table shall be based on accepted principles of engineering which shall consider, but not necessarily be limited to, the permeability of the soil, the rate at which water enters the drainage system, the rated capacity of pumps, the head against which pumps are to pump, and the rated capacity of the disposal area of the system.

2. Wood foundation systems constructed in accordance with Chapter 18, Division II, are to be provided with additional moisture-control measures as specified in Section 1812.

SECTION 1827 — FLOOR WATERPROOFING

1827.1 General. Floors required to be waterproofed shall be of concrete designed to withstand anticipated hydrostatic pressure.

1827.2 Waterproofing Materials. Waterproofing of floors shall be accomplished by placing under the slab a membrane of rubberized asphalt, polymer-modified asphalt, butyl rubber, neoprene, or not less than 6-mil (0.15 mm) polyvinyl chloride or polyethylene, or other approved materials capable of bridging nonstructural cracks. Joints in the membrane shall be lapped not less than 6 inches (152 mm) and sealed in an approved manner.

SECTION 1828 — WALL WATERPROOFING

1828.1 General. Walls required to be waterproofed shall be of concrete or masonry designed to withstand the anticipated hydrostatic pressure and other lateral loads.

1828.2 Wall Preparation. Prior to the application of waterproofing materials on concrete or masonry walls, the wall surfaces shall be prepared in accordance with Section 1824.2.

1828.3 Where Required. Waterproofing shall be applied from a point 12 inches (305 mm) above the maximum elevation of the groundwater table down to the top of the spread portion of the footing. The remainder of the wall located below grade shall be dampproofed with materials in accordance with Section 1824.3.

1828.4 Waterproofing Materials. Waterproofing shall consist of rubberized asphalt, polymer-modified asphalt, butyl rubber, or other approved materials capable of bridging nonstructural cracks. Joints in the membrane shall be lapped and sealed in an approved manner.

1828.5 Joints. Joints in walls and floors, and between the wall and floor, and penetrations of the wall and floor shall be made watertight using approved methods and materials.

SECTION 1829 — OTHER DAMPPROOFING AND WATERPROOFING REQUIREMENTS

1829.1 Placement of Backfill. The excavation outside the foundation shall be backfilled with soil which is free of organic material, construction debris and large rocks. The backfill shall be placed in lifts and compacted in a manner which does not damage the waterproofing or dampproofing material or structurally damage the wall.

1829.2 Site Grading. The ground immediately adjacent to the foundation shall be sloped away from the building at not less than 1 unit vertical in 12 units horizontal (8.3% slope) for a minimum distance of 6 feet (1829 mm) measured perpendicular to the face of the wall or an approved alternate method of diverting water away from the foundation shall be used. Consideration shall be given to possible additional settlement of the backfill when establishing final ground level adjacent to the foundation.

1829.3 Erosion Protection. Where water impacts the ground from the edge of the roof, downspout, scupper, valley, or other rainwater collection or diversion device, provisions shall be used to prevent soil erosion and direct the water away from the foundation.

Appendix Chapter 19 is printed in its entirety in Volume 2 of the *Uniform Building Code*. Excerpts from Appendix Chapter 19 are reprinted herein.

Excerpts from Appendix Chapter 19
PROTECTION OF RESIDENTIAL CONCRETE EXPOSED TO FREEZING AND THAWING

SECTION 1928 — GENERAL

1928.1 Purpose. The purpose of this appendix is to provide minimum standards for the protection of residential concrete exposed to freezing and thawing conditions.

1928.2 Scope. The provisions of this appendix apply to concrete used in buildings of Groups R and U Occupancies that are three stories or less in height.

1928.3 Special Provisions. Normal-weight aggregate concrete used in buildings of Groups R and U Occupancies three stories or less in height which are subject to de-icer chemicals or freezing and thawing conditions as determined from Figure A-19-1 shall comply with the requirements of Table A-19-A.

TABLE A-19-A—MINIMUM SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE[1]

TYPE OR LOCATION OF CONCRETE CONSTRUCTION	MINIMUM SPECIFIED COMPRESSIVE STRENGTH[2] (f'_c) × 6.89 for kPa		
	Weathering Potential[3]		
	Negligible	Moderate	Severe
Basement walls and foundations not exposed to the weather	2,500	2,500	2,500[4]
Basement slabs and interior slabs on grade, except garage floor slabs	2,500	2,500	2,500[4]
Basement walls, foundation walls, exterior walls and other vertical concrete work exposed to the weather	2,500	3,000[5]	3,000[5]
Porches, carport slabs and steps exposed to the weather, and garage floor slabs	2,500	3,000[5]	3,500[5]

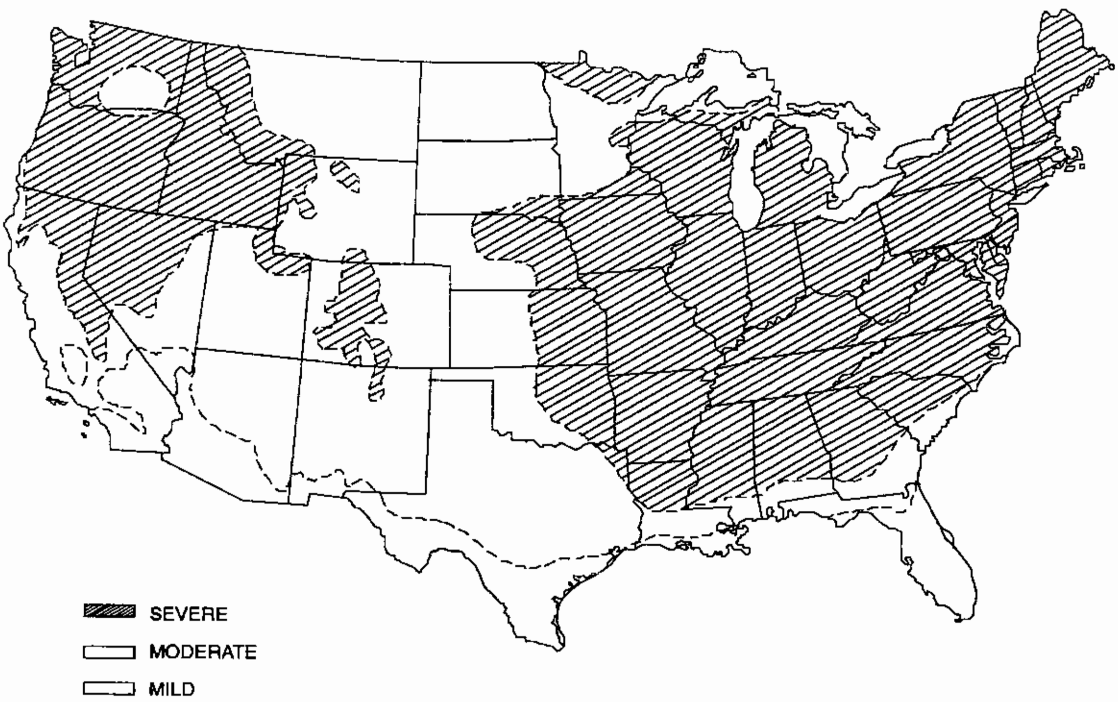
[1]Increases in compressive strength above those used in the design shall not cause implementation of the special inspection provisions of Section 1701.5, Item 1.

[2]At 28 days, pounds per square inch (kPa).

[3]See Figure A-19-1 for weathering potential.

[4]Concrete in these locations which may be subject to freezing and thawing during construction shall be air-entrained concrete in accordance with Footnote 5.

[5]Concrete shall be air entrained. Total air content (percentage by volume of concrete) shall not be less than 5 percent or more than 7 percent.



WEATHERING REGIONS (WEATHERING INDEX)

FIGURE A-19-1—WEATHERING REGIONS FOR RESIDENTIAL CONCRETE

NOTES:

[1]The three exposures are:

A. Severe—Outdoor exposure in a cold climate where concrete may be exposed to the use of de-icing salts or where there may be a continuous presence of moisture during frequent cycles of freezing and thawing. Examples are pavements, driveways, walks, curbs, steps, porches and slabs in unheated garages. Destructive action from de-icing salts may occur either from direct application or from being carried onto an unsalted area from a salted area, such as on the undercarriage of a car traveling on a salted street but parked on an unsalted driveway or garage slab.

B. Moderate—Outdoor exposure in a climate where concrete will not be exposed to the application of de-icing salts but will occasionally be exposed to freezing and thawing.

C. Mild—Any exposure where freezing and thawing in the presence of moisture is rare or totally absent.

[2]Data needed to determine the weathering index for any locality may be found or estimated from the tables of Local Climatological Data, published by the Weather Bureau, U.S. Department of Commerce.

[3]The weathering regions map provides the location of severe, moderate and mild winter weathering areas as they occur in the United States (Alaska and Hawaii are classified as severe and mild, respectively). The map cannot be precise. This is especially true in mountainous areas where conditions change dramatically within very short distances. It is intended to classify as severe any area in which weathering conditions may cause de-icing salt to be used, either by individuals or for street or highway maintenance. These conditions are significant snowfall combined with extended periods during which there is little or no natural thawing. If there is any doubt about which of two regions is applicable, the more severe exposure should be selected.

[4]The Weathering Index:

Severe—As a guideline, the number of days during which the temperature does not rise above 32°F (0°C) is multiplied by the inches of snowfall. An index of 150 or more is classified as severe. Cold, humid climates may be more severe than cold, dry climates for a given index.

Moderate, Mild—Multiply the inches of precipitation times the number of days the temperature registers below 32°F (0°C) Use the occurrence between the first day in the fall and the last day in the spring that the temperature registers below 32°F (0°C) An index above 200 is moderate. An index below 200 is mild.

Appendix Chapter 21 is printed in its entirety in Volume 2 of the *Uniform Building Code*. Excerpts from Appendix Chapter 21 are reprinted herein.

Excerpts from Appendix Chapter 21
PRESCRIPTIVE MASONRY CONSTRUCTION IN HIGH-WIND AREAS

SECTION 2112 — GENERAL

2112.1 Purpose. The provisions of this chapter are intended to promote public safety and welfare by reducing the risk of wind-induced damages to masonry construction.

2112.2 Scope. The requirements of this chapter shall apply to masonry construction in buildings when all of the following conditions are met:

1. The building is located in an area with a basic wind speed from 80 through 110 miles per hour (mph) (129 km/h through 177 km/h).

2. The building is located in Seismic Zone 0, 1 or 2.

3. The building does not exceed two stories.

4. Floor and roof joists shall be wood or steel or of precast hollowcore concrete planks with a maximum span of 32 feet (9754 mm) between bearing walls. Masonry walls shall be provided for the support of steel joists or concrete planks.

5. The building is of regular shape.

2112.3 General. The requirements of Chapter 21 are applicable except as specifically modified by this chapter. Other methods may be used provided a satisfactory design is submitted showing compliance with the provisions of Chapter 16, Part II, and other applicable provisions of this code.

Wood floor, roof and interior walls shall be constructed as specified in Appendix Chapter 23 and as further regulated in this section.

In areas where the wind speed exceeds 110 mph (177 km/h), masonry buildings shall be designed in accordance with Chapter 16, Part II, and other applicable provisions of this code.

Buildings of unusual shape or size, or split-level construction, shall be designed in accordance with Chapter 16, Part II, and other applicable provisions of this code.

In addition to the other provisions of this chapter, foundations for buildings in areas subject to wave action or tidal surge shall be designed in accordance with approved national standards.

All metal connectors and fasteners used in exposed locations or in areas otherwise subject to corrosion shall be of corrosion-resistant or noncorrosive material. When the terms "corrosion resistant" or "noncorrosive" are used in this chapter, they shall mean having a corrosion resistance equal to or greater than a hot-dipped galvanized coating of 1.5 ounces of zinc per square foot (3.95 g/m^2) of surface area. When an element is required to be corrosion resistant or noncorrosive, all of its parts, such as screws, nails, wire, dowels, bolts, nuts, washers, shims, anchors, ties and attachments, shall be corrosion resistant.

2112.4 Materials.

2112.4.1 General. All masonry materials shall comply with Section 2102.2 as applicable for standards of quality.

2112.4.2 Hollow-unit masonry.

1. Exterior concrete block shall be a minimum of Grade N-II with a compressive strength of not less than 1,900 pounds per square inch (psi) (13 091 kPa) on the net area.

2. Interior concrete block shall be a minimum of Grade S-II with a compressive strength of not less than 700 psi (4823 kPa) on the gross area.

3. Exterior clay or shale hollow brick shall have a compressive strength of not less than 2,500 psi (17 225 kPa) on the net area. Such hollow brick shall be at least Grade MW except that where subject to severe freezing it shall be Grade SW.

4. Interior clay or shale hollow brick shall be Grade MW with a compressive strength of 2,000 psi (13 780 kPa) on the net area.

2112.4.3 Solid masonry.

1. Exterior clay or shale bricks shall have a compressive strength of not less than 2,500 psi (17 225 kPa) on the net area.

2. Exterior clay or shale bricks shall be Grade MW, except that where subject to severe freezing they shall be Grade SW.

3. Interior clay or shale bricks shall have a compressive strength of not less than 2,000 psi (13 780 kPa).

2112.4.4 Grout. Grout shall achieve a compressive strength of not less than 2,000 psi (13 780 kPa).

2112.4.5 Mortar. Mortar for exterior walls and for interior shear walls shall be Type M or Type S.

2112.5 Construction Requirements. Grouted cavity wall and block wall construction shall comply with Section 2104.

Unburned clay masonry and stone masonry shall not be used.

2112.6 Foundations. Footings shall have a thickness of not less than 8 inches (203 mm) and shall comply with Tables A-21-A-1 and A-21-A-2 for width. See Figure A-21-1 for other applicable details.

Footings shall extend 18 inches (457 mm) below the undisturbed ground surface or the frost depth, whichever is deeper.

Foundation stem walls shall be as wide as the wall they support. They shall be reinforced with reinforcing bar sizes and spacing to match the reinforcement of the walls they support.

Basement and other below-grade walls shall comply with Table A-21-B.

2112.7 Drainage. Basement walls and other walls or portions thereof retaining more than 3 feet (914 mm) of earth and enclosing interior spaces or floors below grade shall have a minimum 4-inch-diameter (102 mm) footing drain as illustrated in Table A-21-B and Figure A-21-3.

The finish elevations around the building shall be graded to provide a slope away from the building of not less than $^1/_4$ unit vertical in 12 units horizontal (2% slope).

2112.8 Wall Construction.

2112.8.1 Minimum thickness. Reinforced exterior bearing walls shall have a minimum 8-inch (203 mm) nominal thickness.

Interior masonry nonbearing walls shall have a minimum 6-inch (152 mm) nominal thickness. Unreinforced grouted brick walls shall have a minimum 10-inch (254 mm) thickness. Unreinforced hollow-unit and solid masonry shall have a minimum 8-inch (203 mm) nominal thickness.

EXCEPTION: In buildings not more than two stories or 26 feet (7924.8 mm) in height, masonry walls may be of 8-inch (203 mm) nominal thickness. Solid masonry walls in one-story buildings may be of 6-inch (152 mm) nominal thickness when not over 9 feet (2743 mm) in height, provided that when gable construction is used an additional 6 feet (1829 mm) are permitted to the peak of the gable.

2112.8.2 Lateral support and height. All walls shall be laterally supported at the top and bottom. The maximum unsupported height of bearing walls or other masonry walls shall be 12 feet (3658 mm). Gable-end walls may be 15 feet (4572 mm) at their peak.

Wood-framed gable-end walls on buildings shall comply with Table A-21-I and Figure A-21-17 or A-21-18.

2112.8.3 Walls in Seismic Zone 2 and use of stack bond. In Seismic Zone 2, walls shall comply with Figure A-21-2 as a minimum. Walls with stack bond shall be designed.

2112.8.4 Lintels. The span of lintels over openings shall not exceed 12 feet (3658 mm), and lintels shall be reinforced. The reinforcement bars shall extend not less than 2 feet (610 mm) beyond the edge of opening and into lintel supports.

Lintel reinforcement shall be within fully grouted cells in accordance with Table A-21-E.

2112.8.5 Reinforcement. Walls shall be reinforced as shown in Tables A-21-C-1 through A-21-C-5 and Figure A-21-2.

2112.8.6 Anchorage of walls to floors and roofs. Anchors between walls and floors or roofs shall be embedded in grouted cells or cavities and shall conform to Section 2112.9.

2112.9 Floor and Roof Systems. The anchorage of wood roof systems which are supported by masonry walls shall comply with Appendix Sections 2337.5.1 and 2337.5.8, Table A-21-D and Figure A-21-7.

Wood roof and floor systems which are supported by ledgers at the inside face of masonry walls shall comply with Table A-21-D, Part I.

The ends of joist girders shall extend a distance of not less than 6 inches (152 mm) over masonry or concrete supports and be attached to a steel bearing plate. This plate is to be located not more than $^1/_2$ inch (12.7 mm) from the face of the wall and is to be not less than 9 inches (229 mm) wide perpendicular to the length of the joist girder. Ends of joist girders resting on steel bearing plates on masonry or structural concrete shall be attached thereto with a minimum of two $^1/_4$-inch (6.4 mm) fillet welds 2 inches (51 mm) long, or with two $^3/_4$-inch (19 mm) bolts.

Ends of joist girders resting on steel supports shall be connected thereto with a minimum of two $^1/_4$-inch (6.4 mm) fillet welds 2 inches (51 mm) long, or with two $^3/_4$-inch (19 mm) bolts. In steel frames, joist girders at column lines shall be field bolted to the columns to provide lateral stability during construction.

Steel joist roof and floor systems shall be anchored in accordance with Table A-21-H.

Wall ties spaced as shown in Table A-21-D, Part II, shall connect to framing or blocking at roofs and walls. Wall ties shall enter grouted cells or cavities and shall be $1^1/_8$-inch (29 mm) minimum width by 0.036 inch (0.91 mm) (No. 20 galvanized sheet gage) sheet steel.

Roof and floor hollow-core precast plank systems shall be anchored in accordance with Table A-21-G.

Roof uplift anchorage shall enter a grouted bond beam reinforced with horizontal bars as shown in Tables A-21-C-1 through A-21-C-5 and Figure A-21-7.

2112.10 Lateral Force Resistance.

2112.10.1 Complete load path and uplift resistance. Strapping, approved framing anchors, and mechanical fasteners, bond beams, and vertical reinforcement shall be installed to provide a continuous tie from the roof to the foundation system. (See Figure A-21-8.) In addition, roof and floor systems, masonry shear walls, or masonry or wood cross walls shall provide lateral stability.

2112.10.2 Floor and roof diaphragms. Floor and roof diaphragms shall be connected to masonry walls as shown in Table A-21-F, Part II.

Gabled and sloped roof members not supported at the ridge shall be tied by ceiling joists or equivalent lateral ties located as close to where the roof member bears on the wall as is practically possible, at not more than 48 inches (1219 mm) on center. Collar ties shall not be used for these lateral ties. (See Figure A-21-17 and Table A-21-I.)

2112.10.3 Walls. Masonry walls shall be provided around all sides of floor and roof systems in accordance with Figure A-21-9 and Table A-21-F.

The cumulative length of exterior masonry walls along each side of the floor or roof systems shall be at least 20 percent of the parallel dimension. Required elements shall be without openings and shall not be less than 48 inches (1219 mm) in width.

Interior cross walls (nonbearing) at right angles to bearing walls shall be provided when the length of the building perpendicular to the span of the floor or roof framing exceeds twice the distance between shear walls or 32 feet (9754 mm), whichever is greater. Cross walls, when required, shall conform to Section 2112.10.4.

2112.10.4 Interior cross walls. When required by Table A-21-F, Part I, masonry walls shall be at least 6 feet (1829 mm) long and reinforced with 9 gage wire joint reinforcement spaced not more than 16 inches (406 mm) on center. Cross walls shall comply with Footnote 3 of Table A-21-F, Part I.

Interior wood stud walls may be used to resist the wind load from one-story masonry buildings in areas where the basic wind speed is 100 mph (161 km/h), Exposure C or less, and 110 mph (177 km/h), Exposure B. When wood stud walls are so used, they shall:

1. Be perpendicular to exterior masonry walls at 15 feet (4572 mm) or less on center.

2. Be at least 8 feet (2438 mm) long without openings and be sheathed on at least one side with $^{15}/_{32}$-inch (12 mm) wood structural panel nailed with 8d common or galvanized box nails at 6 inches (152 mm) on center edge and field nailing. All unsupported edges of wood structural panels shall be blocked.

3. Be connected to wood blocking or wood joists below with two 16d nails at 16 inches (406 mm) on center through their sill plates. They shall be connected to footings with $^1/_2$-inch-diameter (12.7 mm) bolts at 3 feet 6 inches (1067 mm) on center.

4. Connect to wood roof systems as outlined in Table A-21-F, Part II, as a cross wall. Wood structural panel roof sheathing shall have all unsupported edges blocked.

TABLE A-21-A-1—EXTERIOR FOUNDATION REQUIREMENTS FOR MASONRY BUILDINGS WITH 6- AND 8-INCH-THICK WALLS (Wood or Steel Framing) (Width of Footings in Inches)[1,2,3] See Figure A-21-1 for typical details.

WALL HEIGHT (feet)	SPAN TO BEARING WALLS (feet)	ONE-STORY BUILDINGS Roof Live Load[4] × 0.0479 for kN/m²			TWO-STORY BUILDINGS Roof Live Load[4] (psf) × 0.0479 for kN/m²					
					20		30		40	
					Plus Floor Live Load[5] (psf) × 0.0479 for kN/m²					
		20 psf (inches)	30 psf (inches)	40 psf (inches)	50	100	50	100	50	100
		Minimum Width of Footing (inches)								
× 304.8 for mm		× 25.4 for mm								
8	8	12			12	12	12	12	12	12
	16				12	14	12	14	12	14
	24				14	18	14	18	16	18
	32				16	20	18	20	18	20
10	8	12			12	12	12	12	12	12
	16				14	16	14	16	14	16
	24				16	20	16	18	16	20
	32				20	24	20	22	20	24
12	8	12	12	12	12	14	12	14	12	14
	16	12	12	12	16	18	16	16	14	16
	24	12	12	14	18	20	18	20	18	20
	32	12	14	16	20	22	22	22	22	24

[1]For buildings with under-floor space or basements, footing thickness is to be a minimum of 12 inches (305 mm). It shall be reinforced with No. 4 bars at 24 inches (610 mm) on center when its width is required to be 18 inches (457 mm) or larger and it supports more than the roof and one floor.

[2]Soil to be at least Class 4 as shown in Table 18-I-A.

[3]Footings are a minimum of 10 inches (254 mm) thick for a one-story building and 12 inches (305 mm) thick for a two-story building. Bottom of footing to be 18 inches (457 mm) below grade or the frost depth, whichever is deeper. Footing to be reinforced with No. 4 bars at 24 inches (610 mm) on center when supporting more than the roof and one floor.

[4]From Table 21-C or local snow load tables. For areas without snow loads use 20 pounds per square foot (0.96 kN/m²).

[5]From Table 21-A. For intermediate floor loads go to next higher value.

TABLE A-21-A-2—INTERIOR FOUNDATION REQUIREMENTS FOR MASONRY BUILDINGS WITH 6- AND 8-INCH-THICK WALLS (Wood or Steel Framing) (Width of Footings in Inches)[1,2,3,4] See Figure A-21-1 for typical details.

WALL HEIGHT (feet)	SPAN TO BEARING WALLS (feet)	ONE-STORY BUILDINGS Roof Live Load[5] × 0.0479 for kN/m²			TWO-STORY BUILDINGS Roof Live Load[5] (psf) × 0.0479 for kN/m²					
					20		30		40	
					Plus Floor Live Load[6] (psf) × 0.0479 for kN/m²					
		20 psf (inches)	30 psf (inches)	40 psf (inches)	50	100	50	100	50	100
× 304.8 for mm		Minimum Width of Footing (inches) × 25.4 for mm								
8	8	12	12	12	12	14	12	14	12	14
	16	12	12	12	16	20	18	20	18	22
	24	12	12	14	20	26	22	28	22	28
	32	14	14	16	24	28	26	32	28	34
10	8	12	12	12	14	16	14	16	14	16
	16	12	12	12	20	24	20	22	20	22
	24	12	14	14	22	28	22	28	22	28
	32	14	14	16	26	34	26	32	28	34
12	8	12	12	12	14	16	16	18	16	18
	16	12	14	16	20	24	20	22	20	22
	24	14	14	16	24	28	22	28	24	28
	32	16	16	18	28	30	28	32	28	34

[1]For buildings with under-floor space or basements, footing thickness is to be a minimum of 12 inches (305 mm). It shall be reinforced with No. 4 bars at 24 inches (610 mm) on center when its width is required to be 18 inches (457 mm) or larger and it supports more than the roof and one floor.

[2]Soil to be at least Class 4 as shown in Table 18-I-A.

[3]Footings are 10 inches (254 mm) thick for up to 24 inches (610 mm) wide and 12 inches (305 mm) thick for up to 34 inches (864 mm) wide. Footings shall be reinforced with No. 4 bars at 24 inches (610 mm) on center when supporting more than the roof and one floor.

[4]These interior footings support roof-ceiling or floors or both for a distance on each side equal to the span length shown. A tributary width equal to the span length may be used.

[5]From Table 16-C or local snow load tables. For areas without snow loads use 20 pounds per square foot (0.96 kN/m²).

[6]From Table 16-A. For intermediate floor loads go to next higher value.

TABLE A-21-B—VERTICAL REINFORCEMENT AND TOP RESTRAINT FOR VARIOUS HEIGHTS OF BASEMENT AND OTHER BELOW-GRADE WALLS

DESIGN ASSUMPTIONS

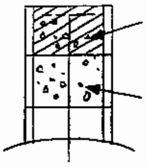
A. Materials:
1. **Concrete Masonry Units**—Grade hollow load-bearing units conforming to Section 2112.4.2 for strength of units should not be less than that required for applicable f'_m.
2. **Mortar**—Type M, 2,500 psi (17 240 kPa) strength.
3. **Corefill**—Fine or coarse grout (UBC Standard 21-19) with an ultimate strength (28 days) of at least 2,500 psi. (17 240 kPa)
4. **Reinforcement**—Deformed billet-steel bars.
5. 1,500 psi (71.8 kPa) soil bearing required.[1]

B. Allowable stresses in accordance with Section 2106 and Table 21-M.

Soil Equiv.-fluid wt. = 30 pcf[1] (4.71 kN/m^3)			Vertical Reinforcement with Axial Compressive Load (P) Equal to or Less than 5,000 lb./lin. ft. (72.92 kN/m)			
Wall Depth below Grade h (feet)	Floor Connection[2,3]		f'_m = 1,500 psi (10 335 kPa)			
	Wood Floor		Spacing of Reinforcement (inches)[4]			
× 304.8 for mm	Bolt and Spacing	Angle Clip Spacing	× 25.4 for mm			
8-inch Walls			No. 3	No. 4	No. 5	
× 25.4 for mm						
4	$^1/_2$″ at 60″	48″ o.c.	24	40	56	
5	$^1/_2$″ at 40″	32″ o.c.	16	24	40	
6	$^5/_8$″ at 32″	20″ o.c.	—	16	24	
10-inch Walls			Spacing of Reinforcement (inches)			
			× 25.4 for mm			
× 25.4 for mm			No. 4	No. 5	No. 6	No. 7
6	$^5/_8$″ at 32″	20″ o.c.	40	56	64	72
7	$^5/_8$″ at 24″	16″ o.c.	24	40	48	56
9	$^3/_4$″ at 20″	2 at 24″ o.c.	16	24	32	40
12-inch Walls			Spacing of Reinforcement (inches)			
			× 25.4 for mm			
× 25.4 for mm			No. 4	No. 5	No. 6	No. 7
7	$^5/_8$″ at 24″	16″ o.c.	40	56	80	80
8	$^3/_4$″ at 20″	2 at 24″ o.c.	32	48	56	64
9	$^7/_8$″ at 18″	2 at 18″ o.c.	24	40	48	48
10	1″ at 16″	2 at 16″ o.c.	16	32	40	40

[1]Soil type is at least Class 4 as shown in Table 18-I-A.
[2]There shall be no backfill placed until after the wall is anchored to the floor and seven days have passed after grouting.
[3]For Figure A-21-4 only.
[4]See Figure A-21-5 for placement of reinforcement.

TABLE A-21-C-1—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 6-INCH-THICK (153 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5]
(Wood or Steel Roof and Floor Framing)



Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m^2 to 1.9 kN/m^2); Floor Live Load = 50 psf (2.4 kN/m^2); enclosed building[6]

EXPOSURE	STORIES	UNSUPPORTED HEIGHT (feet) × 304.8 for mm	80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet) × 304.8 for mm															
			8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
			Size of Rebar and Spacing (inches) × 25.4 for mm															
B	One-story building	8	NR*								No. 4 80	No. 4 80	No. 4 80	No. 4 80	No. 4 64	No. 4 64	No. 4 72	No. 4 88
		10	No. 4 80	No. 4 88	No. 4 96	No. 4 96	No. 4 64	No. 4 64	No. 4 72	No. 4 80	No. 4 48	No. 4 48	No. 4 48	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 48
		12	No. 4 48	No. 4 48	No. 4 56	No. 4 64	No. 4 40	No. 4 40	No. 4 48	No. 4 48	No. 5 48	No. 5 48	No. 5 56	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40
	Two-story building		Design required or use 8-inch or larger units for two-story condition.															
C	One-story building	8	No. 4 72	No. 4 72	No. 4 72	No. 4 96	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 48	No. 4 48	No. 4 32	No. 4 32	No. 4 32	No. 4 40
		10	No. 4 40	No. 4 40	No. 4 40	No. 4 48	No. 4 32	No. 4 32	No. 4 32	No. 4 32	No. 5 40	No. 5 40	No. 5 40	No. 5 48	No. 5 32	No. 5 32	No. 5 32	No. 5 40
		12	No. 5 40	No. 5 48	No. 5 48	No. 5 48	No. 5 32	No. 5 32	No. 5 32	No. 5 40	Use 8-inch or larger units							
	Two-story building		Design required or use 8-inch or larger units for two-story condition.															
D	One-story building	8	No. 4 56	No. 4 56	No. 4 64	No. 4 80	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 4 32	No. 4 40	No. 4 40	No. 4 40	No. 4 32	No. 4 32	No. 4 32	No. 4 32
		10	No. 4 32	No. 4 32	No. 4 32	No. 4 40	No. 5 40	No. 5 40	No. 5 48	No. 5 48	No. 5 48	No. 5 32	No. 5 32	No. 5 40				
		12	No. 5 32	No. 5 40	No. 5 40	No. 5 40	Use 8-inch or larger units											
	Two-story building		Design required or use 8-inch or larger units for two-story condition.															

*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.

[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60. The vertical bars are centered in the middle of the wall.

[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.

[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.

[5]Hook vertical bars over bond beam bars as shown. Extend bars into footing using lap splices where necessary.

[6]Design required for open buildings of 6-inch-thick (153 mm) masonry.

To use this table, check criteria by the following method:

[6.1]Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.

[6.2]Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.

[6.3]Choose proper floor load from Table 16-A. [For loads less than 50 pounds per square foot (psf) (2.4 kN/m^2), use 50 psf (2.4 kN/m^2), and for loads between 50 psf (2.4 kN/m^2) and 100 psf (4.8 kN/m^2), use 100 psf (4.8 kN/m^2).]

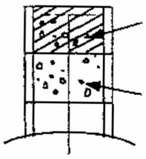
[6.4]Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.

[6.5]Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.

[6.6]Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)

[6.7]For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-C-2—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 8-INCH-THICK (203 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5] (Wood or Steel Roof and Floor Framing)



Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m² to 1.9 kN/m²); Floor Live Load = 50 psf (2.4 kN/m²); enclosed building

EXPOSURE	STORIES	UNSUPPORTED HEIGHT (feet)	80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet) × 304.8 for mm															
			8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
		× 304.8 for mm	Size of Rebar and Spacing (Inches) × 25.4 for mm															
B	One-story building or top story of two-story building	8	NR*												No. 3 56	No. 3 56	No. 3 64	No. 3 64
		10	NR*				No. 4 80	No. 4 80	No. 4 88	No. 4 88	No. 4 64	No. 4 64	No. 4 64	No. 4 72	No. 4 48	No. 4 48	No. 4 56	No. 4 56
		12	No. 4 64	No. 4 72	No. 4 72	No. 4 72	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 5 64	No. 5 64	No. 5 56	No. 5 56	No. 5 56	No. 5 56
	First story of a two-story building	8	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 88	No. 3 80	No. 3 72	No. 3 72	No. 3 72	No. 3 64	No. 3 64
		10	No. 3 88	No. 3 80	No. 3 72	No. 3 64	No. 3 64	No. 3 64	No. 3 56	No. 3 56	No. 4 72	No. 4 72	No. 4 64	No. 4 64	No. 4 64	No. 4 56	No. 4 56	No. 4 56
		12	No. 4 80	No. 4 72	No. 4 64	No. 4 64	No. 4 64	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 5 64	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48
C	One-story building or top story of two-story building	8	NR*				No. 3 48	No. 3 48	No. 3 48	No. 3 56	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 48	No. 4 56	No. 4 56	No. 4 56
		10	No. 4 56	No. 4 56	No. 4 64	No. 4 64	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		12	No. 5 56	No. 5 64	No. 5 64	No. 5 64	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 6 56	No. 6 56	No. 6 56	No. 6 56	No. 6 40	No. 6 40	No. 6 40	No. 6 48
	First story of a two-story building	8	No. 3 80	No. 3 80	No. 3 56	No. 3 72	No. 3 56	No. 3 56	No. 3 56	No. 3 56	No. 4 72	No. 4 72	No. 4 72	No. 4 64	No. 4 56	No. 4 56	No. 4 56	No. 4 56
		10	No. 4 72	No. 4 64	No. 4 64	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 5 64	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		12	No. 5 64	No. 5 64	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 6 56	No. 6 56	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40
D	One-story building or top story of two-story building	8	No. 3 48	No. 3 48	No. 3 56	No. 3 56	No. 4 64	No. 4 72	No. 4 72	No. 4 80	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 48	No. 4 48	No. 4 48
		10	No. 4 48	No. 4 48	No 4 48	No. 4 56	No. 5 56	No. 5 64	No. 5 64	No. 5 64	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40
		12	No. 5 48	No. 5 48	No. 5 56	No. 5 56	No. 6 56	No. 6 56	No. 6 56	No. 6 56	No. 6 48	No. 6 48	No .6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40
	First story of a two-story building	8	No. 3 64	No. 3 64	No. 3 64	No. 3 56	No. 4 80	No. 4 80	No. 4 72	No. 4 72	No. 4 64	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 4 48
		10	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 5 64	No. 5 64	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 32
		12	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 6 56	No. 6 56	No. 6 56	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32

*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.

[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60.

[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.

[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.

[5]Hook vertical bars over bond beam as shown. Extend bars into footing using lap splices where necessary. Where second-story bar spacing does not match those on the first story, hook bars around floor bond beam also.

To use this table, check criteria by the following method:

5.1 Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.

5.2 Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.

5.3 Choose proper floor load from Table 16-A. [For loads less that 50 psf (2.4 kN/m²), use 50 psf (2.4 kN/m²), and for loads between 50 psf (2.4 kN/m²) and 100 psf (4.8 kN/m²), use 100 psf (4.8 kN/m²).]

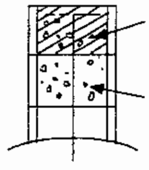
5.4 Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.

5.5 Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.

5.6 Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)

5.7 For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-C-3—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 8-INCH-THICK (203 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5] (Wood or Steel Roof and Floor Framing)



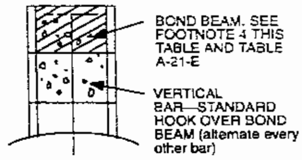
Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m² to 1.9 kN/m²); Floor Live Load = 100 psf (4.8 kN/m²); enclosed building

EXPOSURE	STORIES	UNSUPPORTED HEIGHT (feet) × 304.8 for mm	80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet) × 304.8 for mm															
			8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
			Size of Rebar and Spacing (inches) × 25.4 for mm															
B	One-story building or top story of two-story building	8	NR*												No. 3 56	No. 3 56	No. 3 64	No. 3 64
		10	NR*				No. 4 64	No. 4 64	No. 4 64	No. 4 72	No. 4 64	No. 4 64	No. 4 64	No. 4 72	No. 4 48	No. 4 48	No. 4 56	No. 4 56
		12	No. 4 64	No. 4 72	No. 4 72	No. 4 72	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 56	No. 5 56	No. 5 56	No. 5 56
	First story of a two-story building	8	No. 3 96	No. 3 96	No. 3 80	No. 3 64	No. 3 96	No. 3 88	No. 3 72	No. 3 56	No. 3 80	No. 3 64	No. 3 56	No. 3 48	No. 3 64	No. 3 56	No. 3 48	No. 4 64
		10	No. 3 72	No. 3 64	No. 3 56	No. 3 48	No. 3 56	No. 3 48	No. 4 64	No. 4 56	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 5 56
		12	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 4 40	No. 4 48	No. 4 40	No. 5 48	No. 5 48	No. 5 56	No. 5 48	No. 5 48	No. 5 40
C	One-story building or top story of two-story building	8	NR*				No. 3 48	No. 3 48	No. 3 48	No. 3 56	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 48	No. 4 56	No. 4 56	No. 4 56
		10	No. 4 56	No. 4 56	No. 4 64	No. 4 64	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		12	No. 4 40	No. 5 64	No. 5 64	No. 5 64	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 6 56	No. 6 56	No. 6 56	No. 6 40	No. 6 40	No. 6 40	No. 5 32
	First story of a two-story building	8	No. 3 72	No. 3 64	No. 3 56	No. 3 48	No. 3 56	No. 3 48	No. 4 64	No. 4 56	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 5 56
		10	No. 4 64	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40
		12	No. 4 40	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 6 48	No. 5 40	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 32
D	One-story building or top story of two-story building	8	No. 3 48	No. 3 48	No. 3 56	No. 3 56	No. 3 64	No. 4 72	No. 4 72	No. 4 80	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 48	No. 4 48	No. 4 48
		10	No. 4 48	No. 4 48	No 4 48	No. 4 56	No. 5 56	No. 5 64	No. 5 64	No. 5 64	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40
		12	No. 5 48	No. 5 48	No. 5 56	No. 5 56	No. 5 40	No. 5 40	No. 6 56	No. 6 56	No. 6 48	No. 6 48	No .6 48	No. 5 32	No. 6 40	No. 6 40	No. 6 40	No. 6 40
	First story of a two-story building	8	No. 3 56	No. 3 56	No. 3 48	No. 4 64	No. 3 48	No. 4 64	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 5 64	No. 4 48	No. 5 64	No. 5 56	No. 5 56
		10	No. 4 56	No. 4 48	No. 4 48	No. 5 56	No. 5 64	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48
		12	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 40	No. 6 48	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32	No. 6 32	No. 6 24

*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.
[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60.
[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.
[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.
[5]Hook vertical bars over bond beam as shown. Extend bars into footing using lap splices where necessary. Where second-story bar spacing does not match those on the first story, hook bars around floor bond beam also.
To use this table, check criteria by the following method:
[5.1]Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.
[5.2]Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.
[5.3]Choose proper floor load from Table 16-A. [For loads less than 50 psf (2.4 kN/m²), use 50 psf (2.4 kN/m²), and for loads between 50 psf (2.4 kN/m²) and 100 psf (4.8 kN/m²), use 100 psf (4.8 kN/m²).]
[5.4]Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.
[5.5]Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.
[5.6]Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)
[5.7]For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-C-4—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 8-INCH-THICK (203 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5] (Wood or Steel Roof and Floor Framing)



Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m² to 1.9 kN/m²); Floor Live Load = 50 psf (2.4 kN/m²); partially enclosed building

EXPOSURE	STORIES	UNSUPPORTED HEIGHT (feet) × 304.8 for mm	80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet) × 304.8 for mm															
			8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
			Size of Rebar and Spacing (inches) × 25.4 for mm															
B	One-story building or top story of two-story building	8	No. 4 96	No. 4 96	No. 3 80	No. 3 88	No. 3 56	No. 3 56	No. 3 64	No. 3 64	No. 3 40	No. 3 48	No. 3 48	No. 3 48	No. 4 64	No. 4 64	No. 4 64	No. 4 72
		10	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 48	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 56	No. 5 56	No. 5 56
		12	No. 4 40	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 48
	First story of a two-story building	8	No. 3 96	No. 3 96	No. 3 88	No. 3 80	No. 3 72	No. 3 72	No. 3 64	No. 3 64	No. 3 48	No. 3 48	No. 3 48	No. 3 48	No. 4 64	No. 4 64	No. 4 64	No. 4 64
		10	No. 3 48	No. 3 48	No. 3 48	No. 3 48	No. 4 64	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 4 40	No.4 40	No. 5 56	No. 5 56	No. 5 48
		12	No. 4 48	No. 4 48	No. 4 48	No. 4 40	No. 4 40	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 48
C	One-story building or top story of two-story building	8	No. 3 40	No. 3 40	No. 3 40	No. 3 40	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56
		10	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 32	No. 5 32	No. 5 40	No. 5 40	No. 6 40	No. 6 40	No. 6 40	No. 6 40
		12	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 40	No. 6 48	No. 6 48	No. 6 48	No. 6 32	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
	First story of a two-story building	8	No. 3 48	No. 3 48	No. 3 48	No. 3 48	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 40	No. 4 40	No. 5 56	No. 5 56	No. 5 56	No. 5 48
		10	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40
		12	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
D	One-story building or top story of two-story building	8	No. 4 56	No. 4 56	No. 4 56	No. 4 64	No. 4 40	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		10	No. 5 48	No. 5 48	No. 5 48	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 56	No. 6 48	No. 6 48	No. 6 48	No. 6 32	No. 6 32	No. 6 40	No. 6 40
		12	No. 6 48	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 24	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
	First story of a two-story building	8	No. 4 64	No. 4 64	No. 4 64	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 4 40	No. 4 40	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 40
		10	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32
		12	No. 6 48	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	Use 10-inch or larger units									

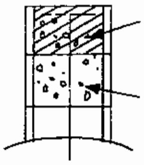
*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.
[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60.
[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.
[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.
[5]Hook vertical bars over bond beam as shown. Extend bars into footing using lap splices where necessary.

To use this table, check criteria by the following method:

5.1 Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.
5.2 Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.
5.3 Choose proper floor load from Table 16-A. [For loads less than 50 psf (2.4 kN/m²), use 50 psf (2.4 kN/m²), and for loads between 50 psf (2.4 kN/m²) and 100 psf (4.8 kN/m²), use 100 psf (4.8 kN/m²).]
5.4 Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.
5.5 Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.
5.6 Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)
5.7 For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-C-5—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 8-INCH-THICK (203 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5] (Wood or Steel Roof and Floor Framing)



Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m^2 to 1.9 kN/m^2); Floor Live Load = 100 psf (4.8 kN/m^2); partially enclosed building

			80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet)															
			× 304.8 for mm															
		UNSUPPORTED HEIGHT (feet)	8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
			Size of Rebar and Spacing (inches)															
EXPOSURE	STORIES	× 304.8 for mm	× 25.4 for mm															
B	One-story building or top story of two-story building	8	No. 3 72	No. 4 96	No. 3 80	No. 3 88	No. 3 56	No. 3 56	No. 3 64	No. 3 64	No. 4 80	No. 4 80	No. 4 80	No. 4 88	No. 4 64	No. 4 64	No. 4 64	No. 4 72
		10	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 48	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 56	No. 5 56	No. 5 56
		12	No. 4 40	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 48
	First story of a two-story building	8	No. 3 88	No. 3 96	No. 3 56	No. 4 72	No. 3 64	No. 3 56	No. 3 64	No. 4 64	No. 4 80	No. 4 72	No. 4 64	No. 4 56	No. 4 64	No. 4 56	No. 4 48	No. 4 48
		10	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 4 40	No. 4 48	No. 4 40	No. 5 56	No. 5 48	No. 5 56	No. 5 48	No. 5 48	No. 5 40
		12	No. 4 48	No. 4 40	No. 4 40	No. 5 48	No. 5 56	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40
C	One-story building or top story of two-story building	8	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56
		10	No. 5 56	No. 5 56	No. 4 40	No. 4 40	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 32	No. 6 56	No. 6 56	No. 5 40	No. 6 40	No. 6 40	No. 6 40	No. 6 40
		12	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 40	No. 6 48	No. 6 48	No. 6 48	No. 6 32	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
	First story of a two-story building	8	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 56	No. 5 48	No. 5 48	No. 5 40
		10	No. 5 64	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 32
		12	No. 5 40	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units				
D	One-story building or top story of two-story building	8	No. 4 56	No. 4 56	No. 4 56	No. 4 64	No. 4 40	No. 5 72	No. 5 72	No. 5 72	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		10	No. 5 48	No. 5 48	No. 5 48	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 56	No. 6 48	No. 6 48	No. 6 48	No. 6 32	No. 6 32	No. 6 40	No. 6 40
		12	No. 6 48	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 24	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
	First story of a two-story building	8	No. 4 64	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 5 64	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40
		10	No. 5 56	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32
		12	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units							

*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.

[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60.

[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.

[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.

[5]Hook vertical bars over bond beam as shown. Extend bars into footing using lap splices where necessary.

To use this table, check criteria by the following method:

5.1 Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.

5.2 Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.

5.3 Choose proper floor load from Table 16-A. [For loads less than 50 psf (2.4 kN/m^2), use 50 psf (2.4 kN/m^2), and for loads between 50 psf (2.4 kN/m^2) and 100 psf (4.8 kN/m^2), use 100 psf (4.8 kN/m^2).]

5.4 Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.

5.5 Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.

5.6 Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)

5.7 For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-D—ANCHORAGE OF WOOD MEMBERS TO EXTERIOR WALLS FOR VERTICAL AND UPLIFT FORCES

[In areas where basic wind speeds are 80 miles per hour (129 km/h) or greater]

See Figure A-21-7 for details

Part I—Anchor bolt size and spacing [in inches (mm)][1,2,3] on wood ledgers carrying vertical loads from roofs and floors[4,5] Douglas fir-larch, California redwood (close grain) and southern pine[6,7]

TYPE OF LOADING	LIVE LOAD[8,9] psf (× 0.0479 for kN/m²)	2-INCH (51 mm) × LEDGER				3-INCH (76 mm) × LEDGER				4-INCH (102 mm) × LEDGER			
		Span between Bearing Walls (feet) × 304.8 for mm											
		8	16	24	32	8	16	24	32	8	16	24	32
		× 25.4 for mm											
Roof	20	$^{1}/_{2}$ 32	(2)$^{1}/_{2}$ 16	$^{5}/_{8}$ 16	$^{7}/_{8}$ 16	$^{1}/_{2}$ 32	$^{1}/_{2}$ 16	(2)$^{1}/_{2}$ 32	$^{7}/_{8}$ 16	— —	$^{5}/_{8}$ 32	$^{7}/_{8}$ 32	(2)$^{5}/_{8}$ 32
	30	(2)$^{1}/_{2}$ 32	$^{1}/_{2}$ 16	$^{3}/_{4}$ 16	$^{7}/_{8}$ 16	$^{1}/_{2}$ 16	(2)$^{7}/_{8}$ 32	$^{7}/_{8}$ 16	$^{7}/_{8}$ 16	— —	(2)$^{1}/_{2}$ 32	$^{5}/_{8}$ 16	$^{3}/_{4}$ 16
	40	$^{1}/_{2}$ 16	$^{5}/_{8}$ 16	$^{3}/_{4}$ 8	— —	$^{5}/_{8}$ 16	(2)$^{5}/_{8}$ 32	$^{7}/_{8}$ 16	1 16	$^{5}/_{8}$ 32	$^{5}/_{8}$ 16	$^{3}/_{4}$ 16	$^{7}/_{8}$ 16
Floor[10]	50	$^{1}/_{2}$ 16	1 12	— —	— —	$^{5}/_{8}$ 24	$^{3}/_{4}$ 32	$^{3}/_{4}$ 12	$1^{1}/_{4}$ 12	$^{5}/_{8}$ 24	$^{7}/_{8}$ 24	$^{7}/_{8}$ 16	$^{7}/_{8}$ 12
	100	1 16	(2)$^{3}/_{4}$ 12	— —	— —	$^{5}/_{8}$ 16	1 12	(2)$^{3}/_{4}$ 12	(2)1 12	$^{7}/_{8}$ 16	$^{3}/_{4}$ 12	1 12	(2)$^{3}/_{4}$ 12

[1]Closer spacing may be used.
[2]Use two bolts, one above the other, at splices and locate them away from the splice end by $3^{1}/_{2}$ inches (89 mm) for $^{1}/_{2}$-inch (13 mm) diameter, $4^{1}/_{2}$ inches (114.3 mm) for $^{5}/_{8}$-inch (15.9 mm) diameter, $5^{1}/_{4}$ inches (133 mm) for $^{3}/_{4}$-inch (19 mm) diameter, $6^{1}/_{4}$ inches (158 mm) for $^{7}/_{8}$-inch (22.2 mm) diameter and 7 inches (178 mm) for 1-inch (25.4 mm) diameter.
[3]See Table A-21-F for lateral force requirements (when applicable).
[4]Tabulated values are based on short-term loading due to roof loads (25 percent) or snow loads (15 percent), whichever controls. No increase is allowed for floor loads.
[5]See details in Figure A-21-7 for location relative to other construction. Note that roofs are concentrically loaded.
[6]See Chapter 23, Division III, Part I, for other species. Adjust spacing in direct proportion to the perpendicular-to-grain values for the applicable ledger and bolt sizes shown using the procedure described in Chapter 23, Division III, Part I. No increase is allowed for special inspection.
[7]Values on top are bolt sizes and underneath are spacing. Multiple bolts are shown in parenthesis: example (2) = two.
[8]See Table 16-C or Appendix Chapter 16, Division I, for values.
[9]Joist spacing is limited to 30 inches (762 mm) on center maximum.
[10]Where two bolts are required they shall be staggered at half the spacing shown or be placed one above the other.

Part II—Uplift anchors[1] for wood roof members [number of common nails in a 0.036 inch (0.91 mm) (No. 20 galvanized sheet gage) by $1^{1}/_{8}$-inch (28.6 mm) tie strap embedded 5 inches (127 mm) into a masonry bond beam[2]]

ENCLOSURE[3]	EXPOSURE[4]	80 MPH				90 MPH				100 MPH				110 MPH			
		× 1.61 for km/h															
		Span between Bearing Walls (feet)[5] × 304.8 for mm															
		8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
Enclosed	B	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	2-8d	2-8d
	C	NR	NR	NR	NR	NR	2-8d	3-8d	4-8d	2-8d	4-8d	5-10d	5-10d	2-10d	4-10d	3-10d 24″	4-10d 24″
	D	NR	2-8d	3-8d	4-8d	2-8d	4-8d	4-10d	5-10d	3-8d	5-8d	5-10d	4-10d 24″	3-10d	5-10d	4-10d 24″	5-10d 24″
Open	B	NR	NR	NR	NR	NR	NR	2-8d	2-8d	NR	2-8d	4-8d	5-10d	2-8d	4-8d	5-8d	6-10d
	C	2-8d	4-8d	5-8d	5-10d	3-8d	5-8d	3-10d 24″	4-10d 24″	3-10d	5-10d	5-10d 24″	5-10d 16″	5-8d	4-10d 24″	5-10d 16″	6-10d 16″
	D	2-8d	5-8d	5-10d	5-10d 24″	4-8d	5-10 d	4-10d 24″	5-10d 24″	5-8d	4-10d 24″	6-10d 24″	6-10d 16″	4-8d	5-10d 24″	6-10d 16″	6-10d 12″

NR — No requirements; use Table 23-II-B-1 minimum.

[1]Tie straps are at 48 inches (1219 mm) on center unless otherwise stated. See Figure A-21-7 for illustration of tie straps.
[2]Bond beam to be at least 48 inches (1219 mm) deep nominal and shall be reinforced as shown in Table A-21-E for lintels, or Tables A-21-C-1 through A-21-C-5 for walls in general where they are more restrictive.
[3]See Chapter 21, Part II, for definitions.
[4]See Section 1616 for definitions.
[5]For flat roofs connected to interior walls, the span shall be one half the larger distance on either side of the wall.

TABLE A-21-E—LINTEL REINFORCEMENT OVER EXTERIOR OPENINGS[1,2]—WOOD AND STEEL FRAMING[3] [Lintels larger than 12 feet 0 inch (3658 mm) shall be designed.][4] 8-INCH (203 mm) MASONRY UNITS[5]

Part I—Roof Loads[5]

ANY WALL HEIGHT (feet)	SPAN TO BEARING WALLS (feet)[9]	SECOND STORY OF A TWO-STORY OR ONE-STORY BUILDINGS ROOF LIVE LOAD[6,7,8]					
		20-30 psf			40 psf		
		× 0.0479 for kN/m²					
		Width of Opening[9] (feet)					
		× 304.8 for mm					
		4	8	12	4	8	12
		Lintel depth (inches) number and size of rebar					
× 304.8 for mm		× 25.4 for mm					
Any (up to 12′)	8	8 1 No. 3	8 1 No. 3	16 1 No. 4 (B)	8 1 No. 3	8 1 No. 4	16 1 No. 4 (B)
	16	8 1 No. 3	8 1 No. 3	16 1 No. 4 (B)	8 1 No. 3	8 2 No. 4 (A)	16 2 No. 5 (B)
	24	8 1 No. 3	8 1 No. 4	16 1 No. 4 (B)	8 1 No. 3	16 1 No. 4 (B)	24 2 No. 5 (B)
	32	8 1 No. 3	16 1 No. 4 (B)	16 1 No. 5 (B)	8 1 No. 3	16 1 No. 5 (B)	24 2 No. 5 (C)

Part II—Floor and Roof Loads[5]

WALL HEIGHT	SPAN TO BEARING[9,11] WALLS (feet)	FIRST STORY OF TWO-STORY BUILDINGS FLOOR LIVE LOAD[10]					
		50 psf			100 psf		
		× 0.0479 for kN/m²					
		Width of Opening[9] (feet)					
		× 304.8 for mm					
		4	8	12	4	8	12
		Lintel depth (inches) number and size of rebar					
× 304.8 for mm		× 25.4 for mm					
Any (up to 12′)	8	8 1 No. 3	8 1 No. 4	16 1 No. 4 (B)	8 1 No. 3	8 2 No. 4 (A)	16 2 No. 5 (B)
	16	8 1 No. 3	8 2 No. 4 (A)	16 2 No. 5 (B)	8 1 No. 3	16 1 No. 4 (B)	24 2 No. 4 (C)
	24	8 1 No. 3	16 1 No. 4 (B)	24 2 No. 5 (B)	8 1 No. 3 (A)	16 1 No. 5 (B)	24 3 No. 5 (C)
	32	8 1 No. 3	16 1 No. 5 (B)	24 2 No. 5 (C)	8 1 No. 4 (B)	24 2 No. 5 (C)	Design Required

[1]The values shown are number and size of A 615, 60 grade steel reinforcement bars: Example—2 No. 4 is two $^1/_2$-inch-diameter (13 mm) deformed reinforcing bars. See also Figure A-21-8 for continuous load path.
[2]Stirrup spacing requirements: A = No. 3 at 8 inches (203 mm) on center, B = No. 3 at 4 inches (102 mm) on center, C = No. 4 at 8 inches (203 mm) on center. None are required unless specifically mentioned in the table.
[3]Design required for lintels supporting precast planks.
[4]Lintels are 8-inch (203 mm) nominal depth where supporting roof loads only and 16-inch (406 mm) nominal depth where supporting floor and roofs unless otherwise stated. All lintels are solidly grouted.
[5]Wall weight is included.
[6]The stirrup size and spacing, where required, as indicated in parenthesis below the reinforcing bar requirements.
[7]All exposure categories are included for wind uplift on the lintel. See Footnote 4 of Tables A-21-C-1 through A-21-C-5 as a minimum bond beam. Table A-21-F may also control.
[8]Two No. 5 vertical bars minimum are required on each side of the lintel for 100 and 110 miles per hour (161 and 177 km/h), Exposure D. Bar to extend 25 inches (635 mm) beyond opening or hook over top bars.
[9]For spans between the figures shown, go to next higher span width.
[10]From Table 21-A. For other floor loads go to next higher value. Where required floor load exceeds 100 pounds per square foot (4.8 kN/m²), a design is required.
[11]When interior walls support floors from each side, these values may be used if the spans on each side are less than 16 feet 0 inch (4877 mm) each. Enter the table with the total of both span widths.

TABLE A-21-F—MASONRY SHEAR WALL[1,2,3] AND DIAPHRAGM REQUIREMENTS IN HIGH-WIND AREAS[4]

Part I—Minimum wall length and horizontal bar reinforcement required for exterior shear walls and cross walls[5] (all wall heights). [Design criteria: 20 psf to 40 psf (0.96 kN/m^2 to 1.9 kN/m^2) roof load; 50 psf or 100 psf (2.4 kN/m^2 or 4.8 kN/m^2) floor load; open or enclosed buildings.]

8-INCH (203 mm) WALLS[6]				
Wind Speed	Exposure	Distance between Shear Resisting Walls[7] "*L*" or "*b*" (feet)	One-story Building or Second Story of a Two-story Building	First Story of a Two-story Building
× 1.61 for km/h		× 304.8 for mm	inch × 25.4 for mm foot × 304.8 mm	
80 mph	B	32	NSR	9′-4″
		48	NSR	5′-4″ DBL (D)
		64	10′-0″	7′-6″ DBL (C)
	C	32	NSR	5′-4″ DBL (C)
		48	11′-0″	8′-8″ DBL (C)
		64	13′-4″	15′-0″ (D)
	D	32	8′-8″	7′-0″ (C)
		48	9′-4″ (C)	10′-8″ (D)
		64	10′-0″ (D)	13′-8″ (D)
90 mph	B	32	NSR	7′-8″ DBL (C)
		48	NSR	8′-0″ (D)
		64	12′-8″	12′-0″ (D)
	C	32	NSR	14′-8″
		48	13′-8″	10′-0″ (D)
		64	10′-8″ (C)	15′-6″ DBL (B)
	D	32	7′-8″ (C)	11′-8″ (D)
		48	12′-0″ (C)	12′-8″ DBL (B)
		64	11′-8″ (D)	18′-4″ DBL (C)
100 mph	B	32	NSR	5′-4″ DBL (C)
		48	10′-0″	10′-0″ (D)
		64	15′-4″	64′-8″ DBL (C)

(Continued)

TABLE A-21-F—MASONRY SHEAR WALL[1,2,3] AND DIAPHRAGM REQUIREMENTS IN HIGH-WIND AREAS[4]—(Part I Continued)

8-INCH (203 mm) WALLS[6]				
Wind Speed		Distance between Shear Resisting Walls[7] "L" or "b" (feet)	One-story Building or Second Story of a Two-story Building	First Story of a Two-story Building
× 1.61 for km/h	Exposure	× 304.8 for mm	inch × 25.4 for mm foot × 304.8 mm	
100 mph (cont.)	C	32	5′-4″ (D)	11′-8″ (D)
		48	12′-8″ (C)	12′-8″ DBL (C)
		64	12′-4″ (D)	19′-8″ DBL (C)
	D	32	5′-4″ DBL (B)	9′-4″ DBL (C)
		48	9′-4″ (D)	14′-8″ DBL (C)
		64	17′-4″ (D)	21′-0″ DBL (C)
110 mph	B	32	NSR	6′-0″ DBL (C)
		48	12′-0″	10′-0″ DBL (C)
		64	12′-8″ (C)	14′-0″ (D)
	C	32	5′-4″ DBL (B)	9′-8″ (D)
		48	12′-0″ (C)	15′-4″ (D)
		64	16′-8″ (C)	18′-8″ DBL (C)
	D	32	8′-8″ (C)	11′-4″ (D)
		48	12′-4″ (C)	18′-0″ (D)
		64	18′-8″ (C)	20′-8″ DBL (C)

*NSR—No special horizontal reinforcement required for shear resistance if 5 feet 4 inches (1626 mm) long minimum.

[1]Cumulative shear wall length is to be at least as long as is shown in this table. However, see Figure A-21-9. The top figure is the minimum length. When required, the figure below it in parenthesis is the spacing of steel reinforcing wire installed as shown in Figure A-21-10, below. (A) = two 0.148 inch (3.76 mm) (No. 9 B.W. gage) at 16 inches (406 mm) on center, (B) = two $^{3}/_{16}$ inch (4.76 mm) at 16 inches (406 mm) on center, (C) = two 0.148 inches (3.76 mm) (No. 9 B.W. gage) at 8 inches (203 mm) on center, (D) = two $^{3}/_{16}$ inch (4.76 mm) at 8 inches (203 mm) on center. The symbol DBL means double these amounts. Equivalent areas of reinforcing bars spaced not over 4 feet 0 inch (1219 mm) on center may be used.

[2]All bearing and shear walls are to be in-plane with vertical reinforcement, when required, extending from one floor to the other as dictated in Tables A-21-C-1 through A-21-C-5.

[3]Minimum bond beam shall be 100 miles per hour (mph) (161 km/h), Exposure B; 90 mph (145 km/h), Exposure B, and 80 mph (129 km/h), Exposures B and C, one No. 4; 100 mph (161 km/h), Exposure C; 80 and 90 mph (129 and 145 km/h); Exposures C and D, two No. 4; all others two No. 5.

[4]Table is adjusted to include provisions for Seismic Zones 0, 1 and 2.

[5]Cross walls are to be at least twice as long as shown in the table for shear walls. The tributary width (L/2) shall be the distance used in the third column above to find minimum reinforcement and length.

[6]For walls which width is equal to or less than half its height, add an extra No. 5 vertical bar at each end.

[7]Use 32-foot (9753 mm) requirements for distances less than 32 feet (9754 mm). Also use it for bearing walls used as shear walls.

(Continued)

TABLE A-21-F—MASONRY SHEAR WALL[1,2,3] AND DIAPHRAGM REQUIREMENTS IN HIGH-WIND AREAS[4]—(Continued)

Part II—Wood floor and roof diaphragms and connections[8,9]
[All wall heights 8 feet to 12 feet (2438 mm to 3657 mm).]

FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE					
Wind Speed	Exposure	Distance between Shear Walls[10] "L" or "b" (feet)	Minimum Wood Structural Panel/Particleboard Size[9] and Nailing[11,12]		
			Thickness (inches)	Common Nail Size (penny)	Nail Spacing (inches)
× 1.61 for km/h		× 304.8 for mm	× 25.4 for mm		× 25.4 for mm
80 mph	B	16	$^{5}/_{16}$	6	6 o.c.
		32	$^{3}/_{8}$	6	6 o.c.
		48	$^{3}/_{8}$	8	6 o.c.
		64	$^{3}/_{8}$	8	6 o.c.
	C	16	$^{3}/_{8}$	8	6 o.c.
		32	$^{1}/_{2}$ or $^{15}/_{32}$	8	6 o.c.
		48	$^{1}/_{2}$ or $^{15}/_{32}$	10	6 o.c.
		64	$^{5}/_{8}$ or $^{19}/_{32}$	10	6 o.c.
	D	16	$^{1}/_{2}$ or $^{15}/_{32}$	8	6 o.c.
		32	$^{5}/_{8}$ or $^{19}/_{32}$	10	6 o.c.
		48	$^{1}/_{2}$ or $^{15}/_{32}$ blocked	8	4/6 o.c.
		64	$^{1}/_{2}$ or $^{15}/_{32}$ blocked	8	4/6 o.c.
90 mph	B	16	$^{5}/_{16}$	6	6 o.c.
		32	$^{3}/_{8}$	8	6 o.c.
		48	$^{3}/_{8}$	8	6 o.c.
		64	$^{3}/_{8}$	8	6 o.c.
	C	16	$^{1}/_{2}$ or $^{15}/_{32}$	10	6 o.c.
		32	$^{3}/_{8}$ blocked	8	4/6 o.c.
		48	$^{3}/_{8}$ blocked	8	4/6 o.c.
		64	$^{5}/_{8}$ or $^{19}/_{32}$ blocked	10	6 o.c.
	D	16	$^{5}/_{8}$ or $^{19}/_{32}$	10	6 o.c.
		32	$^{1}/_{2}$ or $^{15}/_{32}$ blocked	10	4/6 o.c.
		48	$^{1}/_{2}$ or $^{15}/_{32}$ blocked	10	4/6 o.c.
		64	Design required or provide extra cross walls		
100 mph	B	16	$^{3}/_{8}$	8	6 o.c.
		32	$^{1}/_{2}$ or $^{15}/_{32}$	8	6 o.c.
		48	$^{1}/_{2}$ or $^{15}/_{32}$	8	6 o.c.
		64	$^{5}/_{8}$ or $^{19}/_{32}$	10	6 o.c.

(Continued)

TABLE A-21-F—MASONRY SHEAR WALL[1,2,3] AND DIAPHRAGM REQUIREMENTS IN HIGH-WIND AREAS[4]—(Part II Continued)

FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE					
Wind Speed	Exposure	Distance between Shear Walls[10] "L" or "b" (feet)	Minimum Wood Structural Panel/Particleboard Size[9] and Nailing[11,12]		
			Thickness (inches)	Common Nail Size (penny)	Nail Spacing (inches)
× 1.61 for km/h		× 304.8 for mm	× 25.4 for mm		× 25.4 for mm
100 mph (cont.)	C	16	$^3/_8$ blocked	8	4/6 o.c.
		32	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		48	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		64	Design required or provide extra cross walls		
	D	16	$^1/_2$ or $^{15}/_{32}$ blocked	10	4/6 o.c.
		32	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		48	Design required or provide extra cross walls		
		64	Design required or provide extra cross walls		
110 mph	B	16	$^1/_2$ or $^{15}/_{32}$	8	6 o.c.
		32	$^1/_2$ or $^{15}/_{32}$	10	6 o.c.
		48	$^5/_8$ or $^{19}/_{32}$	10	6 o.c.
		64	$^1/_2$ or $^{15}/_{32}$ blocked	8	4/6 o.c.
	C	16	$^1/_2$ or $^{15}/_{32}$ blocked	8	4/6 o.c.
		32	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		48	Design required or provide extra cross walls		
		64	Design required or provide extra cross walls		
	D	16	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		32	Design required or provide extra cross walls		
		48	Design required or provide extra cross walls		
		64	Design required or provide extra cross walls		

[8]These requirements represent the maximum values for a diaphragm which is within a maximum 32-foot-by-64-foot (9.75 m by 19.5 m) module surrounded by shear walls, cross walls or bearing walls. (See Figure A-21-9.)
[9]See Tables 23-II-E-1 and 23-II-E-2 for minimum sizes depending on span between joists.
[10]See Figure A-21-9 for "*L*" and "*b*."
[11]The wood structural panel/particleboard (all grades) thickness is given first. The nailing size and boundary/supported edge spacing is shown next.. Blocking of unsupported edges is stated where required. Twelve-inch (305 mm) spacing required in the field of the roof/floor. Boundary nailing is required over interior walls [see Figure A-21-12 (b)].
[12]Use Case 1 for unblocked diaphragms and any case for blocked diaphragms.

TABLE A-21-G—MINIMUM WALL CONNECTION REQUIREMENTS IN HIGH-WIND AREAS
Precast Hollow-core Plank Floors and Roofs

Spacing of No. 4 bent reinforcing bar in block or brick walls connected to precast concrete planks[1,2]

WIND SPEED AND EXPOSURE	EXTERIOR WALLS	INTERIOR WALLS
	× 25.4 for mm	
90 mph (145 km/h) Exposure C and less 100 mph (161 km/h) Exposure B	32″ o.c.	16″ o.c.
90 mph (145 km/h) Exposure D 100 mph (161 km/h) Exposure C 110 mph (177 km/h) Exposure B	24″ o.c.	12″ o.c.
100 mph (161 km/h) Exposure D 110 mph (177 km/h) Exposures C and D	16″ o.c.	12″ o.c.

[1]This table assumes maximum wall height of 12 feet (3.7 m) and a width-to-length ratio of diaphragm between shear walls of 3:1 or less.
[2]The precast planks shall be designed as shall the walls and footings supporting them.

TABLE A-21-H—MINIMUM HOLD-DOWN REQUIREMENTS IN HIGH-WIND AREAS
Steel Floors and Roofs

WIND SPEED AND EXPOSURE	MAXIMUM SPACING OF ROOF JOISTS WITH CONNECTION SHOWN[1,2,3]
	× 25.4 for mm
100 mph (161 km/h) Exposure B 90 mph (145 km/h) Exposures B and C 80 mph (129 km/h) Exposures B, C and D	48″
110 mph (177 km/h) Exposure B 100 mph (161 km/h) Exposure C	30″
110 mph (177 km/h) Exposures C and D 100 mph (161 km/h) Exposure D	Design required

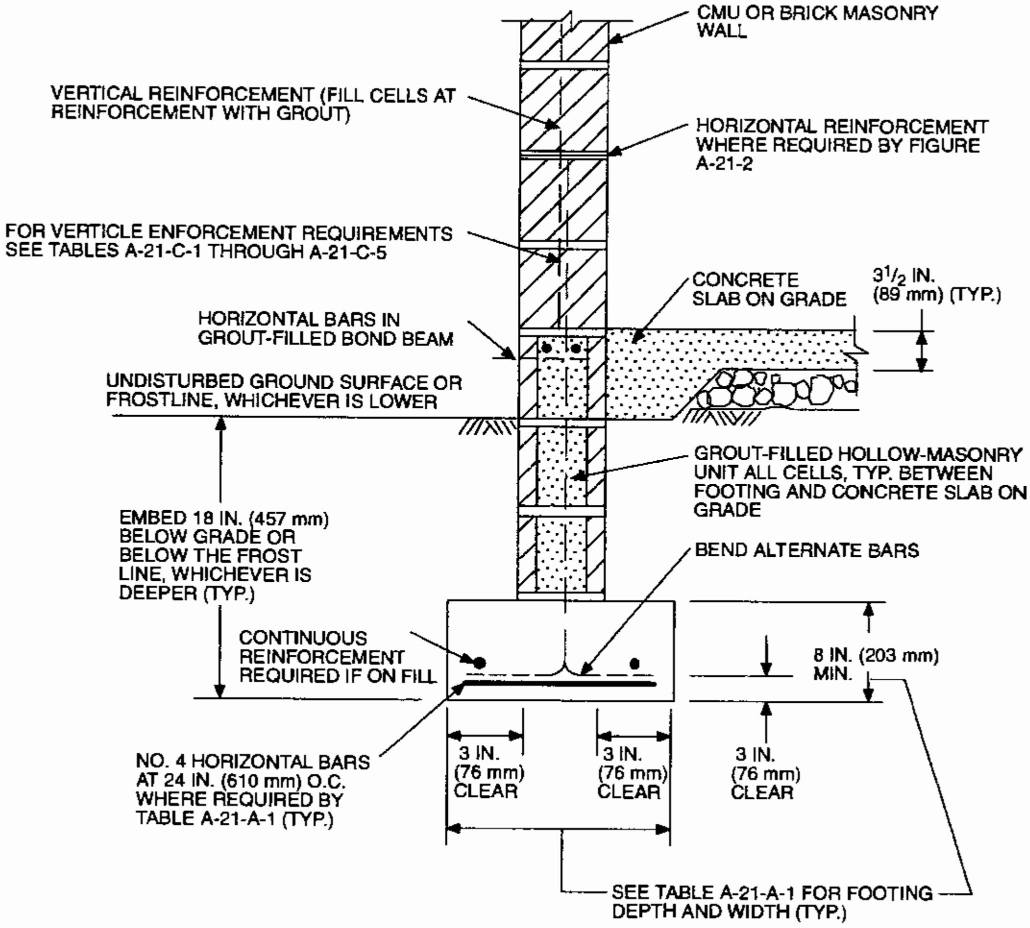
[1]Maximum span is 32 feet (9.75 m) to bearing walls.
[2]Joists and decking to be designed.
[3]Bottom chord of joists to be braced for reversal of stresses caused by wind uplift.

TABLE A-21-I—DIAGONAL BRACING REQUIREMENTS FOR GABLE-END WALL[1,2] ROOF PITCH 3:12 to 5:12

EXPOSURE	BASIC WIND SPEED (mph) × 1.61 for km/h: 80		90		100		110	
	3:12 (25%)	4:12 (33%) and 5:12 (42%)	3:12 (25%)	4:12 (33%) and 5:12 (42%)	3:12 (25%)	4:12 (33%) and 5:12 (42%)	3:12 (25%)	4:12 (33%) and 5:12 (42%)
	× 25.4 for mm							
B	I at 48″ o.c.	III at 48″ o.c.	I at 48″ o.c.	III at 48″ o.c.	I at 24″ o.c.	III at 24″ o.c.	I at 24″ o.c.	III at 24″ o.c.
C	I at 24″ o.c.	III at 48″ o.c.	I at 24″ o.c.	III at 24″ o.c.	II at 24″ o.c.	IV at 24″ o.c.	II at 24″ o.c.	IV at 24″ o.c.
D	I at 24″ o.c.	III at 48″ o.c.	II at 24″ o.c.	IV at 24″ o.c.	II at 24″ o.c.	IV at 24″ o.c.	Two-II at 24″ o.c.	Two-III at 24″ o.c.

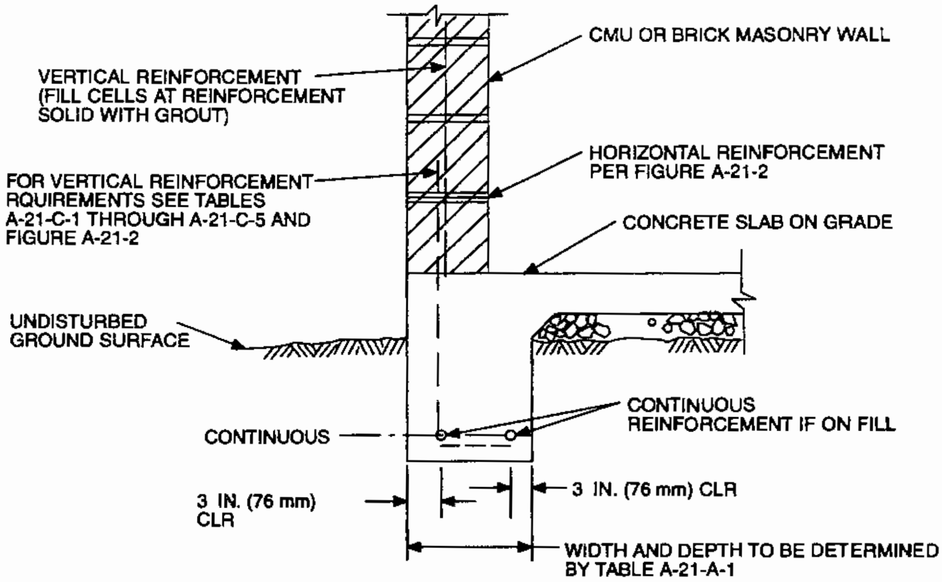
[1] I = 2-inch-by-4-inch brace, one clip angle (51 mm × 102 mm).
II = 2-inch-by-4-inch brace, two clip angles (one each side) (51 mm × 102 mm).
III = 3-inch-by-4-inch brace, one clip angle (76 mm × 102 mm).
IV = 3-inch-by-4-inch brace, two clip angles (one each side) (76 mm × 102 mm).
The spacing requirements of the brace are shown below the symbol.
[2]See Figures A-21-17 and A-21-18 for details and size of clip angles.

NOTE: Horizontal and vertical reinforcement to be determined by Tables A-21-C-1 through A-21-C-5 and A-21-F.

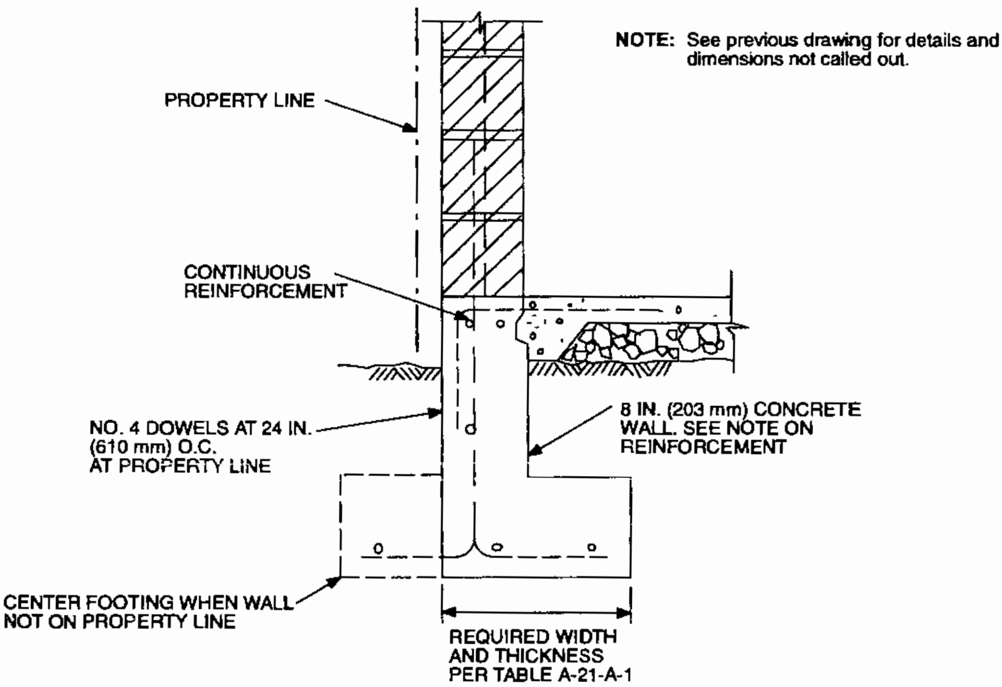


HOLLOW-MASONRY UNIT EXTERIOR FOUNDATION WALL

FIGURE A-21-1—VARIOUS DETAILS OF FOOTINGS
(See Tables A-21-A-1 and A-21-A-2 for widths.)

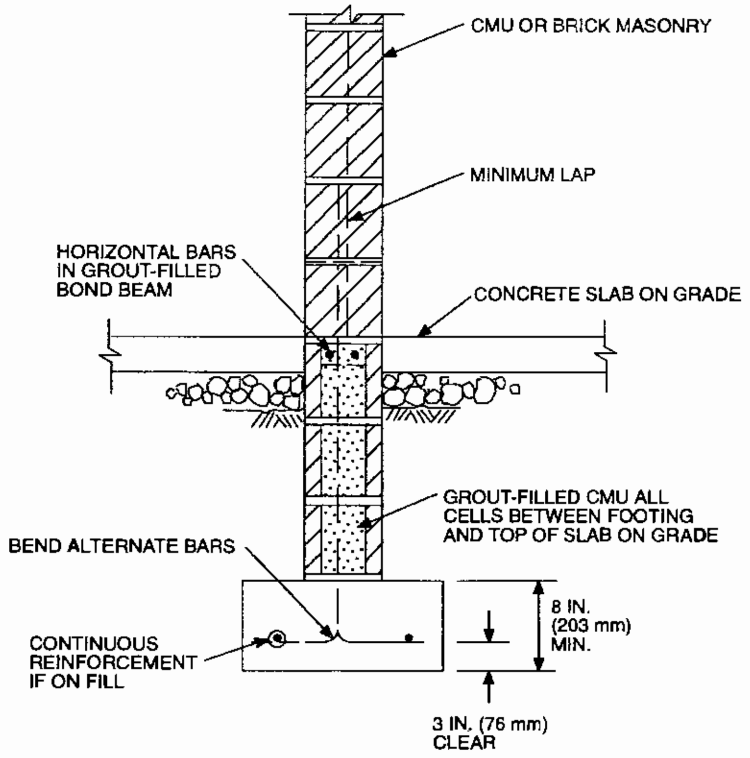


GRADE BEAM OR CONTINUOUS CONCRETE SLAB—TURN DOWN

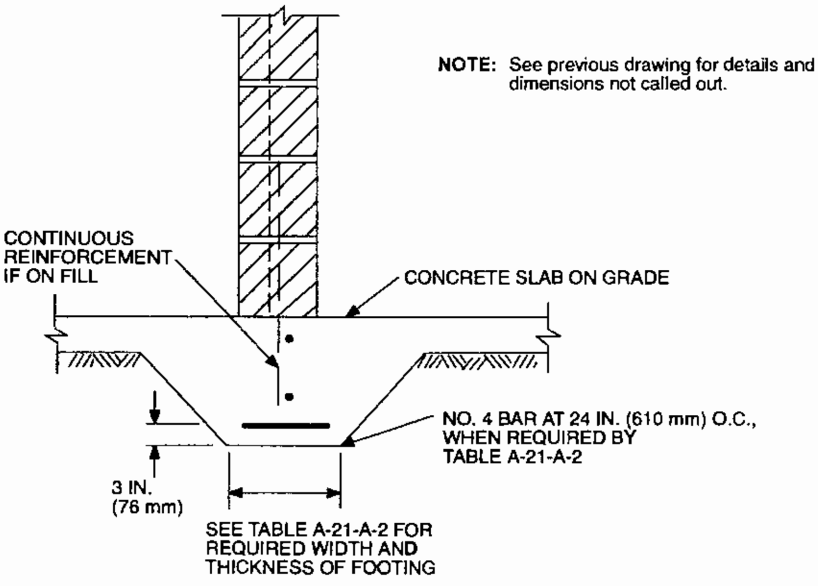


HOLLOW-MASONRY UNIT CONCRETE EXTERIOR FOUNDATION WALL

FIGURE A-21-1—VARIOUS DETAILS OF FOOTINGS—(Continued)
(See Tables A-21-A-1 and A-21-A-2 for widths.)



HOLLOW–MASONRY UNIT INTERIOR FOUNDATION WALL



CONCRETE INTERIOR NONBEARING WALL FOOTING

FIGURE A-21-1—VARIOUS DETAILS OF FOOTINGS—(Continued)
(See Tables A-21-A-1 and A-21-A-2 for widths.)

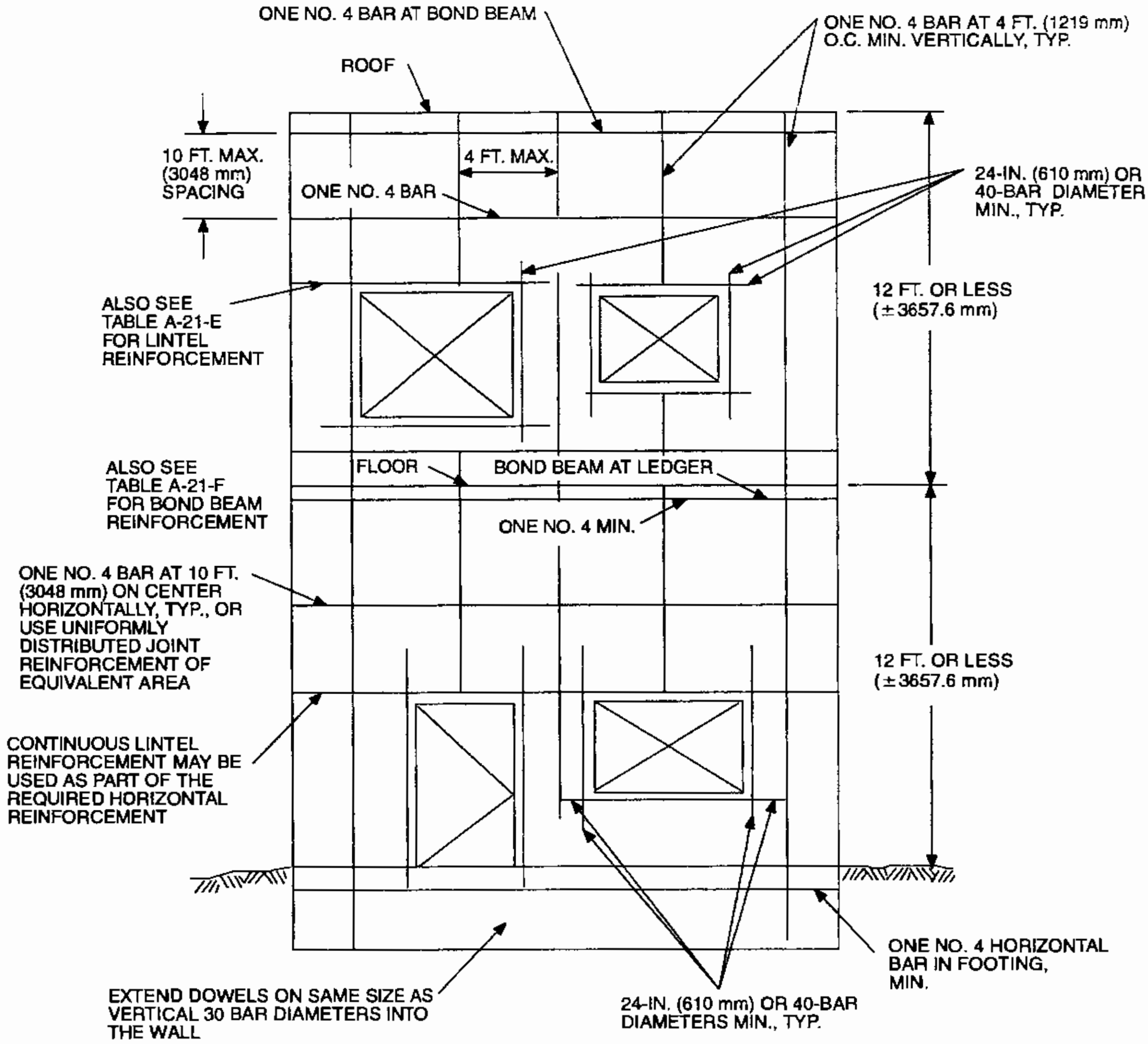


FIGURE A-21-2—MINIMUM MASONRY WALL REQUIREMENTS IN SEISMIC ZONE 2

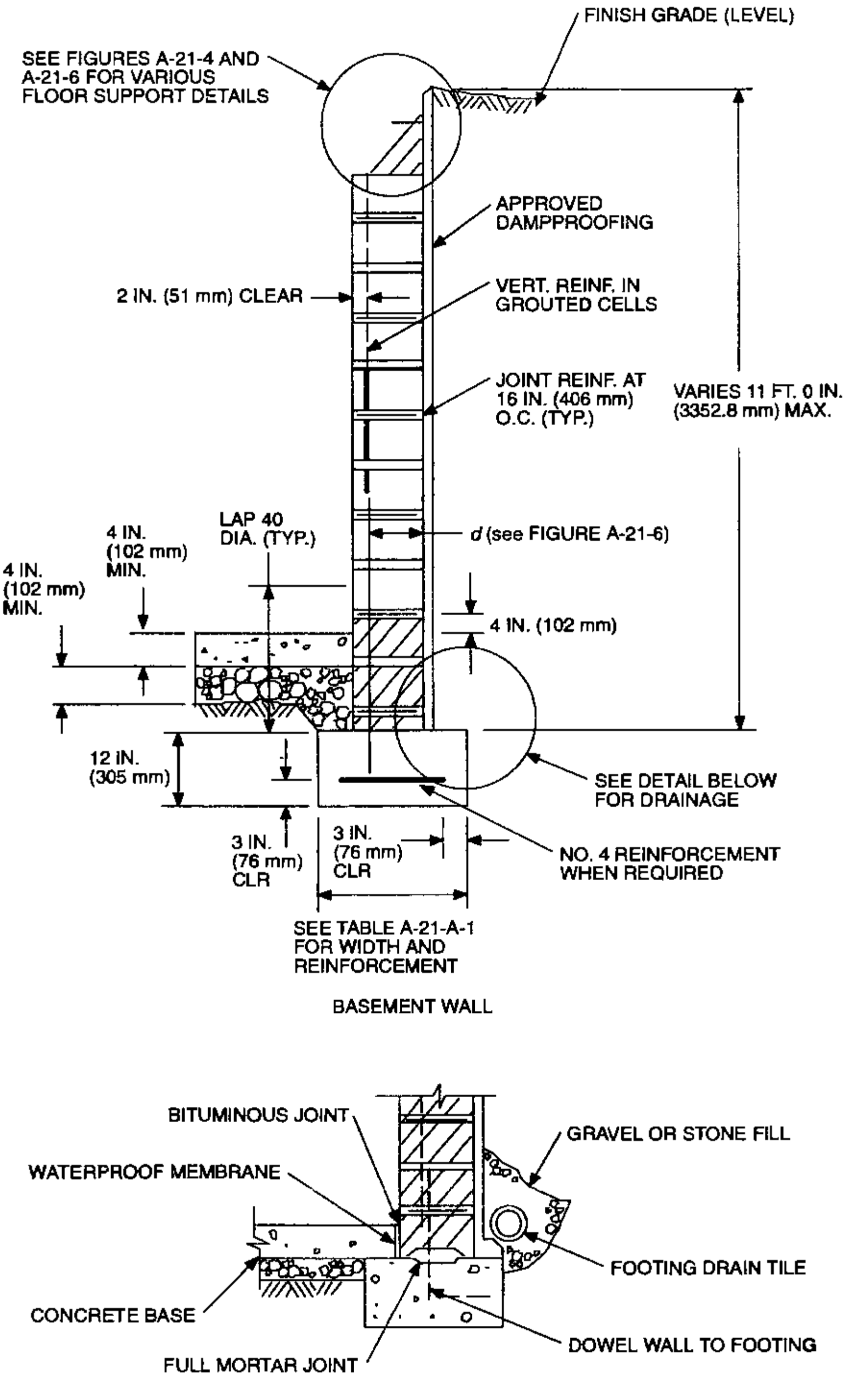


FIGURE A-21-3—BELOW-GRADE WALL AND DRAINAGE DETAILS

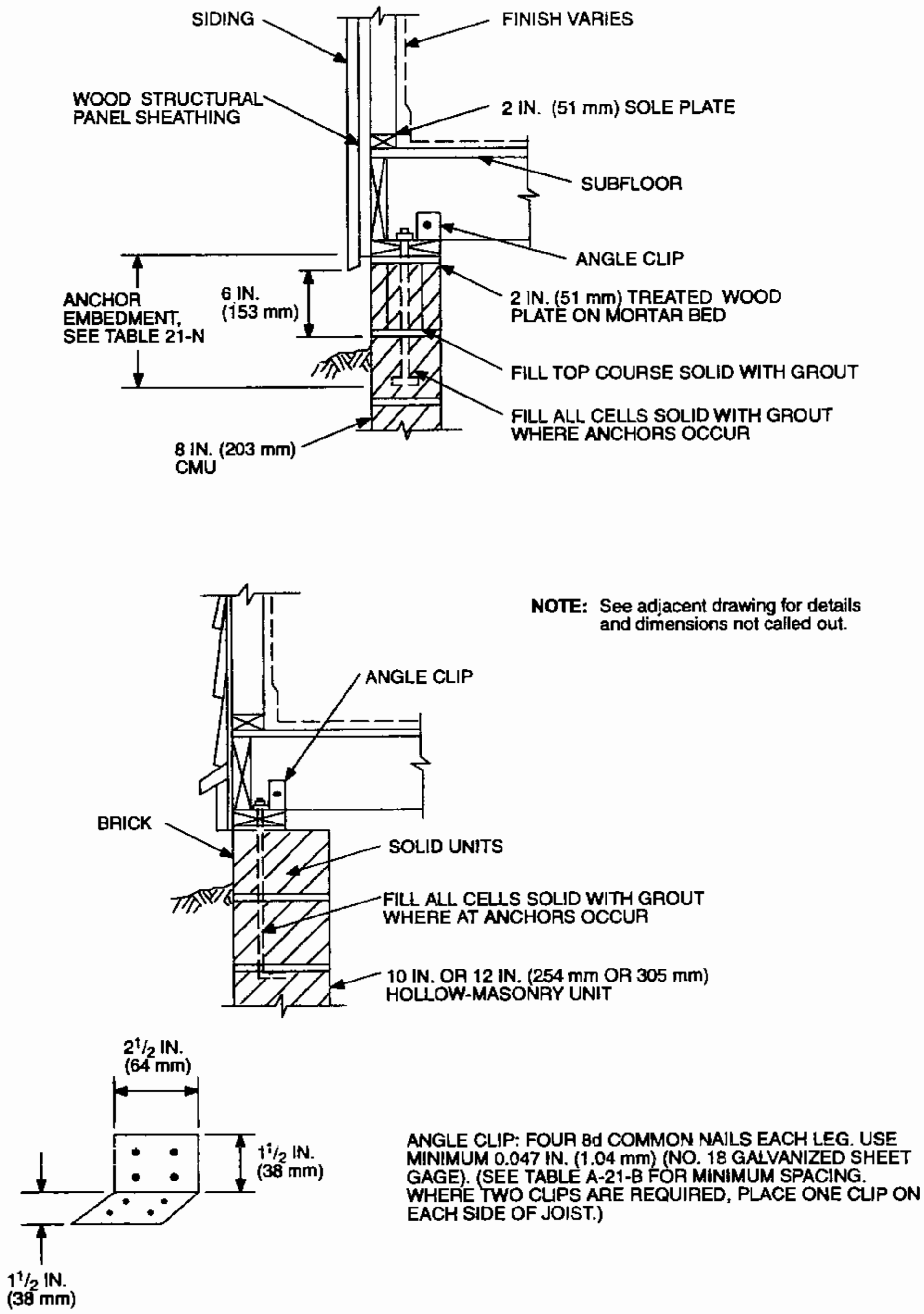
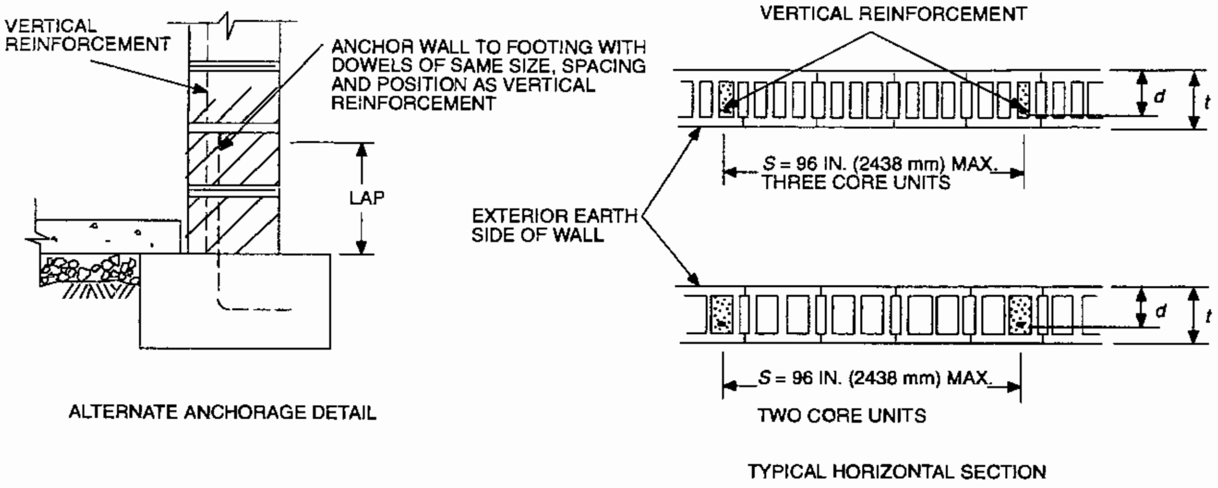
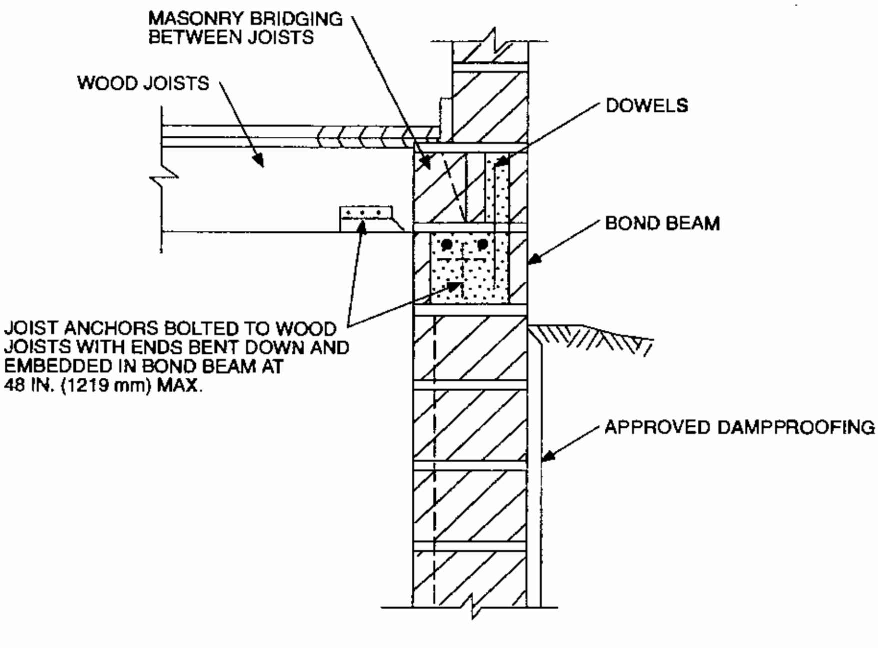


FIGURE A-21-4—HOLLOW-MASONRY UNIT FOUNDATION WALL—WOOD FLOOR



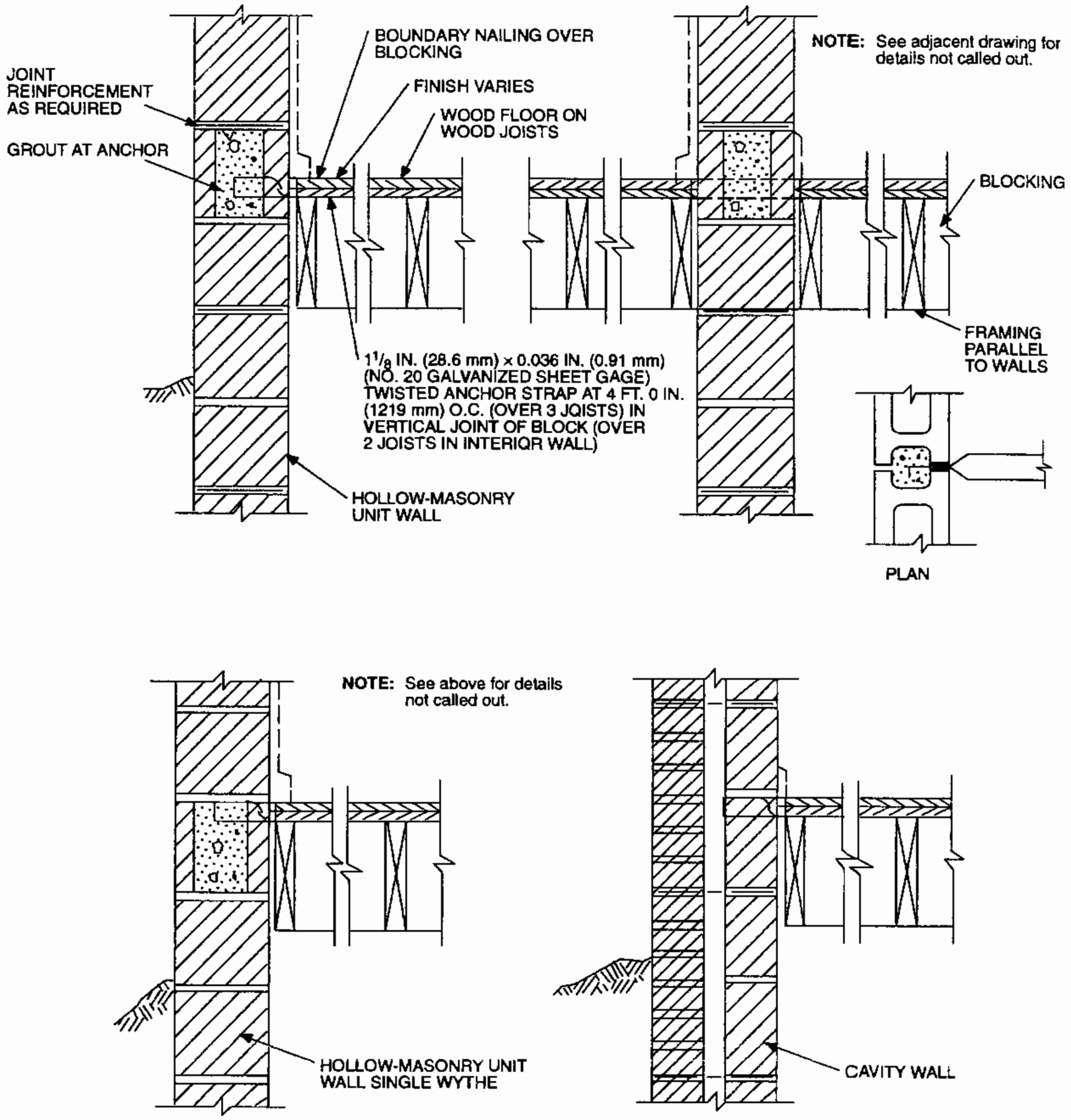
8 IN. (203 mm) WALLS: $t = 7^5/_8$ IN. (194 mm) $d = 5$ IN. (127 mm)
10 IN. (254 mm) WALLS: $t = 9^5/_8$ IN. (245 mm) $d = 7$ IN. (153 mm)
12 IN. (305 mm) WALLS: $t = 11^5/_8$ IN. (295 mm) $d = 8^3/_4$ IN. (225 mm)

FIGURE A-21-5—PLACEMENT OF REINFORCEMENT



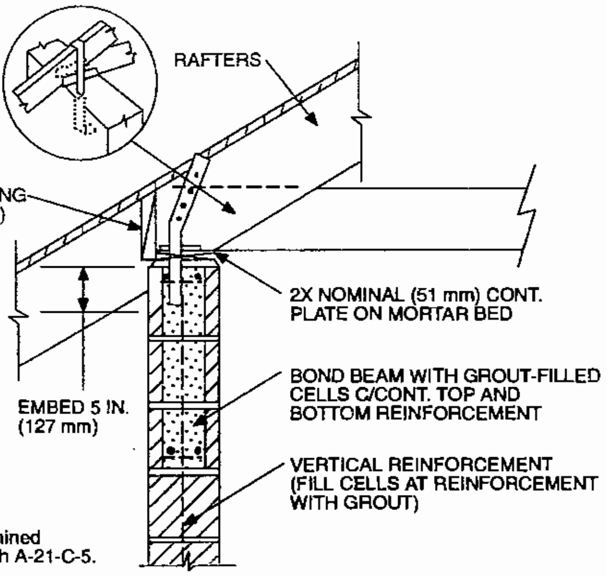
(A) HOLLOW–MASONRY UNIT WALL—WOOD FLOOR

FIGURE A-21-6—VARIOUS CONNECTIONS OF FLOORS TO BASEMENT WALLS



(B) WOOD FLOOR, JOISTS PARALLEL TO WALL

FIGURE A-21-6—VARIOUS CONNECTIONS OF FLOORS TO BASEMENT WALLS—(Continued)



NOTE: Horizontal and vertical reinforcement to be determined by Tables A-21-C-1 through A-21-C-5.

ROOF WITH OVERHANG

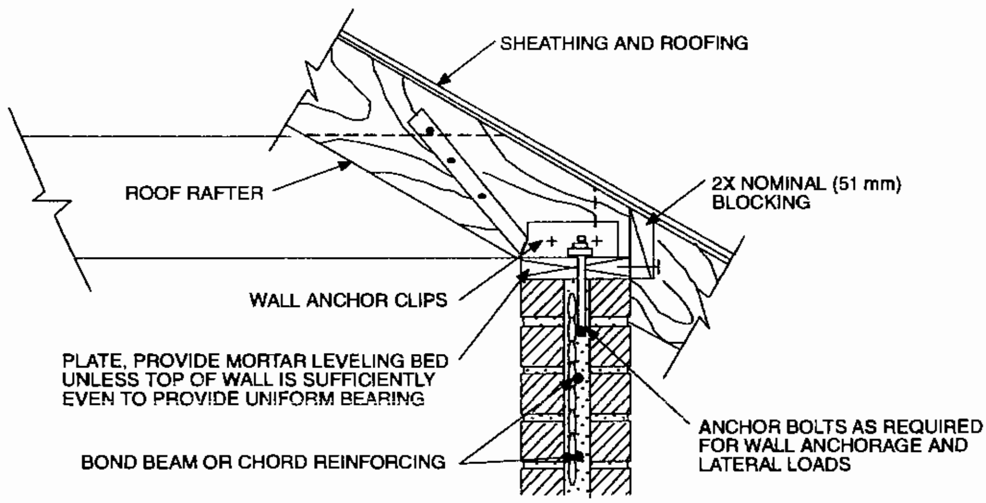
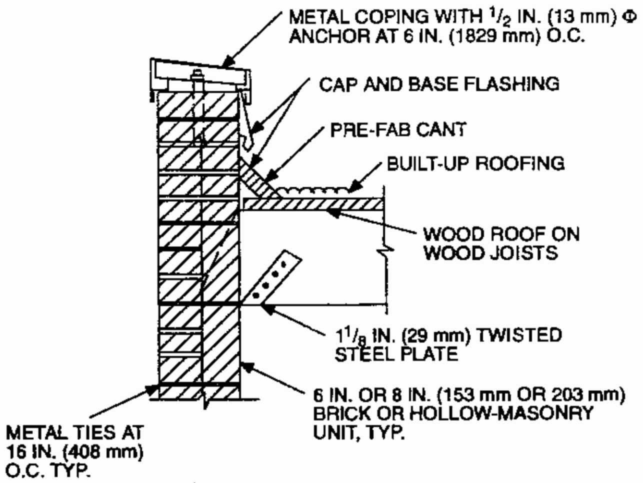
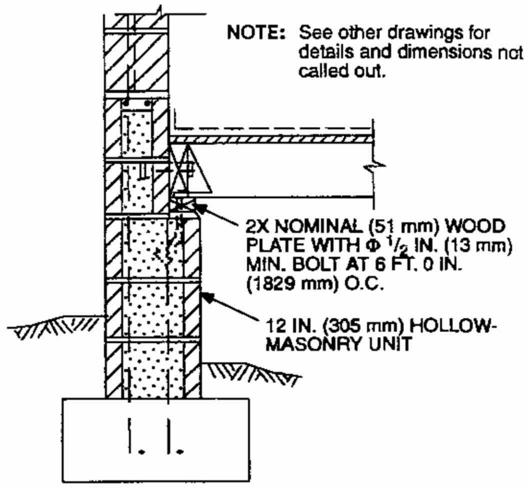


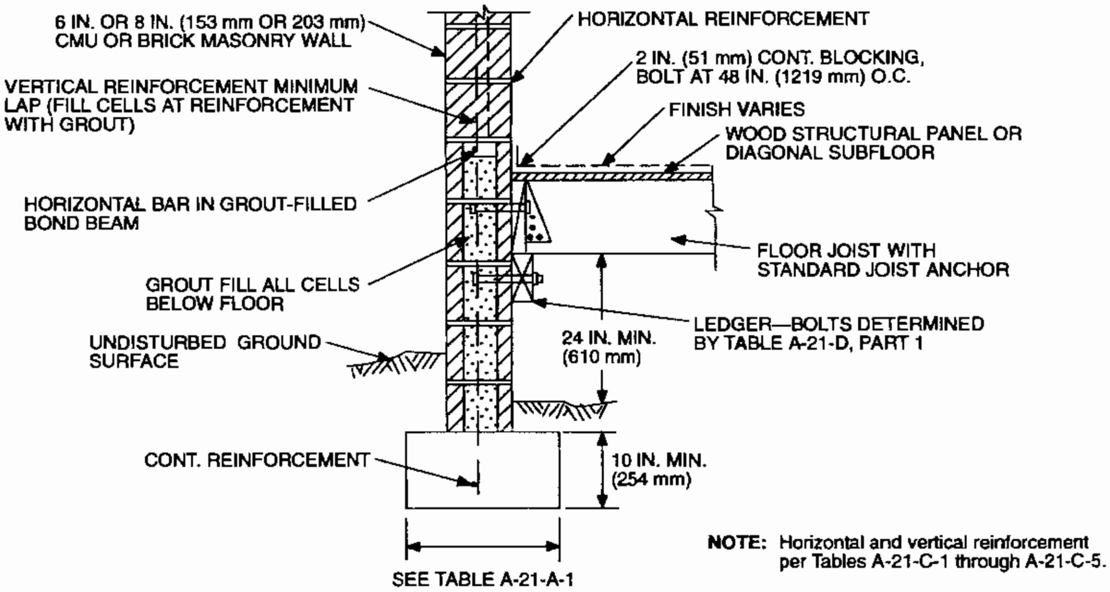
FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)



WOOD JOIST ROOF COMPOSITE WALL

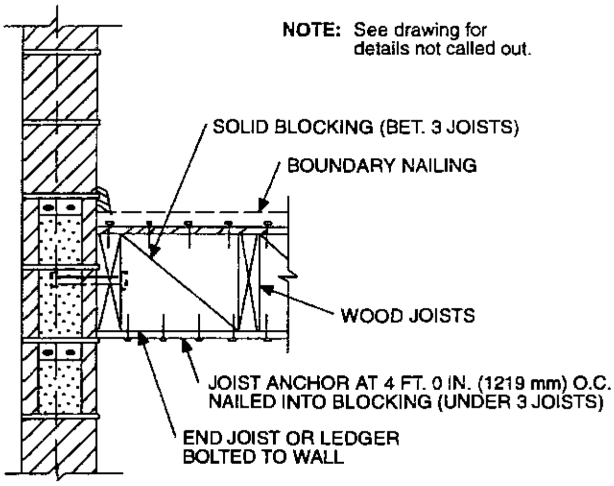


HOLLOW-MASONRY UNIT FOUNDATION WALL—JOIST PERPENDICULAR

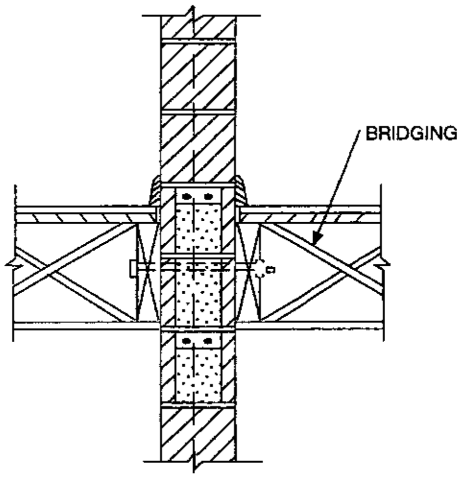


HOLLOW-MASONRY UNIT FOUNDATION WALL—JOIST PERPENDICULAR—(Continued)

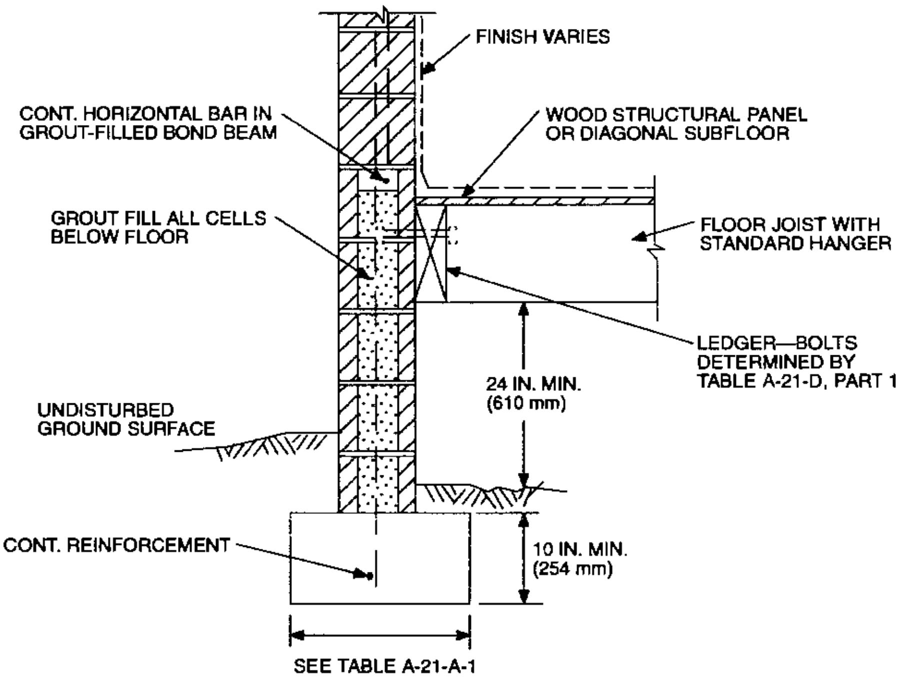
FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)—(Continued)



EXTERIOR WALL—JOIST PARALLEL

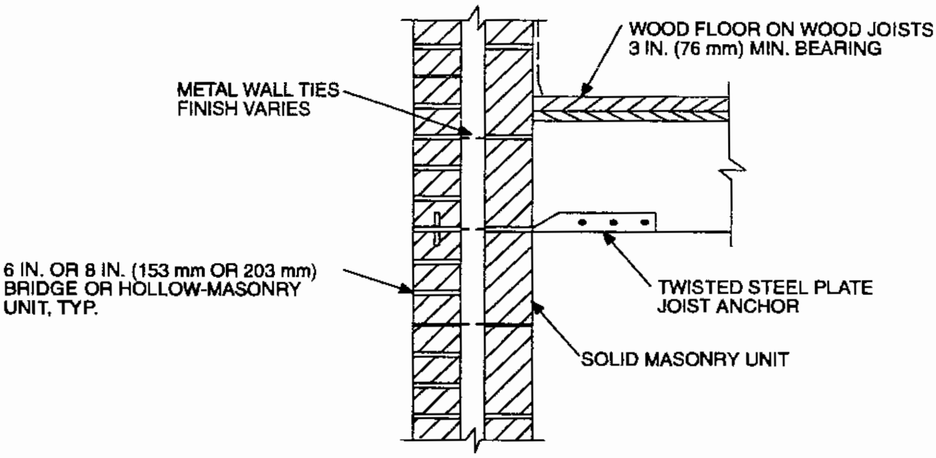


INTERIOR WALL—JOIST PARALLEL

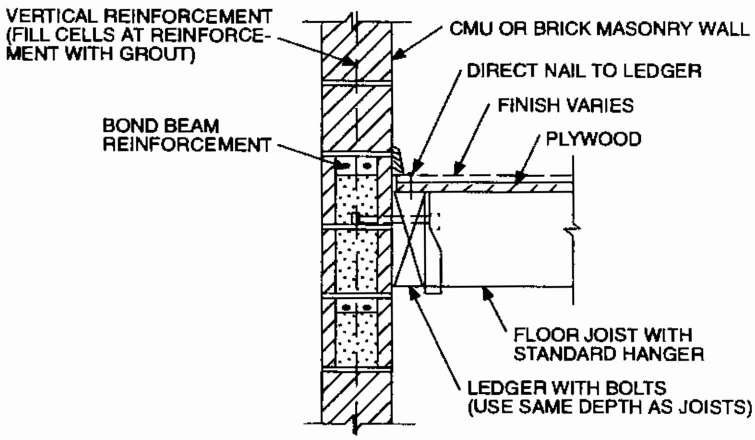


HOLLOW-MASONRY UNIT FOUNDATION
WALL—JOIST PERPENDICULAR

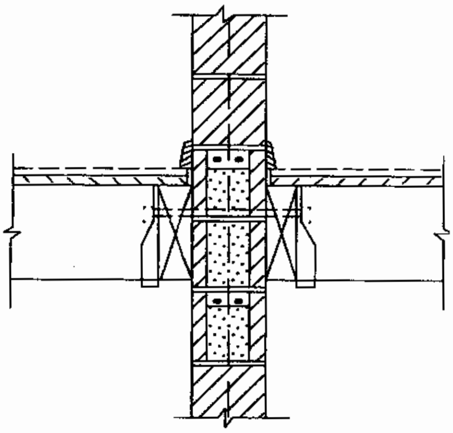
FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)—(Continued)



WOOD FLOOR

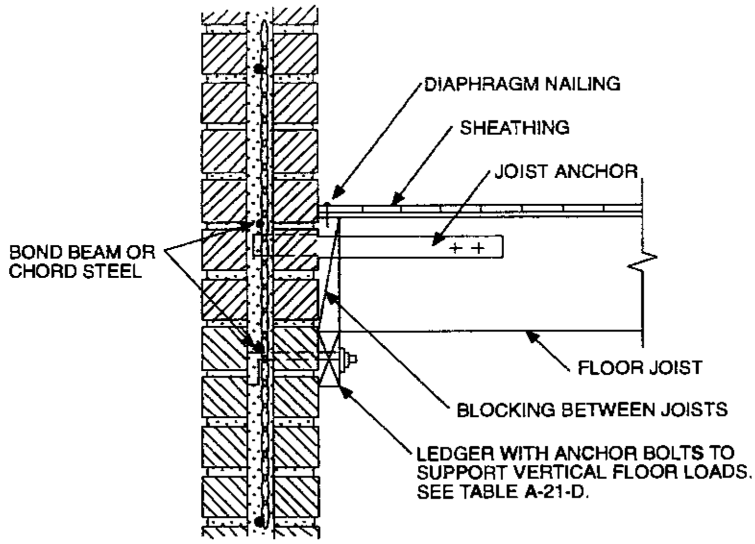


EXTERIOR WALL—
JOIST PERPENDICULAR



INTERIOR WALL—
JOIST PERPENDICULAR

FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)—(Continued)



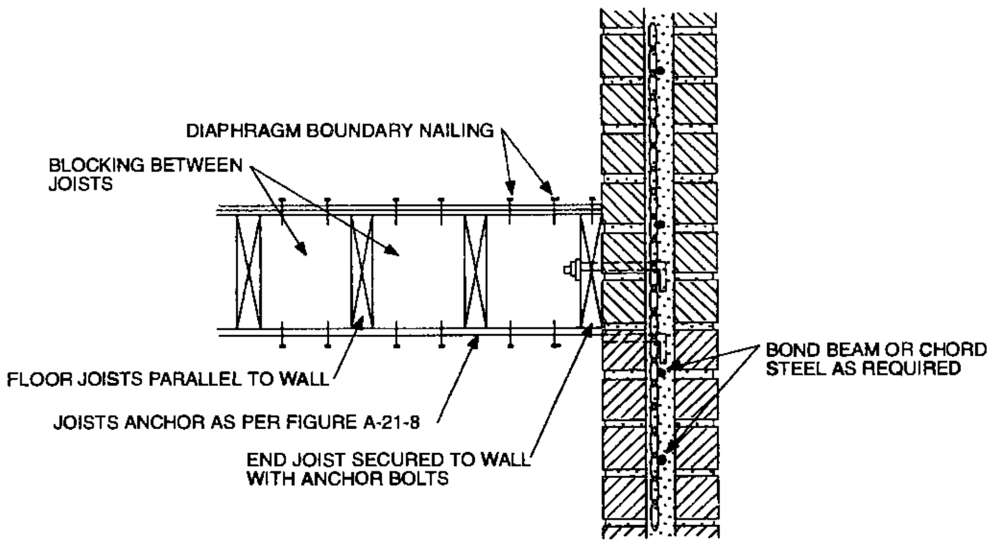


FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)—(Continued)

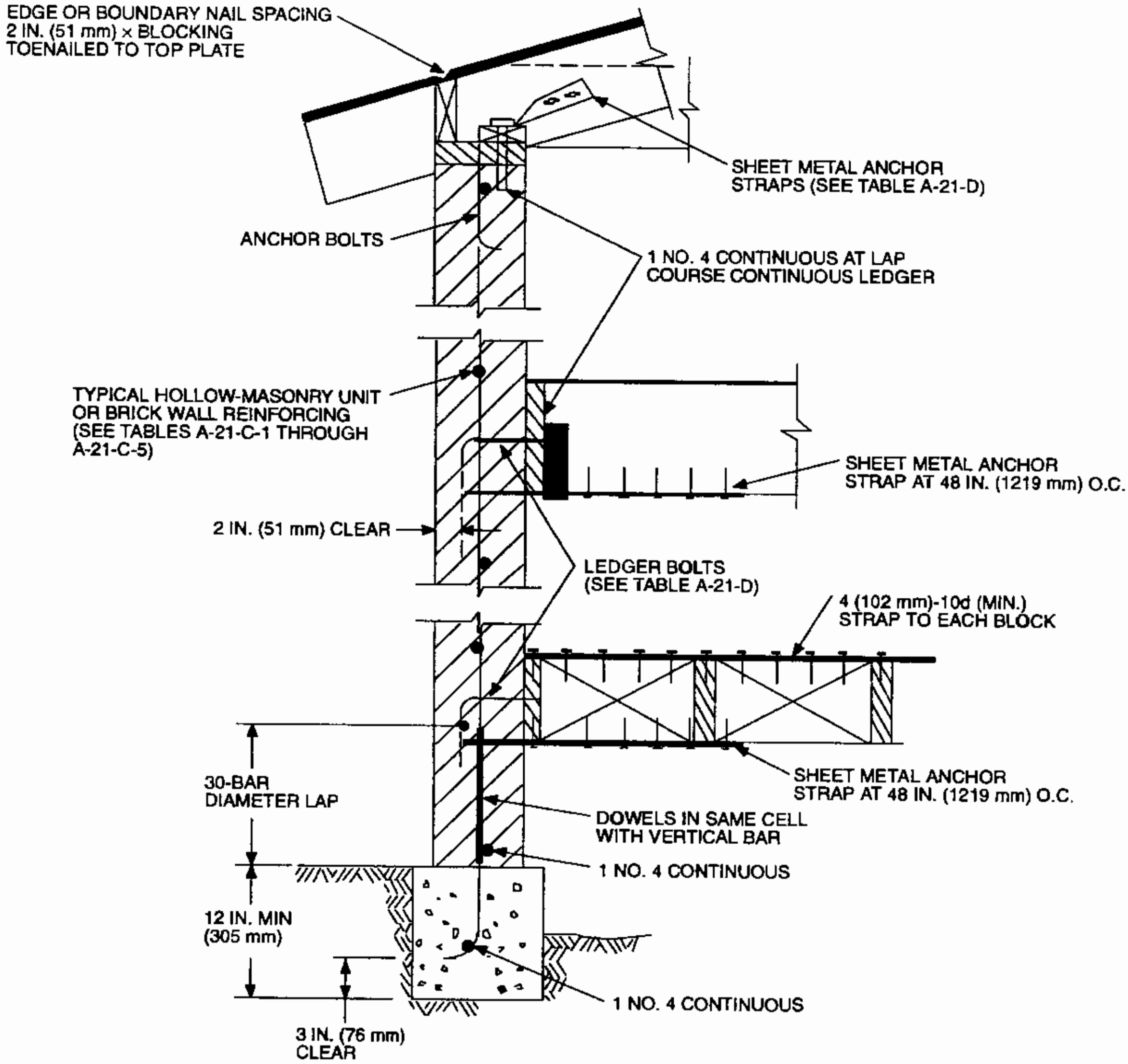
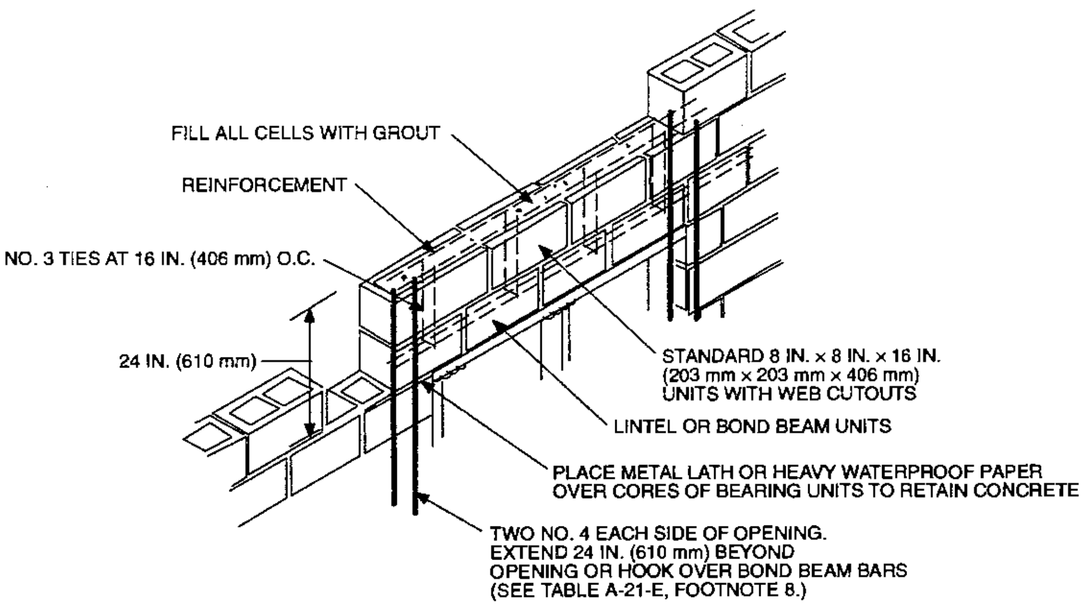
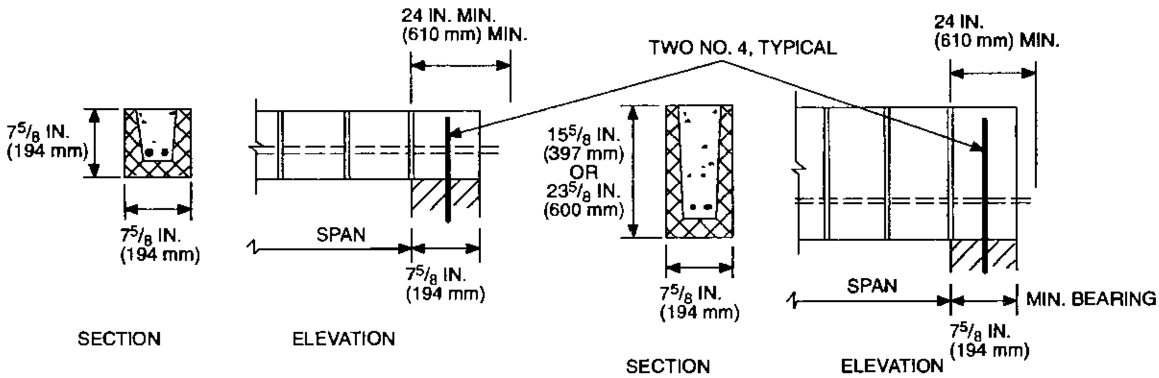


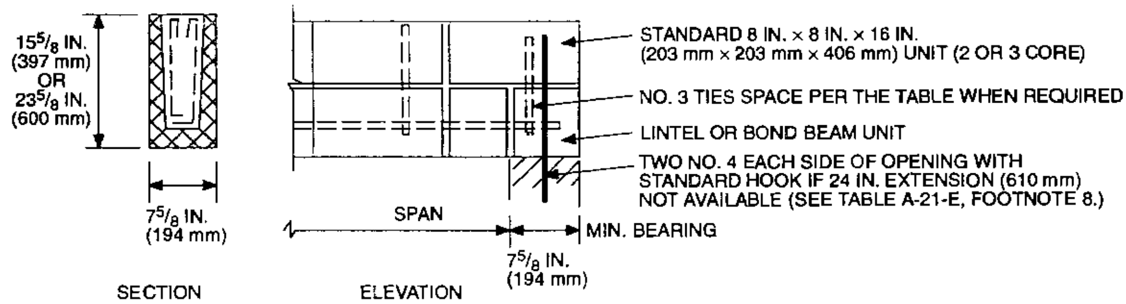
FIGURE A-21-8—CONTINUOUS LOAD PATH



REINFORCING DETAILS



WITHOUT STIRRUPS



WITH STIRRUPS

FIGURE A-21-8—CONTINUOUS LOAD PATH—(Continued)

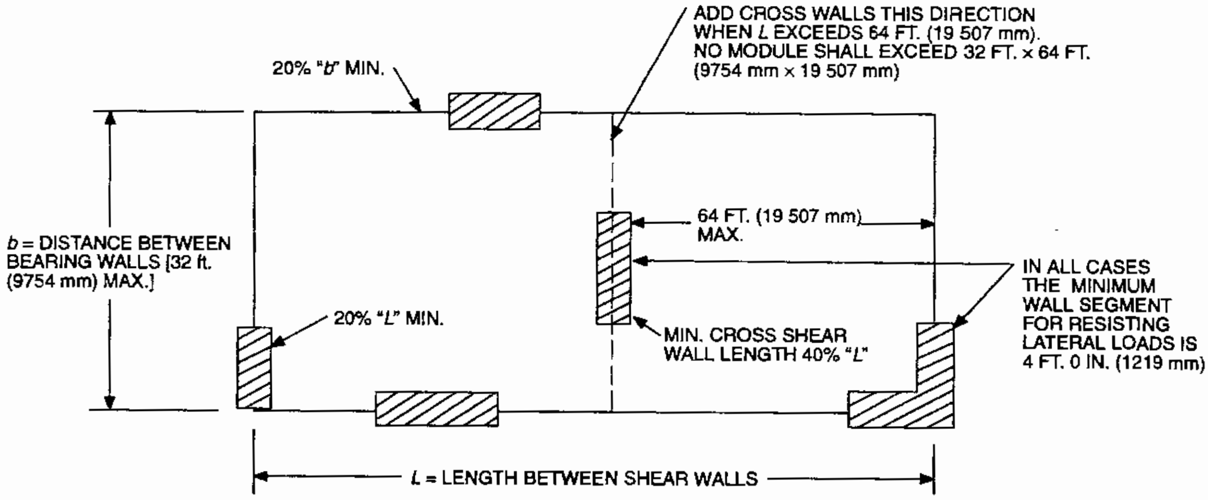


FIGURE A-21-9—SPACING AND LENGTHS OF SHEAR WALLS

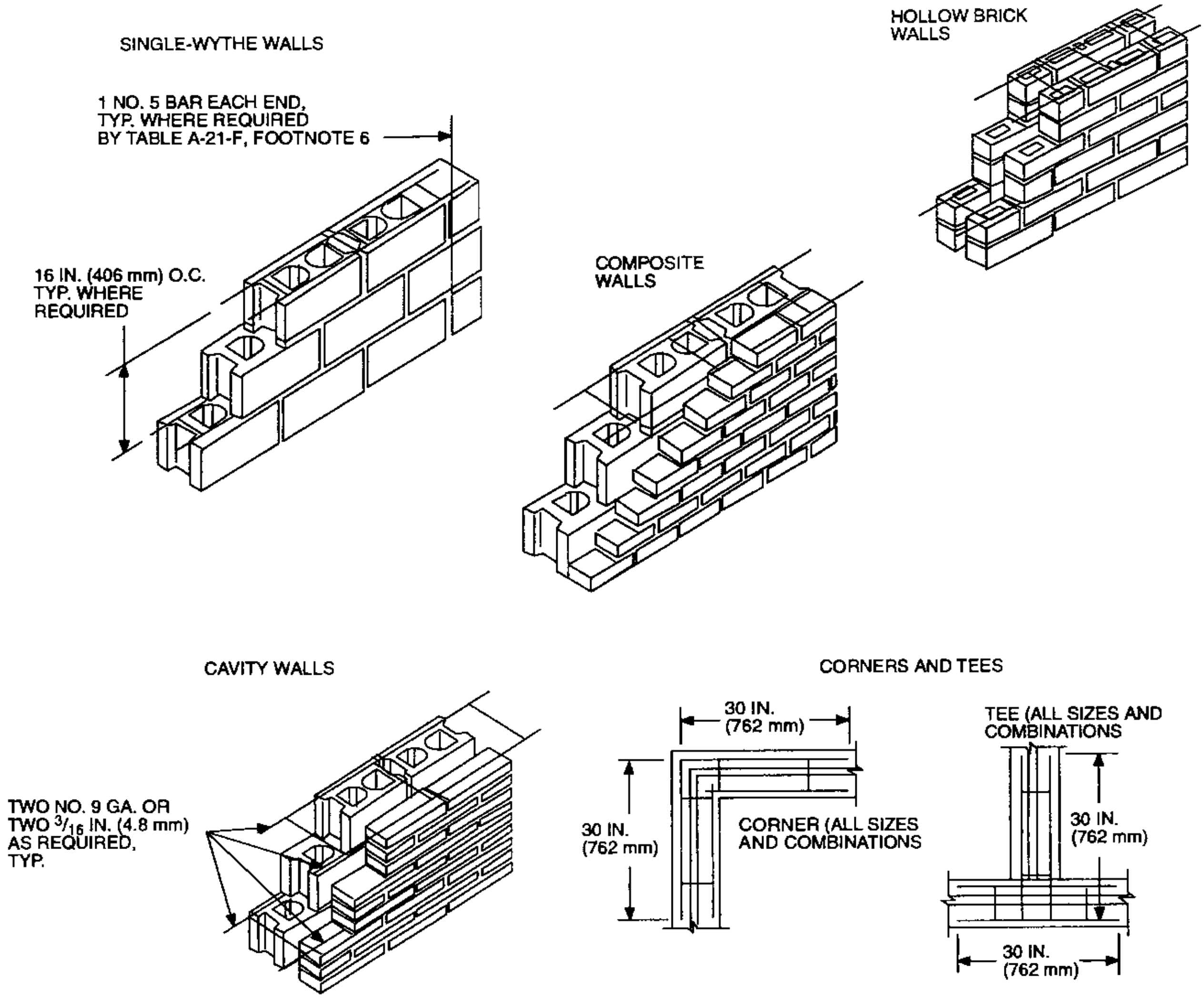


FIGURE A-21-10—SPACING OF STEEL REINFORCING WIRE

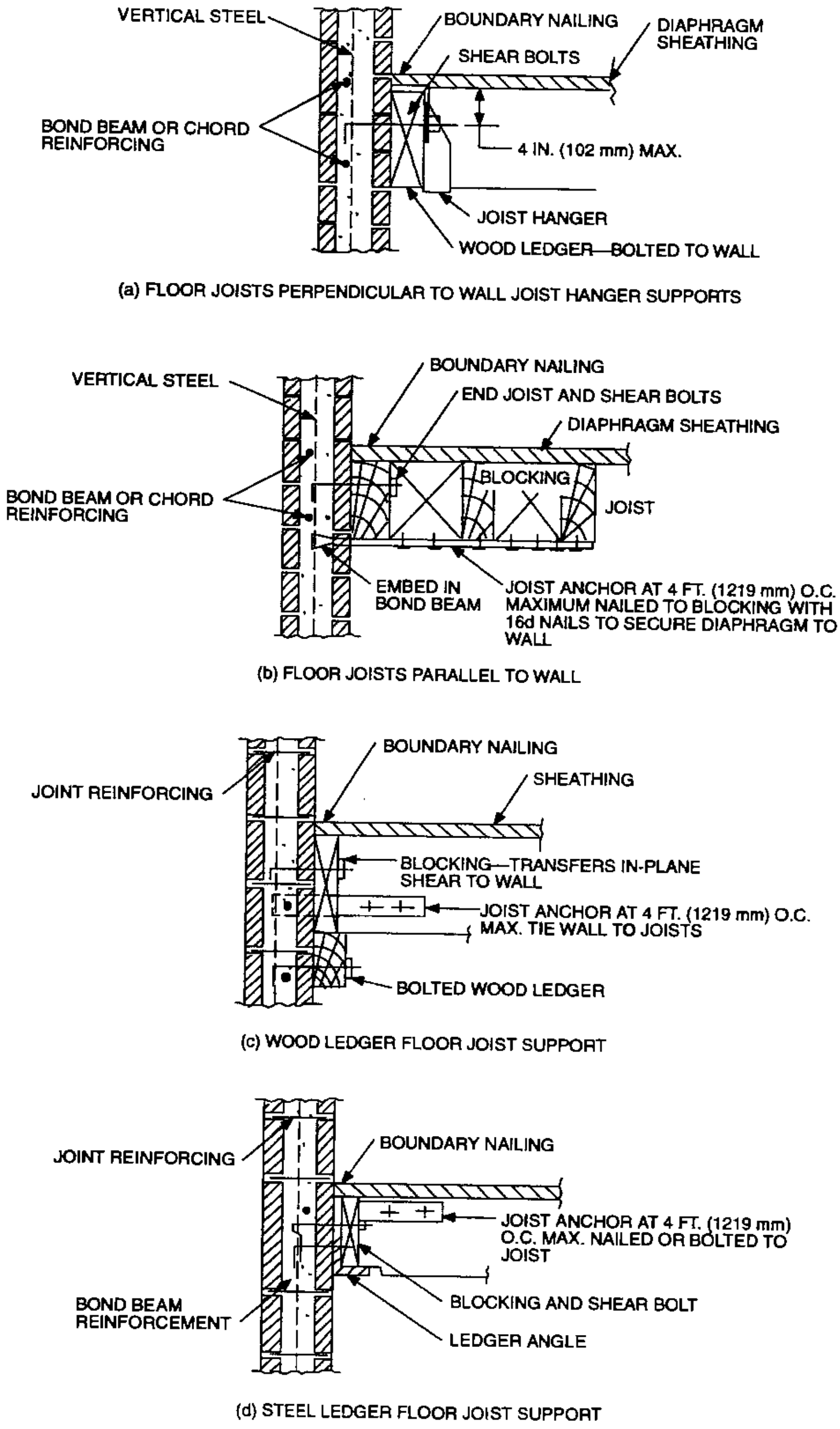
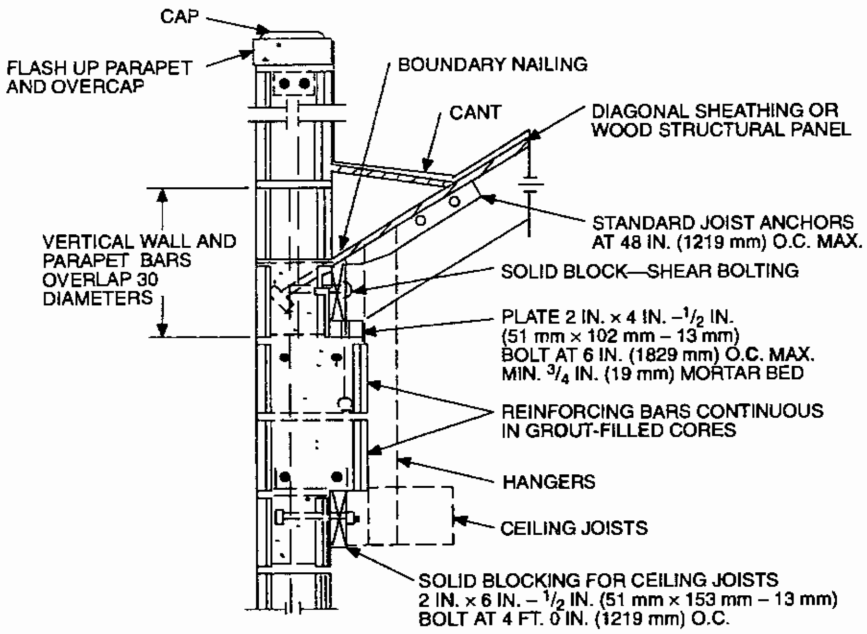
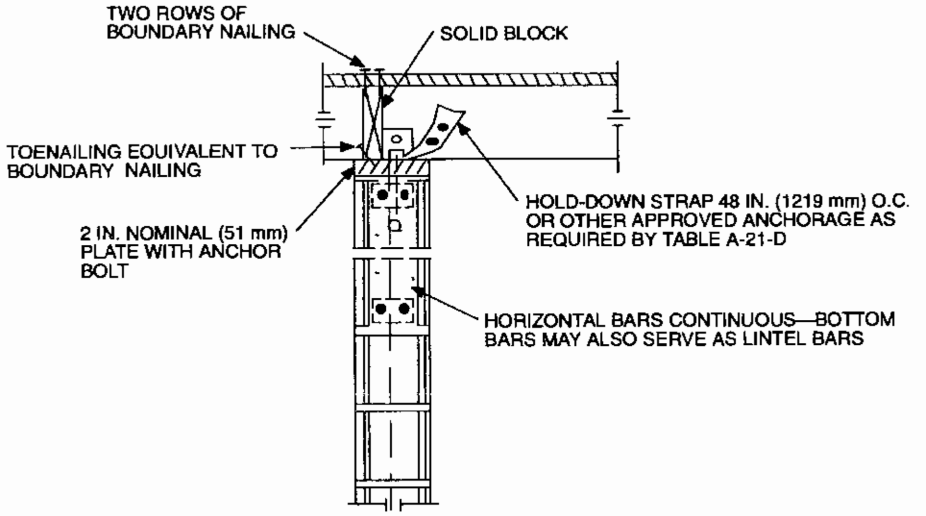


FIGURE A-21-11—FLOOR-TO-WALL CONNECTION DETAILS

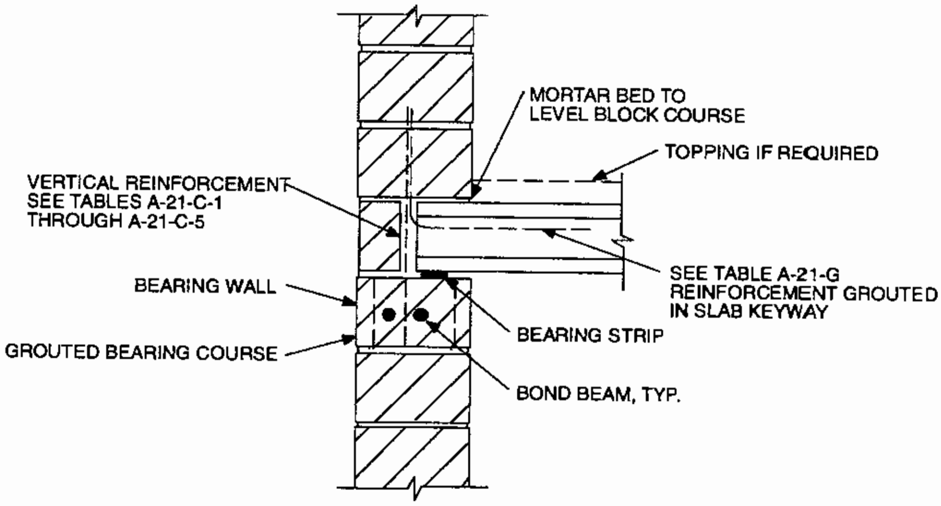


(a) EXTERIOR WALL SUPPORT

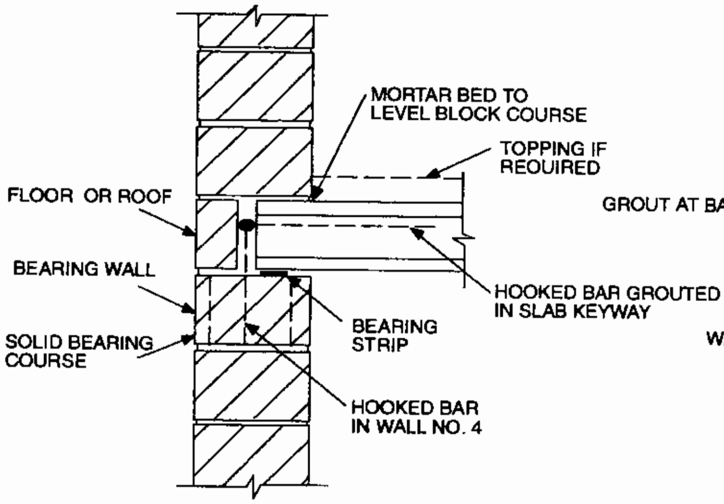


(b) INTERIOR WALL SUPPORT BOND–BEAM SUPPORTS

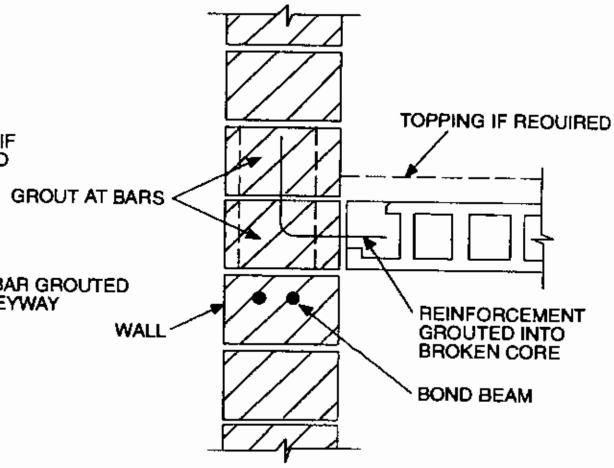
FIGURE A-21-12—ROOF-TO-WALL CONNECTION DETAILS



(a) SLAB PERPENDICULAR TO WALL

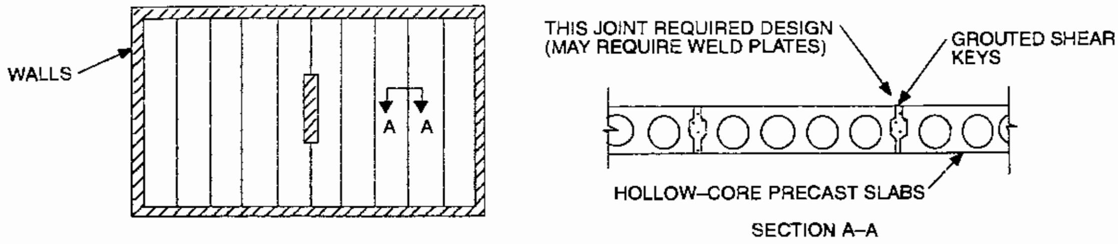


(b) ALTERNATE CONNECTION PERPENDICULAR TO WALL

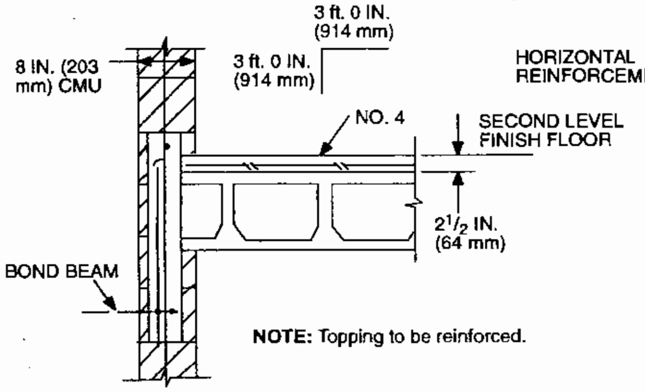


(c) SLAB PARALLEL WITH WALL

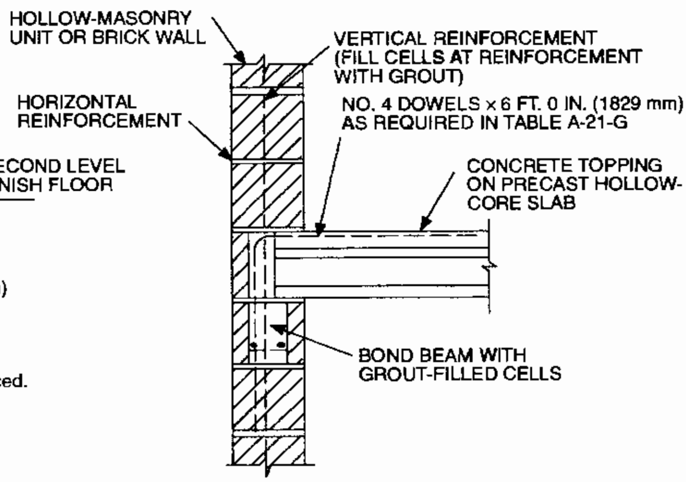
FIGURE A-21-13—VARIOUS TYPES OF WALL CONNECTIONS



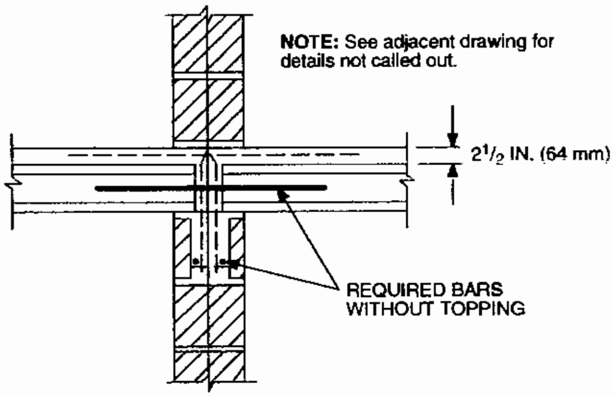
(d) PLAN VIEW OF FLOOR OR ROOF AND CROSS SECTION THROUGH PLANKS



(e) ALTERNATE PLANK PARALLEL WITH WALL WITH TOPPING



(f) ALTERNATE WITH TOPPING



(g) INTERIOR WALL MINIMUM CONNECTION

FIGURE A-21-13—VARIOUS TYPES OF WALL CONNECTIONS—(Continued)

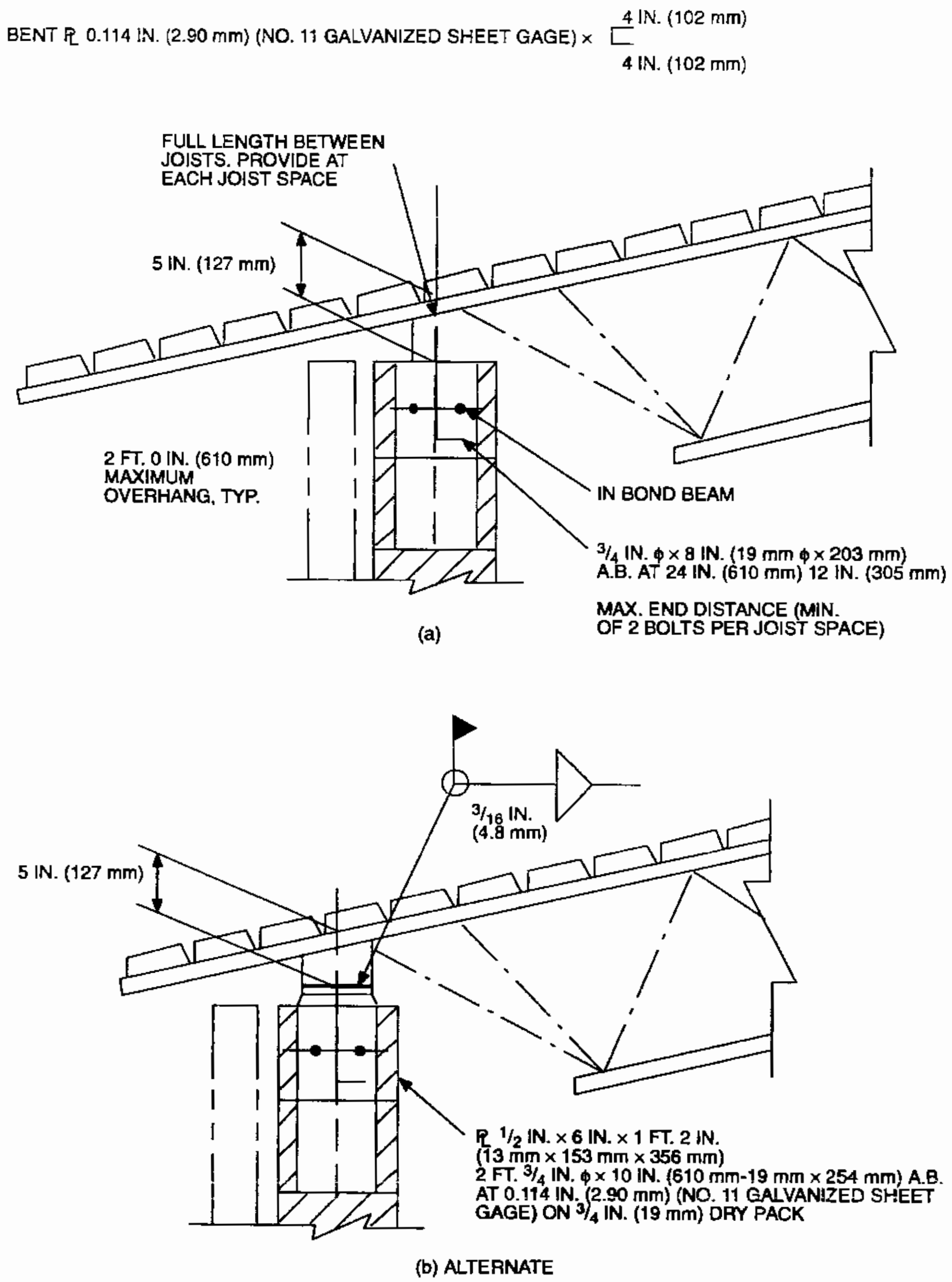
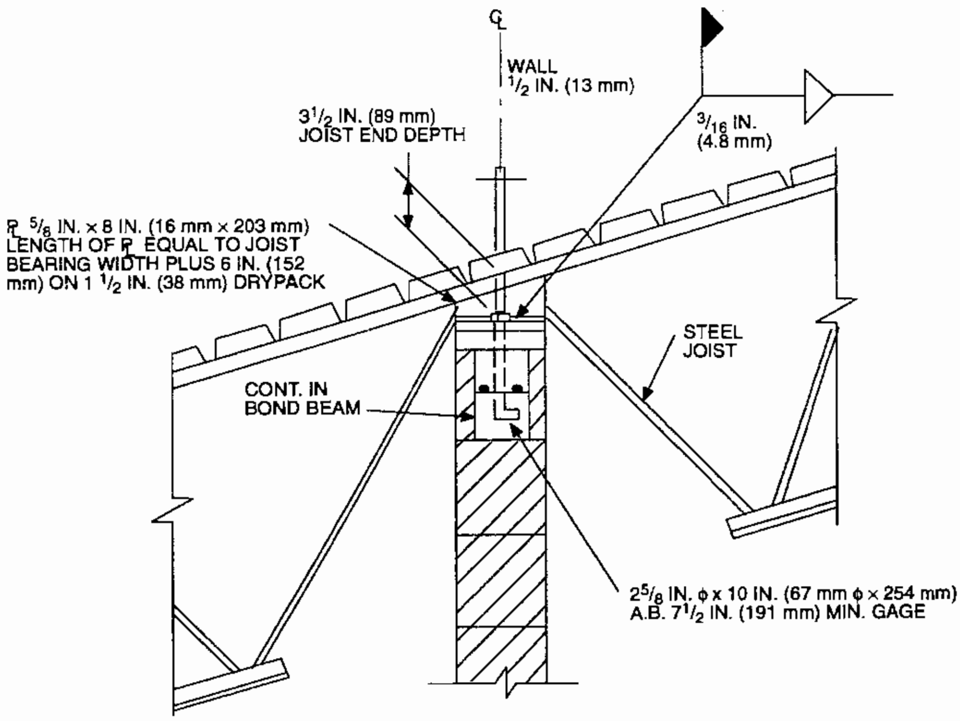


FIGURE A-21-14—EXTERIOR WALL DETAILS



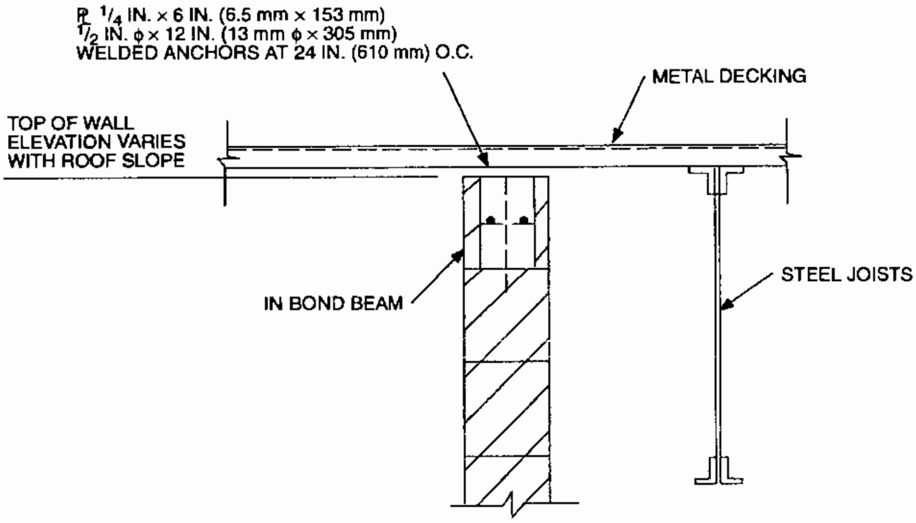
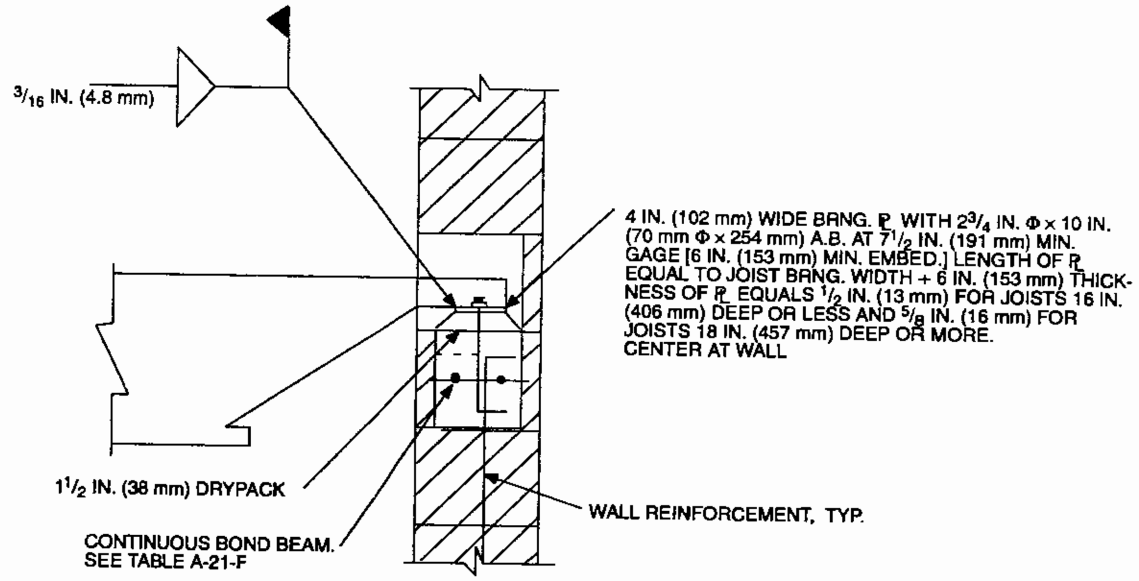
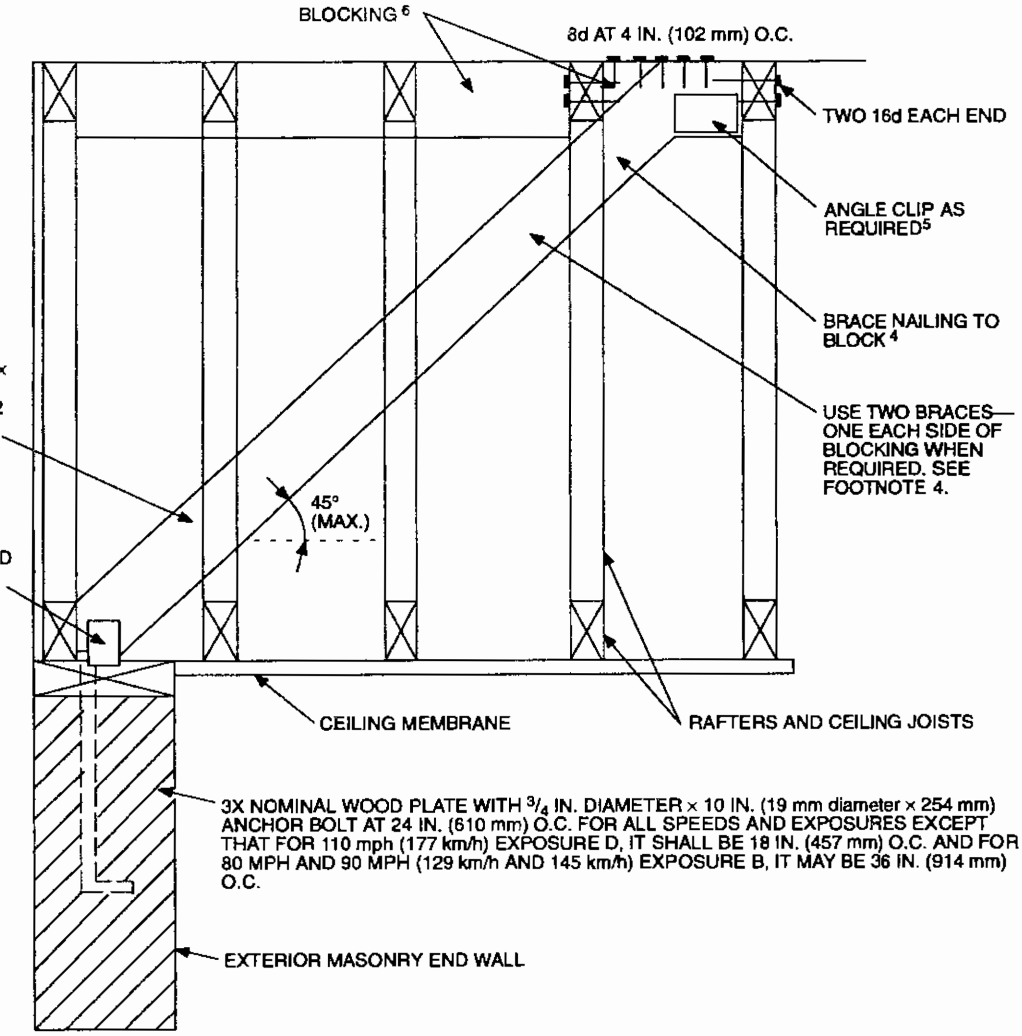


FIGURE A-21-15—INTERIOR WALL DETAILS



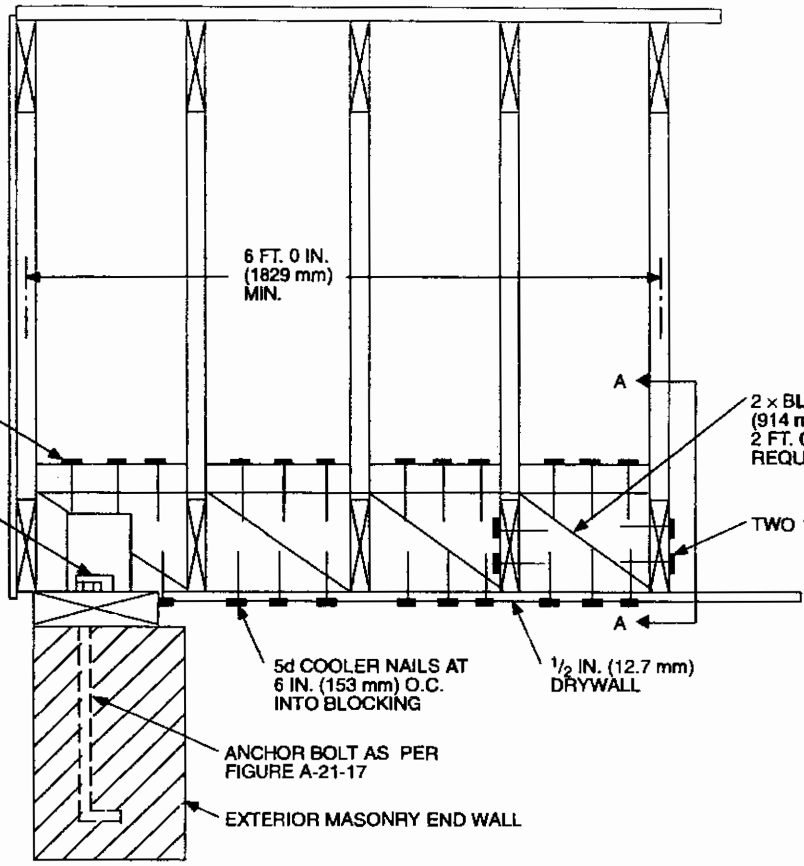
NOTE: Base ℞ to be set over fully grouted masonry course for full 100 percent bearing at bottom side of plate.

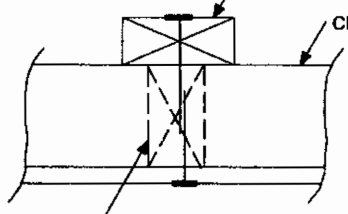
FIGURE A-21-16—FLOOR DETAILS
(Design Required for Joists and Wall)



[1] For roof slopes up to 5 units vertical in 12 units horizontal (42%); see Table A-21-I.
[2] See Detail 2, Table A-21-B, for size of angle clip.
[3] Angle clip one side or both sides as required by Table A-21-I.
[4] Use six 16d nails to fasten brace to block, except use two braces and six 16d nails each for 110 miles per hour (mph) (177 km/h), Exposure D. Place on brace on each side block.
[5] Add angle clip each end of block for 90 mph (145 km/h), Exposure D, and 100 and 110 mph (161 and 177 km/h) for Exposures C and D.
[6] Use 2 in. × 6 in. (51 mm × 153 mm) block with 2 in. (51 mm) × brace, 2 in. × 8 in. (51 mm × 203 mm) block with 3 in. (76 mm) × brace.

FIGURE A-21-17—DIAGONAL BRACING OF GABLE-END WALL[1]





DETAIL A–A

NOTE: This detail may be used for flat roofs also, except use full height blocking connected to roof sheathing in lieu of "T."
2 × 4 "T" at 36 in. (914 mm) on center—90 miles per hour (mph) (145 km/h) Exposure C and less, and 100 mph and 110 mph (161 km/h and 177 km/h), Exposure B.
2 × 4 "T" at 24 in. (610 mm) on center—required for 90 mph (145 mm) exposure.
See Figure A-21-4 for details of clip angle and connections.

FIGURE A-21-18—ALTERNATE HORIZONTAL BRACING OF GABLE-END WALL

Appendix Chapter 23 is printed in its entirety in Volume 2 of the *Uniform Building Code*. Excerpts from Appendix Chapter 23 are reprinted herein.

Excerpts from Appendix Chapter 23
CONVENTIONAL LIGHT-FRAME CONSTRUCTION IN HIGH-WIND AREAS

SECTION 2337 — GENERAL

2337.1 Purpose. The provisions of this chapter are intended to promote public safety and welfare by reducing the risk of wind-induced damages to conventional light-frame construction.

2337.2 Scope. This chapter applies to regular-shaped buildings which have roof structural members spanning 32 feet (9.75 m) or less, are not more than three stories in height, are of conventional light-frame construction and are located in areas with a basic wind speed from 80 through 110 miles per hour (mph) (129 km/h through 177 km/h).

> **EXCEPTION:** Detached carports and garages not exceeding 600 square feet (55.7 m^2) and accessory to Group R, Division 3 Occupancies need only comply with the roof-member-to-wall-tie requirements of Section 2337.5.8.

2337.3 Definitions. For the purpose of this chapter, certain terms are defined as follows:

CORROSION RESISTANT or **NONCORROSIVE** is material having a corrosion resistance equal to or greater than a hot-dipped galvanized coating of 1.5 ounces of zinc per square foot (4 g/m^2) of surface area.

2337.4 General. The requirements of Section 2320 are applicable except as specifically modified by this chapter. Other methods may be used, provided a satisfactory design is submitted showing compliance with the provisions of Section 1611.4 and other applicable portions of this code.

In addition to the other provisions of this chapter, foundations for buildings in areas subject to wave action or tidal surge shall be designed in accordance with approved national standards.

When an element is required to be corrosion resistant or noncorrosive, all of its parts, such as screws, nails, wire, dowels, bolts, nuts, washers, shims, anchors, ties and attachments, shall also be corrosion resistant or noncorrosive.

2337.5 Complete Load Path and Uplift Ties.

2337.5.1 General. Blocking, bridging, straps, approved framing anchors or mechanical fasteners shall be installed to provide continuous ties from the roof to the foundation system. (See Figure A-23-1.)

Tie straps shall be $1^1/_8$-inch (28.6 mm) by 0.036-inch (0.91 mm) (No. 20 gage) sheet steel and shall be corrosion resistant as herein specified. All metal connectors and fasteners used in exposed locations or in areas otherwise subject to corrosion shall be of corrosion-resistant or noncorrosive material.

2337.5.2 Walls-to-foundation tie. Exterior walls shall be tied to a continuous foundation, or an elevated foundation system in accordance with Section 2337.10.

2337.5.3 Sills and foundation tie. Foundation plates resting on concrete or masonry foundations shall be bolted to the foundation with not less than $^1/_2$-inch-diameter (13 mm) anchor bolts with 7-inch-minimum (178 mm) embedment into the foundation. In areas where the basic wind speed is 90 mph (145 km/h) or greater, the maximum spacing of anchor bolts shall be 4 feet (1219 mm) on center. Structures located where the basic wind speed is less than 90 mph (145 km/h) may have anchor bolts spaced not more than 6 feet (1829 mm) on center.

2337.5.4 Floor-to-foundation tie. The lowest-level exterior wall studs shall be connected to the foundation sill plate or an approved elevated foundation system with bent tie straps spaced not more than 48 inches (1219 mm) on center. Tie straps shall be nailed and installed in accordance with Table A-23-B and Figure A-23-1.

2337.5.5 Wall framing details. The spacing of 2-inch-by-4-inch studs (51 mm by 102 mm) in exterior walls shall not exceed 16 inches (406 mm) on center for areas with a basic wind speed of 90 mph (145 km/h) or greater.

Mechanical fasteners complying with this chapter shall be installed as required to connect studs to the sole plates, foundation sill plate and top plates of the wall.

Interior main cross-stud partitions shall be installed approximately perpendicular to the exterior wall when the length of the structure exceeds the width. The maximum distance between these partitions shall not exceed the width of the structure. Interior main cross-stud partition walls shall be securely fastened to exterior walls at the point of intersection with fasteners as required by Table 23-II-B-1. The main cross-stud partitions shall be covered on both sides by materials as described in Section 2337.5.6.

2337.5.6 Wall sheathing. All exterior walls and required interior main cross-stud partitions shall be sheathed in accordance with Table A-23-A. The total width of sheathed wall elements shall not be less than 50 percent of the exterior wall length or 60 percent of the width of the building for required interior main cross-stud partitions. The exterior wall sheathing or covering shall extend from the foundation sill plate or girder to the top plates at the roof level and shall be adequately attached thereto.

A sheathed wall element not less than 4 feet (1219 mm) in width shall be installed at each corner or as near thereto as possible. There shall not be less than one 4-foot (1219 mm) sheathed wall element for every 20 feet (6096 mm) or fraction thereof of wall length. The height-to-length ratio of required sheathed wall elements shall not exceed 3 for wood structural panel or particleboard and $1^1/_2$ (38 mm) for other sheathing materials listed in Table A-23-A.

2337.5.7 Floor-to-floor tie. Upper-level exterior wall studs shall be aligned and connected to the wall studs below with a tie strap as required by Table A-23-B.

2337.5.8 Roof-members-to-wall tie. Tie straps shall be provided from the side of the roof-framing member to the exterior studs, posts or other supporting members below the roof. The wall studs to which the roof-framing members are tied shall be aligned with the roof-framing member and be connected in accordance with Table A-23-B.

The eave overhang shall not exceed 3 feet (914 mm) unless an analysis is provided showing that the required resistance is provided to prevent uplift.

Where openings exceed 6 feet (1829 mm) in width, the required tie straps shall be doubled at each edge of the opening and connected to a doubled full-height wall stud. When openings exceed

12 feet (3658 mm) in width, ties designed to prevent uplift shall be provided.

EXCEPTION: The opening width may be increased to 16 feet (4877 mm) for garages and carports accessory to Group R, Division 3 Occupancies when constructed in accordance with the following:

1. Approved column bases shall be a minimum $^3/_{16}$-inch (4.8 mm) steel plate embedded not less than 8 inches (203 mm) into the concrete footing and connected to a minimum 4-inch-by-4-inch (102 mm by 102 mm) wood post with two $^5/_8$-inch-diameter (15.9 mm) through bolts.
2. Beams over openings shall be connected to minimum 4-inch by 4-inch (102 mm by 102 mm) wood posts below with an approved $^3/_{16}$-inch (4.8 mm) steel post cap with two $^5/_8$-inch-diameter (15.9 mm) through bolts to the posts and to the beams.

2337.5.9 Ridge ties. Opposing rafters shall be aligned at the ridge and be connected at the rafters with a tie strap in accordance with Table A-23-C.

2337.6 Masonry Veneer. Anchor ties shall be spaced so as to support not more than $1^1/_3$ square feet (860 mm^2) of wall area but not more than 12 inches (305 mm) on center vertically. The materials and connection details shall comply with Chapter 14.

2337.7 Roof Sheathing. Solid roof sheathing shall be applied and shall consist of a minimum 1-inch-thick (25 mm) nominal lumber applied diagonally or a minimum $^{15}/_{32}$-inch-thick (11.9 mm) wood structural panel or particleboard or other approved sheathing applied with the long dimension perpendicular to supporting rafters. Sheathing shall be nailed to roof framing in an approved manner. The end joints of wood structural panels or particleboard shall be staggered and shall occur over blocking, rafters or other supports.

2337.8 Gable-end Walls. The roof overhang at gabled ends shall not exceed 2 feet (610 mm) unless an analysis showing that the required resistance to prevent uplift is provided.

Gable-end wall studs shall be continuous between points of lateral support which are perpendicular to the plane of the wall.

Gable-end wall studs shall be attached with approved mechanical fasteners at the top and bottom.

2337.9 Roof Covering. Roof coverings shall be approved and shall be installed and fastened in accordance with Chapter 15 and with the manufacturer's instructions. In areas with basic wind speeds of 90 mph (145 km/h) or greater strip asphalt shingles shall be fastened with a minimum of six fasteners and hand sealed.

2337.10 Elevated Foundation.

2337.10.1 General. When approved, elevated foundations supporting not more than one story and meeting the provisions of this section may be used. A foundation investigation may be required by the building official.

2337.10.2 Material. All exposed wood-framing members shall be treated wood. All metal connectors and fasteners used in exposed locations shall be corrosion-resistant or noncorrosive steel.

2337.10.3 Wood piles. The spacing of wood piles shall not exceed 8 feet (2438 mm) on center. Square piles shall not be less than 10 inches (254 mm) and tapered piles shall have a tip of not less than 8 inches (203 mm). Ten-inch-square (64 516 mm^2) piles shall have a minimum embedment length of 10 feet (3048 mm) and shall project not more than 8 feet (2438 mm) above undisturbed ground surface. Eight-inch (203 mm) taper piles shall have a minimum embedment length of 14 feet (4267 mm) and shall project not more than 7 feet (2134 mm) above undisturbed ground surface.

2337.10.4 Girders. Floor girders shall be solid sawn timber, built-up 2-inch-thick (51 mm) lumber or trusses. Splices shall occur over wood piles. The floor girders shall span in the direction parallel to the potential floodwater and wave action.

2337.10.5 Connections. Wood piles may be notched to provide a shelf for supporting the floor girders. The total notching shall not exceed 50 percent of the pile cross section. Approved bolted connections with $^1/_4$-inch (6.4 mm) corrosion-resistant or noncorrosive steel plates and $^3/_4$-inch-diameter (19 mm) bolts shall be provided. Each end of the girder shall be connected to the piles using a minimum of two $^3/_4$-inch-diameter (19 mm) bolts.

TABLE A-23-A—WALL SHEATHING AT EXTERIOR WALLS AND INTERIOR MAIN CROSS-STUD PARTITIONS[1]

BASIC WIND SPEED (mph) × 1.61 for km/h	STORIES	LEVEL[2]	EXPOSURE B	EXPOSURE C	EXPOSURE D
80	1		A	A	B
	2	2 1	A C	A D	B D
	3	3 2 1	A C C	A D D	B D E
90	1		A	B	B
	2	2 1	A C	B D	B D
	3	3 2 1	A C D	B D E	Not permitted
100	1		A	C	C
	2	2 1	A C	C D	C E
	3	3 2 1	A C D	Not permitted	Not permitted
110	1		B	C	C
	2	2 1	B D	C E	C E

[1]Sheathing types; exterior walls with sheathing at one face, interior main cross-stud partitions with sheathing at each face. The values for sheathing are listed in order of increased capacity. Sheathing with a capacity greater than required may be substituted for the sheathing listed. Particleboard sheathing in accordance with Table 23-IV-D-2 may be substituted for sheathing Types A and B.

A. One-half-inch (12.7 mm) gypsum board or gypsum sheathing with 5d cooler nails at 7 inches (178 mm) or $^3/_8$-inch (9.5 mm) gypsum lath and $^1/_2$-inch (12.7 mm) plaster.

B. One-half-inch (12.7 mm) gypsum board or gypsum sheathing with 5d cooler nails at 4 inches (102 mm).

C. Expanded metal lath and $^7/_8$-inch (22 mm) portland cement plaster.

D. Three-eighths-inch (9.5 mm) wood structural panel or particleboard sheathing with 8d nails at 6 inches (153 mm) all edges and 12 inches (305 mm) intermediate.

E. Three-eighths-inch (9.5 mm) plywood or particleboard sheathing with 8d nails at 4 inches (102 mm) all edges and 12 inches (305 mm) intermediate.

The application of these sheathing materials shall comply with Section 2513.5 and Table 25-I for Types A, B and C, and Section 2315.1 and Table 23-II-I-1 or 23-II-I-2 for Types D and E. All panel edges of Types D and E shall be backed with 2-inch (51 mm) nominal or wider framing.

[2]Level refers to the space between the upper surface of any floor and upper surface of floor next above. The topmost level shall be the space between upper surface of the topmost floor and the ceiling or roof above. Wall sheathing at useable or unused under-floor space shall be provided as required for the level directly above.

TABLE A-23-B—ROOF AND FLOOR ANCHORAGE AT EXTERIOR WALLS

BASIC WIND SPEED (mph) × 1.61 for km/h	LOCATION[1]	NUMBER OF NAILS[2] Exposure B	C	D
80	roof to wall floor to floor floor to foundation	6-8d — —	8-8d 4-10d 4-10d	8-10d 6-10d 4-10d
90	roof to wall floor to floor floor to foundation	8-8d — —	8-10d 6-10d 4-10d	10-10d 8-10d 6-10d
100	roof to wall floor to floor floor to foundation	8-10d 6-10d 4-10d	10-10d 8-10d 6-10d	12-10d 10-10d 8-10d
110	roof to wall floor to floor floor to foundation	10-10d 8-10d 6-10d	12-10d 10-10d 8-10d	12-10d 10-10d 8-10d

[1]For floor-to-foundation anchorage, see Section 2337.5.4.

[2]Number of common nails listed is total required for each tie strap. The tie straps shall be spaced at 48 inches (1219 mm) on center along the length of the wall. The number of nails on each side of the roof or floor plate joints shall be equal. Nails shall be spaced to avoid splitting of the wood. See Figure A-23-1 for illustration of these tie straps.

TABLE A-23-C—RIDGE TIE-STRAP NAILING[1]

BASIC WIND SPEED (mph)	NUMBER OF NAILS[1]		
	Exposure		
× 1.61 for km/h	B	C	D
80	6-10d	8-10d	10-10d
90	8-10d	10-10d	12-10d
100	10-10d	12-10d	14-10d
110	12-10d	14-10d	16-10d

[1]Number of common nails listed is total required for each tie strap. The tie straps shall be spaced at 48 inches (1219 mm) on center along the length of the roof. The number of nails on each side of the rafter/ridge joint shall be equal. Nails shall be spaced to avoid splitting of the wood. See Figure A-23-1 for illustration of these tie straps.

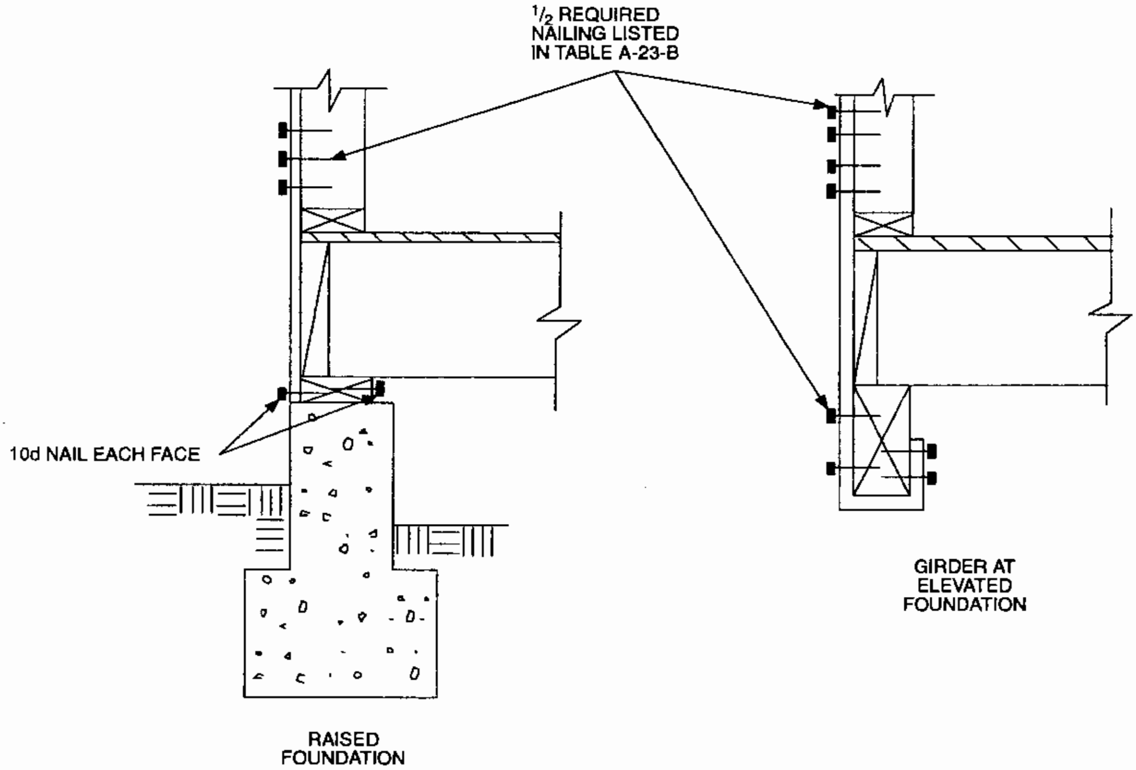


FIGURE A-23-1—COMPLETE LOAD PATH DETAILS

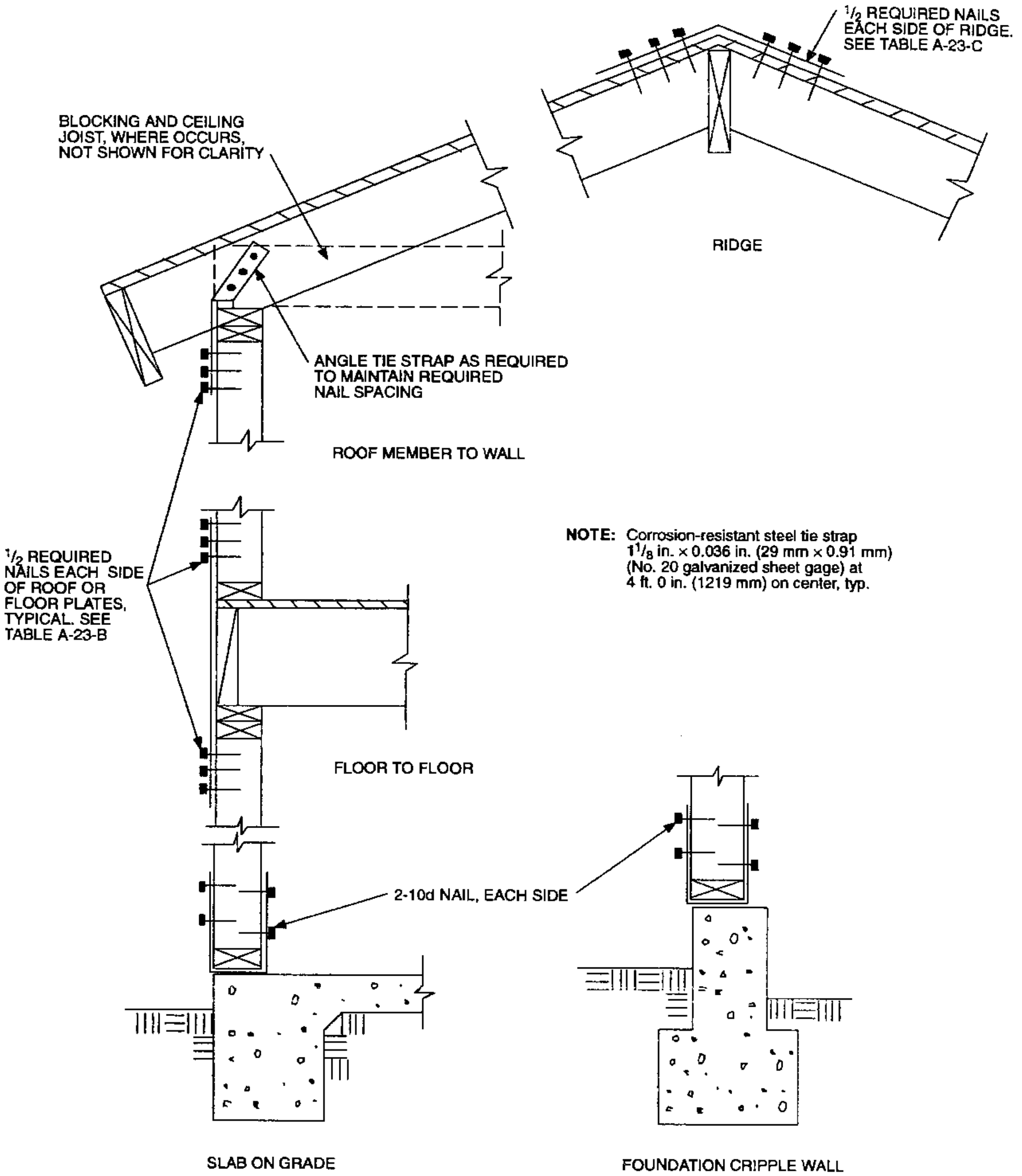


FIGURE A-23-1—COMPLETE LOAD PATH DETAILS—(Continued)

Appendix Chapter 29
MINIMUM PLUMBING FIXTURES

SECTION 2905 — GENERAL

Each building shall be provided with sanitary facilities, including provisions for accessibility in accordance with Chapter 11. Plumbing fixtures shall be provided for the type of building occupancy with the minimum numbers as shown in Table A-29-A. The number of fixtures are the minimum required as shown in Table A-29-A and are assumed to be based on 50 percent male and 50 percent female. The occupant load factors shall be as shown in Table A-29-A.

EXCEPTION: Where circumstances dictate that a different ratio is needed, the adjustment shall be approved by the building official.

TABLE A-29-A—MINIMUM PLUMBING FIXTURES[1,2,3]

TYPE OF BUILDING OR OCCUPANCY[4]	WATER CLOSETS[5] (fixtures per person) MALE	FEMALE	LAVATORIES[6] (fixtures per person) MALE	FEMALE	BATHTUB OR SHOWER (fixtures per person)
For the occupancies listed below, use 30 square feet (2.78 m^2) per occupant for the minimum number of plumbing fixtures.					
Group A Conference rooms, dining rooms, drinking establishments, exhibit rooms, gymnasiums, lounges, stages and similar uses including restaurants classified as Group B Occupancies	1:1-25 2:26-75 3:76-125 4:126-200 5:201-300 6:301-400 Over 400, add one fixture for each additional 200 males or 150 females.	1:1-25 2:26-75 3:76-125 4:126-200 5:201-300 6:301-400	one for each water closet up to four; then one for each two additional water closets		
For the assembly occupancies listed below, use the number of fixed seating or, where no fixed seating is provided, use 15 square feet (1.39 m^2) per occupant for the minimum number of plumbing fixtures.					
Assembly places— Auditoriums, convention halls, dance floors, lodge rooms, stadiums and casinos	1:1-50 2:51-100 3:101-150 4:151-300 Over 300 males, add one fixture for each additional 200, and over 400 females add one for each 125.	3:1-50 4:51-100 6:101-200 8:201-400	1:1-200 2:201-400 3:401-750 Over 750, add one fixture for each additional 500 persons.	1:1-200 2:201-400 3:401-750	
For the assembly occupancies listed below, use the number of fixed seating or, where no fixed seating is provided, use 30 square feet (2.29 m^2) per occupant for the minimum number of plumbing fixtures.					
Worship places Principal assembly area	one per 150	one per 75	one per two water closets		
Worship places Educational and activity unit	one per 125	one per 75	one per two water closets		
For the occupancies listed below, use 200 square feet (18.58 m^2) per occupant for the minimum number of plumbing fixtures.					
Group B Offices or public buildings	1:1-15 2:16-35 3:36-55 Over 55, add one for each 50 persons.	1:1-15 2:16-35 3:36-55	one per two water closets		
For the occupancies listed below, use 50 square feet (4.65 m^2) per occupant for the minimum number of plumbing fixtures.					
Group E Schools—for staff use All schools	1:1-15 2:16-35 3:36-55 Over 55, add one fixture for each additional 40 persons.	1:1-15 2:16-35 3:36-55	one per 40	one per 40	
Schools—for student use Day care	1:1-20 2:21-50 Over 50, add one fixture for each additional 50 persons.	1:1-20 2:21-50	1:1-25 2:26-50 Over 50, add one fixture for each additional 50 persons.	1:1-25 2:26-50	
Elementary	one per 30	one per 25	one per 35	one per 35	
Secondary	one per 40	one per 30	one per 40	one per 40	
For the occupancies listed below, use 50 square feet (4.65 m^2) per occupant for the minimum number of plumbing fixtures.					
Education Facilities other than Group E Others (colleges, universities, adult centers, etc.)	one per 40	one per 30	one per 40	one per 40	

(Continued)

TABLE A-29-A—MINIMUM PLUMBING FIXTURES[1,2,3]—(Continued)

TYPE OF BUILDING OR OCCUPANCY[4]	WATER CLOSETS[5] (fixtures per person) MALE	WATER CLOSETS[5] (fixtures per person) FEMALE	LAVATORIES[6] (fixtures per person) MALE	LAVATORIES[6] (fixtures per person) FEMALE	BATHTUB OR SHOWER (fixtures per person)
For the occupancies listed below, use 2,000 square feet (185.8 m^2) per occupant for the minimum number of plumbing fixtures.					
Group F Workshop, foundries and similar establishments, and Group H Occupancies	1:1-10 2:11-25 3:26-50 4:51-75 5:76-100 Over 100, add one fixture for each additional 300 persons.	1:1-10 2:11-25 3:26-50 4:51-75 5:76-100	one for each two water closets		one shower for each 15 persons exposed to excessive heat or to skin contamination with irritating materials
For the occupancies listed below, use the designated application and 200 square feet (18.58 m^2) per occupant of the general use area for the minimum number of plumbing fixtures.					
Group I Hospital waiting rooms	one per room (usable by either sex)		one per room		
Hospital general use areas	1:1-15 2:16-35 3:36-55 Over 55, add one fixture for each additional 40 persons.	1:1-15 3:16-35 4:36-55	one per each two water closets		
Hospitals Patient room Ward room	one per room one per eight patients		one per room one per 10 patients		one per room one per 20 patients
Jails and reformatories Cell Exercise room	one per cell one per exercise room		one per cell one per exercise room		
Other institutions (on each occupied floor)	one per 25	one per 25	one per 10	one per 10	one per eight
For the occupancies listed below, use 200 square feet (18.58 m^2) per occupant for the minimum number of plumbing fixtures.					
Group M Retail or wholesale stores	1:1-50 2:51-100 3:101-400 Over 400, add one fixture for each additional 500 males and one for each 150 females.	1:1-50 2:51-100 3:101-200 4:201-300 5:301-400	one for each two water closets		
For Group R Occupancies, dwelling units and hotel guest rooms, use the chart. For congregate residences, use 200 square feet (18.58 m^2) for Group R, Division 1 Occupancies and 300 square feet (27.87 m^2) for Group R, Division 3 Occupancies for the minimum plumbing fixtures.					
Group R Dwelling units Hotel guest rooms	one per dwelling unit one per guest room		one per dwelling unit one per guest room		one per dwelling unit one per guest room
Congregate residences	one per 10 Add one fixture for each additional 25 males and one for each additional 20 females.	one per 8	one per 12 Over 12, add one fixture for each additional 20 males and one for each additional 15 females	one per 12	one per eight For females, add one bathtub per 30. Over 150, add one per 20.
For the occupancies listed below, use 5,000 square feet (464.5 m^2) per occupant for the minimum number of plumbing fixtures.					
Group S Warehouses	1:1-10 2:11-25 3:26-50 4:51-75 5:76-100 Over 100, add one for each 300 males and females.	1:1-10 2:11-25 3:26-50 4:51-75 5:76-100	one per 40 occupants of each sex		one shower for each 15 persons exposed to excessive heat or to skin contamination with poisonous, infectious or irritating materials

NOTE: Occupant loads over 30 shall have one drinking fountain for each 150 occupants.

[1]The figures shown are based on one fixture being the minimum required for the number of persons indicated or any fraction thereof.

[2]Drinking fountains shall not be installed in toilet rooms.

[3]When the design occupant load is less than 10 persons, a facility usable by either sex may be approved by the building official.

[4]Any category not mentioned specifically or about which there are any questions shall be classified by the building official and included in the category which it most nearly resembles, based on the expected use of the plumbing facilities.

[5]Where urinals are provided, one water closet less than the number specified may be provided for each urinal installed, except the number of water closets in such cases shall not be reduced to less than one half of the minimum specified.

[6]Twenty-four inches (610 mm) of wash sink or 18 inches (457 mm) of a circular basin, when provided with water outlets for such space, shall be considered equivalent to one lavatory.

Appendix Chapter 30
ELEVATORS, DUMBWAITERS, ESCALATORS AND MOVING WALKS

SECTION 3008 — PURPOSE

The purpose of this appendix is to safeguard life, limb, property and public welfare by establishing minimum requirements regulating the design, construction, alteration, operation and maintenance of elevators, dumbwaiters, escalators and moving walks and by establishing procedures by which these requirements may be enforced.

SECTION 3009 — SCOPE

This appendix shall apply to new and existing installations of elevators, dumbwaiters, escalators and moving walks, requiring permits therefore and providing for the inspection and maintenance of such conveyances.

SECTION 3010 — DEFINITIONS

For purposes of this appendix, certain terms are defined as follows:

ANSI CODE is the ASME/ANSI A17.1-1987 with Supplements A17.1a-1988 and A17.1b-1989, Safety Code for Elevators and Escalators, an American National Standard published by the American Society of Mechanical Engineers.

SECTION 3011 — PERMITS—CERTIFICATES OF INSPECTION

3011.1 Permits Required. It shall be unlawful to hereafter install any new elevator, moving walk, escalator or dumbwaiter, or to make major alterations to any existing elevator, dumbwaiter, escalator or moving walk as defined in Part XII of the ANSI code, without having first obtained a permit for such installation from the building official. Permits shall not be required for maintenance or minor alterations.

3011.2 Certificates of Inspection Required. It shall be unlawful to operate any elevator, dumbwaiter, escalator or moving walk without a current certificate of inspection issued by the building official. Such certificate shall be issued upon payment of prescribed fees and the presentation of a valid inspection report indicating that the conveyance is safe and that the inspections and tests have been performed in accordance with Part X of the ANSI code. Certificates shall not be issued when the conveyance is posted as unsafe pursuant to Section 3015.

EXCEPTION: Certificates of inspection shall not be required for conveyances within a dwelling unit.

3011.3 Application for Permits. Application for a permit to install shall be made on forms provided by the building official, and the permit shall be issued to an owner upon payment of the permit fees specified in this section.

3011.4 Application for Certificates of Inspection. Application for a certificate of inspection shall be made by the owner of an elevator, dumbwaiter, escalator or moving walk. Applications shall be accompanied by an inspection report as described in Section 3014. Fees for certificates of inspection shall be as specified in this section.

3011.5 Fees. A fee for each permit or certificate of inspection shall be paid to the building official as follows:

New Installations:

Passenger or freight elevator, escalator, moving walk:

Up to and including $40,000 of valuation—$89.00

Over $40,000 of valuation—$89.00 plus $1.65 for each $1,000 or fraction thereof over $40,000

Dumbwaiter or Private Residence Elevator:

Up to and including $10,000 of valuation—$25.00

Over $10,000 of valuation—$25.00 plus $1.65 for each $1,000 or fraction thereof over $10,000

Major Alterations:

Fees for major alterations shall be as set forth in Table 1-A.

Installation fees include charges for the first year's annual inspection fee and charges for electrical equipment on the conveyance side of the disconnect switch.

Annual certificates of inspection:

For each elevator	$41.50
For each escalator or moving walk	$24.65
For each commercial dumbwaiter	$16.75

(Each escalator or moving walk unit powered by one motor shall be considered as a separate escalator or moving walk.)

SECTION 3012 — ANSI CODE ADOPTED

New elevators, dumbwaiters, escalators and moving walks and major alterations to such conveyances and the installation thereof shall conform to the requirements of the American National Standards Institute ASME/ANSI A17.1-1987, Safety Code for Elevators and Escalators, including Supplements A17.1a-1988 and A17.1b-1989, published by the American Society of Mechanical Engineers. Existing elevators and escalators shall conform with ASME/ANSI A17.3-1986, Safety Code for Existing Elevators and Escalators, including Supplement A17.3a-1989, published by the American Society of Mechanical Engineers.

SECTION 3013 — DESIGN

For detailed design, construction and installation requirements, see Chapter 16 and the appropriate requirements of the ANSI code.

In Seismic Zones 3 and 4, elevators shall conform to Appendix F of the ANSI code.

SECTION 3014 — REQUIREMENTS FOR OPERATION AND MAINTENANCE

3014.1 General. The owner shall be responsible for the safe operation and maintenance of each elevator, dumbwaiter, escalator or moving walk installation and shall cause periodic inspections, tests and maintenance to be made on such conveyances as required in this section.

3014.2 Periodic Inspections and Tests. Routine and periodic inspections and tests shall be made as required by Part X of the ANSI code.

3014.3 Alterations, Repairs and Maintenance. Alterations, repairs and maintenance shall be made as required by Part XII of the ANSI code.

3014.4 Inspection Costs. All costs of such inspections and tests shall be paid by the owner.

3014.5 Inspection Reports. After each required inspection, a full and correct report of such inspection shall be filed with the building official.

SECTION 3015 — UNSAFE CONDITIONS

When an inspection reveals an unsafe condition, the inspector shall immediately file with the owner and the building official a full and true report of such inspection and such unsafe condition. If the building official finds that the unsafe condition endangers human life, the building official shall cause to be placed on such elevator, escalator or moving walk, in a conspicuous place, a notice stating that such conveyance is unsafe. The owner shall see to it that such notice of unsafe condition is legibly maintained where placed by the building official. The building official shall also issue an order in writing to the owner requiring the repairs or alterations to be made to such conveyance that are necessary to render it safe and may order the operation thereof discontinued until the repairs or alterations are made or the unsafe conditions are removed. A posted notice of unsafe conditions shall be removed only by the building official when satisfied that the unsafe conditions have been corrected.

Appendix Chapter 31
SPECIAL CONSTRUCTION
Division I—FLOOD-RESISTANT CONSTRUCTION

SECTION 3104 — GENERAL

3104.1 Purpose. The provisions of this division are intended to promote public safety and welfare by reducing the risk of flood damage in areas prone to flooding.

3104.2 Scope. Buildings and structures erected in areas prone to flooding shall be constructed as required by the provisions of this division. The base flood elevation shown on the approved flood hazard map is the minimum elevation used to define areas prone to flooding, unless records indicate a higher elevation is to be used. The flood-prone areas are defined in the jurisdiction's floodplain management ordinance.

3104.3 Definitions. For the purpose of this division, certain terms are defined as follows:

BASE FLOOD ELEVATION is the depth or peak elevation of flooding, including wave height, having 1 percent chance of being equaled or exceeded in any given year.

FLOOD HAZARD MAP is a map published by an approved agency that defines the flood boundaries, elevations and insurance risk zones as determined by a detailed flood insurance study.

HAZARD ZONES are areas that have been determined to be prone to flooding and are classified as either flood hazard zones, A zones, or coastal high-hazard zones, V zones, in accordance with Sections 3107.1 and 3108.1.

SECTION 3105 — MANUFACTURED STRUCTURES

New or replacement manufactured structures located in any flood hazard zone shall be located in accordance with the applicable elevation requirements of Sections 3107.2 and 3108.2, and the anchor and tie-down requirements of Section 3110.1.

SECTION 3106 — PROTECTION OF MECHANICAL AND ELECTRICAL SYSTEMS

New or replacement electrical equipment and heating, ventilating, air conditioning and other service facilities shall be either placed above the base flood elevation or protected to prevent water from entering or accumulating within the system components during floods up to the base flood elevation. Installation of electrical wiring and outlets, switches, junction boxes and panels below the base flood elevation shall conform to the provisions of the Electrical Code for such items in wet locations.

SECTION 3107 — FLOOD HAZARD ZONES—A ZONES

3107.1 General. Areas that have been determined as prone to flooding but not subject to wave heights of more than 3 feet (914 mm) are designated as flood hazard zones. Buildings or structures erected in flood hazard zones shall be designed and constructed in accordance with this section.

3107.2 Elevation. Buildings or structures erected within a flood hazard zone shall have the lowest floor, including basement floors, located at or above the base flood elevation.

EXCEPTIONS: 1. Except for Group R Occupancies, any occupancy may have floors below the base flood elevation in accordance with Section 3107.4.

2. Floors of buildings or structures that are used only for building access, means of egress, foyers, storage and parking garages may be below the base flood elevation in accordance with Section 3107.3.

3107.3 Enclosures below Base Flood Elevation. Enclosed spaces below the base flood elevation shall not be used with the exception of building access, means of egress, foyers, storage and parking garages. Enclosed spaces shall be provided with vents, valves or other openings that will automatically equalize the lateral pressure of waters acting on the exterior wall surfaces. The bottom of the openings shall not be higher than 12 inches (305 mm) above finish grade. A minimum of two openings per building, or one opening for each enclosure below the base flood elevation, whichever is greater, shall be provided. The total net area of such openings shall not be less than 4 square feet (0.37 m^2) or 1 square inch for every square foot (0.007 m^2 for every 1 m^2) of enclosed area, whichever is greater.

3107.4 Flood-resistant Construction. Buildings or structures of any occupancy other than Group R may, in lieu of meeting the elevation provisions of Section 3107.2, be erected with floors usable for human occupancy below the base flood elevation, provided the following conditions are met:

1. Space below the base flood elevation shall be constructed with exterior walls and floors that are impermeable to the passage of water.

2. Structural components subject to hydrostatic and hydrodynamic loads during the occurrence of flooding to the base flood elevation shall be capable of resisting such forces, including the effect of buoyancy.

3. Openings below the base flood elevation shall be provided with watertight closures and shall have adequate structural capacity to support flood loads acting upon closure surfaces.

4. Floor and wall penetrations for plumbing, mechanical and electrical systems shall be made watertight to prevent flood water seepage through spaces between penetration and wall construction materials. Sanitary sewer and storm drainage systems that have openings below the base flood elevation shall be provided with closure devices to prevent backwater flow during conditions of flooding.

3107.5 Plan Requirements for Flood-resistant Construction. When buildings or structures are to be constructed in accordance with Section 3107.4, an architect or engineer licensed by the state to practice as such shall prepare plans showing details of the floor wall and foundation support components. Calculations and approved technical data used to comply with the conditions of Section 3107.4 shall also be provided.

SECTION 3108 — COASTAL HIGH HAZARD ZONES—V ZONES

3108.1 General. Areas that have been determined to be subject to wave heights in excess of 3 feet (914 mm) or subject to high-velocity wave run-up or wave-induced erosion are designated as coastal high-hazard zones. Buildings or structures erected in coastal high-hazard zones shall be designed and constructed in accordance with this section.

3108.2 Elevation. Buildings or structures erected within a coastal high-hazard zone shall be elevated so that the lowest portion of horizontal structural members, with the exception of footings, mat or raft foundations, piles, pile caps, columns, grade beams, and bracing, shall be located at or above the base flood elevation.

3108.3 Enclosures below Base Flood Elevation. Spaces below the base flood elevation in a coastal high-hazard zone shall be free of obstruction.

EXCEPTIONS: 1. Footings, mat or raft foundations, piles, pile caps, columns, grade beams, and bracing that provide structural stability for the building.

2. Structural systems of entrances and required exits.

3. Storage of portable or mobile items that can be moved in the event of a storm.

4. Walls or partitions may be used to enclose all or part of the space, provided they are not part of the structural support of the building and are designed to break away under high tides or wave action without causing damage to the structural system of the building (see Section 3110.6.) Screening, lattice-type arrangements or other materials that allow the passage of water may also be used.

3108.4 Foundations. Buildings or structures erected in coastal high-hazard zones shall be supported on piles or columns. When piles are used, they shall have soil penetration to resist the combined wave and wind loads to which they may be subject during a flood equal to the base flood elevation. Pile design shall include consideration of decreased resistance capacity caused by scour of the soil strata surrounding the piles. Pile system design and installation shall be made in accordance with the provisions of this code. When mat or raft foundations are used, they shall be located at a depth to provide protection from erosion or scour.

3108.5 Plan Requirements for Coastal High-hazard Construction. When buildings or structures are to be constructed in accordance with Section 3108, an architect or engineer licensed by the state to practice as such shall submit plans showing details of the foundation support and connection components to comply with the requirements of Section 3108.4. When solid walls or partitions are proposed below the base flood elevation, wall, framing and connection details of such walls in accordance with Section 3108.3 shall be provided.

SECTION 3109 — ELEVATION CERTIFICATION

A land surveyor, architect or engineer licensed by the state to practice as such shall certify that the actual elevation in relation to mean sea level of the lowest floor, if in a flood hazard zone, or the bottom of the lowest horizontal structural member, if in a coastal high-hazard zone, are at or above the minimum elevation when required by the provisions of Sections 3107.2 and 3108.2.

SECTION 3110 — DESIGN REQUIREMENTS

3110.1 Structural Systems. Structural systems of buildings or structures shall be constructed, connected and anchored to resist flotation, collapse or permanent lateral movement due to loads from flooding equal to the base flood elevation.

3110.2 Design Loads. The structural system shall be designed in accordance with well-established engineering principles and with consideration of hydrodynamic and hydrostatic loads. The required loading shall be established by site-specific criteria or approved national standards. Impact loads shall be considered in the analysis of the structural system.

3110.3 Load Combinations. Loading combinations shall be subject to approval by the building official. The structural system shall be designed to resist each combination of loading acting simultaneously. In lieu of site-specific loading requirements, load combinations from an approved national standard may be used.

3110.4 Stress Increases. Allowable stresses may be increased one third for flood loads in combination with dead load or dead and live load combinations. When strength design is used, flood loads may be considered as dead loads when considering dead and live load conditions. Flood loads may be considered as wind loads in other load combinations.

3110.5 Overturning. Buildings and structures and parts or elements shall be designed to resist sliding or overturning by at least 1.5 times the lateral force or overturning moment caused by wind and flood loads acting simultaneously. For the purpose of providing stability, only the dead load shall be considered effective in resisting overturning.

3110.6 Breakaway Walls. When walls or partitions located below the base flood elevation are required to break away in accordance with Section 3108.3, such walls shall be designed for not less than 10 pounds per square foot (psf) (0.48 kN/m^2) or more than 20 psf (0.96 kN/m^2) on the vertical projected area.

Division II—MEMBRANE STRUCTURES

SECTION 3111 — GENERAL

3111.1 Purpose. The purpose of this appendix is to establish minimum standards of safety for the construction and use of air-supported, air-inflated and membrane-covered cable or frame structures, collectively known as membrane structures.

3111.2 Scope. The provisions of this appendix shall apply to membrane structures erected for a period of 180 days or longer. Those erected for a shorter period of time shall comply with applicable provisions of the Fire Code.

> **EXCEPTION:** Water storage facilities, water clarifiers, water treatment plants, sewer plants, aquaculture pond covers, residential and agricultural greenhouses, and similar facilities not used for human occupancy need meet only the requirements of Section 3112.2 and Section 3115.

3111.3 Definitions. For the purpose of this appendix, certain terms are defined as follows:

AIR-INFLATED STRUCTURE is a building where the shape of the structure is maintained by air pressurization of cells or tubes to form a barrel vault over the usable area. Occupants of such a structure do not occupy the pressurized area used to support the structure.

AIR-SUPPORTED STRUCTURE is a building wherein the shape of the structure is attained by air pressure and occupants of the structure are within the elevated pressure area. Air-supported structures are of two basic types:

1. **Single skin**—Where there is only the single outer skin and the air pressure is directly against that skin.

2. **Double skin**—Similar to a single skin, but with an attached liner that is separated from the outer skin and provides an air space that serves for insulation, acoustic, aesthetic or similar purposes.

A cable-restrained air-supported structure is one in which the uplift is resisted by cables or webbing that are anchored to either foundations or deadmen. Reinforcing cable or webbing may be attached by various methods to the membrane or may be an integral part of the membrane. This is not a cable-supported structure.

CABLE STRUCTURE is a nonpressurized structure in which a mast and cable system provide support and tension to the membrane weather barrier and the membrane imparts structural stability to the structure.

FRAME-COVERED STRUCTURE is a nonpressurized building wherein the structure is composed of a rigid framework to support tensioned membrane that provides the weather barrier.

MEMBRANE is a thin, flexible, impervious material capable of being supported by an air pressure of 1.5 inches of water column (373 Pa).

NONCOMBUSTIBLE MEMBRANE STRUCTURE is a membrane structure in which the membrane and all component parts of the structure are noncombustible as defined by Section 215.

TENT is any structure, enclosure or shelter constructed of canvas or pliable material supported by any manner except by air or the contents it protects.

SECTION 3112 — TYPE OF CONSTRUCTION AND GENERAL REQUIREMENTS

3112.1 General. Membrane structures shall be classified as Type V-N construction, except that noncombustible membrane structures may be classified as Type II-N construction.

> **EXCEPTION:** A noncombustible membrane structure used exclusively as a roof and located more than 25 feet (7620 mm) above any floor, balcony or gallery is deemed to comply with the roof construction requirements for Type I and Type II fire-resistant construction, provided that such a structure complies with the requirements of this section.

3112.2 Membrane Material. Membranes shall be either noncombustible as defined by Section 215, or flame retardant conforming to UBC Standard 31-1, which is a part of this code (see Chapter 35).

> **EXCEPTION:** Plastic less than 20-mil (0.51 mm) thickness used in greenhouses and for aquaculture pond covers need not be flame retardant.

3112.3 Applicability of Other Provisions. Except as otherwise specifically required by this section, membrane structures shall meet all applicable provisions of this code. Roof coverings shall be fire retardant.

> **EXCEPTION:** Roof coverings for Group U, Division 1 Occupancies not exceeding 1,000 square feet (93 m^2) in area need not be fire retardant.

3112.4 Allowable Floor Areas. The area of a membrane structure shall not exceed the limits set forth in Table 5-B, except as provided in Section 505.

3112.5 Maximum Height. Membrane structures shall not exceed one story and shall not exceed the height limits in feet (mm) set forth in Table 5-B.

> **EXCEPTION:** Noncombustible membrane structures serving as roofs only.

SECTION 3113 — INFLATION SYSTEMS

3113.1 General. Air-supported and air-inflated structures shall be provided with primary and auxiliary inflation systems to meet the minimum requirements of this section.

3113.2 Equipment Requirements. The inflation system shall consist of one or more blowers and shall include provisions for automatic control to maintain the required inflation pressures. The system shall be so designed as to prevent overpressurization of the system.

In addition to the primary inflation system, in buildings exceeding 1,500 square feet (139.4 m^2) in area, there shall be provided an auxiliary inflation system with sufficient capacity to maintain the inflation of the structure in case of primary system failure.

The auxiliary inflation system shall operate automatically if there is a loss of internal pressure or should the primary blower system become inoperative.

Blower equipment shall meet the following requirements:

1. Blowers shall be powered by continuous rated motors at the maximum power required for any flow condition as required by the structural design.

2. Blowers shall be provided with inlet screens, belt guards and other protective devices as may be required by the building official to provide protection from injury.

3. Blowers shall be housed within a weather-protecting structure.

4. Blowers shall be equipped with back draft check dampers to minimize air loss when inoperative.

5. Blower inlets shall be located to provide protection from air contamination. Location of inlets shall be approved by the building official.

3113.3 Emergency Power. Whenever an auxiliary inflation system is required, an approved standby power-generating system shall be provided. The system shall be equipped with a suitable means for automatically starting the generator set upon failure of the normal electrical service and for automatic transfer and operation of all the required electrical functions at full power within 60 seconds of such normal service failure. Standby power shall be capable of operating independently for a minimum of four hours.

SECTION 3114 — SECTION PROVISIONS

A system capable of supporting the membrane in the event of deflation shall be provided in all air-supported and air-inflated structures having an occupant load of more than 50 or when covering a swimming pool regardless of occupant load. Such system shall maintain the membrane at least 7 feet (2134 mm) above the floor, seating area or surface of the water.

> **EXCEPTION:** Membrane structures used as a roof for Type I or Type II fire-resistant construction must be maintained not less than 25 feet (7620 mm) above floor or seating areas.

SECTION 3115 — ENGINEERING DESIGN

All membrane structures shall be structurally designed in accordance with criteria approved by the building official and developed by an engineer or architect licensed by the state to practice as such.

Division III—PATIO COVERS

SECTION 3116 — PATIO COVERS DEFINED

Patio covers are one-story structures not exceeding 12 feet (3657 mm) in height. Enclosure walls may have any configuration, provided the open area of the longer wall and one additional wall is equal to at least 65 percent of the area below a minimum of 6 feet 8 inches (2032 mm) of each wall, measured from the floor. Openings may be enclosed with insect screening or plastic that is readily removable translucent or transparent plastic not more than 0.125 inch (3.2 mm) in thickness.

Patio covers may be detached or attached to other buildings as accessories to Group U; Group R, Division 3; or single dwelling units in Group R, Division 1 Occupancies. Patio covers shall be used only for recreational, outdoor living purposes and not as carports, garages, storage rooms or habitable rooms.

SECTION 3117 — DESIGN LOADS

Patio covers shall be designed and constructed to sustain the loads required by Chapter 16, combined in accordance with Section 1612.2 for load and resistance factor design or Section 1612.3 for allowable stress design, except that the live load, *L*, shall not be taken as less than 10 pounds per square foot (0.48 kN/m^2) and, where less than 12 feet (3658 mm) high, the horizontal wind load shall be as indicated in Table A-31-A. In addition, they shall be designed to support a minimum wind uplift equal to the horizontal wind load acting vertical upward normal to the roof surface, except that for structures not more than 10 feet (3048 mm) above grade the uplift may be three fourths of the horizontal wind load. When enclosed with insect screening or plastic that is readily removable translucent or transparent plastic not more than 0.125 inch (3.2 mm) in thickness, wind loads shall be applied to the structure, assuming it is fully enclosed.

SECTION 3118 — LIGHT AND VENTILATION

Exterior openings required for light and ventilation may open into a patio structure conforming to Section 3116.

SECTION 3119 — FOOTINGS

A patio cover may be supported on a concrete slab on grade without footings, provided the slab is not less than $3^1/_2$ inches (89 mm) thick and further provided that the columns do not support live and dead loads in excess of 750 pounds (3.34 kN) per column.

TABLE A-31-A—DESIGN WIND PRESSURES FOR PATIO COVERS[1]

HEIGHT ZONE IN FEET	WIND SPEED—MAP AREAS (miles per hour) × 1.61 for km/h						
	70	80	90	100	110	120	130
× 304.8 for mm	× 0.048 for kN/m^2 (psf)						
Less than 12	10	13	15	19	23	27	32

[1]See Chapter 16, Figure 16-1, for basic wind speeds.

Appendix Chapter 33
EXCAVATION AND GRADING

SECTION 3304 — PURPOSE

The purpose of this appendix is to safeguard life, limb, property and the public welfare by regulating grading on private property.

SECTION 3305 — SCOPE

This appendix sets forth rules and regulations to control excavation, grading and earthwork construction, including fills and embankments; establishes the administrative procedure for issuance of permits; and provides for approval of plans and inspection of grading construction.

The standards listed below are recognized standards (see Sections 3503 and 3504).

1. **Testing.**
   - 1.1 ASTM D 1557, Moisture-density Relations of Soils and Soil Aggregate Mixtures
   - 1.2 ASTM D 1556, In Place Density of Soils by the Sand-Cone Method
   - 1.3 ASTM D 2167, In Place Density of Soils by the Rubber-Balloon Method
   - 1.4 ASTM D 2937, In Place Density of Soils by the Drive-Cylinder Method
   - 1.5 ASTM D 2922 and D 3017, In Place Moisture Contact and Density of Soils by Nuclear Methods

SECTION 3306 — PERMITS REQUIRED

3306.1 Permits Required. Except as specified in Section 3306.2 of this section, no person shall do any grading without first having obtained a grading permit from the building official.

3306.2 Exempted Work. A grading permit is not required for the following:

1. When approved by the building official, grading in an isolated, self-contained area if there is no danger to private or public property.

2. An excavation below finished grade for basements and footings of a building, retaining wall or other structure authorized by a valid building permit. This shall not exempt any fill made with the material from such excavation or exempt any excavation having an unsupported height greater than 5 feet (1524 mm) after the completion of such structure.

3. Cemetery graves.

4. Refuse disposal sites controlled by other regulations.

5. Excavations for wells or tunnels or utilities.

6. Mining, quarrying, excavating, processing or stockpiling of rock, sand, gravel, aggregate or clay where established and provided for by law, provided such operations do not affect the lateral support or increase the stresses in or pressure upon any adjacent or contiguous property.

7. Exploratory excavations under the direction of soil engineers or engineering geologists.

8. An excavation that (1) is less than 2 feet (610 mm) in depth or (2) does not create a cut slope greater than 5 feet (1524 mm) in height and steeper than 1 unit vertical in $1^1/_2$ units horizontal (66.7% slope).

9. A fill less than 1 foot (305 mm) in depth and placed on natural terrain with a slope flatter than 1 unit vertical in 5 units horizontal (20% slope), or less than 3 feet (914 mm) in depth, not intended to support structures, that does not exceed 50 cubic yards (38.3 m^3) on any one lot and does not obstruct a drainage course.

Exemption from the permit requirements of this chapter shall not be deemed to grant authorization for any work to be done in any manner in violation of the provisions of this chapter or any other laws or ordinances of this jurisdiction.

SECTION 3307 — HAZARDS

Whenever the building official determines that any existing excavation or embankment or fill on private property has become a hazard to life and limb, or endangers property, or adversely affects the safety, use or stability of a public way or drainage channel, the owner of the property upon which the excavation or fill is located, or other person or agent in control of said property, upon receipt of notice in writing from the building official, shall within the period specified therein repair or eliminate such excavation or embankment to eliminate the hazard and to be in conformance with the requirements of this code.

SECTION 3308 — DEFINITIONS

For the purposes of this appendix, the definitions listed hereunder shall be construed as specified in this section.

APPROVAL shall mean that the proposed work or completed work conforms to this chapter in the opinion of the building official.

AS-GRADED is the extent of surface conditions on completion of grading.

BEDROCK is in-place solid rock.

BENCH is a relatively level step excavated into earth material on which fill is to be placed.

BORROW is earth material acquired from an off-site location for use in grading on a site.

CIVIL ENGINEER is a professional engineer registered in the state to practice in the field of civil works.

CIVIL ENGINEERING is the application of the knowledge of the forces of nature, principles of mechanics and the properties of materials to the evaluation, design and construction of civil works.

COMPACTION is the densification of a fill by mechanical means.

EARTH MATERIAL is any rock, natural soil or fill or any combination thereof.

ENGINEERING GEOLOGIST is a geologist experienced and knowledgeable in engineering geology.

ENGINEERING GEOLOGY is the application of geologic knowledge and principles in the investigation and evaluation of naturally occurring rock and soil for use in the design of civil works.

EROSION is the wearing away of the ground surface as a result of the movement of wind, water or ice.

EXCAVATION is the mechanical removal of earth material.

FILL is a deposit of earth material placed by artificial means.

GEOTECHNICAL ENGINEER. See "soils engineer."

GRADE is the vertical location of the ground surface.

Existing Grade is the grade prior to grading.

Finish Grade is the final grade of the site that conforms to the approved plan.

Rough Grade is the stage at which the grade approximately conforms to the approved plan.

GRADING is any excavating or filling or combination thereof.

KEY is a designed compacted fill placed in a trench excavated in earth material beneath the toe of a proposed fill slope.

PROFESSIONAL INSPECTION is the inspection required by this code to be performed by the civil engineer, soils engineer or engineering geologist. Such inspections include that performed by persons supervised by such engineers or geologists and shall be sufficient to form an opinion relating to the conduct of the work.

SITE is any lot or parcel of land or contiguous combination thereof, under the same ownership, where grading is performed or permitted.

SLOPE is an inclined ground surface the inclination of which is expressed as a ratio of horizontal distance to vertical distance.

SOIL is naturally occurring superficial deposits overlying bedrock.

SOILS ENGINEER (GEOTECHNICAL ENGINEER) is an engineer experienced and knowledgeable in the practice of soils engineering (geotechnical) engineering.

SOILS ENGINEERING (GEOTECHNICAL ENGINEERING) is the application of the principles of soils mechanics in the investigation, evaluation and design of civil works involving the use of earth materials and the inspection or testing of the construction thereof.

TERRACE is a relatively level step constructed in the face of a graded slope surface for drainage and maintenance purposes.

SECTION 3309 — GRADING PERMIT REQUIREMENTS

3309.1 Permits Required. Except as exempted in Section 3306 of this code, no person shall do any grading without first obtaining a grading permit from the building official. A separate permit shall be obtained for each site, and may cover both excavations and fills.

3309.2 Application. The provisions of Section 106.3.1 are applicable to grading. Additionally, the application shall state the estimated quantities of work involved.

3309.3 Grading Designation. Grading in excess of 5,000 cubic yards (3825 m^3) shall be performed in accordance with the approved grading plan prepared by a civil engineer, and shall be designated as "engineered grading." Grading involving less than 5,000 cubic yards (3825 m^3) shall be designated "regular grading" unless the permittee chooses to have the grading performed as engineered grading, or the building official determines that special conditions or unusual hazards exist, in which case grading shall conform to the requirements for engineered grading.

3309.4 Engineered Grading Requirements. Application for a grading permit shall be accompanied by two sets of plans and specifications, and supporting data consisting of a soils engineering report and engineering geology report. The plans and specifications shall be prepared and signed by an individual licensed by the state to prepare such plans or specifications when required by the building official.

Specifications shall contain information covering construction and material requirements.

Plans shall be drawn to scale upon substantial paper or cloth and shall be of sufficient clarity to indicate the nature and extent of the work proposed and show in detail that they will conform to the provisions of this code and all relevant laws, ordinances, rules and regulations. The first sheet of each set of plans shall give location of the work, the name and address of the owner, and the person by whom they were prepared.

The plans shall include the following information:

1. General vicinity of the proposed site.

2. Property limits and accurate contours of existing ground and details of terrain and area drainage.

3. Limiting dimensions, elevations or finish contours to be achieved by the grading, and proposed drainage channels and related construction.

4. Detailed plans of all surface and subsurface drainage devices, walls, cribbing, dams and other protective devices to be constructed with, or as a part of, the proposed work, together with a map showing the drainage area and the estimated runoff of the area served by any drains.

5. Location of any buildings or structures on the property where the work is to be performed and the location of any buildings or structures on land of adjacent owners that are within 15 feet (4572 mm) of the property or that may be affected by the proposed grading operations.

6. Recommendations included in the soils engineering report and the engineering geology report shall be incorporated in the grading plans or specifications. When approved by the building official, specific recommendations contained in the soils engineering report and the engineering geology report, which are applicable to grading, may be included by reference.

7. The dates of the soils engineering and engineering geology reports together with the names, addresses and phone numbers of the firms or individuals who prepared the reports.

3309.5 Soils Engineering Report. The soils engineering report required by Section 3309.4 shall include data regarding the nature, distribution and strength of existing soils, conclusions and recommendations for grading procedures and design criteria for corrective measures, including buttress fills, when necessary, and opinion on adequacy for the intended use of sites to be developed by the proposed grading as affected by soils engineering factors, including the stability of slopes.

3309.6 Engineering Geology Report. The engineering geology report required by Section 3309.4 shall include an adequate description of the geology of the site, conclusions and recommendations regarding the effect of geologic conditions on the proposed development, and opinion on the adequacy for the intended use of sites to be developed by the proposed grading, as affected by geologic factors.

3309.7 Liquefaction Study. The building official may require a geotechnical investigation in accordance with Sections 1804.2 and 1804.5 when, during the course of an investigation, all of the following conditions are discovered, the report shall address the potential for liquefaction:

1. Shallow ground water, 50 feet (15 240 mm) or less.

2. Unconsolidated sandy alluvium.

3. Seismic Zones 3 and 4.

3309.8 Regular Grading Requirements. Each application for a grading permit shall be accompanied by a plan in sufficient clarity to indicate the nature and extent of the work. The plans shall give the location of the work, the name of the owner and the name of the person who prepared the plan. The plan shall include the following information:

1. General vicinity of the proposed site.
2. Limiting dimensions and depth of cut and fill.
3. Location of any buildings or structures where work is to be performed, and the location of any buildings or structures within 15 feet (4572 mm) of the proposed grading.

3309.9 Issuance. The provisions of Section 106.4 are applicable to grading permits. The building official may require that grading operations and project designs be modified if delays occur which incur weather-generated problems not considered at the time the permit was issued.

The building official may require professional inspection and testing by the soils engineer. When the building official has cause to believe that geologic factors may be involved, the grading will be required to conform to engineered grading.

SECTION 3310 — GRADING FEES

3310.1 General. Fees shall be assessed in accordance with the provisions of this section or shall be as set forth in the fee schedule adopted by the jurisdiction.

3310.2 Plan Review Fees. When a plan or other data are required to be submitted, a plan review fee shall be paid at the time of submitting plans and specifications for review. Said plan review fee shall be as set forth in Table A-33-A. Separate plan review fees shall apply to retaining walls or major drainage structures as required elsewhere in this code. For excavation and fill on the same site, the fee shall be based on the volume of excavation or fill, whichever is greater.

3310.3 Grading Permit Fees. A fee for each grading permit shall be paid to the building official as set forth in Table A-33-B. Separate permits and fees shall apply to retaining walls or major drainage structures as required elsewhere in this code. There shall be no separate charge for standard terrace drains and similar facilities.

TABLE A-33-A—GRADING PLAN REVIEW FEES

50 cubic yards (38.2 m^3) or less	No fee
51 to 100 cubic yards (40 m^3 to 76.5 m^3)	$23.50
101 to 1,000 cubic yards (77.2 m^3 to 764.6 m^3)	37.00
1,001 to 10,000 cubic yards (765.3 m^3 to 7645.5 m^3)	49.25
10,001 to 100,000 cubic yards (7646.3 m^3 to 76 455 m^3)—$49.25 for the first 10,000 cubic yards (7645.5 m^3), plus $24.50 for each additional 10,000 yards (7645.5 m^3) or fraction thereof.	
100,001 to 200,000 cubic yards (76 456 m^3 to 152 911 m^3)—$269.75 for the first 100,000 cubic yards (76 455 m^3), plus $13.25 for each additional 10,000 cubic yards (7645.5 m^3) or fraction thereof.	
200,001 cubic yards (152 912 m^3) or more—$402.25 for the first 200,000 cubic yards (152 911 m^3), plus $7.25 for each additional 10,000 cubic yards (7645.5 m^3) or fraction thereof.	
Other Fees: Additional plan review required by changes, additions or revisions to approved plans (minimum charge—one-half hour)	$50.50 per hour*

*Or the total hourly cost to the jurisdiction, whichever is the greatest. This cost shall include supervision, overhead, equipment, hourly wages and fringe benefits of the employees involved.

TABLE A-33-B—GRADING PERMIT FEES[1]

50 cubic yards (38.2 m^3) or less	$23.50
51 to 100 cubic yards (40 m^3 to 76.5 m^3)	37.00
101 to 1,000 cubic yards (77.2 m^3 to 764.6 m^3)—$37.00 for the first 100 cubic yards (76.5 m^3) plus $17.50 for each additional 100 cubic yards (76.5 m^3) or fraction thereof.	
1,001 to 10,000 cubic yards (765.3 m^3 to 7645.5 m^3)—$194.50 for the first 1,000 cubic yards (764.6 m^3), plus $14.50 for each additional 1,000 cubic yards (764.6 m^3) or fraction thereof.	
10,001 to 100,000 cubic yards (7646.3 m^3 to 76 455 m^3)—$325.00 for the first 10,000 cubic yards (7645.5 m^3), plus $66.00 for each additional 10,000 cubic yards (7645.5 m^3) or fraction thereof.	
100,001 cubic yards (76 456 m^3) or more—$919.00 for the first 100,000 cubic yards (76 455 m^3), plus $36.50 for each additional 10,000 cubic yards (7645.5 m^3) or fraction thereof.	
Other Inspections and Fees:	
1. Inspections outside of normal business hours (minimum charge—two hours)	$50.50 per hour[2]
2. Reinspection fees assessed under provisions of Section 108.8	$50.50 per hour[2]
3. Inspections for which no fee is specifically indicated (minimum charge—one-half hour)	$50.50 per hour[2]

[1]The fee for a grading permit authorizing additional work to that under a valid permit shall be the difference between the fee paid for the original permit and the fee shown for the entire project.

[2]Or the total hourly cost to the jurisdiction, whichever is the greatest. This cost shall include supervision, overhead, equipment, hourly wages and fringe benefits of the employees involved.

SECTION 3311 — BONDS

The building official may require bonds in such form and amounts as may be deemed necessary to ensure that the work, if not completed in accordance with the approved plans and specifications, will be corrected to eliminate hazardous conditions.

In lieu of a surety bond the applicant may file a cash bond or instrument of credit with the building official in an amount equal to that which would be required in the surety bond.

SECTION 3312 — CUTS

3312.1 General. Unless otherwise recommended in the approved soils engineering or engineering geology report, cuts shall conform to the provisions of this section.

In the absence of an approved soils engineering report, these provisions may be waived for minor cuts not intended to support structures.

3312.2 Slope. The slope of cut surfaces shall be no steeper than is safe for the intended use and shall be no steeper than 1 unit vertical in 2 units horizontal (50% slope) unless the permittee furnishes a soils engineering or an engineering geology report, or both, stating that the site has been investigated and giving an opinion that a cut at a steeper slope will be stable and not create a hazard to public or private property.

SECTION 3313 — FILLS

3313.1 General. Unless otherwise recommended in the approved soils engineering report, fills shall conform to the provisions of this section.

In the absence of an approved soils engineering report, these provisions may be waived for minor fills not intended to support structures.

3313.2 Preparation of Ground. Fill slopes shall not be constructed on natural slopes steeper than 1 unit vertical in 2 units horizontal (50% slope). The ground surface shall be prepared to receive fill by removing vegetation, noncomplying fill, topsoil and other unsuitable materials scarifying to provide a bond with the new fill and, where slopes are steeper than 1 unit vertical in 5 units horizontal (20% slope) and the height is greater than 5 feet (1524 mm), by benching into sound bedrock or other competent material as determined by the soils engineer. The bench under the toe of a fill on a slope steeper than 1 unit vertical in 5 units horizontal (20% slope) shall be at least 10 feet (3048 mm) wide. The area beyond the toe of fill shall be sloped for sheet overflow or a paved drain shall be provided. When fill is to be placed over a cut, the bench under the toe of fill shall be at least 10 feet (3048 mm) wide but the cut shall be made before placing the fill and acceptance by the soils engineer or engineering geologist or both as a suitable foundation for fill.

3313.3 Fill Material. Detrimental amounts of organic material shall not be permitted in fills. Except as permitted by the building official, no rock or similar irreducible material with a maximum dimension greater than 12 inches (305 mm) shall be buried or placed in fills.

> **EXCEPTION:** The building official may permit placement of larger rock when the soils engineer properly devises a method of placement, and continuously inspects its placement and approves the fill stability. The following conditions shall also apply:
>
> 1. Prior to issuance of the grading permit, potential rock disposal areas shall be delineated on the grading plan.
>
> 2. Rock sizes greater than 12 inches (305 mm) in maximum dimension shall be 10 feet (3048 mm) or more below grade, measured vertically.
>
> 3. Rocks shall be placed so as to assure filling of all voids with well-graded soil.

3313.4 Compaction. All fills shall be compacted to a minimum of 90 percent of maximum density.

3313.5 Slope. The slope of fill surfaces shall be no steeper than is safe for the intended use. Fill slopes shall be no steeper than 1 unit vertical in 2 units horizontal (50% slope).

SECTION 3314 — SETBACKS

3314.1 General. Cut and fill slopes shall be set back from site boundaries in accordance with this section. Setback dimensions shall be horizontal distances measured perpendicular to the site boundary. Setback dimensions shall be as shown in Figure A-33-1.

3314.2 Top of Cut Slope. The top of cut slopes shall not be made nearer to a site boundary line than one fifth of the vertical height of cut with a minimum of 2 feet (610 mm) and a maximum of 10 feet (3048 mm). The setback may need to be increased for any required interceptor drains.

3314.3 Toe of Fill Slope. The toe of fill slope shall be made not nearer to the site boundary line than one half the height of the slope with a minimum of 2 feet (610 mm) and a maximum of 20 feet (6096 mm). Where a fill slope is to be located near the site boundary and the adjacent off-site property is developed, special precautions shall be incorporated in the work as the building official deems necessary to protect the adjoining property from damage as a result of such grading. These precautions may include but are not limited to:

1. Additional setbacks.
2. Provision for retaining or slough walls.
3. Mechanical or chemical treatment of the fill slope surface to minimize erosion.
4. Provisions for the control of surface waters.

3314.4 Modification of Slope Location. The building official may approve alternate setbacks. The building official may require an investigation and recommendation by a qualified engineer or engineering geologist to demonstrate that the intent of this section has been satisfied.

SECTION 3315 — DRAINAGE AND TERRACING

3315.1 General. Unless otherwise indicated on the approved grading plan, drainage facilities and terracing shall conform to the provisions of this section for cut or fill slopes steeper than 1 unit vertical in 3 units horizontal (33.3% slope).

3315.2 Terrace. Terraces at least 6 feet (1829 mm) in width shall be established at not more than 30-foot (9144 mm) vertical intervals on all cut or fill slopes to control surface drainage and debris except that where only one terrace is required, it shall be at midheight. For cut or fill slopes greater than 60 feet (18 288 mm) and up to 120 feet (36 576 mm) in vertical height, one terrace at approximately midheight shall be 12 feet (3658 mm) in width. Terrace widths and spacing for cut and fill slopes greater than 120 feet (36 576 mm) in height shall be designed by the civil engineer and approved by the building official. Suitable access shall be provided to permit proper cleaning and maintenance.

Swales or ditches on terraces shall have a minimum gradient of 5 percent and must be paved with reinforced concrete not less than

3 inches (76 mm) in thickness or an approved equal paving. They shall have a minimum depth at the deepest point of 1 foot (305 mm) and a minimum paved width of 5 feet (1524 mm).

A single run of swale or ditch shall not collect runoff from a tributary area exceeding 13,500 square feet (1254.2 m^2) (projected) without discharging into a down drain.

3315.3 Subsurface Drainage. Cut and fill slopes shall be provided with subsurface drainage as necessary for stability.

3315.4 Disposal. All drainage facilities shall be designed to carry waters to the nearest practicable drainage way approved by the building official or other appropriate jurisdiction as a safe place to deposit such waters. Erosion of ground in the area of discharge shall be prevented by installation of nonerosive downdrains or other devices.

Building pads shall have a drainage gradient of 2 percent toward approved drainage facilities, unless waived by the building official.

> **EXCEPTION:** The gradient from the building pad may be 1 percent if all of the following conditions exist throughout the permit area:
>
> 1. No proposed fills are greater than 10 feet (3048 mm) in maximum depth.
>
> 2. No proposed finish cut or fill slope faces have a vertical height in excess of 10 feet (3048 mm).
>
> 3. No existing slope faces steeper than 1 unit vertical in 10 units horizontal (10% slope) have a vertical height in excess of 10 feet (3048 mm).

3315.5 Interceptor Drains. Paved interceptor drains shall be installed along the top of all cut slopes where the tributary drainage area above slopes toward the cut and has a drainage path greater than 40 feet (12 192 mm) measured horizontally. Interceptor drains shall be paved with a minimum of 3 inches (76 mm) of concrete or gunite and reinforced. They shall have a minimum depth of 12 inches (305 mm) and a minimum paved width of 30 inches (762 mm) measured horizontally across the drain. The slope of drain shall be approved by the building official.

SECTION 3316 — EROSION CONTROL

3316.1 Slopes. The faces of cut and fill slopes shall be prepared and maintained to control against erosion. This control may consist of effective planting. The protection for the slopes shall be installed as soon as practicable and prior to calling for final approval. Where cut slopes are not subject to erosion due to the erosion-resistant character of the materials, such protection may be omitted.

3316.2 Other Devices. Where necessary, check dams, cribbing, riprap or other devices or methods shall be employed to control erosion and provide safety.

SECTION 3317 — GRADING INSPECTION

3317.1 General. Grading operations for which a permit is required shall be subject to inspection by the building official. Professional inspection of grading operations shall be provided by the civil engineer, soils engineer and the engineering geologist retained to provide such services in accordance with Section 3317.5 for engineered grading and as required by the building official for regular grading.

3317.2 Civil Engineer. The civil engineer shall provide professional inspection within such engineer's area of technical specialty, which shall consist of observation and review as to the establishment of line, grade and surface drainage of the development area. If revised plans are required during the course of the work they shall be prepared by the civil engineer.

3317.3 Soils Engineer. The soils engineer shall provide professional inspection within such engineer's area of technical specialty, which shall include observation during grading and testing for required compaction. The soils engineer shall provide sufficient observation during the preparation of the natural ground and placement and compaction of the fill to verify that such work is being performed in accordance with the conditions of the approved plan and the appropriate requirements of this chapter. Revised recommendations relating to conditions differing from the approved soils engineering and engineering geology reports shall be submitted to the permittee, the building official and the civil engineer.

3317.4 Engineering Geologist. The engineering geologist shall provide professional inspection within such engineer's area of technical specialty, which shall include professional inspection of the bedrock excavation to determine if conditions encountered are in conformance with the approved report. Revised recommendations relating to conditions differing from the approved engineering geology report shall be submitted to the soils engineer.

3317.5 Permittee. The permittee shall be responsible for the work to be performed in accordance with the approved plans and specifications and in conformance with the provisions of this code, and the permittee shall engage consultants, if required, to provide professional inspections on a timely basis. The permittee shall act as a coordinator between the consultants, the contractor and the building official. In the event of changed conditions, the permittee shall be responsible for informing the building official of such change and shall provide revised plans for approval.

3317.6 Building Official. The building official shall inspect the project at the various stages of work requiring approval to determine that adequate control is being exercised by the professional consultants.

3317.7 Notification of Noncompliance. If, in the course of fulfilling their respective duties under this chapter, the civil engineer, the soils engineer or the engineering geologist finds that the work is not being done in conformance with this chapter or the approved grading plans, the discrepancies shall be reported immediately in writing to the permittee and to the building official.

3317.8 Transfer of Responsibility. If the civil engineer, the soils engineer, or the engineering geologist of record is changed during grading, the work shall be stopped until the replacement has agreed in writing to accept their responsibility within the area of technical competence for approval upon completion of the work. It shall be the duty of the permittee to notify the building official in writing of such change prior to the recommencement of such grading.

SECTION 3318 — COMPLETION OF WORK

3318.1 Final Reports. Upon completion of the rough grading work and at the final completion of the work, the following reports and drawings and supplements thereto are required for engineered grading or when professional inspection is performed for regular grading, as applicable.

1. An as-built grading plan prepared by the civil engineer retained to provide such services in accordance with Section 3317.5 showing original ground surface elevations, as-graded ground surface elevations, lot drainage patterns, and the locations and elevations of surface drainage facilities and of the outlets of subsurface drains. As-constructed locations, elevations and details of subsurface drains shall be shown as reported by the soils engineer.

Civil engineers shall state that to the best of their knowledge the work within their area of responsibility was done in accordance with the final approved grading plan.

2. A report prepared by the soils engineer retained to provide such services in accordance with Section 3317.3, including locations and elevations of field density tests, summaries of field and laboratory tests, other substantiating data, and comments on any changes made during grading and their effect on the recommendations made in the approved soils engineering investigation report. Soils engineers shall submit a statement that, to the best of their knowledge, the work within their area of responsibilities is in accordance with the approved soils engineering report and applicable provisions of this chapter.

3. A report prepared by the engineering geologist retained to provide such services in accordance with Section 3317.5, including a final description of the geology of the site and any new information disclosed during the grading and the effect of same on recommendations incorporated in the approved grading plan. Engineering geologists shall submit a statement that, to the best of their knowledge, the work within their area of responsibility is in accordance with the approved engineering geologist report and applicable provisions of this chapter.

4. The grading contractor shall submit in a form prescribed by the building official a statement of conformance to said as-built plan and the specifications.

3318.2 Notification of Completion. The permittee shall notify the building official when the grading operation is ready for final inspection. Final approval shall not be given until all work, including installation of all drainage facilities and their protective devices, and all erosion-control measures have been completed in accordance with the final approved grading plan, and the required reports have been submitted.

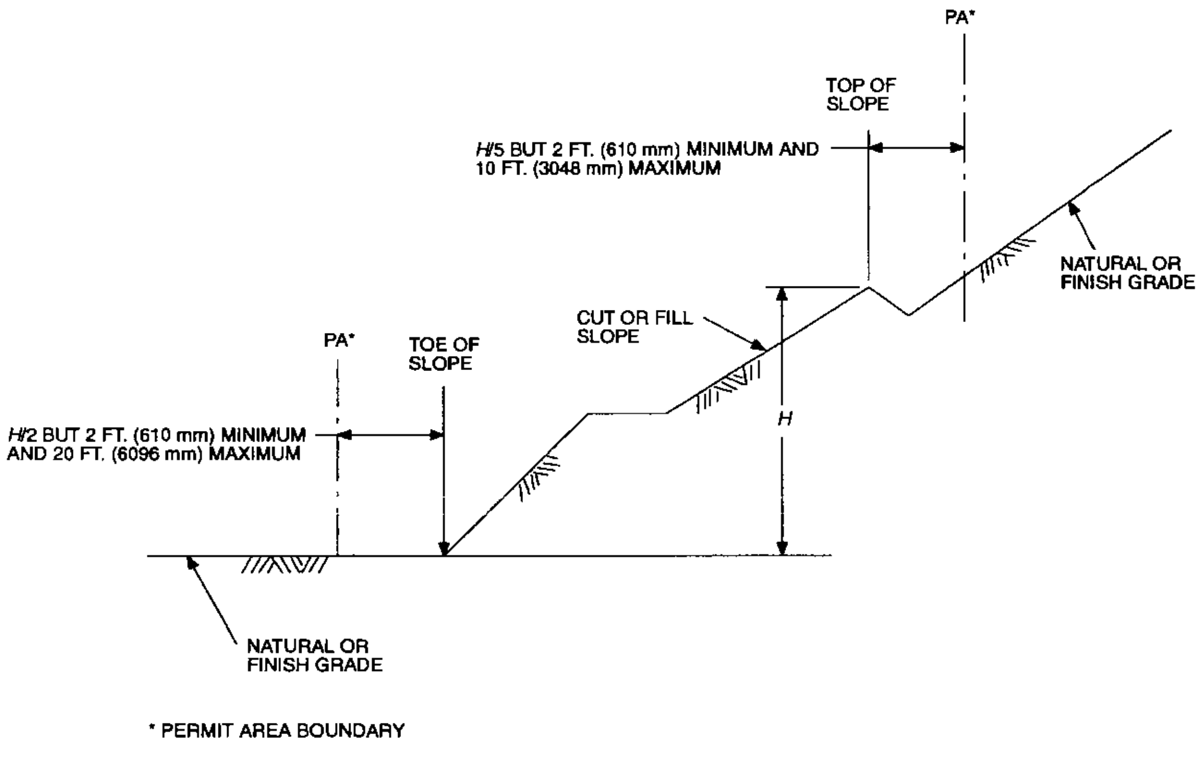


FIGURE A-33-1—SETBACK DIMENSIONS

Appendix Chapter 34
EXISTING STRUCTURES
Division I—LIFE-SAFETY REQUIREMENTS FOR EXISTING BUILDINGS OTHER THAN HIGH-RISE BUILDINGS

SECTION 3406 — GENERAL

3406.1 Purpose. The purpose of this division is to provide a reasonable degree of safety to persons occupying existing buildings by providing for alterations to such existing buildings that do not conform with the minimum requirements of this code.

> **EXCEPTION:** Group U Occupancies regulated by Appendix Chapter 34, Division II, and Group R, Division 3 Occupancies, except that Group R, Division 3 Occupancies shall comply with Section 3411.

3406.2 Effective Date. Within 18 months of the effective date of this division, plans for compliance shall be submitted and approved, and within 18 months thereafter, the work shall be completed or the building shall be vacated until made to conform.

SECTION 3407 — EXITS

3407.1 Number of Means of Egress. Every floor above the first story used for human occupancy shall have at least two means of egress, one of which may be an exterior fire escape complying with Section 3407.4. Subject to the approval of the building official, an approved ladder device may be used in lieu of a fire escape when the construction feature or location of the building on the property makes the installation of a fire escape impracticable.

> **EXCEPTION:** In all occupancies, second stories with an occupant load of 10 or less may have one means of egress.

An exit ladder device when used in lieu of a fire escape shall conform with UBC Standard 10-3, which is a part of this code (see Chapter 35), and the following:

1. Serves an occupant load of 10 or less or a single dwelling unit or guest room.
2. The building does not exceed three stories in height.
3. The access is adjacent to an opening as specified for emergency egress or rescue or from a balcony.
4. Shall not pass in front of any building opening below the unit being served.
5. The availability of activating the device for the ladder is accessible only from the opening or balcony served.
6. Installed so that it will not cause a person using it to be within 6 feet (1829 mm) of exposed electrical wiring.

3407.2 Stair Construction. All required stairs shall have a minimum run of 9 inches (229 mm) and a maximum rise of 8 inches (203 mm) and shall have a minimum width of 30 inches (762 mm) exclusive of handrails. Every stairway shall have at least one handrail. A landing having a minimum 30-inch (762 mm) run in the direction of travel shall be provided at each point of access to the stairway.

> **EXCEPTION:** Fire escapes as provided for in this section.

Exterior stairs shall be of noncombustible construction.

> **EXCEPTION:** On buildings of Types III, IV and V construction, provided the exterior stairs are constructed of wood not less than 2-inch (51 mm) nominal thickness.

3407.3 Corridors. Corridors of Groups A, B, E, F, H, I, M and R, Division 1, and S Occupancies serving an occupant load of 30 or more, shall have walls and ceilings of not less than one-hour fire-resistive construction as required by this code. Existing walls surfaced with wood lath and plaster in good condition or $^{1}/_{2}$-inch (12.7 mm) gypsum wallboard or openings with fixed wired glass set in steel frames are permitted for corridor walls and ceilings and occupancy separations when approved. Doors opening into such corridors shall be protected by 20-minute fire assemblies or solid wood doors not less than $1^{3}/_{4}$ inches (45 mm) thick. Where the existing frame will not accommodate the $1^{3}/_{4}$-inch-thick (45 mm) door, a $1^{3}/_{8}$-inch-thick (35 mm) solid bonded wood-core door or equivalent insulated steel door shall be permitted. Doors shall be self-closing or automatic closing by smoke detection. Transoms and openings other than doors from corridors to rooms shall comply with Section 1004.3.4.3.2 of this code or shall be covered with a minimum of $^{3}/_{4}$-inch (19.1 mm) plywood or $^{1}/_{2}$-inch (12.7 mm) gypsum wallboard or equivalent material on the room side.

> **EXCEPTION:** Existing corridor walls, ceilings and opening protection not in compliance with the above may be continued when such buildings are protected with an approved automatic sprinkler system throughout. Such sprinkler system may be supplied from the domestic water system if it is of adequate volume and pressure.

3407.4 Fire Escapes.

1. Existing fire escapes that, in the opinion of the building official, comply with the intent of this section may be used as one of the required exits. The location and anchorage of fire escapes shall be of approved design and construction.

2. Fire escapes shall comply with the following:

Access from a corridor shall not be through an intervening room.

All openings within 10 feet (3048 mm) shall be protected by three-fourths-hour fire assemblies. When located within a recess or vestibule, adjacent enclosure walls shall not be of less than one-hour fire-resistive construction.

Egress from the building shall be by a clear opening having a minimum dimension of not less than 29 inches (737 mm). Such openings shall be openable from the inside without the use of a key or special knowledge or effort. The sill of an opening giving access shall not be more than 30 inches (762 mm) above the floor of the building or balcony.

Fire escape stairways and balconies shall support the dead load plus a live load of not less than 100 pounds per square foot (4.79 kN/m^2) and shall be provided with a top and intermediate handrail on each side. The pitch of the stairway shall not exceed 60 degrees with a minimum width of 18 inches (457 mm). Treads shall not be less than 4 inches (102 mm) in width and the rise between treads shall not exceed 10 inches (254 mm). All stair and balcony railings shall support a horizontal force of not less than 50 pounds per lineal foot (729.5 N/m) of railing.

Balconies shall not be less than 44 inches (1118 mm) in width with no floor opening other than the stairway opening greater than $^{5}/_{8}$ inch (16 mm) in width. Stairway openings in such balconies shall not be less than 22 inches by 44 inches (599 mm by 1118 mm). The balustrade of each balcony shall not be less than 36 inches (914 mm) high with not more than 9 inches (229 mm) between balusters.

Fire escapes shall extend to the roof or provide an approved gooseneck ladder between the top floor landing and the roof when serving buildings four or more stories in height having roofs with a slope of less than 4 units vertical in 12 units horizontal (33.3%

slope). Fire escape ladders shall be designed and connected to the building to withstand a horizontal force of 100 pounds per lineal foot (1459 N/m); each rung shall support a concentrated load of 500 pounds (2224 N) placed anywhere on the rung. All ladders shall be at least 15 inches (381 mm) wide, located within 12 inches (305 mm) of the building and shall be placed flatwise relative to the face of the building. Ladder rungs shall be $^3/_4$ inch (19 mm) in diameter and shall be located 12 inches (305 mm) on center. Openings for roof access ladders through cornices and similar projections shall have minimum dimensions of 30 inches by 33 inches (762 mm by 838 mm).

The lowest balcony shall not be more than 18 feet (5486 mm) from the ground. Fire escapes shall extend to the ground or be provided with counterbalanced stairs reaching to the ground.

Fire escapes shall not take the place of stairways required by the codes under which the building was constructed.

Fire escapes shall be kept clear and unobstructed at all times and maintained in good working order.

3407.5 Exit and Fire Escape Signs. Exit signs shall be provided as required by this code.

> **EXCEPTION:** The use of existing exit signs may be continued when approved by the building official.

All doors or windows providing access to a fire escape shall be provided with fire escape signs.

SECTION 3408 — ENCLOSURE OF VERTICAL SHAFTS

Interior vertical shafts, including but not limited to stairways, elevator hoistways, service and utility shafts, shall be enclosed by a minimum of one-hour fire-resistive construction. All openings into such shafts shall be protected with one-hour fire assemblies that shall be maintained self-closing or be automatic closing by smoke detection. All other openings shall be fire protected in an approved manner. Existing fusible link-type automatic door-closing devices may be permitted if the fusible link rating does not exceed 135°F (57.2°C).

> **EXCEPTIONS:** 1. In other than Group I Occupancies, an enclosure will not be required for openings serving only one adjacent floor.
>
> 2. Stairways need not be enclosed in a continuous vertical shaft if each story is separated from other stories by one-hour fire-resistive construction or approved wired glass set in steel frames. In addition, all exit corridors shall be sprinklered and the openings between the corridor and occupant space shall have at least one sprinkler head above the openings on the tenant side. The sprinkler system may be supplied from the domestic water supply if of adequate volume and pressure.
>
> 3. Vertical openings need not be protected if the building is protected by an approved automatic sprinkler system.

SECTION 3409 — BASEMENT ACCESS OR SPRINKLER PROTECTION

An approved automatic sprinkler system shall be provided in basements or stories exceeding 1,500 square feet (139.3 m^2) in area and not having a minimum of 20 square feet (1.86 m^2) of opening entirely above the adjoining ground level in each 50 lineal feet (15 240 mm) or fraction thereof of exterior wall on at least one side of the building. Openings shall have a minimum clear dimension of 30 inches (762 mm).

If any portion of a basement is located more than 75 feet (22 860 mm) from required openings, the basement shall be provided with an approved automatic sprinkler system throughout.

SECTION 3410 — STANDPIPES

Any buildings over four stories in height shall be provided with an approved Class I or Class III standpipe system.

SECTION 3411 — SMOKE DETECTORS

3411.1 General. Dwelling units and hotel or lodging house guest rooms that are used for sleeping purposes shall be provided with smoke detectors. Detectors shall be installed in accordance with the approved manufacturer's instructions.

3411.2 Power Source. Smoke detectors may be battery operated or may receive their primary power from the building wiring when such wiring is served from a commercial source. Wiring shall be permanent and without disconnecting switches other than those required for overcurrent protection.

3411.3 Location within Dwelling Units. In dwelling units, detectors shall be mounted on the ceiling or wall at a point centrally located in the corridor or area giving access to each separate sleeping area. Where sleeping rooms are on an upper level, the detector shall be placed at the center of the ceiling directly above the stairway. Detectors shall also be installed in the basements of dwelling units having stairways that open from the basement into the dwelling. Detectors shall sound an alarm audible in all sleeping areas of the dwelling unit in which they are located.

3411.4 Location in Efficiency Dwelling Units and Hotels. In efficiency dwelling units, hotel suites and in hotel sleeping rooms, detectors shall be located on the ceiling or wall of the main room or hotel sleeping room. When sleeping rooms within an efficiency dwelling unit or hotel suite are on an upper level, the detector shall be placed at the center of the ceiling directly above the stairway. When actuated, the detector shall sound an alarm audible within the sleeping area of the dwelling unit, hotel suite or sleeping room in which it is located.

SECTION 3412 — SEPARATION OF OCCUPANCIES

Occupancy separations shall be provided as specified in Section 302 of this code. When approved by the building official, existing wood lath and plaster in good condition or $^1/_2$-inch (12.7 mm) gypsum wallboard may be acceptable where one-hour occupancy separations are required.

Division II—LIFE-SAFETY REQUIREMENTS FOR EXISTING HIGH-RISE BUILDINGS

SECTION 3413 — SCOPE

These provisions apply to existing high-rise buildings constructed prior to the adoption of this division and which house Group B offices or Group R, Division 1 Occupancies, each having floors used for human occupancy located more than 75 feet (22 860 mm) above the lowest level of fire department vehicle access.

SECTION 3414 — GENERAL

Existing high-rise buildings as specified in Section 3413 shall be modified to conform with not less than the minimum provisions specified in Table A-34-A and as further enumerated within this division.

The provisions of this division shall not be construed to allow the elimination of fire-protection systems or a reduction in the level of firesafety provided in buildings constructed in conformance with previously adopted codes.

SECTION 3415 — COMPLIANCE DATA

After adoption of this division, the building official shall duly notify the owners whose buildings are subject to the provisions of this division. Upon receipt of such notice, the owner shall, subject to the following time limits, take necessary actions to comply with the provisions of this division.

Plans and specifications for the necessary alterations shall be filed with the building official within the time period established by the local jurisdiction after the date of owner notification. Work on the required alterations to the building shall commence within 30 months of the date of owner notification and such work shall be completed within five years from the date of owner notification.

The building official shall grant necessary extensions of time when it can be shown that the specified time periods are not physically practical or pose an undue hardship. The granting of an extension of time for compliance shall be based on the showing of good cause and subject to the filing of an acceptable systematic progressive plan of correction with the building official.

SECTION 3416 — AUTHORITY OF THE BUILDING OFFICIAL

For the purpose of applying the provisions of this division, the building official shall have the authority to consider alternative approaches and grant necessary deviations from this division as follows:

1. Allow alternate materials or methods of compliance if such alternate materials or methods of compliance will provide levels of fire and life safety equal to or greater than those specifically set forth in this division.

2. Waive specific individual requirements if it can be shown that such requirements are not physically possible or practical and that a practical alternative cannot be provided.

SECTION 3417 — APPEALS BOARD

Appeals of the determinations of the building official in applying the provisions of this code may be made by an appeal directed to the board of appeals as established by Section 105 of this code.

SECTION 3418 — SPECIFIC PROVISIONS AND ALTERNATES

3418.1 Specific Provisions. The following provisions shall apply when required by Table A-34-A.

3418.1.1 Type of construction. Buildings classified as Type II-N, III-N or V-N construction shall be equipped with an approved automatic sprinkler system installed in accordance with UBC Standard 9-1, which is a part of this code (see Chapter 35).

> **EXCEPTION:** Installation of meters or backflow preventers for the connection to the water works system need not be provided unless required by other regulations of the authority having jurisdiction.

3418.1.2 Automatic sprinklers. All required corridors, stairwells, elevator lobbies, public assembly areas occupied by 100 or more persons and commercial kitchens shall be protected by an approved automatic sprinkler system meeting the design criteria of UBC Standard 9-1, which is a part of this code (see Chapter 35). A minimum of one sprinkler shall be provided on the room side of every corridor opening.

> **EXCEPTION:** Sprinklers may be omitted in stairwells of noncombustible construction.

3418.1.3 Fire department communication system. When it is determined by test that the portable fire department communication equipment is ineffective, a communication system acceptable to the fire department shall be installed within the existing high-rise building to permit emergency communication between fire-suppression personnel.

3418.1.4 Single-station smoke detectors. Single-station smoke detectors shall be installed within all dwelling units or guest rooms in accordance with the manufacturer's installation instructions. In dwelling units, the detector shall be mounted on the ceiling or wall at a point centrally located in the corridor or area giving access to each separate sleeping area. When sleeping rooms are located on an upper level, the detector shall be installed at the center of the ceiling directly above the stairway within the unit. In efficiency dwelling units, hotel suites and in hotel guest rooms, detectors shall be located on the ceiling or wall of the main room or hotel sleeping room. When actuated, the detector shall provide an audible alarm in the sleeping area of the dwelling unit, hotel suite or guest room in which it is located.

Such detectors may be battery operated.

3418.1.5 Manual fire alarm system. An approved manual fire alarm system connected to a central, proprietary or remote station service, or an approved manual fire alarm system that will provide an audible signal at a constantly attended location, shall be provided.

3418.1.6 Occupant voice notification system. An approved occupant voice notification system shall be provided. Such system shall provide communication from a location acceptable to the fire department and shall permit voice notification to at least all normally occupied areas of the building.

The occupant voice notification system may be combined with a fire alarm system, provided the combined system has been approved and listed for such use. The sounding of a fire alarm signal in any given area or floor shall not prohibit voice communication to other areas or floors. Combination systems shall be designed to permit voice transmission to override the fire alarm signal, but the fire alarm shall not terminate in less than three minutes.

3418.1.7 Vertical shaft enclosures. Openings through two or more floors, except mezzanine floors, that contain a stairway or elevator, shall be provided with vertical shaft enclosure protection as specified herein. Such floor openings, when not enclosed by existing shaft enclosure construction, shall be protected by one-hour fire-resistive-rated shaft enclosure construction. For floor openings that are enclosed by existing shaft enclosure construction having fire-resistive capabilities similar to wood lath and plaster in good condition, $^1/_2$-inch (12.7 mm) gypsum wallboard or approved $^1/_4$-inch-thick (6.4 mm) wired glass is acceptable. Wired glass set in a steel frame may be installed in existing shaft enclosure walls but shall be rendered inoperative and be fixed in a closed position.

Openings through two or more floors for other than stairways or elevators, such as openings provided for piping, ducts, gas vents, dumbwaiters, and rubbish and linen chutes, shall be provided with vertical shaft enclosure protection as specified for stairways and elevators.

EXCEPTION: Openings for piping, ducts, gas vents, dumbwaiters, and rubbish and linen chutes of copper or ferrous construction are permitted without a shaft enclosure, provided the floor openings are effectively firestopped at each floor level.

3418.1.8 Shaft enclosure opening protection. Openings other than those provided for elevator doors in new vertical shaft enclosures constructed of one-hour fire-resistive construction shall be equipped with approved fire assemblies having a fire-protection rating of not less than one hour. Openings other than those provided for elevator doors in existing vertical shaft enclosures shall be equipped with approved 20-minute-rated fire assemblies, $1^3/_4$-inch (44 mm) solid wood doors or the equivalent thereto. Doors shall be either self-closing or automatic closing and automatic latching.

All elevators on all floors shall open into elevator lobbies that are separated from the remainder of the building as is required for corridor construction in the Building Code, unless the building is protected throughout by a sprinkler system.

3418.1.9 Manual shutoff of heating, ventilating and air-conditioning (HVAC) systems. Heating, ventilating and air-conditioning systems shall be equipped with manual shutoff controls installed at an approved location when required by the fire department.

3418.1.10 Automatic elevator recall system. Elevators shall be equipped with an approved automatic recall system as required by Section 403.7, Item 2.

3418.1.11 Unlocked stairway doors. Exit doors into exit stairway enclosures shall be maintained unlocked from the stairway side on at least every fifth floor level. All unlocked doors shall bear a sign stating ACCESS ONTO FLOOR THIS LEVEL.

Stairway doors may be locked, subject to the following conditions:

1. Stairway doors that are to be locked from the stairway side shall have the capability of being unlocked simultaneously without unlatching upon a signal from an approved location.

2. A telephone or other two-way communications system connected to an approved emergency service that operates continuously shall be provided at not less than every fifth floor in each required stairway.

3418.1.12 Stair shaft ventilation. Stair shaft enclosures that extend to the roof shall be provided with an approved manually openable hatch to the exterior having an area not less than 16 square feet (1.486 m^2) with a minimum dimension of 2 feet (610 mm).

EXCEPTIONS: 1. Stair shaft enclosures complying with the requirements for pressurized enclosures.

2. Stair shaft enclosures pressurized as required for mechanically operated pressurized enclosures to a minimum of 0.15-inch water column (37 Pa) and a maximum of 0.50-inch water column (124 Pa).

3418.1.13 Elevator shaft ventilation. Elevator shaft enclosures that extend to the roof shall be vented to the outside with vents whose area shall not be less than $3^1/_2$ percent of the area of the elevator shaft, with a minimum of 3 square feet (0.28 m^2) per elevator.

EXCEPTION: Where energy conservation or hoistway pressurization requires that the vents be normally closed, automatic venting by actuation of an elevator lobby detector or power failure may be accepted.

3418.1.14 Posting of elevators. A permanent sign shall be installed in each elevator cab adjacent to the floor status indicator and at each elevator call station on each floor reading IN FIRE EMERGENCY, DO NOT USE ELEVATOR—USE EXIT STAIRS, or similar verbiage approved by the building official.

EXCEPTION: Sign may be omitted at the main entrance floor-level call station.

3418.1.15 Exit stairways. All buildings shall have a minimum of two approved exit stairways.

3418.1.16 Corridor construction. Corridors serving an occupant load of 30 or more shall have walls and ceilings of not less than one-hour fire-resistive construction as required by this code. Existing walls may be surfaced with wood lath and plaster in good condition or $^1/_2$-inch (12.7 mm) gypsum wallboard for corridor walls and ceilings and occupancy separations when approved.

3418.1.17 Corridor openings. Openings in corridor walls and ceilings shall be protected by not less than $1^3/_8$-inch (35 mm) solid-bonded wood-core doors; approved $^1/_4$-inch-thick (6.4 mm) wired glass; approved fire dampers conforming to UBC Standard 7-7, which is a part of this code; or by equivalent protection in lieu of any of these items (see Chapter 35). Transoms shall be fixed closed and covered with $^1/_2$-inch (12.7 mm) Type X gypsum wallboard or equivalent material installed on both sides of the opening.

3418.1.18 Corridor door closers. Exit-access doors into corridors shall be equipped with self-closing devices or shall be automatic closing by actuation of a smoke detector. When spring hinges are used as the closing device, not less than two such hinges shall be installed on each door leaf.

3418.1.19 Corridor dead ends. The length of dead-end corridors serving an occupant load of more than 30 shall not exceed 20 feet (6096 mm).

3418.1.20 Interior finish. The interior finish in corridors, exit stairways and extensions thereof shall conform to the provisions of Chapter 8 of this code.

3418.1.21 Exit stairway illumination. When the building is occupied, exit stairways shall be illuminated with lights having an intensity of not less than 1 footcandle (10.8 lx) at the floor level. Such lighting shall be equipped with an independent alternate source of power such as a battery pack or on-site generator.

3418.1.22 Corridor illumination. When the building is occupied, corridors shall be illuminated with lights having an intensity of not less than 1 footcandle (10.8 lx) at the floor level. Such lighting shall be equipped with an independent alternate source of power such as a battery pack or on-site generator.

3418.1.23 Exit stairway exit signs. The location of exit stairways shall be clearly indicated by illuminated exit signs. Such exit signs shall be equipped with an independent alternate source of power such as a battery pack or on-site generator or shall be of an approved self-illuminating type.

3418.1.24 Exit signs. Illuminated exit signs shall be provided in all means of egress and located in such a manner as to clearly indicate the direction of egress. Such exit signs shall be equipped with an independent alternate source of power such as a battery pack or on-site generator or shall be of an approved self-illuminating type.

3418.1.25 Emergency plan. The management for all buildings shall establish and maintain a written fire- and life-safety emergency plan that has been approved by the chief. The chief shall develop written criteria and guidelines on which all plans shall be based.

3418.1.26 Posting of emergency plan and exit plans. Copies of the emergency plan and exiting plans (including elevator and stairway placarding) shall be posted in locations approved by the chief.

3418.1.27 Fire drills. The management of all buildings shall conduct fire drills for their staff and employees at least every 120 days. The fire department must be advised of such drills at least 24 hours in advance. A written record of each drill shall be maintained in the building management office and made available to the fire department for review.

3418.2 Sprinkler Alternatives. The requirements of Table A-34-A may be modified as specified by the following for existing high-rise buildings of Type I, II-F.R., II One-hour, III One-hour, IV or V One-hour construction when an approved automatic sprinkler system is installed throughout the building in accordance with UBC Standard 9-1:

Item 5—Manual fire alarm system shall not be required.

Item 6—Occupant voice notification system shall not be required; however, if the building is equipped with a public address system, the public address system shall be available for use as an occupant voice notification system.

Item 7—Vertical shaft enclosures may be of nonrated construction for required exit stairway enclosures. Vertical shaft enclosures of openings in floors provided for elevators, escalators and supplemental stairways shall not be required, provided such openings are protected by an approved curtain board and water curtain sprinkler system.

Item 8—Protection of openings in vertical shaft enclosures may be nonrated but shall not be less than a $1^3/_4$-inch (44 mm) solid-wood door or the equivalent thereto. Closing and latching hardware shall be provided.

Item 10—An automatic elevator recall system shall not be required.

Item 12—Stair shaft ventilation shall not be required.

Item 16—Existing corridor construction need not be altered.

Item 17—Door openings into corridors may be protected by assemblies other than those specified in Section 3418.1, provided an effective smoke barrier is maintained. Closing and latching hardware shall be provided. Protection of duct penetrations is not required.

Item 19—The length of existing corridor dead ends shall not be limited.

Item 20—Interior finish in means of egress may be reduced by one classification but shall not be less than Class III.

Installation of meters or backflow preventers for the connection to the water works system need not be provided unless required by other regulations of the authority having jurisdiction.

TABLE A-34-A—OCCUPANCY CLASSIFICATION AND USE[1]

ITEMS REQUIRED	GROUP R, DIVISION 1						GROUP B		
	Apartment			Hotel			Office		
	Height Zones[2]								
	1	2	3	1	2	3	1	2	3
1. Automatic sprinklers in buildings of Type II-N, III-N or V-N construction. See Section 3418.1.1.	R	R	—	R	R	—	R	R	—
2. Automatic sprinklers in corridors, stairways, elevator lobbies, public assembly areas, kitchens and at doors opening to corridors. See Section 3418.1.2.	R	R	R	R	R	R	R	R	R
3. Fire department communication system or radios. See Section 3418.1.3.	R	R	R	R	R	R	R	R	R
4. Single-station smoke detectors. See Section 3418.1.4.	R	R	R	R	R	R	NR	NR	NR
5. Manual fire alarm system. See Section 3418.1.5.	R	R	R	R	R	R	R	R	R
6. Occupant voice notification system. See Section 3418.1.6.	NR	R	R	NR	R	R	NR	NR	NR
7. Vertical shaft enclosure walls of one-hour fire resistance. See Section 3418.1.7.	R	R	R	R	R	R	R	R	R
8. Protection of openings in vertical shaft enclosures by 20-minute-rated assemblies. See Section 3418.1.8.	R	R	R	R	R	R	R	R	R
9. Manual shutoff of HVAC systems. See Section 3418.1.9.	R	R	R	R	R	R	R	R	R
10. Automatic elevator recall system. See Section 3418.1.10.	R	R	R	R	R	R	R	R	R
11. Unlocked stairway doors every fifth floor. See Section 3418.1.11.	R	R	R	R	R	R	NR	R	R
12. Stair shaft ventilation. See Section 3418.1.12.	R	R	R	R	R	R	R	R	R
13. Elevator shaft ventilaton. See Section 3418.1.13.	R	R	R	R	R	R	R	R	R
14. Posting of elevators as not intended for exiting purposes. See Section 3418.1.14.	R	R	R	R	R	R	R	R	R
15. Minimum of two exit stairways. See Section 3418.1.15.	R	R	R	R	R	R	R	R	R
16. Corridor wall construction. See Section 3418.1.16.	R	R	R	R	R	R	R	R	R
17. Protected corridor openings with 20-minute-rated assemblies or $1^3/_4$-inch (44 mm) solid-wood door. See Section 3418.1.17.	R	R	R	R	R	R	NR	NR	NR
18. Corridor doors equipped with self-closing devices. See Section 3418.1.18.	R	R	R	R	R	R	NR	NR	NR
19. Corridor dead ends limited to 20 feet (6096 mm) maximum. See Section 3418.1.19.	R	R	R	R	R	R	NR	NR	NR
20. Interior finish controlled in corridors, exit stairways and extensions thereof. See Section 3418.1.20.	R	R	R	R	R	R	R	R	R
21. Exit stairway illumination. See Section 3418.1.21.	R	R	R	R	R	R	R	R	R
22. Corridor illumination. See Section 3418.1.22.	R	R	R	R	R	R	NR	NR	NR
23. Exit stairway exit signs. See Section 3418.1.23.	R	R	R	R	R	R	R	R	R
24. Exit signs. See Section 3418.1.24.	R	R	R	R	R	R	R	R	R
25. Emergency planning. See Section 3418.1.25.	R	R	R	R	R	R	R	R	R
26. Posting of emergency instructions. See Section 3418.1.26.	R	R	R	R	R	R	R	R	R
27. Fire drills. See Section 3418.1.27.	NR	NR	NR	R	R	R	NR	NR	NR

[1]R—Provisions are required.
NR—Provisions are not required.
[2]Height zones are established based on a building having a floor as measured to the top of the floor surface used for human occupancy located within the ranges of heights above the lowest level of the fire department vehicle access in accordance with the following:
Height Zone 1: More than 75 feet (22 860 mm), but not in excess of 149 feet (45 415 mm).
Height Zone 2: More than 149 feet (45 415 mm), but not in excess of 399 feet (121.6 m).
Height Zone 3: More than 399 feet (121.6 m).

Division III—REPAIRS TO BUILDINGS AND STRUCTURES DAMAGED BY THE OCCURRENCE OF A NATURAL DISASTER

NOTE: This is a new division.

SECTION 3419 — PURPOSE

The purpose of this division is to provide a defined level of repair for buildings damaged by a natural disaster in jurisdictions where a formal state of emergency has been proclaimed.

SECTION 3420 — GENERAL

Required repair levels shall be based on the ratio of the estimated value of the repairs required to restore the structural members to their pre-event condition to the estimated replacement value of the building or structure.

SECTION 3421 — STRUCTURAL REPAIRS

When the damage ratio does not exceed 0.10 (10 percent), buildings and structures, except essential service facilities included as Category I buildings and structures in Table 16-K, shall at a minimum be restored to their pre-event condition.

When the damage ratio is greater than 0.10 (10 percent) but less than 0.5 (50 percent), buildings and structures, except essential service facilities included as Category I buildings and structures in Table 16-K, shall have the damaged structural members including all critical ties and connections associated with the damaged structural members, all structural members supported by the damaged member, and all structural members supporting the damaged members repaired and strengthened to bring them into compliance with the force levels and connection requirements of the Building Code. This criteria shall apply to essential service facilities when the damage ratio is less than 0.3 (30 percent).

EXCEPTION: For buildings with rigid diaphragms where the above-required repair and strengthening increases the rigidity of the resisting members, the entire lateral-force-resisting system of the building shall be investigated. When, in the opinion of the building official, an unsafe or adverse condition has been created as a result of the increase in rigidity, the condition shall be corrected.

When the damage ratio is greater than 0.5 (50 percent), buildings and structures, except essential service facilities included as Category I buildings and structures in Table 16-K, shall at a minimum have the entire building or structure strengthened to comply with the force levels and connection requirements of the Building Code. This criteria shall apply to essential service facilities when the damage ratio is greater than or equal to 0.3 (30 percent).

SECTION 3422 — NONSTRUCTURAL REPAIRS TO LIGHT FIXTURES AND SUSPENDED CEILINGS

Under all damage ratios, when light fixtures and the suspension system of suspended ceiling are damaged, the damaged light fixtures and suspension systems shall be repaired to fully comply with the requirements of this code and UBC Standard 25-2. Undamaged light fixtures and suspension systems shall have the additional support and bracing, provided that is required in UBC Standard 25-2.

UNIT CONVERSION TABLES

SI SYMBOLS AND PREFIXES

BASE UNITS		
Quantity	Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	cd

SI SUPPLEMENTARY UNITS		
Quantity	Unit	Symbol
Plane angle	Radian	rad
Solid angle	Steradian	sr

SI PREFIXES		
Multiplication Factor	Prefix	Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deka	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

SI DERIVED UNIT WITH SPECIAL NAMES			
Quantity	Unit	Symbol	Formula
Frequency (of a periodic phenomenon)	hertz	Hz	1/s
Force	newton	N	kg·m/s^2
Pressure, stress	pascal	Pa	N/m^2
Energy, work, quantity of heat	joule	J	N·m
Power, radiant flux	watt	W	J/s
Quantity of electricity, electric charge	coulomb	C	A·s
Electric potential, potential difference, electromotive force	volt	V	W/A
Capacitance	farad	F	C/V
Electric resistance	ohm	Ω	V/A
Conductance	siemens	S	A/V
Magnetic flux	weber	Wb	V·s
Magnetic flux density	tesla	T	Wb/m^2
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	cd·sr
Illuminance	lux	lx	lm/m^2
Activity (of radionuclides)	becquerel	Bq	1/s
Absorbed dose	gray	Gy	J/kg

CONVERSION FACTORS

To convert	to	multiply by
	LENGTH	
1 mile (U.S. statute)	km	1.609 344
1 yd	m	0.9144
1 ft	m	0.3048
	mm	304.8
1 in	mm	25.4
	AREA	
1 mile^2 (U.S. statute)	km^2	2.589 998
1 acre (U.S. survey)	ha	0.404 6873
	m^2	4046.873
1 yd^2	m^2	0.836 1274
1 ft^2	m^2	0.092 903 04
1 in^2	mm^2	645.16
	VOLUME, MODULUS OF SECTION	
1 acre ft	m^3	1233.489
1 yd^3	m^3	0.764 5549
100 board ft	m^3	0.235 9737
1 ft^3	m^3	0.028 316 85
	L(dm^3)	28.3168
1 in^3	mm^3	16 387.06
	mL (cm^3)	16.3871
1 barrel (42 U.S. gallons)	m^3	0.158 9873
	(FLUID) CAPACITY	
1 gal (U.S. liquid)*	L**	3.785 412
1 qt (U.S. liquid)	mL	946.3529
1 pt (U.S. liquid)	mL	473.1765
1 fl oz (U.S.)	mL	29.5735
1 gal (U.S. liquid) *1 gallon (UK) approx. 1.2 gal (U.S.)	m^3 **1 liter approx. 0.001 cubic meter	0.003 785 412
	SECOND MOMENT OF AREA	
1 in^4	mm^4	416 231 4
	m^4	416 231 4 × 10^{-7}
	PLANE ANGLE	
1° (degree)	rad	0.017 453 29
	mrad	17.453 29
1′ (minute)	urad	290.8882
1″ (second)	urad	4.848 137
	VELOCITY, SPEED	
1 ft/s	m/s	0.3048
1 mile/h	km/h	1.609 344
	m/s	0.447 04
	VOLUME RATE OF FLOW	
1 ft^3/s	m^3/s	0.028 316 85
1 ft^3/min	L/s	0.471 9474
1 gal/min	L/s	0.063 0902
1 gal/min	m^3/min	0.0038
1 gal/h	mL/s	1.051 50
1 million gal/d	L/s	43.8126
1 acre ft/s	m^3/s	1233.49
	TEMPERATURE INTERVAL	
1°F	°C or K	0.555 556 $^5/_9$°C = $^5/_9$K
	EQUIVALENT TEMPERATURE ($t_{°C} = T_K - 273.15$)	
$t_{°F}$	$t_{°C}$	$t_{°F} = {}^9/_5 t_{°C} + 32$

(Continued)

CONVERSION FACTORS—(Continued)

To convert	to	multiply by
MASS		
1 ton (short ***)	metric ton	0.907 185
	kg	907.1847
1 lb	kg	0.453 5924
1 oz	g	28.349 52
***1 long ton (2,240 lb)	kg	1016.047
MASS PER UNIT AREA		
1 lb/ft^2	kg/m^2	4.882 428
1 oz/yd^2	g/m^2	33.905 75
1 oz/ft^2	g/m^2	305.1517
DENSITY (MASS PER UNIT VOLUME)		
1 lb/ft^3	kg/m^3	16.01846
1 lb/yd^3	kg/m^3	0.593 2764
1 ton/yd^3	t/m^3	1.186 553
FORCE		
1 tonf (ton-force)	kN	8.896 44
1 kip (1,000 lbf)	kN	4.448 22
1 lbf (pound-force)	N	4.448 22
MOMENT OF FORCE, TORQUE		
1 lbf·ft	N·m	1.355 818
1 lbf·in	N·m	0.112 9848
1 tonf·ft	kN·m	2.711 64
1 kip·ft	kN·m	1.355 82
FORCE PER UNIT LENGTH		
1 lbf/ft	N/m	14.5939
1 lbf/in	N/m	175.1268
1 tonf/ft	kN/m	29.1878
PRESSURE, STRESS, MODULUS OF ELASTICITY (FORCE PER UNIT AREA) (1 Pa = 1 N/m^2)		
1 tonf/in^2	MPa	13.7895
1 tonf/ft^2	kPa	95.7605
1 kip/in^2	MPa	6.894 757
1 lbf/in^2	kPa	6.894 757
1 lbf/ft^2	Pa	47.8803
Atmosphere	kPa	101.3250
1 inch mercury	kPa	3.376 85
1 foot (water column at 32°F)	kPa	2.988 98
WORK, ENERGY, HEAT (1J = 1N·m = 1W·s)		
1 kWh (550 ft·lbf/s)	MJ	3.6
1 Btu (Int. Table)	kJ	1.055 056
	J	1055.056
1 ft·lbf	J	1.355 818
COEFFICIENT OF HEAT TRANSFER		
1 Btu/(ft^2·h·°F)	W/(m^2·K)	5.678 263
THERMAL CONDUCTIVITY		
1 Btu/(ft·h·°F)	W/(m·K)	1.730 735
ILLUMINANCE		
1 lm/ft^2 (footcandle)	lx (lux)	10.763 91
LUMINANCE		
1 cd/ft^2	cd/m^2	10.7639
1 foot lambert	cd/m^2	3.426 259
1 lambert	kcd/m^2	3.183 099

GAGE CONVERSION TABLE

APPROXIMATE MINIMUM THICKNESS (inch/mm) FOR CARBON SHEET STEEL CORRESPONDING TO MANUFACTURER'S STANDARD GAGE AND GALVANIZED SHEET GAGE NUMBERS

CARBON SHEET STEEL					GALVANIZED SHEET				
Manufacturer's Standard Gage No.	Decimal and Nominal Thickness Equivalent		Recommended Minimum Thickness Equivalent[1]		Galvanized Sheet Gage No.	Decimal and Nominal Thickness Equivalent		Recommended Minimum Thickness Equivalent[1]	
	(inch)	(mm)[2]	(inch)	(mm)[2]		(inch)	(mm)[2]	(inch)	(mm)[2]
8	0.1644	4.17	0.156	3.46	8	0.1681	4.27	0.159	4.04
9	0.1495	3.80	0.142	3.61	9	0.1532	3.89	0.144	3.66
10	0.1345	3.42	0.127	3.23	10	0.1382	3.51	0.129	3.23
11	0.1196	3.04	0.112	2.84	11	0.1233	3.13	0.114	2.90
12	0.1046	2.66	0.097	2.46	12	0.1084	2.75	0.099	2.51
13	0.0897	2.28	0.083	2.11	13	0.0934	2.37	0.084	2.13
14	0.0747	1.90	0.068	1.73	14	0.0785	1.97	0.070	1.78
15	0.0673	1.71	0.062	1.57	15	0.0710	1.80	0.065	1.65
16	0.0598	1.52	0.055	1.40	16	0.0635	1.61	0.058	1.47
17	0.0538	1.37	0.050	1.27	17	0.0575	1.46	0.053	1.35
18	0.0478	1.21	0.044	1.12	18	0.0516	1.31	0.047	1.19
19	0.0418	1.06	0.038	0.97	19	0.0456	1.16	0.041	1.04
20	0.0359	0.91	0.033	0.84	20	0.0396	1.01	0.036	0.91
21	0.0329	0.84	0.030	0.76	21	0.0366	0.93	0.033	0.84
22	0.0299	0.76	0.027	0.69	22	0.0336	0.85	0.030	0.76
23	0.0269	0.68	0.024	0.61	23	0.0306	0.78	0.027	0.69
24	0.0239	0.61	0.021	0.53	24	0.0276	0.70	0.024	0.61
25	0.0209	0.53	0.018	0.46	25	0.0247	0.63	0.021	0.53
26	0.0179	0.45	0.016	0.41	26	0.0217	0.55	0.019	0.48
27	0.0164	0.42	0.014	0.36	27	0.0202	0.51	0.017	0.43
28	0.0149	0.38	0.013	0.33	28	0.0187	0.47	0.016	0.41
					29	0.0172	0.44	0.014	0.36
					30	0.0157	0.40	0.013	0.33

[1]The thickness of the sheets set forth in the code correspond to the thickness shown under these columns. They are the approximate minimum thicknesses and are based on the following references:

Carbon sheet steel—Thickness 0.071 inch and over:
ASTM A 568-74, Table 3, Thickness Tolerances of Hot-Rolled Sheet (Carbon Steel).

Carbon sheet steel—Thickness less than 0.071 inch:
ASTM A 568-74, Table 23, Thickness Tolerances of Cold-Rolled Sheet (Carbon and High Strength Low Alloy).

Galvanized sheet steel—All thicknesses:
ASTM A 525-79, Table 4, Thickness Tolerances of Hot-Dip Galvanized Sheet.

Minimum thickness is the difference between the thickness equivalent of each gage and the maximum negative tolerance for the widest rolled width.

[2]The SI equivalents are calculated and rounded to two significant figures following the decimal point.

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Volume 2

Chapters 1 through 15 are printed in Volume 1 of the *Uniform Building Code.*

Chapter 16
STRUCTURAL DESIGN REQUIREMENTS

NOTE: This chapter has been revised in its entirety.

Division I—GENERAL DESIGN REQUIREMENTS

SECTION 1601 — SCOPE

This chapter prescribes general design requirements applicable to all structures regulated by this code.

SECTION 1602 — DEFINITIONS

The following terms are defined for use in this code:

ALLOWABLE STRESS DESIGN is a method of proportioning structural elements such that computed stresses produced in the elements by the allowable stress load combinations do not exceed specified allowable stress (also called working stress design).

BALCONY, EXTERIOR, is an exterior floor system projecting from a structure and supported by that structure, with no additional independent supports.

DEAD LOADS consist of the weight of all materials and fixed equipment incorporated into the building or other structure.

DECK is an exterior floor system supported on at least two opposing sides by an adjoining structure and/or posts, piers, or other independent supports.

FACTORED LOAD is the product of a load specified in Sections 1606 through 1611 and a load factor. See Section 1612.2 for combinations of factored loads.

LIMIT STATE is a condition in which a structure or component is judged either to be no longer useful for its intended function (serviceability limit state) or to be unsafe (strength limit state).

LIVE LOADS are those loads produced by the use and occupancy of the building or other structure and do not include dead load, construction load, or environmental loads such as wind load, snow load, rain load, earthquake load or flood load.

LOAD AND RESISTANCE FACTOR DESIGN (LRFD) is a method of proportioning structural elements using load and resistance factors such that no applicable limit state is reached when the structure is subjected to all appropriate load combinations. The term "LRFD" is used in the design of steel and wood structures.

STRENGTH DESIGN is a method of proportioning structural elements such that the computed forces produced in the elements by the factored load combinations do not exceed the factored element strength. The term "strength design" is used in the design of concrete and masonry structures.

SECTION 1603 — NOTATIONS

D = dead load.

E = earthquake load set forth in Section 1630.1.

E_m = estimated maximum earthquake force that can be developed in the structure as set forth in Section 1630.1.1.

F = load due to fluids.

H = load due to lateral pressure of soil and water in soil.

L = live load, except roof live load, including any permitted live load reduction.

L_r = roof live load, including any permitted live load reduction.

P = ponding load.

S = snow load.

T = self-straining force and effects arising from contraction or expansion resulting from temperature change, shrinkage, moisture change, creep in component materials, movement due to differential settlement, or combinations thereof.

W = load due to wind pressure.

SECTION 1604 — STANDARDS

The standards listed below are recognized standards (see Section 3504).

1. Wind Design.
   - 1.1 ASCE 7, Chapter 6, Minimum Design Loads for Buildings and Other Structures
   - 1.2 ANSI EIA/TIA 222-E, Structural Standards for Steel Antenna Towers and Antenna Supporting Structures
   - 1.3 ANSI/NAAMM FP1001, Guide Specifications for the Design Loads of Metal Flagpoles

SECTION 1605 — DESIGN

1605.1 General. Buildings and other structures and all portions thereof shall be designed and constructed to sustain, within the limitations specified in this code, all loads set forth in Chapter 16 and elsewhere in this code, combined in accordance with Section 1612. Design shall be in accordance with Strength Design, Load and Resistance Factor Design or Allowable Stress Design methods, as permitted by the applicable materials chapters.

> **EXCEPTION:** Unless otherwise required by the building official, buildings or portions thereof that are constructed in accordance with the conventional light-framing requirements specified in Chapter 23 of this code shall be deemed to meet the requirements of this section.

1605.2 Rationality. Any system or method of construction to be used shall be based on a rational analysis in accordance with well-established principles of mechanics. Such analysis shall result in a system that provides a complete load path capable of transferring all loads and forces from their point of origin to the load-resisting elements. The analysis shall include, but not be limited to, the provisions of Sections 1605.2.1 through 1605.2.3.

1605.2.1 Distribution of horizontal shear. The total lateral force shall be distributed to the various vertical elements of the lateral-force-resisting system in proportion to their rigidities considering the rigidity of the horizontal bracing system or diaphragm. Rigid elements that are assumed not to be part of the lateral-force-resisting system may be incorporated into buildings, provided that their effect on the action of the system is considered and provided for in the design.

Provision shall be made for the increased forces induced on resisting elements of the structural system resulting from torsion due to eccentricity between the center of application of the lateral forces and the center of rigidity of the lateral-force-resisting system. For accidental torsion requirements for seismic design, see Section 1630.6.

1605.2.2 Stability against overturning. Every structure shall be designed to resist the overturning effects caused by the lateral forces specified in this chapter. See Section 1611.6 for retaining walls, Section 1615 for wind and Section 1626 for seismic.

1605.2.3 Anchorage. Anchorage of the roof to walls and columns, and of walls and columns to foundations, shall be provided to resist the uplift and sliding forces that result from the application of the prescribed forces.

Concrete and masonry walls shall be anchored to all floors, roofs and other structural elements that provide lateral support for the wall. Such anchorage shall provide a positive direct connection capable of resisting the horizontal forces specified in this chapter but not less than the minimum forces in Section 1611.4. In addition, in Seismic Zones 3 and 4, diaphragm to wall anchorage using embedded straps shall have the straps attached to or hooked around the reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel. Walls shall be designed to resist bending between anchors where the anchor spacing exceeds 4 feet (1219 mm). Required anchors in masonry walls of hollow units or cavity walls shall be embedded in a reinforced grouted structural element of the wall. See Sections 1632, 1633.2.8 and 1633.2.9 for earthquake design requirements.

1605.3 Erection of Structural Framing. Walls and structural framing shall be erected true and plumb in accordance with the design.

SECTION 1606 — DEAD LOADS

1606.1 General. Dead loads shall be as defined in Section 1602 and this section.

1606.2 Partition Loads. Floors in office buildings and other buildings where partition locations are subject to change shall be designed to support, in addition to all other loads, a uniformly distributed dead load equal to 20 pounds per square foot (psf) (0.96 kN/m^2) of floor area.

> **EXCEPTION:** Access floor systems shall be designed to support, in addition to all other loads, a uniformly distributed dead load not less than 10 psf (0.48 kN/m^2) of floor area.

SECTION 1607 — LIVE LOADS

1607.1 General. Live loads shall be the maximum loads expected by the intended use or occupancy but in no case shall be less than the loads required by this section.

1607.2 Critical Distribution of Live Loads. Where structural members are arranged to create continuity, members shall be designed using the loading conditions, which would cause maximum shear and bending moments. This requirement may be satisfied in accordance with the provisions of Section 1607.3.2 or 1607.4.2, where applicable.

1607.3 Floor Live Loads.

1607.3.1 General. Floors shall be designed for the unit live loads as set forth in Table 16-A. These loads shall be taken as the minimum live loads in pounds per square foot of horizontal projection to be used in the design of buildings for the occupancies listed, and loads at least equal shall be assumed for uses not listed in this section but that create or accommodate similar loadings.

Where it can be determined in designing floors that the actual live load will be greater than the value shown in Table 16-A, the actual live load shall be used in the design of such buildings or portions thereof. Special provisions shall be made for machine and apparatus loads.

1607.3.2 Distribution of uniform floor loads. Where uniform floor loads are involved, consideration may be limited to full dead load on all spans in combination with full live load on adjacent spans and alternate spans.

1607.3.3 Concentrated loads. Provision shall be made in designing floors for a concentrated load, *L*, as set forth in Table 16-A placed upon any space $2^1/_2$ feet (762 mm) square, wherever this load upon an otherwise unloaded floor would produce stresses greater than those caused by the uniform load required therefor.

Provision shall be made in areas where vehicles are used or stored for concentrated loads, *L*, consisting of two or more loads spaced 5 feet (1524 mm) nominally on center without uniform live loads. Each load shall be 40 percent of the gross weight of the maximum-size vehicle to be accommodated. Parking garages for the storage of private or pleasure-type motor vehicles with no repair or refueling shall have a floor system designed for a concentrated load of not less than 2,000 pounds (8.9 kN) acting on an area of 20 square inches (12 903 mm^2) without uniform live loads. The condition of concentrated or uniform live load, combined in accordance with Section 1612.2 or 1612.3 as appropriate, producing the greatest stresses shall govern.

1607.3.4 Special loads. Provision shall be made for the special vertical and lateral loads as set forth in Table 16-B.

1607.3.5 Live loads posted. The live loads for which each floor or portion thereof of a commercial or industrial building is or has been designed shall have such design live loads conspicuously posted by the owner in that part of each story in which they apply, using durable metal signs, and it shall be unlawful to remove or deface such notices. The occupant of the building shall be responsible for keeping the actual load below the allowable limits.

1607.4 Roof Live Loads.

1607.4.1 General. Roofs shall be designed for the unit live loads, L_r, set forth in Table 16-C. The live loads shall be assumed to act vertically upon the area projected on a horizontal plane.

1607.4.2 Distribution of loads. Where uniform roof loads are involved in the design of structural members arranged to create continuity, consideration may be limited to full dead loads on all spans in combination with full roof live loads on adjacent spans and on alternate spans.

> **EXCEPTION:** Alternate span loading need not be considered where the uniform roof live load is 20 psf (0.96 kN/m^2) or more or where load combinations, including snow load, result in larger members or connections.

For those conditions where light-gage metal preformed structural sheets serve as the support and finish of roofs, roof structural members arranged to create continuity shall be considered adequate if designed for full dead loads on all spans in combination with the most critical one of the following superimposed loads:

1. Snow load in accordance with Section 1614.

2. The uniform roof live load, L_r, set forth in Table 16-C on all spans.

3. A concentrated gravity load, L_r, of 2,000 pounds (8.9 kN) placed on any span supporting a tributary area greater than 200 square feet (18.58 m^2) to create maximum stresses in the member,

whenever this loading creates greater stresses than those caused by the uniform live load. The concentrated load shall be placed on the member over a length of $2^1/_2$ feet (762 mm) along the span. The concentrated load need not be applied to more than one span simultaneously.

4. Water accumulation as prescribed in Section 1611.7.

1607.4.3 Unbalanced loading. Unbalanced loads shall be used where such loading will result in larger members or connections. Trusses and arches shall be designed to resist the stresses caused by unit live loads on one half of the span if such loading results in reverse stresses, or stresses greater in any portion than the stresses produced by the required unit live load on the entire span. For roofs whose structures are composed of a stressed shell, framed or solid, wherein stresses caused by any point loading are distributed throughout the area of the shell, the requirements for unbalanced unit live load design may be reduced 50 percent.

1607.4.4 Special roof loads. Roofs to be used for special purposes shall be designed for appropriate loads as approved by the building official.

Greenhouse roof bars, purlins and rafters shall be designed to carry a 100-pound-minimum (444.8 N) concentrated load, L_r, in addition to the uniform live load.

1607.5 Reduction of Live Loads. The design live load determined using the unit live loads as set forth in Table 16-A for floors and Table 16-C, Method 2, for roofs may be reduced on any member supporting more than 150 square feet (13.94 m^2), including flat slabs, except for floors in places of public assembly and for live loads greater than 100 psf (4.79 kN/m^2), in accordance with the following formula:

$$R = r\,(A - 150) \qquad (7\text{-}1)$$

For **SI:**

$$R = r\,(A - 13.94)$$

The reduction shall not exceed 40 percent for members receiving load from one level only, 60 percent for other members or *R*, as determined by the following formula:

$$R = 23.1\,(1 + D/L) \qquad (7\text{-}2)$$

WHERE:

- A = area of floor or roof supported by the member, square feet (m^2).
- D = dead load per square foot (m^2) of area supported by the member.
- L = unit live load per square foot (m^2) of area supported by the member.
- R = reduction in percentage.
- r = rate of reduction equal to 0.08 percent for floors. See Table 16-C for roofs.

For storage loads exceeding 100 psf (4.79 kN/m^2), no reduction shall be made, except that design live loads on columns may be reduced 20 percent.

The live load reduction shall not exceed 40 percent in garages for the storage of private pleasure cars having a capacity of not more than nine passengers per vehicle.

1607.6 Alternate Floor Live Load Reduction. As an alternate to Formula (7-1), the unit live loads set forth in Table 16-A may be reduced in accordance with Formula (7-3) on any member, including flat slabs, having an influence area of 400 square feet (37.2 m^2) or more.

$$L = L_o\left(0.25 + \frac{15}{\sqrt{A_I}}\right) \qquad (7\text{-}3)$$

For **SI:**

$$L = L_o\left[0.25 + 4.57\left(\frac{1}{\sqrt{A_I}}\right)\right]$$

WHERE:

- A_I = influence area, in square feet (m^2). The influence area A_I is four times the tributary area for a column, two times the tributary area for a beam, equal to the panel area for a two-way slab, and equal to the product of the span and the full flange width for a precast T-beam.
- L = reduced design live load per square foot (m^2) of area supported by the member.
- L_o = unreduced design live load per square foot (m^2) of area supported by the member (Table 16-A).

The reduced live load shall not be less than 50 percent of the unit live load L_o for members receiving load from one level only, nor less than 40 percent of the unit live load L_o for other members.

SECTION 1608 — SNOW LOADS

Snow loads shall be determined in accordance with Chapter 16, Division II.

SECTION 1609 — WIND LOADS

Wind loads shall be determined in accordance with Chapter 16, Division III.

SECTION 1610 — EARTHQUAKE LOADS

Earthquake loads shall be determined in accordance with Chapter 16, Division IV.

SECTION 1611 — OTHER MINIMUM LOADS

1611.1 General. In addition to the other design loads specified in this chapter, structures shall be designed to resist the loads specified in this section and the special loads set forth in Table 16-B.

1611.2 Other Loads. Buildings and other structures and portions thereof shall be designed to resist all loads due to applicable fluid pressures, *F*, lateral soil pressures, *H*, ponding loads, *P*, and self-straining forces, *T*. See Section 1611.7 for ponding loads for roofs.

1611.3 Impact Loads. Impact loads shall be included in the design of any structure where impact loads occur.

1611.4 Anchorage of Concrete and Masonry Walls. Concrete and masonry walls shall be anchored as required by Section 1605.2.3. Such anchorage shall be capable of resisting the load combinations of Section 1612.2 or 1612.3 using the greater of the wind or earthquake loads required by this chapter or a minimum horizontal force of 280 pounds per linear foot (4.09 kN/m) of wall, substituted for *E*.

1611.5 Interior Wall Loads. Interior walls, permanent partitions and temporary partitions that exceed 6 feet (1829 mm) in height shall be designed to resist all loads to which they are subjected but not less than a load, *L*, of 5 psf (0.24 kN/m^2) applied perpendicular to the walls. The 5 psf (0.24 kN/m^2) load need not be applied simultaneously with wind or seismic loads. The deflection of such walls under a load of 5 psf (0.24 kN/m^2) shall not exceed $^1/_{240}$ of the span for walls with brittle finishes and $^1/_{120}$ of the span for walls with flexible finishes. See Table 16-O for earthquake design requirements where such requirements are more restrictive.

> **EXCEPTION:** Flexible, folding or portable partitions are not required to meet the load and deflection criteria but must be anchored to the supporting structure to meet the provisions of this code.

1611.6 Retaining Walls. Retaining walls shall be designed to resist loads due to the lateral pressure of retained material in accordance with accepted engineering practice. Walls retaining drained soil, where the surface of the retained soil is level, shall be designed for a load, *H*, equivalent to that exerted by a fluid weighing not less than 30 psf per foot of depth (4.71 kN/m^2/m) and having a depth equal to that of the retained soil. Any surcharge shall be in addition to the equivalent fluid pressure.

Retaining walls shall be designed to resist sliding by at least 1.5 times the lateral force and overturning by at least 1.5 times the overturning moment, using allowable stress design loads.

1611.7 Water Accumulation. All roofs shall be designed with sufficient slope or camber to ensure adequate drainage after the long-term deflection from dead load or shall be designed to resist ponding load, *P,* combined in accordance with Section 1612.2 or 1612.3. Ponding load shall include water accumulation from any source, including snow, due to deflection. See Section 1506 and Table 16-C, Footnote 3, for drainage slope. See Section 1615 for deflection criteria.

1611.8 Hydrostatic Uplift. All foundations, slabs and other footings subjected to water pressure shall be designed to resist a uniformly distributed uplift load, *F,* equal to the full hydrostatic pressure.

1611.9 Flood-resistant Construction. For flood-resistant construction requirements, where specifically adopted, see Appendix Chapter 31, Division I.

1611.10 Heliport and Helistop Landing Areas. In addition to other design requirements of this chapter, heliport and helistop landing or touchdown areas shall be designed for the following loads, combined in accordance with Section 1612.2 or 1612.3:

1. Dead load plus actual weight of the helicopter.

2. Dead load plus a single concentrated impact load, *L*, covering 1 square foot (0.093 m^2) of 0.75 times the fully loaded weight of the helicopter if it is equipped with hydraulic-type shock absorbers, or 1.5 times the fully loaded weight of the helicopter if it is equipped with a rigid or skid-type landing gear.

3. The dead load plus a uniform live load, *L*, of 100 psf (4.8 kN/m^2). The required live load may be reduced in accordance with Section 1607.5 or 1607.6.

1611.11 Prefabricated Construction.

1611.11.1 Connections. Every device used to connect prefabricated assemblies shall be designed as required by this code and shall be capable of developing the strength of the members connected, except in the case of members forming part of a structural frame designed as specified in this chapter. Connections shall be capable of withstanding uplift forces as specified in this chapter.

1611.11.2 Pipes and conduit. In structural design, due allowance shall be made for any material to be removed for the installation of pipes, conduits or other equipment.

1611.11.3 Tests and inspections. See Section 1704 for requirements for tests and inspections of prefabricated construction.

SECTION 1612 — COMBINATIONS OF LOADS

1612.1 General. Buildings and other structures and all portions thereof shall be designed to resist the load combinations specified in Section 1612.2 or 1612.3 and, where required by Chapter 16, Division IV, or Chapters 18 through 23, the special seismic load combinations of Section 1612.4.

The most critical effect can occur when one or more of the contributing loads are not acting. All applicable loads shall be considered, including both earthquake and wind, in accordance with the specified load combinations.

1612.2 Load Combinations Using Strength Design or Load and Resistance Factor Design.

1612.2.1 Basic load combinations. Where Load and Resistance Factor Design (Strength Design) is used, structures and all portions thereof shall resist the most critical effects from the following combinations of factored loads:

$$1.4D \tag{12-1}$$

$$1.2D + 1.6L + 0.5\,(L_r \text{ or } S) \tag{12-2}$$

$$1.2D + 1.6\,(L_r \text{ or } S) + (f_1L \text{ or } 0.8W) \tag{12-3}$$

$$1.2D + 1.3W + f_1L + 0.5\,(L_r \text{ or } S) \tag{12-4}$$

$$1.2D + 1.0E + (f_1L + f_2S) \tag{12-5}$$

$$0.9D \pm (1.0E \text{ or } 1.3W) \tag{12-6}$$

WHERE:

f_1 = 1.0 for floors in places of public assembly, for live loads in excess of 100 psf (4.9 kN/m^2), and for garage live load.

= 0.5 for other live loads.

f_2 = 0.7 for roof configurations (such as saw tooth) that do not shed snow off the structure.

= 0.2 for other roof configurations.

> **EXCEPTIONS:** 1. Factored load combinations for concrete per Section 1909.2 where load combinations do not include seismic forces.
>
> 2. Factored load combinations of this section multiplied by 1.1 for concrete and masonry where load combinations include seismic forces.
>
> 3. Where other factored load combinations are specifically required by the provisions of this code.

1612.2.2 Other loads. Where *F, H, P* or *T* are to be considered in design, each applicable load shall be added to the above combinations factored as follows: 1.3*F,* 1.6*H,* 1.2*P* and 1.2*T.*

1612.3 Load Combinations Using Allowable Stress Design.

1612.3.1 Basic load combinations. Where allowable stress design (working stress design) is used, structures and all portions thereof shall resist the most critical effects resulting from the following combinations of loads:

$$D \tag{12-7}$$

$$D + L + (L_r \text{ or } S) \tag{12-8}$$

$$D + \left(W \text{ or } \frac{E}{1.4}\right) \tag{12-9}$$

$$0.9D \pm \frac{E}{1.4} \tag{12-10}$$

$$D + 0.75\left[L + (L_r \text{ or } S) + \left(W \text{ or } \frac{E}{1.4}\right)\right] \tag{12-11}$$

No increase in allowable stresses shall be used with these load combinations except as specifically permitted elsewhere in this code.

1612.3.2 Alternate basic load combinations. In lieu of the basic load combinations specified in Section 1612.3.1, structures and portions thereof shall be permitted to be designed for the most critical effects resulting from the following load combinations. When using these alternate basic load combinations, a one-third increase shall be permitted in allowable stresses for all combinations including W or E.

$$D + L + (L_r \text{ or } S) \qquad (12\text{-}12)$$

$$D + L + \left(W \text{ or } \frac{E}{1.4}\right) \qquad (12\text{-}13)$$

$$D + L + W + \frac{S}{2} \qquad (12\text{-}14)$$

$$D + L + S + \frac{W}{2} \qquad (12\text{-}15)$$

$$D + L + S + \frac{E}{1.4} \qquad (12\text{-}16)$$

$$0.9D \pm \frac{E}{1.4} \qquad (12\text{-}16\text{-}1)$$

EXCEPTIONS: 1. Crane hook loads need not be combined with roof live load or with more than three fourths of the snow load or one half of the wind load.

2. Design snow loads of 30 psf (1.44 kN/m^2) or less need not be combined with seismic loads. Where design snow loads exceed 30 psf (1.44 kN/m^2), the design snow load shall be included with seismic loads, but may be reduced up to 75 percent where consideration of siting, configuration and load duration warrant when approved by the building official.

1612.3.3 Other loads. Where F, H, P or T are to be considered in design, each applicable load shall be added to the combinations specified in Sections 1612.3.1 and 1612.3.2. When using the alternate load combinations specified in Section 1612.3.2, a one-third increase shall be permitted in allowable stresses for all combinations including W or E.

1612.4 Special Seismic Load Combinations. For both Allowable Stress Design and Strength Design, the following special load combinations for seismic design shall be used as specifically required by Chapter 16, Division IV, or by Chapters 18 through 23:

$$1.2D + f_1 L + 1.0E_m \qquad (12\text{-}17)$$

$$0.9D \pm 1.0E_m \qquad (12\text{-}18)$$

WHERE:

f_1 = 1.0 for floors in places of public assembly, for live loads in excess of 100 psf (4.79 kN/m^2), and for garage live load.

= 0.5 for other live loads.

SECTION 1613 — DEFLECTION

The deflection of any structural member shall not exceed the values set forth in Table 16-D, based on the factors set forth in Table 16-E. The deflection criteria representing the most restrictive condition shall apply. Deflection criteria for materials not specified shall be developed in a manner consistent with the provisions of this section. See Section 1611.7 for camber requirements. Span tables for light wood-frame construction as specified in Chapter 23, Division VII, shall conform to the design criteria contained therein. For concrete, see Section 1909.5.2.6; for aluminum, see Section 2003; for glazing framing, see Section 2404.2.

Division II—SNOW LOADS

SECTION 1614 — SNOW LOADS

Buildings and other structures and all portions thereof that are subject to snow loading shall be designed to resist the snow loads, as determined by the building official, in accordance with the load combinations set forth in Section 1612.2 or 1612.3.

Potential unbalanced accumulation of snow at valleys, parapets, roof structures and offsets in roofs of uneven configuration shall be considered.

Snow loads in excess of 20 psf (0.96 kN/m^2) may be reduced for each degree of pitch over 20 degrees by R_S as determined by the formula:

$$R_s = \frac{S}{40} - \frac{1}{2} \tag{14-1}$$

For **SI:** $$R_s = \frac{S}{40} - 0.024$$

WHERE:

R_S = snow load reduction in pounds per square foot (kN/m^2) per degree of pitch over 20 degrees.

S = total snow load in pounds per square foot (kN/m^2).

For alternate design procedure, where specifically adopted, see Appendix Chapter 16, Division I.

Division III—WIND DESIGN

SECTION 1615 — GENERAL

Every building or structure and every portion thereof shall be designed and constructed to resist the wind effects determined in accordance with the requirements of this division. Wind shall be assumed to come from any horizontal direction. No reduction in wind pressure shall be taken for the shielding effect of adjacent structures.

Structures sensitive to dynamic effects, such as buildings with a height-to-width ratio greater than five, structures sensitive to wind-excited oscillations, such as vortex shedding or icing, and buildings over 400 feet (121.9 m) in height, shall be, and any structure may be, designed in accordance with approved national standards.

The provisions of this section do not apply to building and foundation systems in those areas subject to scour and water pressure by wind and wave action. Buildings and foundations subject to such loads shall be designed in accordance with approved national standards.

SECTION 1616 — DEFINITIONS

The following definitions apply only to this division:

BASIC WIND SPEED is the fastest-mile wind speed associated with an annual probability of 0.02 measured at a point 33 feet (10 000 mm) above the ground for an area having exposure category C.

EXPOSURE B has terrain with buildings, forest or surface irregularities, covering at least 20 percent of the ground level area extending 1 mile (1.61 km) or more from the site.

EXPOSURE C has terrain that is flat and generally open, extending $^1/_2$ mile (0.81 km) or more from the site in any full quadrant.

EXPOSURE D represents the most severe exposure in areas with basic wind speeds of 80 miles per hour (mph) (129 km/h) or greater and has terrain that is flat and unobstructed facing large bodies of water over 1 mile (1.61 km) or more in width relative to any quadrant of the building site. Exposure D extends inland from the shoreline $^1/_4$ mile (0.40 km) or 10 times the building height, whichever is greater.

FASTEST-MILE WIND SPEED is the wind speed obtained from wind velocity maps prepared by the National Oceanographic and Atmospheric Administration and is the highest sustained average wind speed based on the time required for a mile-long sample of air to pass a fixed point.

OPENINGS are apertures or holes in the exterior wall boundary of the structure. All windows or doors or other openings shall be considered as openings unless such openings and their frames are specifically detailed and designed to resist the loads on elements and components in accordance with the provisions of this section.

PARTIALLY ENCLOSED STRUCTURE OR STORY is a structure or story that has more than 15 percent of any windward projected area open and the area of opening on all other projected areas is less than half of that on the windward projection.

SPECIAL WIND REGION is an area where local records and terrain features indicate 50-year fastest-mile basic wind speed is higher than shown in Figure 16-1.

UNENCLOSED STRUCTURE OR STORY is a structure that has 85 percent or more openings on all sides.

SECTION 1617 — SYMBOLS AND NOTATIONS

The following symbols and notations apply to the provisions of this division:

C_e = combined height, exposure and gust factor coefficient as given in Table 16-G.

C_q = pressure coefficient for the structure or portion of structure under consideration as given in Table 16-H.

I_w = importance factor as set forth in Table 16-K.

P = design wind pressure.

q_s = wind stagnation pressure at the standard height of 33 feet (10 000 mm) as set forth in Table 16-F.

SECTION 1618 — BASIC WIND SPEED

The minimum basic wind speed at any site shall not be less than that shown in Figure 16-1. For those areas designated in Figure 16-1 as special wind regions and other areas where local records or terrain indicate higher 50-year (mean recurrence interval) fastest-mile wind speeds, these higher values shall be the minimum basic wind speeds.

SECTION 1619 — EXPOSURE

An exposure shall be assigned at each site for which a building or structure is to be designed.

SECTION 1620 — DESIGN WIND PRESSURES

Design wind pressures for buildings and structures and elements therein shall be determined for any height in accordance with the following formula:

$$P = C_e\, C_q\, q_s\, I_w \qquad (20\text{-}1)$$

SECTION 1621 — PRIMARY FRAMES AND SYSTEMS

1621.1 General. The primary frames or load-resisting system of every structure shall be designed for the pressures calculated using Formula (20-1) and the pressure coefficients, C_q, of either Method 1 or Method 2. In addition, design of the overall structure and its primary load-resisting system shall conform to Section 1605.

The base overturning moment for the entire structure, or for any one of its individual primary lateral-resisting elements, shall not exceed two thirds of the dead-load-resisting moment. For an entire structure with a height-to-width ratio of 0.5 or less in the wind direction and a maximum height of 60 feet (18 290 mm), the combination of the effects of uplift and overturning may be reduced by one third. The weight of earth superimposed over footings may be used to calculate the dead-load-resisting moment.

1621.2 Method 1 (Normal Force Method). Method 1 shall be used for the design of gabled rigid frames and may be used for any structure. In the Normal Force Method, the wind pressures shall be assumed to act simultaneously normal to all exterior surfaces. For pressures on roofs and leeward walls, C_e shall be evaluated at the mean roof height.

1621.3 Method 2 (Projected Area Method). Method 2 may be used for any structure less than 200 feet (60 960 mm) in height except those using gabled rigid frames. This method may be used in stability determinations for any structure less than 200 feet (60 960 mm) high. In the Projected Area Method, horizontal pressures shall be assumed to act upon the full vertical projected area of the structure, and the vertical pressures shall be assumed to act simultaneously upon the full horizontal projected area.

SECTION 1622 — ELEMENTS AND COMPONENTS OF STRUCTURES

Design wind pressures for each element or component of a structure shall be determined from Formula (20-1) and C_q values from Table 16-H, and shall be applied perpendicular to the surface. For outward acting forces the value of C_e shall be obtained from Table 16-G based on the mean roof height and applied for the entire height of the structure. Each element or component shall be designed for the more severe of the following loadings:

1. The pressures determined using C_q values for elements and components acting over the entire tributary area of the element.

2. The pressures determined using C_q values for local areas at discontinuities such as corners, ridges and eaves. These local pressures shall be applied over a distance from a discontinuity of 10 feet (3048 mm) or 0.1 times the least width of the structure, whichever is less.

The wind pressures from Sections 1621 and 1622 need not be combined.

SECTION 1623 — OPEN-FRAME TOWERS

Radio towers and other towers of trussed construction shall be designed and constructed to withstand wind pressures specified in this section, multiplied by the shape factors set forth in Table 16-H.

SECTION 1624 — MISCELLANEOUS STRUCTURES

Greenhouses, lath houses, agricultural buildings or fences 12 feet (3658 mm) or less in height shall be designed in accordance with Chapter 16, Division III. However, three fourths of q_s, but not less than 10 psf (0.48 kN/m^2), may be substituted for q_s in Formula (20-1). Pressures on local areas at discontinuities need not be considered.

SECTION 1625 — OCCUPANCY CATEGORIES

For the purpose of wind-resistant design, each structure shall be placed in one of the occupancy categories listed in Table 16-K. Table 16-K lists importance factors, I_w, for each category.

Division IV—EARTHQUAKE DESIGN

SECTION 1626 — GENERAL

1626.1 Purpose. The purpose of the earthquake provisions herein is primarily to safeguard against major structural failures and loss of life, not to limit damage or maintain function.

1626.2 Minimum Seismic Design. Structures and portions thereof shall, as a minimum, be designed and constructed to resist the effects of seismic ground motions as provided in this division.

1626.3 Seismic and Wind Design. When the code-prescribed wind design produces greater effects, the wind design shall govern, but detailing requirements and limitations prescribed in this section and referenced sections shall be followed.

SECTION 1627 — DEFINITIONS

For the purposes of this division, certain terms are defined as follows:

BASE is the level at which the earthquake motions are considered to be imparted to the structure or the level at which the structure as a dynamic vibrator is supported.

BASE SHEAR, *V*, is the total design lateral force or shear at the base of a structure.

BEARING WALL SYSTEM is a structural system without a complete vertical load-carrying space frame. See Section 1629.6.2.

BOUNDARY ELEMENT is an element at edges of openings or at perimeters of shear walls or diaphragms.

BRACED FRAME is an essentially vertical truss system of the concentric or eccentric type that is provided to resist lateral forces.

BUILDING FRAME SYSTEM is an essentially complete space frame that provides support for gravity loads. See Section 1629.6.3.

CANTILEVERED COLUMN ELEMENT is a column element in a lateral-force-resisting system that cantilevers from a fixed base and has minimal moment capacity at the top, with lateral forces applied essentially at the top.

COLLECTOR is a member or element provided to transfer lateral forces from a portion of a structure to vertical elements of the lateral-force-resisting system.

COMPONENT is a part or element of an architectural, electrical, mechanical or structural system.

COMPONENT, EQUIPMENT, is a mechanical or electrical component or element that is part of a mechanical and/or electrical system.

COMPONENT, FLEXIBLE, is a component, including its attachments, having a fundamental period greater than 0.06 second.

COMPONENT, RIGID, is a component, including its attachments, having a fundamental period less than or equal to 0.06 second.

CONCENTRICALLY BRACED FRAME is a braced frame in which the members are subjected primarily to axial forces.

DESIGN BASIS GROUND MOTION is that ground motion that has a 10 percent chance of being exceeded in 50 years as determined by a site-specific hazard analysis or may be determined from a hazard map. A suite of ground motion time histories with dynamic properties representative of the site characteristics shall be used to represent this ground motion. The dynamic effects of the Design Basis Ground Motion may be represented by the Design Response Spectrum. See Section 1631.2.

DESIGN RESPONSE SPECTRUM is an elastic response spectrum for 5 percent equivalent viscous damping used to represent the dynamic effects of the Design Basis Ground Motion for the design of structures in accordance with Sections 1630 and 1631. This response spectrum may be either a site-specific spectrum based on geologic, tectonic, seismological and soil characteristics associated with a specific site or may be a spectrum constructed in accordance with the spectral shape in Figure 16-3 using the site-specific values of C_a and C_v and multiplied by the acceleration of gravity, 386.4 in./sec.^{2} (9.815 m/sec.^{2}). See Section 1631.2.

DESIGN SEISMIC FORCE is the minimum total strength design base shear, factored and distributed in accordance with Section 1630.

DIAPHRAGM is a horizontal or nearly horizontal system acting to transmit lateral forces to the vertical-resisting elements. The term "diaphragm" includes horizontal bracing systems.

DIAPHRAGM or SHEAR WALL CHORD is the boundary element of a diaphragm or shear wall that is assumed to take axial stresses analogous to the flanges of a beam.

DIAPHRAGM STRUT (drag strut, tie, collector) is the element of a diaphragm parallel to the applied load that collects and transfers diaphragm shear to the vertical-resisting elements or distributes loads within the diaphragm. Such members may take axial tension or compression.

DRIFT. See "story drift."

DUAL SYSTEM is a combination of moment-resisting frames and shear walls or braced frames designed in accordance with the criteria of Section 1629.6.5.

ECCENTRICALLY BRACED FRAME (EBF) is a steel-braced frame designed in conformance with Section 2213.10.

ELASTIC RESPONSE PARAMETERS are forces and deformations determined from an elastic dynamic analysis using an unreduced ground motion representation, in accordance with Section 1630.

ESSENTIAL FACILITIES are those structures that are necessary for emergency operations subsequent to a natural disaster.

FLEXIBLE ELEMENT or system is one whose deformation under lateral load is significantly larger than adjoining parts of the system. Limiting ratios for defining specific flexible elements are set forth in Section 1630.6.

HORIZONTAL BRACING SYSTEM is a horizontal truss system that serves the same function as a diaphragm.

INTERMEDIATE MOMENT-RESISTING FRAME (IMRF) is a concrete frame designed in accordance with Section 1921.8.

LATERAL-FORCE-RESISTING SYSTEM is that part of the structural system designed to resist the Design Seismic Forces.

MOMENT-RESISTING FRAME is a frame in which members and joints are capable of resisting forces primarily by flexure.

MOMENT-RESISTING WALL FRAME (MRWF) is a masonry wall frame especially detailed to provide ductile behavior and designed in conformance with Section 2108.2.5.

ORDINARY BRACED FRAME (OBF) is a steel-braced frame designed in accordance with the provisions of Section

2213.8 or 2214.6, or concrete-braced frame designed in accordance with Section 1921.

ORDINARY MOMENT-RESISTING FRAME (OMRF) is a moment-resisting frame not meeting special detailing requirements for ductile behavior.

ORTHOGONAL EFFECTS are the earthquake load effects on structural elements common to the lateral-force-resisting systems along two orthogonal axes.

OVERSTRENGTH is a characteristic of structures where the actual strength is larger than the design strength. The degree of overstrength is material- and system-dependent.

***P*Δ EFFECT** is the secondary effect on shears, axial forces and moments of frame members induced by the vertical loads acting on the laterally displaced building system.

SHEAR WALL is a wall designed to resist lateral forces parallel to the plane of the wall (sometimes referred to as vertical diaphragm or structural wall).

SHEAR WALL-FRAME INTERACTIVE SYSTEM uses combinations of shear walls and frames designed to resist lateral forces in proportion to their relative rigidities, considering interaction between shear walls and frames on all levels.

SOFT STORY is one in which the lateral stiffness is less than 70 percent of the stiffness of the story above. See Table 16-L.

SPACE FRAME is a three-dimensional structural system, without bearing walls, composed of members interconnected so as to function as a complete self-contained unit with or without the aid of horizontal diaphragms or floor-bracing systems.

SPECIAL CONCENTRICALLY BRACED FRAME (SCBF) is a steel-braced frame designed in conformance with the provisions of Section 2213.9.

SPECIAL MOMENT-RESISTING FRAME (SMRF) is a moment-resisting frame specially detailed to provide ductile behavior and comply with the requirements given in Chapter 19 or 22.

SPECIAL TRUSS MOMENT FRAME (STMF) is a moment-resisting frame specially detailed to provide ductile behavior and comply with the provisions of Section 2213.11.

STORY is the space between levels. Story *x* is the story below Level *x*.

STORY DRIFT is the lateral displacement of one level relative to the level above or below.

STORY DRIFT RATIO is the story drift divided by the story height.

STORY SHEAR, V_x, is the summation of design lateral forces above the story under consideration.

STRENGTH is the capacity of an element or a member to resist factored load as specified in Chapters 16, 18, 19, 21 and 22.

STRUCTURE is an assemblage of framing members designed to support gravity loads and resist lateral forces. Structures may be categorized as building structures or nonbuilding structures.

SUBDIAPHRAGM is a portion of a larger wood diaphragm designed to anchor and transfer local forces to primary diaphragm struts and the main diaphragm.

VERTICAL LOAD-CARRYING FRAME is a space frame designed to carry vertical gravity loads.

WALL ANCHORAGE SYSTEM is the system of elements anchoring the wall to the diaphragm and those elements within the diaphragm required to develop the anchorage forces, including subdiaphragms and continuous ties, as specified in Sections 1633.2.8 and 1633.2.9.

WEAK STORY is one in which the story strength is less than 80 percent of the story above. See Table 16-L.

SECTION 1628 — SYMBOLS AND NOTATIONS

The following symbols and notations apply to the provisions of this division:

A_B = ground floor area of structure in square feet (m^2) to include area covered by all overhangs and projections.

A_c = the combined effective area, in square feet (m^2), of the shear walls in the first story of the structure.

A_e = the minimum cross-sectional area in any horizontal plane in the first story, in square feet (m^2) of a shear wall.

A_x = the torsional amplification factor at Level *x*.

a_p = numerical coefficient specified in Section 1632 and set forth in Table 16-O.

C_a = seismic coefficient, as set forth in Table 16-Q.

C_t = numerical coefficient given in Section 1630.2.2.

C_v = seismic coefficient, as set forth in Table 16-R.

D = dead load on a structural element.

D_e = the length, in feet (m), of a shear wall in the first story in the direction parallel to the applied forces.

E, E_h, E_m, E_v = earthquake loads set forth in Section 1630.1.

F_i, F_n, F_x = Design Seismic Force applied to Level *i*, *n* or *x*, respectively.

F_p = Design Seismic Forces on a part of the structure.

F_{px} = Design Seismic Force on a diaphragm.

F_t = that portion of the base shear, *V*, considered concentrated at the top of the structure in addition to F_n.

f_i = lateral force at Level *i* for use in Formula (30-10).

g = acceleration due to gravity.

h_i, h_n, h_x = height in feet (m) above the base to Level *i*, *n* or *x*, respectively.

I = importance factor given in Table 16-K.

I_p = importance factor specified in Table 16-K.

L = live load on a structural element.

Level *i* = level of the structure referred to by the subscript *i*. "$i = 1$" designates the first level above the base.

Level *n* = that level that is uppermost in the main portion of the structure.

Level *x* = that level that is under design consideration. "$x = 1$" designates the first level above the base.

M = maximum moment magnitude.

N_a = near-source factor used in the determination of C_a in Seismic Zone 4 related to both the proximity of the building or structure to known faults with magnitudes and slip rates as set forth in Tables 16-S and 16-U.

N_v = near-source factor used in the determination of C_v in Seismic Zone 4 related to both the proximity of the building or structure to known faults with magnitudes and slip rates as set forth in Tables 16-T and 16-U.

PI = plasticity index of soil determined in accordance with approved national standards.

R = numerical coefficient representative of the inherent overstrength and global ductility capacity of lateral-force-resisting systems, as set forth in Table 16-N or 16-P.

r = a ratio used in determining ρ. See Section 1630.1.

S_A, S_B, S_C, S_D, S_E, S_F = soil profile types as set forth in Table 16-J.

T = elastic fundamental period of vibration, in seconds, of the structure in the direction under consideration.

V = the total design lateral force or shear at the base given by Formula (30-5), (30-6), (30-7) or (30-11).

V_x = the design story shear in Story x.

W = the total seismic dead load defined in Section 1630.1.1.

w_i, w_x = that portion of W located at or assigned to Level i or x, respectively.

W_p = the weight of an element or component.

w_{px} = the weight of the diaphragm and the element tributary thereto at Level x, including applicable portions of other loads defined in Section 1630.1.1.

Z = seismic zone factor as given in Table 16-I.

Δ_M = Maximum Inelastic Response Displacement, which is the total drift or total story drift that occurs when the structure is subjected to the Design Basis Ground Motion, including estimated elastic and inelastic contributions to the total deformation defined in Section 1630.9.

Δ_S = Design Level Response Displacement, which is the total drift or total story drift that occurs when the structure is subjected to the design seismic forces.

δ_i = horizontal displacement at Level i relative to the base due to applied lateral forces, f, for use in Formula (30-10).

ρ = Redundancy/Reliability Factor given by Formula (30-3).

Ω_o = Seismic Force Amplification Factor, which is required to account for structural overstrength and set forth in Table 16-N.

SECTION 1629 — CRITERIA SELECTION

1629.1 Basis for Design. The procedures and the limitations for the design of structures shall be determined considering seismic zoning, site characteristics, occupancy, configuration, structural system and height in accordance with this section. Structures shall be designed with adequate strength to withstand the lateral displacements induced by the Design Basis Ground Motion, considering the inelastic response of the structure and the inherent redundancy, overstrength and ductility of the lateral-force-resisting system. The minimum design strength shall be based on the Design Seismic Forces determined in accordance with the static lateral force procedure of Section 1630, except as modified by Section 1631.5.4. Where strength design is used, the load combinations of Section 1612.2 shall apply. Where Allowable Stress Design is used, the load combinations of Section 1612.3 shall apply. Allowable Stress Design may be used to evaluate sliding or overturning at the soil-structure interface regardless of the design approach used in the design of the structure, provided load combinations of Section 1612.3 are utilized. One- and two-family dwellings in Seismic Zone 1 need not conform to the provisions of this section.

1629.2 Occupancy Categories. For purposes of earthquake-resistant design, each structure shall be placed in one of the occupancy categories listed in Table 16-K. Table 16-K assigns importance factors, I and I_p, and structural observation requirements for each category.

1629.3 Site Geology and Soil Characteristics. Each site shall be assigned a soil profile type based on properly substantiated geotechnical data using the site categorization procedure set forth in Division V, Section 1636 and Table 16-J.

EXCEPTION: When the soil properties are not known in sufficient detail to determine the soil profile type, Type S_D shall be used. Soil Profile Type S_E or S_F need not be assumed unless the building official determines that Type S_E or S_F may be present at the site or in the event that Type S_E or S_F is established by geotechnical data.

1629.3.1 Soil profile type. Soil Profile Types S_A, S_B, S_C, S_D and S_E are defined in Table 16-J and Soil Profile Type S_F is defined as soils requiring site-specific evaluation as follows:

1. Soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly sensitive clays, and collapsible weakly cemented soils.

2. Peats and/or highly organic clays, where the thickness of peat or highly organic clay exceeds 10 feet (3048 mm).

3. Very high plasticity clays with a plasticity index, $PI > 75$, where the depth of clay exceeds 25 feet (7620 mm).

4. Very thick soft/medium stiff clays, where the depth of clay exceeds 120 feet (36 576 mm).

1629.4 Site Seismic Hazard Characteristics. Seismic hazard characteristics for the site shall be established based on the seismic zone and proximity of the site to active seismic sources, site soil profile characteristics and the structure's importance factor.

1629.4.1 Seismic zone. Each site shall be assigned a seismic zone in accordance with Figure 16-2. Each structure shall be assigned a seismic zone factor Z, in accordance with Table 16-I.

1629.4.2 Seismic Zone 4 near-source factor. In Seismic Zone 4, each site shall be assigned a near-source factor in accordance with Table 16-S and the Seismic Source Type set forth in Table 16-U. The value of N_a used to determine C_a need not exceed 1.1 for structures complying with all the following conditions:

1. The soil profile type is S_A, S_B, S_C or S_D.

2. $\rho = 1.0$.

3. Except in single-story structures, Group R, Division 3 and Group U, Division 1 Occupancies, moment frame systems designated as part of the lateral-force-resisting system shall be special moment-resisting frames.

4. The exceptions to Section 2213.7.5 shall not apply, except for columns in one-story buildings or columns at the top story of multistory buildings.

5. None of the following structural irregularities is present: Type 1, 4 or 5 of Table 16-L, and Type 1 or 4 of Table 16-M.

1629.4.3 Seismic response coefficients. Each structure shall be assigned a seismic coefficient, C_a, in accordance with Table 16-Q and a seismic coefficient, C_v, in accordance with Table 16-R.

1629.5 Configuration Requirements.

1629.5.1 General. Each structure shall be designated as being structurally regular or irregular in accordance with Sections 1629.5.2 and 1629.5.3.

1629.5.2 Regular structures. Regular structures have no significant physical discontinuities in plan or vertical configuration or in their lateral-force-resisting systems such as the irregular features described in Section 1629.5.3.

1629.5.3 Irregular structures.

1. Irregular structures have significant physical discontinuities in configuration or in their lateral-force-resisting systems. Irregular features include, but are not limited to, those described in Tables 16-L and 16-M. All structures in Seismic Zone 1 and Occupancy Categories 4 and 5 in Seismic Zone 2 need to be evaluated only for vertical irregularities of Type 5 (Table 16-L) and horizontal irregularities of Type 1 (Table 16-M).

2. Structures having any of the features listed in Table 16-L shall be designated as if having a vertical irregularity.

> **EXCEPTION:** Where no story drift ratio under design lateral forces is greater than 1.3 times the story drift ratio of the story above, the structure may be deemed to not have the structural irregularities of Type 1 or 2 in Table 16-L. The story drift ratio for the top two stories need not be considered. The story drifts for this determination may be calculated neglecting torsional effects.

3. Structures having any of the features listed in Table 16-M shall be designated as having a plan irregularity.

1629.6 Structural Systems.

1629.6.1 General. Structural systems shall be classified as one of the types listed in Table 16-N and defined in this section.

1629.6.2 Bearing wall system. A structural system without a complete vertical load-carrying space frame. Bearing walls or bracing systems provide support for all or most gravity loads. Resistance to lateral load is provided by shear walls or braced frames.

1629.6.3 Building frame system. A structural system with an essentially complete space frame providing support for gravity loads. Resistance to lateral load is provided by shear walls or braced frames.

1629.6.4 Moment-resisting frame system. A structural system with an essentially complete space frame providing support for gravity loads. Moment-resisting frames provide resistance to lateral load primarily by flexural action of members.

1629.6.5 Dual system. A structural system with the following features:

1. An essentially complete space frame that provides support for gravity loads.

2. Resistance to lateral load is provided by shear walls or braced frames and moment-resisting frames (SMRF, IMRF, MMRWF or steel OMRF). The moment-resisting frames shall be designed to independently resist at least 25 percent of the design base shear.

3. The two systems shall be designed to resist the total design base shear in proportion to their relative rigidities considering the interaction of the dual system at all levels.

1629.6.6 Cantilevered column system. A structural system relying on cantilevered column elements for lateral resistance.

1629.6.7 Undefined structural system. A structural system not listed in Table 16-N.

1629.6.8 Nonbuilding structural system. A structural system conforming to Section 1634.

1629.7 Height Limits. Height limits for the various structural systems in Seismic Zones 3 and 4 are given in Table 16-N.

> **EXCEPTION:** Regular structures may exceed these limits by not more than 50 percent for unoccupied structures, which are not accessible to the general public.

1629.8 Selection of Lateral-force Procedure.

1629.8.1 General. Any structure may be, and certain structures defined below shall be, designed using the dynamic lateral-force procedures of Section 1631.

1629.8.2 Simplified static. The simplified static lateral-force procedure set forth in Section 1630.2.3 may be used for the following structures of Occupancy Category 4 or 5:

1. Buildings of any occupancy (including single-family dwellings) not more than three stories in height excluding basements, that use light-frame construction.

2. Other buildings not more than two stories in height excluding basements.

1629.8.3 Static. The static lateral force procedure of Section 1630 may be used for the following structures:

1. All structures, regular or irregular, in Seismic Zone 1 and in Occupancy Categories 4 and 5 in Seismic Zone 2.

2. Regular structures under 240 feet (73 152 mm) in height with lateral force resistance provided by systems listed in Table 16-N, except where Section 1629.8.4, Item 4, applies.

3. Irregular structures not more than five stories or 65 feet (19 812 mm) in height.

4. Structures having a flexible upper portion supported on a rigid lower portion where both portions of the structure considered separately can be classified as being regular, the average story stiffness of the lower portion is at least 10 times the average story stiffness of the upper portion and the period of the entire structure is not greater than 1.1 times the period of the upper portion considered as a separate structure fixed at the base.

1629.8.4 Dynamic. The dynamic lateral-force procedure of Section 1631 shall be used for all other structures, including the following:

1. Structures 240 feet (73 152 mm) or more in height, except as permitted by Section 1629.8.3, Item 1.

2. Structures having a stiffness, weight or geometric vertical irregularity of Type 1, 2 or 3, as defined in Table 16-L, or structures having irregular features not described in Table 16-L or 16-M, except as permitted by Section 1630.4.2.

3. Structures over five stories or 65 feet (19 812 mm) in height in Seismic Zones 3 and 4 not having the same structural system throughout their height except as permitted by Section 1630.4.2.

4. Structures, regular or irregular, located on Soil Profile Type S_F, that have a period greater than 0.7 second. The analysis shall include the effects of the soils at the site and shall conform to Section 1631.2, Item 4.

1629.9 System Limitations.

1629.9.1 Discontinuity. Structures with a discontinuity in capacity, vertical irregularity Type 5 as defined in Table 16-L, shall not be over two stories or 30 feet (9144 mm) in height where the weak story has a calculated strength of less than 65 percent of the story above.

> **EXCEPTION:** Where the weak story is capable of resisting a total lateral seismic force of Ω_o times the design force prescribed in Section 1630.

1629.9.2 Undefined structural systems. For undefined structural systems not listed in Table 16-N, the coefficient *R* shall be substantiated by approved cyclic test data and analyses. The following items shall be addressed when establishing *R:*

1. Dynamic response characteristics,
2. Lateral force resistance,
3. Overstrength and strain hardening or softening,
4. Strength and stiffness degradation,
5. Energy dissipation characteristics,
6. System ductility, and
7. Redundancy.

1629.9.3 Irregular features. All structures having irregular features described in Table 16-L or 16-M shall be designed to meet the additional requirements of those sections referenced in the tables.

1629.10 Alternative Procedures.

1629.10.1 General. Alternative lateral-force procedures using rational analyses based on well-established principles of mechanics may be used in lieu of those prescribed in these provisions.

1629.10.2 Seismic isolation. Seismic isolation, energy dissipation and damping systems may be used in the design of structures when approved by the building official and when special detailing is used to provide results equivalent to those obtained by the use of conventional structural systems. For alternate design procedures on seismic isolation systems, refer to Appendix Chapter 16, Division III, Earthquake Regulations for Seismic-isolated Structures.

SECTION 1630 — MINIMUM DESIGN LATERAL FORCES AND RELATED EFFECTS

1630.1 Earthquake Loads and Modeling Requirements.

1630.1.1 Earthquake loads. Structures shall be designed for ground motion producing structural response and seismic forces in any horizontal direction. The following earthquake loads shall be used in the load combinations set forth in Section 1612:

$$E = \rho E_h + E_v \tag{30-1}$$

$$E_m = \Omega_o E_h \tag{30-2}$$

WHERE:

E = the earthquake load on an element of the structure resulting from the combination of the horizontal component, E_h, and the vertical component, E_v.

E_h = the earthquake load due to the base shear, V, as set forth in Section 1630.2 or the design lateral force, F_p, as set forth in Section 1632.

E_m = the estimated maximum earthquake force that can be developed in the structure as set forth in Section 1630.1.1.

E_v = the load effect resulting from the vertical component of the earthquake ground motion and is equal to an addition of $0.5C_aID$ to the dead load effect, D, for Strength Design, and may be taken as zero for Allowable Stress Design.

Ω_o = the seismic force amplification factor that is required to account for structural overstrength, as set forth in Section 1630.3.1.

ρ = Reliability/Redundancy Factor as given by the following formula:

$$\rho = 2 - \frac{20}{r_{max}\sqrt{A_B}} \tag{30-3}$$

For **SI:**

$$\rho = 2 - \frac{6.1}{r_{max}\sqrt{A_B}}$$

WHERE:

r_{max} = the maximum element-story shear ratio. For a given direction of loading, the element-story shear ratio is the ratio of the design story shear in the most heavily loaded single element divided by the total design story shear. For any given Story Level i, the element-story shear ratio is denoted as r_i. The maximum element-story shear ratio r_{max} is defined as the largest of the element story shear ratios, r_i, which occurs in any of the story levels at or below the two-thirds height level of the building.

For braced frames, the value of r_i is equal to the maximum horizontal force component in a single brace element divided by the total story shear.

For moment frames, r_i shall be taken as the maximum of the sum of the shears in any two adjacent columns in a moment frame bay divided by the story shear. For columns common to two bays with moment-resisting connections on opposite sides at Level i in the direction under consideration, 70 percent of the shear in that column may be used in the column shear summation.

For shear walls, r_i shall be taken as the maximum value of the product of the wall shear multiplied by $10/l_w$ (For **SI:** $3.05/l_w$) and divided by the total story shear, where l_w is the length of the wall in feet (m).

For dual systems, r_i shall be taken as the maximum value of r_i as defined above considering all lateral-load-resisting elements. The lateral loads shall be distributed to elements based on relative rigidities considering the interaction of the dual system. For dual systems, the value of ρ need not exceed 80 percent of the value calculated above.

ρ shall not be taken less than 1.0 and need not be greater than 1.5, and A_B is the ground floor area of the structure in square feet (m^2). For special moment-resisting frames, except when used in dual systems, ρ shall not exceed 1.25. The number of bays of special moment-resisting frames shall be increased to reduce r, such that ρ is less than or equal to 1.25.

EXCEPTION: A_B may be taken as the average floor area in the upper setback portion of the building where a larger base area exists at the ground floor.

When calculating drift, or when the structure is located in Seismic Zone 0, 1 or 2, ρ shall be taken equal to 1.

The ground motion producing lateral response and design seismic forces may be assumed to act nonconcurrently in the direction of each principal axis of the structure, except as required by Section 1633.1.

Seismic dead load, W, is the total dead load and applicable portions of other loads listed below.

1. In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.

2. Where a partition load is used in the floor design, a load of not less than 10 psf (0.48 kN/m^2) shall be included.

3. Design snow loads of 30 psf (1.44 kN/m^2) or less need not be included. Where design snow loads exceed 30 psf (1.44 kN/m^2), the design snow load shall be included, but may be reduced up to 75 percent where consideration of siting, configuration and load duration warrant when approved by the building official.

4. Total weight of permanent equipment shall be included.

1630.1.2 Modeling requirements. The mathematical model of the physical structure shall include all elements of the lateral-force-resisting system. The model shall also include the stiffness and strength of elements, which are significant to the distribution of forces, and shall represent the spatial distribution of the mass and stiffness of the structure. In addition, the model shall comply with the following:

1. Stiffness properties of reinforced concrete and masonry elements shall consider the effects of cracked sections.

2. For steel moment frame systems, the contribution of panel zone deformations to overall story drift shall be included.

1630.1.3 *P*Δ effects. The resulting member forces and moments and the story drifts induced by $P\Delta$ effects shall be considered in the evaluation of overall structural frame stability and shall be evaluated using the forces producing the displacements of Δ_S. $P\Delta$ need not be considered when the ratio of secondary moment to primary moment does not exceed 0.10; the ratio may be evaluated for any story as the product of the total dead, floor live and snow load, as required in Section 1612, above the story times the seismic drift in that story divided by the product of the seismic shear in that story times the height of that story. In Seismic Zones 3 and 4, $P\Delta$ need not be considered when the story drift ratio does not exceed $0.02/R$.

1630.2 Static Force Procedure.

1630.2.1 Design base shear. The total design base shear in a given direction shall be determined from the following formula:

$$V = \frac{C_v I}{R T} W \qquad (30\text{-}4)$$

The total design base shear need not exceed the following:

$$V = \frac{2.5\ C_a\ I}{R} W \qquad (30\text{-}5)$$

The total design base shear shall not be less than the following:

$$V = 0.11\ C_a\ I\ W \qquad (30\text{-}6)$$

In addition, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$V = \frac{0.8\ Z N_v\ I}{R} W \qquad (30\text{-}7)$$

1630.2.2 Structure period. The value of T shall be determined from one of the following methods:

1. **Method A:** For all buildings, the value T may be approximated from the following formula:

$$T = C_t\,(h_n)^{3/4} \qquad (30\text{-}8)$$

WHERE:

C_t = 0.035 (0.0853) for steel moment-resisting frames.

C_t = 0.030 (0.0731) for reinforced concrete moment-resisting frames and eccentrically braced frames.

C_t = 0.020 (0.0488) for all other buildings.

Alternatively, the value of C_t for structures with concrete or masonry shear walls may be taken as $0.1/\sqrt{A_c}$ (For **SI:** $0.0743/\sqrt{A_c}$ for A_c in m^2).

The value of A_c shall be determined from the following formula:

$$A_c = \Sigma A_e \left[0.2 + (D_e/h_n)^2\right] \qquad (30\text{-}9)$$

The value of D_e/h_n used in Formula (30-9) shall not exceed 0.9.

2. **Method B:** The fundamental period T may be calculated using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis. The analysis shall be in accordance with the requirements of Section 1630.1.2. The value of T from Method B shall not exceed a value 30 percent greater than the value of T obtained from Method A in Seismic Zone 4, and 40 percent in Seismic Zones 1, 2 and 3.

The fundamental period T may be computed by using the following formula:

$$T = 2\pi \sqrt{\left(\sum_{i=1}^{n} w_i\,\delta_i^{\,2}\right) \div \left(g \sum_{i=1}^{n} f_i\,\delta_i\right)} \qquad (30\text{-}10)$$

The values of f_i represent any lateral force distributed approximately in accordance with the principles of Formulas (30-13), (30-14) and (30-15) or any other rational distribution. The elastic deflections, δ_i, shall be calculated using the applied lateral forces, f_i.

1630.2.3 Simplified design base shear.

1630.2.3.1 General. Structures conforming to the requirements of Section 1629.8.2 may be designed using this procedure.

1630.2.3.2 Base shear. The total design base shear in a given direction shall be determined from the following formula:

$$V = \frac{3.0\ C_a}{R} W \qquad (30\text{-}11)$$

where the value of C_a shall be based on Table 16-Q for the soil profile type. When the soil properties are not known in sufficient detail to determine the soil profile type, Type S_D shall be used in Seismic Zones 3 and 4, and Type S_E shall be used in Seismic Zones 1, 2A and 2B. In Seismic Zone 4, the Near-Source Factor, N_a, need not be greater than 1.3 if none of the following structural irregularities are present: Type 1, 4 or 5 of Table 16-L, or Type 1 or 4 of Table 16-M.

1630.2.3.3 Vertical distribution. The forces at each level shall be calculated using the following formula:

$$F_x = \frac{3.0\ C_a}{R} w_i \qquad (30\text{-}12)$$

where the value of C_a shall be determined in Section 1630.2.3.2.

1630.2.3.4 Applicability. Sections 1630.1.2, 1630.1.3, 1630.2.1, 1630.2.2, 1630.5, 1630.9, 1630.10 and 1631 shall not apply when using the simplified procedure.

> **EXCEPTION:** For buildings with relatively flexible structural systems, the building official may require consideration of $P\Delta$ effects and drift in accordance with Sections 1630.1.3, 1630.9 and 1630.10. Δ_S shall be prepared using design seismic forces from Section 1630.2.3.2.

Where used, Δ_M shall be taken equal to 0.01 times the story height of all stories. In Section 1633.2.9, Formula (33-1) shall read $F_{px} = \frac{3.0\ C_a}{R} w_{px}$ and need not exceed 1.0 $C_a\ w_{px}$, but shall not be less than 0.5 $C_a\ w_{px}$. R and Ω_o shall be taken from Table 16-N.

1630.3 Determination of Seismic Factors.

1630.3.1 Determination of Ω_o. For specific elements of the structure, as specifically identified in this code, the minimum design strength shall be the product of the seismic force overstrength factor Ω_o and the design seismic forces set forth in Section 1630. For both Allowable Stress Design and Strength Design, the Seismic Force Overstrength Factor, Ω_o, shall be taken from Table 16-N.

1630.3.2 Determination of *R*. The notation R shall be taken from Table 16-N.

1630.4 Combinations of Structural Systems.

1630.4.1 General. Where combinations of structural systems are incorporated into the same structure, the requirements of this section shall be satisfied.

1630.4.2 Vertical combinations. The value of R used in the design of any story shall be less than or equal to the value of R used in the given direction for the story above.

> **EXCEPTION:** This requirement need not be applied to a story where the dead weight above that story is less than 10 percent of the total dead weight of the structure.

Structures may be designed using the procedures of this section under the following conditions:

1. The entire structure is designed using the lowest R of the lateral-force-resisting systems used, or

2. The following two-stage static analysis procedures may be used for structures conforming to Section 1629.8.3, Item 4.

   2.1 The flexible upper portion shall be designed as a separate structure, supported laterally by the rigid lower portion, using the appropriate values of R and ρ.

   2.2 The rigid lower portion shall be designed as a separate structure using the appropriate values of R and ρ. The reactions from the upper portion shall be those determined from the analysis of the upper portion amplified by the ratio of the (R/ρ) of the upper portion over (R/ρ) of the lower portion.

1630.4.3 Combinations along different axes. In Seismic Zones 3 and 4 where a structure has a bearing wall system in only one direction, the value of R used for design in the orthogonal direction shall not be greater than that used for the bearing wall system.

Any combination of bearing wall systems, building frame systems, dual systems or moment-resisting frame systems may be used to resist seismic forces in structures less than 160 feet (48 768 mm) in height. Only combinations of dual systems and special moment-resisting frames shall be used to resist seismic forces in structures exceeding 160 feet (48 768 mm) in height in Seismic Zones 3 and 4.

1630.4.4 Combinations along the same axis. For other than dual systems and shear wall-frame interactive systems in Seismic Zones 0 and 1, where a combination of different structural systems is utilized to resist lateral forces in the same direction, the value of R used for design in that direction shall not be greater than the least value for any of the systems utilized in that same direction.

1630.5 Vertical Distribution of Force. The total force shall be distributed over the height of the structure in conformance with Formulas (30-13), (30-14) and (30-15) in the absence of a more rigorous procedure.

$$V = F_t + \sum_{i=1}^{n} F_i \qquad (30\text{-}13)$$

The concentrated force F_t at the top, which is in addition to F_n, shall be determined from the formula:

$$F_t = 0.07\ T\ V \qquad (30\text{-}14)$$

The value of T used for the purpose of calculating F_t shall be the period that corresponds with the design base shear as computed using Formula (30-4). F_t need not exceed $0.25V$ and may be considered as zero where T is 0.7 second or less. The remaining portion of the base shear shall be distributed over the height of the structure, including Level n, according to the following formula:

$$F_x = \frac{(V - F_t)\, w_x\, h_x}{\sum_{i=1}^{n} w_i\, h_i} \qquad (30\text{-}15)$$

At each level designated as x, the force F_x shall be applied over the area of the building in accordance with the mass distribution at that level. Structural displacements and design seismic forces shall be calculated as the effect of forces F_x and F_t applied at the appropriate levels above the base.

1630.6 Horizontal Distribution of Shear. The design story shear, V_x, in any story is the sum of the forces F_t and F_x above that story. V_x shall be distributed to the various elements of the vertical lateral-force-resisting system in proportion to their rigidities, considering the rigidity of the diaphragm. See Section 1633.2.4 for rigid elements that are not intended to be part of the lateral-force-resisting systems.

Where diaphragms are not flexible, the mass at each level shall be assumed to be displaced from the calculated center of mass in each direction a distance equal to 5 percent of the building dimension at that level perpendicular to the direction of the force under consideration. The effect of this displacement on the story shear distribution shall be considered.

Diaphragms shall be considered flexible for the purposes of distribution of story shear and torsional moment when the maximum lateral deformation of the diaphragm is more than two times the average story drift of the associated story. This may be determined by comparing the computed midpoint in-plane deflection of the diaphragm itself under lateral load with the story drift of adjoining vertical-resisting elements under equivalent tributary lateral load.

1630.7 Horizontal Torsional Moments. Provisions shall be made for the increased shears resulting from horizontal torsion where diaphragms are not flexible. The most severe load combination for each element shall be considered for design.

The torsional design moment at a given story shall be the moment resulting from eccentricities between applied design lateral forces at levels above that story and the vertical-resisting elements in that story plus an accidental torsion.

The accidental torsional moment shall be determined by assuming the mass is displaced as required by Section 1630.6.

Where torsional irregularity exists, as defined in Table 16-M, the effects shall be accounted for by increasing the accidental torsion at each level by an amplification factor, A_x, determined from the following formula:

$$A_x = \left[\frac{\delta_{max}}{1.2\,\delta_{avg}}\right]^2 \qquad (30\text{-}16)$$

WHERE:

δ_{avg} = the average of the displacements at the extreme points of the structure at Level x.

δ_{max} = the maximum displacement at Level x.

The value of A_x need not exceed 3.0.

1630.8 Overturning.

1630.8.1 General. Every structure shall be designed to resist the overturning effects caused by earthquake forces specified in Section 1630.5. At any level, the overturning moments to be resisted shall be determined using those seismic forces (F_t and F_x) that act on levels above the level under consideration. At any level, the incremental changes of the design overturning moment shall be distributed to the various resisting elements in the manner prescribed in Section 1630.6. Overturning effects on every element shall be carried down to the foundation. See Sections 1612 and 1633 for combining gravity and seismic forces.

1630.8.2 Elements supporting discontinuous systems.

1630.8.2.1 General. Where any portion of the lateral-load-resisting system is discontinuous, such as for vertical irregularity Type 4 in Table 16-L or plan irregularity Type 4 in Table 16-M, concrete, masonry, steel and wood elements supporting such discontinuous systems shall have the design strength to resist the combination loads resulting from the special seismic load combinations of Section 1612.4.

> **EXCEPTIONS:** 1. The quantity E_m in Section 1612.4 need not exceed the maximum force that can be transferred to the element by the lateral-force-resisting system.
>
> 2. Concrete slabs supporting light-frame wood shear wall systems or light-frame steel and wood structural panel shear wall systems.

For Allowable Stress Design, the design strength may be determined using an allowable stress increase of 1.7 and a resistance factor, ϕ, of 1.0. This increase shall not be combined with the one-third stress increase permitted by Section 1612.3, but may be combined with the duration of load increase permitted in Chapter 23, Division III.

1630.8.2.2 Detailing requirements in Seismic Zones 3 and 4. In Seismic Zones 3 and 4, elements supporting discontinuous systems shall meet the following detailing or member limitations:

1. Reinforced concrete elements designed primarily as axial-load members shall comply with Section 1921.4.4.5.

2. Reinforced concrete elements designed primarily as flexural members and supporting other than light-frame wood shear wall systems or light-frame steel and wood structural panel shear wall systems shall comply with Sections 1921.3.2 and 1921.3.3. Strength computations for portions of slabs designed as supporting elements shall include only those portions of the slab that comply with the requirements of these sections.

3. Masonry elements designed primarily as axial-load carrying members shall comply with Sections 2106.1.12.4, Item 1, and 2108.2.6.2.6.

4. Masonry elements designed primarily as flexural members shall comply with Section 2108.2.6.2.5.

5. Steel elements designed primarily as axial-load members shall comply with Sections 2213.5.2 and 2213.5.3.

6. Steel elements designed primarily as flexural members or trusses shall have bracing for both top and bottom beam flanges or chords at the location of the support of the discontinuous system and shall comply with the requirements of Section 2213.7.1.3.

7. Wood elements designed primarily as flexural members shall be provided with lateral bracing or solid blocking at each end of the element and at the connection location(s) of the discontinuous system.

1630.8.3 At foundation. See Sections 1629.1 and 1809.4 for overturning moments to be resisted at the foundation soil interface.

1630.9 Drift. Drift or horizontal displacements of the structure shall be computed where required by this code. For both Allowable Stress Design and Strength Design, the Maximum Inelastic Response Displacement, Δ_M, of the structure caused by the Design Basis Ground Motion shall be determined in accordance with this section. The drifts corresponding to the design seismic forces of Section 1630.2.1, Δ_S, shall be determined in accordance with Section 1630.9.1. To determine Δ_M, these drifts shall be amplified in accordance with Section 1630.9.2.

1630.9.1 Determination of Δ_S. A static, elastic analysis of the lateral force-resisting system shall be prepared using the design seismic forces from Section 1630.2.1. Alternatively, dynamic analysis may be performed in accordance with Section 1631. Where Allowable Stress Design is used and where drift is being computed, the load combinations of Section 1612.2 shall be used. The mathematical model shall comply with Section 1630.1.2. The resulting deformations, denoted as Δ_S, shall be determined at all critical locations in the structure. Calculated drift shall include translational and torsional deflections.

1630.9.2 Determination of Δ_M. The Maximum Inelastic Response Displacement, Δ_M, shall be computed as follows:

$$\Delta_M = 0.7\ R\Delta_S \qquad (30\text{-}17)$$

> **EXCEPTION:** Alternatively, Δ_M may be computed by nonlinear time history analysis in accordance with Section 1631.6.

The analysis used to determine the Maximum Inelastic Response Displacement Δ_M shall consider $P\Delta$ effects.

1630.10 Story Drift Limitation.

1630.10.1 General. Story drifts shall be computed using the Maximum Inelastic Response Displacement, Δ_M.

1630.10.2 Calculated. Calculated story drift using Δ_M shall not exceed 0.025 times the story height for structures having a fundamental period of less than 0.7 second. For structures having a fundamental period of 0.7 second or greater, the calculated story drift shall not exceed 0.020 times the story height.

> **EXCEPTIONS:** 1. These drift limits may be exceeded when it is demonstrated that greater drift can be tolerated by both structural elements and nonstructural elements that could affect life safety. The drift used in this assessment shall be based upon the Maximum Inelastic Response Displacement, Δ_M.
>
> 2. There shall be no drift limit in single-story steel-framed structures classified as Groups B, F and S Occupancies or Group H, Division 4 or 5 Occupancies. In Groups B, F and S Occupancies, the primary use shall be limited to storage, factories or workshops. Minor accessory uses shall be allowed in accordance with the provisions of Section 302. Structures on which this exception is used shall not have equipment attached to the structural frame or shall have such equipment detailed to accommodate the additional drift. Walls that are laterally supported by the steel frame shall be designed to accommodate the drift in accordance with Section 1633.2.4.

1630.10.3 Limitations. The design lateral forces used to determine the calculated drift may disregard the limitations of Formula (30-6) and may be based on the period determined from Formula (30-10) neglecting the 30 or 40 percent limitations of Section 1630.2.2, Item 2.

1630.11 Vertical Component. The following requirements apply in Seismic Zones 3 and 4 only. Horizontal cantilever components shall be designed for a net upward force of $0.7C_aIW_p$.

In addition to all other applicable load combinations, horizontal prestressed components shall be designed using not more than 50 percent of the dead load for the gravity load, alone or in combination with the lateral force effects.

SECTION 1631 — DYNAMIC ANALYSIS PROCEDURES

1631.1 General. Dynamic analyses procedures, when used, shall conform to the criteria established in this section. The analysis shall be based on an appropriate ground motion representation and shall be performed using accepted principles of dynamics.

Structures that are designed in accordance with this section shall comply with all other applicable requirements of these provisions.

1631.2 Ground Motion. The ground motion representation shall, as a minimum, be one having a 10-percent probability of being exceeded in 50 years, shall not be reduced by the quantity R and may be one of the following:

1. An elastic design response spectrum constructed in accordance with Figure 16-3, using the values of C_a and C_v consistent with the specific site. The design acceleration ordinates shall be multiplied by the acceleration of gravity, 386.4 in./sec.^{2} (9.815 m/sec.^{2}).

2. A site-specific elastic design response spectrum based on the geologic, tectonic, seismologic and soil characteristics associated with the specific site. The spectrum shall be developed for a damping ratio of 0.05, unless a different value is shown to be consistent with the anticipated structural behavior at the intensity of shaking established for the site.

3. Ground motion time histories developed for the specific site shall be representative of actual earthquake motions. Response spectra from time histories, either individually or in combination, shall approximate the site design spectrum conforming to Section 1631.2, Item 2.

4. For structures on Soil Profile Type S_F, the following requirements shall apply when required by Section 1629.8.4, Item 4:

   4.1 The ground motion representation shall be developed in accordance with Items 2 and 3.

   4.2 Possible amplification of building response due to the effects of soil-structure interaction and lengthening of building period caused by inelastic behavior shall be considered.

5. The vertical component of ground motion may be defined by scaling corresponding horizontal accelerations by a factor of two-thirds. Alternative factors may be used when substantiated by site-specific data. Where the Near Source Factor, N_a, is greater than 1.0, site-specific vertical response spectra shall be used in lieu of the factor of two-thirds.

1631.3 Mathematical Model. A mathematical model of the physical structure shall represent the spatial distribution of the mass and stiffness of the structure to an extent that is adequate for the calculation of the significant features of its dynamic response. A three-dimensional model shall be used for the dynamic analysis of structures with highly irregular plan configurations such as those having a plan irregularity defined in Table 16-M and having a rigid or semirigid diaphragm. The stiffness properties used in the analysis and general mathematical modeling shall be in accordance with Section 1630.1.2.

1631.4 Description of Analysis Procedures.

1631.4.1 Response spectrum analysis. An elastic dynamic analysis of a structure utilizing the peak dynamic response of all modes having a significant contribution to total structural response. Peak modal responses are calculated using the ordinates of the appropriate response spectrum curve which correspond to the modal periods. Maximum modal contributions are combined in a statistical manner to obtain an approximate total structural response.

1631.4.2 Time-history analysis. An analysis of the dynamic response of a structure at each increment of time when the base is subjected to a specific ground motion time history.

1631.5 Response Spectrum Analysis.

1631.5.1 Response spectrum representation and interpretation of results. The ground motion representation shall be in accordance with Section 1631.2. The corresponding response parameters, including forces, moments and displacements, shall be denoted as Elastic Response Parameters. Elastic Response Parameters may be reduced in accordance with Section 1631.5.4.

1631.5.2 Number of modes. The requirement of Section 1631.4.1 that all significant modes be included may be satisfied by demonstrating that for the modes considered, at least 90 percent of the participating mass of the structure is included in the calculation of response for each principal horizontal direction.

1631.5.3 Combining modes. The peak member forces, displacements, story forces, story shears and base reactions for each mode shall be combined by recognized methods. When three-dimensional models are used for analysis, modal interaction effects shall be considered when combining modal maxima.

1631.5.4 Reduction of Elastic Response Parameters for design. Elastic Response Parameters may be reduced for purposes of design in accordance with the following items, with the limitation that in no case shall the Elastic Response Parameters be reduced such that the corresponding design base shear is less than the Elastic Response Base Shear divided by the value of R.

1. For all regular structures where the ground motion representation complies with Section 1631.2, Item 1, Elastic Response Parameters may be reduced such that the corresponding design base shear is not less than 90 percent of the base shear determined in accordance with Section 1630.2.

2. For all regular structures where the ground motion representation complies with Section 1631.2, Item 2, Elastic Response Parameters may be reduced such that the corresponding design base shear is not less than 80 percent of the base shear determined in accordance with Section 1630.2.

3. For all irregular structures, regardless of the ground motion representation, Elastic Response Parameters may be reduced such that the corresponding design base shear is not less than 100 percent of the base shear determined in accordance with Section 1630.2.

The corresponding reduced design seismic forces shall be used for design in accordance with Section 1612.

1631.5.5 Directional effects. Directional effects for horizontal ground motion shall conform to the requirements of Section 1630.1. The effects of vertical ground motions on horizontal cantilevers and prestressed elements shall be considered in accordance with Section 1630.11. Alternately, vertical seismic response may be determined by dynamic response methods; in no case shall the response used for design be less than that obtained by the static method.

1631.5.6 Torsion. The analysis shall account for torsional effects, including accidental torsional effects as prescribed in Section 1630.7. Where three-dimensional models are used for analysis, effects of accidental torsion shall be accounted for by appropriate adjustments in the model such as adjustment of mass locations, or by equivalent static procedures such as provided in Section 1630.6.

1631.5.7 Dual systems. Where the lateral forces are resisted by a dual system as defined in Section 1629.6.5, the combined system shall be capable of resisting the base shear determined in accordance with this section. The moment-resisting frame shall conform to Section 1629.6.5, Item 2, and may be analyzed using either the procedures of Section 1630.5 or those of Section 1631.5.

1631.6 Time-history Analysis.

1631.6.1 Time history. Time-history analysis shall be performed with pairs of appropriate horizontal ground-motion time-history components that shall be selected and scaled from not less than three recorded events. Appropriate time histories shall have magnitudes, fault distances and source mechanisms that are consistent with those that control the design-basis earthquake (or maximum capable earthquake). Where three appropriate recorded ground-motion time-history pairs are not available, appropriate simulated ground-motion time-history pairs may be used to make up the total number required. For each pair of horizontal ground-motion components, the square root of the sum of the squares (SRSS) of the 5 percent-damped site-specific spectrum of the scaled horizontal components shall be constructed. The motions shall be scaled such that the average value of the SRSS spectra does not fall below 1.4 times the 5 percent-damped spectrum of the design-basis earthquake for periods from $0.2T$ second to $1.5T$ seconds. Each pair of time histories shall be applied simultaneously to the model considering torsional effects.

The parameter of interest shall be calculated for each time-history analysis. If three time-history analyses are performed, then the maximum response of the parameter of interest shall be used for design. If seven or more time-history analyses are performed, then the average value of the response parameter of interest may be used for design.

1631.6.2 Elastic time-history analysis. Elastic time history shall conform to Sections 1631.1, 1631.2, 1631.3, 1631.5.2, 1631.5.4, 1631.5.5, 1631.5.6, 1631.5.7 and 1631.6.1. Response parameters from elastic time-history analysis shall be denoted as Elastic Response Parameters. All elements shall be designed using Strength Design. Elastic Response Parameters may be scaled in accordance with Section 1631.5.4.

1631.6.3 Nonlinear time-history analysis.

1631.6.3.1 Nonlinear time history. Nonlinear time-history analysis shall meet the requirements of Section 1629.10, and time histories shall be developed and results determined in accordance with the requirements of Section 1631.6.1. Capacities and characteristics of nonlinear elements shall be modeled consistent with test data or substantiated analysis, considering the Importance Factor. The maximum inelastic response displacement shall not be reduced and shall comply with Section 1630.10.

1631.6.3.2 Design review. When nonlinear time-history analysis is used to justify a structural design, a design review of the lateral-force-resisting system shall be performed by an independent engineering team, including persons licensed in the appropriate disciplines and experienced in seismic analysis methods. The lateral-force-resisting system design review shall include, but not be limited to, the following:

1. Reviewing the development of site-specific spectra and ground-motion time histories.

2. Reviewing the preliminary design of the lateral-force-resisting system.

3. Reviewing the final design of the lateral-force-resisting system and all supporting analyses.

The engineer of record shall submit with the plans and calculations a statement by all members of the engineering team doing the review stating that the above review has been performed.

SECTION 1632 — LATERAL FORCE ON ELEMENTS OF STRUCTURES, NONSTRUCTURAL COMPONENTS AND EQUIPMENT SUPPORTED BY STRUCTURES

1632.1 General. Elements of structures and their attachments, permanent nonstructural components and their attachments, and the attachments for permanent equipment supported by a structure shall be designed to resist the total design seismic forces prescribed in Section 1632.2. Attachments for floor- or roof-mounted equipment weighing less than 400 pounds (181 kg), and furniture need not be designed.

Attachments shall include anchorages and required bracing. Friction resulting from gravity loads shall not be considered to provide resistance to seismic forces.

When the structural failure of the lateral-force-resisting systems of nonrigid equipment would cause a life hazard, such systems shall be designed to resist the seismic forces prescribed in Section 1632.2.

When permissible design strengths and other acceptance criteria are not contained in or referenced by this code, such criteria shall be obtained from approved national standards subject to the approval of the building official.

1632.2 Design for Total Lateral Force. The total design lateral seismic force, F_p, shall be determined from the following formula:

$$F_p = 4.0\, C_a I_p W_p \qquad (32\text{-}1)$$

Alternatively, F_p may be calculated using the following formula:

$$F_p = \frac{a_p C_a I_p}{R_p}\left(1 + 3\frac{h_x}{h_r}\right) W_p \qquad (32\text{-}2)$$

Except that:

F_p shall not be less than $0.7 C_a I_p W_p$ and
need not be more than $4 C_a I_p W_p$ (32-3)

WHERE:

h_x is the element or component attachment elevation with respect to grade. h_x shall not be taken less than 0.0.

h_r is the structure roof elevation with respect to grade.

a_p is the in-structure Component Amplification Factor that varies from 1.0 to 2.5.

A value for a_p shall be selected from Table 16-O. Alternatively, this factor may be determined based on the dynamic properties or empirical data of the component and the structure that supports it. The value shall not be taken less than 1.0.

R_p is the Component Response Modification Factor that shall be taken from Table 16-O, except that R_p for anchorages shall equal 1.5 for shallow expansion anchor bolts, shallow chemical anchors or shallow cast-in-place anchors. Shallow anchors are those with an embedment length-to-diameter ratio of less than 8. When anchorage is constructed of nonductile materials, or by use of adhesive, R_p shall equal 1.0.

The design lateral forces determined using Formula (32-1) or (32-2) shall be distributed in proportion to the mass distribution of the element or component.

Forces determined using Formula (32-1) or (32-2) shall be used to design members and connections that transfer these forces to the seismic-resisting systems. Members and connection design shall use the load combinations and factors specified in Section 1612.2 or 1612.3. The Reliability/Redundancy Factor, ρ, may be taken equal to 1.0.

For applicable forces and Component Response Modification Factors in connectors for exterior panels and diaphragms, refer to Sections 1633.2.4, 1633.2.8 and 1633.2.9.

Forces shall be applied in the horizontal directions, which result in the most critical loadings for design.

1632.3 Specifying Lateral Forces. Design specifications for equipment shall either specify the design lateral forces prescribed herein or reference these provisions.

1632.4 Relative Motion of Equipment Attachments. For equipment in Categories 1 and 2 buildings as defined in Table 16-K, the lateral-force design shall consider the effects of relative motion of the points of attachment to the structure, using the drift based upon Δ_M.

1632.5 Alternative Designs. Where an approved national standard or approved physical test data provide a basis for the earthquake-resistant design of a particular type of equipment or other nonstructural component, such a standard or data may be accepted as a basis for design of the items with the following limitations:

1. These provisions shall provide minimum values for the design of the anchorage and the members and connections that transfer the forces to the seismic-resisting system.

2. The force, F_p, and the overturning moment used in the design of the nonstructural component shall not be less than 80 percent of the values that would be obtained using these provisions.

SECTION 1633 — DETAILED SYSTEMS DESIGN REQUIREMENTS

1633.1 General. All structural framing systems shall comply with the requirements of Section 1629. Only the elements of the designated seismic-force-resisting system shall be used to resist design forces. The individual components shall be designed to resist the prescribed design seismic forces acting on them. The components shall also comply with the specific requirements for the material contained in Chapters 19 through 23. In addition, such framing systems and components shall comply with the detailed system design requirements contained in Section 1633.

All building components in Seismic Zones 2, 3 and 4 shall be designed to resist the effects of the seismic forces prescribed herein and the effects of gravity loadings from dead, floor live and snow loads.

Consideration shall be given to design for uplift effects caused by seismic loads.

In Seismic Zones 2, 3 and 4, provision shall be made for the effects of earthquake forces acting in a direction other than the principal axes in each of the following circumstances:

The structure has plan irregularity Type 5 as given in Table 16-M.

The structure has plan irregularity Type 1 as given in Table 16-M for both major axes.

A column of a structure forms part of two or more intersecting lateral-force-resisting systems.

> **EXCEPTION:** If the axial load in the column due to seismic forces acting in either direction is less than 20 percent of the column axial load capacity.

The requirement that orthogonal effects be considered may be satisfied by designing such elements for 100 percent of the prescribed design seismic forces in one direction plus 30 percent of the prescribed design seismic forces in the perpendicular direction. The combination requiring the greater component strength shall be used for design. Alternatively, the effects of the two orthogonal directions may be combined on a square root of the sum of the squares (SRSS) basis. When the SRSS method of combining directional effects is used, each term computed shall be assigned the sign that will result in the most conservative result.

1633.2 Structural Framing Systems.

1633.2.1 General. Four types of general building framing systems defined in Section 1629.6 are recognized in these provisions and shown in Table 16-N. Each type is subdivided by the types of vertical elements used to resist lateral seismic forces. Special framing requirements are given in this section and in Chapters 19 through 23.

1633.2.2 Detailing for combinations of systems. For components common to different structural systems, the more restrictive detailing requirements shall be used.

1633.2.3 Connections. Connections that resist design seismic forces shall be designed and detailed on the drawings.

1633.2.4 Deformation compatibility. All structural framing elements and their connections, not required by design to be part of the lateral-force-resisting system, shall be designed and/or detailed to be adequate to maintain support of design dead plus live loads when subjected to the expected deformations caused by seismic forces. $P\Delta$ effects on such elements shall be considered. Expected deformations shall be determined as the greater of the Maximum Inelastic Response Displacement, Δ_M, considering $P\Delta$ effects determined in accordance with Section 1630.9.2 or the deformation induced by a story drift of 0.0025 times the story height. When computing expected deformations, the stiffening effect of those elements not part of the lateral-force-resisting system shall be neglected.

For elements not part of the lateral-force-resisting system, the forces induced by the expected deformation may be considered as ultimate or factored forces. When computing the forces induced by expected deformations, the restraining effect of adjoining rigid structures and nonstructural elements shall be considered and a rational value of member and restraint stiffness shall be used. Inelastic deformations of members and connections may be considered in the evaluation, provided the assumed calculated capacities are consistent with member and connection design and detailing.

For concrete and masonry elements that are part of the lateral-force-resisting system, the assumed flexural and shear stiffness properties shall not exceed one half of the gross section properties unless a rational cracked-section analysis is performed. Additional deformations that may result from foundation flexibility and diaphragm deflections shall be considered. For concrete elements not part of the lateral-force-resisting system, see Section 1921.7.

1633.2.4.1 Adjoining rigid elements. Moment-resisting frames and shear walls may be enclosed by or adjoined by more rigid elements, provided it can be shown that the participation or failure of the more rigid elements will not impair the vertical and lateral-load-resisting ability of the gravity load and lateral-force-resisting systems. The effects of adjoining rigid elements shall be considered when assessing whether a structure shall be designated regular or irregular in Section 1629.5.1.

1633.2.4.2 Exterior elements. Exterior nonbearing, nonshear wall panels or elements that are attached to or enclose the exterior shall be designed to resist the forces per Formula (32-1) or (32–2) and shall accommodate movements of the structure based on Δ_M and temperature changes. Such elements shall be supported by means of cast-in-place concrete or by mechanical connections and fasteners in accordance with the following provisions:

1. Connections and panel joints shall allow for a relative movement between stories of not less than two times story drift caused

by wind, the calculated story drift based on Δ_M or $^1/_2$ inch (12.7 mm), whichever is greater.

2. Connections to permit movement in the plane of the panel for story drift shall be sliding connections using slotted or oversize holes, connections that permit movement by bending of steel, or other connections providing equivalent sliding and ductility capacity.

3. Bodies of connections shall have sufficient ductility and rotation capacity to preclude fracture of the concrete or brittle failures at or near welds.

4. The body of the connection shall be designed for the force determined by Formula (32-2), where R_p = 3.0 and a_p = 1.0.

5. All fasteners in the connecting system, such as bolts, inserts, welds and dowels, shall be designed for the forces determined by Formula (32-2), where R_p = 1.0 and a_p = 1.0.

6. Fasteners embedded in concrete shall be attached to, or hooked around, reinforcing steel or otherwise terminated to effectively transfer forces to the reinforcing steel.

1633.2.5 Ties and continuity. All parts of a structure shall be interconnected and the connections shall be capable of transmitting the seismic force induced by the parts being connected. As a minimum, any smaller portion of the building shall be tied to the remainder of the building with elements having at least a strength to resist 0.5 C_aI times the weight of the smaller portion.

A positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder or truss. This force shall not be less than 0.5 C_aI times the dead plus live load.

1633.2.6 Collector elements. Collector elements shall be provided that are capable of transferring the seismic forces originating in other portions of the structure to the element providing the resistance to those forces.

Collector elements, splices and their connections to resisting elements shall resist the forces determined in accordance with Formula (33-1). In addition, collector elements, splices, and their connections to resisting elements shall have the design strength to resist the combined loads resulting from the special seismic load of Section 1612.4.

> **EXCEPTION:** In structures, or portions thereof, braced entirely by light-frame wood shear walls or light-frame steel and wood structural panel shear wall systems, collector elements, splices and connections to resisting elements need only be designed to resist forces in accordance with Formula (33-1).

The quantity E_M need not exceed the maximum force that can be transferred to the collector by the diaphragm and other elements of the lateral-force-resisting system. For Allowable Stress Design, the design strength may be determined using an allowable stress increase of 1.7 and a resistance factor, ϕ, of 1.0. This increase shall not be combined with the one-third stress increase permitted by Section 1612.3, but may be combined with the duration of load increase permitted in Division III of Chapter 23.

1633.2.7 Concrete frames. Concrete frames required by design to be part of the lateral-force-resisting system shall conform to the following:

1. In Seismic Zones 3 and 4 they shall be special moment-resisting frames.

2. In Seismic Zone 2 they shall, as a minimum, be intermediate moment-resisting frames.

1633.2.8 Anchorage of concrete or masonry walls. Concrete or masonry walls shall be anchored to all floors and roofs that provide out-of-plane lateral support of the wall. The anchorage shall provide a positive direct connection between the wall and floor or roof construction capable of resisting the larger of the horizontal forces specified in this section and Sections 1611.4 and 1632. In addition, in Seismic Zones 3 and 4, diaphragm to wall anchorage using embedded straps shall have the straps attached to or hooked around the reinforcing steel or otherwise terminated to effectively transfer forces to the reinforcing steel. Requirements for developing anchorage forces in diaphragms are given in Section 1633.2.9. Diaphragm deformation shall be considered in the design of the supported walls.

1633.2.8.1 Out-of-plane wall anchorage to flexible diaphragms. This section shall apply in Seismic Zones 3 and 4 where flexible diaphragms, as defined in Section 1630.6, provide lateral support for walls.

1. Elements of the wall anchorage system shall be designed for the forces specified in Section 1632 where R_p = 3.0 and a_p = 1.5.

In Seismic Zone 4, the value of F_p used for the design of the elements of the wall anchorage system shall not be less than 420 pounds per lineal foot (6.1 kN per lineal meter) of wall substituted for E.

See Section 1611.4 for minimum design forces in other seismic zones.

2. When elements of the wall anchorage system are not loaded concentrically or are not perpendicular to the wall, the system shall be designed to resist all components of the forces induced by the eccentricity.

3. When pilasters are present in the wall, the anchorage force at the pilasters shall be calculated considering the additional load transferred from the wall panels to the pilasters. However, the minimum anchorage force at a floor or roof shall be that specified in Section 1633.2.8.1, Item 1.

4. The strength design forces for steel elements of the wall anchorage system shall be 1.4 times the forces otherwise required by this section.

5. The strength design forces for wood elements of the wall anchorage system shall be 0.85 times the force otherwise required by this section and these wood elements shall have a minimum actual net thickness of $2^1/_2$ inches (63.5 mm).

1633.2.9 Diaphragms.

1. The deflection in the plane of the diaphragm shall not exceed the permissible deflection of the attached elements. Permissible deflection shall be that deflection that will permit the attached element to maintain its structural integrity under the individual loading and continue to support the prescribed loads.

2. Floor and roof diaphragms shall be designed to resist the forces determined in accordance with the following formula:

$$F_{p_x} = \frac{F_t + \sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} w_i} w_{px} \qquad (33\text{-}1)$$

The force F_{px} determined from Formula (33-1) need not exceed $1.0C_aIw_{px}$, but shall not be less than $0.5C_aIw_{px}$.

When the diaphragm is required to transfer design seismic forces from the vertical-resisting elements above the diaphragm to other vertical-resisting elements below the diaphragm due to offset in the placement of the elements or to changes in stiffness in the vertical elements, these forces shall be added to those determined from Formula (33-1).

3. Design seismic forces for flexible diaphragms providing lateral supports for walls or frames of masonry or concrete shall be

determined using Formula (33-1) based on the load determined in accordance with Section 1630.2 using a R not exceeding 4.

4. Diaphragms supporting concrete or masonry walls shall have continuous ties or struts between diaphragm chords to distribute the anchorage forces specified in Section 1633.2.8. Added chords of subdiaphragms may be used to form subdiaphragms to transmit the anchorage forces to the main continuous crossties. The maximum length-to-width ratio of the wood structural subdiaphragm shall be $2^1/_2$:1.

5. Where wood diaphragms are used to laterally support concrete or masonry walls, the anchorage shall conform to Section 1633.2.8. In Seismic Zones 2, 3 and 4, anchorage shall not be accomplished by use of toenails or nails subject to withdrawal, wood ledgers or framing shall not be used in cross-grain bending or cross-grain tension, and the continuous ties required by Item 4 shall be in addition to the diaphragm sheathing.

6. Connections of diaphragms to the vertical elements in structures in Seismic Zones 3 and 4, having a plan irregularity of Type 1, 2, 3 or 4 in Table 16-M, shall be designed without considering either the one-third increase or the duration of load increase considered in allowable stresses for elements resisting earthquake forces.

7. In structures in Seismic Zones 3 and 4 having a plan irregularity of Type 2 in Table 16-M, diaphragm chords and drag members shall be designed considering independent movement of the projecting wings of the structure. Each of these diaphragm elements shall be designed for the more severe of the following two assumptions:

Motion of the projecting wings in the same direction.

Motion of the projecting wings in opposing directions.

EXCEPTION: This requirement may be deemed satisfied if the procedures of Section 1631 in conjunction with a three-dimensional model have been used to determine the lateral seismic forces for design.

1633.2.10 Framing below the base. The strength and stiffness of the framing between the base and the foundation shall not be less than that of the superstructure. The special detailing requirements of Chapters 19 and 22, as appropriate, shall apply to columns supporting discontinuous lateral-force-resisting elements and to SMRF, IMRF, EBF, STMF and MMRWF system elements below the base, which are required to transmit the forces resulting from lateral loads to the foundation.

1633.2.11 Building separations. All structures shall be separated from adjoining structures. Separations shall allow for the displacement Δ_M. Adjacent buildings on the same property shall be separated by at least Δ_{MT} where

$$\Delta_{MT} = \sqrt{(\Delta_{M1})^2 + (\Delta_{M2})^2} \qquad (33\text{-}2)$$

and Δ_{M1} and Δ_{M2} are the displacements of the adjacent buildings.

When a structure adjoins a property line not common to a public way, that structure shall also be set back from the property line by at least the displacement Δ_M of that structure.

EXCEPTION: Smaller separations or property line setbacks may be permitted when justified by rational analyses based on maximum expected ground motions.

SECTION 1634 — NONBUILDING STRUCTURES

1634.1 General.

1634.1.1 Scope. Nonbuilding structures include all self-supporting structures other than buildings that carry gravity loads and resist the effects of earthquakes. Nonbuilding structures shall be designed to provide the strength required to resist the displacements induced by the minimum lateral forces specified in this section. Design shall conform to the applicable provisions of other sections as modified by the provisions contained in Section 1634.

1634.1.2 Criteria. The minimum design seismic forces prescribed in this section are at a level that produce displacements in a fixed base, elastic model of the structure, comparable to those expected of the real structure when responding to the Design Basis Ground Motion. Reductions in these forces using the coefficient R is permitted where the design of nonbuilding structures provides sufficient strength and ductility, consistent with the provisions specified herein for buildings, to resist the effects of seismic ground motions as represented by these design forces.

When applicable, design strengths and other detailed design criteria shall be obtained from other sections or their referenced standards. The design of nonbuilding structures shall use the load combinations or factors specified in Section 1612.2 or 1612.3. For nonbuilding structures designed using Section 1634.3, 1634.4 or 1634.5, the Reliability/Redundancy Factor, ρ, may be taken as 1.0.

When applicable design strengths and other design criteria are not contained in or referenced by this code, such criteria shall be obtained from approved national standards.

1634.1.3 Weight *W*. The weight, W, for nonbuilding structures shall include all dead loads as defined for buildings in Section 1630.1.1. For purposes of calculating design seismic forces in nonbuilding structures, W shall also include all normal operating contents for items such as tanks, vessels, bins and piping.

1634.1.4 Period. The fundamental period of the structure shall be determined by rational methods such as by using Method B in Section 1630.2.2.

1634.1.5 Drift. The drift limitations of Section 1630.10 need not apply to nonbuilding structures. Drift limitations shall be established for structural or nonstructural elements whose failure would cause life hazards. $P\Delta$ effects shall be considered for structures whose calculated drifts exceed the values in Section 1630.1.3.

1634.1.6 Interaction effects. In Seismic Zones 3 and 4, structures that support flexible nonstructural elements whose combined weight exceeds 25 percent of the weight of the structure shall be designed considering interaction effects between the structure and the supported elements.

1634.2 Lateral Force. Lateral-force procedures for nonbuilding structures with structural systems similar to buildings (those with structural systems which are listed in Table 16-N) shall be selected in accordance with the provisions of Section 1629.

EXCEPTION: Intermediate moment-resisting frames (IMRF) may be used in Seismic Zones 3 and 4 for nonbuilding structures in Occupancy Categories 3 and 4 if (1) the structure is less than 50 feet (15 240 mm) in height and (2) the value R used in reducing calculated member forces and moments does not exceed 2.8.

1634.3 Rigid Structures. Rigid structures (those with period T less than 0.06 second) and their anchorages shall be designed for the lateral force obtained from Formula (34-1).

$$V = 0.7 C_a \, I W \qquad (34\text{-}1)$$

The force V shall be distributed according to the distribution of mass and shall be assumed to act in any horizontal direction.

1634.4 Tanks with Supported Bottoms. Flat bottom tanks or other tanks with supported bottoms, founded at or below grade, shall be designed to resist the seismic forces calculated using the procedures in Section 1634 for rigid structures considering the entire weight of the tank and its contents. Alternatively, such tanks may be designed using one of the two procedures described below:

1. A response spectrum analysis that includes consideration of the actual ground motion anticipated at the site and the inertial effects of the contained fluid.

2. A design basis prescribed for the particular type of tank by an approved national standard, provided that the seismic zones and occupancy categories shall be in conformance with the provisions of Sections 1629.4 and 1629.2, respectively.

1634.5 Other Nonbuilding Structures. Nonbuilding structures that are not covered by Sections 1634.3 and 1634.4 shall be designed to resist design seismic forces not less than those determined in accordance with the provisions in Section 1630 with the following additions and exceptions:

1. The factors R and Ω_o shall be as set forth in Table 16-P. The total design base shear determined in accordance with Section 1630.2 shall not be less than the following:

$$V = 0.56 C_a I W \qquad (34\text{-}2)$$

Additionally, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$V = \frac{1.6\ Z N_v\ I}{R} W \qquad (34\text{-}3)$$

2. The vertical distribution of the design seismic forces in structures covered by this section may be determined by using the provisions of Section 1630.5 or by using the procedures of Section 1631.

EXCEPTION: For irregular structures assigned to Occupancy Categories 1 and 2 that cannot be modeled as a single mass, the procedures of Section 1631 shall be used.

3. Where an approved national standard provides a basis for the earthquake-resistant design of a particular type of nonbuilding structure covered by this section, such a standard may be used, subject to the limitations in this section:

The seismic zones and occupancy categories shall be in conformance with the provisions of Sections 1629.4 and 1629.2, respectively.

The values for total lateral force and total base overturning moment used in design shall not be less than 80 percent of the values that would be obtained using these provisions.

SECTION 1635 — EARTHQUAKE-RECORDING INSTRUMENTATIONS

For earthquake-recording instrumentations, see Appendix Chapter 16, Division II.

Division V—SOIL PROFILE TYPES

SECTION 1636 — SITE CATEGORIZATION PROCEDURE

1636.1 Scope. This division describes the procedure for determining Soil Profile Types S_A through S_F in accordance with Table 16-J.

1636.2 Definitions. Soil profile types are defined as follows:

S_A Hard rock with measured shear wave velocity, $\bar{v}_s > 5{,}000$ ft./sec. (1500 m/s).

S_B Rock with 2,500 ft./sec. $< \bar{v}_s \le$ 5,000 ft./sec. (760 m/s $< \bar{v}_s \le$ 1500 m/s).

S_C Very dense soil and soft rock with 1,200 ft./sec. $< \bar{v}_s \le$ 2,500 ft./sec. (360 m/s $\bar{v}_s \le$ 760 m/s) or with either $\bar{N} > 50$ or $\bar{s}_u \ge$ 2,000 psf (100 kPa).

S_D Stiff soil with 600 ft./sec. $\le \bar{v}_s \le$ 1,200 ft./sec. (180 m/s $\le \bar{v}_s \le$ 360 m/s) or with $15 \le \bar{N} \le 50$ or 1,000 psf $\le \bar{s}_u \le$ 2,000 psf (50 kPa $\le \bar{s}_u \le$ 100 kPa).

S_E A soil profile with $\bar{v}_s <$ 600 ft./sec. (180 m/s) or any profile with more than 10 ft. (3048 mm) of soft clay defined as soil with $PI > 20$, $w_{mc} \ge$ 40 percent and $s_u <$ 500 psf (25 kPa).

S_F Soils requiring site-specific evaluation:

1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils.

2. Peats and/or highly organic clays [$H >$ 10 ft. (3048 mm) of peat and/or highly organic clay where H = thickness of soil].

3. Very high plasticity clays [$H >$ 25 ft. (7620 mm) with $PI >$ 75].

4. Very thick soft/medium stiff clays [$H >$ 120 ft. (36 580 mm)].

EXCEPTION: When the soil properties are not known in sufficient detail to determine the soil profile type, Type S_D shall be used. Soil Profile Type S_E need not be assumed unless the building official determines that Soil Profile Type S_E may be present at the site or in the event that Type S_E is established by geotechnical data.

The criteria set forth in the definition for Soil Profile Type S_F requiring site-specific evaluation shall be considered. If the site corresponds to this criteria, the site shall be classified as Soil Profile Type S_F and a site-specific evaluation shall be conducted.

1636.2.1 $\bar{v}_s$, Average shear wave velocity. $\bar{v}_s$ shall be determined in accordance with the following formula:

$$\bar{v}_s = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{v_{si}}} \qquad (36\text{-}1)$$

WHERE:

d_i = thickness of Layer i in feet (m).

v_{si} = shear wave velocity in Layer i in ft./sec. (m/sec).

1636.2.2 $\bar{N}$, average field standard penetration resistance and $\bar{N}_{CH}$, average standard penetration resistance for cohesionless soil layers. $\bar{N}$ and $\bar{N}_{CH}$ shall be determined in accordance with the following formula:

$$\bar{N} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{N_i}} \qquad (36\text{-}2)$$

and

$$\bar{N}_{CH} = \frac{d_s}{\sum_{i=1}^{n} \frac{d_i}{N_i}} \qquad (36\text{-}3)$$

WHERE:

d_i = thickness of Layer i in feet (mm).

d_s = the total thickness of cohesionless soil layers in the top 100 feet (30 480 mm).

N_i = the standard penetration resistance of soil layer in accordance with approved nationally recognized standards.

1636.2.3 $\bar{s}_u$, Average undrained shear strength. $\bar{s}_u$ shall be determined in accordance with the following formula:

$$\bar{s}_u = \frac{d_c}{\sum_{i=1}^{n} \frac{d_i}{S_{ui}}} \qquad (36\text{-}4)$$

WHERE:

d_c = the total thickness $(100 - d_s)$ of cohesive soil layers in the top 100 feet (30 480 mm).

S_{ui} = the undrained shear strength in accordance with approved nationally recognized standards, not to exceed 5,000 psf (250 kPa).

1636.2.4 Soft clay profile, S_E. The existence of a total thickness of soft clay greater than 10 feet (3048 mm) shall be investigated where a soft clay layer is defined by $s_u <$ 500 psf (24 kPa), $w_{mc} \ge$ 40 percent and $PI > 20$. If these criteria are met, the site shall be classified as Soil Profile Type S_E.

1636.2.5 Soil profiles S_C, S_D and S_E. Sites with Soil Profile Types S_C, S_D and S_E shall be classified by using one of the following three methods with $\bar{v}_s$, $\bar{N}$ and $\bar{s}_u$ computed in all cases as specified in Section 1636.2.

1. $\bar{v}_s$ for the top 100 feet (30 480 mm) ($\bar{v}_s$ method).

2. $\bar{N}$ for the top 100 feet (30 480 mm) ($\bar{N}$ method).

3. $\bar{N}_{CH}$ for cohesionless soil layers ($PI < 20$) in the top 100 feet (30 480 mm) and average $\bar{s}_u$ for cohesive soil layers ($PI > 20$) in the top 100 feet (30 480 mm) ($\bar{s}_u$ method).

1636.2.6 Rock profiles, S_A and S_B. The shear wave velocity for rock, Soil Profile Type S_B, shall be either measured on site or estimated by a geotechnical engineer, engineering geologist or seismologist for competent rock with moderate fracturing and weathering. Softer and more highly fractured and weathered rock shall either be measured on site for shear wave velocity or classified as Soil Profile Type S_C.

The hard rock, Soil Profile Type S_A, category shall be supported by shear wave velocity measurement either on site or on profiles of the same rock type in the same formation with an equal or greater degree of weathering and fracturing. Where hard rock conditions are known to be continuous to a depth of 100 feet (30 480 mm), surficial shear wave velocity measurements may be extrapolated to assess $\bar{v}_s$. The rock categories, Soil Profile Types S_A and

S_B, shall not be used if there is more than 10 feet (3048 mm) of soil between the rock surface and the bottom of the spread footing or mat foundation.

The definitions presented herein shall apply to the upper 100 feet (30 480 mm) of the site profile. Profiles containing distinctly different soil layers shall be subdivided into those layers designated by a number from 1 to *n* at the bottom, where there are a total of *n* distinct layers in the upper 100 feet (30 480 mm). The symbol *i* then refers to any one of the layers between 1 and *n*.

TABLE 16-A—UNIFORM AND CONCENTRATED LOADS

USE OR OCCUPANCY		UNIFORM LOAD[1] (psf)	CONCENTRATED LOAD (pounds)
Category	Description	× 0.0479 for kN/m²	× 0.004 48 for kN
1. Access floor systems	Office use	50	2,000[2]
	Computer use	100	2,000[2]
2. Armories		150	0
3. Assembly areas[3] and auditoriums and balconies therewith	Fixed seating areas	50	0
	Movable seating and other areas	100	0
	Stage areas and enclosed platforms	125	0
4. Cornices and marquees		60[4]	0
5. Exit facilities[5]		100	0[6]
6. Garages	General storage and/or repair	100	[7]
	Private or pleasure-type motor vehicle storage	50	[7]
7. Hospitals	Wards and rooms	40	1,000[2]
8. Libraries	Reading rooms	60	1,000[2]
	Stack rooms	125	1,500[2]
9. Manufacturing	Light	75	2,000[2]
	Heavy	125	3,000[2]
10. Offices		50	2,000[2]
11. Printing plants	Press rooms	150	2,500[2]
	Composing and linotype rooms	100	2,000[2]
12. Residential[8]	Basic floor area	40	0[6]
	Exterior balconies	60[4]	0
	Decks	40[4]	0
	Storage	40	0
13. Restrooms[9]			
14. Reviewing stands, grandstands, bleachers, and folding and telescoping seating		100	0
15. Roof decks	Same as area served or for the type of occupancy accommodated		
16. Schools	Classrooms	40	1,000[2]
17. Sidewalks and driveways	Public access	250	[7]
18. Storage	Light	125	
	Heavy	250	
19. Stores		100	3,000[2]
20. Pedestrian bridges and walkways		100	

[1]See Section 1607 for live load reductions.
[2]See Section 1607.3.3, first paragraph, for area of load application.
[3]Assembly areas include such occupancies as dance halls, drill rooms, gymnasiums, playgrounds, plazas, terraces and similar occupancies that are generally accessible to the public.
[4]When snow loads occur that are in excess of the design conditions, the structure shall be designed to support the loads due to the increased loads caused by drift buildup or a greater snow design as determined by the building official. See Section 1614. For special-purpose roofs, see Section 1607.4.4.
[5]Exit facilities shall include such uses as corridors serving an occupant load of 10 or more persons, exterior exit balconies, stairways, fire escapes and similar uses.
[6]Individual stair treads shall be designed to support a 300-pound (1.33 kN) concentrated load placed in a position that would cause maximum stress. Stair stringers may be designed for the uniform load set forth in the table.
[7]See Section 1607.3.3, second paragraph, for concentrated loads. See Table 16-B for vehicle barriers.
[8]Residential occupancies include private dwellings, apartments and hotel guest rooms.
[9]Restroom loads shall not be less than the load for the occupancy with which they are associated, but need not exceed 50 pounds per square foot (2.4 kN/m^2).

TABLE 16-B—SPECIAL LOADS[1]

USE		VERTICAL LOAD	LATERAL LOAD
Category	Description	(pounds per square foot unless otherwise noted)	
		$\times$ 0.0479 for kN/m^2	
1. Construction, public access at site (live load)	Walkway, see Section 3303.6	150	
	Canopy, see Section 3303.7	150	
2. Grandstands, reviewing stands, bleachers, and folding and telescoping seating (live load)	Seats and footboards	120[2]	See Footnote 3
3. Stage accessories (live load)	Catwalks	40	
	Followspot, projection and control rooms	50	
4. Ceiling framing (live load)	Over stages	20	
	All uses except over stages	10[4]	
5. Partitions and interior walls, see Sec. 1611.5 (live load)			5
6. Elevators and dumbwaiters (dead and live loads)		2 $\times$ total loads[5]	
7. Mechanical and electrical equipment (dead load)		Total loads	
8. Cranes (dead and live loads)	Total load including impact increase	1.25 $\times$ total load[6]	0.10 $\times$ total load[7]
9. Balcony railings and guardrails	Exit facilities serving an occupant load greater than 50		50[8]
	Other than exit facilities		20[8]
	Components		25[9]
10. Vehicle barriers	See Section 311.2.3.5		6,000[10]
11. Handrails		See Footnote 11	See Footnote 11
12. Storage racks	Over 8 feet (2438 mm) high	Total loads[12]	See Table 16-O
13. Fire sprinkler structural support		250 pounds (1112 N) plus weight of water-filled pipe[13]	See Table 16-O
14. Explosion exposure	Hazardous occupancies, see Section 307.10		

[1]The tabulated loads are minimum loads. Where other vertical loads required by this code or required by the design would cause greater stresses, they shall be used.
[2]Pounds per lineal foot ($\times$ 14.6 for N/m).
[3]Lateral sway bracing loads of 24 pounds per foot (350 N/m) parallel and 10 pounds per foot (145.9 N/m) perpendicular to seat and footboards.
[4]Does not apply to ceilings that have sufficient total access from below, such that access is not required within the space above the ceiling. Does not apply to ceilings if the attic areas above the ceiling are not provided with access. This live load need not be considered as acting simultaneously with other live loads imposed upon the ceiling framing or its supporting structure.
[5]Where Appendix Chapter 30 has been adopted, see reference standard cited therein for additional design requirements.
[6]The impact factors included are for cranes with steel wheels riding on steel rails. They may be modified if substantiating technical data acceptable to the building official is submitted. Live loads on crane support girders and their connections shall be taken as the maximum crane wheel loads. For pendant-operated traveling crane support girders and their connections, the impact factors shall be 1.10.
[7]This applies in the direction parallel to the runway rails (longitudinal). The factor for forces perpendicular to the rail is 0.20 $\times$ the transverse traveling loads (trolley, cab, hooks and lifted loads). Forces shall be applied at top of rail and may be distributed among rails of multiple rail cranes and shall be distributed with due regard for lateral stiffness of the structures supporting these rails.
[8]A load per lineal foot ($\times$ 14.6 for N/m) to be applied horizontally at right angles to the top rail.
[9]Intermediate rails, panel fillers and their connections shall be capable of withstanding a load of 25 pounds per square foot (1.2 kN/m^2) applied horizontally at right angles over the entire tributary area, including openings and spaces between rails. Reactions due to this loading need not be combined with those of Footnote 8.
[10]A horizontal load in pounds (N) applied at right angles to the vehicle barrier at a height of 18 inches (457 mm) above the parking surface. The force may be distributed over a 1-foot-square (304.8-millimeter-square) area.
[11]The mounting of handrails shall be such that the completed handrail and supporting structure are capable of withstanding a load of at least 200 pounds (890 N) applied in any direction at any point on the rail. These loads shall not be assumed to act cumulatively with Item 9.
[12]Vertical members of storage racks shall be protected from impact forces of operating equipment, or racks shall be designed so that failure of one vertical member will not cause collapse of more than the bay or bays directly supported by that member.
[13]The 250-pound (1.11 kN) load is to be applied to any single fire sprinkler support point but not simultaneously to all support joints.

TABLE 16-C—MINIMUM ROOF LIVE LOADS[1]

ROOF SLOPE	METHOD 1: Tributary Loaded Area in Square Feet for Any Structural Member (× 0.0929 for m²) 0 to 200 — Uniform Load (psf)	201 to 600	Over 600	METHOD 2: Uniform Load[2] (psf)	Rate of Reduction r (percentage)	Maximum Reduction R (percentage)
	× 0.0479 for kN/m²					
1. Flat[3] or rise less than 4 units vertical in 12 units horizontal (33.3% slope). Arch or dome with rise less than one eighth of span	20	16	12	20	.08	40
2. Rise 4 units vertical to less than 12 units vertical in 12 units horizontal (33% to less than 100% slope). Arch or dome with rise one eighth of span to less than three eighths of span	16	14	12	16	.06	25
3. Rise 12 units vertical in 12 units horizontal (100% slope) and greater. Arch or dome with rise three eighths of span or greater	12	12	12	12	No reductions permitted	
4. Awnings except cloth covered[4]	5	5	5	5		
5. Greenhouses, lath houses and agricultural buildings[5]	10	10	10	10		

[1]Where snow loads occur, the roof structure shall be designed for such loads as determined by the building official. See Section 1614. For special-purpose roofs, see Section 1607.4.4.
[2]See Sections 1607.5 and 1607.6 for live load reductions. The rate of reduction r in Section 1607.5 Formula (7-1) shall be as indicated in the table. The maximum reduction R shall not exceed the value indicated in the table.
[3]A flat roof is any roof with a slope of less than $^1/_4$ unit vertical in 12 units horizontal (2% slope). The live load for flat roofs is in addition to the ponding load required by Section 1611.7.
[4]As defined in Section 3206.
[5]See Section 1607.4.4 for concentrated load requirements for greenhouse roof members.

TABLE 16-D—MAXIMUM ALLOWABLE DEFLECTION FOR STRUCTURAL MEMBERS[1]

TYPE OF MEMBER	MEMBER LOADED WITH LIVE LOAD ONLY *(L.)*	MEMBER LOADED WITH LIVE LOAD PLUS DEAD LOAD *(L. + K.D.)*
Roof member supporting plaster or floor member	l/360	l/240

[1]Sufficient slope or camber shall be provided for flat roofs in accordance with Section 1611.7.

L.—live load.

D.— dead load.

K.— factor as determined by Table 16-E.

l— length of member in same units as deflection.

TABLE 16-E—VALUE OF "K"

WOOD: Unseasoned	WOOD: Seasoned[1]	REINFORCED CONCRETE[2]	STEEL
1.0	0.5	$T/(1+50\rho')$	0

[1]Seasoned lumber is lumber having a moisture content of less than 16 percent at time of installation and used under dry conditions of use such as in covered structures.
[2]See also Section 1909 for definitions and other requirements.
ρ' shall be the value at midspan for simple and continuous spans, and at support for cantilevers. Time-dependent factor T for sustained loads may be taken equal to:

five years or more	2.0
twelve months	1.2
six months	1.4
three months	1.0

TABLE 16-F—WIND STAGNATION PRESSURE (q_s) AT STANDARD HEIGHT OF 33 FEET (10 058 mm)

Basic wind speed (mph)[1] (× 1.61 for km/h)	70	80	90	100	110	120	130
Pressure q_s (psf) (× 0.0479 for kN/m^2)	12.6	16.4	20.8	25.6	31.0	36.9	43.3

[1]Wind speed from Section 1618.

TABLE 16-G—COMBINED HEIGHT, EXPOSURE AND GUST FACTOR COEFFICIENT (C_e)[1]

HEIGHT ABOVE AVERAGE LEVEL OF ADJOINING GROUND (feet) × 304.8 for mm	EXPOSURE D	EXPOSURE C	EXPOSURE B
0-15	1.39	1.06	0.62
20	1.45	1.13	0.67
25	1.50	1.19	0.72
30	1.54	1.23	0.76
40	1.62	1.31	0.84
60	1.73	1.43	0.95
80	1.81	1.53	1.04
100	1.88	1.61	1.13
120	1.93	1.67	1.20
160	2.02	1.79	1.31
200	2.10	1.87	1.42
300	2.23	2.05	1.63
400	2.34	2.19	1.80

[1]Values for intermediate heights above 15 feet (4572 mm) may be interpolated.

TABLE 16-H—PRESSURE COEFFICIENTS (C_q)

STRUCTURE OR PART THEREOF	DESCRIPTION	C_q FACTOR
1. Primary frames and systems	**Method 1** (Normal force method)	
	Walls:	
	Windward wall	0.8 inward
	Leeward wall	0.5 outward
	Roofs[1]:	
	Wind perpendicular to ridge	
	Leeward roof or flat roof	0.7 outward
	Windward roof	
	less than 2:12 (16.7%)	0.7 outward
	Slope 2:12 (16.7%) to less than 9:12 (75%)	0.9 outward or 0.3 inward
	Slope 9:12 (75%) to 12:12 (100%)	0.4 inward
	Slope > 12:12 (100%)	0.7 inward
	Wind parallel to ridge and flat roofs	0.7 outward
	Method 2 (Projected area method)	
	On vertical projected area	
	Structures 40 feet (12 192 mm) or less in height	1.3 horizontal any direction
	Structures over 40 feet (12 192 mm) in height	1.4 horizontal any direction
	On horizontal projected area[1]	0.7 upward
2. Elements and components not in areas of discontinuity[2]	Wall elements	
	All structures	1.2 inward
	Enclosed and unenclosed structures	1.2 outward
	Partially enclosed structures	1.6 outward
	Parapets walls	1.3 inward or outward
	Roof elements[3]	
	Enclosed and unenclosed structures	
	Slope < 7:12 (58.3%)	1.3 outward
	Slope 7:12 (58.3%) to 12:12 (100%)	1.3 outward or inward
	Partially enclosed structures	
	Slope < 2:12 (16.7%)	1.7 outward
	Slope 2:12 (16.7%) to 7:12 (58.3%)	1.6 outward or 0.8 inward
	Slope > 7:12 (58.3%) to 12:12 (100%)	1.7 outward or inward
3. Elements and components in areas of discontinuities[2,4,5]	Wall corners[6]	1.5 outward or 1.2 inward
	Roof eaves, rakes or ridges without overhangs[6]	
	Slope < 2:12 (16.7%)	2.3 upward
	Slope 2:12 (16.7%) to 7:12 (58.3%)	2.6 outward
	Slope > 7:12 (58.3%) to 12:12 (100%)	1.6 outward
	For slopes less than 2:12 (16.7%)	
	Overhangs at roof eaves, rakes or ridges, and canopies	0.5 added to values above
4. Chimneys, tanks and solid towers	Square or rectangular	1.4 any direction
	Hexagonal or octagonal	1.1 any direction
	Round or elliptical	0.8 any direction
5. Open-frame towers[7,8]	Square and rectangular	
	Diagonal	4.0
	Normal	3.6
	Triangular	3.2
6. Tower accessories (such as ladders, conduit, lights and elevators)	Cylindrical members	
	2 inches (51 mm) or less in diameter	1.0
	Over 2 inches (51 mm) in diameter	0.8
	Flat or angular members	1.3
7. Signs, flagpoles, lightpoles, minor structures[8]		1.4 any direction

[1]For one story or the top story of multistory partially enclosed structures, an additional value of 0.5 shall be added to the outward C_q. The most critical combination shall be used for design. For definition of partially enclosed structures, see Section 1616.

[2]C_q values listed are for 10-square-foot (0.93 m^2) tributary areas. For tributary areas of 100 square feet (9.29 m^2), the value of 0.3 may be subtracted from C_q, except for areas at discontinuities with slopes less than 7 units vertical in 12 units horizontal (58.3% slope) where the value of 0.8 may be subtracted from C_q. Interpolation may be used for tributary areas between 10 and 100 square feet (0.93 m^2 and 9.29 m^2). For tributary areas greater than 1,000 square feet (92.9 m^2), use primary frame values.

[3]For slopes greater than 12 units vertical in 12 units horizontal (100% slope), use wall element values.

[4]Local pressures shall apply over a distance from the discontinuity of 10 feet (3048 mm) or 0.1 times the least width of the structure, whichever is smaller.

[5]Discontinuities at wall corners or roof ridges are defined as discontinuous breaks in the surface where the included interior angle measures 170 degrees or less.

[6]Load is to be applied on either side of discontinuity but not simultaneously on both sides.

[7]Wind pressures shall be applied to the total normal projected area of all elements on one face. The forces shall be assumed to act parallel to the wind direction.

[8]Factors for cylindrical elements are two thirds of those for flat or angular elements.

TABLE 16-I—SEISMIC ZONE FACTOR Z

ZONE	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

NOTE: The zone shall be determined from the seismic zone map in Figure 16-2.

TABLE 16-J—SOIL PROFILE TYPES

SOIL PROFILE TYPE	SOIL PROFILE NAME/GENERIC DESCRIPTION	AVERAGE SOIL PROPERTIES FOR TOP 100 FEET (30 480 mm) OF SOIL PROFILE		
		Shear Wave Velocity, $\bar{v}_s$ feet/second (m/s)	Standard Penetration Test, $\bar{N}$ [or $\bar{N}_{CH}$ for cohesionless soil layers] (blows/foot)	Undrained Shear Strength, $\bar{s}_u$ psf (kPa)
S_A	Hard Rock	> 5,000 (1,500)	—	—
S_B	Rock	2,500 to 5,000 (760 to 1,500)		
S_C	Very Dense Soil and Soft Rock	1,200 to 2,500 (360 to 760)	> 50	> 2,000 (100)
S_D	Stiff Soil Profile	600 to 1,200 (180 to 360)	15 to 50	1,000 to 2,000 (50 to 100)
S_E[1]	Soft Soil Profile	< 600 (180)	< 15	< 1,000 (50)
S_F	Soil Requiring Site-specific Evaluation. See Section 1629.3.1.			

[1]Soil Profile Type S_E also includes any soil profile with more than 10 feet (3048 mm) of soft clay defined as a soil with a plasticity index, $PI > 20$, $w_{mc} \geq 40$ percent and $s_u < 500$ psf (24 kPa). The Plasticity Index, PI, and the moisture content, w_{mc}, shall be determined in accordance with approved national standards.

TABLE 16-K—OCCUPANCY CATEGORY

OCCUPANCY CATEGORY	OCCUPANCY OR FUNCTIONS OF STRUCTURE	SEISMIC IMPORTANCE FACTOR, I	SEISMIC IMPORTANCE[1] FACTOR, I_p	WIND IMPORTANCE FACTOR, I_w
1. Essential facilities[2]	Group I, Division 1 Occupancies having surgery and emergency treatment areas Fire and police stations Garages and shelters for emergency vehicles and emergency aircraft Structures and shelters in emergency-preparedness centers Aviation control towers Structures and equipment in government communication centers and other facilities required for emergency response Standby power-generating equipment for Category 1 facilities Tanks or other structures containing housing or supporting water or other fire-suppression material or equipment required for the protection of Category 1, 2 or 3 structures	1.25	1.50	1.15
2. Hazardous facilities	Group H, Divisions 1, 2, 6 and 7 Occupancies and structures therein housing or supporting toxic or explosive chemicals or substances Nonbuilding structures housing, supporting or containing quantities of toxic or explosive substances that, if contained within a building, would cause that building to be classified as a Group H, Division 1, 2 or 7 Occupancy	1.25	1.50	1.15
3. Special occupancy structures[3]	Group A, Divisions 1, 2 and 2.1 Occupancies Buildings housing Group E, Divisions 1 and 3 Occupancies with a capacity greater than 300 students Buildings housing Group B Occupancies used for college or adult education with a capacity greater than 500 students Group I, Divisions 1 and 2 Occupancies with 50 or more resident incapacitated patients, but not included in Category 1 Group I, Division 3 Occupancies All structures with an occupancy greater than 5,000 persons Structures and equipment in power-generating stations, and other public utility facilities not included in Category 1 or Category 2 above, and required for continued operation	1.00	1.00	1.00
4. Standard occupancy structures[3]	All structures housing occupancies or having functions not listed in Category 1, 2 or 3 and Group U Occupancy towers	1.00	1.00	1.00
5. Miscellaneous structures	Group U Occupancies except for towers	1.00	1.00	1.00

[1]The limitation of I_p for panel connections in Section 1633.2.4 shall be 1.0 for the entire connector.
[2]Structural observation requirements are given in Section 1702.
[3]For anchorage of machinery and equipment required for life-safety systems, the value of I_p shall be taken as 1.5.

TABLE 16-L—VERTICAL STRUCTURAL IRREGULARITIES

IRREGULARITY TYPE AND DEFINITION	REFERENCE SECTION
1. **Stiffness irregularity—soft story** A soft story is one in which the lateral stiffness is less than 70 percent of that in the story above or less than 80 percent of the average stiffness of the three stories above.	1629.8.4, Item 2
2. **Weight (mass) irregularity** Mass irregularity shall be considered to exist where the effective mass of any story is more than 150 percent of the effective mass of an adjacent story. A roof that is lighter than the floor below need not be considered.	1629.8.4, Item 2
3. **Vertical geometric irregularity** Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral-force-resisting system in any story is more than 130 percent of that in an adjacent story. One-story penthouses need not be considered.	1629.8.4, Item 2
4. **In-plane discontinuity in vertical lateral-force-resisting element** An in-plane offset of the lateral-load-resisting elements greater than the length of those elements.	1630.8.2
5. **Discontinuity in capacity—weak story** A weak story is one in which the story strength is less than 80 percent of that in the story above. The story strength is the total strength of all seismic-resisting elements sharing the story shear for the direction under consideration.	1629.9.1

TABLE 16-M—PLAN STRUCTURAL IRREGULARITIES

IRREGULARITY TYPE AND DEFINITION	REFERENCE SECTION
1. **Torsional irregularity—to be considered when diaphragms are not flexible** Torsional irregularity shall be considered to exist when the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts of the two ends of the structure.	1633.1, 1633.2.9, Item 6
2. **Re-entrant corners** Plan configurations of a structure and its lateral-force-resisting system contain re-entrant corners, where both projections of the structure beyond a re-entrant corner are greater than 15 percent of the plan dimension of the structure in the given direction.	1633.2.9, Items 6 and 7
3. **Diaphragm discontinuity** Diaphragms with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 50 percent of the gross enclosed area of the diaphragm, or changes in effective diaphragm stiffness of more than 50 percent from one story to the next.	1633.2.9, Item 6
4. **Out-of-plane offsets** Discontinuities in a lateral force path, such as out-of-plane offsets of the vertical elements.	1630.8.2; 1633.2.9, Item 6; 2213.9.1
5. **Nonparallel systems** The vertical lateral-load-resisting elements are not parallel to or symmetric about the major orthogonal axes of the lateral-force-resisting system.	1633.1

TABLE 16-N—STRUCTURAL SYSTEMS[1]

BASIC STRUCTURAL SYSTEM[2]	LATERAL-FORCE-RESISTING SYSTEM DESCRIPTION	*R*	Ω_o	HEIGHT LIMIT FOR SEISMIC ZONES 3 AND 4 (feet) × 304.8 for mm
1. Bearing wall system	1. Light-framed walls with shear panels			
	a. Wood structural panel walls for structures three stories or less	5.5	2.8	65
	b. All other light-framed walls	4.5	2.8	65
	2. Shear walls			
	a. Concrete	4.5	2.8	160
	b. Masonry	4.5	2.8	160
	3. Light steel-framed bearing walls with tension-only bracing	2.8	2.2	65
	4. Braced frames where bracing carries gravity load			
	a. Steel	4.4	2.2	160
	b. Concrete[3]	2.8	2.2	—
	c. Heavy timber	2.8	2.2	65
2. Building frame system	1. Steel eccentrically braced frame (EBF)	7.0	2.8	240
	2. Light-framed walls with shear panels			
	a. Wood structural panel walls for structures three stories or less	6.5	2.8	65
	b. All other light-framed walls	5.0	2.8	65
	3. Shear walls			
	a. Concrete	5.5	2.8	240
	b. Masonry	5.5	2.8	160
	4. Ordinary braced frames			
	a. Steel	5.6	2.2	160
	b. Concrete[3]	5.6	2.2	—
	c. Heavy timber	5.6	2.2	65
	5. Special concentrically braced frames			
	a. Steel	6.4	2.2	240
3. Moment-resisting frame system	1. Special moment-resisting frame (SMRF)			
	a. Steel	8.5	2.8	N.L.
	b. Concrete[4]	8.5	2.8	N.L.
	2. Masonry moment-resisting wall frame (MMRWF)	6.5	2.8	160
	3. Concrete intermediate moment-resisting frame (IMRF)[5]	5.5	2.8	—
	4. Ordinary moment-resisting frame (OMRF)			
	a. Steel[6]	4.5	2.8	160
	b. Concrete[7]	3.5	2.8	—
	5. Special truss moment frames of steel (STMF)	6.5	2.8	240
4. Dual systems	1. Shear walls			
	a. Concrete with SMRF	8.5	2.8	N.L.
	b. Concrete with steel OMRF	4.2	2.8	160
	c. Concrete with concrete IMRF[5]	6.5	2.8	160
	d. Masonry with SMRF	5.5	2.8	160
	e. Masonry with steel OMRF	4.2	2.8	160
	f. Masonry with concrete IMRF[3]	4.2	2.8	—
	g. Masonry with masonry MMRWF	6.0	2.8	160
	2. Steel EBF			
	a. With steel SMRF	8.5	2.8	N.L.
	b. With steel OMRF	4.2	2.8	160
	3. Ordinary braced frames			
	a. Steel with steel SMRF	6.5	2.8	N.L.
	b. Steel with steel OMRF	4.2	2.8	160
	c. Concrete with concrete SMRF[3]	6.5	2.8	—
	d. Concrete with concrete IMRF[3]	4.2	2.8	—
	4. Special concentrically braced frames			
	a. Steel with steel SMRF	7.5	2.8	N.L.
	b. Steel with steel OMRF	4.2	2.8	160
5. Cantilevered column building systems	1. Cantilevered column elements	2.2	2.0	35[7]
6. Shear wall-frame interaction systems	1. Concrete[8]	5.5	2.8	160
7. Undefined systems	See Sections 1629.6.7 and 1629.9.2	—	—	—

N.L.—no limit

[1]See Section 1630.4 for combination of structural systems.

[2]Basic structural systems are defined in Section 1629.6.

[3]Prohibited in Seismic Zones 3 and 4.

[4]Includes precast concrete conforming to Section 1921.2.7.

[5]Prohibited in Seismic Zones 3 and 4, except as permitted in Section 1634.2.

[6]Ordinary moment-resisting frames in Seismic Zone 1 meeting the requirements of Section 2211.6 may use a *R* value of 8.

[7] Total height of the building including cantilevered columns.

[8]Prohibited in Seismic Zones 2A, 2B, 3 and 4. See Section 1633.2.7.

TABLE 16-O—HORIZONTAL FORCE FACTORS, a_p AND R_p

ELEMENTS OF STRUCTURES AND NONSTRUCTURAL COMPONENTS AND EQUIPMENT[1]	a_p	R_p	FOOTNOTE
1. Elements of Structures A. Walls including the following: (1) Unbraced (cantilevered) parapets.	2.5	3.0	
(2) Exterior walls at or above the ground floor and parapets braced above their centers of gravity.	1.0	3.0	2
(3) All interior-bearing and nonbearing walls.	1.0	3.0	2
B. Penthouse (except when framed by an extension of the structural frame).	2.5	4.0	
C. Connections for prefabricated structural elements other than walls. See also Section 1632.2.	1.0	3.0	3
2. Nonstructural Components A. Exterior and interior ornamentations and appendages.	2.5	3.0	
B. Chimneys, stacks and trussed towers supported on or projecting above the roof: (1) Laterally braced or anchored to the structural frame at a point below their centers of mass.	2.5	3.0	
(2) Laterally braced or anchored to the structural frame at or above their centers of mass.	1.0	3.0	
C. Signs and billboards.	2.5	3.0	
D. Storage racks (include contents) over 6 feet (1829 mm) tall.	2.5	4.0	4
E. Permanent floor-supported cabinets and book stacks more than 6 feet (1829 mm) in height (include contents).	1.0	3.0	5
F. Anchorage and lateral bracing for suspended ceilings and light fixtures.	1.0	3.0	3, 6, 7, 8
G. Access floor systems.	1.0	3.0	4, 5, 9
H. Masonry or concrete fences over 6 feet (1829 mm) high.	1.0	3.0	
I. Partitions.	1.0	3.0	
3. Equipment A. Tanks and vessels (include contents), including support systems.	1.0	3.0	
B. Electrical, mechanical and plumbing equipment and associated conduit and ductwork and piping.	1.0	3.0	5, 10, 11, 12, 13, 14, 15, 16
C. Any flexible equipment laterally braced or anchored to the structural frame at a point below their center of mass.	2.5	3.0	5, 10, 14, 15, 16
D. Anchorage of emergency power supply systems and essential communications equipment. Anchorage and support systems for battery racks and fuel tanks necessary for operation of emergency equipment. See also Section 1632.2.	1.0	3.0	17, 18
E. Temporary containers with flammable or hazardous materials.	1.0	3.0	19
4. Other Components A. Rigid components with ductile material and attachments.	1.0	3.0	1
B. Rigid components with nonductile material or attachments.	1.0	1.5	1
C. Flexible components with ductile material and attachments.	2.5	3.0	1
D. Flexible components with nonductile material or attachments.	2.5	1.5	1

[1]See Section 1627 for definitions of flexible components and rigid components.

[2]See Sections 1633.2.4 and 1633.2.8 for concrete and masonry walls and Section 1632.2 for connections for panel connectors for panels.

[3]Applies to Seismic Zones 2, 3 and 4 only.

[4]Ground supported steel storage racks may be designed using the provisions of Section 1634. Chapter 22, Division VI, may be used for design, provided seismic design forces are equal to or greater than those specified in Section 1632.2 or 1634.2, as appropriate.

[5]Only attachments, anchorage or restraints need be designed.

[6]Ceiling weight shall include all light fixtures and other equipment or partitions that are laterally supported by the ceiling. For purposes of determining the seismic force, a ceiling weight of not less than 4 psf (0.19 kN/m^2) shall be used.

[7]Ceilings constructed of lath and plaster or gypsum board screw or nail attached to suspended members that support a ceiling at one level extending from wall to wall need not be analyzed, provided the walls are not over 50 feet (15 240 mm) apart.

[8]Light fixtures and mechanical services installed in metal suspension systems for acoustical tile and lay-in panel ceilings shall be independently supported from the structure above as specified in UBC Standard 25-2, Part III.

[9]W_p for access floor systems shall be the dead load of the access floor system plus 25 percent of the floor live load plus a 10-psf (0.48 kN/m^2) partition load allowance.

[10]Equipment includes, but is not limited to, boilers, chillers, heat exchangers, pumps, air-handling units, cooling towers, control panels, motors, switchgear, transformers and life-safety equipment. It shall include major conduit, ducting and piping, which services such machinery and equipment and fire sprinkler systems. See Section 1632.2 for additional requirements for determining a_p for nonrigid or flexibly mounted equipment.

[11]Seismic restraints may be omitted from piping and duct supports if all the following conditions are satisfied:

[11.1]Lateral motion of the piping or duct will not cause damaging impact with other systems.

[11.2]The piping or duct is made of ductile material with ductile connections.

[11.3]Lateral motion of the piping or duct does not cause impact of fragile appurtenances (e.g., sprinkler heads) with any other equipment, piping or structural member.

[11.4]Lateral motion of the piping or duct does not cause loss of system vertical support.

[11.5]Rod-hung supports of less than 12 inches (305 mm) in length have top connections that cannot develop moments.

[11.6]Support members cantilevered up from the floor are checked for stability.

(Continued)

FOOTNOTES TO TABLE 16-O—(Continued)

[12]Seismic restraints may be omitted from electrical raceways, such as cable trays, conduit and bus ducts, if all the following conditions are satisfied:

[12.1]Lateral motion of the raceway will not cause damaging impact with other systems.

[12.2]Lateral motion of the raceway does not cause loss of system vertical support.

[12.3]Rod-hung supports of less than 12 inches (305 mm) in length have top connections that cannot develop moments.

[12.4]Support members cantilevered up from the floor are checked for stability.

[13]Piping, ducts and electrical raceways, which must be functional following an earthquake, spanning between different buildings or structural systems shall be sufficiently flexible to withstand relative motion of support points assuming out-of-phase motions.

[14]Vibration isolators supporting equipment shall be designed for lateral loads or restrained from displacing laterally by other means. Restraint shall also be provided, which limits vertical displacement, such that lateral restraints do not become disengaged. a_p and R_p for equipment supported on vibration isolators shall be taken as 2.5 and 1.5, respectively, except that if the isolation mounting frame is supported by shallow or expansion anchors, the design forces for the anchors calculated by Formula (32-1), (32-2) or (32-3) shall be additionally multiplied by a factor of 2.0.

[15]Equipment anchorage shall not be designed such that lateral loads are resisted by gravity friction (e.g., friction clips).

[16]Expansion anchors, which are required to resist seismic loads in tension, shall not be used where operational vibrating loads are present.

[17]Movement of components within electrical cabinets, rack- and skid-mounted equipment and portions of skid-mounted electromechanical equipment that may cause damage to other components by displacing, shall be restricted by attachment to anchored equipment or support frames.

[18]Batteries on racks shall be restrained against movement in all directions due to earthquake forces.

[19]Seismic restraints may include straps, chains, bolts, barriers or other mechanisms that prevent sliding, falling and breach of containment of flammable and toxic materials. Friction forces may not be used to resist lateral loads in these restraints unless positive uplift restraint is provided which ensures that the friction forces act continuously.

TABLE 16-P—R AND Ω_o FACTORS FOR NONBUILDING STRUCTURES

STRUCTURE TYPE	R	Ω_o
1. Vessels, including tanks and pressurized spheres, on braced or unbraced legs.	2.2	2.0
2. Cast-in-place concrete silos and chimneys having walls continuous to the foundations.	3.6	2.0
3. Distributed mass cantilever structures such as stacks, chimneys, silos and skirt-supported vertical vessels.	2.9	2.0
4. Trussed towers (freestanding or guyed), guyed stacks and chimneys.	2.9	2.0
5. Cantilevered column-type structures.	2.2	2.0
6. Cooling towers.	3.6	2.0
7. Bins and hoppers on braced or unbraced legs.	2.9	2.0
8. Storage racks.	3.6	2.0
9. Signs and billboards.	3.6	2.0
10. Amusement structures and monuments.	2.2	2.0
11. All other self-supporting structures not otherwise covered.	2.9	2.0

TABLE 16-Q—SEISMIC COEFFICIENT C_a

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR, Z				
	Z = 0.075	Z = 0.15	Z = 0.2	Z = 0.3	Z = 0.4
S_A	0.06	0.12	0.16	0.24	$0.32N_a$
S_B	0.08	0.15	0.20	0.30	$0.40N_a$
S_C	0.09	0.18	0.24	0.33	$0.40N_a$
S_D	0.12	0.22	0.28	0.36	$0.44N_a$
S_E	0.19	0.30	0.34	0.36	$0.36N_a$
S_F	See Footnote 1				

[1]Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for Soil Profile Type S_F.

TABLE 16-R—SEISMIC COEFFICIENT C_v

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR, Z				
	Z = 0.075	Z = 0.15	Z = 0.2	Z = 0.3	Z = 0.4
S_A	0.06	0.12	0.16	0.24	$0.32N_v$
S_B	0.08	0.15	0.20	0.30	$0.40N_v$
S_C	0.13	0.25	0.32	0.45	$0.56N_v$
S_D	0.18	0.32	0.40	0.54	$0.64N_v$
S_E	0.26	0.50	0.64	0.84	$0.96N_v$
S_F	See Footnote 1				

[1]Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for Soil Profile Type S_F.

TABLE 16-S—NEAR-SOURCE FACTOR N_a[1]

SEISMIC SOURCE TYPE	CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE[2,3]		
	≤ 2 km	5 km	≥ 10 km
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

[1]The Near-Source Factor may be based on the linear interpolation of values for distances other than those shown in the table.

[2]The location and type of seismic sources to be used for design shall be established based on approved geotechnical data (e.g., most recent mapping of active faults by the United States Geological Survey or the California Division of Mines and Geology).

[3]The closest distance to seismic source shall be taken as the minimum distance between the site and the area described by the vertical projection of the source on the surface (i.e., surface projection of fault plane). The surface projection need not include portions of the source at depths of 10 km or greater. The largest value of the Near-Source Factor considering all sources shall be used for design.

TABLE 16-T—NEAR-SOURCE FACTOR N_v[1]

SEISMIC SOURCE TYPE	CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE[2,3]			
	≤ 2 km	5 km	10 km	≥ 15 km
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

[1]The Near-Source Factor may be based on the linear interpolation of values for distances other than those shown in the table.

[2]The location and type of seismic sources to be used for design shall be established based on approved geotechnical data (e.g., most recent mapping of active faults by the United States Geological Survey or the California Division of Mines and Geology).

[3]The closest distance to seismic source shall be taken as the minimum distance between the site and the area described by the vertical projection of the source on the surface (i.e., surface projection of fault plane). The surface projection need not include portions of the source at depths of 10 km or greater. The largest value of the Near-Source Factor considering all sources shall be used for design.

TABLE 16-U—SEISMIC SOURCE TYPE[1]

SEISMIC SOURCE TYPE	SEISMIC SOURCE DESCRIPTION	SEISMIC SOURCE DEFINITION[2]	
		Maximum Moment Magnitude, M	Slip Rate, SR (mm/year)
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity	$M \geq 7.0$	$SR \geq 5$
B	All faults other than Types A and C	$M \geq 7.0$ $M < 7.0$ $M \geq 6.5$	$SR < 5$ $SR > 2$ $SR < 2$
C	Faults that are not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity	$M < 6.5$	$SR \leq 2$

[1]Subduction sources shall be evaluated on a site-specific basis.

[2]Both maximum moment magnitude and slip rate conditions must be satisfied concurrently when determining the seismic source type.

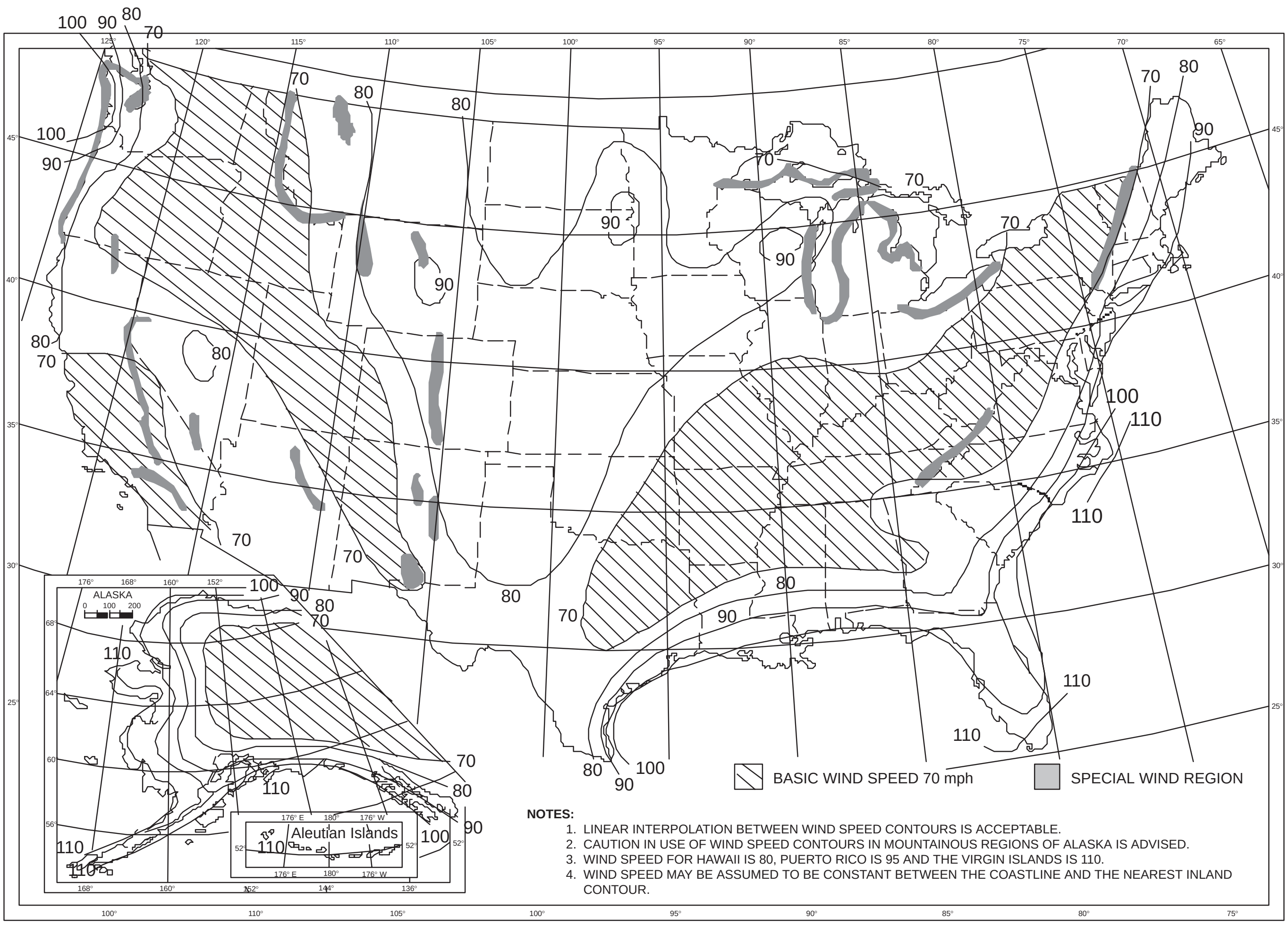


FIGURE 16-1—MINIMUM BASIC WIND SPEEDS IN MILES PER HOUR (× 1.61 for km/h)

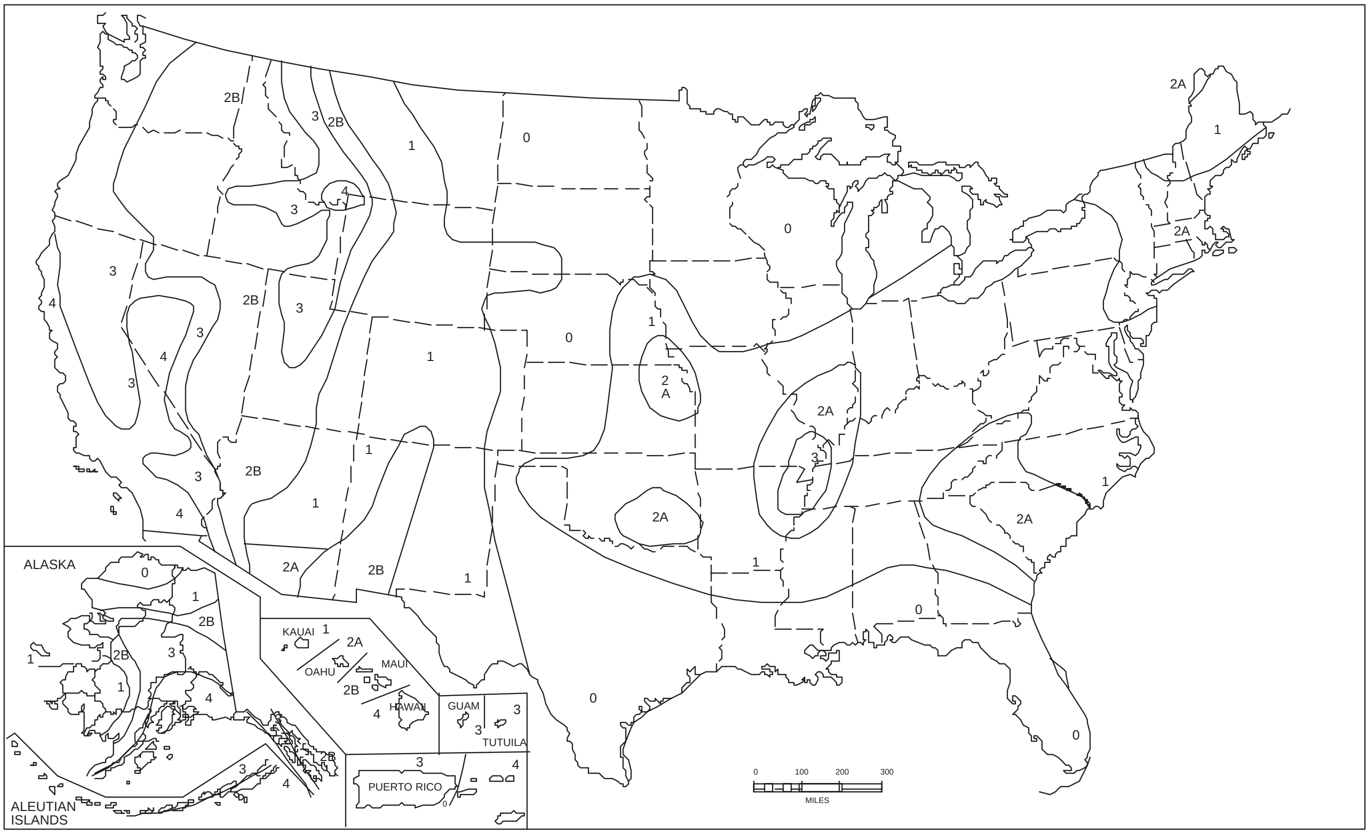


FIGURE 16-2—SEISMIC ZONE MAP OF THE UNITED STATES
For areas outside of the United States, see Appendix Chapter 16.

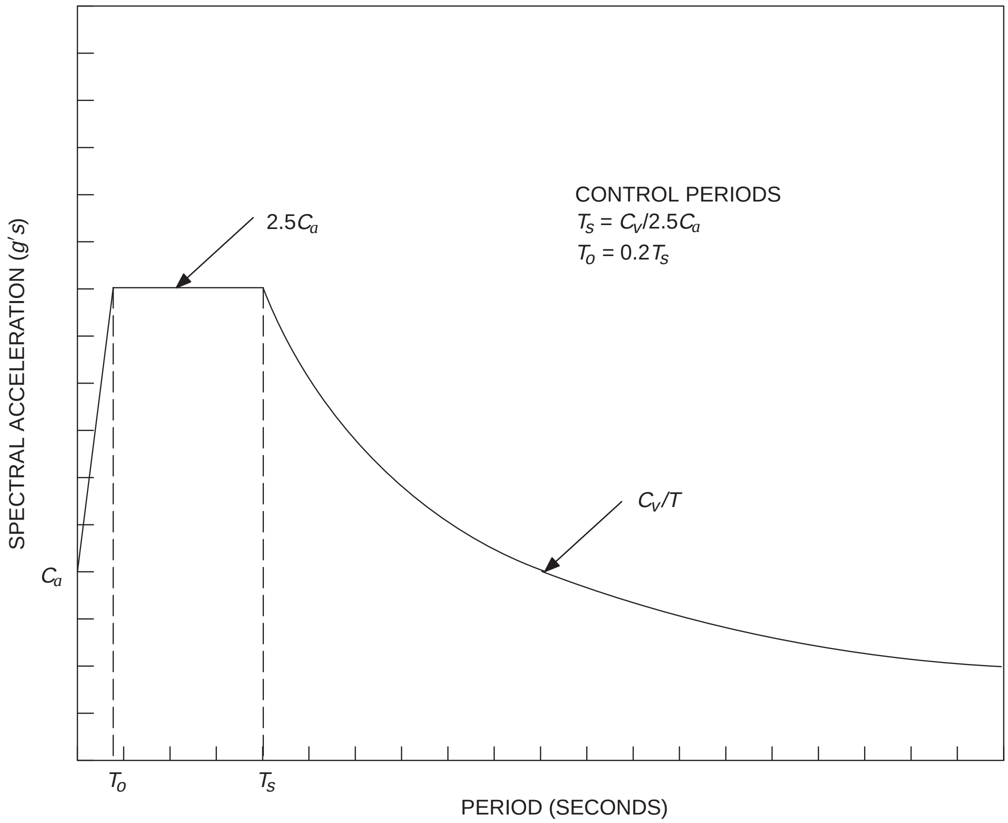


FIGURE 16-3—DESIGN RESPONSE SPECTRA

Chapter 17
STRUCTURAL TESTS AND INSPECTIONS

SECTION 1701 — SPECIAL INSPECTIONS

1701.1 General. In addition to the inspections required by Section 108, the owner or the engineer or architect of record acting as the owner's agent shall employ one or more special inspectors who shall provide inspections during construction on the types of work listed under Section 1701.5.

EXCEPTION: The building official may waive the requirement for the employment of a special inspector if the construction is of a minor nature.

1701.2 Special Inspector. The special inspector shall be a qualified person who shall demonstrate competence, to the satisfaction of the building official, for inspection of the particular type of construction or operation requiring special inspection.

1701.3 Duties and Responsibilities of the Special Inspector. The special inspector shall observe the work assigned for conformance to the approved design drawings and specifications.

The special inspector shall furnish inspection reports to the building official, the engineer or architect of record, and other designated persons. All discrepancies shall be brought to the immediate attention of the contractor for correction, then, if uncorrected, to the proper design authority and to the building official.

The special inspector shall submit a final signed report stating whether the work requiring special inspection was, to the best of the inspector's knowledge, in conformance to the approved plans and specifications and the applicable workmanship provisions of this code.

1701.4 Standards of Quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards. (See Sections 3503 and 3504.)

1. **Concrete.**

ASTM C 94, Ready-mixed Concrete

2. **Connections.**

Specification for Structural Joints Using ASTM A 325 or A 490 Bolts-Load and Resistance Factor Design, Research Council of Structural Connections, Section 1701.5, Item 6.

Specification for Structural Joints Using ASTM A 325 or A 490 Bolts-Allowable Stress Design, Research Council of Structural Connections, Section 1701.5, Item 6.

3. **Spray-applied Fire-resistive Materials.**

UBC Standard 7-6, Thickness and Density Determination for Spray-applied Fire-resistive Materials

1701.5 Types of Work. Except as provided in Section 1701.1, the types of work listed below shall be inspected by a special inspector.

1. **Concrete.** During the taking of test specimens and placing of reinforced concrete. See Item 12 for shotcrete.

EXCEPTIONS: 1. Concrete for foundations conforming to minimum requirements of Table 18-I-C or for Group R, Division 3 or Group U, Division 1 Occupancies, provided the building official finds that a special hazard does not exist.

2. For foundation concrete, other than cast-in-place drilled piles or caissons, where the structural design is based on an f'_c no greater than 2,500 pounds per square inch (psi) (17.2 MPa).

3. Nonstructural slabs on grade, including prestressed slabs on grade when effective prestress in concrete is less than 150 psi (1.03 MPa).

4. Site work concrete fully supported on earth and concrete where no special hazard exists.

2. **Bolts installed in concrete.** Prior to and during the placement of concrete around bolts when stress increases permitted by Footnote 5 of Table 19-D or Section 1923 are utilized.

3. **Special moment-resisting concrete frame.** For moment frames resisting design seismic load in structures within Seismic Zones 3 and 4, the special inspector shall provide reports to the person responsible for the structural design and shall provide continuous inspection of the placement of the reinforcement and concrete.

4. **Reinforcing steel and prestressing steel tendons.**

4.1 During all stressing and grouting of tendons in prestressed concrete.

4.2 During placing of reinforcing steel and prestressing tendons for all concrete required to have special inspection by Item 1.

EXCEPTION: The special inspector need not be present continuously during placing of reinforcing steel and prestressing tendons, provided the special inspector has inspected for conformance to the approved plans prior to the closing of forms or the delivery of concrete to the jobsite.

5. **Structural welding.**

5.1 **General.** During the welding of any member or connection that is designed to resist loads and forces required by this code.

EXCEPTIONS: 1. Welding done in an approved fabricator's shop in accordance with Section 1701.7.

2. The special inspector need not be continuously present during welding of the following items, provided the materials, qualifications of welding procedures and welders are verified prior to the start of work; periodic inspections are made of work in progress; and a visual inspection of all welds is made prior to completion or prior to shipment of shop welding:

2.1 Single-pass fillet welds not exceeding $^5/_{16}$ inch (7.9 mm) in size.

2.2 Floor and roof deck welding.

2.3 Welded studs when used for structural diaphragm or composite systems.

2.4 Welded sheet steel for cold-formed steel framing members such as studs and joists.

2.5 Welding of stairs and railing systems.

5.2 **Special moment-resisting steel frames.** During the welding of special moment-resisting steel frames. In addition to Item 5.1 requirements, nondestructive testing as required by Section 1703 of this code.

5.3 **Welding of reinforcing steel.** During the welding of reinforcing steel.

EXCEPTION: The special inspector need not be continuously present during the welding of ASTM A 706 reinforcing steel not larger than No. 5 bars used for embedments, provided the materials, qualifications of welding procedures and welders are verified prior to the start of work; periodic inspections are made of work in progress; and a visual inspection of all welds is made prior to completion or prior to shipment of shop welding.

6. **High-strength bolting.** The inspection of high-strength A 325 and A 490 bolts shall be in accordance with approved

nationally recognized standards and the requirements of this section.

While the work is in progress, the special inspector shall determine that the requirements for bolts, nuts, washers and paint; bolted parts; and installation and tightening in such standards are met. Such inspections may be performed on a periodic basis in accordance with the requirements of Section 1701.6. The special inspector shall observe the calibration procedures when such procedures are required by the plans or specifications and shall monitor the installation of bolts to determine that all plies of connected materials have been drawn together and that the selected procedure is properly used to tighten all bolts.

7. **Structural masonry.**

7.1 For masonry, other than fully grouted open-end hollow-unit masonry, during preparation and taking of any required prisms or test specimens, placing of all masonry units, placement of reinforcement, inspection of grout space, immediately prior to closing of clean-outs, and during all grouting operations.

EXCEPTION: For hollow-unit masonry where the f'_m is no more than 1,500 psi (10.34 MPa) for concrete units or 2,600 psi (17.93 MPa) for clay units, special inspection may be performed as required for fully grouted open-end hollow-unit masonry specified in Item 7.2.

7.2 For fully grouted open-end hollow-unit masonry during preparation and taking of any required prisms or test specimens, at the start of laying units, after the placement of reinforcing steel, grout space prior to each grouting operation, and during all grouting operations.

EXCEPTION: Special inspection as required in Items 7.1 and 7.2 need not be provided when design stresses have been adjusted as specified in Chapter 21 to permit noncontinuous inspection.

8. **Reinforced gypsum concrete.** When cast-in-place Class B gypsum concrete is being mixed and placed.

9. **Insulating concrete fill.** During the application of insulating concrete fill when used as part of a structural system.

EXCEPTION: The special inspections may be limited to an initial inspection to check the deck surface and placement of reinforcing. The special inspector shall supervise the preparation of compression test specimens during this initial inspection.

10. **Spray-applied fire-resistive materials.** As required by UBC Standard 7-6.

11. **Piling, drilled piers and caissons.** During driving and testing of piles and construction of cast-in-place drilled piles or caissons. See Items l and 4 for concrete and reinforcing steel inspection.

12. **Shotcrete.** During the taking of test specimens and placing of all shotcrete and as required by Sections 1924.10 and 1924.11.

EXCEPTION: Shotcrete work fully supported on earth, minor repairs and when, in the opinion of the building official, no special hazard exists.

13. **Special grading, excavation and filling.** During earth-work excavations, grading and filling operations inspection to satisfy requirements of Chapter 18 and Appendix Chapter 33.

14. **Smoke-control system.**

14.1 During erection of ductwork and prior to concealment for the purposes of leakage testing and recording of device location.

14.2 Prior to occupancy and after sufficient completion for the purposes of pressure difference testing, flow measurements, and detection and control verification.

15. **Special cases.** Work that, in the opinion of the building official, involves unusual hazards or conditions.

1701.6 Continuous and Periodic Special Inspection.

1701.6.1 Continuous special inspection. Continuous special inspection means that the special inspector is on the site at all times observing the work requiring special inspection.

1701.6.2 Periodic special inspection. Some inspections may be made on a periodic basis and satisfy the requirements of continuous inspection, provided this periodic scheduled inspection is performed as outlined in the project plans and specifications and approved by the building official.

1701.7 Approved Fabricators. Special inspections required by this section and elsewhere in this code are not required where the work is done on the premises of a fabricator registered and approved by the building official to perform such work without special inspection. The certificate of registration shall be subject to revocation by the building official if it is found that any work done pursuant to the approval is in violation of this code. The approved fabricator shall submit a certificate of compliance that the work was performed in accordance with the approved plans and specifications to the building official and to the engineer or architect of record. The approved fabricator's qualifications shall be contingent on compliance with the following:

1. The fabricator has developed and submitted a detailed fabrication procedural manual reflecting key quality control procedures that will provide a basis for inspection control of workmanship and the fabricator plant.

2. Verification of the fabricator's quality control capabilities, plant and personnel as outlined in the fabrication procedural manual shall be by an approved inspection or quality control agency.

3. Periodic plant inspections shall be conducted by an approved inspection or quality control agency to monitor the effectiveness of the quality control program.

4. It shall be the responsibility of the inspection or quality control agency to notify the approving authority in writing of any change to the procedural manual. Any fabricator approval may be revoked for just cause. Reapproval of the fabricator shall be contingent on compliance with quality control procedures during the past year.

SECTION 1702 — STRUCTURAL OBSERVATION

Structural observation shall be provided in Seismic Zone 3 or 4 when one of the following conditions exists:

1. The structure is defined in Table 16-K as Occupancy Category 1, 2 or 3,

2. The structure is required to comply with Section 403,

3. The structure is in Seismic Zone 4, N_a as set forth in Table 16-S is greater than one, and a lateral design is required for the entire structure,

EXCEPTION: One- and two-story Group R, Division 3 and Group U Occupancies and one- and two-story Groups B, F, M and S Occupancies.

4. When so designated by the architect or engineer of record, or

5. When such observation is specifically required by the building official.

The owner shall employ the engineer or architect responsible for the structural design, or another engineer or architect designated by the engineer or architect responsible for the structural design, to perform structural observation as defined in Section 220. Observed deficiencies shall be reported in writing to the owner's representative, special inspector, contractor and the building official. The structural observer shall submit to the building official a written statement that the site visits have been made and identifying any reported deficiencies that, to the best of the structural observer's knowledge, have not been resolved.

SECTION 1703 — NONDESTRUCTIVE TESTING

In Seismic Zones 3 and 4, welded, fully restrained connections between the primary members of ordinary moment frames and special moment-resisting frames shall be tested by nondestructive methods for compliance with approved standards and job specifications. This testing shall be a part of the special inspection requirements of Section 1701.5. A program for this testing shall be established by the person responsible for structural design and as shown on plans and specifications.

As a minimum, this program shall include the following:

1. All complete penetration groove welds contained in joints and splices shall be tested 100 percent either by ultrasonic testing or by radiography.

> **EXCEPTIONS:** 1. When approved, the nondestructive testing rate for an individual welder or welding operator may be reduced to 25 percent, provided the reject rate is demonstrated to be 5 percent or less of the welds tested for the welder or welding operator. A sampling of at least 40 completed welds for a job shall be made for such reduction evaluation. Reject rate is defined as the number of welds containing rejectable defects divided by the number of welds completed. For evaluating the reject rate of continuous welds over 3 feet (914 mm) in length where the effective throat thickness is 1 inch (25 mm) or less, each 12-inch increment (305 mm) or fraction thereof shall be considered as one weld. For evaluating the reject rate on continuous welds over 3 feet (914 mm) in length where the effective throat thickness is greater than 1 inch (25 mm), each 6 inches (152 mm) of length or fraction thereof shall be considered one weld.
>
> 2. For complete penetration groove welds on materials less than $^5/_{16}$ inch (7.9 mm) thick, nondestructive testing is not required; for this welding, continuous inspection is required.
>
> 3. When approved by the building official and outlined in the project plans and specifications, this nondestructive ultrasonic testing may be performed in the shop of an approved fabricator utilizing qualified test techniques in the employment of the fabricator.

2. Partial penetration groove welds when used in column splices shall be tested either by ultrasonic testing or radiography when required by the plans and specifications. For partial penetration groove welds when used in column splices, with an effective throat less than $^3/_4$ inch (19.1 mm) thick, nondestructive testing is not required; for this welding, continuous special inspection is required.

3. Base metal thicker than $1^1/_2$ inches (38 mm), when subjected to through-thickness weld shrinkage strains, shall be ultrasonically inspected for discontinuities directly behind such welds after joint completion.

Any material discontinuities shall be accepted or rejected on the basis of the defect rating in accordance with the (larger reflector) criteria of approved national standards.

SECTION 1704 — PREFABRICATED CONSTRUCTION

1704.1 General.

1704.1.1 Purpose. The purpose of this section is to regulate materials and establish methods of safe construction where any structure or portion thereof is wholly or partially prefabricated.

1704.1.2 Scope. Unless otherwise specifically stated in this section, all prefabricated construction and all materials used therein shall conform to all the requirements of this code. (See Section 104.2.8.)

1704.1.3 Definition.

PREFABRICATED ASSEMBLY is a structural unit, the integral parts of which have been built up or assembled prior to incorporation in the building.

1704.2 Tests of Materials. Every approval of a material not specifically mentioned in this code shall incorporate as a proviso the kind and number of tests to be made during prefabrication.

1704.3 Tests of Assemblies. The building official may require special tests to be made on assemblies to determine their durability and weather resistance.

1704.4 Connections. See Section 1611.11.1 for design requirements of connections for prefabricated assemblies.

1704.5 Pipes and Conduits. See Section 1611.11.2 for design requirements for removal of material for pipes, conduit and other equipment.

1704.6 Certificate and Inspection.

1704.6.1 Materials. Materials and the assembly thereof shall be inspected to determine compliance with this code. Every material shall be graded, marked or labeled where required elsewhere in this code.

1704.6.2 Certificate. A certificate of approval shall be furnished with every prefabricated assembly, except where the assembly is readily accessible to inspection at the site. The certificate of approval shall certify that the assembly in question has been inspected and meets all the requirements of this code. When mechanical equipment is installed so that it cannot be inspected at the site, the certificate of approval shall certify that such equipment complies with the laws applying thereto.

1704.6.3 Certifying agency. To be acceptable under this code, every certificate of approval shall be made by an approved agency.

1704.6.4 Field erection. Placement of prefabricated assemblies at the building site shall be inspected by the building official to determine compliance with this code.

1704.6.5 Continuous inspection. If continuous inspection is required for certain materials where construction takes place on the site, it shall also be required where the same materials are used in prefabricated construction.

> **EXCEPTION:** Continuous inspection will not be required during prefabrication if the approved agency certifies to the construction and furnishes evidence of compliance.

Chapter 18
FOUNDATIONS AND RETAINING WALLS
Division I—GENERAL

SECTION 1801 — SCOPE

1801.1 General. This chapter sets forth requirements for excavation and fills for any building or structure and for foundations and retaining structures.

Reference is made to Appendix Chapter 33 for requirements governing excavation, grading and earthwork construction, including fills and embankments.

1801.2 Standards of Quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code.

1. **Testing.**

   1.1 UBC Standard 18-1, Soils Classification

   1.2 UBC Standard 18-2, Expansion Index Test

SECTION 1802 — QUALITY AND DESIGN

The quality and design of materials used structurally in excavations, footings and foundations shall conform to the requirements specified in Chapters 16, 19, 21, 22 and 23.

Excavations and fills shall comply with Chapter 33.

Allowable bearing pressures, allowable stresses and design formulas provided in this chapter shall be used with the allowable stress design load combinations specified in Section 1612.3.

SECTION 1803 — SOIL CLASSIFICATION— EXPANSIVE SOIL

1803.1 General. For the purposes of this chapter, the definition and classification of soil materials for use in Table 18-I-A shall be according to UBC Standard 18-1.

1803.2 Expansive Soil. When the expansive characteristics of a soil are to be determined, the procedures shall be in accordance with UBC Standard 18-2 and the soil shall be classified according to Table 18-I-B. Foundations for structures resting on soils with an expansion index greater than 20, as determined by UBC Standard 18-2, shall require special design consideration. If the soil expansion index varies with depth, the variation is to be included in the engineering analysis of the expansive soil effect upon the structure.

SECTION 1804 — FOUNDATION INVESTIGATION

1804.1 General. The classification of the soil at each building site shall be determined when required by the building official. The building official may require that this determination be made by an engineer or architect licensed by the state to practice as such.

1804.2 Investigation. The classification shall be based on observation and any necessary tests of the materials disclosed by borings or excavations made in appropriate locations. Additional studies may be necessary to evaluate soil strength, the effect of moisture variation on soil-bearing capacity, compressibility, liquefaction and expansiveness.

In Seismic Zones 3 and 4, when required by the building official, the potential for seismically induced soil liquefaction and soil instability shall be evaluated as described in Section 1804.5.

EXCEPTIONS: 1. The building official may waive this evaluation upon receipt of written opinion of a qualified geotechnical engineer or geologist that liquefaction is not probable.

2. A detached, single-story dwelling of Group R, Division 3 Occupancy with or without attached garages.

3. Group U, Division 1 Occupancies.

4. Fences.

1804.3 Reports. The soil classification and design-bearing capacity shall be shown on the plans, unless the foundation conforms to Table 18-I-C. The building official may require submission of a written report of the investigation, which shall include, but need not be limited to, the following information:

1. A plot showing the location of all test borings and/or excavations.

2. Descriptions and classifications of the materials encountered.

3. Elevation of the water table, if encountered.

4. Recommendations for foundation type and design criteria, including bearing capacity, provisions to mitigate the effects of expansive soils, provisions to mitigate the effects of liquefaction and soil strength, and the effects of adjacent loads.

5. Expected total and differential settlement.

1804.4 Expansive Soils. When expansive soils are present, the building official may require that special provisions be made in the foundation design and construction to safeguard against damage due to this expansiveness. The building official may require a special investigation and report to provide these design and construction criteria.

1804.5 Liquefaction Potential and Soil Strength Loss. When required by Section 1804.2, the potential for soil liquefaction and soil strength loss during earthquakes shall be evaluated during the geotechnical investigation. The geotechnical report shall assess potential consequences of any liquefaction and soil strength loss, including estimation of differential settlement, lateral movement or reduction in foundation soil-bearing capacity, and discuss mitigating measures. Such measures shall be given consideration in the design of the building and may include, but are not limited to, ground stabilization, selection of appropriate foundation type and depths, selection of appropriate structural systems to accommodate anticipated displacements, or any combination of these measures.

The potential for liquefaction and soil strength loss shall be evaluated for a site peak ground acceleration that, as a minimum, conforms to the probability of exceedance specified in Section 1631.2. Peak ground acceleration may be determined based on a site-specific study taking into account soil amplification effects. In the absence of such a study, peak ground acceleration may be assumed equal to the seismic zone factor in Table 16-I.

1804.6 Adjacent Loads. Where footings are placed at varying elevations, the effect of adjacent loads shall be included in the foundation design.

1804.7 Drainage. Provisions shall be made for the control and drainage of surface water around buildings. (See also Section 1806.5.5.)

SECTION 1805 — ALLOWABLE FOUNDATION AND LATERAL PRESSURES

The allowable foundation and lateral pressures shall not exceed the values set forth in Table 18-I-A unless data to substantiate the use of higher values are submitted. Table 18-I-A may be used for design of foundations on rock or nonexpansive soil for Type II One-hour, Type II-N and Type V buildings that do not exceed three stories in height or for structures that have continuous footings having a load of less than 2,000 pounds per lineal foot (29.2 kN/m) and isolated footings with loads of less than 50,000 pounds (222.4 kN).

Allowable bearing pressures provided in Table 18-I-A shall be used with the allowable stress design load combinations specified in Section 1612.3.

SECTION 1806 — FOOTINGS

1806.1 General. Footings and foundations shall be constructed of masonry, concrete or treated wood in conformance with Division II and shall extend below the frost line. Footings of concrete and masonry shall be of solid material. Foundations supporting wood shall extend at least 6 inches (152 mm) above the adjacent finish grade. Footings shall have a minimum depth as indicated in Table 18-I-C, unless another depth is recommended by a foundation investigation.

The provisions of this section do not apply to building and foundation systems in those areas subject to scour and water pressure by wind and wave action. Buildings and foundations subject to such loads shall be designed in accordance with approved national standards. See Section 3302 for subsoil preparation and wood form removal.

1806.2 Footing Design. Except for special provisions of Section 1808 covering the design of piles, all portions of footings shall be designed in accordance with the structural provisions of this code and shall be designed to minimize differential settlement when necessary and the effects of expansive soils when present.

Slab-on-grade and mat-type footings for buildings located on expansive soils may be designed in accordance with the provisions of Division III or such other engineering design based on geotechnical recommendation as approved by the building official.

1806.3 Bearing Walls. Bearing walls shall be supported on masonry or concrete foundations or piles or other approved foundation system that shall be of sufficient size to support all loads. Where a design is not provided, the minimum foundation requirements for stud bearing walls shall be as set forth in Table 18-I-C, unless expansive soils of a severity to cause differential movement are known to exist.

> **EXCEPTIONS:** 1. A one-story wood- or metal-frame building not used for human occupancy and not over 400 square feet (37.2 m^2) in floor area may be constructed with walls supported on a wood foundation plate when approved by the building official.
>
> 2. The support of buildings by posts embedded in earth shall be designed as specified in Section 1806.8. Wood posts or poles embedded in earth shall be pressure treated with an approved preservative. Steel posts or poles shall be protected as specified in Section 1807.9.

1806.4 Stepped Foundations. Foundations for all buildings where the surface of the ground slopes more than 1 unit vertical in 10 units horizontal (10% slope) shall be level or shall be stepped so that both top and bottom of such foundation are level.

1806.5 Footings on or Adjacent to Slopes.

1806.5.1 Scope. The placement of buildings and structures on or adjacent to slopes steeper than 1 unit vertical in 3 units horizontal (33.3% slope) shall be in accordance with this section.

1806.5.2 Building clearance from ascending slopes. In general, buildings below slopes shall be set a sufficient distance from the slope to provide protection from slope drainage, erosion and shallow failures. Except as provided for in Section 1806.5.6 and Figure 18-I-1, the following criteria will be assumed to provide this protection. Where the existing slope is steeper than 1 unit vertical in 1 unit horizontal (100% slope), the toe of the slope shall be assumed to be at the intersection of a horizontal plane drawn from the top of the foundation and a plane drawn tangent to the slope at an angle of 45 degrees to the horizontal. Where a retaining wall is constructed at the toe of the slope, the height of the slope shall be measured from the top of the wall to the top of the slope.

1806.5.3 Footing setback from descending slope surface. Footing on or adjacent to slope surfaces shall be founded in firm material with an embedment and setback from the slope surface sufficient to provide vertical and lateral support for the footing without detrimental settlement. Except as provided for in Section 1806.5.6 and Figure 18-I-1, the following setback is deemed adequate to meet the criteria. Where the slope is steeper than 1 unit vertical in 1 unit horizontal (100% slope), the required setback shall be measured from an imaginary plane 45 degrees to the horizontal, projected upward from the toe of the slope.

1806.5.4 Pools. The setback between pools regulated by this code and slopes shall be equal to one half the building footing setback distance required by this section. That portion of the pool wall within a horizontal distance of 7 feet (2134 mm) from the top of the slope shall be capable of supporting the water in the pool without soil support.

1806.5.5 Foundation elevation. On graded sites, the top of any exterior foundation shall extend above the elevation of the street gutter at point of discharge or the inlet of an approved drainage device a minimum of 12 inches (305 mm) plus 2 percent. The building official may approve alternate elevations, provided it can be demonstrated that required drainage to the point of discharge and away from the structure is provided at all locations on the site.

1806.5.6 Alternate setback and clearance. The building official may approve alternate setbacks and clearances. The building official may require an investigation and recommendation of a qualified engineer to demonstrate that the intent of this section has been satisfied. Such an investigation shall include consideration of material, height of slope, slope gradient, load intensity and erosion characteristics of slope material.

1806.6 Foundation Plates or Sills. Wood plates or sills shall be bolted to the foundation or foundation wall. Steel bolts with a minimum nominal diameter of $^1/_2$ inch (12.7 mm) shall be used in Seismic Zones 0 through 3. Steel bolts with a minimum nominal diameter of $^5/_8$ inch (16 mm) shall be used in Seismic Zone 4. Bolts shall be embedded at least 7 inches (178 mm) into the concrete or masonry and shall be spaced not more than 6 feet (1829 mm) apart. There shall be a minimum of two bolts per piece with one bolt located not more than 12 inches (305 mm) or less than seven bolt diameters from each end of the piece. A properly sized nut and washer shall be tightened on each bolt to the plate. Foundation plates and sills shall be the kind of wood specified in Section 2306.4.

1806.6.1 Additional requirements in Seismic Zones 3 and 4. The following additional requirements shall apply in Seismic Zones 3 and 4.

1. Sill bolt diameter and spacing for three-story raised wood floor buildings shall be specifically designed.

2. Plate washers a minimum of 2 inch by 2 inch by $^3/_{16}$ inch (51 mm by 51 mm by 4.8 mm) thick shall be used on each bolt.

1806.7 Seismic Zones 3 and 4. In Seismic Zones 3 and 4, horizontal reinforcement in accordance with Sections 1806.7.1 and 1806.7.2 shall be placed in continuous foundations to minimize differential settlement. Foundation reinforcement shall be provided with cover in accordance with Section 1907.7.1.

1806.7.1 Foundations with stemwalls. Foundations with stemwalls shall be provided with a minimum of one No. 4 bar at the top of the wall and one No. 4 bar at the bottom of the footing.

1806.7.2 Slabs–on–ground with turned–down footings. Slabs–on–ground with turned-down footings shall have a minimum of one No. 4 bar at the top and bottom.

> **EXCEPTION:** For slabs-on-ground cast monolithically with a footing, one No. 5 bar may be located at either the top or bottom.

1806.8 Designs Employing Lateral Bearing.

1806.8.1 General. Construction employing posts or poles as columns embedded in earth or embedded in concrete footings in the earth may be used to resist both axial and lateral loads. The depth to resist lateral loads shall be determined by means of the design criteria established herein or other methods approved by the building official.

1806.8.2 Design criteria.

1806.8.2.1 Nonconstrained. The following formula may be used in determining the depth of embedment required to resist lateral loads where no constraint is provided at the ground surface, such as rigid floor or rigid ground surface pavement.

$$d = \frac{A}{2}\left(1 + \sqrt{1 + \frac{4.36h}{A}}\right) \qquad (6\text{-}1)$$

WHERE:

$A = \dfrac{2.34P}{S_1 b}$

b = diameter of round post or footing or diagonal dimension of square post or footing, feet (m).

d = depth of embedment in earth in feet (m) but not over 12 feet (3658 mm) for purpose of computing lateral pressure.

h = distance in feet (m) from ground surface to point of application of "P."

P = applied lateral force in pounds (kN).

S_1 = allowable lateral soil-bearing pressure as set forth in Table 18-I-A based on a depth of one third the depth of embedment (kPa).

S_3 = allowable lateral soil-bearing pressure as set forth in Table 18-I-A based on a depth equal to the depth of embedment (kPa).

1806.8.2.2 Constrained. The following formula may be used to determine the depth of embedment required to resist lateral loads where constraint is provided at the ground surface, such as a rigid floor or pavement.

$$d^2 = 4.25\frac{Ph}{S_3 b} \qquad (6\text{-}2)$$

1806.8.2.3 Vertical load. The resistance to vertical loads is determined by the allowable soil-bearing pressure set forth in Table 18-I-A.

1806.8.3 Backfill. The backfill in the annular space around columns not embedded in poured footings shall be by one of the following methods:

1. Backfill shall be of concrete with an ultimate strength of 2,000 pounds per square inch (13.79 MPa) at 28 days. The hole shall not be less than 4 inches (102 mm) larger than the diameter of the column at its bottom or 4 inches (102 mm) larger than the diagonal dimension of a square or rectangular column.

2. Backfill shall be of clean sand. The sand shall be thoroughly compacted by tamping in layers not more than 8 inches (203 mm) in depth.

1806.8.4 Limitations. The design procedure outlined in this section shall be subject to the following limitations:

The frictional resistance for retaining walls and slabs on silts and clays shall be limited to one half of the normal force imposed on the soil by the weight of the footing or slab.

Posts embedded in earth shall not be used to provide lateral support for structural or nonstructural materials such as plaster, masonry or concrete unless bracing is provided that develops the limited deflection required.

1806.9 Grillage Footings. When grillage footings of structural steel shapes are used on soils, they shall be completely embedded in concrete with at least 6 inches (152 mm) on the bottom and at least 4 inches (102 mm) at all other points.

1806.10 Bleacher Footings. Footings for open-air seating facilities shall comply with Chapter 18.

> **EXCEPTIONS:** Temporary open-air portable bleachers as defined in Section 1008.2 may be supported upon wood sills or steel plates placed directly upon the ground surface, provided soil pressure does not exceed 1,200 pounds per square foot (57.5 kPa).

SECTION 1807 — PILES — GENERAL REQUIREMENTS

1807.1 General. Pile foundations shall be designed and installed on the basis of a foundation investigation as defined in Section 1804 where required by the building official.

The investigation and report provisions of Section 1804 shall be expanded to include, but not be limited to, the following:

1. Recommended pile types and installed capacities.

2. Driving criteria.

3. Installation procedures.

4. Field inspection and reporting procedures (to include procedures for verification of the installed bearing capacity where required).

5. Pile load test requirements.

The use of piles not specifically mentioned in this chapter shall be permitted, subject to the approval of the building official upon submission of acceptable test data, calculations or other information relating to the properties and load-carrying capacities of such piles.

1807.2 Interconnection. Individual pile caps and caissons of every structure subjected to seismic forces shall be interconnected by ties. Such ties shall be capable of resisting, in tension or compression, a minimum horizontal force equal to 10 percent of the larger column vertical load.

EXCEPTION: Other approved methods may be used where it can be demonstrated that equivalent restraint can be provided.

1807.3 Determination of Allowable Loads. The allowable axial and lateral loads on piles shall be determined by an approved formula, by load tests or by a foundation investigation.

1807.4 Static Load Tests. When the allowable axial load of a single pile is determined by a load test, one of the following methods shall be used:

Method 1. It shall not exceed 50 percent of the yield point under test load. The yield point shall be defined as that point at which an increase in load produces a disproportionate increase in settlement.

Method 2. It shall not exceed one half of the load which causes a net settlement, after deducting rebound, of 0.01 inch per ton (0.000565 mm/N) of test load which has been applied for a period of at least 24 hours.

Method 3. It shall not exceed one half of that load under which, during a 40-hour period of continuous load application, no additional settlement takes place.

1807.5 Column Action. All piles standing unbraced in air, water or material not capable of lateral support, shall conform with the applicable column formula as specified in this code. Such piles driven into firm ground may be considered fixed and laterally supported at 5 feet (1524 mm) below the ground surface and in soft material at 10 feet (3048 mm) below the ground surface unless otherwise prescribed by the building official after a foundation investigation by an approved agency.

1807.6 Group Action. Consideration shall be given to the reduction of allowable pile load when piles are placed in groups. Where soil conditions make such load reductions advisable or necessary, the allowable axial load determined for a single pile shall be reduced by any rational method or formula approved by the building official.

1807.7 Piles in Subsiding Areas. Where piles are driven through subsiding fills or other subsiding strata and derive support from underlying firmer materials, consideration shall be given to the downward frictional forces which may be imposed on the piles by the subsiding upper strata.

Where the influence of subsiding fills is considered as imposing loads on the pile, the allowable stresses specified in this chapter may be increased if satisfactory substantiating data are submitted.

1807.8 Jetting. Jetting shall not be used except where and as specifically permitted by the building official. When used, jetting shall be carried out in such a manner that the carrying capacity of existing piles and structures shall not be impaired. After withdrawal of the jet, piles shall be driven down until the required resistance is obtained.

1807.9 Protection of Pile Materials. Where the boring records of site conditions indicate possible deleterious action on pile materials because of soil constituents, changing water levels or other factors, such materials shall be adequately protected by methods or processes approved by the building official. The effectiveness of such methods or processes for the particular purpose shall have been thoroughly established by satisfactory service records or other evidence which demonstrates the effectiveness of such protective measures.

1807.10 Allowable Loads. The allowable loads based on soil conditions shall be established in accordance with Section 1807.

EXCEPTION: Any uncased cast-in-place pile may be assumed to develop a frictional resistance equal to one sixth of the bearing value of the soil material at minimum depth as set forth in Table 18-I-A but not to exceed 500 pounds per square foot (24 kPa) unless a greater value is allowed by the building official after a soil investigation as specified in Section 1804 is submitted. Frictional resistance and bearing resistance shall not be assumed to act simultaneously unless recommended after a foundation investigation as specified in Section 1804.

1807.11 Use of Higher Allowable Pile Stresses. Allowable compressive stresses greater than those specified in Section 1808 shall be permitted when substantiating data justifying such higher stresses are submitted to and approved by the building official. Such substantiating data shall include a foundation investigation including a report in accordance with Section 1807.1 by a soils engineer defined as a civil engineer experienced and knowledgeable in the practice of soils engineering.

SECTION 1808 — SPECIFIC PILE REQUIREMENTS

1808.1 Round Wood Piles.

1808.1.1 Material. Except where untreated piles are permitted, wood piles shall be pressure treated. Untreated piles may be used only when it has been established that the cutoff will be below lowest groundwater level assumed to exist during the life of the structure.

1808.1.2 Allowable stresses. The allowable unit stresses for round wood piles shall not exceed those set forth in Chapter 23, Division III, Part I.

The allowable values listed in Chapter 23, Division III, Part I, for compression parallel to the grain at extreme fiber in bending are based on load sharing as occurs in a pile cluster. For piles which support their own specific load, a safety factor of 1.25 shall be applied to compression parallel to the grain values and 1.30 to extreme fiber in bending values.

1808.2 Uncased Cast-in-place Concrete Piles.

1808.2.1 Material. Concrete piles cast in place against earth in drilled or bored holes shall be made in such a manner as to ensure the exclusion of any foreign matter and to secure a full-sized shaft. The length of such pile shall be limited to not more than 30 times the average diameter. Concrete shall have a specified compressive strength f'_c of not less than 2,500 psi (17.24 MPa).

EXCEPTION: The length of pile may exceed 30 times the diameter provided the design and installation of the pile foundation is in accordance with an approved investigation report.

1808.2.2 Allowable stresses. The allowable compressive stress in the concrete shall not exceed $0.33f'_c$. The allowable compressive stress of reinforcement shall not exceed 34 percent of the yield strength of the steel or 25,500 psi (175.7 MPa).

1808.3 Metal-cased Concrete Piles.

1808.3.1 Material. Concrete used in metal-cased concrete piles shall have a specified compressive strength f'_c of not less than 2,500 psi (17.24 MPa).

1808.3.2 Installation. Every metal casing for a concrete pile shall have a sealed tip with a diameter of not less than 8 inches (203 mm).

Concrete piles cast in place in metal shells shall have shells driven for their full length in contact with the surrounding soil and left permanently in place. The shells shall be sufficiently strong to resist collapse and sufficiently watertight to exclude water and foreign material during the placing of concrete.

Piles shall be driven in such order and with such spacing as to ensure against distortion of or injury to piles already in place. No pile shall be driven within four and one-half average pile diameters of a pile filled with concrete less than 24 hours old unless approved by the building official.

1808.3.3 Allowable stresses. Allowable stresses shall not exceed the values specified in Section 1808.2.2, except that the allowable concrete stress may be increased to a maximum value of $0.40f'_c$ for that portion of the pile meeting the following conditions:

1. The thickness of the metal casing is not less than 0.068 inch (1.73 mm) (No. 14 carbon sheet steel gage).

2. The casing is seamless or is provided with seams of equal strength and is of a configuration that will provide confinement to the cast-in-place concrete.

3. The specified compressive strength f'_c shall not exceed 5,000 psi (34.47 MPa) and the ratio of steel minimum specified yield strength f_y to concrete specified compressive strength f'_c shall not be less than 6.

4. The pile diameter is not greater than 16 inches (406 mm).

1808.4 Precast Concrete Piles.

1808.4.1 Materials. Precast concrete piles shall have a specified compressive strength f'_c of not less than 3,000 psi (20.68 MPa), and shall develop a compressive strength of not less than 3,000 psi (20.68 MPa) before driving.

1808.4.2 Reinforcement ties. The longitudinal reinforcement in driven precast concrete piles shall be laterally tied with steel ties or wire spirals. Ties and spirals shall not be spaced more than 3 inches (76 mm) apart, center to center, for a distance of 2 feet (610 mm) from the ends and not more than 8 inches (203 mm) elsewhere. The gage of ties and spirals shall be as follows:

For piles having a diameter of 16 inches (406 mm) or less, wire shall not be smaller than 0.22 inch (5.6 mm) (No. 5 B.W. gage).

For piles having a diameter of more than 16 inches (406 mm) and less than 20 inches (508 mm), wire shall not be smaller than 0.238 inch (6.0 mm) (No. 4 B.W. gage).

For piles having a diameter of 20 inches (508 mm) and larger, wire shall not be smaller than $^1/_4$ inch (6.4 mm) round or 0.259 inch (6.6 mm) (No. 3 B.W. gage).

1808.4.3 Allowable stresses. Precast concrete piling shall be designed to resist stresses induced by handling and driving as well as by loads. The allowable stresses shall not exceed the values specified in Section 1808.2.2.

1808.5 Precast Prestressed Concrete Piles (Pretensioned).

1808.5.1 Materials. Precast prestressed concrete piles shall have a specified compressive strength f'_c of not less than 5,000 psi (34.48 MPa) and shall develop a compressive strength of not less than 4,000 psi (27.58 MPa) before driving.

1808.5.2 Reinforcement. The longitudinal reinforcement shall be high-tensile seven-wire strand. Longitudinal reinforcement shall be laterally tied with steel ties or wire spirals.

Ties or spiral reinforcement shall not be spaced more than 3 inches (76 mm) apart, center to center, for a distance of 2 feet (610 mm) from the ends and not more than 8 inches (203 mm) elsewhere.

At each end of the pile, the first five ties or spirals shall be spaced 1 inch (25 mm) center to center.

For piles having a diameter of 24 inches (610 mm) or less, wire shall not be smaller than 0.22 inch (5.6 mm) (No. 5 B.W. gage). For piles having a diameter greater than 24 inches (610 mm) but less than 36 inches (914 mm), wire shall not be smaller than 0.238 inch (6.0 mm) (No. 4 B.W. gage). For piles having a diameter greater than 36 inches (914 mm), wire shall not be smaller than $^1/_4$ inch (6.4 mm) round or 0.259 inch (6.6 mm) (No. 3 B.W. gage).

1808.5.3 Allowable stresses. Precast prestressed piling shall be designed to resist stresses induced by handling and driving as well as by loads. The effective prestress in the pile shall not be less than 400 psi (2.76 MPa) for piles up to 30 feet (9144 mm) in length, 550 psi (3.79 MPa) for piles up to 50 feet (15 240 mm) in length, and 700 psi (4.83 MPa) for piles greater than 50 feet (15 240 mm) in length.

The compressive stress in the concrete due to externally applied load shall not exceed:

$$f_c = 0.33f'_c - 0.27fp_c$$

WHERE:

fp_c = effective prestress stress on the gross section.

Effective prestress shall be based on an assumed loss of 30,000 psi (206.85 MPa) in the prestressing steel. The allowable stress in the prestressing steel shall not exceed the values specified in Section 1918.

1808.6 Structural Steel Piles.

1808.6.1 Material. Structural steel piles, steel pipe piles and fully welded steel piles fabricated from plates shall conform to UBC Standard 22-1 and be identified in accordance with Section 2202.2.

1808.6.2 Allowable stresses. The allowable axial stresses shall not exceed 0.35 of the minimum specified yield strength F_y or 12,600 psi (86.88 MPa), whichever is less.

> **EXCEPTION:** When justified in accordance with Section 1807.11, the allowable axial stress may be increased above 12,600 psi (86.88 MPa) and $0.35F_y$, but shall not exceed $0.5F_y$.

1808.6.3 Minimum dimensions. Sections of driven H-piles shall comply with the following:

1. The flange projection shall not exceed 14 times the minimum thickness of metal in either the flange or the web, and the flange widths shall not be less than 80 percent of the depth of the section.

2. The nominal depth in the direction of the web shall not be less than 8 inches (203 mm).

3. Flanges and webs shall have a minimum nominal thickness of $^3/_8$ inch (9.5 mm).

Sections of driven pipe piles shall have an outside diameter of not less than 10 inches (254 mm) and a minimum thickness of not less than $^1/_4$ inch (6.4 mm).

1808.7 Concrete-filled Steel Pipe Piles.

1808.7.1 Material. The concrete-filled steel pipe piles shall conform to UBC Standard 22-1 and shall be identified in accordance with Section 2202.2. The concrete-filled steel pipe piles shall have a specified compressive strength f'_c of not less than 2,500 psi (17.24 MPa).

1808.7.2 Allowable stresses. The allowable axial stresses shall not exceed 0.35 of the minimum specified yield strength F_y of the steel plus 0.33 of the specified compressive strength f'_c of concrete, provided F_y shall not be assumed greater than 36,000 psi (248.22 MPa) for computational purposes.

> **EXCEPTION:** When justified in accordance with Section 2807.11, the allowable stresses may be increased to 0.50 F_y.

1808.7.3 Minimum dimensions. Driven piles of uniform section shall have a nominal outside diameter of not less than 8 inches (203 mm).

SECTION 1809 — FOUNDATION CONSTRUCTION—SEISMIC ZONES 3 AND 4

1809.1 General. In Seismic Zones 3 and 4 the further requirements of this section shall apply to the design and construction of foundations, foundation components and the connection of superstructure elements thereto.

1809.2 Soil Capacity. The foundation shall be capable of transmitting the design base shear and overturning forces prescribed in Section 1630 from the structure into the supporting soil. The short-term dynamic nature of the loads may be taken into account in establishing the soil properties.

1809.3 Superstructure-to-Foundation Connection. The connection of superstructure elements to the foundation shall be adequate to transmit to the foundation the forces for which the elements were required to be designed.

1809.4 Foundation-Soil Interface. For regular buildings, the force F_t as provided in Section 1630.5 may be omitted when determining the overturning moment to be resisted at the foundation-soil interface.

1809.5 Special Requirements for Piles and Caissons.

1809.5.1 General. Piles, caissons and caps shall be designed according to the provisions of Section 1603, including the effects of lateral displacements. Special detailing requirements as described in Section 1809.5.2 shall apply for a length of piles equal to 120 percent of the flexural length. Flexural length shall be considered as a length of pile from the first point of zero lateral deflection to the underside of the pile cap or grade beam.

1809.5.2 Steel piles, nonprestressed concrete piles and prestressed concrete piles.

1809.5.2.1 Steel piles. Piles shall conform to width-thickness ratios of stiffened, unstiffened and tubular compression elements as shown in Chapter 22, Division VIII.

1809.5.2.2 Nonprestressed concrete piles. Piles shall have transverse reinforcement meeting the requirements of Section 1921.4.

> **EXCEPTION:** Transverse reinforcement need not exceed the amount determined by Formula (21-2) in Section 1921.4.4.1 for spiral or circular hoop reinforcement or by Formula (21-4) in Section 1921.4.4.1 for rectangular hoop reinforcement.

1809.5.2.3 Prestressed concrete piles. Piles shall have a minimum volumetric ratio of spiral reinforcement no less than 0.021 for 14-inch (356 mm) square and smaller piles, and 0.012 for 24-inch (610 mm) square and larger piles unless a smaller value can be justified by rational analysis. Interpolation may be used between the specified ratios for intermediate sizes.

TABLE 18-I-A—ALLOWABLE FOUNDATION AND LATERAL PRESSURE

CLASS OF MATERIALS[1]	ALLOWABLE FOUNDATION PRESSURE (psf)[2] × 0.0479 for kPa	LATERAL BEARING LBS./SQ./FT./FT. OF DEPTH BELOW NATURAL GRADE[3] × 0.157 for kPa per meter	LATERAL SLIDING[4] Coefficient[5]	LATERAL SLIDING[4] Resistance (psf)[6] × 0.0479 for kPa
1. Massive crystalline bedrock	4,000	1,200	0.70	
2. Sedimentary and foliated rock	2,000	400	0.35	
3. Sandy gravel and/or gravel (GW and GP)	2,000	200	0.35	
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	1,500	150	0.25	
5. Clay, sandy clay, silty clay and clayey silt (CL, ML, MH and CH)	1,000[7]	100		130

[1]For soil classifications OL, OH and PT (i.e., organic clays and peat), a foundation investigation shall be required.
[2]All values of allowable foundation pressure are for footings having a minimum width of 12 inches (305 mm) and a minimum depth of 12 inches (305 mm) into natural grade. Except as in Footnote 7, an increase of 20 percent shall be allowed for each additional foot (305 mm) of width or depth to a maximum value of three times the designated value. Additionally, an increase of one third shall be permitted when considering load combinations, including wind or earthquake loads, as permitted by Section 1612.3.2.
[3]May be increased the amount of the designated value for each additional foot (305 mm) of depth to a maximum of 15 times the designated value. Isolated poles for uses such as flagpoles or signs and poles used to support buildings that are not adversely affected by a $^1/_2$-inch (12.7 mm) motion at ground surface due to short-term lateral loads may be designed using lateral bearing values equal to two times the tabulated values.
[4]Lateral bearing and lateral sliding resistance may be combined.
[5]Coefficient to be multiplied by the dead load.
[6]Lateral sliding resistance value to be multiplied by the contact area. In no case shall the lateral sliding resistance exceed one half the dead load.
[7]No increase for width is allowed.

TABLE 18-I-B—CLASSIFICATION OF EXPANSIVE SOIL

EXPANSION INDEX	POTENTIAL EXPANSION
0-20	Very low
21-50	Low
51-90	Medium
91-130	High
Above 130	Very high

TABLE 18-I-C—FOUNDATIONS FOR STUD BEARING WALLS—MINIMUM REQUIREMENTS[1,2,3]

NUMBER OF FLOORS SUPPORTED BY THE FOUNDATION[4]	THICKNESS OF FOUNDATION WALL (inches) × 25.4 for mm: Concrete	THICKNESS OF FOUNDATION WALL (inches) × 25.4 for mm: Unit Masonry	WIDTH OF FOOTING (inches) × 25.4 for mm	THICKNESS OF FOOTING (inches) × 25.4 for mm	DEPTH BELOW UNDISTURBED GROUND SURFACE (inches) × 25.4 for mm
1	6	6	12	6	12
2	8	8	15	7	18
3	10	10	18	8	24

[1]Where unusual conditions or frost conditions are found, footings and foundations shall be as required in Section 1806.1.
[2]The ground under the floor may be excavated to the elevation of the top of the footing.
[3]Interior stud bearing walls may be supported by isolated footings. The footing width and length shall be twice the width shown in this table and the footings shall be spaced not more than 6 feet (1829 mm) on center.
[4]Foundations may support a roof in addition to the stipulated number of floors. Foundations supporting roofs only shall be as required for supporting one floor.

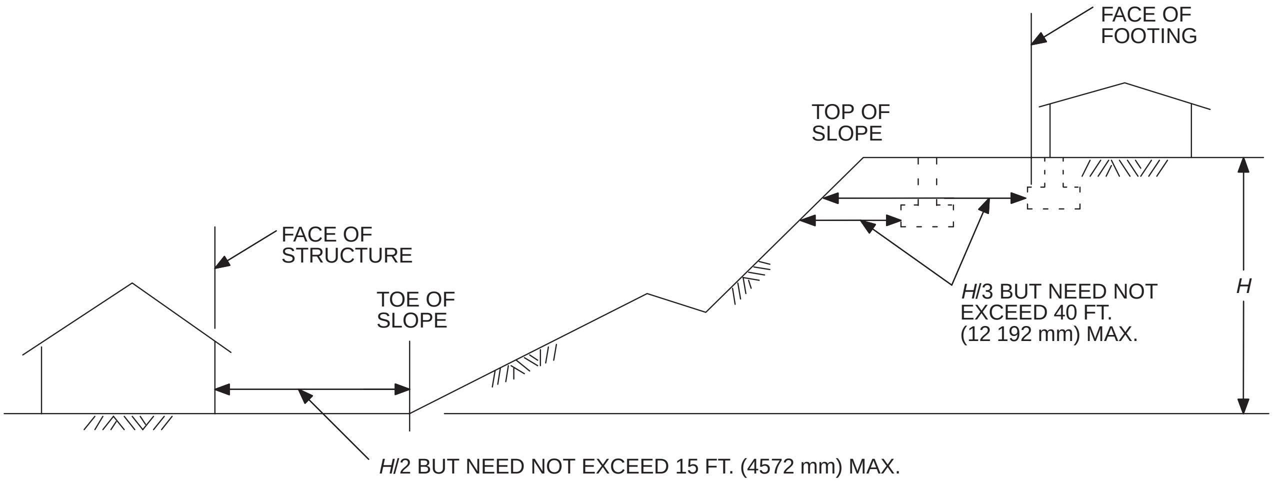


FIGURE 18-I-1—SETBACK DIMENSIONS

Division II—DESIGN STANDARD FOR TREATED WOOD FOUNDATION SYSTEM

Based on National Forest Products Association, Technical Report No. 7

SECTION 1810 — SCOPE

The basic design and construction requirements for treated wood foundation systems are set forth in this division. Included are criteria for materials, preservative treatment, soil characteristics, environmental control, design loads and structural design.

SECTION 1811 — MATERIALS

1811.1 Lumber. Lumber shall be of a species and grade for which allowable unit stresses are set forth in Chapter 23, Division III, Part I, and shall bear the grade mark of, or have a certificate of inspection issued by, an approved lumber grading or inspection bureau or agency.

1811.2 Plywood. All plywood shall be bonded with exterior glue and be grade marked indicating conformance with UBC Standard 23-2 and shall bear the grade mark of an approved plywood inspection agency.

1811.3 Fasteners in Preservative-treated Wood. Fasteners in preservative-treated wood shall be approved silicon bronze or copper, stainless steel or hot-dipped zinc-coated steel. Silicon bronze, copper and stainless steel fasteners are acceptable for all ground contact and moisture situations. Hot-dipped zinc-coated nails may be used for basement and crawl space wall construction where polyethylene sheeting is applied to the below-grade portion of the exterior wall and for wood basement floor construction, provided the polyethylene sheeting is placed in accordance with Section 1812.4. In addition, crawl space construction shall be located in soils having good drainage, such as GW, GP, SW, SP, GM and SM types. Other types of steel or metal fasteners shall be permitted only if adequate comparative tests for corrosion resistance, including the effects associated with the wood treating chemicals, indicate an equal or better performance. Zinc-coated fasteners shall be coated after manufacture to their final form, including pointing, heating, threading or twisting, as applicable. Electrogalvanized nails or staples and hot-dipped zinc-coated staples shall not be used.

Framing anchors shall be of hot-dipped zinc-coated A-446 Grade A sheet steel conforming to UBC Standard 22-1.

1811.4 Gravel, Sand or Crushed Stone for Footings Fill. Gravel shall be washed and well graded. The maximum size stone shall not exceed $^3/_4$ inch (19 mm). Gravel shall be free from organic, clayey or silty soils.

Sand shall be coarse, not smaller than $^1/_{16}$-inch (1.6 mm) grains and shall be free from organic, clayey or silty soils.

Crushed stone shall have a maximum size of $^1/_2$ inch (12.7 mm).

1811.5 Polyethylene Sheeting. Polyethylene sheeting shall conform to requirements approved by the building official.

1811.6 Sealants. The materials used to attach the polyethylene sheets to each other or to the plywood shall be capable of adhering to those materials to form a continuous seal.

The material used for caulking joints in plywood sheathing shall be capable of adhering to the wood to provide a moisture seal under the conditions of temperature and moisture content at which it will be applied and used.

1811.7 Preservative Treatment. All lumber and plywood required to be preservative treated shall be pressure treated and bear the FDN grade mark. After treatment, each piece of lumber and plywood shall be dried to a moisture content not exceeding 19 percent. Each piece of treated lumber and plywood shall bear an approved quality mark or that of an approved inspection agency which maintains continuing supervision, testing and inspection over the quality of the product, and shall be identified.

Where FDN lumber is cut or drilled after treatment, the cut surface shall be field treated with the following preservatives by repeated brushing, dipping or soaking until the wood absorbs no more preservative: ammoniacal copper arsenate (ACA), chromated copper arsenate (CCA), fluor chrome arsenate phenol (FCAP), acid copper chromate (ACC), or copper napthenate.

Copper napthenate shall be prepared with a solvent conforming to AWPA Standard P5. The preservative concentration shall contain a minimum of 2 percent copper metal. Preparations made by manufacturers of preservatives can also be used.

Waterborne preservatives ACA and CCA, Types A, B and C, shall have a minimum concentration of 3 percent in solution. Waterborne preservatives FCAP and ACC may be used for field treatment of material originally treated with CCA and ACA waterborne preservatives and the concentration of FCAP or ACC shall be a minimum of 5 percent in solution.

All lumber and plywood used in exterior foundation walls (except the upper top plate), all interior-bearing wall framing and sheathing posts or other wood supports used in crawl spaces; all sleepers, joists, blocking and plywood subflooring used in basement floors; and all other plates, framing and sheathing in the ground or in direct contact with concrete shall be preservative treated. Where a significant portion of a bottom story wall is above adjacent ground level, such as when a building is situated on sloping terrain, the portion of wall to be considered as foundation wall shall be based on good engineering practice. Some members in such a wall may not require preservative treatment, such as window or door headers or the top plate. As a minimum, all exterior wall framing lumber and plywood sheathing less than 6 inches (152 mm) above finished grade shall be preservative treated.

1811.8 Soil Characteristics. Soils are defined herein in accordance with the Unified Soil Classification System (see UBC Standard 18-1). Design properties are provided in Table 18-I-A or by a qualified soils engineer who, by approval of the building official, may assign other values based on soil tests or local experience.

Backfill of CH type (inorganic clays of high plasticity) or other types of expansive soils shall not be compacted dry. Backfill with MH soil types (inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts) shall be well compacted to prevent surface water infiltration.

Organic soils, OL, OH and P_t are unsatisfactory for foundations unless specifically approved by the building official after a qualified soils engineer advises on the design of the entire soil-structural system.

SECTION 1812 — DRAINAGE AND MOISTURE CONTROL

1812.1 General. The following sections present requirements to achieve dry and energy-efficient below-grade habitable space that is located above the permanent water table. Floors located below the permanent water table are not permitted unless special moisture control measures are designed by persons qualified in accordance with the authority having jurisdiction. (See Section 1804.7.)

1812.2 Area Drainage. Adjacent ground surface shall be sloped away from the structure with a gradient of at least $^1/_2$ inch (12.7 mm) per foot for a distance of 6 feet (1829 mm) or more. Provisions shall be made for drainage to prevent accumulation of surface water.

1812.3 Subgrade Drainage. A porous layer of gravel, crushed stone or sand shall be placed to a minimum thickness of 4 inches (102 mm) under basement floor slabs and all wall footings. For basement construction in MH and CH type soils, the porous layer under footings and slab shall be at least 6 inches (152 mm) thick.

Where there is basement space below grade, a sump shall be provided to drain the porous layer unless the foundation is installed in GW-, GP-, SW-, SP-, GM- and SM-type soils. The sump shall be at least 24-inch (610 mm) diameter or 20-inch (508 mm) square, shall extend at least 24 inches (610 mm) below the bottom of the basement floor slab and shall be capable of positive gravity or mechanical drainage to remove any accumulated water.

1812.4 Sheeting and Caulking. Polyethylene sheeting of 6-mil (0.153 mm) thickness shall be applied over the porous layer. A concrete slab shall be poured over the sheeting or a wood basement floor system shall be constructed on the sheeting. Where wood floors are used, the polyethylene sheeting shall be placed over wood sleepers supporting the floor joists. Sheeting should not extend beneath the wood footing plate.

In basement construction, joints between plywood panels in the foundation walls shall be sealed full length with caulking compound. Any unbacked panel joints shall be caulked at the time the panels are fastened to the framing.

Six-mil-thick (0.153 mm) polyethylene sheeting shall be applied over the below-grade portion of exterior basement walls prior to backfilling, except in GW-, GP-, SW-, SP-, GM- and SM-type soils. Joints in the polyethylene sheeting shall be lapped 6 inches (152 mm) and bonded with a sealant. The top edge of the polyethylene sheeting shall be bonded with a sealant to the plywood sheeting. A treated lumber or plywood strip shall be attached to the wall to cover the top edge of the polyethylene sheeting. The wood strip shall extend at least 2 inches (51 mm) above and 5 inches (127 mm) below finish grade level to protect the polyethylene from exposure to light and from mechanical damage at or near grade. The joint between the strip and the wall shall be caulked full length prior to fastening the strip to the wall. Alternatively, asbestos-cement board, brick, stucco or other covering appropriate to the architectural treatment may be used in place of the wood strip. The polyethylene sheeting shall extend down to the bottom of the wood footing plate, but shall not overlap or extend into the gravel footing.

1812.5 Perimeter Drainage Control. The space between the side of a basement excavation and the exterior of a basement wall shall be backfilled for half the height of the excavation with the same material used for footings, except that for basements located in GW-, GP-, SW-, SP-, GM- and SM-type soils, or other sites that are well drained and acceptable to the authority having jurisdiction, the granular fill need not exceed a height of 1 foot (305 mm) above the footing. The top of this granular fill outside basement foundation walls and footings shall be covered with strips of 6-mil-thick (0.153 mm) polyethylene sheeting or Type 30 felt, with adjacent strips lapped to provide for water seepage while preventing excessive infiltration of fine soils. Perforated sheeting or other filter membrane may also be used to control infiltration of fines.

1812.6 Alternate Drainage System. If a continuous concrete footing rather than a composite wood and gravel footing is used with the wood foundation in basement construction, the concrete shall be placed over a 4-inch-thick (102 mm) layer of gravel, crushed stone or sand that is arranged to allow drainage of water from the granular backfill outside the footing to the porous layer under the slab. Alternately, drainage across the concrete footing shall be provided by transverse pipes or drain tiles embedded in the concrete every 6 linear feet (1829 mm) around the foundation.

1812.7 Insulation. Where insulation is applied between studs in exterior basement walls but the insulation is not flush with the exterior wall sheathing and does not extend down to the bottom plate, blocking shall be installed between the studs at the lower end of the insulation to prevent convection currents.

SECTION 1813 — DESIGN LOADS

1813.1 General. All parts of the wood foundation system shall be designed and constructed to provide safe support for all anticipated loads within the stress limits specified by this code. Design loads shall not be less than those specified in Chapter 16.

Design loads shall include downward forces acting on the wall from dead loads and roof and floor live loads, plus the lateral pressure from soil. Where applicable, the foundation also shall be designed to resist wind, earthquake and other static or dynamic forces. The foundation system shall be designed for the most severe distribution, concentration or combination of design loads deemed proper to act on the structure simultaneously.

1813.2 Soil Loads. Lateral pressure of the soil on the wall shall be considered in accordance with Section 1611.6.

SECTION 1814 — STRUCTURAL DESIGN

1814.1 General. Structural design of wood foundations shall be in accordance with established structural engineering and wood design practices as set forth in Chapter 23.

1814.2 Allowable Stresses. Allowable unit stresses for lumber and plywood shall be as provided in Section 2304. Design stresses for framing lumber shall be based on use under dry conditions (19 percent maximum moisture content), except that stresses for footing plates and crawl space framing shall be based on use under wet conditions. Design stresses for plywood sheathing shall be based on use under damp (moisture content 16 percent or more) conditions.

1814.3 Allowable Loads on Fastenings. Allowable loads for steel nails and framing anchors shall be in accordance with Section 2318. Allowable loads for stainless steel Type 304 or 316, silicon bronze or copper nails shall be developed on a comparable basis to loads allowed for common steel nails. Allowable loads for stainless steel Type 304 or 316, silicon bronze or copper staples or other fasteners shall be in accordance with good engineering practice.

1814.4 Footing Design. The treated wood foundation systems incorporate a composite footing consisting of a wood footing plate and a layer of gravel, coarse sand or crushed stone. The wood footing plate distributes the axial design load from the framed wall to the gravel layer which in turn distributes it to the supporting soil.

Soil-bearing pressure under the gravel, sand or crushed stone footings shall not exceed the allowable soil bearing values from Table 18-I-A except as permitted by Section 1805.

Footing plate width shall be determined by allowable bearing pressure between the footing plate and the granular part of the footing. Gravel, sand or crushed stone under the footing plate shall be compacted to provide an allowable bearing capacity of 3,000 psf (144 kPa) when required by the design, otherwise an allowable bearing capacity of 2,000 psf (96 kPa) shall be assumed.

When the footing plate is wider than the bottom wall plate, the tension stress perpendicular to grain induced in the bottom face of the footing plate shall not exceed one third the allowable unit shear stress for the footing plate. Use of plywood strips to reinforce the lumber footing plate is acceptable.

Thickness and width of the granular footing shall be determined by allowable bearing pressure between the gravel, sand or crushed stone and the supporting soil, assuming the downward load from the wood footing plate is distributed outward through the gravel, sand or crushed stone footing at an angle of 30 degrees from vertical at each edge of the footing plate. Additionally, the gravel, sand or crushed stone footing shall have a width not less than twice the width and a thickness not less than three-quarters the width of the wood footing plate and shall be confined laterally by backfill, granular fill, undisturbed soil, the foundation wall or other equivalent means.

The bottom of the wood footing plate shall not be above the maximum depth of frost penetration unless the gravel, sand or crushed stone footing extends to the maximum depth of frost penetration and is either connected to positive mechanical or gravity drainage, at or below the frost line, or is installed in GW-, GP-, SW-, SP-, GM- and SM-type soils where the permanent water table is below the frost line. A granular footing connected to a positively drained sump (see Section 1812.3) by a trench filled with gravel, sand or crushed stone, or by an acceptable pipe connection, shall be considered to be drained to the level of the bottom of the sump or the bottom of the connecting trench or pipe, whichever is higher.

Where the bottom of the wood footing plate of a crawl space wall is not below the frost line, the top of the gravel, sand or crushed stone outside the wall shall be covered as required in Section 1812.5 for basement construction to prevent excessive infiltration of fine soils.

Where a wood footing plate is close to finished grade, such as when a deep granular footing is used to reach the frost line, the granular footing shall be protected against surface erosion or mechanical disturbance.

Posts and piers and their footings in basements or crawl spaces shall be in accordance with Sections 1806 and 2306.

Footings under posts or piers may be of treated wood, treated wood and gravel, precast concrete or other approved material.

1814.5 Foundation Wall Design. Foundation wall studs shall be designed for stresses due to combined bending moment and axial loading resulting from lateral soil pressure and downward live and dead loads on the foundation wall, and for shear stresses due to lateral soil pressure. Top and bottom wall plates shall be designed for bearing of the studs on the plates. Joints in footing plate and upper top plate shall be staggered at least one stud space from joints in the adjacent plate to provide continuity between wall panels. Framing at openings in wall and floor systems and at other points of concentrated loads shall be designed with adequate capacity for the concentrated loads.

Plywood wall sheathing shall be designed for the shear and bending moment between studs due to soil pressures.

Joints, fastenings and connections in the wood foundation system shall be adequate to transfer all vertical and horizontal forces to the footing or to the applicable floor system. Connections at the top of the foundation wall shall be designed to transfer lateral soil load into the floor assembly. Lateral load at the bottom of a basement wall shall be transferred to the basement floor through bearing of the studs against the floor. Lateral load at the bottom of a crawl space wall shall be resisted by the soil inside the footing.

Foundation walls subject to racking loads due to earthquake, wind or differential soil pressure forces shall be designed with adequate shear strength to resist the most severe racking load or combination of loads, but earthquake and wind forces shall not be assumed to act simultaneously. Where a bottom wall plate of 1-inch (25 mm) nominal thickness has been used, the bottom of the wall shall be considered an unsupported panel edge when determining shear resistance of the wall.

1814.6 Interior Load-bearing Walls. Interior load-bearing walls in basements or crawl spaces shall be designed to carry the applicable dead and live loads in accordance with standard engineering practice and the requirements of this code.

1814.7 Basement Floor Design. Concrete slab basement floors shall be designed in accordance with requirements of this code but shall not be less than $3^1/_2$ inches (89 mm) in thickness.

Wood basement floors shall be designed to withstand axial forces and bending moments resulting from lateral soil pressures at the base of the exterior foundation walls and floor and live and dead loads. Floor framing shall be designed to meet joist deflection requirements of this code.

Unless special provision is made to resist sliding caused by unbalanced lateral soil loads, wood basement floors shall be limited to applications where the differential depth of fill on opposing exterior foundation walls is 2 feet (610 mm) or less.

Joists in wood basement floors shall bear tightly against the narrow face of studs in the foundation wall or directly against a band joist that bears on the studs. Plywood subfloor shall be continuous overlapped joists or over butt joints between in-line joists. Where joists are parallel to the wall, sufficient blocking shall be provided between joists to transfer lateral forces from the base of the wall into the floor system.

Where required, resistance to uplift or restraint against buckling shall be provided by interior-bearing walls or appropriately designed stub walls anchored in the supporting soil below.

Sleepers, joists, blocking and plywood subflooring used in basement floors shall meet the treatment requirements of Section 1811.7.

1814.8 Uplift or Overturning. Design of the structure for uplift or overturning shall be in accordance with the requirements of this code.

Division III—DESIGN STANDARD FOR DESIGN OF SLAB-ON-GROUND FOUNDATIONS TO RESIST THE EFFECTS OF EXPANSIVE SOILS AND COMPRESSIBLE SOILS

SECTION 1815 — DESIGN OF SLAB-ON-GROUND FOUNDATIONS [BASED ON DESIGN OF SLAB-ON-GROUND FOUNDATIONS OF THE WIRE REINFORCEMENT INSTITUTE, INC. (AUGUST, 1981)]

1815.1 Scope. This section covers a procedure for the design of slab-on-ground foundations to resist the effects of expansive soils in accordance with Division I. Use of this section shall be limited to buildings three stories or less in height in which gravity loads are transmitted to the foundation primarily by means of bearing walls constructed of masonry, wood or steel studs, and with or without masonry veneer.

1815.2 Symbols and Notations.

$1\text{-}c$ = soil/climatic rating factor. See Figure 18-III-8.
A_s = area of steel reinforcing (square inch per foot) (mm^2 per m) in slab. See Figure 18-III-1.
C_o = overconsolidation coefficient. See Figure 18-III-2.
C_s = soil slope coefficient. See Figure 18-III-3.
C_w = climatic rating. See Figure 18-III-4.
E_c = creep modulus of elasticity of concrete.
f_y = yield strength of reinforcing.
I_c = cracked moment of inertia of cross section.
k_l = length modification factor-long direction. See Figure 18-III-5.
k_s = length modification factor-short direction. See Figure 18-III-5.
L = total length of slab in prime direction.
L' = total length of slab (width) perpendicular to L.
L_c = design cantilever length ($l_c k$)—See Figures 18-III-5 and 18-III-6.
l_c = cantilever length as soil function.
M_l = design moment in long direction.
M_s = design moment in short direction.
PI = plasticity index.
S = maximum spacing of beams. See Figure 18-III-7.
V = design shear force (total).
w = weight per square foot (N/m^2) of building and slab.
q_u = unconfined compressive strength of soil.
Δ = deflection of slab, inch (mm).

1815.3 Foundation Investigation. A foundation investigation of the site shall be conducted in accordance with the provisions of Section 1804.

1815.4 Design Procedure.

1815.4.1 Loads. The foundation shall be designed for a uniformly distributed load which shall be determined by dividing the actual dead and live loads for which the superstructure is designed, plus the dead and live loads contributed by the foundation, by the area of the foundation.

EXCEPTIONS: 1. For one-story metal and wood stud buildings, with or without masonry veneer, and when the design floor live load is 50 pounds per square foot (2.4 kN/m^2) or less, a uniformly distributed load of 200 pounds per square foot (9.6 kN/m^2) may be assumed in lieu of calculating the effects of specific dead and live loads.

2. Those conditions where concentrated loads are of such magnitude that they must be considered are not covered by this section.

1815.4.2 Determining the effective plasticity index. The effective plasticity index to be used in the design shall be determined in accordance with the following procedures:

1. The plasticity index shall be determined for the upper 15 feet (4572 mm) of the soil layers and where the plasticity index varies between layers shall be weighted in accordance with the procedures outlined in Figure 18-III-9.

2. Where the natural ground slopes, the plasticity index shall be increased by the factor C_s determined in accordance with Figure 18-III-3.

3. Where the unconfined compressive strength of the foundation materials exceeds 6,000 pounds per square foot (287.4 kPa), the plasticity index shall be modified by the factor C_o determined in accordance with Figure 18-III-2. Where the unconfined compressive strength of the foundation materials is less than 6,000 pounds per square foot (287.4 kPa), the plasticity index may be modified by the factor C_o determined in accordance with Figure 18-III-2.

The value of the effective plasticity index is that determined from the following equation:

$$\text{Effective plasticity index} = \text{weighted plasticity index} \times C_s \times C_o$$

Other factors that are capable of modifying the plasticity index such as fineness of soil particles and the moisture condition at the time of construction shall be considered.

1815.5 Beam Spacing and Location. Reinforced concrete beams shall be provided around the perimeter of the slab, and interior beams shall be placed at spacings not to exceed that determined from Figure 18-III-7. Slabs of irregular shape shall be divided into rectangles (which may overlap) so that the resulting overall boundary of the rectangles is coincident with that of the slab perimeter. See Figure 18-III-10.

1815.6 Beam Design. The following formulas shall be used to calculate the moment, shear and deflections, and are based on the assumption that the zone of seasonal moisture changes under the perimeter of the slab is such that the beams resist loads as a cantilever of length L_c:

$$M = \frac{w\,L'\,(L_c)^2}{2}$$

$$V = wL'L_c$$

$$\Delta = \frac{w\,L'\,(L_c)^4}{4\,E_c\,I_c}$$

The calculations shall be performed for both the long and short directions. Deflection shall not exceed $L_c/480$.

1815.7 Slab Reinforcing. The minimum slab thickness shall be 4 inches (102 mm), and the maximum spacing of reinforcing bars shall be 18 inches (457 mm). The amount of reinforcing shall be determined in accordance with Figure 18-III-1. Slab reinforcing shall be placed in both directions at the specified amounts and spacing.

SECTION 1816 — DESIGN OF POSTTENSIONED SLABS ON GROUND (BASED ON DESIGN SPECIFICATION OF THE POSTTENSIONING INSTITUTE)

1816.1 Scope. This section covers a procedure for the design of slab-on-ground foundations to resist the effects of expansive soils in accordance with Division I. Use of this section shall be limited to buildings three stories or less in height in which gravity loads are transmitted to the foundation primarily by means of bearing walls constructed of masonry, wood or steel studs, and with or without masonry veneer.

1816.2 List of Symbols and Notations.

A = area of gross concrete cross section, in.^{2} (mm^2).

A_b = bearing area beneath a tendon anchor, in.^{2} (mm^2).

A'_b = maximum area of the portion of the supporting surface that is geometrically similar to and concentric with the loaded area, in.^{2} (mm^2).

A_{bm} = total area of beam concrete, in.^{2} (mm^2).

AC = activity ratio of clay.

A_o = coefficient in Formula (16-13-1).

A_{ps} = area of prestressing steel in.^{2} (mm^2).

A_{sl} = total area of slab concrete, in.^{2} (mm^2).

B = constant used in Formula (16-13-1).

b = width of an individual stiffening beam, in. (mm).

B_w = assumed slab width (used in Section 1816.4.12), in. (mm).

C = constant used in Formula (16-13-1).

c = distance between *CGC* and extreme cross-section fibers, in. (mm).

$CEAC$ = cation exchange activity.

CGC = geometric centroid of gross concrete section.

CGS = center of gravity of prestressing force.

C_p = coefficient in Formula (16-35) for slab stress due to partition load—function of k_s.

C_Δ = coefficient used to establish allowable differential deflection (see Table 18-III-GG).

e = eccentricity of posttensioning force (perpendicular distance between the *CGS* and the *CGC*), in. (mm).

E_c = long-term or creep modulus of elasticity of concrete, psi (MPa).

EI = expansion index (see Table 18-I-B and UBC Standard 18-2).

e_m = edge moisture variation distance, ft. (m).

e_n = base of natural (Naperian) logarithms.

E_s = modulus of elasticity of the soil, psi (MPa).

f = applied flexural concrete stress (tension or compression), psi (MPa).

f_B = section modulus factor for bottom fiber.

f_{bp} = allowable bearing stress under tendon anchorages, psi (MPa).

f_c = allowable concrete compressive stress, psi (MPa).

f'_c = 28-day concrete compressive strength, psi (MPa).

f'_{ci} = concrete compressive strength at time of stressing tendons, psi (MPa).

f_{cr} = concrete modulus of rupture, flexural tension stress which produces first cracking, psi (MPa).

f_e = effective prestress force, lbs. (N).

f_p = minimum average residual prestress compressive stress, psi (MPa).

f_{pi} = allowable tendon stress immediately after stressing, psi (MPa).

f_{pj} = allowable tendon stress due to tendon jacking force, psi (MPa).

f_{pu} = specified maximum tendon tensile stress, psi (MPa).

f_T = section modulus factor for top fiber.

f_t = allowable concrete flexural tension stress, psi (MPa).

g = moment of inertia factor.

H = thickness of a uniform thickness foundation, in. (mm).

h = total depth of stiffening beam, measured from top surface of slab to bottom of beam (formerly *d*, changed for consistency with ACI-318), in. (mm).

I = gross concrete moment of inertia, in.^{4} (mm^4).

k = depth-to-neutral axis ratio; also abbreviation for "kips" (kN).

k_s = soil subgrade modulus, pci (N/mm^3).

L = total slab length (or total length of design rectangle) in the direction being considered (short or long), perpendicular to *W*, ft. (m).

L_L = long length of the design rectangle, ft. (m).

L_S = short length of the design rectangle, ft. (m).

M_L = maximum applied service load moment in the long direction (causing bending stresses on the short cross section) from either center lift or edge lift swelling condition, ft.-kips/ft. (kN·m/m).

M_{max} = maximum moment in slab under load-bearing partition, ft.-kips/ft. (kN·m/m).

M_S = maximum applied service load moment in the short direction (causing bending stresses on the long cross section) from either center lift or edge lift swelling condition, ft.-kips/ft. (kN·m/m).

n = number of stiffening beams in a cross section of width *W*.

P = a uniform unfactored service line load *(P)* acting along the entire length of the perimeter stiffening beams representing the weight of the exterior building material and that portion of the superstructure dead and live loads that frame into the exterior wall. *P* does not include any portion of the foundation concrete, lbs./ft. (N/m).

P_e = effective prestress force after losses due to elastic shortening, creep and shrinkage of concrete, and steel relaxation, kips (kN).

PI = plasticity index.

P_i = prestress force immediately *after* stressing and anchoring tendons, kips (kN).

P_r = resultant prestress force after *all* losses (including those due to subgrade friction), kips (kN).

q_{allow} = allowable soil-bearing pressure, psf (N/m^2).

q_u = unconfined compressive strength of the soil, psf (N/m^2).

S = interior stiffening beam spacing, ft. If beam spacings vary, the average spacing may be used if the ratio between the largest and smallest spacing does not exceed 1.5. If the ratio between the largest and smallest spacing exceeds 1.5, use $S = 0.85x$ (largest spacing).

S_b = section modulus with respect to bottom fiber, in.^{3} (mm^3).

SG = prestress loss due to subgrade friction, kips (kN).
S_T = section modulus with respect to top fiber, in.^{3} (mm^3).
t = slab thickness in a ribbed (stiffened) foundation, in. (mm).
V = controlling service load shear force, larger of V_S or V_L, kips/ft. (kN/m).
v = service load shear stress, psi (MPa).
v_c = allowable concrete shear stress, psi (MPa).
V_L = maximum service load shear force in the long direction from either center lift or edge lift swelling condition, kips/ft. (kN/m).
V_S = maximum service load shear force in the short direction from either center lift or edge lift swelling condition, kips/ft. (kN/m).
W = foundation width (or width of design rectangle) in the direction being considered (short or long), perpendicular to L, ft. (m).
W_{slab} = foundation weight, lbs. (kg).
y_m = maximum differential soil movement or swell, in. (mm).
α = slope of tangent to tendon, radians.
β = relative stiffness length, approximate distance from edge of slab to point of maximum moment, ft. (m).
Δ = expected service load differential deflection of slab, including correction for prestressing, in. (mm) ($\Delta = \Delta_o \pm \Delta_p$).
Δ_{allow} = allowable differential deflection of slab, in. (mm).
Δ_o = expected service load differential deflection of slab (without deflection caused by prestressing), in. (mm).
Δ_p = deflection caused by prestressing, in. (mm).
μ = coefficient of friction between slab and subgrade.

1816.3 Foundation Investigation. A foundation investigation of the site shall be conducted in accordance with the provisions of Section 1804.

1816.4 Structural Design Procedure for Slabs on Expansive Soils.

1816.4.1 General. This procedure can be used for slabs with stiffening beams (ribbed foundations) or uniform thickness foundations. To design a uniform thickness foundation, the designer must first design a ribbed foundation that satisfies all requirements of the design procedure for ribbed foundations. The fully conformant ribbed foundation is then converted to an equivalent uniform thickness foundation.

The design procedure for posttensioned foundations constructed over expansive clays should include the following steps, with the pertinent sections shown in parentheses:

1. Assemble all the known design data (Section 1816.4.2).

2. Divide an irregular foundation plan into overlapping rectangles and design each rectangular section separately (Figure 18-III-11).

3. Assume a trial section for a ribbed foundation in both the long and short directions of the design rectangle (Section 1816.4.3).

4. Calculate the applied service moment the section will be expected to experience in each direction for either the center lift or edge lift condition (Section 1816.4.7).

5. Determine the flexural concrete stresses caused by the applied service moments and compare to the allowable flexural concrete stresses (Sections 1816.4.4 and 1816.4.7).

6. Determine the expected differential deflections and compare with the allowable differential deflections (Section 1816.4.9).

7. Calculate the applied service shear force and shear stress in the assumed sections and compare the applied shear stress with the allowable shear stress (Section 1816.4.10).

8. Convert the ribbed foundation to an equivalent uniform thickness foundation, if desired (Section 1816.4.11).

9. Repeat Steps 4 through 8 for the opposite swelling condition.

10. Check the design for the first swelling condition to ascertain if adjustments are necessary to compensate for any design changes resulting from the second design swelling condition addressed in Step 9.

11. Check the effect of slab-subgrade friction to ensure a residual compressive stress of 50 psi (0.35 MPa) at the center of each design rectangle in both directions. Adjust posttensioning force, if necessary (Section 1816.4.6).

12. Calculate stresses due to any heavy concentrated loads on the slab and provide special load transfer details when necessary (Section 1816.4.12).

1816.4.2 Required design data. The soils and structural properties needed for design are as follows:

1. **Soils properties.**
   1.1 Allowable soil-bearing pressure, q_{allow}, in pounds per square foot (newtons per square meter).
   1.2 Edge moisture variation distance, e_m, in feet (meters)
   1.3 Differential soil movement, y_m, in inches (millimeters).
   1.4 Slab-subgrade friction coefficient, μ.
2. **Structural data and materials properties.**
   2.1 Slab length, L, in feet (meters) (both directions).
   2.2 Perimeter loading, P, in pounds per foot (newtons per meter).
   2.3 Average stiffening beam spacing, S, in feet (meters) (both directions).
   2.4 Beam depth, h, in inches (millimeters).
   2.5 Compressive strength of the concrete, f'_c, in pounds per square inch (MPa).
   2.6 Allowable flexural tensile stress in the concrete, f_t, in pounds per square inch (MPa).
   2.7 Allowable compressive stress in the concrete, f_c, in pounds per square inch (MPa).
   2.8 Type, grade and strength of the prestressing steel.
   2.9 Prestress losses in kips per inch (kN per mm).

1816.4.3 Trial section assumptions.

1816.4.3.1 Assume beam depth and spacing. An initial estimate of the depth of the stiffening beam can be obtained from solving either Formula (16-21) or Formula (16-22) for the beam depth yielding the maximum allowable differential deflection. The procedure is as follows:

1. Determine the maximum distance over which the allowable differential deflection will occur, L or 6β, whichever is smaller. As a first approximation, use β = 8 feet (2.44 m).

2. Select the allowable differential deflection Δ_{allow}:
   2.1 Center lift (assume C_Δ = 360):

$$\Delta_{allow} = \frac{12(L \text{ or } 6\beta)}{C_\Delta} = \frac{12(L \text{ or } 6\beta)}{360} \qquad (16\text{-}1)$$

For **SI:** 1 inch = 25.4 mm.

2.2 Edge lift (assume $C_\Delta = 720$):

$$\Delta_{allow} = \frac{12(L \text{ or } 6\beta)}{C_\Delta} = \frac{12(L \text{ or } 6\beta)}{720} \quad (16\text{-}2)$$

For **SI:** 1 inch = 25.4 mm.

Alternatively, C_Δ may be selected from Table 18-III-GG, which presents sample C_Δ values for various types of superstructures.

3. Assume a beam spacing, *S*, and solve for beam depth, *h*:

3.1 Center lift (from Formula 16-20):

$$h^{1.214} = \frac{(y_m L)^{0.205}(S)^{1.059}(P)^{0.523}(e_m)^{1.296}}{380\Delta_{allow}} \quad (16\text{-}3\text{-}1)$$

$$h = \left(\frac{(y_m L)^{0.205}(S)^{1.059}(P)^{0.523}(e_m)^{1.296}}{380\Delta_{allow}}\right)^{0.824} \quad (16\text{-}3\text{-}2)$$

For **SI:** 1 inch = 25.4 mm.

3.2 Edge lift (from Formula 16-21):

$$h^{0.85} = \frac{(L)^{0.35}(S)^{0.88}(e_m)^{0.74}(y_m)^{0.76}}{15.9\Delta_{allow}(P)^{0.01}} \quad (16\text{-}4\text{-}1)$$

$$h = \left(\frac{(L)^{0.35}(S)^{0.88}(e_m)^{0.74}(y_m)^{0.76}}{15.9\Delta_{allow}(P)^{0.01}}\right)^{1.176} \quad (16\text{-}4\text{-}2)$$

For **SI:** 1 inch = 25.4 mm.

Select the larger *h* from Formula (16-3-2) or (16-4-2). In the analysis procedure, the beam depth *h* must be the same for all beams in both directions. If different beam depths are selected for the *actual* structure (such as a deeper edge beam), the analysis shall be based on the smallest beam depth actually used.

1816.4.3.2 Determine section properties. The moment of inertia, section modulus, and cross-sectional area of the slabs and beams, and eccentricity of the prestressing force shall be calculated for the trial beam depth determined above in accordance with normal structural engineering procedures.

1816.4.4 Allowable stresses.

The following allowable stresses are recommended:

1. **Allowable concrete flexural tensile stress:**

$$f_t = 6\sqrt{f'_c} \quad (16\text{-}5)$$

For **SI:** $f_t = 0.5\sqrt{f'_c}$

2. **Allowable concrete flexural compressive stress:**

$$f_c = 0.45f'_c \quad (16\text{-}6)$$

3. **Allowable concrete bearing stress at anchorages.**

3.1 At service load:

$$f_{bp} = 0.6f'_c\sqrt{\frac{A'_b}{A_b}} \le f'_c \quad (16\text{-}7)$$

3.2 At transfer:

$$f_{bp} = 0.8f'_{ci}\sqrt{\frac{A'_b}{A_b} - 0.2} \le 1.25f'_{ci} \quad (16\text{-}8)$$

4. **Allowable concrete shear stress:**

$$v_c = 1.7\sqrt{f'_c} + 0.2f_p \quad (16\text{-}9)$$

For **SI:** $v_c = 0.14\sqrt{f'_c} + 0.2f_p$

5. **Allowable stresses in prestressing steel.**

5.1 Allowable stress due to tendon jacking force:

$$f_{pj} = 0.8f_{pu} \le 0.94f_{py} \quad (16\text{-}10)$$

5.2 Allowable stress immediately after prestress transfer:

$$f_{pi} = 0.7f_{pu} \quad (16\text{-}11)$$

1816.4.5 Prestress losses. Loss of prestress due to friction, elastic shortening, creep and shrinkage of the concrete, and steel relaxation shall be calculated in accordance with Section 1918.6.

1816.4.6 Slab-subgrade friction. The effective prestressing force in posttensioned slabs-on-ground is further reduced by the frictional resistance to movement of the slab on the subgrade during stressing as well as the frictional resistance to dimensional changes due to concrete shrinkage, creep and temperature variations. The resultant prestress force, P_r , is the difference between the effective prestress force and the losses due to subgrade friction:

$$P_r = P_e - SG \quad (16\text{-}12\text{-}1)$$

For **SI:** 1 pound = 4.45 kN.

where *SG* can be conservatively taken as:

$$SG = \frac{W_{slab}}{2000}\mu \quad (16\text{-}12\text{-}2)$$

For **SI:** 1 pound = 4.45 kN.

The largest amount of prestress loss due to slab-subgrade friction occurs in the center regions of the slab. The greatest structural requirement for prestress force, however, is at the location of the maximum moment, which occurs at approximately one β-length inward from the edge of the slab. For normal construction practices, the value of the coefficient of friction μ should be taken as 0.75 for slabs on polyethylene and 1.00 for slabs cast directly on a sand base.

The maximum spacing of tendons shall not exceed that which would produce a minimum average effective prestress compression of 50 psi (0.35 MPa) after allowance for slab-subgrade friction.

1816.4.7 Maximum applied service moments. The maximum moment will vary, depending on the swelling mode and the slab direction being designed. For design rectangles with a ratio of long side to short side less than 1.1, the formulas for M_L [Formulas (16-13-1) and (16-15)] shall be used for moments in both directions.

1. **Center lift moment.**

1.1 Long direction:

$$M_L = A_o\left[B(e_m)^{1.238} + C\right] \quad (16\text{-}13\text{-}1)$$

For **SI:** 1 ft.·kips/ft. = 4.45 kN·m/m.

WHERE:

$$A_o = \frac{1}{727}\left[(L)^{0.013}(S)^{0.306}(h)^{0.688}(P)^{0.534}(y_m)^{0.193}\right] \quad (16\text{-}13\text{-}2)$$

and for:

$$0 \leq e_m \leq 5 \quad B = 1, \; C = 0 \qquad (16\text{-}13\text{-}3)$$

$$e_m > 5 \quad B = \left(\frac{y_m - 1}{3}\right) \leq 1.0 \qquad (16\text{-}13\text{-}4)$$

$$C = \left[8 - \frac{P - 613}{255}\right]\left[\frac{4 - y_m}{3}\right] \geq 0 \qquad (16\text{-}13\text{-}5)$$

1.2 Short direction.

For $L_L/L_S \geq 1.1$:

$$M_S = \left[\frac{58 + e_m}{60}\right] M_L \qquad (16\text{-}14)$$

For **SI:** 1 ft.·kips/ft. = 4.45 kN·m/m.

For $L_L/L_S < 1.1$:

$$M_S = M_L$$

2. **Edge lift moment.**

2.1 Long direction:

$$M_L = \frac{(S)^{0.10}(he_m)^{0.78}(y_m)^{0.66}}{7.2(L)^{0.0065}(P)^{0.04}} \qquad (16\text{-}15)$$

For **SI:** 1 ft.·kips/ft. = 4.45 kN·m/m.

2.2 Short direction.

For $L_L/L_S \geq 1.1$:

$$M_S = h^{0.35}\left[\frac{19 + e_m}{57.75}\right] M_L \qquad (16\text{-}16)$$

For **SI:** 1 ft.·kips/ft. = 4.45 kN·m/m.

For $L_L/L_S < 1.1$:

$$M_S = M_L$$

Concrete flexural stresses produced by the applied service moments shall be calculated with the following formula:

$$f = \frac{P_r e}{A} \pm \frac{M_{L,S}}{S_{t,b}} \pm \frac{P_r e}{S_{t,b}} \qquad (16\text{-}17)$$

For **SI:** 1 pound per square inch = 0.0069 MPa.

The applied concrete flexural stresses f shall not exceed f_t in tension and f_c in compression.

1816.4.8 Cracked section considerations. This design method limits concrete flexural tensile stresses to $6\sqrt{f'_c}$ (For **SI:** $0.5\sqrt{f'_c}$). Since the modulus of rupture of concrete is commonly taken as $f_{cr} = 7.5\sqrt{f'_c}$ (For **SI:** $f_{cr} = 0.625\sqrt{f'_c}$), slabs designed with this method will theoretically have no *flexural* cracking. Some cracking from restraint to slab shortening is inevitable in posttensioned slabs on ground, as it is in elevated posttensioned concrete members. Nevertheless, the limitation of flexural tensile stresses to a value less than the modulus of rupture justifies the use of the gross concrete cross section for calculating all section properties. This is consistent with standard practices in elevated posttensioned concrete members.

1816.4.9 Differential deflections. Allowable and expected differential deflections may be calculated from the formulas presented in the following sections.

1816.4.9.1 Relative stiffness length. β may be calculated as follows:

$$\beta = \frac{1}{12}\sqrt[4]{\frac{E_c I}{E_s}} \qquad (16\text{-}18)$$

For **SI:** $\beta = \dfrac{1}{1000}\sqrt[4]{\dfrac{E_c I}{E_s}}$

If the creep modulus of elasticity of the concrete E_c is not known, it can be closely approximated by using half of the normal or early life concrete modulus of elasticity. If the modulus of elasticity of the clay soil E_S is not known, use 1,000 psi (6.89 MPa). I in Formula (16-18) is the gross moment of inertia for the entire slab cross section of width W, in the appropriate direction (short or long).

1816.4.9.2 Differential deflection distance. The differential deflection may not occur over the entire length of the slab, particularly if the slab is longer than approximately 50 feet (15.24 m). Thus, the effective distance for determining the allowable differential deflection is the smaller of the two distances, L or 6β, both expressed in feet (meters).

1816.4.9.3 Allowable differential deflection, Δ_{allow} (in inches) (mm).

1. Center lift or edge lift:

$$\Delta_{allow} = \frac{12(L \text{ or } 6\beta)}{C_\Delta} \qquad (16\text{-}19)$$

For **SI:** $\Delta_{allow} = \dfrac{1000(L \text{ or } 6\beta)}{C_\Delta}$

The coefficient C_Δ is a function of the type of superstructure material and the swelling condition (center or edge lift). Sample values of C_Δ for both swelling conditions and various superstructure materials are shown in Table 18-III-GG.

1816.4.9.4 Expected differential deflection without prestressing, Δ_o (in inches) (mm):

1. Center lift:

$$\Delta_o = \frac{(y_m L)^{0.205}(S)^{1.059}(P)^{0.523}(e_m)^{1.296}}{380(h)^{1.214}} \qquad (16\text{-}20)$$

For **SI:** 1 inch = 25.4 mm.

2. Edge lift:

$$\Delta_o = \frac{(L)^{0.35}(S)^{0.88}(e_m)^{0.74}(y_m)^{0.76}}{15.9(h)^{0.85}(P)^{0.01}} \qquad (16\text{-}21)$$

For **SI:** 1 inch = 25.4 mm.

1816.4.9.5 Deflection caused by prestressing, Δ_p (in inches) (mm). Additional slab deflection is produced by prestressing if the prestressing force at the slab edge is applied at any point other than the *CGC*. The deflection caused by prestressing can be approximated with reasonable accuracy by assuming it is produced by a concentrated moment of $P_e e$ applied at the end of a cantilever with a span length of β. The deflection is:

$$\Delta_p = \frac{P_e e \beta^2}{2E_c I} \qquad (16\text{-}22)$$

For **SI:** 1 inch = 25.4 mm.

If the tendon *CGS* is higher than the concrete *CGC* (a typical condition), Δ_p increases the edge lift deflection and decreases the center lift deflection. Deflection caused by prestressing is normally small and can justifiably be ignored in the design of most posttensioned slabs on ground.

1816.4.9.6 Compare expected to allowable differential deflection. If the expected differential deflection as calculated by either Formula (16-20) or (16-21), adjusted for the effect of prestressing, exceeds that determined from Formula (16-19) for the appropriate swelling condition, the assumed section must be stiffened.

1816.4.10 Shear.

1816.4.10.1 Applied service load shear. Expected values of service shear forces in kips per foot (kN per meter) of width of slab and stresses in kips per square inch (kN per square millimeter) shall be calculated from the following formulas:

1. Center lift.

 1.2 Long direction shear:

$$V_L = \frac{1}{1940}\left[(L)^{0.09}(S)^{0.71}(h)^{0.43}(P)^{0.44}(y_m)^{0.16}(e_m)^{0.93}\right] \quad (16\text{-}23)$$

For **SI:** 1 kips/ft. = 14.59 kN/m.

 1.1 Short direction shear:

$$V_s = \frac{1}{1350}\left[(L)^{0.19}(S)^{0.45}(h)^{0.20}(P)^{0.54}(y_m)^{0.04}(e_m)^{0.97}\right] \quad (16\text{-}24)$$

For **SI:** 1 kips/ft. = 14.59 kN/m.

2. Edge lift (for both directions):

$$V_S \text{ or } V_L = \frac{(L)^{0.07}(h)^{0.4}(P)^{0.03}(e_m)^{0.16}(y_m)^{0.67}}{3.0(S)^{0.015}} \quad (16\text{-}25)$$

For **SI:** 1 kips/ft. = 14.59 kN/m.

1816.4.10.2 Applied service load shear stress, *v*. Only the beams are considered in calculating the cross-sectional area resisting shear force in a ribbed slab:

1. Ribbed foundations:

$$v = \frac{VW}{nhb} \quad (16\text{-}26)$$

For **SI:** 1 pound per square inch = 0.0069 MPa.

2. Uniform thickness foundations:

$$v = \frac{V}{12H} \quad (16\text{-}27)$$

For **SI:** 1 pound per square inch = 0.0069 MPa.

1816.4.10.3 Compare v to v_c. If v exceeds v_c, shear reinforcement in accordance with ACI 318-95 shall be provided. Possible alternatives to shear reinforcement include:

1. Increasing the beam depth,
2. Increasing the beam width,
3. Increasing the number of beams (decrease the beam spacing).

1816.4.11 Uniform thickness conversion. Once the ribbed foundation has been designed to satisfy moment, shear and differential deflection requirements, it may be converted to an equivalent uniform thickness foundation with thickness H, if desired. To convert a ribbed slab of width, W (ft.) (m) and moment of inertia, I (in.^{4}) (mm^4) to a uniform thickness foundation of width, W (ft.) (m) and depth, H (ft.) (m), use the following formula:

$$I = \frac{(12W)H^3}{12} \quad (16\text{-}28)$$

Solve for H:

$$H = \sqrt[3]{\frac{I}{W}} \quad (16\text{-}29)$$

For **SI:** $H = \sqrt[3]{\dfrac{12I}{1000W}}$

1816.4.12 Calculation of stress in slabs due to load-bearing partitions. The formula for the allowable tensile stress in a slab beneath a bearing partition may be derived from beam-on-elastic foundation theory. The maximum moment directly under a point load P in such a beam is:

$$M_{\max} = -\frac{P\beta}{4} \quad (16\text{-}30)$$

For **SI:** 1 ft.·kips/ft. = 4.45 kN·m/m.

WHERE:

$$\beta = \left[\frac{4E_cI}{k_sB_w}\right]^{0.25} \leq S_{t,b} \quad (16\text{-}31)$$

For **SI:** 1 ft.·kips/ft. = 4.45 kN·m/m.

with E_c = 1,500,000 psi (10 341 MPa) and k_s = 4 pci (0.001 N/mm^3):

$$\frac{I}{B_w} = \frac{B_wt^3}{12B_w} = \frac{t^3}{12}$$

$$\beta = \left[\frac{4(1,500,000)t^3}{4(12)}\right]^{0.25} = 18.8t^{0.75} \quad (16\text{-}32)$$

therefore:

$$M_{\max} = -\frac{18.8Pt^{0.75}}{4} = -4.7Pt^{0.75} \quad (16\text{-}33)$$

For **SI:** 1 ft.·kips/ft. = 4.45 kN·m/m.

The formula for applied tensile stress f_t is:

$$f_t = \frac{P_r}{A} - \frac{M_{\max}c}{I} \quad (16\text{-}34)$$

For **SI:** 1 pound per square inch = 0.0069 MPa.

and since:

$$\frac{I}{c} = \frac{B_wt^3}{12}\left(\frac{2}{t}\right) = \frac{B_wt^2}{6} = \frac{12t^2}{6} = 2t^2$$

the applied tensile stress is:

$$f = \frac{P_r}{A} - \frac{4.7Pt^{0.75}}{2t^2} = \frac{P_r}{A} - C_p\frac{P}{t^{1.25}} \quad (16\text{-}35)$$

For **SI:** 1 pound per square inch = 0.0069 MPa.

For uniform thickness foundations substitute H for t in Formulas (16-32), (16-33) and (16-35). The value of C_p depends on the assumed value of the subgrade modulus k_s. The following table illustrates the variation in C_p for different values of k_s:

TYPE OF SUBGRADE	k_s, lb./in.^{3} (0.00027 for N/mm^3)	C_p
Lightly compacted, high plastic compressible soil	4	2.35
Compacted, low plastic soil	40	1.34
Stiff, compacted, select granular or stabilized fill	400	0.74

If the allowable tensile stress is exceeded by the results of the above analysis, a thicker slab section should be used under the loaded area, or a stiffening beam should be placed directly beneath the concentrated line load.

SECTION 1817 — APPENDIX A (A PROCEDURE FOR ESTIMATION OF THE AMOUNT OF CLIMATE CONTROLLED DIFFERENTIAL MOVEMENT OF EXPANSIVE SOILS)

In general, the amount of differential movement to be expected in a given expansive soil should be based on recommendations supplied by a registered geotechnical engineer. The geotechnical engineer may use various soil testing procedures to provide a basis for these recommendations. A procedure developed in part through the PTI-sponsored research project at Texas A & M University that may be used by geotechnical engineers (in conjunction with accumulated experience with local soils conditions) as an aid for estimation of expected differential movements of expansive soils is presented in this appendix. This procedure is applicable only in those cases where site conditions have been corrected so that soil moisture conditions are controlled by the climate alone.

The information necessary to determine the differential movement using the procedure in this appendix is the type and amount of clay, the depth to constant or equilibrium suction, the edge moisture variation distance, the magnitude of the equilibrium suction, and the field moisture velocity. With this information either known or estimated, differential movements may be selected from Tables 18-III-A to 18-III-O for the center lift condition, or Tables 18-III-P to 18-III-DD for the edge lift condition.

Procedures for determining or estimating the necessary items of soil information are as follows:

1. Select a Thornthwaite Moisture Index from Figure 18-III-14 or 18-III-15. Alternatively, extreme annual values of the Thornthwaite Index may be calculated for a given site using Thornthwaite's procedures.

2. Obtain an estimate of the edge moisture variation distance, e_m, for both edge lift and center lift loading conditions from Figure 18-III-14.

3. Determine the percent of clay in the soil and the predominant clay mineral. The predominant type of clay can be determined by performing the following tests and calculations and by using Figure 18-III-15.

3.1 Determine the plastic limit (*PL*) and the plasticity index (*PI*) of the soil.

3.2 Determine the percentage of clay sizes in the material passing the U.S. No. 200 (75 μm) sieve (Hydrometer Test).

3.3 Calculate the activity ratio of the soil:

$$A_c = \frac{PI}{(\text{Percent passing U.S. No. 200 } [75\ \mu\text{m}] \text{ sieve } \leq 0.002\text{mm})} \qquad (1)$$

3.4 Calculate the Cation Exchange Activity. A discussion of procedures for determining Cation Exchange Capacity for use in calculating Cation Exchange Activity is presented in Appendix B.

$$CEAC = \frac{PI^{1.17}}{(\text{Percent passing U.S. No. 200 } [75\ \mu\text{m}] \text{ sieve } \leq 0.002\text{mm})} \qquad (2)$$

3.5 Enter Figure 18-III-15 with the A_c and *CEAC*. The soil type is determined by the intersection of the two entries. Note that the same mineral type is obtained from Figure 18-III-15 for a significant range of values of A_c and *CEAC*. This indicates that the determination of the mineral type is relatively insensitive to the precision by which the Atterberg Limits and other soil parameters have been determined. In the case of doubt as to the predominant mineral type, the clay may be conservatively classified as montmorillonite.

4. Depth to constant soil suction can be estimated as the depth below which the ratio of water content to plastic limit is constant. At times it will be the depth to an inert material, an unweathered shale, or to a high water table. Constant soil suction can be estimated with reasonable accuracy from Figure 18-III-16 if it is not actually determined in the laboratory; however, for most practical applications, the design soil suction value will seldom exceed a magnitude of *pF* 3.6.

5. Moisture velocity can be approximated by using a velocity equal to one half of the Thornthwaite Moisture Index [expressed in inches/year (mm/year)] for the construction site, converted to inches/month. To allow for extreme local variations in moisture velocity, this value shall not be assumed to be less than 0.5 in./month (12.7 mm/month), and the maximum moisture velocity shall be 0.7 in./month (17.8 mm/month).

6. Using values of edge moisture distance variation, e_m, percent clay, predominant clay mineral (kaolinite, illite, or montmorillonite), depth to constant suction, soil suction, *pF,* and velocity of moisture flow determined in steps 1 through 5 above, enter the appropriate tables, Tables 18-III-A to 18-III-O for center lift and Tables 18-III-P to 18-III-DD for edge lift, and find the corresponding soil differential movements, y_m. The values of swell presented in the tables were obtained from a computer program based on the permeability of clays and the total potential of the soil water.

SECTION 1818 — APPENDIX B (SIMPLIFIED PROCEDURES FOR DETERMINING CATION EXCHANGE CAPACITY AND CATION EXCHANGE ACTIVITY)

Simplified Procedure for Determining Cation Exchange Capacity Using a Spectrophotometer

The Cation Exchange Capacity of soil samples may be determined by comparative means in the standard spectrophotometer device. This method of determining the Cation Exchange Capacity is used by the U.S. Soil Conservation Service. Data obtained by this method should be comparable with data for similar soils that have been measured by the U.S. Conservation Service. This simplified procedure is:

1. Place 10 grams of clay soil in a beaker and 100 ml of neutral 1 N ammonium acetate (NH_4AC) is added. This solution is allowed to stand overnight.

2. Filter the solution of Step 1 by washing through filter paper with 50 ml of NH_4AC.

3. Wash the material retained on the filter paper of Step 2 with two 150 ml washings of isopropyl alcohol, using suction. The isopropyl alcohol wash fluid should be added in increments of approximately 25 ml and the sample allowed to drain well between additions.

4. Transfer the soil and filter paper to a 800-ml flask. Add 50 ml M_gCI_2 solution and allow to set at least 30 minutes, but preferably 24 hours.

5. Under suction, filter the fluid resulting from Step 4.

6. Normally, the solution of M_gCI_2 must be diluted before it is placed in the spectrophotometer in Step 10. The dilution will vary from one piece of equipment to the next. The calculations given at the end of this section assume that 200 ml of distilled water have

been used to dilute l ml of the M_gCI_2 solution. The 200-to-1 dilution is fairly typical.

7. Prepare a standard curve by using 10 µg of nitrogen (in the NH_4 form) per ml of a standard solution in a 50 ml volumetric flask. Adjust the volume to approximately 25 ml, add 1 ml of 10 percent tartrate solution, and shake. Add 2 ml of Nessler's aliquot with rapid mixing. Add sufficient distilled water to bring the total volume to 50 ml. Allow color to develop for 30 minutes.

8. Repeat Step 7 for 1.0, 2.0, 4.0, and 8.0 ml aliquots of standard solution.

9. Insert the standard solution resulting from Steps 7 and 8 into the spectrophotometer. Record readings and plot the results to construct a standard curve. (The spectrophotometer is calibrated beforehand with distilled water.)

10. Extract 2.0 ml of sample aliquot from Step 6 and add 25 ml of distilled water in a 50 ml volumetric flask. Add 1 ml of 10 percent tartrate and shake. Add 2 ml of Nessler's aliquot with rapid mixing. Add sufficient distilled water to bring the total volume to 50 ml. Let the solution stand for 30 minutes and then insert into the spectrophotometer and record the transparency reading.

11. Typical calculations:

Weight of dry soil	=	10.64 grams
Spectrophotometer	=	81 percent
	=	24.5 µg/g from standard curve

Conversion:

$$\frac{24.5\mu g}{2\ ml/aliquot} \times \frac{200\ ml}{1\ ml} \times \frac{50\ ml}{10.64\mu g} \times \frac{1}{1,000\mu/mg} \times$$

$$\frac{1}{14\ mg/meq} \times 100\ g = 82.2\ meq/100g$$

Equation for Cation Exchange Capacity

A 1979 study at Texas Tech University resulted in the following proposed modifications to the Pearring and Holt equations for Clay Activity, Cation Exchange Capacity, and Cation Exchange Activity:

Clay Activity $A_c = \dfrac{PI}{\%\ Clay}$

Cation Exchange Capacity:

$CEC = (PL)^{1.17}$

Cation Exchange Activity:

$CEAC = \dfrac{(PL)^{1.17}}{\%\ Clay}$

Symbols and Notations

PI = plasticity index.

PL = plastic limit.

% Clay = % Passing U.S. No. 200 sieve (75 µm) $\leq$ 0.002 mm.

Comparison of Methods of Determining Cation Exchange Capacity in Predominant Clay Mineral

A comparison of values of Cation Exchange Capacity using atomic absorption and spectrophotometer techniques is presented in Table 18-III-EE.

Comparison of clay mineral determination between atomic absorption of the correlation equations presented above is presented in Table 18-III-FF and Figure 18-III-17.

SECTION 1819 — DESIGN OF POSTTENSIONED SLABS ON COMPRESSIBLE SOILS (BASED ON DESIGN SPECIFICATIONS OF THE POSTTENSIONING INSTITUTE)

1819.1 General. The design procedure for foundations on compressible soils is similar to the structural design procedure in Section 1816.4, except that different equations are used and the primary bending deformation is usually similar to the edge lift loading case.

1819.2 List of Symbols and Notations.

M_{cs} = applied service moment in slab on compressible soil, ft.-kips/ft. (kN·m/m).

M_{ns} = moment occurring in the "no swell" condition, ft.-kips/ft. (kN·m/m).

V_{cs} = maximum service load shear force in slab on compressible soil, kips/ft. (kN/m).

V_{ns} = service load shear force in the "no swell" condition, kips/ft. (kN/m).

Δ_{cs} = differential deflection in a slab on compressible soil, in. (mm).

Δ_{ns} = differential deflection in the "no swell" condition, in. (mm).

δ = expected settlement, reported by the geotechnical engineer occurring in compressible soil due to the total load expressed as a uniform load, in. (mm).

1819.3 Slabs-on-ground Constructed on Compressible Soils. Design of slabs constructed on compressible soils can be done in a manner similar to that of the edge lift condition for slabs on expansive soils. Compressible soils are normally assumed to have allowable values of soil-bearing capacity, q_{allow}, equal to or less than 1,500 pounds per square foot (71.9 kN/m^2). Special design equations are necessary for this problem due to the expected in situ elastic property differences between compressible soils and the stiffer expansive soils. These formulas are:

1. **Moment.**

1.1 Long direction:

$$M_{cs_L} = \left(\frac{\delta}{\Delta_{ns_L}}\right)^{0.5} M_{ns_L} \qquad (19\text{-}1)$$

1.2 Short direction:

$$M_{cs_S} = \left(\frac{970 - h}{880}\right) M_{cs_L} \qquad (19\text{-}2)$$

For **SI:** $$M_{cs_S} = \left(\frac{24\,638 - h}{22\,352}\right) M_{cs_L}$$

WHERE:

$$M_{ns_L} = \frac{(h)^{1.35}(S)^{0.36}}{80(L)^{0.12}(P)^{0.10}} \qquad (19\text{-}3)$$

For **SI:** $$1\ \frac{\text{ft.}\cdot\text{kip}}{\text{ft.}} = 4\,448\,031\ \frac{\text{kN}\cdot\text{m}}{\text{m}}$$

$$\Delta_{ns_L} = \frac{(L)^{1.28}(S)^{0.80}}{133(h)^{0.28}(P)^{0.62}} \qquad (19\text{-}4)$$

For **SI:** 1 inch = 25.4 mm.

2. **Differential deflection:**

$$\Delta_{cs} = \delta e_n^{[1.78 - 0.103(h) - 1.65x10^{-3}(P) + 3.95x10^{-7}(P)^2]} \qquad (19\text{-}5)$$

3. **Shear.**

3.1 Long direction:

$$V_{cs_L} = \left[\frac{\delta}{\Delta_{ns_L}}\right]^{0.30} V_{ns_L} \qquad (19\text{-}6)$$

WHERE:

$$V_{ns_L} = \frac{(h)^{0.90}(PS)^{0.30}}{550(L)^{0.10}} \qquad (19\text{-}7)$$

For **SI:** $1\ \frac{\text{kip}}{\text{ft.}} = 2100\,\frac{\text{kN}}{\text{m}}$

3.2 Short direction:

$$V_{cs_S} = \left[\frac{116 - h}{94}\right] V_{cs_L} \qquad (19\text{-}8)$$

For **SI:** $V_{cs_S} = \left[\frac{2946.4 - h}{2387.6}\right] V_{cs_L}$

TABLE 18-III-A—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (30 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
30	3	3.2	0.5	0.003	0.005	0.008	0.011	0.015	0.018	0.021	0.025
			0.7	0.004	0.008	0.012	0.017	0.021	0.026	0.032	0.038
		3.4	0.5	0.006	0.012	0.019	0.026	0.034	0.044	0.054	0.067
			0.7	0.008	0.017	0.027	0.038	0.052	0.069	0.091	0.124
		3.6	0.5	0.014	0.030	0.050	0.077	0.117	0.192	0.370	0.881
			0.7	0.018	0.042	0.074	0.125	0.226	0.487	1.252	3.530
	5	3.2	0.5	0.007	0.013	0.020	0.028	0.035	0.043	0.051	0.060
			0.7	0.009	0.019	0.029	0.040	0.051	0.062	0.075	0.089
		3.4	0.5	0.014	0.028	0.043	0.060	0.079	0.100	0.125	0.153
			0.7	0.018	0.039	0.062	0.088	0.119	0.157	0.207	0.279
		3.6	0.5	0.030	0.067	0.112	0.171	0.258	0.413	0.776	1.797
			0.7	0.042	0.096	0.166	0.276	0.486	1.009	2.499	6.879
	7	3.2	0.5	0.012	0.025	0.038	0.051	0.065	0.080	0.095	0.111
			0.7	0.017	0.035	0.063	0.073	0.093	0.115	0.139	0.164
		3.4	0.5	0.024	0.050	0.079	0.110	0.144	0.184	0.228	0.281
			0.7	0.034	0.071	0.113	0.616	0.218	0.287	0.379	0.514
		3.58	0.5	0.051	0.110	0.182	0.272	0.396	0.596	1.006	2.098
			0.7	0.071	0.157	0.269	0.431	0.712	1.346	3.081	8.129

TABLE 18-III-B—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (40 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
40	3	3.2	0.5	0.004	0.008	0.012	0.016	0.020	0.024	0.029	0.034
			0.7	0.005	0.010	0.016	0.022	0.029	0.035	0.043	0.050
		3.4	0.5	0.007	0.016	0.074	0.037	0.046	0.058	0.073	0.090
			0.7	0.011	0.023	0.036	0.051	0.070	0.092	0.122	0.166
		3.6	0.5	0.018	0.040	0.066	0.102	0.157	0.256	0.496	1.181
			0.7	0.025	0.056	0.100	0.168	0.303	0.653	1.677	4.728
	5	3.2	0.5	0.009	0.018	0.027	0.037	0.047	0.057	0.068	0.080
			0.7	0.012	0.025	0.038	0.053	0.067	0.083	0.100	0.118
		3.4	0.5	0.018	0.037	0.148	0.081	0.106	0.134	0.167	0.206
			0.7	0.025	0.052	0.083	0.118	0.159	0.210	0.277	0.374
		3.6	0.5	0.041	0.090	0.150	0.229	0.346	0.553	1.040	2.408
			0.7	0.057	0.128	0.224	0.371	0.652	1.353	3.349	9.215
	7	3.2	0.5	0.016	0.033	0.051	0.069	0.087	0.107	0.127	0.148
			0.7	0.023	0.046	0.071	0.098	0.125	0.155	0.186	0.220
		3.4	0.5	0.033	0.069	0.107	0.148	0.194	0.246	0.306	0.377
			0.7	0.045	0.095	0.152	0.216	0.292	0.385	0.507	0.689
		3.58	0.5	0.069	0.148	0.244	0.365	0.531	0.799	1.348	2.791
			0.7	0.095	0.210	0.360	0.577	0.953	1.803	4.126	—

TABLE 18-III-C—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (50 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm: 1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
50	3	3.2	0.5	0.004	0.009	0.014	0.019	0.025	0.030	0.036	0.042
			0.7	0.006	0.013	0.020	0.028	0.036	0.044	0.053	0.063
		3.4	0.5	0.009	0.020	0.031	0.043	0.057	0.073	0.091	0.113
			0.7	0.013	0.028	0.044	0.064	0.086	0.115	0.153	0.207
		3.6	0.5	0.022	0.049	0.083	0.127	0.196	0.321	0.620	1.480
			0.7	0.031	0.070	0.124	0.210	0.380	0.818	2.103	5.926
	5	3.2	0.5	0.011	0.022	0.034	0.046	0.059	0.072	0.086	0.100
			0.7	0.015	0.031	0.048	0.066	0.084	0.104	0.125	0.148
		3.4	0.5	0.023	0.047	0.073	0.101	0.133	0.168	0.209	0.258
			0.7	0.031	0.066	0.105	0.148	0.200	0.264	0.347	0.469
		3.6	0.5	0.051	0.113	0.188	0.288	0.434	0.694	1.303	3.018
			0.7	0.071	0.160	0.281	0.465	0.817	1.696	4.196	—
	7	3.2	0.5	0.021	0.042	0.064	0.086	0.110	0.134	0.159	0.186
			0.7	0.028	0.058	0.090	0.122	0.157	0.194	0.233	0.276
		3.4	0.5	0.041	0.085	0.133	0.185	0.243	0.308	0.383	0.472
			0.7	0.057	0.120	0.191	0.272	0.366	0.483	0.636	0.864
		3.58	0.5	0.086	0.186	0.306	0.457	0.666	1.001	1.690	3.499
			0.7	0.119	0.263	0.452	0.723	1.194	2.260	5.172	—

TABLE 18-III-D—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (60 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm: 1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
60	3	3.2	0.5	0.006	0.012	0.018	0.024	0.030	0.037	0.044	0.052
			0.7	0.008	0.017	0.025	0.034	0.044	0.054	0.065	0.077
		3.4	0.5	0.012	0.024	0.038	0.053	0.069	0.088	0.110	0.136
			0.7	0.016	0.033	0.053	0.077	0.104	0.138	0.184	0.249
		3.6	0.5	0.026	0.059	0.099	0.154	0.236	0.386	0.745	1.779
			0.7	0.036	0.083	0.149	0.252	0.455	0.983	2.527	7.124
	5	3.2	0.5	0.013	0.027	0.041	0.056	0.071	0.087	0.103	0.120
			0.7	0.019	0.038	0.058	0.080	0.102	0.126	0.151	0.178
		3.4	0.5	0.028	0.056	0.087	0.122	0.160	0.202	0.252	0.310
			0.7	0.037	0.078	0.125	0.177	0.240	0.316	0.417	0.564
		3.6	0.5	0.062	0.135	0.226	0.345	0.521	0.834	1.566	3.628
			0.7	0.086	0.193	0.337	0.559	0.982	2.039	5.049	—
	7	3.2	0.5	0.025	0.050	0.077	0.104	0.132	0.161	0.192	0.224
			0.7	0.034	0.070	0.108	0.147	0.189	0.233	0.281	0.332
		3.4	0.5	0.050	0.103	0.160	0.223	0.292	0.371	0.461	0.568
			0.7	0.069	0.144	0.229	0.326	0.440	0.580	0.765	1.038
		3.58	0.5	0.103	0.223	0.367	0.549	0.800	1.203	2.031	4.205
			0.7	0.142	0.316	0.543	0.870	1.436	2.717	6.217	—

TABLE 18-III-E—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (70 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm Edge Distance Penetration × 304.8 for mm							
				1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
70	3	3.2	0.5 0.7	0.006 0.010	0.013 0.019	0.020 0.029	0.027 0.040	0.035 0.051	0.042 0.063	0.051 0.076	0.060 0.089
		3.4	0.5 0.7	0.014 0.019	0.028 0.039	0.044 0.063	0.062 0.090	0.081 0.122	0.103 0.162	0.129 0.215	0.159 0.292
		3.6	0.5 0.7	0.032 0.043	0.069 0.098	0.117 0.174	0.180 0.294	0.276 0.532	0.451 1.148	0.871 2.952	2.079 8.322
	5	3.2	0.5 0.7	0.016 0.022	0.032 0.044	0.048 0.068	0.065 0.093	0.083 0.119	0.101 0.146	0.120 0.176	0.140 0.208
		3.4	0.5 0.7	0.031 0.043	0.065 0.082	0.101 0.146	0.141 0.207	0.185 0.280	0.235 0.370	0.293 0.487	0.361 0.659
		3.6	0.5 0.7	0.072 0.100	0.158 0.225	0.264 0.394	0.404 0.653	0.609 1.147	0.974 2.381	1.830 5.893	4.239 —
	7	3.2	0.5 0.7	0.030 0.040	0.059 0.082	0.090 0.126	0.121 0.172	0.154 0.221	0.188 0.273	0.224 0.328	0.262 0.388
		3.4	0.5 0.7	0.057 0.080	0.119 0.168	0.186 0.267	0.260 0.381	0.341 0.514	0.432 0.678	0.538 0.893	0.663 1.213
		3.58	0.5 0.7	0.120 0.166	0.260 0.369	0.429 0.634	0.642 1.016	0.935 1.677	1.406 3.175	2.373 7.263	4.913 —

TABLE 18-III-F—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (30 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm Edge Distance Penetration × 304.8 for mm							
				1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
30	3	3.2	0.5 0.7	0.006 0.008	0.012 0.016	0.018 0.024	0.024 0.033	0.030 0.043	0.037 0.053	0.044 0.064	0.051 0.075
		3.4	0.5 0.7	0.011 0.016	0.024 0.034	0.037 0.054	0.052 0.077	0.068 0.104	0.087 0.138	0.109 0.182	0.135 0.248
		3.6	0.5 0.7	0.027 0.036	0.058 0.083	0.098 0.147	0.152 0.249	0.234 0.451	0.382 0.973	0.737 2.500	1.760 7.049
	5	3.2	0.5 0.7	0.013 0.018	0.027 0.037	0.041 0.057	0.055 0.078	0.070 0.100	0.086 0.124	0.102 0.149	0.119 0.176
		3.4	0.5 0.7	0.027 0.037	0.055 0.078	0.086 0.124	0.120 0.176	0.157 0.238	0.200 0.319	0.248 0.413	0.306 0.558
		3.6	0.5 0.7	0.062 0.084	0.134 0.190	0.224 0.333	0.342 0.553	0.516 0.971	0.825 2.016	1.551 4.991	3.591 —
	7	3.2	0.5 0.7	0.025 0.034	0.050 0.070	0.076 0.107	0.103 0.146	0.131 0.187	0.160 0.231	0.190 0.278	0.221 0.329
		3.4	0.5 0.7	0.048 0.068	0.102 0.143	0.158 0.227	0.221 0.323	0.288 0.436	0.367 0.574	0.456 0.757	0.562 1.028
		3.58	0.5 0.7	0.103 0.141	0.221 0.313	0.363 0.537	0.543 0.861	0.792 1.421	1.191 2.689	2.010 6.153	4.162 —

TABLE 18-III-G—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (40 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
40	3	3.2	0.5	0.008	0.016	0.025	0.034	0.043	0.052	0.063	0.073
			0.7	0.011	0.023	0.035	0.048	0.062	0.076	0.092	0.109
		3.4	0.5	0.017	0.034	0.054	0.075	0.099	0.126	0.157	0.194
			0.7	0.023	0.048	0.077	0.110	0.149	0.198	0.263	0.357
		3.6	0.5	0.039	0.085	0.142	0.220	0.338	0.552	1.065	2.542
			0.7	0.053	0.120	0.213	0.360	0.651	1.405	3.611	—
	5	3.2	0.5	0.019	0.039	0.059	0.080	0.101	0.124	0.147	0.172
			0.7	0.026	0.054	0.083	0.113	0.145	0.179	0.215	0.254
		3.4	0.5	0.039	0.080	0.124	0.173	0.227	0.288	0.358	0.442
			0.7	0.053	0.112	0.178	0.254	0.343	0.452	0.596	0.805
		3.6	0.5	0.089	0.194	0.323	0.494	0.745	1.192	2.239	5.184
			0.7	0.122	0.275	0.482	0.799	1.403	2.912	7.207	—
	7	3.2	0.5	0.035	0.072	0.109	0.148	0.188	0.230	0.274	0.320
			0.7	0.049	0.100	0.154	0.210	0.270	0.330	0.401	0.474
		3.4	0.5	0.070	0.146	0.228	0.318	0.417	0.528	0.657	0.811
			0.7	0.098	0.207	0.328	0.466	0.629	0.829	1.093	1.484
		3.58	0.5	0.147	0.318	0.524	0.784	1.143	1.719	2.902	6.008
			0.7	0.203	0.451	0.775	1.242	2.051	3.883	8.882	—

TABLE 18-III-H—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (50 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
50	3	3.2	0.5	0.010	0.021	0.033	0.042	0.056	0.069	0.082	0.096
			0.7	0.014	0.030	0.046	0.063	0.081	0.099	0.120	0.142
		3.4	0.5	0.022	0.045	0.070	0.098	0.129	0.164	0.205	0.254
			0.7	0.030	0.063	0.101	0.144	0.196	0.260	0.344	0.467
		3.6	0.5	0.050	0.111	0.185	0.287	0.441	0.721	1.391	3.322
			0.7	0.069	0.156	0.278	0.470	0.851	1.836	4.720	—
	5	3.2	0.5	0.025	0.051	0.077	0.104	0.133	0.162	0.193	0.225
			0.7	0.035	0.071	0.110	0.148	0.190	0.235	0.282	0.333
		3.4	0.5	0.051	0.104	0.163	0.227	0.298	0.377	0.469	0.579
			0.7	0.070	0.147	0.233	0.332	0.449	0.592	0.779	1.054
		3.6	0.5	0.116	0.253	0.423	0.646	0.974	1.558	2.927	6.778
			0.7	0.159	0.359	0.629	1.043	1.834	3.807	9.422	—
	7	3.2	0.5	0.046	0.094	0.143	0.193	0.246	0.301	0.358	0.418
			0.7	0.064	0.131	0.201	0.275	0.353	0.436	0.524	0.620
		3.4	0.5	0.092	0.192	0.299	0.416	0.546	0.692	0.860	1.061
			0.7	0.129	0.271	0.429	0.610	0.823	1.085	1.429	1.940
		3.58	0.5	0.193	0.417	0.685	1.026	1.495	2.248	3.795	7.856
			0.7	0.265	0.590	1.013	1.624	2.682	5.075	—	—

TABLE 18-III-I—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (60 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
60	3	3.2	0.5 0.7	0.013 0.018	0.027 0.037	0.040 0.057	0.055 0.078	0.070 0.100	0.085 0.123	0.102 0.148	0.119 0.176
		3.4	0.5 0.7	0.027 0.037	0.055 0.078	0.087 0.124	0.121 0.178	0.159 0.241	0.203 0.320	0.253 0.424	0.314 0.576
		3.6	0.5 0.7	0.062 0.085	0.136 0.194	0.229 0.344	0.355 0.582	0.544 1.052	0.890 2.268	1.659 5.831	4.104 —
	5	3.2	0.5 0.7	0.031 0.043	0.062 0.088	0.095 0.134	0.129 0.183	0.164 0.235	0.200 0.290	0.238 0.348	0.277 0.411
		3.4	0.5 0.7	0.062 0.086	0.129 0.181	0.201 0.288	0.280 0.410	0.367 0.554	0.466 0.730	0.579 0.962	0.714 1.301
		3.6	0.5 0.7	0.144 0.197	0.313 0.444	0.522 0.778	0.797 1.289	1.203 2.265	1.924 4.702	3.615 —	8.371 —
	7	3.2	0.5 0.7	0.057 0.079	0.116 0.162	0.176 0.249	0.239 0.340	0.304 0.436	0.372 0.538	0.442 0.647	0.516 0.766
		3.4	0.5 0.7	0.114 0.156	0.237 0.333	0.369 0.528	0.514 0.752	0.674 1.015	0.855 1.340	1.063 1.764	1.310 2.395
		3.58	0.5 0.7	0.238 0.328	0.514 0.730	0.846 1.252	1.266 2.006	1.846 3.312	2.776 6.268	4.687 —	9.702 —

TABLE 18-III-J—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (70 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
70	3	3.2	0.5 0.7	0.016 0.021	0.032 0.044	0.048 0.068	0.066 0.092	0.083 0.119	0.102 0.147	0.121 0.177	0.141 0.209
		3.4	0.5 0.7	0.032 0.044	0.066 0.093	0.103 0.148	0.144 0.212	0.190 0.287	0.242 0.381	0.302 0.510	0.374 0.686
		3.6	0.5 0.7	0.074 0.101	0.162 0.231	0.273 0.409	0.423 0.692	0.648 1.251	1.061 2.700	2.047 6.940	4.885 —
	5	3.2	0.5 0.7	0.037 0.051	0.074 0.104	0.113 0.159	0.153 0.218	0.195 0.279	0.238 0.345	0.283 0.414	0.330 0.489
		3.4	0.5 0.7	0.073 0.102	0.153 0.215	0.239 0.342	0.330 0.487	0.437 0.659	0.554 0.869	0.689 1.145	0.850 1.548
		3.6	0.5 0.7	0.170 0.234	0.372 0.528	0.620 0.925	0.948 1.534	1.431 2.696	2.290 5.597	4.302 —	9.964 —
	7	3.2	0.5 0.7	0.068 0.094	0.138 0.193	0.210 0.296	0.284 0.404	0.362 0.519	0.442 0.640	0.526 0.771	0.614 0.911
		3.4	0.5 0.7	0.136 0.188	0.282 0.396	0.439 0.629	0.612 0.895	0.803 1.209	1.018 1.594	1.265 2.100	1.560 2.851
		3.58	0.5 0.7	0.283 0.391	0.612 0.869	1.007 1.490	1.507 2.388	2.197 3.943	3.304 7.462	5.579 —	11.549 —

TABLE 18-III-K—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (30 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm: 1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
30	3	3.2	0.5 0.7	0.006 0.010	0.013 0.019	0.020 0.029	0.027 0.040	0.035 0.051	0.043 0.063	0.051 0.076	0.060 0.089
		3.4	0.5 0.7	0.014 0.019	0.028 0.039	0.044 0.063	0.062 0.089	0.081 0.122	0.102 0.162	0.128 0.214	0.159 0.291
		3.6	0.5 0.7	0.031 0.043	0.069 0.098	0.116 0.173	0.179 0.294	0.275 0.532	0.450 1.145	0.868 2.945	2.073 8.301
	5	3.2	0.5 0.7	0.016 0.022	0.032 0.044	0.048 0.068	0.065 0.093	0.083 0.119	0.101 0.147	0.120 0.176	0.140 0.208
		3.4	0.5 0.7	0.032 0.043	0.065 0.091	0.102 0.145	0.141 0.207	0.186 0.280	0.235 0.369	0.293 0.486	0.361 0.657
		3.6	0.5 0.7	0.072 0.100	0.158 0.224	0.264 0.393	0.403 0.651	0.607 1.144	0.972 2.375	1.826 5.870	2.514 —
	7	3.2	0.5 0.7	0.029 0.039	0.059 0.081	0.089 0.125	0.121 0.171	0.154 0.219	0.188 0.271	0.223 0.326	0.261 0.386
		3.4	0.5 0.7	0.058 0.081	0.120 0.169	0.187 0.268	0.261 0.381	0.342 0.514	0.433 0.677	0.537 0.892	0.662 1.211
		3.58	0.5 0.7	0.120 0.165	0.259 0.368	0.427 0.632	0.639 1.013	0.932 1.672	1.402 3.165	2.367 7.244	4.900 —

TABLE 18-III-L—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (40 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm: 1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
40	3	3.2	0.5 0.7	0.009 0.014	0.019 0.027	0.029 0.042	0.040 0.057	0.050 0.074	0.062 0.091	0.074 0.109	0.086 0.129
		3.4	0.5 0.7	0.019 0.027	0.040 0.057	0.063 0.091	0.088 0.130	0.116 0.177	0.148 0.234	0.185 0.311	0.229 0.422
		3.6	0.5 0.7	0.046 0.062	0.100 0.142	0.168 0.251	0.260 0.425	0.399 0.769	0.652 1.660	1.258 4.267	3.004 7.762
	5	3.2	0.5 0.7	0.023 0.032	0.046 0.064	0.069 0.098	0.094 0.134	0.120 0.172	0.147 0.212	0.174 0.255	0.203 0.301
		3.4	0.5 0.7	0.045 0.063	0.094 0.133	0.147 0.211	0.205 0.300	0.269 0.405	0.341 0.535	0.424 0.704	0.522 0.952
		3.6	0.5 0.7	0.105 0.144	0.229 0.325	0.382 0.569	0.584 0.944	0.880 1.658	1.408 3.441	2.645 8.517	6.127 —
	7	3.2	0.5 0.7	0.042 0.059	0.085 0.119	0.129 0.183	0.175 0.249	0.223 0.320	0.272 0.394	0.324 0.475	0.378 0.561
		3.4	0.5 0.7	0.084 0.116	0.173 0.244	0.270 0.387	0.377 0.550	0.494 0.743	0.626 0.980	0.778 1.291	0.960 1.753
		3.56	0.5 0.7	0.158 0.218	0.339 0.480	0.553 0.813	0.815 1.271	1.160 2.004	1.668 3.504	2.583 7.412	4.748 —

TABLE 18-III-M—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (50 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
50	3	3.2	0.5 0.7	0.012 0.018	0.026 0.036	0.038 0.055	0.052 0.075	0.066 0.096	0.081 0.119	0.097 0.143	0.113 0.169
		3.4	0.5 0.7	0.026 0.036	0.053 0.075	0.083 0.119	0.116 0.170	0.153 0.231	0.195 0.307	0.243 0.407	0.301 0.553
		3.6	0.5 0.7	0.059 0.082	0.131 0.186	0.220 0.330	0.340 0.558	0.522 1.008	0.854 2.175	1.648 5.590	3.935 —
	5	3.2	0.5 0.7	0.030 0.041	0.060 0.083	0.091 0.128	0.124 0.175	0.157 0.224	0.192 0.277	0.228 0.333	0.266 0.394
		3.4	0.5 0.7	0.059 0.083	0.123 0.174	0.193 0.276	0.268 0.393	0.352 0.531	0.446 0.700	0.555 0.923	0.684 1.247
		3.6	0.5 0.7	0.137 0.189	0.299 0.426	0.500 0.745	0.764 1.236	1.152 2.712	1.844 4.508	3.464 —	8.025 —
	7	3.2	0.5 0.7	0.055 0.076	0.111 0.155	0.169 0.238	0.229 0.326	0.291 0.418	0.356 0.516	0.423 0.621	0.495 0.734
		3.4	0.5 0.7	0.106 0.152	0.226 0.320	0.354 0.507	0.493 0.721	0.646 0.973	0.819 1.283	1.019 1.692	1.256 2.256
		3.56	0.5 0.7	0.207 0.286	0.444 0.629	0.724 1.066	1.068 1.665	1.519 2.625	2.185 4.590	3.382 —	6.219 —

TABLE 18-III-N—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (60 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
60	3	3.2	0.5 0.7	0.015 0.022	0.031 0.044	0.048 0.068	0.065 0.092	0.082 0.119	0.101 0.147	0.120 0.176	0.140 0.209
		3.4	0.5 0.7	0.031 0.044	0.065 0.093	0.102 0.147	0.143 0.211	0.189 0.286	0.240 0.380	0.300 0.503	0.372 0.683
		3.6	0.5 0.7	0.073 0.101	0.161 0.229	0.272 0.407	0.420 0.689	0.645 1.246	1.056 2.689	2.037 6.912	4.865 —
	5	3.2	0.5 0.7	0.037 0.050	0.074 0.103	0.113 0.158	0.153 0.217	0.194 0.278	0.237 0.343	0.282 0.412	0.329 0.487
		3.4	0.5 0.7	0.073 0.102	0.152 0.214	0.237 0.341	0.331 0.485	0.435 0.655	0.551 0.865	0.686 1.140	0.846 1.541
		3.6	0.5 0.7	0.169 0.234	0.370 0.526	0.618 0.922	0.945 1.528	1.425 2.686	2.280 5.574	4.284 —	9.923 —
	7	3.2	0.5 0.7	0.068 0.093	0.137 0.191	0.209 0.294	0.283 0.402	0.360 0.516	0.441 0.637	0.524 0.767	0.612 0.907
		3.4	0.5 0.7	0.135 0.188	0.280 0.395	0.438 0.627	0.609 0.892	0.799 1.204	1.013 1.587	1.260 2.092	1.553 2.840
		3.56	0.5 0.7	0.256 0.354	0.549 0.779	0.895 1.317	1.320 2.059	1.879 3.247	2.702 5.677	4.182 —	8.216 —

TABLE 18-III-O—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR A CENTER LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (70 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm; Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
70	3	3.2	0.5	0.018	0.037	0.057	0.077	0.098	0.120	0.143	0.167
			0.7	0.026	0.052	0.082	0.110	0.141	0.174	0.210	0.248
		3.4	0.5	0.038	0.078	0.122	0.171	0.225	0.287	0.358	0.443
			0.7	0.052	0.110	0.176	0.251	0.341	0.452	0.600	0.814
		3.6	0.5	0.088	0.192	0.324	0.502	0.769	1.258	2.428	5.796
			0.7	0.120	0.273	0.485	0.821	1.485	3.203	8.234	—
	5	3.2	0.5	0.044	0.088	0.134	0.182	0.231	0.283	0.336	0.392
			0.7	0.060	0.123	0.189	0.258	0.331	0.409	0.491	0.580
		3.4	0.5	0.088	0.182	0.284	0.395	0.519	0.658	0.818	1.008
			0.7	0.121	0.256	0.406	0.578	0.781	1.031	1.358	1.837
		3.6	0.5	0.202	0.441	0.737	1.126	1.698	2.717	5.104	11.822
			0.7	0.278	0.627	1.098	1.820	3.199	6.640	—	—
	7	3.2	0.5	0.081	0.163	0.249	0.338	0.429	0.525	0.624	0.729
			0.7	0.112	0.229	0.351	0.480	0.616	0.759	0.915	1.081
		3.4	0.5	0.162	0.334	0.522	0.727	0.952	1.207	1.501	1.851
			0.7	0.224	0.470	0.747	1.063	1.435	1.891	2.492	3.383
		3.56	0.5	0.305	0.655	1.067	1.573	2.239	3.219	4.983	9.162
			0.7	0.421	0.928	1.569	2.453	3.868	6.763	—	—

TABLE 18-III-P—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (30 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm; Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
30	3	3.2	0.5	0.003	0.005	0.007	0.010	0.012	0.014	0.017	0.019
			0.7	0.004	0.007	0.010	0.013	0.017	0.020	0.023	0.026
		3.4	0.5	0.005	0.010	0.015	0.020	0.025	0.029	0.033	0.037
			0.7	0.007	0.014	0.021	0.027	0.033	0.039	0.045	0.050
		3.6	0.5	0.013	0.025	0.035	0.046	0.055	0.064	0.072	0.080
			0.7	0.018	0.034	0.048	0.061	0.073	0.084	0.094	0.104
		3.8	0.5	0.031	0.056	0.078	0.097	0.114	0.129	0.143	0.156
			0.7	0.042	0.075	0.102	0.125	0.145	0.164	0.180	0.195
	5	3.2	0.5	0.006	0.011	0.016	0.021	0.027	0.032	0.037	0.041
			0.7	0.008	0.015	0.022	0.030	0.037	0.044	0.050	0.057
		3.4	0.5	0.012	0.023	0.034	0.045	0.055	0.065	0.075	0.084
			0.7	0.016	0.032	0.047	0.061	0.075	0.089	0.101	0.114
		3.6	0.5	0.029	0.056	0.081	0.104	0.126	0.147	0.167	0.186
			0.7	0.041	0.077	0.110	0.141	0.169	0.195	0.220	0.243
		3.8	0.5	0.072	0.131	0.183	0.228	0.270	0.307	0.342	0.374
			0.7	0.100	0.178	0.244	0.300	0.350	0.395	0.436	0.474
	7	3.2	0.5	0.010	0.019	0.028	0.037	0.046	0.055	0.064	0.072
			0.7	0.013	0.026	0.039	0.052	0.064	0.076	0.088	0.099
		3.4	0.5	0.021	0.041	0.060	0.079	0.097	0.115	0.132	0.149
			0.7	0.029	0.056	0.083	0.108	0.133	0.157	0.180	0.202
		3.6	0.5	0.052	0.100	0.145	0.187	0.227	0.264	0.300	0.335
			0.7	0.073	0.138	0.198	0.254	0.305	0.353	0.399	0.441

TABLE 18-III-Q—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (40 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
40	3	3.2	0.5	0.003	0.007	0.010	0.013	0.016	0.019	0.022	0.025
			0.7	0.006	0.009	0.014	0.018	0.022	0.026	0.030	0.034
		3.4	0.5	0.007	0.014	0.020	0.027	0.033	0.039	0.045	0.050
			0.7	0.010	0.019	0.028	0.037	0.045	0.052	0.060	0.067
		3.6	0.5	0.017	0.033	0.047	0.061	0.074	0.086	0.097	0.108
			0.7	0.024	0.045	0.064	0.081	0.098	0.112	0.126	0.139
		3.8	0.5	0.041	0.075	0.104	0.129	0.152	0.173	0.192	0.209
			0.7	0.056	0.100	0.136	0.167	0.195	0.219	0.241	0.261
	5	3.2	0.5	0.007	0.015	0.022	0.029	0.035	0.042	0.049	0.056
			0.7	0.010	0.020	0.030	0.040	0.049	0.058	0.067	0.076
		3.4	0.5	0.016	0.031	0.046	0.060	0.074	0.087	0.100	0.113
			0.7	0.022	0.043	0.063	0.082	0.101	0.119	0.136	0.152
		3.6	0.5	0.039	0.075	0.108	0.140	0.169	0.197	0.223	0.249
			0.7	0.064	0.103	0.147	0.188	0.226	0.261	0.295	0.326
		3.8	0.5	0.096	0.176	0.245	0.306	0.361	0.411	0.458	0.501
			0.7	0.134	0.239	0.326	0.402	0.469	0.529	0.584	0.634
	7	3.2	0.5	0.013	0.025	0.038	0.050	0.062	0.074	0.085	0.097
			0.7	0.018	0.035	0.052	0.069	0.085	0.102	0.117	0.133
		3.4	0.5	0.028	0.054	0.080	0.105	0.130	0.154	0.177	0.200
			0.7	0.039	0.076	0.111	0.145	0.178	0.210	0.241	0.271
		3.6	0.5	0.069	0.134	0.194	0.250	0.304	0.354	0.402	0.448
			0.7	0.098	0.185	0.266	0.340	0.409	0.473	0.534	0.591

TABLE 18-III-R—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (50 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
50	3	3.2	0.5	0.004	0.008	0.012	0.016	0.020	0.024	0.028	0.032
			0.7	0.006	0.012	0.017	0.023	0.028	0.033	0.038	0.043
		3.4	0.5	0.009	0.017	0.026	0.034	0.041	0.049	0.056	0.063
			0.7	0.012	0.024	0.035	0.046	0.056	0.066	0.075	0.084
		3.6	0.5	0.022	0.042	0.059	0.076	0.092	0.107	0.121	0.135
			0.7	0.030	0.056	0.080	0.102	0.122	0.141	0.158	0.175
		3.8	0.5	0.052	0.094	0.130	0.162	0.191	0.217	0.240	0.262
			0.7	0.071	0.126	0.171	0.210	0.244	0.275	0.302	0.328
	5	3.2	0.5	0.009	0.018	0.027	0.036	0.044	0.053	0.061	0.070
			0.7	0.013	0.025	0.038	0.050	0.062	0.073	0.084	0.096
		3.4	0.5	0.020	0.039	0.057	0.075	0.092	0.109	0.126	0.142
			0.7	0.028	0.054	0.079	0.103	0.126	0.149	0.170	0.191
		3.6	0.5	0.049	0.094	0.136	0.175	0.212	0.247	0.280	0.312
			0.7	0.068	0.129	0.185	0.236	0.283	0.328	0.369	0.408
		3.8	0.5	0.120	0.220	0.307	0.384	0.453	0.516	0.574	0.628
			0.7	0.168	0.299	0.409	0.504	0.588	0.663	0.732	0.795
	7	3.2	0.5	0.016	0.032	0.047	0.062	0.077	0.092	0.107	0.121
			0.7	0.022	0.044	0.066	0.087	0.107	0.127	0.147	0.167
		3.4	0.5	0.035	0.068	0.100	0.132	0.163	0.193	0.222	0.250
			0.7	0.048	0.095	0.139	0.182	0.223	0.263	0.302	0.339
		3.6	0.5	0.087	0.168	0.243	0.314	0.381	0.444	0.504	0.562
			0.7	0.122	0.232	0.333	0.426	0.512	0.593	0.669	0.741

TABLE 18-III-S—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (60 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm; Edge Distance Penetration × 304.8 for mm: 1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
60	3	3.2	0.5 0.7	0.005 0.007	0.010 0.014	0.015 0.021	0.020 0.027	0.024 0.033	0.029 0.040	0.033 0.046	0.038 0.052
		3.4	0.5 0.7	0.011 0.015	0.021 0.029	0.031 0.042	0.040 0.055	0.049 0.067	0.058 0.079	0.067 0.090	0.076 0.101
		3.6	0.5 0.7	0.026 0.036	0.050 0.068	0.071 0.097	0.092 0.123	0.111 0.147	0.129 0.169	0.146 0.190	0.162 0.210
		3.8	0.5 0.7	0.062 0.085	0.113 0.151	0.157 0.205	0.195 0.252	0.229 0.293	0.260 0.330	0.289 0.363	0.315 0.394
	5	3.2	0.5 0.7	0.011 0.015	0.022 0.031	0.033 0.045	0.043 0.060	0.053 0.074	0.064 0.088	0.074 0.101	0.084 0.115
		3.4	0.5 0.7	0.024 0.033	0.046 0.065	0.069 0.095	0.090 0.124	0.111 0.152	0.131 0.179	0.151 0.205	0.170 0.230
		3.6	0.5 0.7	0.059 0.082	0.113 0.155	0.163 0.222	0.210 0.284	0.255 0.341	0.297 0.394	0.337 0.444	0.375 0.491
		3.8	0.5 0.7	0.144 0.201	0.265 0.360	0.369 0.492	0.461 0.606	0.544 0.707	0.620 0.798	0.690 0.880	0.754 0.956
	7	3.2	0.5 0.7	0.019 0.027	0.038 0.053	0.057 0.079	0.075 0.104	0.093 0.129	0.111 0.153	0.128 0.177	0.146 0.201
		3.4	0.5 0.7	0.042 0.058	0.082 0.114	0.121 0.167	0.159 0.219	0.196 0.268	0.232 0.316	0.267 0.363	0.301 0.408
		3.6	0.5 0.7	0.105 0.147	0.201 0.279	0.292 0.400	0.377 0.512	0.457 0.616	0.534 0.713	0.606 0.804	0.675 0.891

TABLE 18-III-T—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY KAOLINITE CLAY SOIL (70 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm; Edge Distance Penetration × 304.8 for mm: 1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
70	3	3.2	0.5 0.7	0.006 0.008	0.012 0.016	0.017 0.024	0.023 0.032	0.028 0.039	0.034 0.046	0.039 0.054	0.044 0.061
		3.4	0.5 0.7	0.012 0.017	0.024 0.034	0.036 0.049	0.047 0.064	0.058 0.079	0.068 0.092	0.078 0.106	0.088 0.118
		3.6	0.5 0.7	0.030 0.042	0.058 0.079	0.084 0.113	0.107 0.143	0.130 0.172	0.151 0.198	0.170 0.222	0.189 0.245
		3.8	0.5 0.7	0.072 0.099	0.132 0.176	0.183 0.240	0.228 0.295	0.268 0.343	0.304 0.386	0.338 0.425	0.369 0.460
	5	3.2	0.5 0.7	0.013 0.018	0.026 0.036	0.038 0.053	0.050 0.070	0.062 0.086	0.074 0.103	0.086 0.119	0.098 0.134
		3.4	0.5 0.7	0.028 0.039	0.054 0.075	0.080 0.111	0.105 0.145	0.130 0.177	0.153 0.209	0.176 0.239	0.199 0.268
		3.6	0.5 0.7	0.068 0.096	0.132 0.181	0.191 0.259	0.246 0.331	0.298 0.398	0.347 0.460	0.393 0.518	0.438 0.574
		3.8	0.5 0.7	0.169 0.235	0.309 0.420	0.431 0.575	0.539 0.708	0.636 0.826	0.724 0.932	0.806 1.028	0.881 1.117
	7	3.2	0.5 0.7	0.022 0.031	0.044 0.062	0.066 0.092	0.087 0.121	0.109 0.150	0.129 0.179	0.150 0.207	0.170 0.234
		3.4	0.5 0.7	0.048 0.068	0.095 0.133	0.141 0.195	0.185 0.256	0.228 0.314	0.270 0.370	0.311 0.424	0.351 0.476
		3.6	0.5 0.7	0.122 0.172	0.235 0.326	0.341 0.468	0.441 0.598	0.534 0.719	0.623 0.833	0.708 0.940	0.789 1.041

TABLE 18-III-U—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (30 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
				1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
30	3	3.2	0.5	0.006	0.010	0.015	0.019	0.024	0.029	0.333	0.037
			0.7	0.007	0.014	0.020	0.027	0.033	0.039	0.045	0.051
		3.4	0.5	0.011	0.021	0.030	0.040	0.049	0.058	0.066	0.075
			0.7	0.015	0.029	0.042	0.054	0.067	0.078	0.089	0.100
		3.6	0.5	0.026	0.049	0.071	0.091	0.110	0.128	0.144	0.160
			0.7	0.036	0.067	0.096	0.121	0.145	0.168	0.186	0.208
		3.8	0.5	0.061	0.112	0.155	0.193	0.227	0.258	0.286	0.312
			0.7	0.084	0.149	0.203	0.250	0.290	0.327	0.360	0.390
	5	3.2	0.5	0.011	0.022	0.032	0.043	0.053	0.063	0.073	0.083
			0.7	0.015	0.030	0.045	0.059	0.073	0.087	0.100	0.114
		3.4	0.5	0.023	0.046	0.068	0.089	0.110	0.130	0.149	0.168
			0.7	0.033	0.064	0.094	0.123	0.150	0.177	0.202	0.227
		3.6	0.5	0.058	0.112	0.161	0.208	0.252	0.294	0.333	0.371
			0.7	0.081	0.154	0.220	0.281	0.337	0.390	0.439	0.486
		3.8	0.5	0.143	0.262	0.365	0.456	0.539	0.613	0.683	0.746
			0.7	0.199	0.356	0.487	0.600	0.699	0.789	0.871	0.946
	7	3.2	0.5	0.019	0.038	0.056	0.074	0.092	0.110	0.127	0.144
			0.7	0.027	0.052	0.078	0.103	0.127	0.152	0.176	0.198
		3.4	0.5	0.041	0.081	0.119	0.157	0.194	0.229	0.264	0.298
			0.7	0.058	0.113	0.166	0.217	0.266	0.313	0.359	0.404
		3.6	0.5	0.103	0.199	0.289	0.373	0.453	0.528	0.600	0.668
			0.7	0.145	0.276	0.396	0.507	0.609	0.706	0.796	0.882

TABLE 18-III-V—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (40 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
				1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
40	3	3.2	0.5	0.007	0.014	0.021	0.028	0.035	0.041	0.048	0.054
			0.7	0.010	0.020	0.029	0.039	0.048	0.057	0.065	0.074
		3.4	0.5	0.015	0.030	0.044	0.058	0.071	0.083	0.096	0.108
			0.7	0.021	0.041	0.060	0.079	0.096	0.113	0.129	0.145
		3.6	0.5	0.037	0.071	0.102	0.131	0.158	0.184	0.208	0.231
			0.7	0.051	0.097	0.138	0.175	0.210	0.242	0.272	0.300
		3.8	0.5	0.088	0.161	0.224	0.278	0.328	0.372	0.413	0.451
			0.7	0.122	0.216	0.294	0.360	0.419	0.472	0.519	0.563
	5	3.2	0.5	0.016	0.031	0.047	0.062	0.076	0.091	0.105	0.120
			0.7	0.022	0.044	0.065	0.085	0.106	0.125	0.145	0.164
		3.4	0.5	0.034	0.066	0.098	0.129	0.158	0.187	0.216	0.243
			0.7	0.047	0.092	0.135	0.177	0.217	0.255	0.292	0.328
		3.6	0.5	0.084	0.161	0.233	0.300	0.364	0.424	0.481	0.535
			0.7	0.117	0.222	0.317	0.405	0.487	0.563	0.634	0.701
		3.8	0.5	0.206	0.378	0.527	0.659	0.777	0.886	0.985	1.078
			0.7	0.288	0.514	0.703	0.866	1.010	1.139	1.257	1.366
	7	3.2	0.5	0.027	0.054	0.081	0.107	0.133	0.158	0.183	0.208
			0.7	0.038	0.076	0.112	0.149	0.184	0.219	0.253	0.286
		3.4	0.5	0.059	0.117	0.172	0.227	0.279	0.331	0.381	0.430
			0.7	0.083	0.163	0.239	0.313	0.384	0.452	0.518	0.583
		3.6	0.5	0.149	0.288	0.417	0.539	0.654	0.762	0.866	0.965
			0.7	0.210	0.399	0.572	0.731	0.880	1.019	1.149	1.273

TABLE 18-III-W—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (50 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
				1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
50	3	3.2	0.5	0.009	0.019	0.028	0.037	0.045	0.054	0.062	0.071
			0.7	0.013	0.026	0.038	0.051	0.062	0.074	0.086	0.097
		3.4	0.5	0.020	0.039	0.057	0.075	0.092	0.109	0.125	0.141
			0.7	0.028	0.054	0.079	0.103	0.126	0.148	0.169	0.189
		3.6	0.5	0.048	0.093	0.134	0.172	0.207	0.241	0.272	0.303
			0.7	0.067	0.127	0.180	0.229	0.274	0.316	0.356	0.392
		3.8	0.5	0.116	0.211	0.292	0.364	0.428	0.486	0.540	0.589
			0.7	0.159	0.282	0.384	0.471	0.548	0.616	0.679	0.736
	5	3.2	0.5	0.021	0.041	0.061	0.080	0.100	0.119	0.138	0.156
			0.7	0.029	0.057	0.085	0.112	0.138	0.164	0.190	0.215
		3.4	0.5	0.044	0.087	0.128	0.168	0.207	0.245	0.282	0.318
			0.7	0.062	0.121	0.177	0.231	0.283	0.334	0.382	0.429
		3.6	0.5	0.109	0.211	0.305	0.393	0.476	0.554	0.629	0.700
			0.7	0.153	0.290	0.415	0.530	0.636	0.736	0.829	0.917
		3.8	0.5	0.269	0.494	0.689	0.861	1.016	1.158	1.288	1.409
			0.7	0.376	0.672	0.919	1.132	1.320	1.490	1.644	1.785
	7	3.2	0.5	0.036	0.071	0.106	0.140	0.173	0.207	0.240	0.272
			0.7	0.050	0.099	0.147	0.194	0.240	0.286	0.331	0.375
		3.4	0.5	0.077	0.153	0.225	0.296	0.365	0.432	0.498	0.562
			0.7	0.109	0.213	0.313	0.409	0.501	0.591	0.678	0.762
		3.6	0.5	0.195	0.376	0.545	0.704	0.854	0.997	1.132	1.261
			0.7	0.274	0.522	0.748	0.956	1.150	1.332	1.503	1.664

TABLE 18-III-X—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (60 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
				1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
60	3	3.2	0.5	0.012	0.023	0.034	0.045	0.056	0.067	0.077	0.087
			0.7	0.016	0.032	0.047	0.062	0.077	0.092	0.106	0.119
		3.4	0.5	0.025	0.048	0.071	0.093	0.114	0.135	0.155	0.174
			0.7	0.034	0.067	0.097	0.127	0.155	0.182	0.208	0.234
		3.6	0.5	0.060	0.114	0.165	0.212	0.256	0.297	0.337	0.374
			0.7	0.083	0.156	0.223	0.283	0.339	0.391	0.439	0.485
		3.8	0.5	0.143	0.260	0.361	0.450	0.529	0.601	0.667	0.728
			0.7	0.196	0.348	0.474	0.582	0.677	0.761	0.838	0.909
	5	3.2	0.5	0.025	0.050	0.075	0.099	0.123	0.147	0.170	0.193
			0.7	0.036	0.070	0.104	0.138	0.171	0.203	0.234	0.265
		3.4	0.5	0.055	0.107	0.158	0.208	0.256	0.303	0.348	0.393
			0.7	0.076	0.149	0.219	0.286	0.350	0.412	0.472	0.530
		3.6	0.5	0.135	0.260	0.376	0.485	0.588	0.685	0.777	0.864
			0.7	0.189	0.358	0.512	0.654	0.786	0.908	1.024	1.133
		3.8	0.5	0.333	0.611	0.851	1.064	1.255	1.430	1.591	1.740
			0.7	0.465	0.830	1.135	1.398	1.631	1.840	2.030	2.205
	7	3.2	0.5	0.044	0.088	0.130	0.173	0.214	0.255	0.296	0.336
			0.7	0.062	0.122	0.182	0.240	0.297	0.353	0.408	0.463
		3.4	0.5	0.096	0.188	0.278	0.366	0.451	0.534	0.615	0.694
			0.7	0.134	0.263	0.386	0.505	0.619	0.730	0.837	0.941
		3.6	0.5	0.241	0.465	0.674	0.870	1.055	1.231	1.398	0.558
			0.7	0.339	0.644	0.924	1.181	1.421	1.645	1.856	2.055

TABLE 18-III-Y—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY ILLITE CLAY SOIL (70 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm: 1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
70	3	3.2	0.5 0.7	0.014 0.019	0.027 0.038	0.041 0.056	0.054 0.074	0.067 0.092	0.079 0.109	0.092 0.126	0.104 0.142
		3.4	0.5 0.7	0.029 0.041	0.057 0.079	0.084 0.116	0.111 0.151	0.136 0.185	0.160 0.217	0.184 0.248	0.207 0.278
		3.6	0.5 0.7	0.071 0.099	0.136 0.186	0.196 0.265	0.252 0.337	0.305 0.403	0.354 0.465	0.401 0.523	0.445 0.577
		3.8	0.5 0.7	0.170 0.234	0.310 0.415	0.430 0.564	0.535 0.692	0.630 0.805	0.715 0.906	0.794 0.998	0.866 1.082
	5	3.2	0.5 0.7	0.030 0.042	0.060 0.084	0.089 0.124	0.118 0.164	0.147 0.203	0.175 0.241	0.202 0.279	0.230 0.315
		3.4	0.5 0.7	0.065 0.091	0.128 0.177	0.188 0.260	0.247 0.340	0.305 0.417	0.360 0.490	0.414 0.562	0.467 0.631
		3.6	0.5 0.7	0.161 0.225	0.309 0.426	0.448 0.610	0.577 0.779	0.699 0.935	0.815 1.081	0.925 1.219	1.029 1.348
		3.8	0.5 0.7	0.396 0.563	0.727 0.988	1.013 1.351	1.266 1.664	1.494 1.941	1.702 2.190	1.894 2.417	2.072 2.625
	7	3.2	0.5 0.7	0.062 0.074	0.104 0.146	0.155 0.216	0.205 0.285	0.255 0.354	0.304 0.420	0.352 0.486	0.400 0.551
		3.4	0.5 0.7	0.114 0.160	0.224 0.313	0.331 0.459	0.436 0.601	0.537 0.737	0.636 0.869	0.732 0.996	0.826 1.120
		3.6	0.5 0.7	0.287 0.403	0.553 0.767	0.802 1.099	1.036 1.406	1.256 1.691	1.465 1.958	1.664 2.209	1.854 2.447

TABLE 18-III-Z—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (30 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm: 1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
30	3	3.2	0.5 0.7	0.006 0.008	0.012 0.016	0.017 0.024	0.023 0.032	0.028 0.039	0.034 0.046	0.039 0.053	0.044 0.060
		3.4	0.5 0.7	0.012 0.017	0.024 0.034	0.036 0.049	0.047 0.064	0.058 0.078	0.068 0.092	0.078 0.105	0.088 0.118
		3.6	0.5 0.7	0.030 0.042	0.058 0.079	0.083 0.112	0.107 0.143	0.129 0.171	0.150 0.197	0.170 0.222	0.189 0.245
		3.8	0.5 0.7	0.072 0.099	0.132 0.176	0.182 0.239	0.227 0.294	0.267 0.342	0.303 0.385	0.337 0.423	0.368 0.459
	5	3.2	0.5 0.7	0.013 0.018	0.026 0.036	0.038 0.053	0.050 0.070	0.062 0.086	0.074 0.102	0.086 0.118	0.098 0.134
		3.4	0.5 0.7	0.028 0.039	0.054 0.075	0.080 0.110	0.105 0.144	0.129 0.177	0.153 0.208	0.176 0.238	0.198 0.268
		3.6	0.5 0.7	0.068 0.095	0.131 0.181	0.190 0.259	0.245 0.330	0.297 0.397	0.346 0.459	0.392 0.517	0.437 0.572
		3.8	0.5 0.7	0.168 0.235	0.308 0.419	0.430 0.573	0.537 0.706	0.634 0.824	0.722 0.929	0.804 1.025	0.879 1.114
	7	3.2	0.5 0.7	0.022 0.031	0.044 0.062	0.066 0.092	0.087 0.121	0.108 0.150	0.129 0.178	0.150 0.206	0.170 0.234
		3.4	0.5 0.7	0.048 0.068	0.095 0.133	0.141 0.195	0.185 0.255	0.228 0.313	0.270 0.369	0.311 0.423	0.361 0.475
		3.6	0.5 0.7	0.122 0.171	0.235 0.326	0.340 0.466	0.439 0.597	0.533 0.718	0.622 0.831	0.706 0.937	0.787 1.038

TABLE 18-III-AA—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (40 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
				1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
40	3	3.2	0.5	0.009	0.017	0.025	0.033	0.041	0.049	0.056	0.064
			0.7	0.012	0.023	0.035	0.046	0.056	0.067	0.077	0.087
		3.4	0.5	0.018	0.035	0.052	0.068	0.084	0.099	0.113	0.128
			0.7	0.025	0.049	0.071	0.093	0.114	0.133	0.153	0.171
		3.6	0.5	0.044	0.084	0.121	0.155	0.187	0.218	0.246	0.274
			0.7	0.061	0.114	0.163	0.207	0.248	0.286	0.321	0.355
		3.8	0.5	0.105	0.191	0.264	0.329	0.387	0.440	0.488	0.533
			0.7	0.144	0.255	0.347	0.426	0.495	0.557	0.614	0.665
	5	3.2	0.5	0.019	0.037	0.055	0.073	0.090	0.107	0.125	0.141
			0.7	0.026	0.052	0.076	0.101	0.125	0.148	0.171	0.194
		3.4	0.5	0.040	0.078	0.116	0.152	0.187	0.221	0.255	0.287
			0.7	0.056	0.109	0.160	0.209	0.256	0.302	0.345	0.388
		3.6	0.5	0.099	0.190	0.275	0.355	0.430	0.501	0.568	0.633
			0.7	0.138	0.262	0.375	0.479	0.575	0.665	0.749	0.829
		3.8	0.5	0.244	0.447	0.623	0.779	0.919	1.047	1.164	1.274
			0.7	0.340	0.607	0.831	1.023	1.193	1.347	1.486	1.614
	7	3.2	0.5	0.032	0.064	0.095	0.126	0.157	0.187	0.217	0.246
			0.7	0.045	0.089	0.133	0.176	0.217	0.258	0.299	0.339
		3.4	0.5	0.070	0.138	0.204	0.268	0.330	0.391	0.450	0.508
			0.7	0.098	0.192	0.283	0.369	0.453	0.534	0.613	0.689
		3.6	0.5	0.176	0.340	0.493	0.637	0.772	0.901	1.023	1.140
			0.7	0.248	0.472	0.676	0.864	1.040	1.204	1.358	1.504

TABLE 18-III-BB—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (50 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.) × 304.8 for mm	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month) × 25.4 for mm/month	DIFFERENTIAL SWELL (inch) × 25.4 for mm — Edge Distance Penetration × 304.8 for mm							
				1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
50	3	3.2	0.5	0.011	0.022	0.033	0.043	0.054	0.064	0.074	0.084
			0.7	0.016	0.031	0.045	0.060	0.074	0.088	0.101	0.115
		3.4	0.5	0.024	0.046	0.068	0.089	0.109	0.129	0.148	0.167
			0.7	0.033	0.064	0.093	0.122	0.149	0.175	0.200	0.224
		3.6	0.5	0.057	0.110	0.158	0.203	0.245	0.285	0.323	0.358
			0.7	0.079	0.150	0.213	0.271	0.325	0.375	0.421	0.465
		3.8	0.5	0.137	0.250	0.346	0.431	0.507	0.576	0.639	0.698
			0.7	0.188	0.334	0.454	0.558	0.649	0.730	0.804	0.871
	5	3.2	0.5	0.024	0.048	0.072	0.095	0.118	0.141	0.163	0.185
			0.7	0.034	0.067	0.100	0.132	0.163	0.194	0.224	0.254
		3.4	0.5	0.052	0.103	0.152	0.199	0.245	0.290	0.334	0.376
			0.7	0.073	0.143	0.210	0.274	0.335	0.395	0.452	0.508
		3.6	0.5	0.130	0.249	0.361	0.465	0.563	0.656	0.745	0.829
			0.7	0.181	0.343	0.491	0.627	0.753	0.871	0.981	1.086
		3.8	0.5	0.319	0.585	0.816	1.020	1.204	1.371	1.525	1.668
			0.7	0.445	0.796	1.088	1.340	1.563	1.764	1.946	2.114
	7	3.2	0.5	0.042	0.084	0.125	0.165	0.205	0.245	0.284	0.322
			0.7	0.059	0.117	0.174	0.230	0.285	0.339	0.391	0.443
		3.4	0.5	0.092	0.181	0.267	0.351	0.433	0.512	0.590	0.665
			0.7	0.129	0.252	0.370	0.484	0.594	0.700	0.802	0.902
		3.6	0.5	0.231	0.446	0.646	0.834	1.012	1.180	1.341	1.494
			0.7	0.325	0.618	0.885	1.132	1.362	1.577	1.779	1.970

TABLE 18-III-CC—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (60 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch)							
				× 25.4 for mm							
				Edge Distance Penetration							
				× 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
60	3	3.2	0.5 0.7	0.014 0.019	0.027 0.038	0.041 0.056	0.054 0.074	0.066 0.091	0.079 0.109	0.091 0.125	0.104 0.142
		3.4	0.5 0.7	0.029 0.041	0.057 0.079	0.084 0.116	0.110 0.151	0.135 0.184	0.160 0.216	0.183 0.247	0.206 0.277
		3.6	0.5 0.7	0.071 0.098	0.136 0.186	0.195 0.264	0.251 0.336	0.303 0.402	0.352 0.463	0.399 0.521	0.433 0.575
		3.8	0.5 0.7	0.169 0.233	0.309 0.413	0.428 0.562	0.533 0.690	0.627 0.802	0.712 0.903	0.790 0.994	0.863 1.077
	5	3.2	0.5 0.7	0.030 0.042	0.060 0.083	0.090 0.124	0.118 0.163	0.146 0.202	0.174 0.240	0.202 0.278	0.229 0.314
		3.4	0.5 0.7	0.065 0.090	0.127 0.177	0.188 0.259	0.246 0.339	0.303 0.415	0.359 0.488	0.413 0.559	0.465 0.628
		3.6	0.5 0.7	0.160 0.224	0.308 0.425	0.446 0.607	0.575 0.775	0.697 0.931	0.812 1.077	0.921 1.214	1.025 1.343
		3.8	0.5 0.7	0.395 0.551	0.724 0.984	1.009 1.345	1.261 1.657	1.488 1.933	1.695 2.181	1.886 2.407	2.063 2.614
	7	3.2	0.5 0.7	0.052 0.073	0.104 0.145	0.155 0.215	0.205 0.284	0.254 0.352	0.303 0.419	0.351 0.484	0.398 0.548
		3.4	0.5 0.7	0.113 0.159	0.223 0.311	0.330 0.458	0.434 0.598	0.535 0.734	0.633 0.865	0.729 0.992	0.823 1.115
		3.6	0.5 0.7	0.286 0.402	0.551 0.764	0.799 1.095	1.031 1.400	1.251 1.684	1.459 1.950	1.658 2.200	1.847 2.437

TABLE 18-III-DD—DIFFERENTIAL SWELL OCCURRING AT THE PERIMETER OF A SLAB FOR AN EDGE LIFT SWELLING CONDITION IN PREDOMINANTLY MONTMORILLONITE CLAY SOIL (70 PERCENT CLAY)

PERCENT CLAY (%)	DEPTH TO CONSTANT SUCTION (ft.)	CONSTANT SUCTION (*pF*)	VELOCITY OF MOISTURE FLOW (inches/month)	DIFFERENTIAL SWELL (inch)							
				× 25.4 for mm							
				Edge Distance Penetration							
				× 304.8 for mm							
	× 304.8 for mm		× 25.4 for mm/month	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.
70	3	3.2	0.5 0.7	0.016 0.023	0.032 0.045	0.048 0.067	0.064 0.088	0.079 0.109	0.094 0.129	0.109 0.149	0.123 0.169
		3.4	0.5 0.7	0.035 0.048	0.068 0.094	0.100 0.138	0.131 0.179	0.161 0.219	0.190 0.258	0.219 0.294	0.246 0.330
		3.6	0.5 0.7	0.084 0.117	0.162 0.221	0.233 0.314	0.299 0.400	0.361 0.479	0.420 0.552	0.475 0.620	0.528 0.684
		3.8	0.5 0.7	0.202 0.277	0.368 0.492	0.510 0.669	0.635 0.822	0.747 0.955	0.849 1.075	0.942 1.184	1.028 1.284
	5	3.2	0.5 0.7	0.036 0.050	0.071 0.099	0.106 0.147	0.140 0.195	0.174 0.241	0.207 0.286	0.240 0.331	0.273 0.374
		3.4	0.5 0.7	0.077 0.108	0.151 0.210	0.223 0.309	0.293 0.403	0.361 0.494	0.427 0.582	0.492 0.666	0.554 0.748
		3.6	0.5 0.7	0.191 0.267	0.367 0.506	0.531 0.724	0.685 0.924	0.830 1.110	0.967 1.283	1.097 1.446	1.221 1.600
		3.8	0.5 0.7	0.470 0.656	0.862 1.172	1.262 1.603	1.502 1.974	1.773 2.303	2.020 2.598	2.247 2.867	2.458 3.114
	7	3.2	0.5 0.7	0.062 0.087	0.124 0.173	0.184 0.256	0.244 0.339	0.303 0.419	0.361 0.499	0.418 0.577	0.475 0.653
		3.4	0.5 0.7	0.135 0.189	0.266 0.371	0.393 0.545	0.517 0.713	0.637 0.875	0.754 1.031	0.869 1.182	0.980 1.329
		3.6	0.5 0.7	0.341 0.479	0.656 0.910	0.951 1.304	1.229 1.668	1.490 2.006	1.739 2.323	1.975 2.621	2.200 2.903

TABLE 18-III-EE—COMPARISON OF METHODS OF DETERMINING CATION EXCHANGE CAPACITY

SOIL SAMPLE	CATION EXCHANGE CAPACITY (meq/100gm)	
	Atomic Absorption	Spectrophotometer[1]
01 - 01	21.1	20.2
31 - 02	28.2	26.2
53 - 05	14.7	7.0
72 - 06	71.4	72.8
73 - 06	21.6	18.9
86 - 08	45.0	50.0

[1]Bausch & Lomb "Spectronic-20."

TABLE 18-III-FF—COMPARISON OF CLAY MINERAL DETERMINATION METHODS

SOIL SAMPLE	PERCENT CLAY	ATTERBERG LIMITS		C.E.C. (meq./100 gm)		AC	*CEAC*		PREDOMINANT CLAY MINERAL		
		PL	*PI*	Flame Photometer	Correlation Equation		Flame Photometer	Correlation Equation	Flame Photometer	Correlation Equation	X-ray Defraction Analysis
31-02	33.5	16.5	26.6	28.2	26.6	0.79	0.84	0.80	Smectite	Smectite	Smectite
72-06	50.0	32.5	41.8	71.4	58.7	0.84	1.43	1.17	Smectite	Smectite	Smectite
86-08	47.0	25.1	36.4	45.0	43.4	0.77	0.96	0.92	Smectite	Smectite	Smectite

TABLE 18-III-GG—SAMPLE VALUES C_Δ

MATERIAL	CENTER LIFT	EDGE LIFT
Wood Frame	240	480
Stucco or Plaster	360	720
Brick Veneer	480	960
Concrete Masonry Units	960	1,920
Prefab Roof Trusses[1]	1,000	2,000

[1]Trusses that clearspan the full length or width of the foundation from edge to edge.

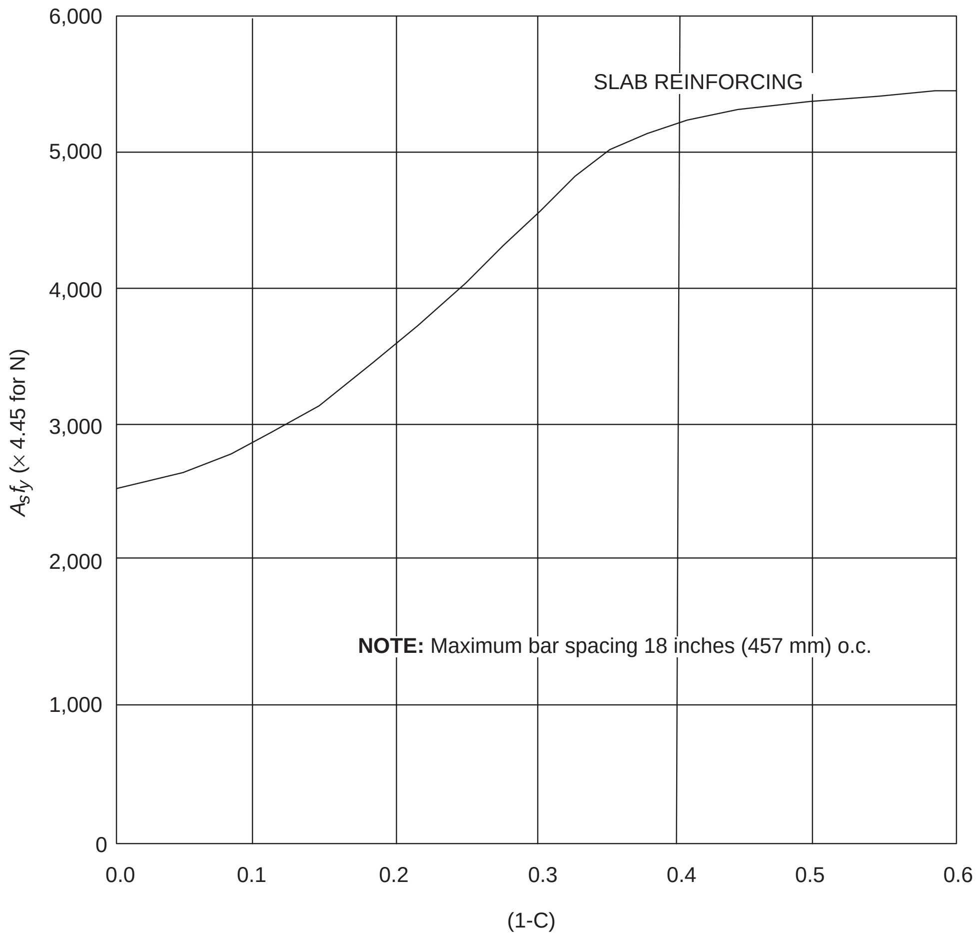


FIGURE 18-III-1—(1-C) VERSUS $A_s f_y$

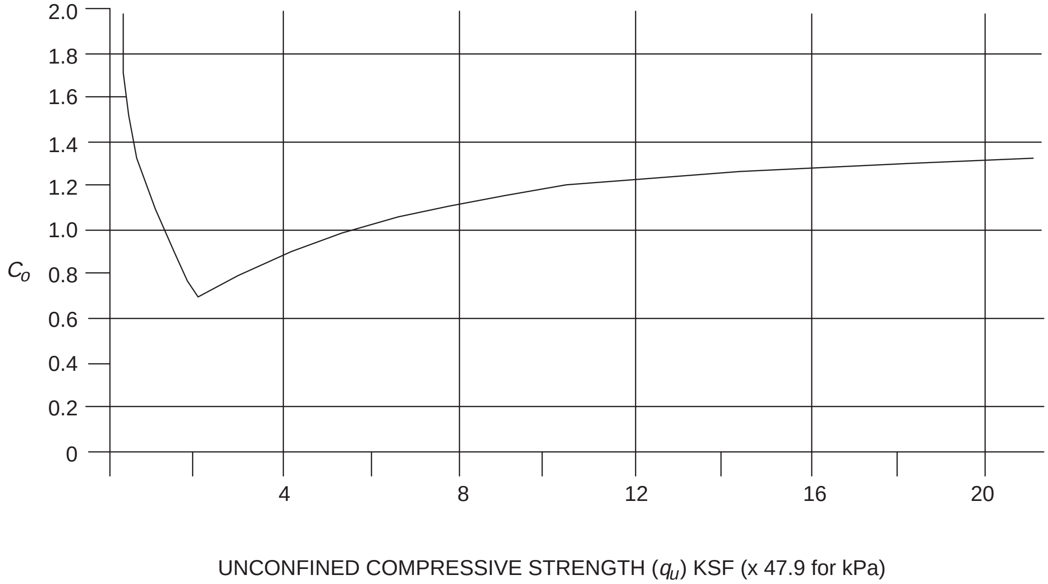


FIGURE 18-III-2—UNCONFINED COMPRESSIVE STRENGTH VERSUS OVERCONSOLIDATED CORRECTION COEFFICIENT

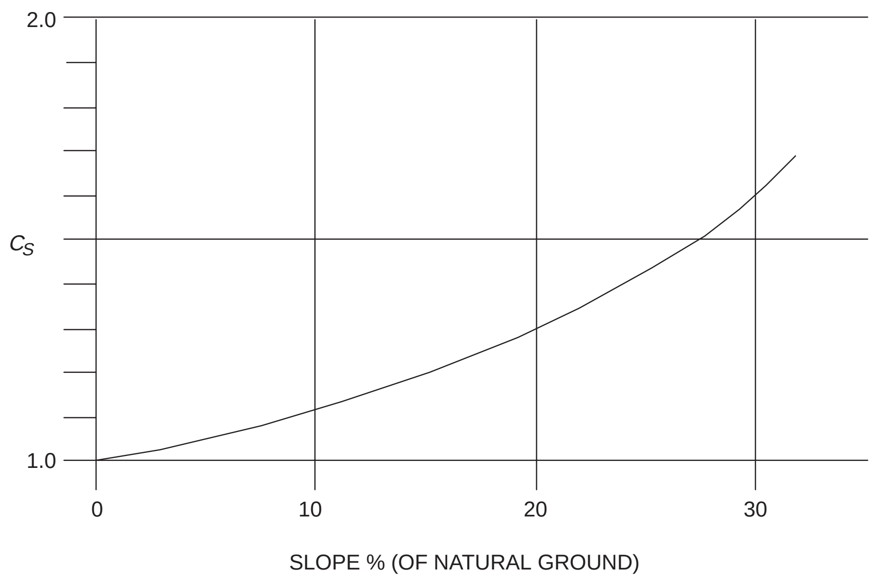


FIGURE 18-III-3—SLOPE OF NATURAL GROUND VERSUS SLOPE CORRECTION COEFFICIENT

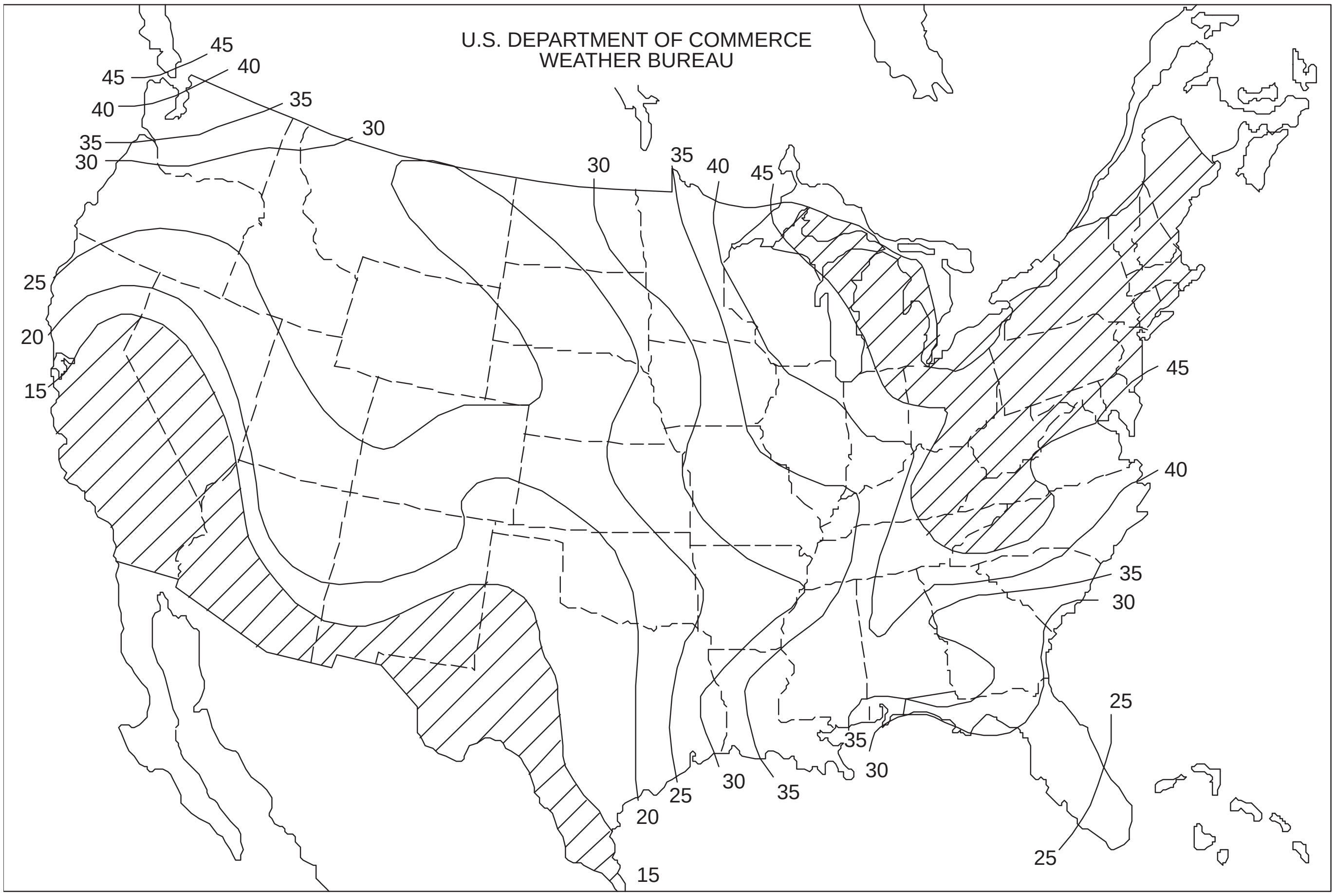


FIGURE 18-III-4—CLIMATIC RATING (C_W) CHART

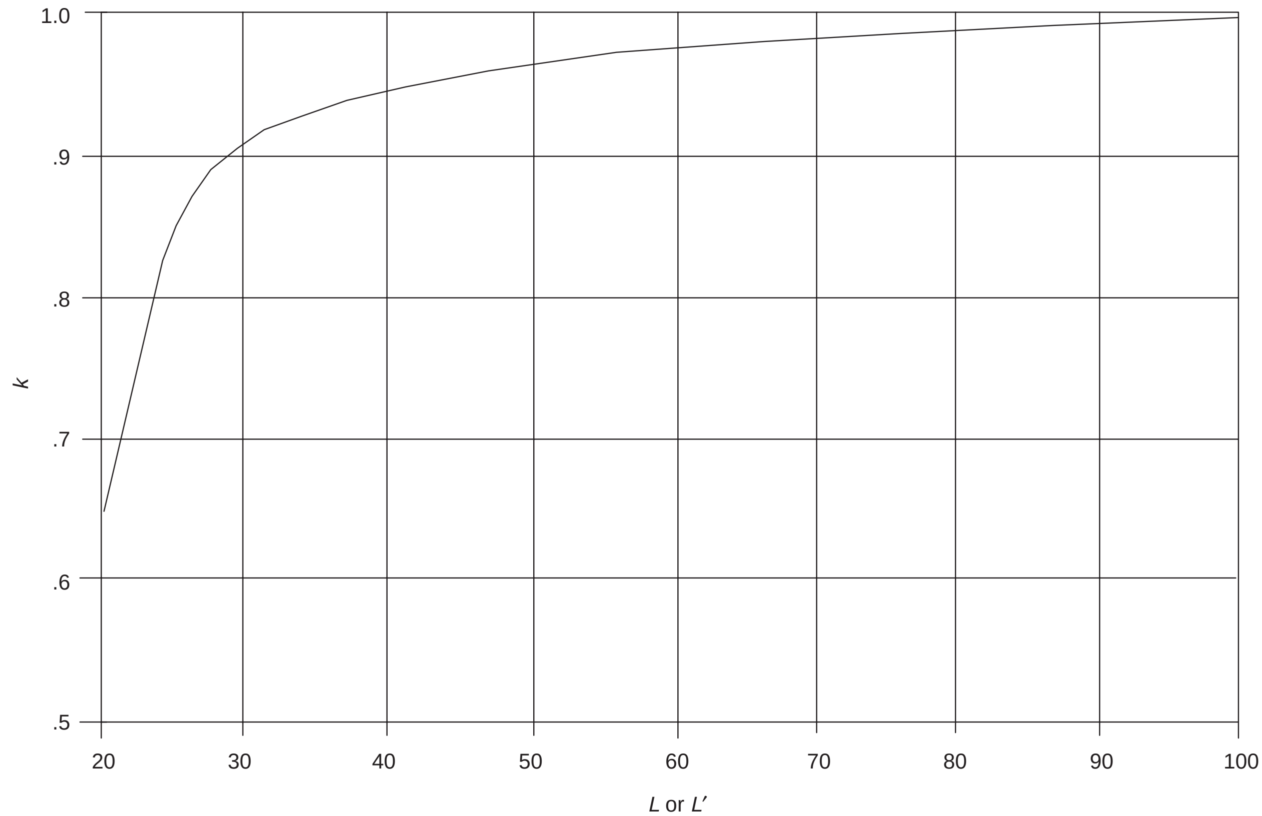


FIGURE 18-III-5—*L* or *L′* VERSUS *k*

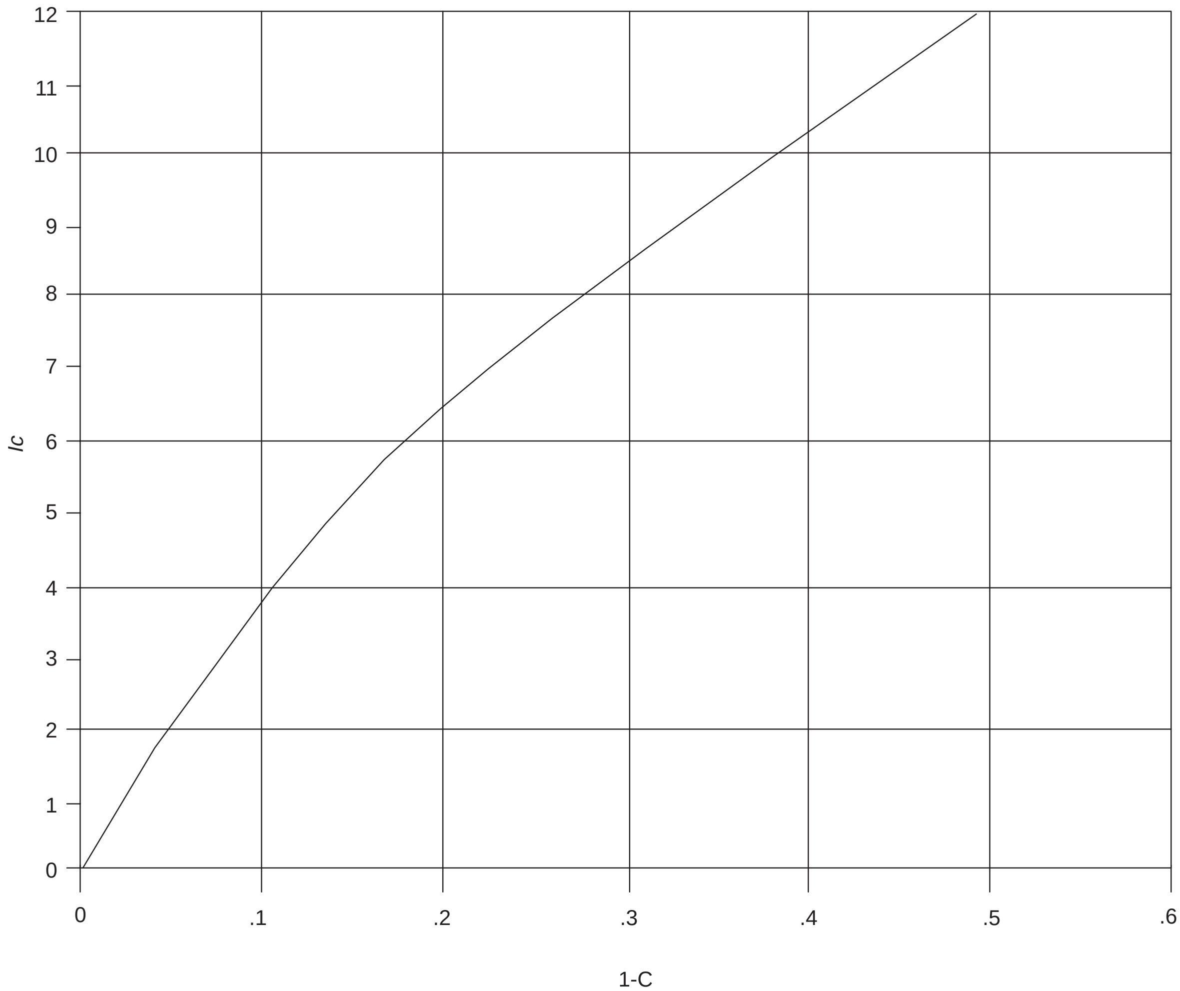


FIGURE 18-III-6—1-C VERSUS CANTILEVER LENGTH (*lc*)

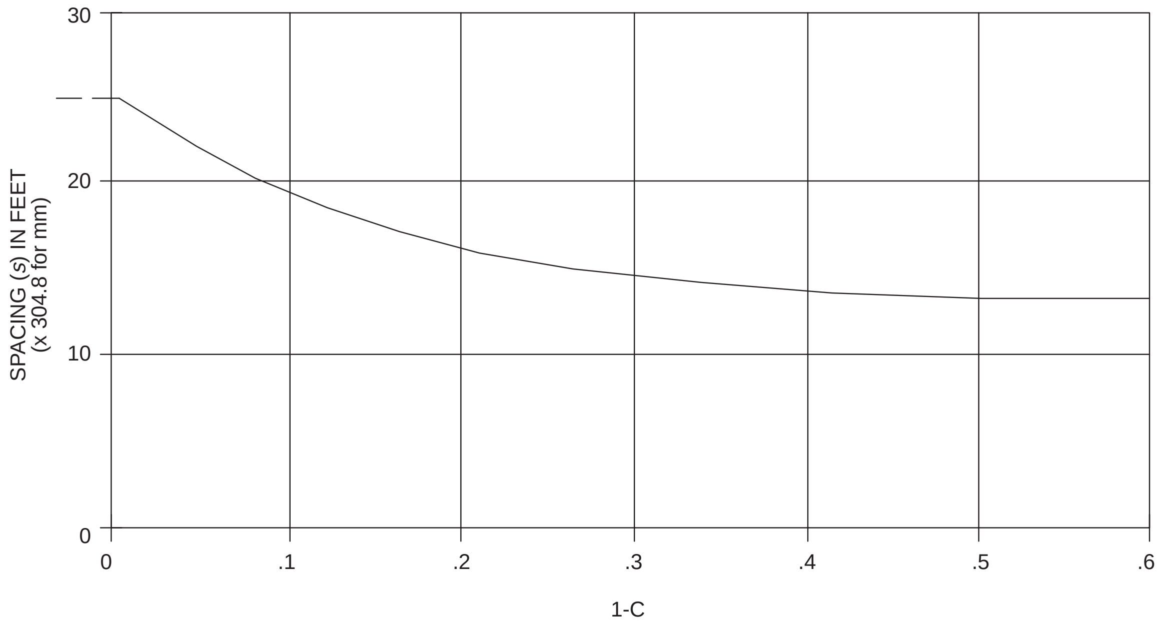


FIGURE 18-III-7—1-C VERSUS MAXIMUM BEAM SPACING

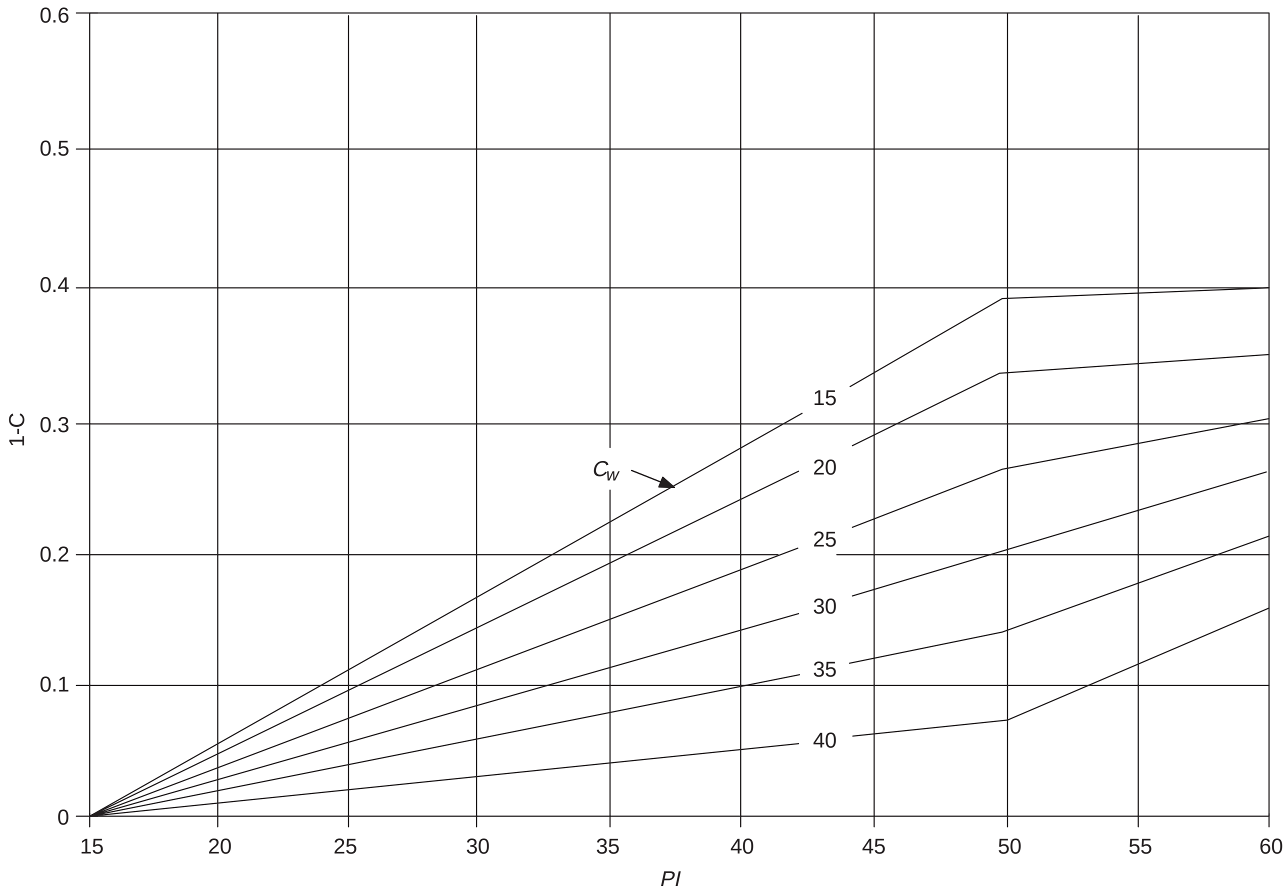
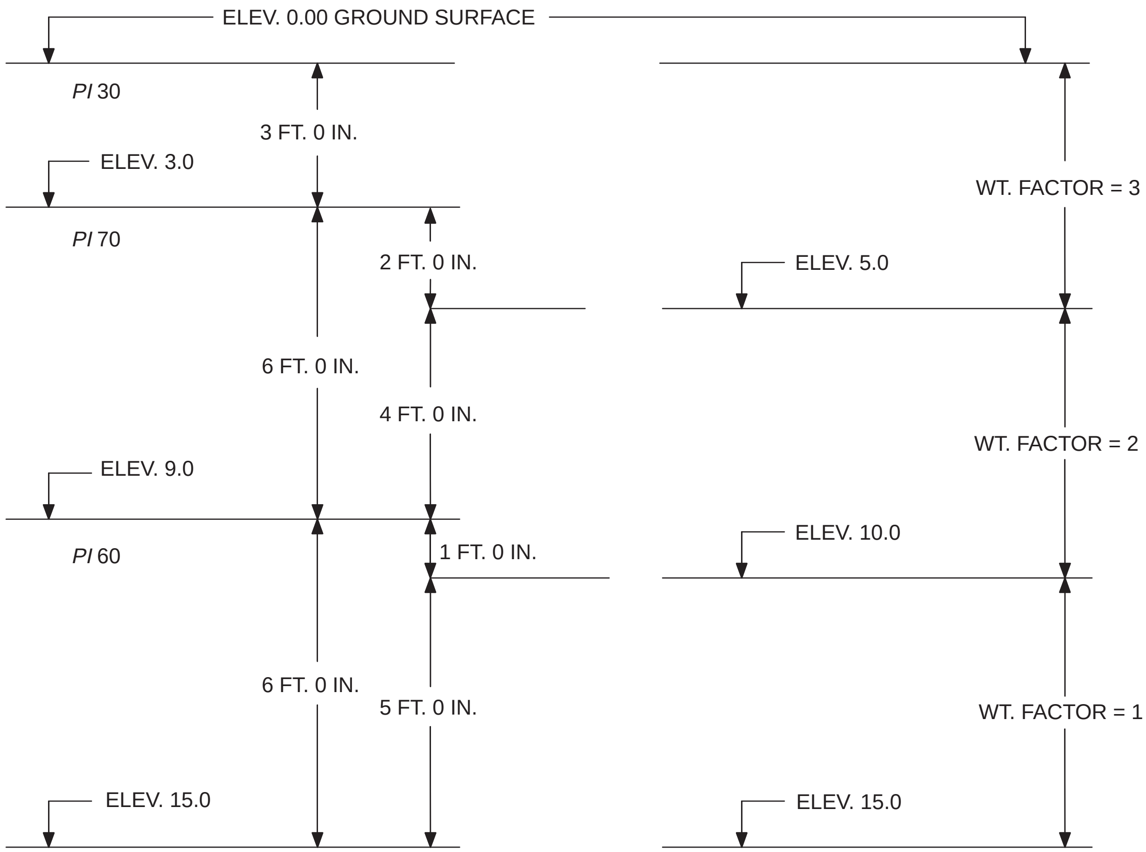


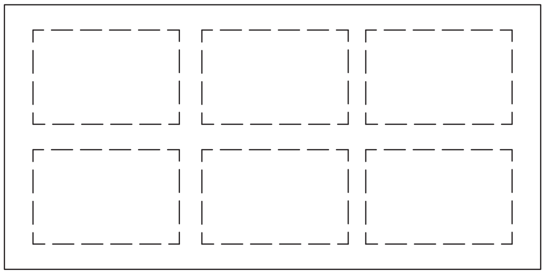
FIGURE 18-III-8—*PI* VERSUS (1-C)



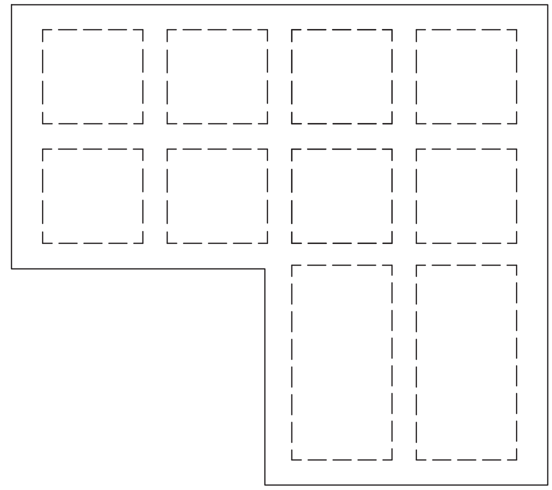
Weight Factor *F*	Depth *D*	$F \times D$	*PI*	$F \times D \times PI$	
3	3	9	30	=	270
3	2	6	70	=	420
2	4	8	70	=	560
2	1	2	60	=	120
1	5	5	60	=	300
		30			1670

Weighted *PI* = 1670/30 = 55.67
= 56

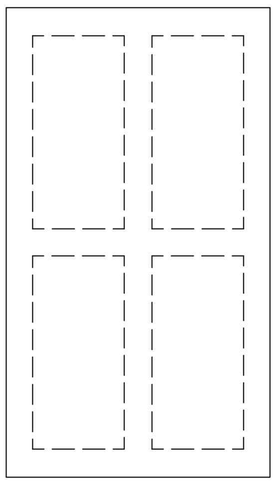
FIGURE 18-III-9—DETERMINING THE WEIGHTED PLASTICITY INDEX (*PI*)



SLAB 1



COMBINED SLABS



SLAB 2

FIGURE 18-III-10—SLAB SEGMENTS AND COMBINED

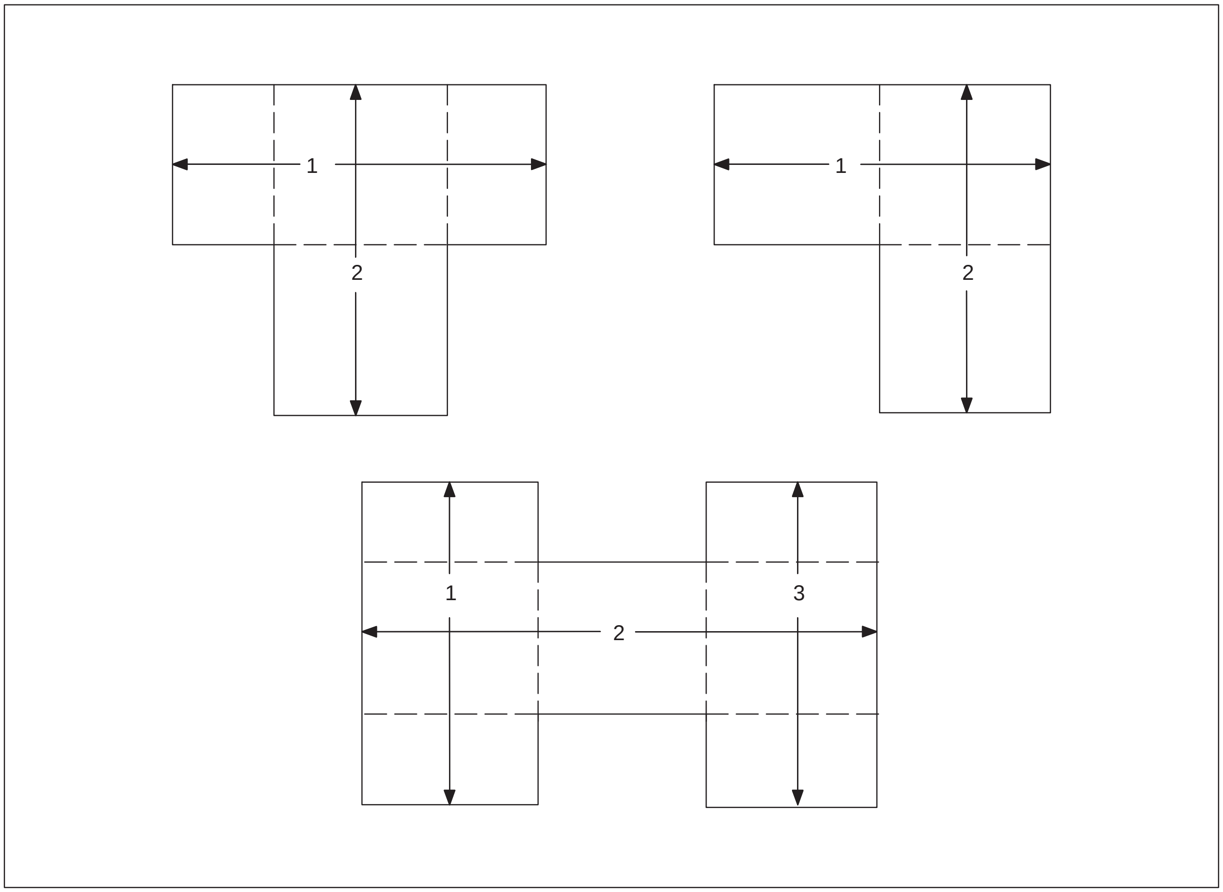


FIGURE 18-III-11—DESIGN RECTANGLES FOR SLABS OF IRREGULAR SHAPE

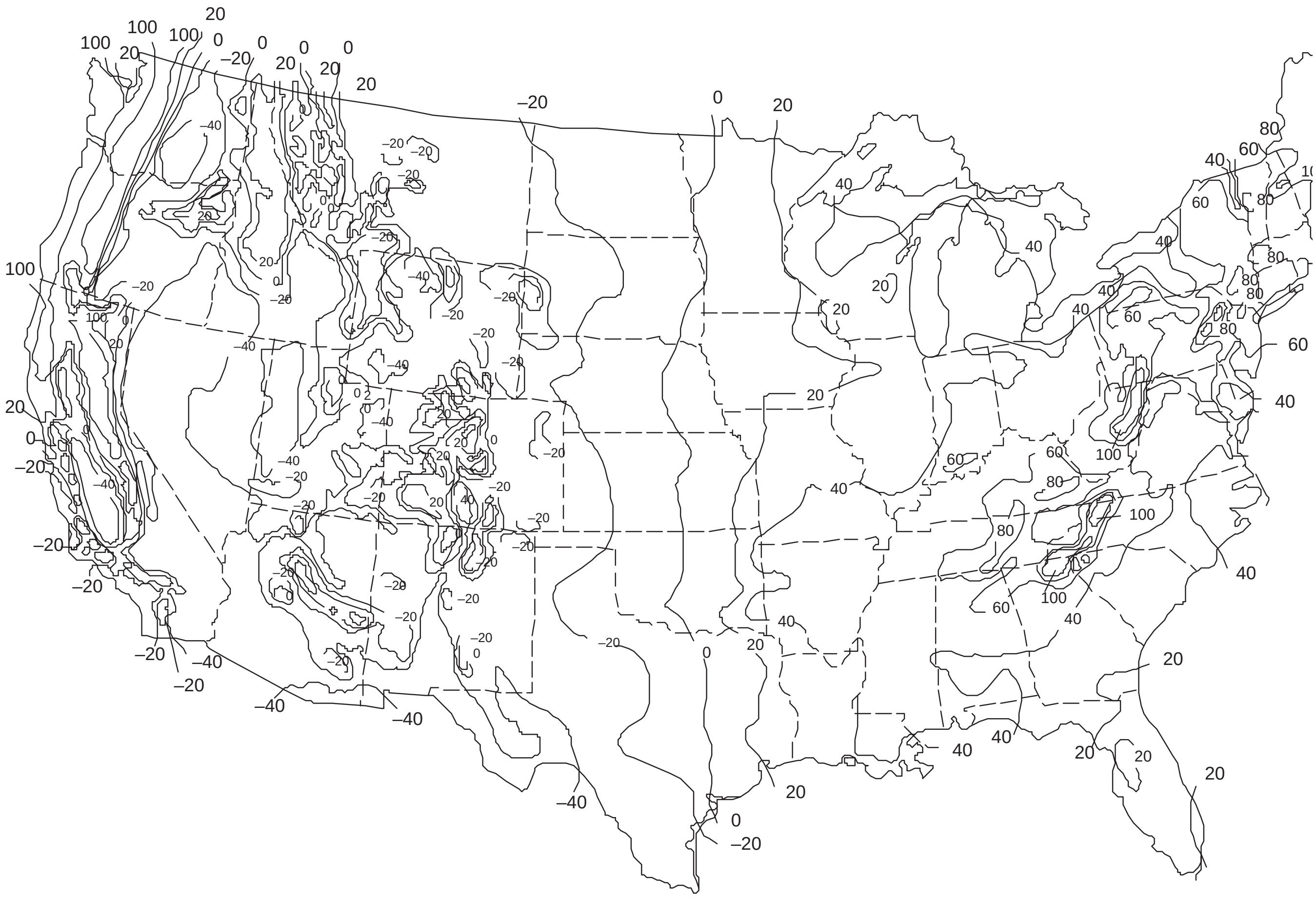


FIGURE 18-III-12—THORNTHWAITE MOISTURE INDEX DISTRIBUTION IN THE UNITED STATES

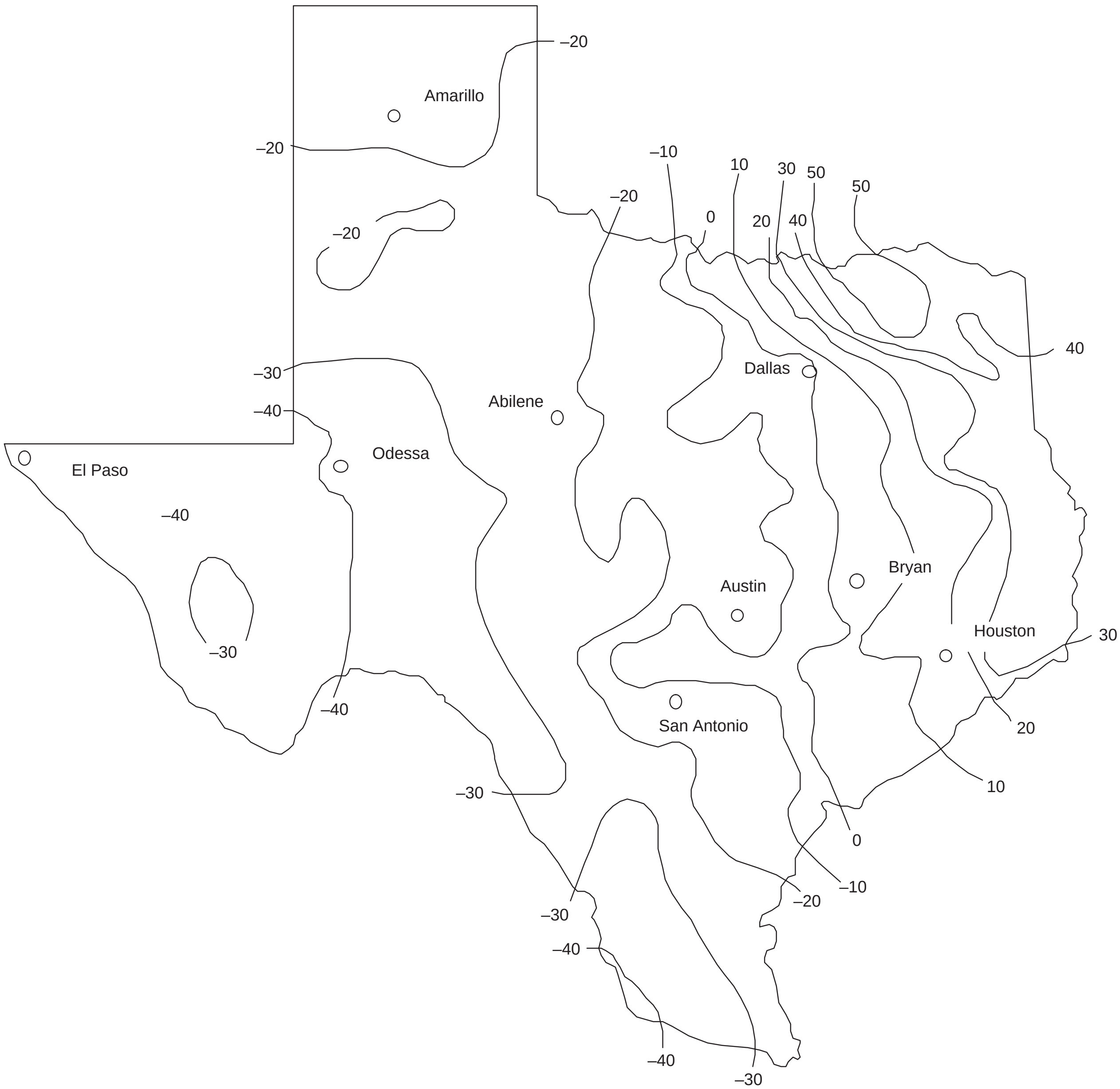


FIGURE 18-III-13-1—THORNTHWAITE MOISTURE INDEX DISTRIBUTION FOR TEXAS (20-YEAR AVERAGE, 1955-1974)

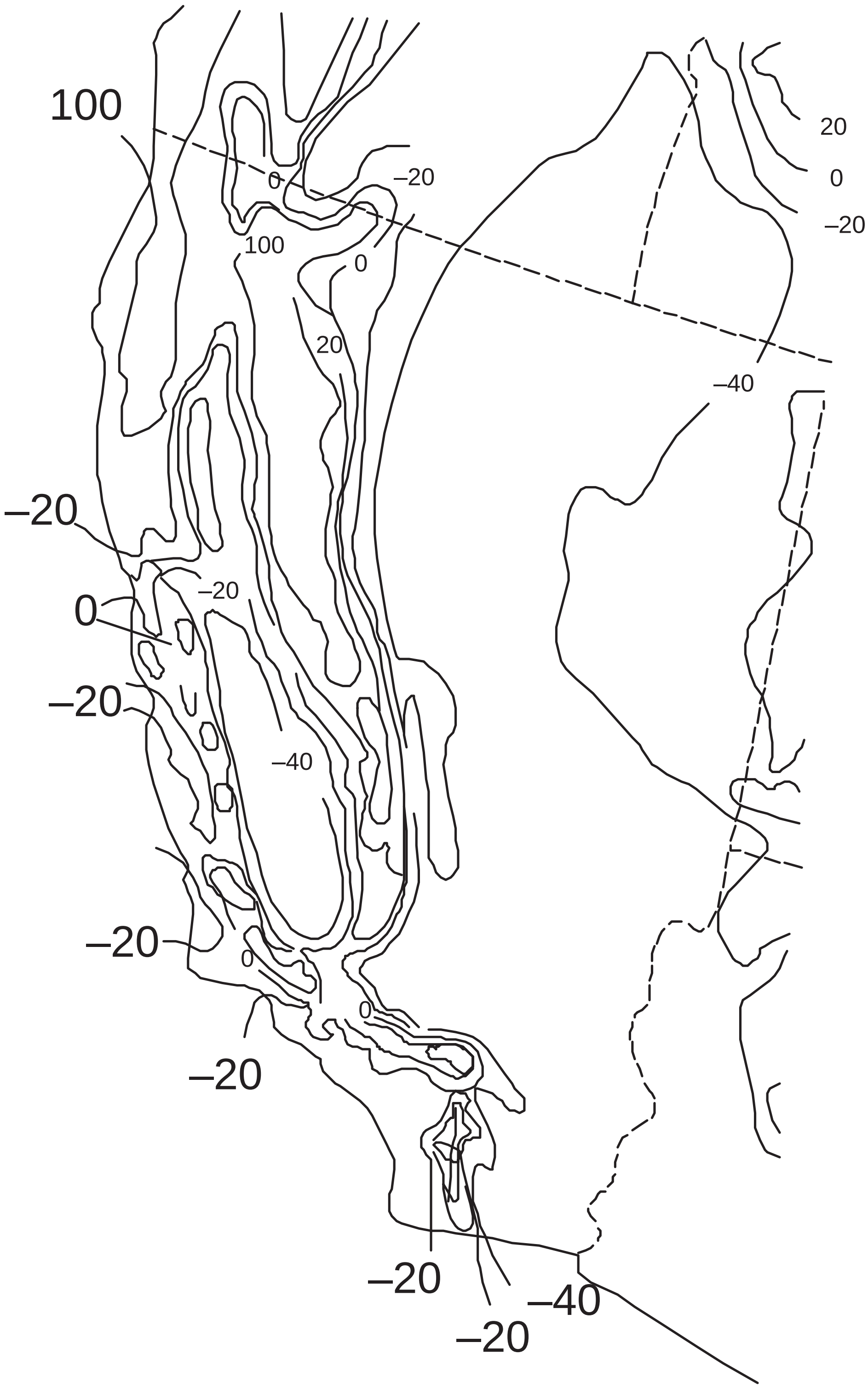
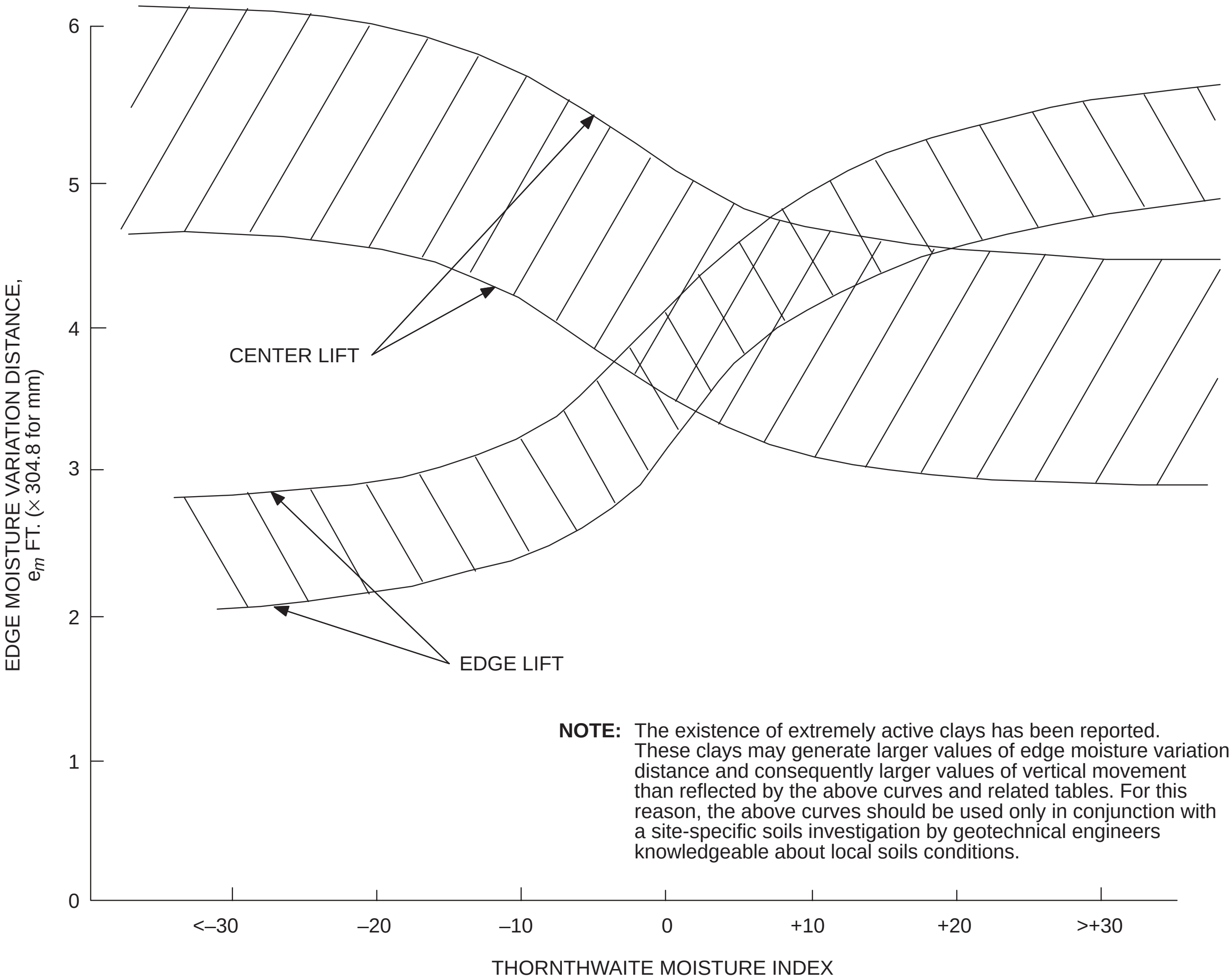


FIGURE 18-III-13-2—THORNTHWAITE MOISTURE INDEX DISTRIBUTION IN CALIFORNIA



NOTE: The existence of extremely active clays has been reported. These clays may generate larger values of edge moisture variation distance and consequently larger values of vertical movement than reflected by the above curves and related tables. For this reason, the above curves should be used only in conjunction with a site-specific soils investigation by geotechnical engineers knowledgeable about local soils conditions.

FIGURE 18-III-14—APPROXIMATE RELATIONSHIP BETWEEN THORNTHWAITE INDEX AND MOISTURE VARIATION DISTANCE

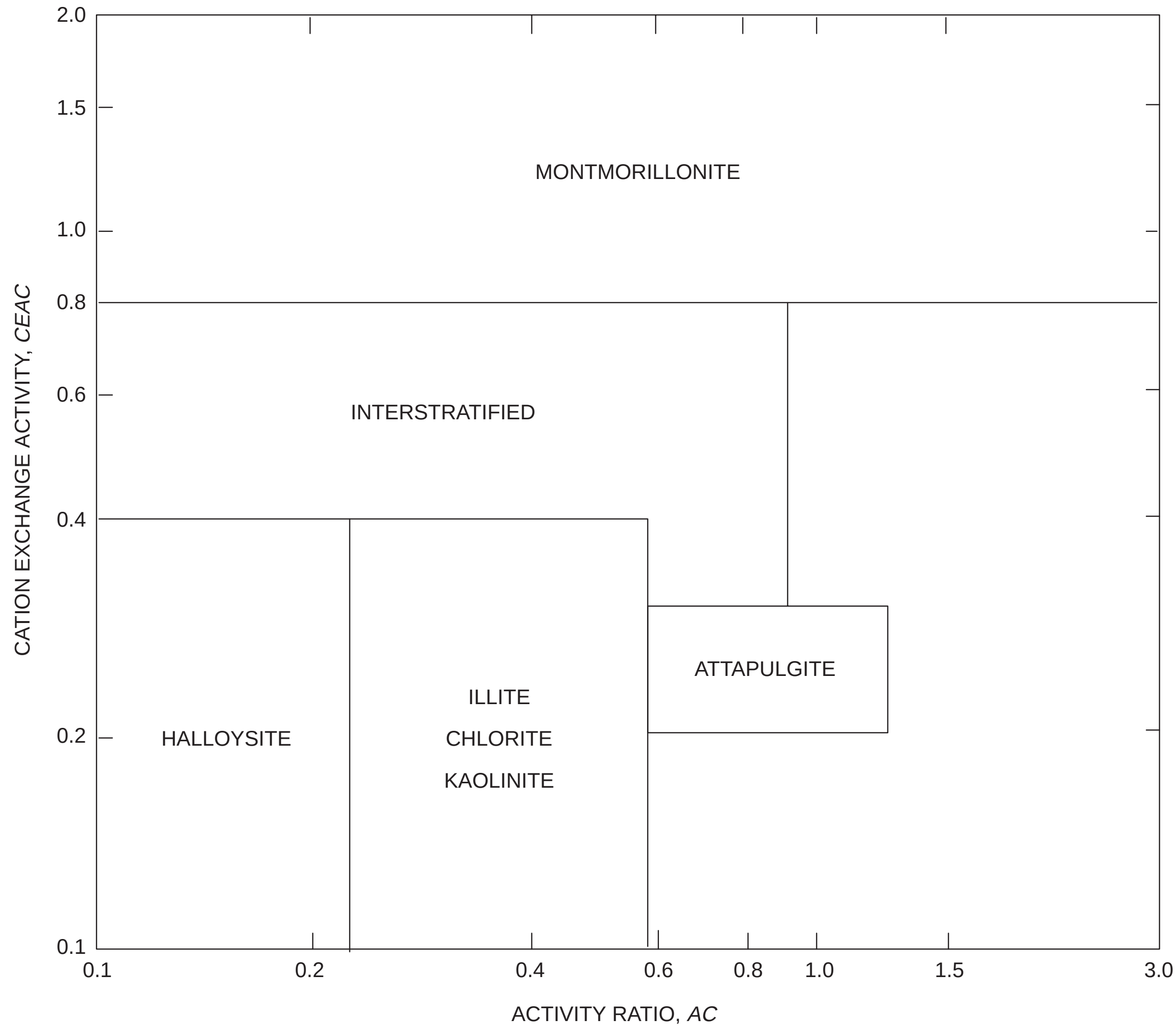


FIGURE 18-III-15—CLAY TYPE CLASSIFICATION TO CATION EXCHANGE AND CLAY ACTIVITY RATIO AFTER PEARRING AND HOLT

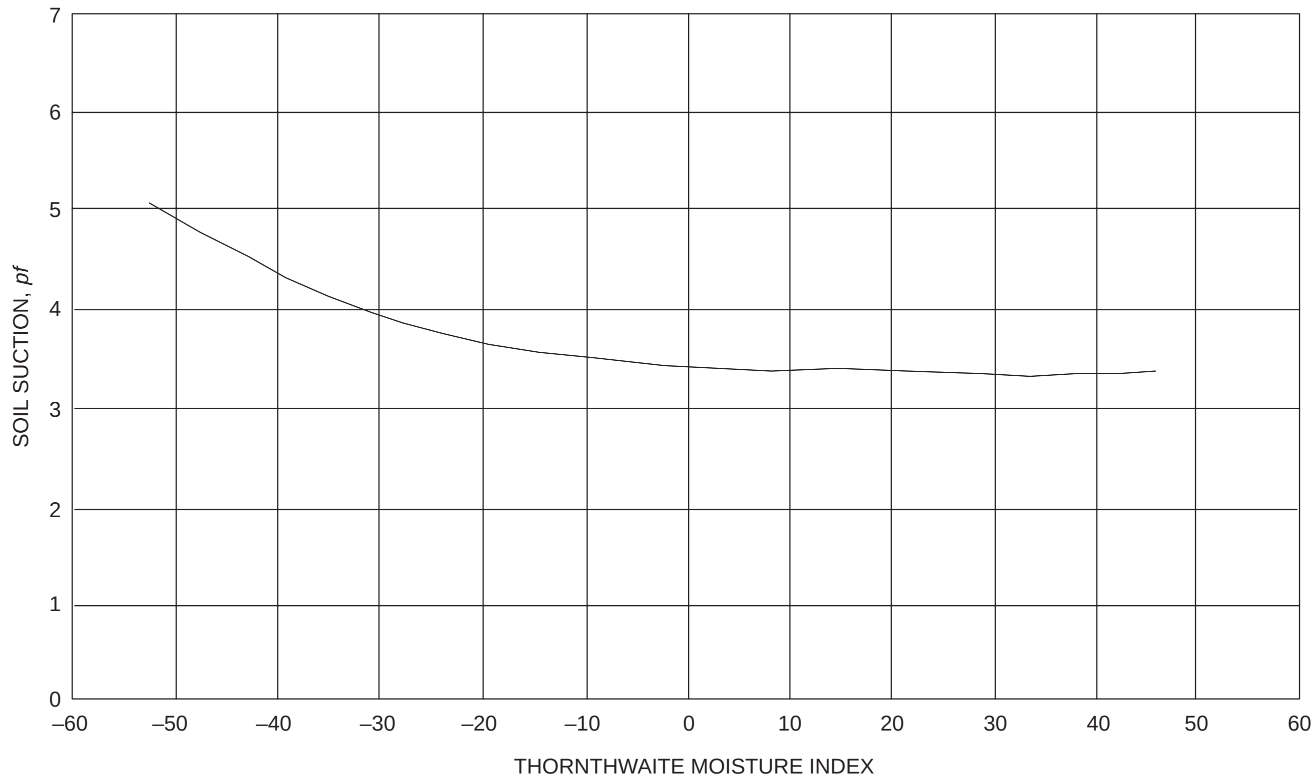


FIGURE 18-III-16—VARIATION OF CONSTANT SOIL SUCTION WITH THORNTHWAITE INDEX

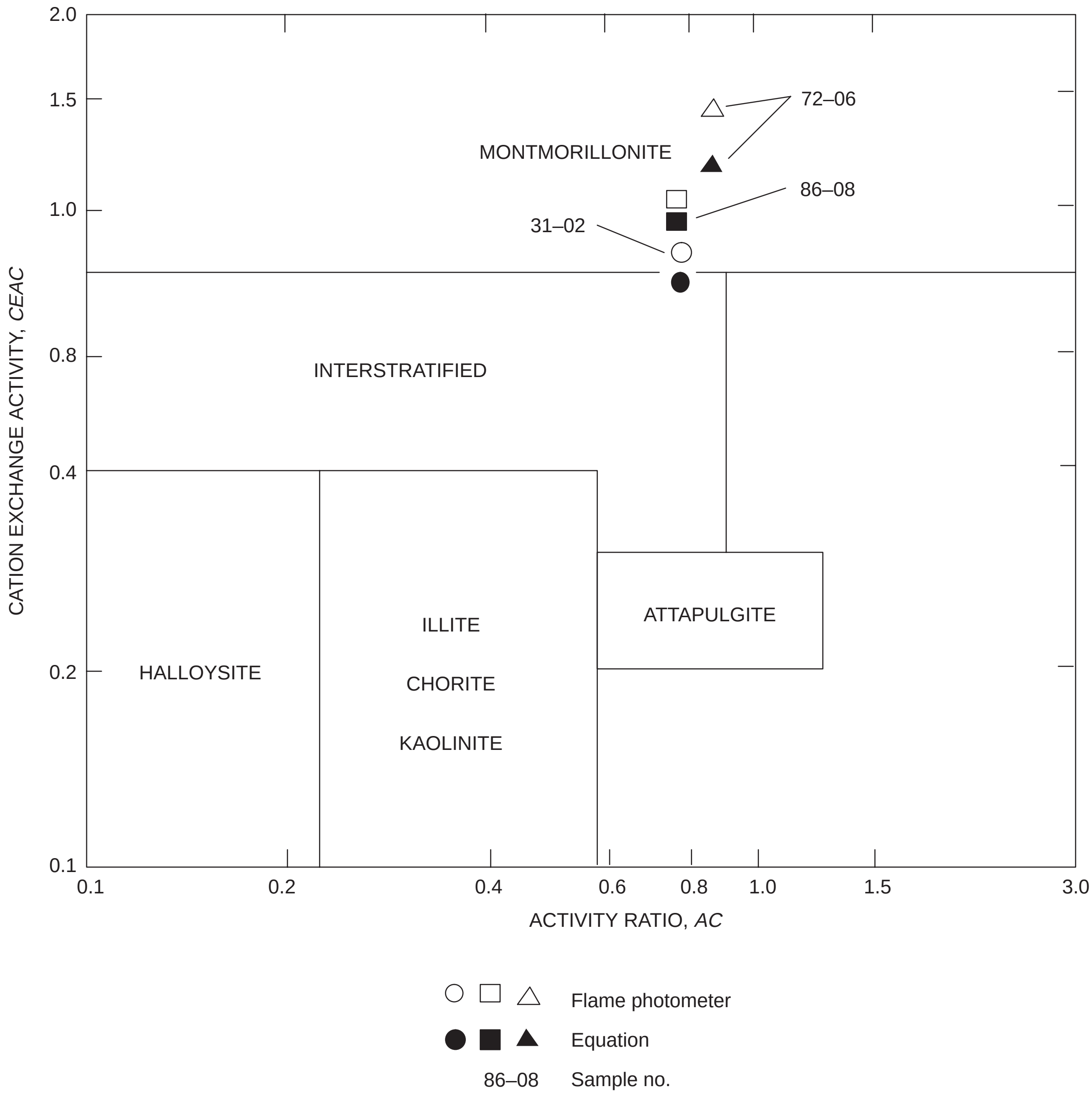


FIGURE 18-III-17—COMPARISON OF CLAY MINERAL DETERMINATION USING ATOMIC ABSORPTION AND CORRELATION EQUATIONS

UNIFORM BUILDING CODE STANDARD 18-1
SOILS CLASSIFICATION

Based on Standard Method D 2487-69 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 1801.2 and 1803.1, *Uniform Building Code*

SECTION 18.101 — SCOPE

This standard describes a system for classifying mineral and organomineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit and plasticity index.

SECTION 18.102 — APPARATUS

Apparatus of an approved type shall be used to perform the following tests and procedures: Preparation of soil samples, liquid limit test, plastic limit test and particle-size analysis.

SECTION 18.103 — SAMPLING

Sampling shall be conducted in accordance with approved methods for soil investigation and sampling by auger borings, for Penetration Test and Split-barrel Sampling of Soils, and for Thin-walled Tube Sampling of Soils.

The sample shall be carefully identified as to origin by a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated center line.

The sample should also be described in accordance with an approved visual-manual procedure. (A soil which is composed primarily of undecayed or partially decayed organic matter and has a fibrous texture, dark brown to black color, and organic odor should be designated as a highly organic soil, PT, and not subjected to the classification procedures described hereafter.)

SECTION 18.104 — TEST SAMPLE

Test samples shall represent that portion of the field sample finer than the 3-inch (76 mm) sieve and shall be obtained as follows:

Air dry the field sample; weigh the field sample; and separate the field sample into two fractions on a 3-inch (76 mm) sieve. Weigh the fraction retained on the 3-inch (76 mm) sieve. Compute the percentage of plus 3-inch (76 mm) material in the field sample and note this percentage as auxiliary information. Thoroughly mix the fraction passing the 3-inch (76 mm) sieve and select test samples.

SECTION 18.105 — PRELIMINARY CLASSIFICATION PROCEDURE

Procedure for the determination of percentage finer than the No. 200 (75 μm) sieve is as follows:

1. From the material passing the 3-inch (76 mm) sieve, select a test sample and determine the percentage of the test sample finer than the No. 200 (75 μm) sieve. (This step may be omitted if the soil can obviously be classified as fine-grained by visual inspection.)

2. Classify the soil as coarse-grained if more than 50 percent of the test sample is retained on the No. 200 (75 μm) sieve.

3. Classify the soil as fine-grained if 50 percent or more of the test sample passes the No. 200 (75 μm) sieve.

SECTION 18.106 — PROCEDURE FOR CLASSIFICATION OF COARSE-GRAINED SOILS (MORE THAN 50 PERCENT RETAINED)

Select test samples from the material passing the 3-inch (76 mm) sieve for the determination of particle-size characteristics, liquid limit and plasticity index. Determine the cumulative particle-size distribution of the fraction coarser than the No. 200 (75 μm) sieve.

Classify the sample as *gravel*, G, if 50 percent or more of the coarse fraction [plus No. 200 (75 μm) sieve] is retained on the No. 4 (4.75 mm) sieve. Classify the sample as *sand*, S, if more than 50 percent of the coarse fraction [plus No. 200 (75 μm) sieve] passes the No. 4 (75 mm) sieve.

If less than 5 percent of the test sample passed the No. 200 (75 μm) sieve, compute the coefficient of uniformity, C_u, and coefficient of curvature, C_z, as given in Formulas 18-1-1 and 18-1-2:

$$C_u = \frac{D_{60}}{D_{10}} \qquad (18\text{-}1\text{-}1)$$

$$C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}} \qquad (18\text{-}1\text{-}2)$$

in which D_{10}, D_{30} and D_{60} are the particle size diameters corresponding respectively to 10, 30 and 60 percent passing on the cumulative particle size distribution curve.

Classify the sample as well-graded gravel, GW, or well-graded sand, SW, if C_u is greater than 4 for gravel and 6 for sand, and C_z is between 1 and 3. Classify the sample as poorly graded gravel, GP, or poorly graded sand, SP, if either the C_u or the C_z criteria for well-graded soils are not satisfied.

If more than 12 percent of the test sample passed the No. 200 (75 μm) sieve, determine the liquid limit and the plasticity index of a portion of the test sample passing the No. 40 (425 μm) sieve in accordance with approved methods.

Classify the sample as silty gravel, GM, or silty sand, SM, if the results of the limits tests show that the fines are silty, that is, the plot of the liquid limit versus plasticity index falls below the “A” line (see Plasticity Table 18-1-A) or the plasticity index is less than 4.

Classify the sample as clayey gravel, GC, or clayey sand, SC, if the fines are clayey, that is, the plot of liquid limit versus plasticity index falls above the “A” line and the plasticity index is greater than 7.

If the fines are intermediate between silt and clay, that is, the plot of liquid limit versus plasticity index falls on or practically on the “A” line or falls above the “A” line but the plasticity index is in the range of 4 to 7, the soil should be given a borderline classification, such as GM-GC or SM-SC.

If 5 to 12 percent of the test sample passed the No. 200 (75 μm) sieve, the soil should be given a borderline classification based on both its gradation and limit test characteristics, such as GW-GC or SP-SM. (In doubtful cases the rule is to favor the less plastic classification. Example: A gravel with 10 percent fines, a C_u of 20, a C_z of 2.0, and a plasticity index of 6 would be classified as GW-GM rather than GW-GC.)

SECTION 18.107 — PROCEDURE FOR CLASSIFICATION OF FINE-GRAINED SOILS (50 PERCENT OR MORE PASSING)

From the material passing the 3-inch (76 mm) sieve, select a test sample for the determination of the liquid limit and plasticity index. The method for wet preparation shall be used for soils containing organic matter or irreversible mineral colloids.

Determine the liquid limit and the plasticity index of a portion of the test sample passing the No. 40 (425 µm) sieve.

Classify the soil as inorganic clay, C, if the plot of liquid limit versus plasticity index falls above the “A” line and the plasticity index is greater than 7.

Classify the soil as inorganic clay of low to medium plasticity, CL, if the liquid limit is less than 50 and the plot of liquid limit versus plasticity index falls above the “A” line and the plasticity index is greater than 7. See area identified as CL on the Plasticity Chart of Table 18-1-A.

Classify the soil as inorganic clay of high plasticity, CH, if the liquid limit is greater than 50 and the plot of liquid limit versus plasticity index falls above the “A” line. In cases where the liquid limit exceeds 100 or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scales on both axes and extending the “A” line at the indicated slope. See areas identified as CH on the Plasticity Chart, Table 18-1-A.

Classify the soil as inorganic silt, M, if the plot of liquid limit versus plasticity index falls below the “A” line or if the plasticity index is less than 4, unless it is suspected that organic matter is present in sufficient amounts to influence the soil properties, then tentatively classify the soil as organic silt or clay, O.

If the soil has a dark color and an organic odor when moist and warm, a second liquid limit test should be performed on a test sample which has been oven dried at 110°C ± 5°C for 24 hours.

Classify the soil as organic silt or clay, O, if the liquid limit after oven drying is less than three fourths of the liquid limit of the original sample determined before drying.

Classify the soil as inorganic silt of low plasticity, ML, or as organic silt of low plasticity, ML, or as organic silt or silt-clay of low plasticity, OL, if the liquid limit is less than 50 and the plot of liquid limit versus plasticity index falls below the “A” line or the plasticity index is less than 4. See area identified as ML and OL on the Plasticity Chart, Table 18-1-A.

Classify the soil as inorganic silt of medium to high plasticity, MH, or as organic clay or silt-clay of medium to high plasticity, OH, if the liquid limit is more than 50 and the plot of liquid limit versus plasticity index falls below the “A” line. See area identified as MH and OH on the Plasticity Chart of Table 18-1-A.

In order to indicate their borderline characteristics, some fine-grained soils should be classified by dual symbols.

If the plot of liquid limit versus plasticity index falls on or practically on the “A” line or above the “A” line where the plasticity index is in the range of 4 to 7, the soil should be given an appropriate borderline classification such as CL-ML or CH-OH.

If the plot of liquid limit versus plasticity index falls on or practically on the line liquid limit = 50, the soil should be given an appropriate borderline classification such as CL-CH or ML-MH. (In doubtful cases the rule for classification is to favor the more plastic classification. Example: a fine-grained soil with a liquid limit of 50 and a plasticity index of 22 would be classified as CH-MH rather than CL-ML.)

TABLE 18-1-A—SOIL CLASSIFICATION CHART

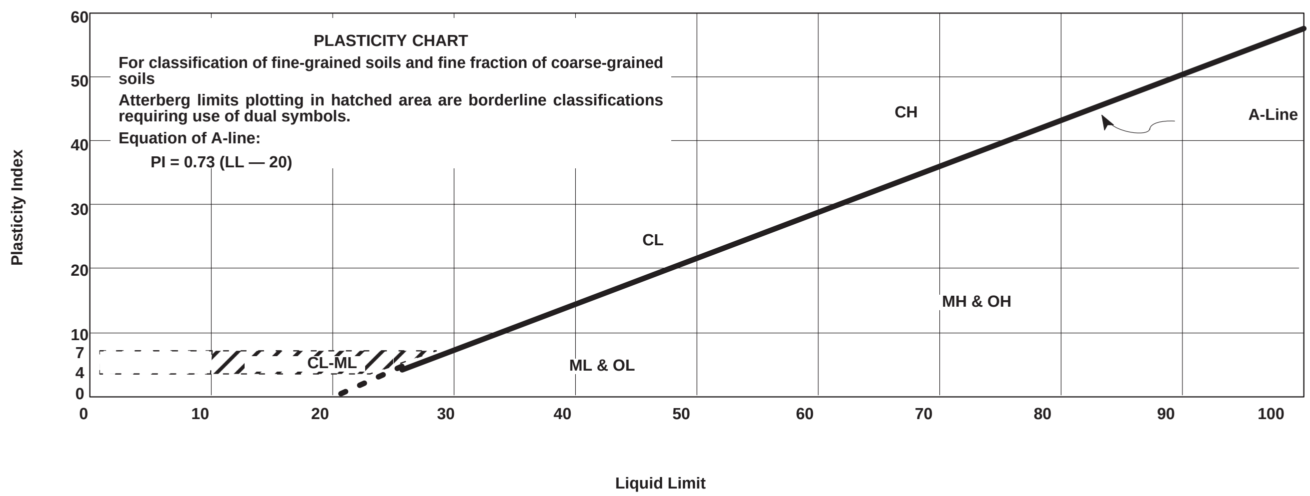
	MAJOR DIVISIONS		GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS More than 50% retained on No. 200 (75 µm) sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 (4.75 mm) sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 (4.75 mm) sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly and sands, little or no fines
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS 50% or more passes No. 200 (75 µm) sieve[1]	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
	Highly Organic Soils		PT	Peat, muck and other highly organic soils

[1]Based on the material passing the 3-inch (76 mm) sieve.

TABLE 18-1-A—SOIL CLASSIFICATION CHART—(Continued)

CLASSIFICATION CRITERIA

CLASSIFICATION ON BASIS OF PERCENTAGE OF FINES		
Less than 5%, Pass No. 200 (75 μm) sieve — GW, GP, SW, SP More than 12% Pass N. 200 (75 μm) sieve — GM, GC, SM, SC 5% to 12% Pass No. 200 (75 μm) sieve — Borderline Classification requiring use of dual symbols	C_u = D_{60}/D_{10} Greater than 4 $C_z = \dfrac{(D_{30})^3}{D_{10} \times D_{60}}$ Between 1 and 3	
	Not meeting both criteria for GW	
	Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
	Atterberg limits plot below "A" line and plasticity index greater than 7	
	C_u = D_{60}/D_{10} Greater than 6 $C_z = \dfrac{(D_{30})^3}{D_{10} \times D_{60}}$ Between 1 and 3	
	Not meeting both criteria for SW	
	Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
	Atterberg limits plot above "A" line and plasticity index greater than 7	



Visual-Manual Identification

UNIFORM BUILDING CODE STANDARD 18-2
EXPANSION INDEX TEST

Based on Recommendations of the Los Angeles Section ASCE Soil Committee

See Sections 1801.2 and 1803.1, *Uniform Building Code*

SECTION 18.201 — SCOPE

The expansion index test is designed to measure a basic index property of the soil and in this respect is comparable to other index tests such as the Atterberg limits. In formulating the test procedures no attempt has been made to duplicate any particular moisture or loading conditions which may occur in the field. Rather, an attempt has been made to control all variables which influence the expansive characteristics of a particular soil and still retain a practical test for general engineering usage.

SECTION 18.202 — APPARATUS

18.202.1 Mold. The mold shall be cylindrical in shape, made of metal and have the capacity and dimensions indicated in Figure 18-2-1. It shall have a detachable collar inscribed with a mark 2.00 inches (50.8 mm) above the base. The lower section of the mold is designed to retain a removable stainless steel ring 1.00 inch (25.4 mm) in height, 4.01-inch (101.85 mm) internal diameter and 0.120-inch (3.048 mm) wall thickness.

18.202.2 Tamper. A metal tamper having a 2-inch-diameter (50.8 mm) circular face and weighing 5.5 pounds (2.5 kg) shall be equipped with a suitable arrangement to control height of drop to a free fall of 12 inches (305 mm) above the top of the soil.

18.202.3 Balance. A balance or scale of at least 1,000-gram capacity sensitive to 0.1 gram.

18.202.4 Drying Oven. A thermostatically controlled drying oven capable of maintaining a temperature of 230°F ± 9°F (110°C ± 5°C), for drying moisture samples.

18.202.5 Straight Edge. Steel straight edge 12 inches (305 mm) in length and having one bevelled edge.

18.202.6 Sieves. A No. 4 (4.75 mm) sieve conforming to the requirements of the specifications for sieves for testing purposes.

18.202.7 Mixing Tools. Miscellaneous tools such as mixing pans, spoons, trowels, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

SECTION 18.203 — SAMPLE PREPARATION

18.203.1 Preparation for Sieving. If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of the individual particles. If particles larger than $^1/_4$ inch (6.4 mm) are possibly expansive, such as claystone, shale or weathered volcanic rock, they should be broken down so as to pass the No. 4 (4.75 mm) sieve.

18.203.2 Sieving. Sieve an adequate quantity of the representative pulverized soil over the No. 4 (4.75 mm) sieve. Record the percentage of coarse material retained on the No. 4 (4.75 mm) sieve and discard.

18.203.3 Sample. Select a representative sample, weighing approximately 2 pounds (0.91 kg) or more, of the soil prepared as described in Sections 18.203.1 and 18.203.2 above.

SECTION 18.204 — SPECIMEN PREPARATION

18.204.1 Moisture Determination. Thoroughly mix the selected representative sample with sufficient distilled water to bring the soil to approximately optimum moisture content. After mixing, take a representative sample of the material for moisture determination and seal the remainder of the soil in a close-fitting airtight container for a period of at least six hours.

Weigh the moisture sample immediately and dry in an oven at 230° ± 9°F (110°C ± 5°C), for at least 12 hours or to a constant weight to determine the moisture content. Moisture sample shall not weigh less than 300 grams.

18.204.2 Specimen Molding. Form a specimen by compacting the cured soil in the 4-inch-diameter (102 mm) mold in two equal layers to give a total compacted depth of approximately 2 inches (51 mm). Compact each layer by 15 uniformly distributed blows of the tamper dropping free from a height of 12 inches (305 mm) above the top of the soil, when a sleeve-type rammer is used, or from 12 inches (305 mm) above the approximate elevation of each finally compacted layer when a stationary mounted type of tamper is used. During the compaction the mold shall rest on a uniform, rigid foundation, such as provided by a cube of concrete weighing at least 200 pounds (90.72 kg).

18.204.3 Trim Specimen. Following compaction, remove the upper and lower portions of the mold from the inner ring and carefully trim the top and bottom of the ring by means of the straight edge.

18.204.4 Saturation. Weigh the compacted sample and determine the percent saturation. Adjust the moisture content to achieve 50 percent saturation by the addition of water or air drying the sample. Repeat Sections 18.204.2 and 18.204.3 above.

18.204.5 Specific Gravity. Repeat Section 18.204.4 until the saturation of the compacted sample is between 49 percent and 51 percent for a specific gravity of 2.7.

SECTION 18.205 — EXPANSION MEASUREMENT

18.205.1 Consolidometer. Place the soil specimen in a consolidometer or equivalent loading device with porous stones at the top and bottom. Place on the specimen a total load of 12.63 pounds (56.2 N), including the weight of the upper porous stone and any unbalanced weight of the loading machine. Allow the specimen to consolidate under this load for a period of 10 minutes, after which time make the initial reading on the consolidometer dial indicator to an accuracy of 0.0005 inch (0.010 mm).

18.205.2 Sample Submersion. Submerge the sample in distilled water, making periodic readings on the dial indicator for a period of 24 hours or until the rate of expansion becomes less than 0.0002 inch (0.0051 mm) per hour but not less than three hours submerged time.

18.205.3 Weighing. Remove the sample from the loading machine after the final reading and weigh the specimen to the nearest 0.1 gram.

SECTION 18.206 — CALCULATIONS AND REPORT

18.206.1 Expansion Index. Calculate the expansion index as follows:

$$E.I. = \frac{\text{(final thickness} - \text{initial thickness)}}{\text{initial thickness}} \times 1{,}000$$

Report the expansion index to the nearest whole number. If the initial sample thickness is greater than the final sample thickness, report the expansion index as 0. The molding moisture content and initial dry density of the specimen should accompany the expansion index in the complete presentation of results.

18.206.2 Weighted Expansion Index. The weighted expansion index for a particular soil profile shall be determined as the summation of the products obtained by multiplying the expansion index by the factor appropriate to its elevation.

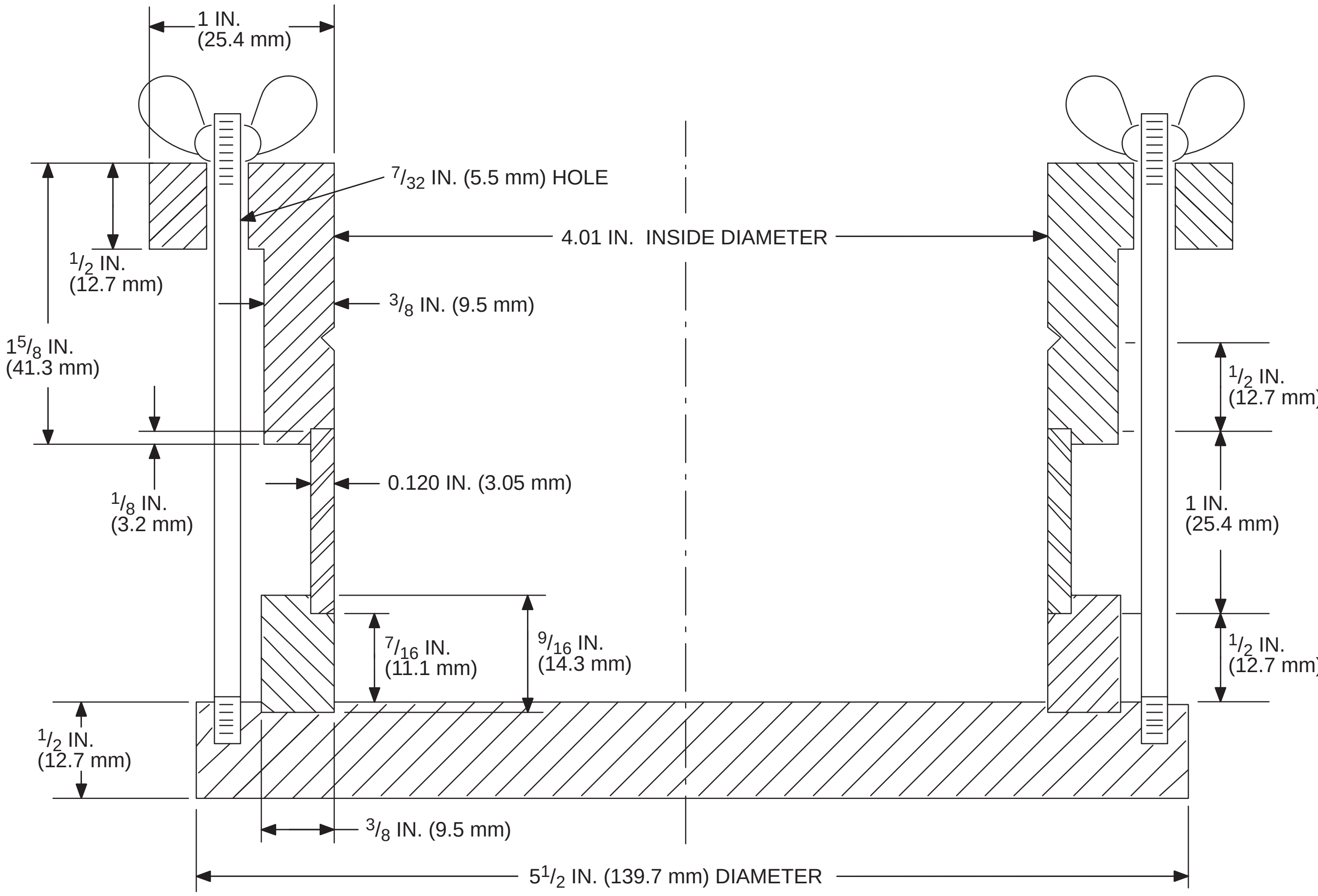


FIGURE 18-2-1—EXPANSION TEST MOLD

Chapter 19
CONCRETE
NOTE: This is a new division.

Division I — GENERAL

SECTION 1900 — GENERAL

1900.1 Scope. The design of concrete structures of cast-in-place or precast construction, plain, reinforced or prestressed shall conform to the rules and principles specified in this chapter.

1900.2 General Requirements. All concrete structures shall be designed and constructed in accordance with the requirements of Division II and the additional requirements contained in Section 1900.4 of this division.

1900.3 Design Methods. The design of concrete structures shall be in accordance with one of the following methods.

1900.3.1 Strength design (load and resistance factor design). The design of concrete structures using the strength design method shall be in accordance with the requirements of Division II.

1900.3.2 Allowable stress design. The design of concrete structures using the Allowable Stress Design Method shall be in accordance with the requirements of Division VI, Section 1926.

1900.4 Additional Design and Construction Requirements.

1900.4.1 Anchorage. Anchorage of bolts and headed stud anchors to concrete shall be in accordance with Division III.

1900.4.2 Shotcrete. In addition to the requirements of Division II, design and construction of shotcrete structures shall meet the requirements of Division IV.

1900.4.3 Reinforced gypsum concrete. Reinforced gypsum concrete shall be in accordance with Division V.

1900.4.4 Minimum slab thickness. The minimum thickness of concrete floor slabs supported directly on the ground shall not be less than $3^1/_2$ inches (89 mm).

1900.4.5 Unified design provisions for reinforced and prestressed concrete flexural and compression members. It shall be permitted to use the alternate flexural and axial load design provisions in accordance with Division VII, Section 1927.

1900.4.6 Alternative load-factor combination and strength-reduction factors. It shall be permitted to use the alternative load-factor and strength-reduction factors in accordance with Division VIII, Section 1928.

Division II

The contents of this division are patterned after, and in general conformity with, the provisions of Building Code Requirements for Reinforced Concrete (ACI 318-95) and commentary—ACI 318 R-95. For additional background information and research data, see the referenced American Concrete Institute (ACI) publication.

To make reference to the ACI commentary easier for users of the code, the section designations of this division have been made similar to those found in ACI 318. The first two digits of a section number indicates this chapter number and the balance matches the ACI chapter and section designation wherever possible. Italics are used in this chapter to indicate where the *Uniform Building Code* differs substantively from the ACI standard.

SECTION 1901 — SCOPE

The design of structures in concrete of cast-in-place or precast construction, plain, reinforced or prestressed, shall conform to the rules and principles specified in this chapter.

SECTION 1902 — DEFINITIONS

The following terms are defined for general use in this code. Specialized definitions appear in individual *sections.*

ADMIXTURE is material other than water, aggregate, or hydraulic cement used as an ingredient of concrete and added to concrete before or during its mixing to modify its properties.

AGGREGATE is granular material, such as sand, gravel, crushed stone and iron blast-furnace slag, and when used with a cementing medium forms a hydraulic cement concrete or mortar.

AGGREGATE, LIGHTWEIGHT, is aggregate with a dry, loose weight of 70 pounds per cubic foot (pcf) (1120 kg/m^3) or less.

AIR-DRY WEIGHT *is the unit weight of a lightweight concrete specimen cured for seven days with neither loss nor gain of moisture at 60°F to 80°F (15.6°C to 26.7°C) and dried for 21 days in 50 ± 7 percent relative humidity at 73.4°F ± 2°F (23.0°C ± 1.1°C).*

ANCHORAGE in posttensioning is a device used to anchor tendons to concrete member; in pretensioning, a device used to anchor tendons during hardening of concrete.

BONDED TENDON is a prestressing tendon that is bonded to concrete either directly or through grouting.

CEMENTITIOUS MATERIALS are materials as specified in Section 1903 which have cementing value when used in concrete either by themselves, such as portland cement, blended hydraulic cements and expansive cement, or such materials in combination with fly ash, raw or other calcined natural pozzolans, silica fume, or ground granulated blast-furnace slag.

COLUMN is a member with a ratio of height-to-least-lateral dimension of 3 or greater used primarily to support axial compressive load.

COMPOSITE CONCRETE FLEXURAL MEMBERS are concrete flexural members of precast and cast-in-place concrete elements or both constructed in separate placements but so interconnected that all elements respond to loads as a unit.

COMPRESSION-CONTROLLED SECTION is a cross section in which the net tensile strain in the extreme tension steel at nominal strength is less than or equal to the compression-controlled strain limit.

COMPRESSION-CONTROLLED STRAIN LIMIT is the net tensile strain at balanced strain conditions. (See *Section* B1910.3.2.)

CONCRETE is a mixture of portland cement or any other hydraulic cement, fine aggregate, coarse aggregate and water, with or without admixtures.

CONCRETE, SPECIFIED COMPRESSIVE STRENGTH OF (f'_c), is the compressive strength of concrete used in design and evaluated in accordance with provisions of Section 1905, expressed in pounds per square inch (psi) (MPa). Whenever the quantity f'_c is under a radical sign, square root of numerical value only is intended, and result has units of psi (MPa).

CONCRETE, STRUCTURAL LIGHTWEIGHT, is concrete containing lightweight aggregate having an air-dry unit weight as determined by definition above, not exceeding 115 pcf (1840 kg/m^3). In this code, a lightweight concrete without natural sand is termed ‘‘all-lightweight concrete’’ and lightweight concrete in which all fine aggregate consists of normal-weight sand is termed “sand-lightweight concrete.’’

CONTRACTION JOINT is a formed, sawed, or tooled groove in a concrete structure to create a weakened plane and regulate the location of cracking resulting from the dimensional change of different parts of the structure.

CURVATURE FRICTION is friction resulting from bends or curves in the specified prestressing tendon profile.

DEFORMED REINFORCEMENT is deformed reinforcing bars, bar and rod mats, deformed wire, welded smooth wire fabric and welded deformed wire fabric.

DEVELOPMENT LENGTH is the length of embedded reinforcement required to develop the design strength of reinforcement at a critical section. See Section 1909.3.3.

EFFECTIVE DEPTH OF SECTION ***(d)*** is the distance measured from extreme compression fiber to centroid of tension reinforcement.

EFFECTIVE PRESTRESS is the stress remaining in prestressing tendons after all losses have occurred, excluding effects of dead load and superimposed load.

EMBEDMENT LENGTH is the length of embedded reinforcement provided beyond a critical section.

EXTREME TENSION STEEL is the reinforcement (prestressed or nonprestressed) that is the farthest from the extreme compression fiber.

ISOLATION JOINT is a separation between adjoining parts of a concrete structure, usually a vertical plane, at a designed location such as to interfere least with performance of the structure, yet such as to allow relative movement in three directions and avoid formation of cracks elsewhere in the concrete and through which all or part of the bonded reinforcement is interrupted.

JACKING FORCE is the temporary force exerted by device that introduces tension into prestressing tendons in prestressed concrete.

LOAD, DEAD, is the dead weight supported by a member, as defined by *Section 1602* (without load factors).

LOAD, FACTORED, is the load, multiplied by appropriate load factors, used to proportion members by the strength design method of this code. See Sections 1908.1.1 and 1909.2.

LOAD, LIVE, *is the live load specified by Section 1602* (without load factors).

LOAD, SERVICE, *is the live and dead loads* (without load factors).

MODULUS OF ELASTICITY is the ratio of normal stress to corresponding strain for tensile or compressive stresses below proportional limit of material. See Section 1908.5.

NET TENSILE STRAIN is the tensile strain at nominal strength exclusive of strains due to effective prestress, creep, shrinkage and temperature.

PEDESTAL is an upright compression member with a ratio of unsupported height to average least lateral dimension of 3 or less.

PLAIN CONCRETE is structural concrete with no reinforcement or with less reinforcement than the minimum amount specified for reinforced concrete.

PLAIN REINFORCEMENT is reinforcement that does not conform to definition of deformed reinforcement.

POSTTENSIONING is a method of prestressing in which tendons are tensioned after concrete has hardened.

PRECAST CONCRETE is a structural concrete element cast in other than its final position in the structure.

PRESTRESSED CONCRETE is structural concrete in which internal stresses have been introduced to reduce potential tensile stresses in concrete resulting from loads.

PRETENSIONING is a method of prestressing in which tendons are tensioned before concrete is placed.

REINFORCED CONCRETE is structural concrete reinforced with no less than the minimum amounts of prestressing tendons or nonprestressed reinforcement specified in this code.

REINFORCEMENT is material that conforms to Section 1903.5.1, excluding prestressing tendons unless specifically included.

RESHORES are shores placed snugly under a concrete slab or other structural member after the original forms and shores have been removed from a larger area, thus requiring the new slab or structural member to deflect and support its own weight and existing construction loads applied prior to the installation of the reshores.

SHORES are vertical or inclined support members designed to carry the weight of the formwork, concrete and construction loads above.

SPAN LENGTH. See Section 1908.7.

SPIRAL REINFORCEMENT is continuously wound reinforcement in the form of a cylindrical helix.

SPLITTING TENSILE STRENGTH (f_{ct}) is the tensile strength of concrete. See Section 1905.1.4.

STIRRUP is reinforcement used to resist shear and torsion stresses in a structural member; typically bars, wires, or welded wire fabric (smooth or deformed) bent into L, U or rectangular shapes and located perpendicular to or at an angle to longitudinal reinforcement. (The term “stirrups’’ is usually applied to lateral reinforcement in flexural members and the term ‘‘ties’’ to those in compression members.) See “tie.”

STRENGTH, DESIGN, is the nominal strength multiplied by a strength-reduction factor ϕ. See Section 1909.3.

STRENGTH, NOMINAL, is the strength of a member or cross section calculated in accordance with provisions and assumptions of the strength design method of this code before application of any strength-reduction factors. See Section 1909.3.1.

STRENGTH, REQUIRED, is the strength of a member or cross section required to resist factored loads or related internal moments and forces in such combinations as are stipulated in this code. See Section 1909.1.1.

STRESS is the intensity of force per unit area.

STRUCTURAL CONCRETE is all concrete used for structural purposes, including plain and reinforced concrete.

TENDON is a steel element such as wire, cable, bar, rod or strand, or a bundle of such elements, used to impart prestress to concrete.

TENSION-CONTROLLED SECTION is a cross section in which the net tensile strain in the extreme tension steel at nominal strength is greater than or equal to 0.005.

TIE is a loop of reinforcing bar or wire enclosing longitudinal reinforcement. A continuously wound bar or wire in the form of a circle, rectangle or other polygon shape without re-entrant corners is acceptable. See “stirrup.”

TRANSFER is the act of transferring stress in prestressing tendons from jacks or pretensioning bed to concrete member.

WALL is a member, usually vertical, used to enclose or separate spaces.

WOBBLE FRICTION in prestressed concrete, is friction caused by unintended deviation of prestressing sheath or duct from its specified profile.

YIELD STRENGTH is the specified minimum yield strength or yield point of reinforcement in psi.

SECTION 1903 — SPECIFICATIONS FOR TESTS AND MATERIALS

1903.0 Notation.

f_y = specified yield strength of nonprestressed reinforcement, psi (MPa).

1903.1 Tests of Materials.

1903.1.1 The building official may require the testing of any materials used in concrete construction to determine if materials are of quality specified.

1903.1.2 Tests of materials and of concrete shall be made *by an approved agency and at no expense to the jurisdiction. Such tests shall be made in accordance with the standards listed in Section 1903.*

1903.1.3 A complete record of tests of materials and of concrete shall be available for inspection during progress of work and for two years after completion of the project, and shall be preserved by the inspecting engineer or architect for that purpose.

1903.1.4 Material and test standards. *The standards listed in this chapter labeled a “UBC Standard” are also listed in Chapter 35, Part II, and are part of this code. The other standards listed in this chapter are recognized standards. (See Sections 3503 and 3504.)*

1903.2 Cement.

1. ASTM C 845, Expansive Hydraulic Cement
2. ASTM C 150, Portland Cement
3. ASTM C 595 or ASTM C 1157, Blended Hydraulic Cements

1903.3 Aggregates.

1903.3.1 Recognized standards.

1. ASTM C 33, Concrete Aggregates

2. ASTM C 330, Lightweight Aggregates for Structural Concrete

3. ASTM C 332, Lightweight Aggregates for Insulating Concrete

4. ASTM C 144, Aggregate for Masonry Mortar

5. Aggregates failing to meet the above specifications but which have been shown by special test or actual service to produce concrete of adequate strength and durability may be used where authorized by the building official.

1903.3.2 The nominal maximum size of coarse aggregate shall not be larger than:

1. One fifth the narrowest dimension between sides of forms, or
2. One third the depth of slabs, or
3. Three fourths the minimum clear spacing between individual reinforcing bars or wires, bundles of bars, or prestressing tendons or ducts.

These limitations may be waived if, in the judgment of the *building official,* workability and methods of consolidation are such that concrete can be placed without honeycomb or voids.

1903.4 Water.

1903.4.1 Water used in mixing concrete shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials or other substances deleterious to concrete or reinforcement.

1903.4.2 Mixing water for prestressed concrete or for concrete that will contain aluminum embedments, including that portion of mixing water contributed in the form of free moisture on aggregates, shall not contain deleterious amounts of chloride ions. See Section 1904.4.1.

1903.4.3 Nonpotable water shall not be used in concrete unless the following are satisfied:

1903.4.3.1 Selection of concrete proportions shall be based on concrete mixes using water from the same source.

1903.4.3.2 Mortar test cubes made with nonpotable mixing water shall have seven-day and 28-day strengths equal to at least 90 percent of strengths of similar specimens made with potable water. Strength test comparison shall be made on mortars, identical except for the mixing water, prepared and tested in accordance with ASTM C 109 (Compressive Strength of Hydraulic Cement Mortars).

1903.5 Steel Reinforcement.

1903.5.1 Reinforcement shall be deformed reinforcement, except that plain reinforcement may be used for spirals or tendons, and reinforcement consisting of structural steel, steel pipe or steel tubing may be used as specified in this chapter.

1903.5.2 Welding of reinforcing bars shall conform to *approved nationally recognized standards.* Type and location of welded splices and other required welding of reinforcing bars shall be indicated on the design drawings or in the project specifications. ASTM reinforcing bar specifications, except for A 706, shall be supplemented to require a report of material properties necessary to conform to requirements in UBC Standard 19-1.

1903.5.3 Deformed reinforcements.

1903.5.3.1 ASTM A 615, A 616, A 617, A 706, A 767 and A 775, Reinforcing Bars for Concrete.

1903.5.3.2 Deformed reinforcing bars with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa) may be used, provided f_y shall be the stress corresponding to a strain of 0.35 percent and the bars otherwise conform to approved national standards, see *ASTM A 615, A 616, A 617, A 706, A 767 and A 775.* See Section 1909.4.

1903.5.3.3 ASTM A 184, Fabricated Deformed Steel Bar Mats. For reinforced bars used in bar mats, see ASTM A 615, A 616, A 617, A 706, A 767 or A 775.

1903.5.3.4 ASTM A 496, Steel Wire, Deformed, for Concrete Reinforcement.

For deformed wire for concrete reinforcement, see *ASTM A 496,* except that wire shall not be smaller than size D4, and for wire with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa), f_y shall be the stress corresponding to a strain of 0.35 percent, if the yield strength specified in design exceeds 60,000 psi (413.7 MPa).

1903.5.3.5 ASTM A 185, Steel Welded Wire, Fabric, Plain for Concrete Reinforcement.

For welded plain wire fabric for concrete reinforcement, see *ASTM 185,* except that for wire with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa), f_y shall be the stress corresponding to a strain of 0.35 percent, if the yield strength specified in design exceeds 60,000 psi (413.7 MPa). Welded intersections shall not be spaced farther apart than 12 inches (305 mm) in direction of calculated stress, except for wire fabric used as stirrups in accordance with Section 1912.14.

1903.5.3.6 ASTM A 497, Welded Deformed Steel Wire Fabric for Concrete Reinforcement.

For welded deformed wire fabric for concrete reinforcement, see *ASTM A 497,* except that for wire with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa), f_y shall be the stress corresponding to a strain of 0.35 percent, if the yield strength specified in design exceeds 60,000 psi (413.7 MPa). Welded intersections shall not be spaced farther apart than 16 inches (406 mm) in direction of calculated stress, except for wire fabric used as stirrups in accordance with Section 1912.13.2.

1903.5.3.7 Deformed reinforcing bars may be galvanized or epoxy coated. For zinc or epoxy-coated reinforcement, see ASTM A 615, A 616, A 617, A 706, A 767 and A 775 and ASTM A 934 *(Epoxy-Coated Steel Reinforcing Bars).*

1903.5.3.8 Epoxy-coated wires and welded wire fabric shall comply with ASTM A 884 (*Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Fabric for Reinforcement*). Epoxy-coated wires shall conform to Section 1903.5.3.4 and epoxy-coated welded wire fabric shall conform to Section 1903.5.3.5 or 1903.5.3.6.

1903.5.4 Plain reinforcement.

1903.5.4.1 Plain bars for spiral reinforcement shall conform to approved national standards, see ASTM *A 615, A 616 and A 617.*

1903.5.4.2 For plain wire for spiral reinforcement, see *ASTM A 82* except that for wire with a specified yield strength f_y exceeding 60,000 psi (413.7 MPa), f_y shall be the stress corresponding to a strain of 0.35 percent, if the yield strength specified in design exceeds 60,000 psi (413.7 MPa).

1903.5.5 Prestressing tendons.

1903.5.5.1 1. ASTM A 416, Uncoated Seven-wire Stress-relieved Steel Strand for Prestressed Concrete

2. ASTM A 421, Uncoated Stress-relieved Wire for Prestressed Concrete

3. ASTM A 722, Uncoated High-strength Steel Bar for Prestressing Concrete

1903.5.5.2 Wire, strands and bars not specifically listed in *ASTM A 416, A 421 and A 722* may be used, provided they conform to minimum requirements of these specifications and do not have properties that make them less satisfactory than those listed.

1903.5.6 Structural steel, steel pipe or tubing.

1903.5.6.1 For structural steel used with reinforcing bars in composite compression members meeting requirements of Section 1910.16.7 or 1910.16.8, see *ASTM A 36, A 242, A 572 and A 588.*

1903.5.6.2 For steel pipe or tubing for composite compression members composed of a steel-encased concrete core meeting requirements of Section 1910.16.4, see *ASTM A 53, A 500 and A 501.*

1903.5.7 *UBC Standard 19-1, Welding Reinforcing Steel, Metal Inserts and Connections in Reinforced Concrete Construction*

1903.6 Admixtures.

1903.6.1 Admixtures to be used in concrete shall be subject to prior approval by the *building official.*

1903.6.2 An admixture shall be shown capable of maintaining essentially the same composition and performance throughout the work as the product used in establishing concrete proportions in accordance with Section 1905.2.

1903.6.3 Calcium chloride or admixtures containing chloride from other than impurities from admixture ingredients shall not be used in prestressed concrete, in concrete containing embedded aluminum, or in concrete cast against stay-in-place galvanized steel forms. See Sections 1904.3.2 and 1904.4.1.

1903.6.4 ASTM C 260, Air-entraining Admixtures for Concrete

1903.6.5 ASTM C 494 and C 1017, Chemical Admixtures for Concrete

1903.6.6 ASTM C 618, Fly Ash and Raw or Calcined Natural Pozzolans for Use as Admixtures in Portland Cement Concrete

1903.6.7 ASTM C 989, Ground-iron Blast-furnace Slag for Use in Concrete and Mortars

1903.6.8 Admixtures used in concrete containing ASTM C 845 expansive cements shall be compatible with the cement and produce no deleterious effects.

1903.6.9 Silica fume used as an admixture shall conform to ASTM C 1240 (*Silica Fume for Use in Hydraulic Cement Concrete and Mortar*).

1903.7 Storage of Materials.

1903.7.1 Cementitious materials and aggregate shall be stored in such manner as to prevent deterioration or intrusion of foreign matter.

1903.7.2 Any material that has deteriorated or has been contaminated shall not be used for concrete.

1903.8 Concrete Testing.

1. ASTM C 192, Making and Curing Concrete Test Specimens in the Laboratory

2. ASTM C 31, Making and Curing Concrete Test Specimens in the Field

3. ASTM C 42, Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

4. ASTM C 39, Compressive Strength of Cylindrical Concrete Specimens

5. ASTM C 172, Sampling Freshly Mixed Concrete

6. ASTM C 496, Splitting Tensile Strength of Cylindrical Concrete Specimens

7. ASTM C 1218, Water-Soluble Chloride in Mortar and Concrete

1903.9 Concrete Mix.

1. ASTM C 94, Ready-mixed Concrete

2. ASTM C 685, Concrete Made by Volumetric Batching and Continuous Mixing

3. UBC Standard 19-2, Mill-mixed Gypsum Concrete and Poured Gypsum Roof Diaphragms

4. ASTM C 109, Compressive Strength of Hydraulic Cement Mortars

5. ASTM C 567, Unit Weight of Structural Lightweight Concrete

1903.10 Welding. *The welding of reinforcing steel, metal inserts and connections in reinforced concrete construction shall conform to UBC Standard 19-1.*

1903.11 Glass Fiber Reinforced Concrete. Recommended Practice for Glass Fiber Reinforced Concrete Panels, Manual 128.

SECTION 1904 — DURABILITY REQUIREMENTS

1904.0 Notation.

f'_c = specified compressive strength of concrete, psi (MPa).

1904.1 Water-Cementitious Materials Ratio.

1904.1.1 The water-cementitious materials ratios specified in Tables 19-A-2 and 19-A-4 shall be calculated using the weight of cement meeting ASTM C 150, C 595 or C 845 plus the weight of fly ash and other pozzolans meeting ASTM C 618, slag meeting ASTM C 989, and silica fume meeting ASTM C 1240, if any, except that when concrete is exposed to deicing chemicals, Section 1904.2.3 further limits the amount of fly ash, pozzolans, silica fume, slag or the combination of these materials.

1904.2 Freezing and Thawing Exposures.

1904.2.1 Normal-weight and lightweight concrete exposed to freezing and thawing or deicing chemicals shall be air entrained with air content indicated in Table 19-A-1. Tolerance on air content as delivered shall be ± 1.5 percent. For specified compressive strength f'_c greater than 5,000 psi (34.47 MPa), reduction of air content indicated in Table 19-A-1 by 1.0 percent shall be permitted.

1904.2.2 Concrete that will be subjected to the exposures given in Table 19-A-2 shall conform to the corresponding maximum water-cementitious materials ratios and minimum specified concrete compressive strength requirements of that table. In addition, concrete that will be exposed to deicing chemicals shall conform to the limitations of Section 1904.2.3.

1904.2.3 For concrete exposed to deicing chemicals, the maximum weight of fly ash, other pozzolans, silica fume or slag that is included in the concrete shall not exceed the percentages of the total weight of cementitious materials given in Table 19-A-3.

1904.3 Sulfate Exposure.

1904.3.1 Concrete to be exposed to sulfate-containing solutions or soils shall conform to the requirements of Table 19-A-4 or shall be concrete made with a cement that provides sulfate resistance and that has a maximum water-cementitious materials ratio and minimum compressive strength set forth in Table 19-A-4.

1904.3.2 Calcium chloride as an admixture shall not be used in concrete to be exposed to severe or very severe sulfate-containing solutions, as defined in Table 19-A-4.

1904.4 Corrosion Protection of Reinforcement.

1904.4.1 For corrosion protection of reinforcement in concrete, maximum water soluble chloride ion concentrations in hardened concrete at ages from 28 to 42 days contributed from the ingredients, including water, aggregates, cementitious materials and admixtures shall not exceed the limits of Table 19-A-5. When testing is performed to determine water soluble chloride ion content, test procedures shall conform to ASTM C 1218.

1904.4.2 If concrete with reinforcement will be exposed to chlorides from deicing chemicals, salt, salt water, brackish water, sea water or spray from these sources, requirements of Table 19-A-2 for water-cementitious materials ratio and concrete strength and the minimum concrete cover requirements of Section 1907.7 shall be satisfied. In addition, see Section 1918.14 for unbonded prestressed tendons.

SECTION 1905 — CONCRETE QUALITY, MIXING AND PLACING

1905.0 Notations.

f'_c = specified compressive strength of concrete, psi (MPa).

f'_{cr} = required average compressive strength of concrete used as the basis for selection of concrete proportions, psi (MPa).

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, psi (MPa).

s = standard deviation, psi (MPa).

1905.1 General.

1905.1.1 Concrete shall be proportioned to provide an average compressive strength as prescribed in Section 1905.3.2, as well as satisfy the durability criteria of Section 1904. Concrete shall be produced to minimize frequency of strengths below f'_c as prescribed in Section 1905.6.2.3.

1905.1.2 Requirements for f'_c shall be based on tests of cylinders made and tested as prescribed in Section 1905.6.2.

1905.1.3 Unless otherwise specified, f'_c shall be based on 28-day tests. If other than 28 days, test age for f'_c shall be as indicated in design drawings or specifications.

Design drawings shall show specified compressive strength of concrete f'_c for which each part of structure is designed.

1905.1.4 Where design criteria in Sections 1909.5.2.3, 1911.2; and 1912.2.4, provide for use of a splitting tensile strength value of concrete, laboratory tests shall be made to establish value of f_{ct} corresponding to specified values of f'_c.

1905.1.5 Splitting tensile strength tests shall not be used as a basis for field acceptance of concrete.

1905.2 Selection of Concrete Proportions.

1905.2.1 Proportions of materials for concrete shall be established to provide:

1. Workability and consistency to permit concrete to be worked readily into forms and around reinforcement under conditions of placement to be employed without segregation or excessive bleeding.

2. Resistance to special exposures as required by Section 1904.

3. Conformance with strength test requirements of Section 1905.6.

1905.2.2 Where different materials are to be used for different portions of proposed work, each combination shall be evaluated.

1905.2.3 Concrete proportions, including water-cementitious materials ratio, shall be established on the basis of field experience and/or trial mixtures with materials to be employed (see Section 1905.3), except as permitted in Section 1905.4 or required by Section 1904.

1905.3 Proportioning on the Basis of Field Experience and Trial Mixtures.

1905.3.1 Standard deviation.

1905.3.1.1 Where a concrete production facility has test records, a standard deviation shall be established. Test records from which a standard deviation is calculated:

1. Must represent materials, quality control procedures and conditions similar to those expected, and changes in materials and proportions within the test records shall not have been more restricted than those for proposed work.

2. Must represent concrete produced to meet a specified strength or strengths f'_c within 1,000 psi (6.89 MPa) of that specified for proposed work.

3. Must consist of at least 30 consecutive tests or two groups of consecutive tests totaling at least 30 tests as defined in Section 1905.6.1.4, except as provided in Section 1905.3.1.2.

1905.3.1.2 Where a concrete production facility does not have test records meeting requirements of Section 1905.3.1.1, but does have a record based on 15 to 29 consecutive tests, a standard deviation may be established as the product of the calculated standard deviation and the modification factor of Table 19-A-6. To be acceptable, the test record must meet the requirements of Section 1905.3.1.1, Items 1 and 2, and represent only a single record of consecutive tests that span a period of not less than 45 calendar days.

1905.3.2 Required average strength.

1905.3.2.1 Required average compressive strength f'_{cr} used as the basis for selection of concrete proportions shall be the larger of Formula (5-1) or (5-2) using a standard deviation calculated in accordance with Section 1905.3.1.1 or 1905.3.1.2.

$$f'_{cr} = f'_c + 1.34s \tag{5-1}$$

or

$$f'_{cr} = f'_c + 2.33s - 500 \tag{5-2}$$

For **SI:** $f'_{cr} = f'_c + 2.33s - 3.45$

1905.3.2.2 When a concrete production facility does not have field strength test records for calculation of standard deviation meeting requirements of Section 1905.3.1.1 or 1905.3.1.2, required average strength f'_{cr} shall be determined from Table 19-B and documentation of average strength shall be in accordance with requirements of Section 1905.3.3.

1905.3.3 Documentation of average strength. Documentation that proposed concrete proportions will produce an average compressive strength equal to or greater than required average compressive strength (see Section 1905.3.2) shall consist of a field strength test record, several strength test records, or trial mixtures.

1905.3.3.1 When test records are used to demonstrate that proposed concrete proportions will produce the required average strength f'_{cr} (see Section 1905.3.2), such records shall represent materials and conditions similar to those expected. Changes in materials, conditions and proportions within the test records shall not have been more restricted than those for proposed work. For the purpose of documenting average strength potential, test records consisting of less than 30 but not less than 10 consecutive tests may be used, provided test records encompass a period of time not less than 45 days. Required concrete proportions may be established by interpolation between the strengths and proportions of two or more test records each of which meets other requirements of this section.

1905.3.3.2 When an acceptable record of field test results is not available, concrete proportions established from trial mixtures meeting the following restrictions shall be permitted:

1. Combination of materials shall be those for proposed work.
2. Trial mixtures having proportions and consistencies required for proposed work shall be made using at least three different water-cementitious materials ratios or cementitious materials contents that will produce a range of strengths encompassing the required average strength f'_{cr}.
3. Trial mixture shall be designed to produce a slump within $\pm$ 0.75 inch ($\pm$ 19 mm) of maximum permitted, and for air-entrained concrete, within $\pm$ 0.5 percent of maximum allowable air content.
4. For each water-cementitious materials ratio or cementitious materials content, at least three test cylinders for each test age shall be made and cured. Cylinders shall be tested at 28 days or at test age designated for determination of f'_c.
5. From results of cylinder tests, a curve shall be plotted showing relationship between water-cementitious materials ratio or cementitious materials content and compressive strength at designated test age.
6. Maximum water-cementitious materials ratio or minimum cementitious materials content for concrete to be used in proposed work shall be that shown by the curve to produce the average strength required by Section 1905.3.2, unless a lower water-cementitious materials ratio or higher strength is required by Section 1904.

1905.4 Proportioning without Field Experience or Trial Mixtures.

1905.4.1 If data required by Section 1905.3 are not available, concrete proportions shall be based upon other experience or information, if approved by the building official. The required average compressive strength f'_{cr} of concrete produced with materials similar to those proposed for use shall be at least 1,200 psi (8.3 MPa) greater than the specified compressive strength, f'_c. This alternative shall not be used for specified compressive strength greater than 4,000 psi (27.58 MPa).

1905.4.2 Concrete proportioned by Section 1905.4 shall conform to the durability requirements of Section 1904 and to compressive strength test criteria of Section 1905.6.

1905.5 Average Strength Reduction. As data become available during construction, it shall be permitted to reduce the amount by which f'_{cr} must exceed the specified value of f'_c, provided:

1. Thirty or more test results are available and average of test results exceeds that required by Section 1905.3.2.1, using a standard deviation calculated in accordance with Section 1905.3.1.1, or
2. Fifteen to 29 test results are available and average of test results exceeds that required by Section 1905.3.2.1, using a standard deviation calculated in accordance with Section 1905.3.1.2, and
3. Special exposure requirements of Section 1904 are met.

1905.6 Evaluation and Acceptance of Concrete.

1905.6.1 Frequency of testing.

1905.6.1.1 Samples for strength tests of each class of concrete placed each day shall be taken not less than once a day, or not less than once for each 150 cubic yards (115 m^3) of concrete, or not less than once for each 5,000 square feet (465 m^2) of surface area for slabs or walls.

1905.6.1.2 On a given project, if the total volume of concrete is such that the frequency of testing required by Section 1905.6.1.1 would provide less than five strength tests for a given class of concrete, tests shall be made from at least five randomly selected batches or from each batch if fewer than five batches are used.

1905.6.1.3 When total quantity of a given class of concrete is less than 50 cubic yards (38 m^3), strength tests are not required when evidence of satisfactory strength is submitted to and approved by the building official.

1905.6.1.4 A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days or at test age designated for determination of f'_c.

1905.6.2 Laboratory-cured specimens.

1905.6.2.1 Samples for strength tests shall be taken.

1905.6.2.2 Cylinders for strength tests shall be molded and laboratory cured and tested.

1905.6.2.3 Strength level of an individual class of concrete shall be considered satisfactory if both the following requirements are met:

1. Every arithmetic average of any three consecutive strength tests equals or exceeds f'_c.
2. No individual strength test (average of two cylinders) falls below f'_c by more than 500 psi (3.45 MPa).

1905.6.2.4 If either of the requirements of Section 1905.6.2.3 are not met, steps shall be taken to increase the average of subsequent strength test results. Requirements of Section 1905.6.4 shall be observed if the requirement of Item 2 of Section 1905.6.2.3 is not met.

1905.6.3 Field-cured specimens.

1905.6.3.1 If required by the building official, results of strength tests of cylinders cured under field conditions shall be provided.

1905.6.3.2 Field-cured cylinders shall be cured under field conditions, in accordance with Section 1903.8.

1905.6.3.3 Field-cured test cylinders shall be molded at the same time and from the same samples as laboratory-cured test cylinders.

1905.6.3.4 Procedures for protecting and curing concrete shall be improved when strength of field-cured cylinders at test age designated for determination of f'_c is less than 85 percent of that of companion laboratory-cured cylinders. The 85 percent limitation shall not apply if field-cured strength exceeds f'_c by more than 500 psi (3.45 MPa).

1905.6.4 Investigation of low-strength test results.

1905.6.4.1 If any strength test (see Section 1905.6.1.4) of laboratory-cured cylinders falls below specified values of f'_c by more than 500 psi (3.45 MPa) (see Section 1905.6.2.3, Item 2) or if tests of field-cured cylinders indicate deficiencies in protection and curing (see Section 1905.6.3.4), steps shall be taken to ensure that load-carrying capacity of the structure is not jeopardized.

1905.6.4.2 If the likelihood of low-strength concrete is confirmed and calculations indicate that load-carrying capacity is significantly reduced, tests of cores drilled from the area in question shall be permitted. In such case, three cores shall be taken for each strength test more than 500 psi (3.45 MPa) below specified value of f'_c.

1905.6.4.3 If concrete in the structure will be dry under service conditions, cores shall be air dried [temperatures 60°F to 80°F (15.6°C to 26.7°C), relative humidity less than 60 percent] for seven days before test and shall be tested dry. If concrete in the structure will be more than superficially wet under service conditions, cores shall be immersed in water for at least 40 hours and be tested wet.

1905.6.4.4 Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equal to at least 85 percent of f'_c and if no single core is less than 75 percent of f'_c. Additional testing of cores extracted from locations represented by erratic core strength results shall be permitted.

1905.6.4.5 If criteria of Section 1905.6.4.4 are not met, and if structural adequacy remains in doubt, the responsible authority shall be permitted to order a strength evaluation in accordance with Section 1920 for the questionable portion of the structure, or take other appropriate action.

1905.7 Preparation of Equipment and Place of Deposit.

1905.7.1 Preparation before concrete placement shall include the following:

1. All equipment for mixing and transporting concrete shall be clean.

2. All debris and ice shall be removed from spaces to be occupied by concrete.

3. Forms shall be properly coated.

4. Masonry filler units that will be in contact with concrete shall be well drenched.

5. Reinforcement shall be thoroughly clean of ice or other deleterious coatings.

6. Water shall be removed from place of deposit before concrete is placed unless a tremie is to be used or unless otherwise permitted by the building official.

7. All laitance and other unsound material shall be removed before additional concrete is placed against hardened concrete.

1905.8 Mixing.

1905.8.1 All concrete shall be mixed until there is a uniform distribution of materials and shall be discharged completely before mixer is recharged.

1905.8.2 Ready-mixed concrete shall be mixed and delivered in accordance with requirements of *ASTM C 94 (Ready-Mixed Concrete) or ASTM C 685 (Concrete Made by Volumetric Batching and Continuous Mixing).*

1905.8.3 Job-mixed concrete shall be mixed in accordance with the following:

1. Mixing shall be done in a batch mixer of an approved type.

2. Mixer shall be rotated at a speed recommended by the manufacturer.

3. Mixing shall be continued for at least $1^1/_2$ minutes after all materials are in the drum, unless a shorter time is shown to be satisfactory by the mixing uniformity tests of *ASTM C 94 (Ready-Mixed Concrete).*

4. Materials handling, batching and mixing shall conform to applicable provisions of *ASTM C 94 (Ready-Mixed Concrete).*

5. A detailed record shall be kept to identify:

5.1 Number of batches produced;

5.2 Proportions of materials used;

5.3 Approximate location of final deposit in structure;

5.4 Time and date of mixing and placing.

1905.9 Conveying.

1905.9.1 Concrete shall be conveyed from mixer to place of final deposit by methods that will prevent separation or loss of materials.

1905.9.2 Conveying equipment shall be capable of providing a supply of concrete at site of placement without separation of ingredients and without interruptions sufficient to permit loss of plasticity between successive increments.

1905.10 Depositing.

1905.10.1 Concrete shall be deposited as nearly as practicable in its final position to avoid segregation due to rehandling or flowing.

1905.10.2 Concreting shall be carried on at such a rate that concrete is at all times plastic and flows readily into spaces between reinforcement.

1905.10.3 Concrete that has partially hardened or been contaminated by foreign materials shall not be deposited in the structure.

1905.10.4 Retempered concrete or concrete that has been remixed after initial set shall not be used unless approved by the *building official.*

1905.10.5 After concreting is started, it shall be carried on as a continuous operation until placing of a panel or section, as defined by its boundaries or predetermined joints, is completed, except as permitted or prohibited by Section 1906.4.

1905.10.6 Top surfaces of vertically formed lifts shall be generally level.

1905.10.7 When construction joints are required, joints shall be made in accordance with Section 1906.4.

1905.10.8 All concrete shall be thoroughly consolidated by suitable means during placement and shall be thoroughly worked around reinforcement and embedded fixtures and into corners of forms.

1905.11 Curing.

1905.11.1 Concrete (other than high-early-strength) shall be maintained above 50°F (10.0°C) and in a moist condition for at least the first seven days after placement, except when cured in accordance with Section 1905.11.3.

1905.11.2 High-early-strength concrete shall be maintained above 50°F (10.0°C) and in a moist condition for at least the first three days, except when cured in accordance with Section 1905.11.3.

1905.11.3 Accelerated curing.

1905.11.3.1 Curing by high-pressure steam, steam at atmospheric pressure, heat and moisture or other accepted processes, may be employed to accelerate strength gain and reduce time of curing.

1905.11.3.2 Accelerated curing shall provide a compressive strength of the concrete at the load stage considered at least equal to required design strength at that load stage.

1905.11.3.3 Curing process shall be such as to produce concrete with a durability at least equivalent to the curing method of Section 1905.11.1 or 1905.11.2.

1905.11.3.4 When required by the building official, supplementary strength tests in accordance with Section 1905.6.3 shall be performed to assure that curing is satisfactory.

1905.12 Cold Weather Requirements.

1905.12.1 Adequate equipment shall be provided for heating concrete materials and protecting concrete during freezing or near-freezing weather.

1905.12.2 All concrete materials and all reinforcement, forms, fillers and ground with which concrete is to come in contact shall be free from frost.

1905.12.3 Frozen materials or materials containing ice shall not be used.

1905.13 Hot Weather Requirements. During hot weather, proper attention shall be given to ingredients, production methods, handling, placing, protection and curing to prevent excessive concrete temperatures or water evaporation that may impair required strength or serviceability of the member or structure.

SECTION 1906 — FORMWORK, EMBEDDED PIPES AND CONSTRUCTION JOINTS

1906.1 Design of Formwork.

1906.1.1 Forms shall result in a final structure that conforms to shapes, lines and dimensions of the members as required by the design drawings and specifications.

1906.1.2 Forms shall be substantial and sufficiently tight to prevent leakage of mortar.

1906.1.3 Forms shall be properly braced or tied together to maintain position and shape.

1906.1.4 Forms and their supports shall be designed so as not to damage previously placed structure.

1906.1.5 Design of formwork shall include consideration of the following factors:

1. Rate and method of placing concrete.

2. Construction loads, including vertical, horizontal and impact loads.

3. Special form requirements for construction of shells, folded plates, domes, architectural concrete or similar types of elements.

1906.1.6 Forms for prestressed concrete members shall be designed and constructed to permit movement of the member without damage during application of prestressing force.

1906.2 Removal of Forms, Shores and Reshoring.

1906.2.1 Removal of forms. Forms shall be removed in such a manner as not to impair safety and serviceability of the structure. Concrete to be exposed by form removal shall have sufficient strength not to be damaged by removal operation.

1906.2.2 Removal of shores and reshoring. The provisions of Section 1906.2.2.1 through 1906.2.2.3 shall apply to slabs and beams except where cast on the ground.

1906.2.2.1 Before starting construction, the contractor shall develop a procedure and schedule for removal of shores and installation of reshores and for calculating the loads transferred to the structure during the process.

1. The structural analysis and concrete strength data used in planning and implementing form removal and shoring shall be furnished by the contractor to the building official when so requested.

2. Construction loads shall *not* be supported on, or any shoring removed from, any part of the structure under construction except when that portion of the structure in combination with remaining forming and shoring system has sufficient strength to support safely its weight and loads placed thereon.

3. Sufficient strength shall be demonstrated by structural analysis considering proposed loads, strength of forming and shoring system and concrete strength data. Concrete strength data may be based on tests of field-cured cylinders or, when approved by the building official, on other procedures to evaluate concrete strength.

1906.2.2.2 Construction loads exceeding the combination of superimposed dead load plus specified live load shall *not* be supported on any unshored portion of the structure under construction, unless analysis indicates adequate strength to support such additional loads.

1906.2.2.3 Form supports for prestressed concrete members shall not be removed until sufficient prestressing has been applied to enable prestressed members to carry their dead load and anticipated construction loads.

1906.3 Conduits and Pipes Embedded in Concrete.

1906.3.1 Conduits, pipes and sleeves of any material not harmful to concrete and within limitations of this subsection may be embedded in concrete with approval of the *building official,* provided they are not considered to replace structurally the displaced concrete.

1906.3.2 Conduits and pipes of aluminum shall not be embedded in structural concrete unless effectively coated or covered to prevent aluminum-concrete reaction or electrolytic action between aluminum and steel.

1906.3.3 Conduits, pipes and sleeves passing through a slab, wall or beam shall not impair significantly the strength of the construction.

1906.3.4 Conduits and pipes, with their fittings, embedded within a column shall not displace more than 4 percent of the area of cross section on which strength is calculated or which is required for fire protection.

1906.3.5 Except when plans for conduits and pipes are approved by the *building official,* conduits and pipes embedded within a slab, wall or beam (other than those merely passing through) shall satisfy the following:

1906.3.5.1 They shall not be larger in outside dimension than one third the overall thickness of slab, wall or beam in which they are embedded.

1906.3.5.2 They shall be spaced not closer than three diameters or widths on center.

1906.3.5.3 They shall not impair significantly the strength of the construction.

1906.3.6 Conduits, pipes and sleeves may be considered as replacing structurally in compression the displaced concrete, provided:

1906.3.6.1 They are not exposed to rusting or other deterioration.

1906.3.6.2 They are of uncoated or galvanized iron or steel not thinner than standard Schedule 40 steel pipe.

1906.3.6.3 They have a nominal inside diameter not over 2 inches (51 mm) and are spaced not less than three diameters on centers.

1906.3.7 Pipes and fittings shall be designed to resist effects of the material, pressure and temperature to which they will be subjected.

1906.3.8 No liquid, gas or vapor, except water not exceeding 90°F (32.2°C) or 50 psi (0.34 MPa) pressure, shall be placed in the pipes until the concrete has attained its design strength.

1906.3.9 In solid slabs, piping, unless it is used for radiant heating or snow melting, shall be placed between top and bottom reinforcement.

1906.3.10 Concrete cover for pipes, conduit and fittings shall not be less than $1^1/_2$ inches (38 mm) for concrete exposed to earth or weather, or less than $^3/_4$ inch (19 mm) for concrete not exposed to weather or in contact with ground.

1906.3.11 Reinforcement with an area not less than 0.002 times the area of concrete section shall be provided normal to the piping.

1906.3.12 Piping and conduit shall be so fabricated and installed that cutting, bending or displacement of reinforcement from its proper location will not be required.

1906.4 Construction Joints.

1906.4.1 Surface of concrete construction joints shall be cleaned and laitance removed.

1906.4.2 Immediately before new concrete is placed, all construction joints shall be wetted and standing water removed.

1906.4.3 Construction joints shall be so made and located as not to impair the strength of the structure. Provision shall be made for transfer of shear and other forces through construction joints. See Section 1911.7.9.

1906.4.4 Construction joints in floors shall be located within the middle third of spans of slabs, beams and girders. Joints in girders shall be offset a minimum distance of two times the width of intersecting beams.

1906.4.5 Beams, girders or slabs supported by columns or walls shall not be cast or erected until concrete in the vertical support members is no longer plastic.

1906.4.6 Beams, girders, haunches, drop panels and capitals shall be placed monolithically as part of a slab system, unless otherwise shown in design drawings or specifications.

SECTION 1907 — DETAILS OF REINFORCEMENT

1907.0 Notations.

d = distance from extreme compression fiber to centroid of tension reinforcement, inches (mm).

d_b = nominal diameter of bar, wire or prestressing strand, inches (mm).

f_y = specified yield strength of nonprestressed reinforcement, psi (MPa).

l_d = development length, inches (mm). See Section 1912.

1907.1 Standard Hooks. ''Standard hook'' as used in this code is one of the following:

1907.1.1 One-hundred-eighty-degree bend plus $4d_b$ extension, but not less than $2^1/_2$ inches (64 mm) at free end of bar.

1907.1.2 Ninety-degree bend plus $12d_b$ extension at free end of bar.

1907.1.3 For stirrup and tie hooks:

1. No. 5 bar and smaller, 90-degree bend plus $6d_b$ extension at free end of bar, or
2. No. 6, No. 7 and No. 8 bar, 90-degree bend, plus $12d_b$ extension at free end of bar, or
3. No. 8 bar and smaller, 135-degree bend plus $6d_b$ extension at free end of bar.
4. *For stirrups and tie hooks in Seismic Zones 3 and 4, refer to the hoop and crosstie provisions of Section 1921.1.*

1907.2 Minimum Bend Diameters.

1907.2.1 Diameter of bend measured on the inside of the bar, other than for stirrups and ties in sizes No. 3 through No. 5, shall not be less than the values in Table 19-B.

1907.2.2 Inside diameter of bends for stirrups and ties shall not be less than $4d_b$ for No. 5 bar and smaller. For bars larger than No. 5, diameter of bend shall be in accordance with Table 19-B.

1907.2.3 Inside diameter of bends in welded wire fabric (plain or deformed) for stirrups and ties shall not be less than $4d_b$ for deformed wire larger than D6 and $2d_b$ for all other wires. Bends with inside diameter of less than $8d_b$ shall not be less than $4d_b$ from nearest welded intersection.

1907.3 Bending.

1907.3.1 All reinforcement shall be bent cold, unless otherwise permitted by the *building official.*

1907.3.2 Reinforcement partially embedded in concrete shall not be field bent, except as shown on the design drawings or permitted by the *building official.*

1907.4 Surface Conditions of Reinforcement.

1907.4.1 At the time concrete is placed, reinforcement shall be free from mud, oil or other nonmetallic coatings that decrease bond. Epoxy coatings of bars in accordance with Section 1903.5.3.7 shall be permitted.

1907.4.2 Reinforcement, except prestressing tendons, with rust, mill scale or a combination of both, shall be considered satisfactory, provided the minimum dimensions (including height of deformations) and weight of a hand-wire-brushed test specimen are not less than applicable specification requirements.

1907.4.3 Prestressing tendons shall be clean and free of oil, dirt, scale, pitting and excessive rust. A light oxide shall be permitted.

1907.5 Placing Reinforcement.

1907.5.1 Reinforcement, prestressing tendons and ducts shall be accurately placed and adequately supported before concrete is placed, and shall be secured against displacement within tolerances of this section.

1907.5.2 Unless otherwise *approved by the building official,* reinforcement, prestressing tendons and prestressing ducts shall be placed within the following tolerances:

1907.5.2.1 Tolerance for depth *d,* and minimum concrete cover in flexural members, walls and compression members shall be as follows:

	TOLERANCE ON d	TOLERANCE ON MINIMUM CONCRETE COVER
$d \leq$ 8 in. (203 mm)	$\pm\ ^3/_8$ in. (9.5 mm)	$-\ ^3/_8$ in. (9.5 mm)
$d >$ 8 in. (203 mm)	$\pm\ ^1/_2$ in. (12.7 mm)	$-\ ^1/_2$ in. (12.7 mm)

except that tolerance for the clear distance to formed soffits shall be minus $^1/_4$ inch (6.4 mm) and tolerance for cover shall not exceed minus one third the minimum concrete cover required by the approved plans or specifications.

1907.5.2.2 Tolerance for longitudinal location of bends and ends of reinforcement shall be $\pm$ 2 inches ($\pm$ 51 mm) except at discontinuous ends of members where tolerance shall be $\pm\ ^1/_2$ inch ($\pm$ 12.7 mm).

1907.5.3 Welded wire fabric (with wire size not greater than W5 or D5) used in slabs not exceeding 10 feet (3048 mm) in span shall be permitted to be curved from a point near the top of slab over the support to a point near the bottom of slab at midspan, provided such reinforcement is either continuous over, or securely anchored at, support.

1907.5.4 Welding of crossing bars shall not be permitted for assembly of reinforcement.

EXCEPTIONS: *1. Reinforcing steel not required by design.*

2. When specifically approved by the building official, welding of crossing bars for assembly purposes in Seismic Zones 0, 1 and 2 may be permitted, provided that data are submitted to the building official to show that there is no detrimental effect on the action of the structural member as a result of welding of the crossing bars.

1907.6 Spacing Limits for Reinforcement.

1907.6.1 The minimum clear spacing between parallel bars in a layer shall be d_b but not less than 1 inch (25 mm). See also Section 1903.3.2.

1907.6.2 Where parallel reinforcement is placed in two or more layers, bars in the upper layers shall be placed directly above bars in the bottom layer with clear distance between layers not less than 1 inch (25 mm).

1907.6.3 In spirally reinforced or tied reinforced compression members, clear distance between longitudinal bars shall not be less than $1.5d_b$ or less than $1^1/_2$ inches (38 mm). See also Section 1903.3.2.

1907.6.4 Clear distance limitation between bars shall apply also to the clear distance between a contact lap splice and adjacent splices or bars.

1907.6.5 In walls and slabs other than concrete joist construction, primary flexural reinforcement shall not be spaced farther apart than three times the wall or slab thickness, or 18 inches (457 mm).

1907.6.6 Bundled bars.

1907.6.6.1 Groups of parallel reinforcing bars bundled in contact to act as a unit shall be limited to four bars in one bundle.

1907.6.6.2 Bundled bars shall be enclosed within stirrups or ties.

1907.6.6.3 Bars larger than No. 11 shall not be bundled in beams.

1907.6.6.4 Individual bars within a bundle terminated within the span of flexural members shall terminate at different points with at least $40d_b$ stagger.

1907.6.6.5 Where spacing limitations and minimum concrete cover are based on bar diameter d_b, a unit of bundled bars shall be treated as a single bar of a diameter derived from the equivalent total area.

1907.6.7 Prestressing tendons and ducts.

1907.6.7.1 Clear distance between pretensioning tendons at each end of a member shall not be less than $4d_b$ for wire, or $3d_b$ for strands. See also Section 1903.3.2. Closer vertical spacing and bundling of tendons shall be permitted in the middle portion of a span.

1907.6.7.2 Bundling of posttensioning ducts shall be permitted if it is shown that concrete can be satisfactorily placed and if provision is made to prevent the tendons, when tensioned, from breaking through the duct.

1907.7 Concrete Protection for Reinforcement.

1907.7.1 Cast-in-place concrete (nonprestressed). The following minimum concrete cover shall be provided for reinforcement:

		MINIMUM COVER, inches (mm)
1.	Concrete cast against and permanently exposed to earth	3 (76)
2.	Concrete exposed to earth or weather:	
	No. 6 through No. 18 bar	2 (51)
	No. 5 bar, W31 or D31 wire, and smaller	$1^1/_2$ (38)
3.	Concrete not exposed to weather or in contact with ground:	
	Slabs, walls, joists:	
	No. 14 and No. 18 bar	$1^1/_2$ (38)
	No. 11 bar and smaller	$^3/_4$ (19)
	Beams, columns:	
	Primary reinforcement, ties, stirrups, spirals	$1^1/_2$ (38)
	Shells, folded plate members:	
	No. 6 bar and larger	$^3/_4$ (19)
	No. 5 bar, W31 or D31 wire, and smaller	$^1/_2$ (12.7)
4.	*Concrete tilt-up panels cast against a rigid horizontal surface, such as a concrete slab, exposed to the weather:*	
	No. 8 and smaller	*1 (25)*
	No. 9 through No. 18	*2 (51)*

1907.7.2 Precast concrete (manufactured under plant control conditions). The following minimum concrete cover shall be provided for reinforcement:

	MINIMUM COVER, inches (mm)
1. Concrete exposed to earth or weather:	
Wall panels:	
No. 14 and No. 18 bar	$1^1/_2$ (38)
No. 11 bar and smaller	$^3/_4$ (19)
Other members:	
No. 14 and No. 18 bar	2 (51)
No. 6 through No. 11 bar	$1^1/_2$ (38)
No. 5 bar W31 or D31 wire, and smaller	$1^1/_4$ (32)
2. Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists:	
No. 14 and No. 18 bar	$1^1/_4$ (32)
No. 11 bar and smaller	$^5/_8$ (16)
Beams, columns:	
Primary reinforcement	d_b but not less than $^5/_8$ (16) and need not exceed $1^1/_2$ (38)
Ties, stirrups, spirals	$^3/_8$ (9.5)
Shells, folded plate members:	
No. 6 bar and larger	$^5/_8$ (16)
No. 5 bar, W31 or D31 wire, and smaller	$^3/_8$ (9.5)

1907.7.3 Prestressed concrete.

1907.7.3.1 The following minimum concrete cover shall be provided for prestressed and nonprestressed reinforcement, ducts and end fittings, except as provided in Sections 1907.7.3.2 and 1907.7.3.3.

	MINIMUM COVER, inches (mm)
1. Concrete cast against and permanently exposed to earth	3 (76)
2. Concrete exposed to earth or weather:	
Wall panels, slabs, joists	1 (25)
Other members	$1^1/_2$ (32)
3. Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists	$^3/_4$ (19)
Beams, columns:	
Primary reinforcement	$1^1/_2$ (38)
Ties, stirrups, spirals	1 (25)
Shells, folded plate members:	
No. 5 bars, W31 or D31 wire, and smaller	$^3/_8$ (9.5)
Other reinforcement	d_b but not less than $^3/_4$ (19)

1907.7.3.2 For prestressed concrete members exposed to earth, weather or corrosive environments, and in which permissible tensile stress of Section 1918.4.2, Item 3, is exceeded, minimum cover shall be increased 50 percent.

1907.7.3.3 For prestressed concrete members manufactured under plant control conditions, minimum concrete cover for nonprestressed reinforcement shall be as required in Section 1907.7.2.

1907.7.4 Bundled bars. For bundled bars, minimum concrete cover shall be equal to the equivalent diameter of the bundle, but need not be greater than 2 inches (51 mm); except for concrete cast against and permanently exposed to earth, minimum cover shall be 3 inches (76 mm).

1907.7.5 Corrosive environments. In corrosive environments or other severe exposure conditions, amount of concrete protection shall be suitably increased, and denseness and nonporosity of protecting concrete shall be considered, or other protection shall be provided.

1907.7.6 Future extensions. Exposed reinforcement, inserts and plates intended for bonding with future extensions shall be protected from corrosion.

1907.7.7 Fire protection. When a thickness of cover for fire protection greater than the minimum concrete cover specified in Section 1907.7 is required, such greater thickness shall be used.

1907.8 Special Reinforcement Details for Columns.

1907.8.1 Offset bars. Offset bent longitudinal bars shall conform to the following:

1907.8.1.1 Slope of inclined portion of an offset bar with axis of column shall not exceed 1 in 6.

1907.8.1.2 Portions of bar above and below an offset shall be parallel to axis of column.

1907.8.1.3 Horizontal support at offset bends shall be provided by lateral ties, spirals or parts of the floor construction. Horizontal support provided shall be designed to resist one and one-half times the horizontal component of the computed force in the inclined portion of an offset bar. Lateral ties or spirals, if used, shall be placed not more than 6 inches (152 mm) from points of bend.

1907.8.1.4 Offset bars shall be bent before placement in the forms. See Section 1907.3.

1907.8.1.5 Where a column face is offset 3 inches (76 mm) or greater, longitudinal bars shall not be offset bent. Separate dowels, lap spliced with the longitudinal bars adjacent to the offset column faces, shall be provided. Lap splices shall conform to Section 1912.17.

1907.8.2 Steel cores. Load transfer in structural steel cores of composite compression members shall be provided by the following:

1907.8.2.1 Ends of structural steel cores shall be accurately finished to bear at end-bearing splices, with positive provision for alignment of one core above the other in concentric contact.

1907.8.2.2 At end-bearing splices, bearing shall be considered effective to transfer not more than 50 percent of the total compressive stress in the steel core.

1907.8.2.3 Transfer of stress between column base and footing shall be designed in accordance with Section 1915.8.

1907.8.2.4 Base of structural steel section shall be designed to transfer the total load from the entire composite member to the footing; or, the base may be designed to transfer the load from the steel core only, provided ample concrete section is available for transfer of the portion of the total load carried by the reinforced concrete section to the footing by compression in the concrete and by reinforcement.

1907.9 Connections.

1907.9.1 At connections of principal framing elements (such as beams and columns), enclosure shall be provided for splices of continuing reinforcement and for anchorage of reinforcement terminating in such connections.

1907.9.2 Enclosure at connections may consist of external concrete or internal closed ties, spirals or stirrups.

1907.10 Lateral Reinforcement for Compression Members.

1907.10.1 Lateral reinforcement for compression members shall conform to the provisions of Sections 1907.10.4 and 1907.10.5

and, where shear or torsion reinforcement is required, shall also conform to provisions of Section 1911.

1907.10.2 Lateral reinforcement requirements for composite compression members shall conform to Section 1910.16. Lateral reinforcement requirements for prestressing tendons shall conform to Section 1918.11.

1907.10.3 It shall be permitted to waive the lateral reinforcement requirements of Sections 1907.10, 1910.16 and 1918.11 where tests and structural analyses show adequate strength and feasibility of construction.

1907.10.4 Spirals. Spiral reinforcement for compression members shall conform to Section 1910.9.3 and to the following:

1907.10.4.1 Spirals shall consist of evenly spaced continuous bar or wire of such size and so assembled as to permit handling and placing without distortion from designed dimensions.

1907.10.4.2 For cast-in-place construction, size of spirals shall not be less than $^3/_8$-inch (9.5 mm) diameter.

1907.10.4.3 Clear spacing between spirals shall not exceed 3 inches (76 mm) or be less than 1 inch (25 mm). See also Section 1903.3.2.

1907.10.4.4 Anchorage of spiral reinforcement shall be provided by one and one-half extra turns of spiral bar or wire at each end of a spiral unit.

1907.10.4.5 Splices in spiral reinforcement shall be lap splices of $48d_b$, but not less than 12 inches (305 mm) or welded.

1907.10.4.6 Spirals shall extend from top of footing or slab in any story to level of lowest horizontal reinforcement in members supported above.

1907.10.4.7 Where beams or brackets do not frame into all sides of a column, ties shall extend above termination of spiral to bottom of slab or drop panel.

1907.10.4.8 In columns with capitals, spirals shall extend to a level at which the diameter or width of capital is two times that of the column.

1907.10.4.9 Spirals shall be held firmly in place and true to line.

1907.10.5 Ties. Tie reinforcement for compression members shall conform to the following:

1907.10.5.1 All nonprestressed bars shall be enclosed by lateral ties, at least No. 3 in size for longitudinal bars No. 10 or smaller, and at least No. 4 in size for Nos. 11, 14 and 18 and bundled longitudinal bars. Deformed wire or welded wire fabric of equivalent area shall be permitted.

1907.10.5.2 Vertical spacing of ties shall not exceed 16 longitudinal bar diameters, 48 tie bar or wire diameters, or least dimension of the compression member.

1907.10.5.3 Ties shall be arranged such that every corner and alternate longitudinal bar shall have lateral support provided by the corner of a tie with an included angle of not more than 135 degrees and a bar shall be not farther than 6 inches (152 mm) clear on each side along the tie from such a laterally supported bar. Where longitudinal bars are located around the perimeter of a circle, a complete circular tie shall be permitted.

1907.10.5.4 Ties shall be located vertically not more than one half a tie spacing above the top of footing or slab in any story and shall be spaced as provided herein to not more than one half a tie spacing below the lowest horizontal reinforcement *in members supported above.*

1907.10.5.5 Where beams or brackets frame from four directions into a column, termination of ties not more than 3 inches (76 mm) below reinforcement in shallowest of such beams or brackets shall be permitted.

1907.10.5.6 *Column ties shall have hooks as specified in Section 1907.1.3.*

1907.11 Lateral Reinforcement for Flexural Members.

1907.11.1 Compression reinforcement in beams shall be enclosed by ties or stirrups satisfying the size and spacing limitations in Section 1907.10.5 or by welded wire fabric of equivalent area. Such ties or stirrups shall be provided throughout the distance where compression reinforcement is required.

1907.11.2 Lateral reinforcement for flexural framing members subject to stress reversals or to torsion at supports shall consist of closed ties, closed stirrups, or spirals extending around the flexural reinforcement.

1907.11.3 Closed ties or stirrups may be formed in one piece by overlapping standard stirrup or tie end hooks around a longitudinal bar, or formed in one or two pieces lap spliced with a Class B splice (lap of 1.3 l_d), or anchored in accordance with Section 1912.13.

1907.12 Shrinkage and Temperature Reinforcement.

1907.12.1 Reinforcement for shrinkage and temperature stresses normal to flexural reinforcement shall be provided in structural slabs where the flexural reinforcement extends in one direction only.

1907.12.1.1 Shrinkage and temperature reinforcement shall be provided in accordance with either Section 1907.12.2 or 1907.12.3 below.

1907.12.1.2 Where shrinkage and temperature movements are significantly restrained, the requirements of Sections 1908.2.4 and 1909.2.7 shall be considered.

1907.12.2 Deformed reinforcement conforming to Section 1903.5.3 used for shrinkage and temperature reinforcement shall be provided in accordance with the following:

1907.12.2.1 Area of shrinkage and temperature reinforcement shall provide at least the following ratios of reinforcement area to gross concrete area, but not less than 0.0014:

1. Slabs where Grade 40 or 50 deformed bars are used 0.0020
2. Slabs where Grade 60 deformed bars or welded wire fabric (smooth or deformed) are used 0.0018
3. Slabs where reinforcement with yield stress exceeding 60,000 psi (413.7 MPa) measured at a yield strain of 0.35 percent is used

$$\frac{0.0018 \times 60,000}{f_y}$$

For **SI:**

$$\frac{0.0018 \times 413.7}{f_y}$$

1907.12.2.2 Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness, or 18 inches (457 mm).

1907.12.2.3 At all sections where required, reinforcement for shrinkage and temperature stresses shall develop the specified yield strength f_y in tension in accordance with Section 1912.

1907.12.3 Prestressing tendons conforming to Section 1903.5.5 used for shrinkage and temperature reinforcement shall be provided in accordance with the following:

1907.12.3.1 Tendons shall be proportioned to provide a minimum average compressive stress of 100 psi (0.69 MPa) on gross concrete area using effective prestress, after losses, in accordance with Section 1918.6.

1907.12.3.2 Spacing of prestressed tendons shall not exceed 6 feet (1829 mm).

1907.12.3.3 When the spacing of prestressed tendons exceeds 54 inches (1372 mm), additional bonded shrinkage and temperature reinforcement conforming with Section 1907.12.2 shall be provided between the tendons at slab edges extending from the slab edge for a distance equal to the tendon spacing.

1907.13 Requirements for Structural Integrity.

1907.13.1 In the detailing of reinforcement and connections, members of a structure shall be effectively tied together to improve integrity of the overall structure.

1907.13.2 For cast-in-place construction, the following shall constitute minimum requirements:

1907.13.2.1 In joist construction, at least one bottom bar shall be continuous or shall be spliced over the support with a Class A tension splice and at noncontinuous supports be terminated with a standard hook.

1907.13.2.2 Beams at the perimeter of the structure shall have at least one sixth of the tension reinforcement required for negative moment at the support and one-quarter of the positive moment reinforcement required at midspan made continuous around the perimeter and tied with closed stirrups or stirrups anchored around the negative moment reinforcement with a hook having a bend of at least 135 degrees. Stirrups need not be extended through any joints. When splices are needed, the required continuity shall be provided with top reinforcement spliced at midspan and bottom reinforcement spliced at or near the support with Class A tension splices.

1907.13.2.3 In other than perimeter beams, when closed stirrups are not provided, at least one-quarter of the positive moment reinforcement required at midspan shall be continuous or shall be spliced over the support with a Class A tension splice and at noncontinuous supports be terminated with a standard hook.

1907.13.2.4 For two-way slab construction, see Section 1913.3.8.5.

1907.13.3 For precast concrete construction, tension ties shall be provided in the transverse, longitudinal, and vertical directions and around the perimeter of the structure to effectively tie elements together. The provisions of Section 1916.5 shall apply.

1907.13.4 For lift-slab construction, see Sections 1913.3.8.6 and 1918.12.6.

SECTION 1908 — ANALYSIS AND DESIGN

1908.0 Notations.

A_s = area of nonprestressed tension reinforcement, square inches (mm^2).

A'_s = area of compression reinforcement, square inches (mm^2).

b = width of compression face of member, inches (mm).

d = distance from extreme compression fiber to centroid of tension reinforcement, inches (mm).

E_c = modulus of elasticity of concrete, pounds per square inch (MPa). See Section 1908.5.1.

E_s = modulus of elasticity of reinforcement, pounds per square inch (MPa). See Sections 1908.2 and 1908.5.3.

f'_c = specified compressive strength of concrete, pounds per square inch (MPa).

f_y = specified yield strength of nonprestressed reinforcement, pounds per square inch (MPa).

l_n = clear span for positive moment or shear and average of adjacent clear spans for negative moment.

V_c = nominal shear strength provided by concrete.

w_c = unit weight of concrete, pounds per cubic foot (kg/m^3).

w_u = factored load per unit length of beam or per unit area of slab.

β_1 = factor defined in Section 1910.2.7.3.

ε_t = net tensile strain in extreme tension steel at nominal strength.

ρ = ratio of nonprestressed tension reinforcement.
= A_s/bd.

ρ' = ratio of nonprestressed compression reinforcement.
= A'_s/bd.

ρ_b = reinforcement ratio producing balanced strain conditions. See Section 1910.3.2.

ϕ = strength-reduction factor. See Section 1909.3.

1908.1 Design Methods.

1908.1.1 In design of structural concrete, members shall be proportioned for adequate strength in accordance with provisions of this code, using load factors and strength-reduction factors ϕ specified in Section 1909.

1908.1.2 Nonprestressed reinforced concrete members shall be permitted to be designed using the provisions of Section 1926.

1908.1.3 Design of reinforced concrete using Section 1927 shall be permitted.

1908.2 Loading.

1908.2.1 Design provisions of this code are based on the assumption that structures shall be designed to resist all applicable loads.

1908.2.2 Service loads shall be in accordance with Chapter 16 with appropriate live load reductions as permitted therein.

1908.2.3 In design for wind and earthquake loads, integral structural parts shall be designed to resist the total lateral loads.

1908.2.4 Consideration shall be given to effects of forces due to prestressing, crane loads, vibration, impact, shrinkage, temperature changes, creep, expansion of shrinkage-compensating concrete and unequal settlement of supports.

1908.3 Methods of Analysis.

1908.3.1 All members of frames or continuous construction shall be designed for the maximum effects of factored loads as determined by the theory of elastic analysis, except as modified by Section 1908.4. It is permitted to simplify the design by using the assumptions specified in Sections 1908.6 through 1908.9.

1908.3.2 Except for prestressed concrete, approximate methods of frame analysis may be used for buildings of usual types of construction, spans and story heights.

1908.3.3 As an alternate to frame analysis, the following approximate moments and shears shall be permitted to be used in design of continuous beams and one-way slabs (slabs reinforced to resist flexural stresses in only one direction), provided:

1. There are two or more spans,

2. Spans are approximately equal, with the larger of two adjacent spans not greater than the shorter by more than 20 percent,

3. Loads are uniformly distributed, and

4. Unit live load does not exceed three times unit dead load, and

5. Members are prismatic.

Positive moment:

End spans

Discontinuous end unrestrained . . . . $w_u l_n^2/11$

Discontinuous end integral with support . . . . . $w_u l_n^2/14$

Interior spans . . . . $w_u l_n^2/16$

Negative moment at exterior face of first interior support

Two spans . . . . $w_u l_n^2/9$

More than two spans . . . . $w_u l_n^2/10$

Negative moment at other faces of interior supports . . . . $w_u l_n^2/11$

Negative moment at face of all supports for:

Slabs with spans not exceeding 10 feet (3048 mm), and beams where ratio of sum of column stiffnesses to beam stiffness exceeds eight at each end of the span . . . . $w_u l_n^2/12$

Negative moment at interior face of exterior support for members built integrally with supports:

Where support is a spandrel beam . . . . $w_u l_n^2/24$

Where support is a column . . . . $w_u l_n^2/16$

Shear in end members at face of first interior support . . . . 1.15 $w_u l_n/2$

Shear at face of all other supports . . . . $w_u l_n/2$

1908.4 Redistribution of Negative Moments in Continuous Nonprestressed Flexural Members.

1908.4.1 Except where approximate values for moments are used, it is permitted to increase or decrease negative moments calculated by elastic theory at supports of continuous flexural members for any assumed loading arrangement by not more than

$$20\left(1-\frac{\rho-\rho'}{\rho_b}\right)\text{ percent}$$

1908.4.2 The modified negative moments shall be used for calculating moments at sections within the spans.

1908.4.3 Redistribution of negative moments shall be made only when the section, at which moment is reduced, is so designed that ρ or $\rho - \rho'$ is not greater than 0.50 ρ_b, where

$$\rho_b = \frac{0.85\beta_1 f'_c}{f_y}\,\frac{87,000}{87,000 + f_y} \qquad (8\text{-}1)$$

For **SI:**
$$\rho_b = \frac{0.85\beta_1 f'_c}{f_y}\,\frac{600}{600 + f_y}$$

1908.4.4 *For criteria on moment redistribution for prestressed concrete members, see Section 1918.*

1908.5 Modulus of Elasticity.

1908.5.1 Modulus of elasticity E_c for concrete shall be permitted to be taken as $w_c^{1.5}33\sqrt{f'_c}$ (in psi) [For **SI:** $w_c^{1.5}0.043\sqrt{f'_c}$ (in MPA)] for values of w_c between 90 pcf and 155 pcf (1440 kg/m^3 and 2420 kg/m^3). For normal-weight concrete, E_c shall be permitted to be taken as $57,000\sqrt{f'_c}$ (For **SI:** $4730\sqrt{f'_c}$).

1908.5.2 Modulus of elasticity E_s for nonprestressed reinforcement shall be permitted to be taken as 29,000,000 psi (200 000 MPa).

1908.5.3 Modulus of elasticity E_s for prestressing tendons shall be determined by tests or supplied by the manufacturer.

1908.6 Stiffness.

1908.6.1 Use of any set of reasonable assumptions shall be permitted for computing relative flexural and torsional stiffnesses of columns, walls, floors and roof systems. The assumptions adopted shall be consistent throughout analysis.

1908.6.2 Effect of haunches shall be considered both in determining moments and in design of members.

1908.7 Span Length.

1908.7.1 Span length of members not built integrally with supports shall be considered the clear span plus depth of member, but need not exceed distance between centers of supports.

1908.7.2 In analysis of frames or continuous construction for determination of moments, span length shall be taken as the distance center to center of supports.

1908.7.3 For beams built integrally with supports, design on the basis of moments at faces of support shall be permitted.

1908.7.4 It shall be permitted to analyze solid or ribbed slabs built integrally with supports, with clear spans not more than 10 feet (3048 mm), as continuous slabs on knife edge supports with spans equal to the clear spans of the slab and width of beams otherwise neglected.

1908.8 Columns.

1908.8.1 Columns shall be designed to resist the axial forces from factored loads on all floors or roof and the maximum moment from factored loads on a single adjacent span of the floor or roof under consideration. Loading condition giving the maximum ratio of moment to axial load shall also be considered.

1908.8.2 In frames or continuous construction, consideration shall be given to the effect of unbalanced floor or roof loads on both exterior and interior columns and of eccentric loading due to other causes.

1908.8.3 In computing gravity load moments in columns, it shall be permitted to assume far ends of columns built integrally with the structure to be fixed.

1908.8.4 Resistance to moments at any floor or roof level shall be provided by distributing the moment between columns immediately above and below the given floor in proportion to the relative column stiffnesses and conditions of restraint.

1908.9 Arrangement of Live Load.

1908.9.1 It is permissible to assume that:

1. the live load is applied only to the floor or roof under consideration, and

2. the far ends of columns built integrally with the structure are considered to be fixed.

1908.9.2 It is permitted to assume that the arrangement of live load is limited to combinations of:

1. Factored dead load on all spans with full-factored live load on two adjacent spans, and

2. Factored dead load on all spans with full-factored live load on alternate spans.

1908.10 T-beam Construction.

1908.10.1 In T-beam construction, the flange and web shall be built integrally or otherwise effectively bonded together.

1908.10.2 Width of slab effective as a T-beam flange shall not exceed one fourth the span length of the beam, and the effective overhanging slab width on each side of the web shall not exceed:

1. Eight times the slab thickness, or
2. One half the clear distance to the next web.

1908.10.3 For beams with a slab on one side only, the effective overhanging flange width shall not exceed:

1. One twelfth the span length of the beam,
2. Six times the slab thickness, or
3. One half the clear distance to the next web.

1908.10.4 Isolated beams, in which the T-shape is used to provide a flange for additional compression area, shall have a flange thickness not less than one half the width of web and an effective flange width not more than four times the width of web.

1908.10.5 Where primary flexural reinforcement in a slab that is considered as a T-beam flange (excluding joist construction) is parallel to the beam, reinforcement perpendicular to the beam shall be provided in the top of the slab in accordance with the following:

1908.10.5.1 Transverse reinforcement shall be designed to carry the factored load on the overhanging slab width assumed to act as a cantilever. For isolated beams, the full width of overhanging flange shall be considered. For other T-beams, only the effective overhanging slab width need be considered.

1908.10.5.2 Transverse reinforcement shall be spaced not farther apart than five times the slab thickness or 18 inches (457 mm).

1908.11 Joist Construction.

1908.11.1 Joist construction consists of a monolithic combination of regularly spaced ribs and a top slab arranged to span in one direction or two orthogonal directions.

1908.11.2 Ribs shall not be less than 4 inches (102 mm) in width and shall have a depth of not more than three and one-half times the minimum width of rib.

1908.11.3 Clear spacing between ribs shall not exceed 30 inches (762 mm).

1908.11.4 Joist construction not meeting the limitations of the preceding two paragraphs shall be designed as slabs and beams.

1908.11.5 When permanent burned clay or concrete tile fillers of material having a unit compressive strength at least equal to that of the specified strength of concrete in the joists are used:

1908.11.5.1 For shear and negative-moment strength computations, it shall be permitted to include the vertical shells of fillers in contact with ribs. Other portions of fillers shall not be included in strength computations.

1908.11.5.2 Slab thickness over permanent fillers shall not be less than one twelfth the clear distance between ribs nor less than $1^1/_2$ inches (38 mm).

1908.11.5.3 In one-way joists, reinforcement normal to the ribs shall be provided in the slab as required by Section 1907.12.

1908.11.6 When removable forms or fillers not complying with Section 1908.11.5 are used:

1908.11.6.1 Slab thickness shall not be less than one twelfth the clear distance between ribs, or less than 2 inches (51 mm).

1908.11.6.2 Reinforcement normal to the ribs shall be provided in the slab as required for flexure, considering load concentrations, if any, but not less than required by Section 1907.12.

1908.11.7 Where conduits or pipes as permitted by Section 1906.3 are embedded within the slab, slab thickness shall be at least 1 inch (25 mm) greater than the total overall depth of the conduits or pipes at any point. Conduits or pipes shall not impair significantly the strength of the construction.

1908.11.8 For joist construction, contribution of concrete to shear strength V_c is permitted to be 10 percent more than that specified in Section 1911. It shall be permitted to increase shear strength using shear reinforcement or by widening the ends of the ribs.

1908.12 Separate Floor Finish.

1908.12.1 A floor finish shall not be included as part of a structural member unless placed monolithically with the floor slab or designed in accordance with requirements of Section 1917.

1908.12.2 It shall be permitted to consider all concrete floor finishes may be considered as part of required cover or total thickness for nonstructural considerations.

SECTION 1909 — STRENGTH AND SERVICEABILITY REQUIREMENTS

1909.0 Notations.

A_g = gross area of section, square inches (mm^2).

A'_s = area of compression reinforcement, square inches (mm^2).

b = width of compression face of member, inches (mm).

c = distance from extreme compression fiber to neutral axis in inches (mm).

D = dead loads, or related internal moments and forces.

d = distance from extreme compression fiber to centroid of tension reinforcement, inches (mm).

d' = distance from extreme compression fiber to centroid of compression reinforcement, inches (mm).

d_s = distance from extreme tension fiber to centroid of tension reinforcement, inches (mm).

d_t = distance from extreme compression fiber to extreme tension steel, inches (mm).

E = load effects of earthquake, or related internal moments and forces.

E_c = modulus of elasticity of concrete, pounds per square inch (MPa). See Section 1908.1.

F = loads due to weight and pressures of fluids with well-defined densities and controllable maximum heights, or related internal moments and forces.

f'_c = specified compressive strength of concrete, pounds per square inch (MPa).

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, pounds per square inch (MPa).

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, pounds per square inch (MPa).

f_r = modulus of rupture of concrete, pounds per square inch (MPa).

f_y = specified yield strength of nonprestressed reinforcement, pounds per square inch (MPa).

H = loads due to weight and pressure of soil, water in soil, or other materials, or related internal moments and forces.

h = overall thickness of member, inches (mm).

I_{cr} = moment of inertia of cracked section transformed to concrete.

I_e = effective moment of inertia for computation of deflection.

I_g = moment of inertia of gross concrete section about centroidal axis, neglecting reinforcement.

L = live loads, or related internal moments and forces.

l = span length of beam or one-way slab, as defined in Section 1908.7; clear projection of cantilever, inches (mm).

l_n = length of clear span in long direction of two-way construction, measured face to face of supports in slabs without beams and face to face of beams or other supports in other cases.

M_a = maximum moment in member at stage deflection is computed.

M_{cr} = cracking moment. See Formula (9-8).

P_b = nominal axial load strength at balanced strain conditions. See Section 1910.3.2.

P_n = nominal axial load strength at given eccentricity.

T = cumulative effects of temperature, creep, shrinkage, differential settlement and shrinkage compensating concrete.

U = required strength to resist factored loads or related internal moments and forces.

W = wind load, or related internal moments and forces.

w_c = weight of concrete, pounds per cubic foot (kg/m^3).

y_t = distance from centroidal axis of gross section, neglecting reinforcement, to extreme fiber in tension.

α = ratio of flexural stiffness of beam section to flexural stiffness of a width of slab bounded laterally by center line of adjacent panel (if any) on each side of beam. See Section 1913.

α_m = average value of α for all beams on edges of a panel.

β = ratio of clear spans in long-to-short direction of two-way slabs.

ξ = time-dependent factor for sustained load. See Section 1909.5.2.5.

ε_t = net tensile strain in extreme tension steel at nominal strength.

λ = multiplier for additional long-time deflection as defined in Section 1909.5.2.5.

ρ = ratio of nonprestressed tension reinforcement, A_s/bd.

ρ' = reinforcement ratio for nonprestressed compression reinforcement, A'_g/bd.

ρ_b = reinforcement ratio producing balanced strain conditions. See Section B1910.3.2.

ϕ = strength-reduction factor. See Section 1909.3.

1909.1 General.

1909.1.1 Structures and structural members shall be designed to have design strengths at all sections at least equal to the required strengths calculated for the factored loads and forces in such combinations as are stipulated in this code.

1909.1.2 Members also shall meet all other requirements of this code to ensure adequate performance at service load levels.

1909.2 Required Strength.

1909.2.1 Required strength U to resist dead load D and live load L shall be at least equal to

$$U = 1.4D + 1.7L \tag{9-1}$$

1909.2.2 If resistance to structural effects of a specified wind load W are included in design, the following combinations of D, L and W shall be investigated to determine the greatest required strength U

$$U = 0.75\,(1.4D + 1.7L + 1.7W) \tag{9-2}$$

where load combinations shall include both full value and zero value of L to determine the more severe condition, and

$$U = 0.9D + 1.3W \tag{9-3}$$

but for any combination of D, L and W, required strength U shall not be less than Formula (9-1).

1909.2.3 If resistance to specified earthquake loads or forces E are included in design, load combinations of Section *1612.2.1* shall apply.

1909.2.4 If resistance to earth pressure H is included in design, required strength U shall be at least equal to

$$U = 1.4D + 1.7L + 1.7H \tag{9-4}$$

except that where D or L reduces the effect of H, 0.9D shall be substituted for 1.4D and zero value of L shall be used to determine the greatest required strength U. For any combination of D, L and H, required strength U shall not be less than Formula (9-1).

1909.2.5 If resistance to loadings due to weight and pressure of fluids with well-defined densities and controllable maximum heights F is included in design, such loading shall have a load factor of 1.4 and be added to all loading combinations that include live load.

1909.2.6 If resistance to impact effects is taken into account in design, such effects shall be included with live load L.

1909.2.7 Where structural effects T of differential settlement, creep, shrinkage, expansion of shrinkage-compensating concrete or temperature change may be significant in design, required strength U shall be at least equal to

$$U = 0.75\,(1.4D + 1.4T + 1.7L) \tag{9-5}$$

but required strength U shall not be less than

$$U = 1.4\,(D + T) \tag{9-6}$$

Estimations of differential settlement, creep, shrinkage, expansion of shrinkage-compensating concrete or temperature change shall be based on a realistic assessment of such effects occurring in service.

1909.3 Design Strength.

1909.3.1 Design strength provided by a member, its connection to other members and its cross sections, in terms of flexure, axial load, shear and tension, shall be taken as the nominal strength calculated in accordance with requirements and assumptions of this code, multiplied by a strength-reduction factor ϕ in Sections 1909.3.2 and 1909.3.4.

1909.3.1.1 If the structural framing includes primary members of other materials proportioned to satisfy the load-factor combinations of Section 1928.1.2, it shall be permitted to proportion the concrete members using the set of strength-reduction factors, ϕ, listed in Section 1928.1.1 and the load-factor combinations in Section 1928.1.2.

1909.3.2 Strength-reduction factor ϕ shall be as follows:

1909.3.2.1 Flexure, without axial load 0.90

1909.3.2.2 Axial load and axial load with flexure. (For axial load with flexure, both axial load and moment nominal strength shall be multiplied by appropriate single value of ϕ.)

Axial tension and axial tension with flexure 0.90

Axial compression and axial compression with flexure:

Members with spiral reinforcement conforming to Section 1910.9.3 . . . . 0.75

Other reinforced members 0.70

except that for low values of axial compression, ϕ shall be permitted to be increased in accordance with the following:

For members in which f_y does not exceed 60,000 psi (413.7 MPa), with symmetric reinforcement, and with $(h - d' - d_s)/h$ not less than 0.70, ϕ shall be permitted to be increased linearly to 0.90 as ϕP_n decreases from $0.10 f'_c \; A_g$ to zero.

For other reinforced members, ϕ shall be permitted to be increased linearly to 0.90 as ϕP_n decreases from $0.10 f'_c \; A_g$ or ϕP_b, whichever is smaller, to zero.

1909.3.2.3 Shear and torsion *(See also Section 1909.3.4 for shear walls and frames in Seismic Zones 3 and 4)* 0.85

1909.3.2.4 Bearing on concrete (See also Section 1918.13) 0.70

1909.3.3 Development lengths specified in Section 1912 do not require a ϕ factor.

1909.3.4 *In Seismic Zones 3 and 4,* strength-reduction factors ϕ shall be as given above except for the following:

1909.3.4.1 *The shear strength-reduction factor shall be 0.6 for the design of walls, topping slabs used as diaphragms over precast concrete members and structural framing members, with the exception of joints, if their nominal shear strength is less than the shear corresponding to development of their nominal flexural strength.* The nominal flexural strength shall be determined *corresponding to* the most critical factored axial loads including earthquake effects. *The shear strength reduction factor for joints shall be 0.85.*

1909.3.4.2 *Reinforcement used for diaphragm chords or collectors placed in topping slabs over precast concrete members shall be designed using a strength-reduction factor of 0.6.*

1909.3.5 Strength reduction factor ϕ for flexure compression, shear and bearing of structural plain concrete in Section 1922 shall be 0.65.

1909.4 Design Strength for Reinforcement. Designs shall not be based on a yield strength of reinforcement f_y in excess of 80,000 psi (551.6 MPa), except for prestressing tendons.

1909.5 Control of Deflections.

1909.5.1 Reinforced concrete members subject to flexure shall be designed to have adequate stiffness to limit deflections or any deformations that affect strength or serviceability of a structure adversely.

1909.5.2 One-way construction (nonprestressed).

1909.5.2.1 Minimum thickness stipulated in Table 19-C-1 shall apply for one-way construction not supporting or attached to partitions or other construction likely to be damaged by large deflections, unless computation of deflection indicates a lesser thickness may be used without adverse effects.

1909.5.2.2 Where deflections are to be computed, deflections that occur immediately on application of load shall be computed by usual methods or formulas for elastic deflections, considering effects of cracking and reinforcement on member stiffness.

1909.5.2.3 Unless stiffness values are obtained by a more comprehensive analysis, immediate deflection shall be computed with the modulus of elasticity E_c for concrete as specified in Section 1908.5.1 (normal-weight or lightweight concrete) and with the effective moment of inertia as follows, but not greater than I_g.

$$I_e = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left[1 - \left(\frac{M_{cr}}{M_a}\right)^3\right] I_{cr} \qquad (9\text{-}7)$$

WHERE:

$$M_{cr} = \frac{f_r I_g}{y_t} \qquad (9\text{-}8)$$

and for normal-weight concrete

$$f_r = 7.5\sqrt{f'_c} \qquad (9\text{-}9)$$

For **SI:** $\quad f_r = 0.62\sqrt{f'_c}$

When lightweight aggregate concrete is used, one of the following modifications shall apply:

1. When f_{ct} is specified and concrete is proportioned in accordance with Section 1905.2, f_r shall be modified by substituting $f_{ct}/6.7$ (For **SI:** $1.8f_{ct}$) for $\sqrt{f'_c}$, but the value of $f_{ct}/6.7$ (For **SI:** $1.8f_{ct}$) shall not exceed $\sqrt{f'_c}$.
2. When f_{ct} is not specified, f_r shall be multiplied by 0.75 for ‘‘all-lightweight’’ concrete, and 0.85 for “sand-lightweight’’ concrete. Linear interpolation shall be permitted to be used when partial sand replacement is used.

1909.5.2.4 For continuous members, effective moment of inertia shall be permitted to be taken as the average of values obtained from Formula (9-7) for the critical positive and negative moment sections. For prismatic members, effective moment of inertia shall be permitted to be taken as the value obtained from Formula (9-7) at midspan for simple and continuous spans, and at support for cantilevers.

1909.5.2.5 Unless values are obtained by a more comprehensive analysis, additional longtime deflection resulting from creep and shrinkage of flexural members (normal-weight or lightweight concrete) shall be determined by multiplying the immediate deflection caused by the sustained load considered, by the factor

$$\lambda = \frac{\xi}{1 + 50\rho'} \qquad (9\text{-}10)$$

where ρ' shall be the value at midspan for simple and continuous spans, and at support for cantilevers. It is permitted to assume the time-dependent factor for sustained loads to be equal to

Five years or more	2.0
12 months	1.4
Six months	1.2
Three months	1.0

1909.5.2.6 Deflection computed in accordance with this section shall not exceed limits stipulated in Table *19-C-2*.

1909.5.3 Two-way construction (nonprestressed).

1909.5.3.1 This section shall govern the minimum thickness of slabs or other two-way construction designed in accordance with the provisions of Section 1913 and conforming with the requirements of Section 1913.6.1.2. The thickness of slabs without interior beams spanning between the supports on all sides shall satisfy the requirements of Section 1909.5.3.2 or 1909.5.3.4. Thickness of slabs with beams spanning between the supports on all sides shall satisfy the requirements of Section 1909.5.3.3 or 1909.5.3.4.

1909.5.3.2 For slabs without interior beams spanning between the supports and having a ratio of long to short span not greater than 2, the minimum thickness shall be in accordance with the provisions of Table 19-C-3 and shall not be less than the following values:

1. Slabs without drop panels as defined in Sections 1913.3.7.1 and 1913.3.7.2 . . 5 inches (127 mm)
2. Slabs with drop panels as defined in Sections 1913.3.7.1 and 1913.3.7.2 . . 4 inches (102 mm)

1909.5.3.3 For slabs with beams spanning between the supports on all sides, the minimum thickness shall be as follows:

1. For α_m equal to or less than 0.2, the provisions of Section 1909.5.3.2 shall apply.
2. For α_m greater than 0.2 but not greater than 2.0, the thickness shall not be less than

$$h = \frac{l_n\left(0.8 + \frac{f_y}{200{,}000}\right)}{36 + 5\beta(\alpha_m - 0.2)} \qquad (9\text{-}11)$$

For **SI:**

$$h = \frac{l_n\left(0.8 + \frac{f_y}{1370}\right)}{36 + 5\beta(\alpha_m - 0.2)}$$

but not less than 5 inches (127 mm).

3. For α_m greater than 2.0, the thickness shall not be less than

$$h = \frac{l_n\left(0.8 + \frac{f_y}{200{,}000}\right)}{36 + 9\beta} \qquad (9\text{-}12)$$

For **SI:**

$$h = \frac{l_n\left(0.8 + \frac{f_y}{1370}\right)}{36 + 9\beta}$$

but not less than 3.5 inches (89 mm).

4. At discontinuous edges, an edge beam shall be provided with a stiffness ratio α not less than 0.80; or the minimum thickness required by Formula (9-11) or (9-12) shall be increased by at least 10 percent in the panel with a discontinuous edge.

1909.5.3.4 Slab thickness less than the minimum thickness required by Sections 1909.5.3.1, 1909.5.3.2 and 1909.5.3.3 shall be permitted to be used if shown by computation that the deflection will not exceed the limits stipulated in Table 19-C-2. Deflections shall be computed taking into account size and shape of the panel, conditions of support, and nature of restraints at the panel edges. The modulus of elasticity of concrete E_c shall be as specified in Section 1908.5.1. The effective moment of inertia shall be that given by Formula (9-7); other values shall be permitted to be used if they result in computed deflections in reasonable agreement with the results of comprehensive tests. Additional long-term deflection shall be computed in accordance with Section 1909.5.2.5.

1909.5.4 Prestressed concrete construction.

1909.5.4.1 For flexural members designed in accordance with provisions of Section 1918, immediate deflection shall be computed by usual methods or formulas for elastic deflections, and the moment of inertia of the gross concrete section shall be permitted to be used for uncracked sections.

1909.5.4.2 Additional long-time deflection of prestressed concrete members shall be computed taking into account stresses in concrete and steel under sustained load and including effects of creep and shrinkage of concrete and relaxation of steel.

1909.5.4.3 Deflection computed in accordance with this section shall not exceed limits stipulated in Table *19-C-2*.

1909.5.5 Composite construction.

1909.5.5.1 Shored construction. If composite flexural members are supported during construction so that, after removal of temporary supports, dead load is resisted by the full composite section, it shall be permitted to consider the composite member equivalent to a monolithically cast member for computation of deflection. For nonprestressed members, the portion of the member in compression shall determine whether values in Table 19-C-1 for normal-weight or lightweight concrete shall apply. If deflection is computed, account shall be taken of curvatures resulting from differential shrinkage of precast and cast-in-place components, and of axial creep effects in a prestressed concrete member.

1909.5.5.2 Unshored construction. If the thickness of a nonprestressed precast flexural member meets the requirements of Table 19-C-1, deflection need not be computed. If the thickness of a nonprestressed composite member meets the requirements of Table *19-C-1*, it is not required to compute deflection occurring after the member becomes composite, but the long-time deflection of the precast member shall be investigated for magnitude and duration of load prior to beginning of effective composite action.

1909.5.5.3 Deflection computed in accordance with this section shall not exceed limits stipulated in *Table 19-C-2.*

SECTION 1910 — FLEXURE AND AXIAL LOADS

1910.0 Notations.

A = effective tension area of concrete surrounding the flexural tension reinforcement and having the same centroid as that reinforcement, divided by the number of bars or wires, square inches (mm^2). When the flexural reinforcement consists of different bar or wire sizes, the number of bars or wires shall be computed as the total area of reinforcement divided by the area of the largest bar or wire used.

A_c = area of core of spirally reinforced compression member measured to outside diameter of spiral, square inches (mm^2).

A_g = gross area of section, square inches (mm^2).

A_s = area of nonprestressed tension reinforcement, square inches (mm^2).

$A_{s,min}$ = minimum amount of flexural reinforcement, inches squared (mm^2). See Section 1910.5.

A_{sk} = area of skin reinforcement per unit height in one side face, square inches per foot (mm^2/m).

A_{st} = total area of longitudinal reinforcement (bars or steel shapes), square inches (mm^2).

A_t = area of structural steel shape, pipe or tubing in a composite section, square inches (mm^2).

A_1 = loaded area.

A_2 = the area of the lower base of the largest frustum of a pyramid, cone, or tapered wedge contained wholly within the support and having for its upper base the loaded area, and having side slopes of 1 unit vertical in 2 units horizontal (50% slope).

a = depth of equivalent rectangular stress block as defined in Section 1910.2.7.1.

b = width of compression face of member, inches (mm).

b_w = web width, inches (mm).

C_m = a factor relating actual moment diagram to an equivalent uniform moment diagram.

c = distance from extreme compression fiber to neutral axis, inches (mm).

d = distance from extreme compression fiber to centroid of tension reinforcement, inches (mm).

d_c = thickness of concrete cover measured from extreme tension fiber to center of bar or wire located closest thereto, inches (mm).

d_t = distance from extreme compression fiber to extreme tension steel, inches (mm).

E_c = modulus of elasticity of concrete, pounds per square inch (MPa). See Section 1908.5.1.

E_s = modulus of elasticity of reinforcement, pounds per square inch (MPa). See Sections 1908.5.2 and 1908.5.3.

EI = flexural stiffness of compression member. See Formula (10-9).

f'_c = specified compressive strength of concrete, pounds per square inch (MPa).

f_s = calculated stress in reinforcement at service loads, kips per square inch (MPa).

f_y = specified yield strength of nonprestressed reinforcement, pounds per square inch (MPa).

h = overall dimension of member in direction of action considered, inches (mm).

I_g = moment of inertia of gross concrete section about centroidal axis, neglecting reinforcement.

I_{se} = moment of inertia of reinforcement about centroidal axis of member cross section.

I_t = moment of inertia of structural steel shape, pipe or tubing about centroidal axis of composite member cross section.

k = effective length factor for compression members.

l_c = length of a compression member in a frame, measured from center to center of the joints in the frame.

l_u = unsupported length of compression member.

M_c = factored moment to be used for design of compression member.

M_s = moment due to loads causing appreciable sway.

M_u = factored moment at section.

M_1 = smaller factored end moment on a compression member, positive if member is bent in single curvature, negative if bent in double curvature.

M_{1ns} = factored end moment on a compression member at the end at which M_1 acts, due to loads that cause no appreciable sidesway, calculated using a first-order elastic frame analysis.

M_{1s} = factored end moment on compression members at the end at which M_1 acts, due to loads that cause appreciable sidesway, calculated using a first-order elastic frame analysis.

M_2 = larger factored end moment on compression member, always positive.

$M_{2,min}$ = minimum value of M_2.

M_{2ns} = factored end moment on compression member at the end at which M_2 acts, due to loads that cause no appreciable sidesway, calculated using a first-order elastic frame analysis.

M_{2s} = factored end moment on compression member at the end at which M_2 acts, due to loads that cause appreciable sidesway, calculated using a first-order elastic frame analysis.

P_b = nominal axial load strength at balanced strain conditions. See Section 1910.3.2.

P_c = critical load. See Formula (10-9).

P_n = nominal axial load strength at given eccentricity.

P_o = nominal axial load strength at zero eccentricity.

P_u = factored axial load at given eccentricity $\leq \phi P_n$.

Q = stability index for a story. See Section 1910.11.4.

r = radius of gyration of cross section of a compression member.

V_u = factored horizontal shear in a story.

z = quantity limiting distribution of flexural reinforcement. See Section 1910.6.

β_1 = factor defined in Section 1910.2.7.3.

β_d = (a) for nonsway frames, β_d is the ratio of the maximum factored axial dead load to the total factored axial load.

= (b) for sway frames, except as required in Item 3, β_d is the ratio of the maximum factored sustained shear within a story to the total factored shear in that story.

= (c) for stability checks of sway frames carried out in accordance with Section 1910.13.6, β_d is the ratio of the maximum factored sustained axial load to the total factored axial load.

Δ_o = relative lateral deflection between the top and bottom of a story due to V_u, computed using a first-order elastic frame analysis and stiffness values satisfying Section 1910.11.1.

δ_{ns} = moment magnification factor for frames braced against sidesway to reflect effects of member curvature between ends of compression members.

δ_s = moment magnification factor for frames not braced against sidesway to reflect lateral drift resulting from lateral and gravity loads.

ε_t = net tensile strain in extreme tension steel at nominal strength.

ρ = ratio of nonprestressed tension reinforcement.

= A_s/bd.

ρ_b = reinforcement ratio producing balanced strain conditions. See Section 1910.3.2.

ρ_s = ratio of volume of spiral reinforcement to total volume of core (out-to-out of spirals) of a spirally reinforced compression member.

ϕ = strength-reduction factor. See Section 1909.3.

ϕ_k = stiffness reduction factor.

1910.1 Scope. Provisions of Section 1910 shall apply for design of members subject to flexure or axial loads or to combined flexure and axial loads.

1910.2 Design Assumptions.

1910.2.1 Strength design of members for flexure and axial loads shall be based on assumptions given in *the following items* and on satisfaction of applicable conditions of equilibrium and compatibility of strains.

1910.2.2 Strain in reinforcement and concrete shall be assumed directly proportional to the distance from the neutral axis, except, for deep flexural members with overall depth-to-clear-span ratios greater than two fifths for continuous spans and four fifths for simple spans, a nonlinear distribution of strain shall be considered. See Section 1910.7.

1910.2.3 Maximum usable strain at extreme concrete compression fiber shall be assumed equal to 0.003.

1910.2.4 Stress in reinforcement below specified yield strength f_y for grade of reinforcement used shall be taken as E_s times steel strain. For strains greater than that corresponding to f_y, stress in reinforcement shall be considered independent of strain and equal to f_y.

1910.2.5 Tensile strength of concrete shall be neglected in axial and flexural calculations of reinforced concrete, except where meeting requirements of Section 1918.4.

1910.2.6 Relationship between concrete compressive stress distribution and concrete strain shall be assumed to be rectangular, trapezoidal, parabolic or any other shape that results in prediction of strength in substantial agreement with results of comprehensive tests.

1910.2.7 Requirements of Section 1910.2.6 may be considered satisfied by an equivalent rectangular concrete stress distribution defined by the following:

1910.2.7.1 Concrete stress of $0.85f'_c$ shall be assumed uniformly distributed over an equivalent compression zone bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance $a = \beta_1 c$ from the fiber of maximum compressive strain.

1910.2.7.2 Distance c from fiber of maximum strain to the neutral axis shall be measured in a direction perpendicular to the axis.

1910.2.7.3 Factor β_1 shall be taken as 0.85 for concrete strengths f'_c up to and including 4,000 psi (27.58 MPa). For strengths above 4,000 psi (27.58 MPa), β_1 shall be reduced continuously at a rate of 0.05 for each 1,000 psi (6.89 MPa) of strength in excess of 4,000 psi (27.58 MPa), but β_1 shall not be taken less than 0.65.

1910.3 General Principles and Requirements.

1910.3.1 Design of cross section subject to flexure or axial loads or to combined flexure and axial loads shall be based on stress and strain compatibility using assumptions in Section 1910.2.

1910.3.2 Balanced strain conditions exist at a cross section when tension reinforcement reaches the strain corresponding to its specified yield strength f_y just as concrete in compression reaches its assumed ultimate strain of 0.003.

1910.3.3 For flexural members, and for members subject to combined flexure and compressive axial load when the design axial load strength ϕP_n is less than the smaller of 0.10 $f'_c A_g$ or ϕP_b, the ratio of reinforcement ρ provided shall not exceed 0.75 of the ratio ρ_b that would produce balanced strain conditions for the section under flexure without axial load. For members with compression reinforcement, the portion of ρ_b equalized by compression reinforcement need not be reduced by the 0.75 factor.

1910.3.4 Use of compression reinforcement shall be permitted in conjunction with additional tension reinforcement to increase the strength of flexural members.

1910.3.5 Design axial load strength ϕP_n of compression members shall not be taken greater than the following:

1910.3.5.1 For nonprestressed members with spiral reinforcement conforming to Section 1907.10.4 or composite members conforming to Section 1910.16:

$$\phi P_{n(max.)} = 0.85\phi[0.85f'_c(A_g - A_{st}) + f_y A_{st}] \quad (10\text{-}1)$$

1910.3.5.2 For nonprestressed members with tie reinforcement conforming to Section 1907.10.5:

$$\phi P_{n(max.)} = 0.80\phi[0.85f'_c(A_g - A_{st}) + f_y A_{st}] \quad (10\text{-}2)$$

1910.3.5.3 For prestressed members, design axial load strength ϕP_n shall not be taken greater than 0.85 (for members with spiral reinforcement) or 0.80 (for members with tie reinforcement) of the design axial load strength at zero eccentricity ϕP_o.

1910.3.6 Members subject to compressive axial load shall be designed for the maximum moment that can accompany the axial load. The factored axial load P_u at given eccentricity shall not exceed that given in Section 1910.3.5. The maximum factored moment M_u shall be magnified for slenderness effects in accordance with Section 1910.10.

1910.4 Distance between Lateral Supports of Flexural Members.

1910.4.1 Spacing of lateral supports for a beam shall not exceed 50 times the least width b of compression flange or face.

1910.4.2 Effects of lateral eccentricity of load shall be taken into account in determining spacing of lateral supports.

1910.5 Minimum Reinforcement of Flexural Members.

1910.5.1 At every section of a flexural member where tensile reinforcement is required by analysis, except as provided in Sections 1910.5.2, 1910.5.3 and 1910.5.4, the area A_s provided shall not be less than that given by:

$$A_{s,\min} = \frac{3\sqrt{f'_c}}{f_y} b_w d \text{ and not less than } \frac{200 b_w d}{f_y} \quad (10\text{-}3)$$

1910.5.2 For a statically determinate T-section with flange in tension, the area $A_{s,min}$ shall be equal to or greater than the smaller value given either by:

$$A_{s,\min} = \frac{6\sqrt{f'_c}}{f_y} b_w d \quad (10\text{-}4)$$

or Formula (10-3) with b_w set equal to the width of the flange.

1910.5.3 The requirements of Sections 1910.5.1 and 1910.5.2 need not be applied if at every section the area of tensile reinforcement provided is at least one-third greater than that required by analysis.

1910.5.4 For structural slabs and footings of uniform thickness, the minimum area of tensile reinforcement in the direction of span shall be the same as that required by Section 1907.12. Maximum spacing of this reinforcement shall not exceed the lesser of three times the thickness and 18 inches (457 mm).

1910.6 Distribution of Flexural Reinforcement in Beams and One-way Slabs.

1910.6.1 The rules for distribution of flexural reinforcement to control flexural cracking in beams and in one-way slabs (slabs reinforced to resist flexural stresses in only one direction) are as follows:

1910.6.2 Distribution of flexural reinforcement in two-way slabs shall be as required by Section 1913.3.

1910.6.3 Flexural tension reinforcement shall be well distributed within maximum flexural tension zones of a member cross section as required by Section 1910.6.4.

1910.6.4 When design yield strength f_y for tension reinforcement exceeds 40,000 psi (275.8 MPa), cross sections of maximum positive and negative moment shall be so proportioned that the quantity *z* given by:

$$z = f_s \sqrt[3]{d_c A} \qquad (10\text{-}5)$$

does not exceed 175 kips per inch (30.6 MN/m) for interior exposure and 145 kips per inch (25.4 MN/m) for exterior exposure. Calculated stress in reinforcement at service load f_s (kips per square inch) (MPa) shall be computed as the moment divided by the product of steel area and internal moment arm. Alternatively, it shall be permitted to take f_s as 60 percent of specified yield strength f_y.

1910.6.5 Provisions of Section 1910.6.4 may not be sufficient for structures subject to very aggressive exposure or designed to be watertight. For such structures, special investigations and precautions are required.

1910.6.6 Where flanges of T-beam construction are in tension, part of the flexural tension reinforcement shall be distributed over an effective flange width as defined in Section 1908.10, or a width equal to one tenth the span, whichever is smaller. If the effective flange width exceeds one tenth the span, some longitudinal reinforcement shall be provided in the outer portions of the flange.

1910.6.7 If the effective depth *d* of a beam or joist exceeds 36 inches (914 mm), longitudinal skin reinforcement shall be uniformly distributed along both side faces of the member for a distance *d*/2 nearest the flexural tension reinforcement. The area of skin reinforcement, A_{sk}, per foot (per mm) of height on each side face shall be $\geq$ 0.012 (d – 30) [For **SI:** $\geq$ 0.012 (d – 762)]. The maximum spacing of the skin reinforcement shall not exceed the lesser of *d*/6 and 12 inches (305 mm). It shall be permitted to include such reinforcement in strength computations if a strain compatibility analysis is made to determine stresses in the individual bars or wires. The total area of longitudinal skin reinforcement in both faces need not exceed one half of the required flexural tensile reinforcement.

1910.7 Deep Flexural Members.

1910.7.1 Flexural members with overall depth-to-clear-span ratios greater than two fifths for continuous spans, or four fifths for simple spans, shall be designed as deep flexural members, taking into account nonlinear distribution of strain and lateral buckling.

1910.7.2 Shear strength of deep flexural members shall be in accordance with Section 1911.8.

1910.7.3 Minimum flexural tension reinforcement shall conform to Section 1910.5.

1910.7.4 Minimum horizontal and vertical reinforcement in the side faces of deep flexural members shall be the greater of the requirements of Sections 1911.8.8 and 1911.8.9 or Sections 1914.3.2 and 1914.3.3.

1910.8 Design Dimensions for Compression Members.

1910.8.1 Isolated compression member with multiple spirals. Outer limits of the effective cross section of a compression member with two or more interlocking spirals shall be taken at a distance outside the extreme limits of the spirals equal to the minimum concrete cover required by Section 1907.7.

1910.8.2 Compression member built monolithically with wall. Outer limits of the effective cross section of a spirally reinforced or tied reinforced compression member built monolithically with a concrete wall or pier shall be taken not greater than $1^1/_2$ inches (38 mm) outside the spiral or tie reinforcement.

1910.8.3 As an alternate to using the full gross area for design of a compressive member with a square, octagonal or other shaped cross section, it shall be permitted to use a circular section with a diameter equal to the least lateral dimension of the actual shape.

1910.8.4 Limits of section. For a compression member with a cross section larger than required by considerations of loading, it shall be permitted to base the minimum reinforcement and *design* strength on a reduced effective area A_g not less than one half the total area. This provision shall not apply in Seismic Zones 3 and 4.

1910.9 Limits for Reinforcement of Compression Members.

1910.9.1 Area of longitudinal reinforcement for noncomposite compression members shall not be less than 0.01 or more than 0.08 times gross area A_g of section.

1910.9.2 Minimum number of longitudinal bars in compression members shall be four for bars within rectangular or circular ties, three for bars within triangular ties, and six for bars enclosed by spirals conforming to *the following ratio:*

1910.9.3 Ratio of spiral reinforcement ρ_s shall not be less than the value given by

$$\rho_s = 0.45\left(\frac{A_g}{A_c} - 1\right)\frac{f'_c}{f_y} \qquad (10\text{-}6)$$

where f_y is the specified yield strength of spiral reinforcement but not more than 60,000 psi (413.7 MPa).

1910.10 Slenderness Effects in Compression Members.

1910.10.1 Except as allowed in Section 1910.10.2, the design of compression members, restraining beams and other supporting members shall be based on the factored forces and moments from a second order analysis considering materials nonlinearity and cracking, as well as the effects of member curvature and lateral drift, duration of loads, shrinkage and creep, and interaction with the supporting foundation. The dimensions of each member cross section used in the analysis shall be within 10 percent of the dimensions of the members shown on the design drawings and the analysis shall be repeated. The analysis procedure shall have been shown to result in prediction of strength in substantial agreement with the results of comprehensive tests of columns in statically indeterminate reinforced concrete structures.

1910.10.2 As an alternate of the procedure prescribed in Section 1910.10.1, it shall be permitted to base the design of compression members, restraining beams, and other supporting members on axial forces and moments from the analyses described in Section 1910.11.

1910.11 Magnified Moments—General.

1910.11.1 The factored axial forces, P_u, the factored moments, M_1 and M_2, at the ends of the column and, where required, the relative lateral story deflections, Δ_o, shall be computed using an elastic first-order frame analysis with the section properties determined taking into account the influence of axial loads, the presence of cracked regions along the length of the member and effects of duration of loads. Alternatively, it shall be permitted to use the following properties for the members in the structure:

1. Modulus of elasticity = E_c from Section 1908.5.1.
2. Moment of inertia:

Beams	$0.35\ I_g$
Columns	$0.70\ I_g$
Walls—Uncracked	$0.70\ I_g$
—Cracked	$0.35\ I_g$
Flat plates and flat slabs	$0.25\ I_g$

3. Area 1.0 A_g

The moments of inertia shall be divided by (1 + $ß_d$) when:

1. sustained lateral loads act, or for
2. stability checks made in accordance with Section 1910.13.6.

1910.11.2 It shall be permitted to take the radius of gyration, r, equal to 0.30 times the overall dimension of the direction stability is being considered for rectangular compression members and 0.25 times the diameter for circular compression members. For other shapes, it shall be permitted to compute the radius of gyration for the gross concrete section.

1910.11.3 Unsupported length of compression members.

1910.11.3.1 The unsupported length l_u of a compression member shall be taken as the clear distance between floor slabs, beams or other members capable of providing lateral support in the direction being considered.

1910.11.3.2 Where column capitals or haunches are present, the unsupported length shall be measured to the lower extremity of the capital or haunch in the plane considered.

1910.11.4 Columns and stories in structures shall be designated as nonsway or sway columns or stories. The design of columns in nonsway frames or stories shall be based on Section 1910.12. The design of columns in sway frames or stories shall be based on Section 1910.13.

1910.11.4.1 It shall be permitted to assume a column in a structure is nonsway if the increase in column end moments due to second-order effects does not exceed 5 percent of the first-order end moments.

1910.11.4.2 It also shall be permitted to assume a story within a structure is nonsway if:

$$Q = \frac{\sum P_u \Delta_o}{V_u l_c} \text{ is less than or equal to 0.05,} \qquad (10\text{-}7)$$

where ΣP_u and V_u are the total vertical load and the story shear, respectively, in the story in question and Δ_o is the first-order relative deflection between the top and bottom of that story due to V_u.

1910.11.5 Where an individual compression member in the frame has a slenderness, kl_u/r, of more than 100, Section 1910.10.1 shall be used to compute the forces and moments in the frame.

1910.11.6 For compression members subject to bending about both principal axes, the moment about each axis shall be magnified separately based on the conditions of restraint corresponding to that axis.

1910.12 Magnified Moments—Nonsway Frames.

1910.12.1 For compression members in nonsway frames, the effective length factor k shall be taken as 1.0, unless analysis shows that a lower value is justified. The calculation of k shall be based on the E and I values used in Section 1910.11.1.

1910.12.2 In nonsway frames, it shall be permitted to ignore slenderness effect for compression members which satisfy:

$$\frac{kl_u}{r} \leq 34 - 12\ (M_1/M_2) \qquad (10\text{-}8)$$

where M_1/M_2 is not taken less than –0.5. The term M_1/M_2 is positive if the column is bent in single curvature.

1910.12.3 Compression members shall be designed for the factored axial load, P_u, and the moment amplified for the effects of member curvature, M_c, as follows:

$$M_c = \delta_{ns} M_2 \qquad (10\text{-}9)$$

WHERE:

$$\delta_{ns} = \frac{C_m}{1 - \frac{P_u}{0.75P_c}} \geq 1.0 \qquad (10\text{-}10)$$

$$P_c = \frac{\pi^2 EI}{(kl_u)^2} \qquad (10\text{-}11)$$

EI shall be taken as

$$EI = \frac{(0.2E_c I_g + E_s I_{se})}{1 + \beta_d} \qquad (10\text{-}12)$$

or

$$EI = \frac{0.40E_c\ I_g}{1 + \beta_d} \qquad (10\text{-}13)$$

1910.12.3.1 For members without transverse loads between supports, C_m shall be taken as

$$C_m = 0.6 + 0.4\frac{M_1}{M_2} \geq 0.4 \qquad (10\text{-}14)$$

where M_1/M_2 is positive if the column is bent in single curvature. For members with transverse loads between supports, C_m shall be taken as 1.0.

1910.12.3.2 The factored moment M_2 in Formula (10-9) shall not be taken less than

$$M_{2,\min} = P_u\ (0.6 + 0.03h) \qquad (10\text{-}15)$$

about each axis separately, where 0.6 and h are in inches. For members for which $M_{2,min}$ exceeds M_2, the value of C_m in Formula (10-14) shall either be taken equal to 1.0, or shall be based on the ratio of the computed end moments M_1 and M_2.

1910.13 Magnified Moments—Sway Frames.

1910.13.1 For compression members not braced against sidesway, the effective length factor k shall be determined using E and I values in accordance with Section 1910.11.1 and shall be greater than 1.0.

1910.13.2 For compression members not braced against sidesway, effects of slenderness may be neglected when kl_u/r is less than 22.

1910.13.3 The moments M_1 and M_2 at the ends of an individual compression member shall be taken as

$$M_1 = M_{1ns} + \delta_s M_{1s} \qquad (10\text{-}16)$$

$$M_2 = M_{2ns} + \delta_s M_{2s} \qquad (10\text{-}17)$$

where $\delta_s M_s$ and $\delta_s M_{2s}$ shall be computed according to Section 1910.13.4.

1910.13.4 Calculation of $\delta_s M_s$.

1910.13.4.1 The magnified sway moments $\delta_s M_s$ shall be taken as the column end moments calculated using a second-order elastic analysis based on the member stiffnesses given in Section 1910.11.1.

1910.13.4.2 Alternatively, it shall be permitted to calculate $\delta_s M_s$ as

$$\delta_s M_s = \frac{M_s}{1 - Q} \geq M_s \qquad (10\text{-}18)$$

If δ_s calculated in this way exceeds 1.5, $\delta_s M_s$ shall be calculated using Section 1910.13.4.1 or 1910.13.4.3.

1910.13.4.3 Alternatively, it shall be permitted to calculate the magnified sway moment $\delta_s M_s$ as

$$\delta_s M_s = \frac{M_s}{1 - \frac{\Sigma P_u}{0.75 \Sigma P_c}} \geq M_s \qquad (10\text{-}19)$$

where ΣP_u is the summation for all the vertical loads in a story and ΣP_c is the summation for all sway resisting columns in a story, P_c is calculated using Formula (10-11) using k from Section 1910.13.1 and EI from Formula (10-12) or (10-13).

1910.13.5 If an individual compression member has

$$\frac{l_u}{r} > \frac{35}{\sqrt{\frac{P_u}{f'_c A_g}}} \qquad (10\text{-}20)$$

it shall be designed for the factored axial load, P_u, and the moment, M_c, calculated using Section 1910.12.3 in which M_1 and M_2 are computed in accordance with Section 1910.13.3, β_d as defined for the load combination under consideration and k as defined in Section 1910.12.1.

1910.13.6 In addition to load cases involving lateral loads, the strength and stability of the structure as a whole under factored gravity loads shall be considered.

1. When $\delta_s M_s$ is computed from Section 1910.13.4.1, the ratio of second-order lateral deflections to first-order lateral deflections for 1.4 dead load and 1.7 live load plus lateral load applied to the structure shall not exceed 2.5.

2. When $\delta_s M_s$ is computed according to Section 1910.13.4.2, the value of Q computed using ΣP_u for 1.4 dead load plus 1.7 live load shall not exceed 0.60.

3. When $\delta_s M_s$ is computed from Section 1910.13.4.3, δ_s computed using ΣP_u and ΣP_c corresponding to the factored dead and live loads shall be positive and shall not exceed 2.5.

In cases 1, 2 and 3 above, β_d shall be taken as the ratio of the maximum factored sustained axial load to the total factored axial load.

1910.13.7 In sway frames, flexural members shall be designed for the total magnified end moments of the compression members at the joint.

1910.14 Axially Loaded Members Supporting Slab System. Axially loaded members supporting slab system included within the scope of Section 1913.1 shall be designed as provided in Section 1910 and in accordance with the additional requirements of Section 1913.

1910.15 Transmission of Column Loads through Floor System. When the specified compressive strength of concrete in a column is greater than 1.4 times that specified for a floor system, transmission of load through the floor system shall be provided by one of the following:

1910.15.1 Concrete of strength specified for the column shall be placed in the floor at the column location. Top surface of the column concrete shall extend 2 feet (610 mm) into the slab from face of column. Column concrete shall be well integrated with floor concrete, and shall be placed in accordance with Sections 1906.4.5 and 1906.4.6.

1910.15.2 Strength of a column through a floor system shall be based on the lower value of concrete strength with vertical dowels and spirals as required.

1910.15.3 For columns laterally supported on four sides by beams of approximately equal depth or by slabs, strength of the column may be based on an assumed concrete strength in the column joint equal to 75 percent of column concrete strength plus 35 percent of floor concrete strength.

1910.16 Composite Compression Members.

1910.16.1 Composite compression members shall include all such members reinforced longitudinally with structural steel shapes, pipe or tubing with or without longitudinal bars.

1910.16.2 Strength of a composite member shall be computed for the same limiting conditions applicable to ordinary reinforced concrete members.

1910.16.3 Any axial load strength assigned to concrete of a composite member shall be transferred to the concrete by members or brackets in direct bearing on the composite member concrete.

1910.16.4 All axial load strength not assigned to concrete of a composite member shall be developed by direct connection to the structural steel shape, pipe or tube.

1910.16.5 For evaluation of slenderness effects, radius of gyration of a composite section shall not be greater than the value given by:

$$r = \sqrt{\frac{(E_c I_g/5) + E_s I_t}{(E_c A_g/5) + E_s A_t}} \qquad (10\text{-}21)$$

and, as an alternative to a more accurate calculation, EI in Formula (10-11) shall be taken either as Formula (10-12) or

$$EI = \frac{E_c I_g/5}{1 + \beta_d} + E_s I_t \qquad (10\text{-}22)$$

1910.16.6 Structural steel-encased concrete core.

1910.16.6.1 For a composite member with concrete core encased by structural steel, thickness of the steel encasement shall not be less than

$$b\sqrt{\frac{f_y}{3E_s}}, \text{ for each face of width } b$$

nor

$$h\sqrt{\frac{f_y}{8E_s}}, \text{ for circular sections of diameter } h$$

1910.16.6.2 Longitudinal bars located within the encased concrete core shall be permitted to be used in computing A_t and I_t.

1910.16.7 Spiral reinforcement around structural steel core. A composite member with spirally reinforced concrete around a structural steel core shall conform to the following:

1910.16.7.1 Specified compressive strength of concrete f'_c shall not be less than 2,500 psi (17.24 MPa).

1910.16.7.2 Design yield strength of structural steel core shall be the specified minimum yield strength for grade of structural steel used but not to exceed 50,000 psi (344.7 MPa).

1910.16.7.3 Spiral reinforcement shall conform to Section 1910.9.3.

1910.16.7.4 Longitudinal bars located within the spiral shall not be less than 0.01 or more than 0.08 times net area of concrete section.

1910.16.7.5 Longitudinal bars located within the spiral shall be permitted to be used in computing A_t and I_t.

1910.16.8 Tie reinforcement around structural steel core. A composite member with laterally tied concrete around a structural steel core shall conform to the following:

1910.16.8.1 Specified compressive strength of concrete f'_c shall not be less than 2,500 psi (17.24 MPa).

1910.16.8.2 Design yield strength of structural steel core shall be the specified minimum yield strength for grade of structural steel used but not to exceed 50,000 psi (344.7 MPa).

1910.16.8.3 Lateral ties shall extend completely around the structural steel core.

1910.16.8.4 Lateral ties shall have a diameter not less than $^1/_{50}$ times the greatest side dimension of composite member, except that ties shall not be smaller than No. 3 and are not required to be larger than No. 5. Welded wire fabric of equivalent area shall be permitted.

1910.16.8.5 Vertical spacing of lateral ties shall not exceed 16 longitudinal bar diameters, 48 tie bar diameters, or one half times the least side dimension of the composite member.

1910.16.8.6 Longitudinal bars located within the ties shall not be less than 0.01 or more than 0.08 times net area of concrete section.

1910.16.8.7 A longitudinal bar shall be located at every corner of a rectangular cross section, with other longitudinal bars spaced not farther apart than one half the least side dimension of the composite member.

1910.16.8.8 Longitudinal bars located within the ties shall be permitted to be used in computing A_t for strength but not in computing I_t for evaluation of slenderness effects.

1910.17 Bearing Strength.

1910.17.1 Design bearing strength on concrete shall not exceed ϕ $(0.85 f'_c A_1)$, except when the supporting surface is wider on all sides than the loaded area, design bearing strength on the loaded area shall be permitted to be multiplied by $\sqrt{A_2/A_1}$, but not more than 2.

1910.17.2 Section 1910.17 does not apply to posttensioning anchorages.

SECTION 1911 — SHEAR AND TORSION

1911.0 Notations.

A_c = area of concrete section resisting shear transfer, square inches (mm²).

A_{cp} = area enclosed by outside perimeter of concrete cross section, inches squared (mm²). See Section 1911.6.1.

A_f = area of reinforcement in bracket or corbel resisting factored moment $[V_u\, a + N_{uc}\,(h–d)]$, square inches (mm²).

A_g = gross area of section, square inches (mm²).

A_h = area of shear reinforcement parallel to flexural tension reinforcement, square inches (mm²).

A_l = total area of longitudinal reinforcement to resist torsion, square inches (mm²).

A_n = area of reinforcement in bracket or corbel resisting tensile force N_{uc}, square inches (mm²).

A_o = gross area enclosed by shear flow, inches squared (mm²).

A_{oh} = area enclosed by centerline of the outermost closed transverse torsional reinforcement, inches squared (mm²).

A_{ps} = area of prestressed reinforcement in tension zone, square inches (mm²).

A_s = area of nonprestressed tension reinforcement, square inches (mm²).

A_t = area of one leg of a closed stirrup resisting torsion within a distance s, square inches (mm²).

A_v = area of shear reinforcement within a distance s, or area of shear reinforcement perpendicular to flexural tension reinforcement within a distance s for deep flexural members, square inches (mm²).

A_{vf} = area of shear-friction reinforcement, square inches (mm²).

A_{vh} = area of shear reinforcement parallel to flexural tension reinforcement within a distance s_2, square inches (mm²).

a = shear span, distance between concentrated load and face of supports.

b = width of compression face of member, inches (mm).

b_o = perimeter of critical section for slabs and footings, inches (mm).

b_t = width of that part of cross section containing the closed stirrups resisting torsion.

b_w = web width, or diameter of circular section, inches (mm).

b_1 = width of the critical section defined in Section 1911.12.6.1 measured in the direction of the span for which moments are determined, inches (mm).

b_2 = width of the critical section defined in Section 1911.12.6.1 measured in the direction perpendicular to b_1, inches (mm).

c_1 = size of rectangular or equivalent rectangular column, capital or bracket measured in the direction of the span for which moments are being determined, inches (mm).

c_2 = size of rectangular or equivalent rectangular column, capital or bracket measured transverse to the direction of the span for which moments are being determined, inches (mm).

d = distance from extreme compression fiber to centroid of longitudinal tension reinforcement, but need not be less than $0.80h$ for prestressed members, inches (mm). (For circular sections, d need not be less than the distance from extreme compression fiber to centroid of tension reinforcement in opposite half of member.)

f'_c = specified compressive strength of concrete, pounds per square inch (MPa).

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, pounds per square inch (MPa).

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, pounds per square inch (MPa).

f_d = stress due to unfactored dead load, at extreme fiber of section where tensile stress is caused by externally applied loads, pounds per square inch (MPa).

f_{pc} = compressive stress in concrete (after allowance for all prestress losses) at centroid of cross section resisting externally applied loads or at junction of web and flange when the centroid lies within the flange, pounds per square inch (MPa). (In a composite member, f_{pc} is resultant compressive stress at centroid of composite section, or at junction of web and flange when the centroid lies within the flange, due to both prestress and moments resisted by precast member acting alone.)

f_{pe} = compressive stress in concrete due to effective prestress forces only (after allowance for all prestress losses) at extreme fiber of section where tensile stress is caused by externally applied loads, pounds per square inch (MPa).

f_{pu} = specified tensile strength of prestressing tendons, pounds per square inch (MPa).

f_y = specified yield strength of nonprestressed reinforcement, pounds per square inch (MPa).

f_{yl} = yield strength of longitudinal torsional reinforcement.

f_{yv} = yield strength of closed transverse torsional reinforcement.

h = overall thickness of member, inches (mm).

h_v = total depth of shearhead cross section, inches (mm).

h_w = total height of wall from base to top, inches (mm).

I = moment of inertia of section resisting externally applied factored loads.

l_n = clear span measured face to face of supports.

l_v = length of shearhead arm from centroid of concentrated load or reaction, inches (mm).

l_w = horizontal length of wall, inches (mm).

M_{cr} = moment causing flexural cracking at section due to externally applied loads. See Section 1911.4.2.1.

M_m = modified moment.

M_{max} = maximum factored moment at section due to externally applied loads.

M_p = required plastic moment strength of shearhead cross section.

M_u = factored moment at section.

M_v = moment resistance contributed by shearhead reinforcement.

N_u = factored axial load normal to cross section occurring simultaneously with V_u; to be taken as positive for compression, negative for tension, and to include effects of tension due to creep and shrinkage.

N_{uc} = factored tensile force applied at top of bracket or corbel acting simultaneously with V_u to be taken as positive for tension.

P_{cp} = outside perimeter of the concrete cross section, inches (mm).

Ph = perimeter of centerline of outermost closed transverse torsional reinforcement, inches (mm).

s = spacing of shear or torsion reinforcement in direction parallel to longitudinal reinforcement, inches (mm).

s_1 = spacing of vertical reinforcement in wall, inches (mm).

s_2 = spacing of shear or torsion reinforcement in direction perpendicular to longitudinal reinforcement—or spacing of horizontal reinforcement in wall, inches (mm).

T_n = nominal torsional moment strength.

T_u = factored torsional moment at section.

t = thickness of a wall of a hollow section, inches (mm).

V_c = nominal shear strength provided by concrete.

V_{ci} = nominal shear strength provided by concrete when diagonal cracking results from combined shear and moment.

V_{cw} = nominal shear strength provided by concrete when diagonal cracking results from excessive principal tensile stress in web.

V_d = shear force at section due to unfactored dead load.

V_i = factored shear force at section due to externally applied loads occurring simultaneously with M_{max}.

V_n = nominal shear strength.

V_p = vertical component of effective prestress force at section.

V_s = nominal shear strength provided by shear reinforcement.

V_u = factored shear force at section.

v_n = nominal shear stress, pounds per square inch (MPa). See Section 1911.12.6.2.

y_t = distance from centroidal axis of gross section, neglecting reinforcement, to extreme fiber in tension.

α = angle between included stirrups and longitudinal axis of member.

α_f = angle between shear-friction reinforcement and shear plane.

α_s = constant used to compute V_c in slabs and footings.

α_v = ratio of stiffness of shearhead arm to surrounding composite slab section. See Section 1911.12.4.5.

β_c = ratio of long side to short side of concentrated load or reaction area.

β_d = constant used to compute V_c in prestressed slabs.

γ_f = fraction of unbalanced moment transferred by flexure at slab-column connection. See Section 1913.5.3.2.

γ_v = fraction of unbalanced moment transferred by eccentricity of shear at slab-column connections. See Section 1911.12.6.1.

= $1 - \gamma_f$.

η = number of identical arms of shearhead.

μ = coefficient of friction. See Section 1911.7.4.3.

λ = correction factor related to unit weight of concrete.

ρ = ratio of nonprestressed tension reinforcement.

= A_s/bd.

ρ_h = ratio of horizontal shear reinforcement area to gross concrete area of vertical section.

ρ_n = ratio of vertical shear reinforcement area to gross concrete area of horizontal section.

ρ_w = $A_s/b_w d$.

θ = angle of compression diagonals in truss analogy for torsion.

ϕ = strength-reduction factor. See Section 1909.3.

1911.1 Shear Strength.

1911.1.1 Design of cross sections subject to shear shall be based on

$$\phi V_n \geq V_u \tag{11-1}$$

where V_u is factored shear force at section considered and V_n is nominal shear strength computed by

$$V_n = V_c + V_s \tag{11-2}$$

where V_c is nominal shear strength provided by concrete in accordance with Section 1911.3 or Section 1911.4, and V_s is nominal shear strength provided by shear reinforcement in accordance with Section 1911.5.6.

1911.1.1.1 In determining shear strength V_n, the effect of any openings in members shall be considered.

1911.1.1.2 In determining shear strength V_c, whenever applicable, effects of axial tension due to creep and shrinkage in restrained members shall be considered and effects of inclined flexural compression in variable-depth members shall be permitted to be included.

1911.1.2 The values of $\sqrt{f'_c}$ used in Section 1911 shall not exceed 100 psi (0.69 MPa).

> **EXCEPTION:** Values of $\sqrt{f'_c}$ greater than 100 psi (0.69 MPa) is allowed in computing V_c, V_{ci} and V_{cw} for reinforced or prestressed concrete beams and concrete joist construction having minimum web reinforcement equal to f'_c/5,000 (f'_c/34.47) times, but not more than three times the amounts required by Sections 1911.5.5.3, 1911.5.5.4 and 1911.6.5.2.

1911.1.3 Computations of maximum factored shear force V_u at supports in accordance with Section 1911.1.3.1 or 1911.1.3.2 shall be permitted when both of the following two conditions are satisfied:

1. Support reaction, in direction of applied shear, introduces compression into the end regions of member, and

2. No concentrated load occurs between face of support and location of critical section defined in *this section.*

1911.1.3.1 For nonprestressed members, sections located less than a distance d from face of support shall be permitted to be designed for the same shear V_u as that computed at a distance d.

1911.1.3.2 For prestressed members, sections located less than a distance $h/2$ from face of support shall be permitted to be designed for the same shear V_u as that computed at a distance $h/2$.

1911.1.4 For deep flexural members, brackets and corbels, walls and slabs and footings, the special provisions of Sections 1911.8 through 1911.12 shall apply.

1911.2 Lightweight Concrete.

1911.2.1 Provisions for shear strength V_c apply to normal-weight concrete. When lightweight aggregate concrete is used, one of the following modifications shall apply:

1911.2.1.1 When f_{ct} is specified and concrete is proportioned in accordance with Section 1905.2, provisions for V_c shall be modified by substituting $f_{ct}/6.7$ (For **SI:** $1.8\sqrt{f'_c}$) for $\sqrt{f'_c}$, but the value of $f_{ct}/6.7$ (For **SI:** $1.8\sqrt{f'_c}$) shall not exceed $\sqrt{f'_c}$.

1911.2.1.2 When f_{ct} is not specified, all values of $\sqrt{f'_c}$ affecting V_c, T_c and M_{cr} shall be multiplied by 0.75 for all-lightweight concrete and 0.85 for sand-lightweight concrete. Linear interpolation shall be permitted when partial sand replacement is used.

1911.3 Shear Strength Provided by Concrete for Nonprestressed Members.

1911.3.1 Shear strength V_c shall be computed by provisions of Sections 1911.3.1.1 through 1911.3.1.3 unless a more detailed calculation is made in accordance with Section 1911.3.2.

1911.3.1.1 For members subject to shear and flexure only,

$$V_c = 2\sqrt{f'_c}\,b_w d \tag{11-3}$$

For **SI:** $$V_c = 0.166\sqrt{f'_c}\,b_w d$$

1911.3.1.2 For members subject to axial compression,

$$V_c = 2\left(1 + \frac{N_u}{2,000\,A_g}\right)\sqrt{f'_c}\,b_w d \tag{11-4}$$

For **SI:** $$V_c = 0.166\left(1 + 0.073\frac{N_u}{A_g}\right)\sqrt{f'_c}\,b_w d$$

Quantity N_u/A_g shall be expressed in psi (MPa).

1911.3.1.3 For members subject to significant axial tension, shear reinforcement shall be designed to carry total shear, unless a more detailed analysis is made using Section 1911.3.2.3.

1911.3.2 Shear strength V_c shall be permitted to be computed by the more detailed calculation of Sections 1911.3.2.1 through 1911.3.2.3.

1911.3.2.1 For members subject to shear and flexure only,

$$V_c = \left(1.9\sqrt{f'_c} + 2,500\rho_w\frac{V_u d}{M_u}\right)b_w d \tag{11-5}$$

For **SI:** $$V_c = \left(0.158\sqrt{f'_c} + 17.1\rho_w\frac{V_u d}{M_u}\right)b_w d$$

but not greater than $3.5\sqrt{f'_c}\,b_w d$ (For **SI:** $0.29\sqrt{f'_c}\,b_w d$). Quantity $V_u d/M_u$ shall not be taken greater than 1.0 in computing V_c by Formula (11-5), where M_u is factored moment occurring simultaneously with V_u at section considered.

1911.3.2.2 For members subject to axial compression, it shall be permitted to compute V_c using Formula (11-5) with M_m substituted for M_u and $V_u d/M_u$ not then limited to 1.0, where

$$M_m = M_u - N_u\frac{(4h - d)}{8} \tag{11-6}$$

However, V_c shall not be taken greater than

$$V_c = 3.5\sqrt{f'_c}\,b_w d\sqrt{1 + \frac{N_u}{500A_g}} \tag{11-7}$$

For **SI:** $$V_c = 0.29\sqrt{f'_c}\,b_w d\sqrt{1 + 0.29\frac{N_u}{A_g}}$$

Quantity N_u/A_g shall be expressed in psi (MPa). When M_m as computed by Formula (11-6) is negative, V_c shall be computed by Formula (11-7).

1911.3.2.3 For members subject to significant axial tension,

$$V_c = 2\left(1 + \frac{N_u}{500A_g}\right)\sqrt{f'_c}\,b_w \tag{11-8}$$

For **SI:** $$V_c = 0.166\left(1 + 0.29\frac{N_u}{A_g}\right)\sqrt{f'_c}\,b_w d$$

but not less than zero, where N_u is negative for tension. Quantity N_u/A_g shall be expressed in psi (MPa).

1911.4 Shear Strength Provided by Concrete for Prestressed Members.

1911.4.1 For members with effective prestress force not less than 40 percent of the tensile strength of flexural reinforcement, unless a more detailed calculation is made in accordance with Section 1911.4.2.

$$V_c = \left(0.6\sqrt{f'_c} + 700\frac{V_u d}{M_u}\right) b_w d \qquad (11\text{-}9)$$

For **SI:** $$V_c = \left(0.05\sqrt{f'_c} + 4.8\frac{V_u d}{M_u}\right) b_w d$$

but V_c need not be taken less than $2\sqrt{f'_c}\, b_w d$ (For **SI:** $0.166\sqrt{f'_c}\, b_w d$) nor shall V_c be taken greater than $5\sqrt{f'_c}\, b_w d$ (For **SI:** $0.42\sqrt{f'_c}\, b_w d$) or the value given in Section 1911.4.3 or 1911.4.4. The quantity $V_u d/M_u$ shall not be taken greater than 1.0, where M_u is factored moment occurring simultaneously with V_u at section considered. When applying Formula (11-9), d in the term $V_u d/M_u$ shall be the distance from extreme compression fiber to centroid of prestressed reinforcement.

1911.4.2 Shear strength V_c shall be permitted to be computed in accordance with Sections 1911.4.2.1 and 1911.4.2.2 where V_c shall be the lesser of V_{ci} or V_{cw}.

1911.4.2.1 Shear strength V_{ci} shall be computed by

$$V_{ci} = 0.6\sqrt{f'_c}\, b_w d + V_d + \frac{V_i M_{cr}}{M_{max}} \qquad (11\text{-}10)$$

For **SI:** $$V_{ci} = 0.05\sqrt{f'_c}\, b_w d + V_d + \frac{V_i M_{cr}}{M_{max}}$$

but V_{ci} need not be taken less than $1.7\sqrt{f'_c}\, b_w d$ ($0.14\sqrt{f'_c}\, b_w d$), where

$$M_{cr} = (l/y_t)\,(6\sqrt{f'_c} + f_{pe} - f_d) \qquad (11\text{-}11)$$

For **SI:** $$M_{cr} = (l/y_t)\,(0.5\sqrt{f'_c} + f_{pe} - f_d)$$

and values of M_{max} and V_i shall be computed from the load combination causing maximum moment to occur at the section.

1911.4.2.2 Shear strength V_{cw} shall be computed by

$$V_{cw} = (3.5\sqrt{f'_c} + 0.3 f_{pc})\, b_w d + V_P \qquad (11\text{-}12)$$

For **SI:** $$V_{cw} = (0.29\sqrt{f'_c} + 0.3 f_{pc})\, b_w d + V_P$$

Alternatively, V_{cw} may be computed as the shear force corresponding to dead load plus live load that results in a principal tensile stress of $4\sqrt{f'_c}$ (For **SI:** $0.33\sqrt{f'_c}$) at centroidal axis of member, or at intersection of flange and web when centroidal axis is in the flange. In composite members, principal tensile stress shall be computed using the cross section that resists live load.

1911.4.2.3 In Formulas (11-10) and (11-12), d shall be the distance from extreme compression fiber to centroid of prestressed reinforcement or 0.8h, whichever is greater.

1911.4.3 In a pretensioned member in which the section at a distance h/2 from face of support is closer to end of member than the transfer length of the prestressing tendons, the reduced prestress shall be considered when computing V_{cw}. This value of V_{cw} shall also be taken as the maximum limit for Formula (11-9). Prestress force may be assumed to vary linearly from zero at end of tendon to a maximum at a distance from end of tendon equal to the transfer length, assumed to be 50 diameters for strand and 100 diameters for single wire.

1911.4.4 In a pretensioned member where bonding of some tendons does not extend to end of member, a reduced prestress shall be considered when computing V_c in accordance with Section 1911.4.1 or 1911.4.2. Value of V_{cw} calculated using the reduced prestress shall also be taken as the maximum limit for Formula (11-9). Prestress force due to tendons for which bonding does not extend to end of member may be assumed to vary linearly from zero at the point at which bonding commences to a maximum at a distance from this point equal to the transfer length, assumed to be 50 diameters for strand and 100 diameters for single wire.

1911.5 Shear Strength Provided by Shear Reinforcement.

1911.5.1 Types of shear reinforcement.

1911.5.1.1 Shear reinforcement consisting of the following shall be permitted:

1. Stirrups perpendicular to axis of member.
2. Welded wire fabric with wires located perpendicular to axis of member.

1911.5.1.2 For nonprestressed members, shear reinforcement shall be permitted to also consist of:

1. Stirrups making an angle of 45 degrees or more with longitudinal tension reinforcement.
2. Longitudinal reinforcement with bent portion making an angle of 30 degrees or more with the longitudinal tension reinforcement.
3. Combination of stirrups and bent longitudinal reinforcement.
4. Spirals.

1911.5.2 Design yield strength of shear reinforcement shall not exceed 60,000 psi (413.7 MPa), except that the design yield strength of welded deformed wire fabric shall not exceed 80,000 psi (551.6 MPa).

1911.5.3 Stirrups and other bars or wires used as shear reinforcement shall extend to a distance d from extreme compression fiber and shall be anchored at both ends according to Section 1912.13 to develop the design yield strength of reinforcement.

1911.5.4 Spacing limits for shear reinforcement.

1911.5.4.1 Spacing of shear reinforcement placed perpendicular to axis of member shall not exceed d/2 in nonprestressed members and ($^3/_4$)h in prestressed members or 24 inches (610 mm).

1911.5.4.2 Inclined stirrups and bent longitudinal reinforcement shall be so spaced that every 45-degree line, extending toward the reaction from middepth of member d/2 to longitudinal tension reinforcement, shall be crossed by at least one line of shear reinforcement.

1911.5.4.3 When V_s exceeds $4\sqrt{f'_c}\, b_w d$ (For **SI:** $0.33\sqrt{f'_c}\, b_w d$), maximum spacings given in the paragraphs above shall be reduced by one half.

1911.5.5 Minimum shear reinforcement.

1911.5.5.1 A minimum area of shear reinforcement shall be provided in all reinforced concrete flexural members (prestressed and nonprestressed) where factored shear force V_u exceeds one half the shear strength provided by concrete ϕV_c, except:

1. Slabs and footings.
2. Concrete joist construction defined by Section 1908.11.
3. Beams with total depth not greater than 10 inches (254 mm), two and one half times thickness of flange or one half the width of web, whichever is greater.

1911.5.5.2 Minimum shear reinforcement requirements of Section 1911.5.5.1 shall be waived if shown by test that required nominal flexural and shear strengths can be developed when shear reinforcement is omitted. Such tests shall simulate effects of differential settlement, creep, shrinkage and temperature change, based on a realistic assessment of such effects occurring in service.

1911.5.5.3 Where shear reinforcement is required by Section 1911.5.5.1 or for strength and where Section 1911.6.1 allows torsion to be neglected, the minimum area of shear reinforcement for prestressed (except as provided in Section 1911.5.5.4) and nonprestressed members shall be computed by:

$$A_v = 50\frac{b_w s}{f_y} \qquad (11\text{-}13)$$

For **SI:** $$A_v = 0.34\frac{b_w s}{f_y}$$

where b_w and s are in inches.

1911.5.5.4 For prestressed members with effective prestress force not less than 40 percent of the tensile strength of flexural reinforcement, the area of shear reinforcement shall not be less than the smaller A_v, computed by Formula (11-13) or (11-14).

$$A_v = \frac{A_{ps}}{80}\frac{f_{pu}}{f_y}\frac{s}{d}\sqrt{\frac{d}{b_w}} \qquad (11\text{-}14)$$

1911.5.6 Design of shear reinforcement.

1911.5.6.1 Where factored shear force V_u exceeds shear strength ϕV_c, shear reinforcement shall be provided to satisfy Formulas (11-1) and (11-2), where shear strength V_s shall be computed in accordance with Sections 1911.5.6.2 through 1911.5.6.8.

1911.5.6.2 When shear reinforcement perpendicular to axis of member is used,

$$V_s = \frac{A_v f_y d}{s} \qquad (11\text{-}15\text{-}1)$$

where A_v is the area of shear reinforcement within a distance s.

For circular columns, the area used to compute V_c shall be 0.8 A_g. The shear strength V_s provided by the circular transverse reinforcing shall be computed by

$$V_s = \frac{\pi \; A_b \; f_{yh} D'}{2 \; s} \qquad (11\text{-}15\text{-}2)$$

where A_b is the area of the hoop or spiral bar of yield strength f_{yh} with pitch s and hoop diameter D'.

1911.5.6.3 When inclined stirrups are used as shear reinforcement,

$$V_s = \frac{A_v f_y (\sin \alpha + \cos \alpha) d}{s} \qquad (11\text{-}16)$$

1911.5.6.4 When shear reinforcement consists of a single bar or a single group of parallel bars, all bent up at the same distance from the support,

$$V_s = A_v f_y \sin \alpha \qquad (11\text{-}17)$$

but not greater than $3\sqrt{f'_c}\, b_w d$ (For **SI:** $0.25\sqrt{f'_c}\, b_w d$).

1911.5.6.5 When shear reinforcement consists of a series of parallel bent-up bars or groups of parallel bent-up bars at different distances from the support, shear strength V_s shall be computed by Formula (11-16).

1911.5.6.6 Only the center three fourths of the inclined portion of any longitudinal bent bar shall be considered effective for shear reinforcement.

1911.5.6.7 Where more than one type of shear reinforcement is used to reinforce the same portion of a member, shear strength V_s shall be computed as the sum of the V_s values computed for the various types.

1911.5.6.8 Shear strength V_s shall not be taken greater than $8\sqrt{f'_c}\, b_w d$ (For **SI:** $0.66\sqrt{f'_c}\, b_w d$).

1911.6 Design for Torsion.

1911.6.1 It shall be permitted to neglect torsion effects when the factored torsional moment T_u is less than:

1. for nonprestressed members:

$$\phi \sqrt{f'_c}\left(\frac{A_{cp}^2}{P_{cp}}\right)$$

2. for prestressed members:

$$\phi \sqrt{f'_c}\left(\frac{A_{cp}^2}{P_{cp}}\right)\sqrt{1 + \frac{f_{pc}}{4\sqrt{f'_c}}}$$

For members cast monolithically with a slab, the overhanging flange width used in computing A_{cp} and P_{cp} shall conform to Section 1913.2.4.

1911.6.2 Calculation of factored torsional moment T_u.

1911.6.2.1 If the factored torsional moment T_u in a member is required to maintain equilibrium and exceeds the minimum value given in Section 1911.6.1, the member shall be designed to carry that torsional moment in accordance with Sections 1911.6.3 through 1911.6.6.

1911.6.2.2 In a statically indeterminate structure where reduction of the torsional moment in a member can occur due to redistribution of internal forces upon cracking, the maximum factored torsional moment T_u shall be permitted to be reduced to

1. for nonprestressed members, at the sections described in Section 1911.6.2.4:

$$\phi_4 \sqrt{f'_c}\left(\frac{A_{cp}^2}{P_{cp}}\right)$$

2. for prestressed members, at the sections described in Section 1911.6.2.5:

$$\phi_4 \sqrt{f'_c}\left(\frac{A_{cp}^2}{P_{cp}}\right)\sqrt{1 + \frac{f_{pc}}{4\sqrt{f'_c}}}$$

In such a case, the correspondingly redistributed bending moments and shears in the adjoining members shall be used in the design of those members.

1911.6.2.3 Unless determined by a more exact analysis, it shall be permitted to take the torsional loading from a slab as uniformly distributed along the member.

1911.6.2.4 In nonprestressed members, sections located less than a distance d from the face of a support shall be designed for not less than the torsion T_u computed at a distance d. If a concentrated torque occurs within this distance, the critical section for design shall be at the face of the support.

1911.6.2.5 In prestressed members, sections located less than a distance $h/2$ from the face of a support shall be designed for not less than the torsion T_u computed at a distance $h/2$. If a concentrated torque occurs within this distance, the critical section for design shall be at the face of the support.

1911.6.3 Torsional moment strength.

1911.6.3.1 The cross-sectional dimensions shall be such that:

1. for solid sections:

$$\sqrt{\left(\frac{V_u}{b_w d}\right)^2 + \left(\frac{T_u p_h}{1.7A_{oh}^2}\right)^2} \leq \phi\left(\frac{V_c}{b_w d} + 8\sqrt{f'_c}\right) \quad \text{(11-18)}$$

2. for hollow sections:

$$\sqrt{\left(\frac{V_u}{b_w d}\right) + \left(\frac{T_u p_h}{1.7A_{oh}^2}\right)} \leq \phi\left(\frac{V_c}{b_w d} + 8\sqrt{f'_c}\right) \quad \text{(11-19)}$$

1911.6.3.2 If the wall thickness varies around the perimeter of a hollow section, Formula (11-19) shall be evaluated at the location where the left-hand side of Formula (11-19) is a maximum.

1911.6.3.3 If the wall thickness is less than A_{oh}/p_h, the second term in Formula (11-19) shall be taken as:

$$\left(\frac{T_u}{1.7\,A_{oh}t}\right)$$

where t is the thickness of the wall of the hollow section at the location where the stresses are being checked.

1911.6.3.4 Design yield strength of nonprestressed torsion reinforcement shall not exceed 60,000 psi (413.7 MPa).

1911.6.3.5 The reinforcement required for torsion shall be determined from:

$$\phi T_n \quad \geq \quad T_u \qquad \text{(11-20)}$$

1911.6.3.6 The transverse reinforcement for torsion shall be designed using:

$$T_n \quad = \quad \frac{2A_oA_t\ f_{yv}}{s}\ \cot\theta \qquad \text{(11-21)}$$

where A_o shall be determined by analysis except that it shall be permitted to take A_o equal to $0.85A_{oh}$; θ shall not be taken smaller than 30 degrees nor larger than 60 degrees. It shall be permitted to take θ equal to:

1. 45 degrees for nonprestressed members or members with less prestress than in Item 2 below,

2. 37.5 degrees for prestressed members with an effective prestress force not less than 40 percent of the tensile strength of the longitudinal reinforcement.

1911.6.3.7 The additional longitudinal reinforcement required for torsion shall not be less than:

$$A_l \quad = \quad \frac{A_t}{s}\ p_h\left(\frac{f_{yv}}{f_{yl}}\right)\ \cot^2\theta \qquad \text{(11-22)}$$

where θ shall be the same value used in Formula (11-21) and A_t/s shall be taken as the amount computed from Formula (11-21) not modified in accordance with Section 1911.6.5.2 or 1911.6.5.3.

1911.6.3.8 Reinforcement required for torsion shall be added to that required for the shear, moment and axial force that act in combination with the torsion. The most restrictive requirements for reinforcement spacing and placement must be met.

1911.6.3.9 It shall be permitted to reduce the area of longitudinal torsion reinforcement in the flexural compression zone by an amount equal to $M_u/(0.9df_{yl})$, where M_u is the factored moment acting at the section in combination with T_u, except that the reinforcement provided shall not be less than that required by Section 1911.6.5.3 or 1911.6.6.2.

1911.6.3.10 In prestressed beams:

1. The total longitudinal reinforcement including tendons at each section shall resist the factored bending moment at that section plus an additional concentric longitudinal tensile force equal to $A_l f_{yl}$, based on the factored torsion at that section, and

2. The spacing of the longitudinal reinforcement including tendons shall satisfy the requirements in Section 1911.6.6.2.

1911.6.3.11 In prestressed beams, it shall be permitted to reduce the area of longitudinal torsional reinforcement on the side of the member in compression due to flexure below that required by Section 1911.6.3.10 in accordance with Section 1911.6.3.9.

1911.6.4 Details of torsional reinforcement.

1911.6.4.1 Torsion reinforcement shall consist of longitudinal bars or tendons and one or more of the following:

1. Closed stirrups or closed ties, perpendicular to the axis of the member, or

2. A closed cage of welded wire fabric with transverse wires perpendicular to the axis of the member, or

3. In nonprestressed beams, spiral reinforcement.

1911.6.4.2 Transverse torsional reinforcement shall be anchored by one of the following:

1. A 135-degree standard hook around a longitudinal bar, or

2. According to Section 1912.13.2.1, 1912.13.2.2 or 1912.13.2.3 in regions where the concrete surrounding the anchorage is restrained against spalling by a flange or slab or similar member.

1911.6.4.3 Longitudinal torsion reinforcement shall be developed at both ends.

1911.6.4.4 For hollow sections in torsion, the distance measured from the centerline of the transverse torsional reinforcement to the inside face of the wall of a hollow section shall not be less than $0.5A_{oh}/p_h$.

1911.6.5 Minimum torsion reinforcement.

1911.6.5.1 A minimum area of torsion reinforcement shall be provided in all regions where the factored torsional moment T_u exceeds the values specified in Section 1911.6.1.

1911.6.5.2 Where torsional reinforcement is required by Section 1911.6.5.1, the minimum area of transverse closed stirrups shall be computed by:

$$(A_v \quad + \quad 2A_t) \quad \geq \quad \frac{50b_w s}{f_{yv}} \qquad \text{(11-23)}$$

1911.6.5.3 Where torsional reinforcement is required by Section 1911.6.5.1, the minimum total area of longitudinal torsional reinforcement shall be computed by:

$$A_{l,\min} \quad = \quad \frac{5\sqrt{f'_c}A_{cp}}{f_{yl}} \quad - \quad \left(\frac{A_t}{s}\right)\ p_h\ \frac{f_{yv}}{f_{yl}} \qquad \text{(11-24)}$$

where A_t/s shall not be taken less than $25b_w/f_{yv}$.

1911.6.6 Spacing of torsion reinforcement.

1911.6.6.1 The spacing of transverse torsion reinforcement shall not exceed the smaller of $p_h/8$ or 12 inches (305 mm).

1911.6.6.2 The longitudinal reinforcement required for torsion shall be distributed around the perimeter of the closed stirrups with a maximum spacing of 12 inches (305 mm). The longitudinal bars or tendons shall be inside the stirrups. There shall be at least one longitudinal bar or tendon in each corner of the stirrups. Bars shall have a diameter at least $^1/_{24}$ of the stirrup spacing but not less than a No. 3 bar.

1911.6.6.3 Torsion reinforcement shall be provided for a distance of at least (b_t + d) beyond the point theoretically required.

1911.7 Shear-friction.

1911.7.1 The following provisions shall be applied where it is appropriate to consider shear transfer across a given plane, such as an existing or potential crack, an interface between dissimilar materials, or an interface between two concretes cast at different times.

1911.7.2 Design of cross sections subject to shear transfer as described in Section 1911.7 shall be based on Formula (11-1) where V_n is calculated in accordance with provisions of Section 1911.7.3 or 1911.7.4.

1911.7.3 A crack shall be assumed to occur along the shear plane considered. Required area of shear-friction reinforcement A_{vf} across the shear plane may be designed using either Section 1911.7.4 or any other shear transfer design methods that result in prediction of strength in substantial agreement with results of comprehensive tests.

1911.7.3.1 Provisions of Sections 1911.7.5 through 1911.7.10 shall apply for all calculations of shear transfer strength.

1911.7.4 Shear-friction design methods.

1911.7.4.1 When shear-friction reinforcement is perpendicular to shear plane, shear strength V_n shall be computed by

$$V_n = A_{vf} f_y \mu \qquad (11\text{-}25)$$

where μ is coefficient of friction in accordance with Section 1911.7.4.3.

1911.7.4.2 When shear-friction reinforcement is inclined to shear plane such that the shear force produces tension in shear-friction reinforcement, shear strength V_n shall be computed by

$$V_n = A_{vf} f_y (\mu \sin \alpha_1 + \cos \alpha_1) \qquad (11\text{-}26)$$

where α_1 is angle between shear-friction reinforcement and shear plane.

1911.7.4.3 Coefficient of friction μ in Formula (11-25) and Formula (11-26) shall be

Concrete placed monolithically	1.4λ
Concrete placed against hardened concrete with surface intentionally roughened as specified in Section 1911.7.9	1.0λ
Concrete placed against hardened concrete not intentionally roughened	0.6λ
Concrete anchored to as-rolled structural steel by headed studs or by reinforcing bars (see Section 1911.7.10)	0.7λ

where λ = 1.0 for normal-weight concrete, 0.85 for sand-lightweight concrete and 0.75 for all-lightweight concrete. Linear interpolation shall be permitted when partial sand replacement is used.

1911.7.5 Shear strength V_n shall not be taken greater than $0.2f'_cA_c$ or 800 A_c in pounds (5.5 A_c in newtons), where A_c is area of concrete section resisting shear transfer.

1911.7.6 Design yield strength of shear-friction reinforcement shall not exceed 60,000 psi (413.7 MPa).

1911.7.7 Net tension across shear plane shall be resisted by additional reinforcement. Permanent net compression across shear plane shall be permitted to be taken as additive to the force in the shear-friction reinforcement $A_{vf}f_y$ when calculating required A_{vf}.

1911.7.8 Shear-friction reinforcement shall be appropriately placed along the shear plane and shall be anchored to develop the specified yield strength on both sides by embedment, hooks or welding to special devices.

1911.7.9 For the purpose of Section 1911.7, when concrete is placed against previously hardened concrete, the interface for shear transfer shall be clean and free of laitance. If μ is assumed equal to 1.0λ, interface shall be roughened to a full amplitude of approximately $^1/_4$ inch (6.4 mm).

1911.7.10 When shear is transferred between as-rolled steel and concrete using headed studs or welded reinforcing bars, steel shall be clean and free of paint.

1911.8 Special Provisions for Deep Flexural Members.

1911.8.1 Provisions of this section shall apply for members with l_n/d less than 5 that are loaded on one face and supported on the opposite face so that the compression struts can develop between the loads and the supports. See also Section 1912.10.6.

1911.8.2 The design of simple supported deep flexural members for shear shall be based on Formulas (11-1) and (11-2), where shear strength V_c shall be in accordance with Section 1911.8.6 or 1911.8.7, and shear strength V_s shall be in accordance with Section 1911.8.8.

1911.8.3 The design of continuous deep flexural members for shear shall be based on Sections 1911.1 through 1911.5 with Section 1911.8.5 substituted for Section 1911.1.3, or on methods satisfying equilibrium and strength requirements. In either case, the design shall also satisfy Sections 1911.8.4, 1911.8.9 and 1911.8.10.

1911.8.4 Shear strength V_n for deep flexural members shall not be taken greater than $8\sqrt{f'_c}b_wd$ (For **SI:** $0.66\sqrt{f'_c}b_wd$) when l_n/d is less than 2. When l_n/d is between 2 and 5,

$$V_n = \frac{2}{3}\left(10 + \frac{l_n}{d}\right)\sqrt{f'_c}b_wd \qquad (11\text{-}27)$$

For **SI:** $$V_n = 0.055\left(10 + \frac{l_n}{d}\right)\sqrt{f'_c}b_wd$$

1911.8.5 Critical section for shear measured from face of support shall be taken at a distance $0.15l_n$ for uniformly loaded beams and $0.50a$ for beams with concentrated loads, but not greater than d.

1911.8.6 Unless a more detailed calculation is made in accordance with Section 1911.8.7.

$$V_c = 2\sqrt{f'_c}b_wd \qquad (11\text{-}28)$$

For **SI:** $$V_c = 0.166\sqrt{f'_c}b_wd$$

1911.8.7 Shear strength V_c shall be permitted to be computed by

$$V_c = \left(3.5 - 2.5\frac{M_u}{V_u d}\right)\left(1.9\sqrt{f'_c} + 2{,}500\rho_w\frac{V_u d}{M_u}\right)b_w d \qquad (11\text{-}29)$$

For **SI:**

$$V_c = \left(3.5 - 2.5\frac{M_u}{V_u d}\right)\left(0.16\sqrt{f'_c} + 17.2\rho_w\frac{V_u d}{M_u}\right)b_w d$$

except that the term

$$\left(3.5 - 2.5\frac{M_u}{V_u d}\right)$$

shall not exceed 2.5, and V_c shall not be taken greater than $6\sqrt{f'_c}\,b_w d$ (For **SI:** $0.5\sqrt{f'_c}\,b_w d$). M_u is factored moment occurring simultaneously with V_u at the critical section defined in Section 1911.8.5.

1911.8.8 Where factored shear force V_u exceeds shear strength ϕV_c, shear reinforcement shall be provided to satisfy Formulas (11-1) and (11-2), where shear strength V_s shall be computed by

$$V_s = \left[\frac{A_v}{s}\left(\frac{1 + \frac{l_n}{d}}{12}\right) + \frac{A_{vh}}{s_2}\left(\frac{11 - \frac{l_n}{d}}{12}\right)\right]f_y d \qquad (11\text{-}30)$$

where A_v is area of shear reinforcement perpendicular to flexural tension reinforcement within a distance s, and A_{vh} is area of shear reinforcement parallel to flexural reinforcement within a distance s_2.

1911.8.9 Area of shear reinforcement A_v shall not be less than $0.0015\,b_w s$, and s shall not exceed d/5 or 18 inches (457 mm).

1911.8.10 Area of horizontal shear reinforcement A_{vh} shall not be less than $0.0025\,b_w s_2$, and s_2 shall not exceed d/3 or 18 inches (457 mm).

1911.8.11 Shear reinforcement required at the critical section defined in Section 1911.8.5 shall be used throughout the span.

1911.9 Special Provisions for Brackets and Corbels.

1911.9.1 The following provisions apply to brackets and corbels with a shear span-to-depth ratio a/d not greater than unity, and subject to a horizontal tensile force N_{uc} not larger than V_u. Distance d shall be measured at face of support.

1911.9.2 Depth at outside edge of bearing area shall not be less than $0.5d$.

1911.9.3 Section at face of support shall be designed to resist simultaneously a shear V_u, a moment $[V_u a + N_{uc}(h - d)]$, and a horizontal tensile force N_{uc}.

1911.9.3.1 In all design calculations in accordance with Section 1911.9, strength-reduction factor ϕ shall be taken equal to 0.85.

1911.9.3.2 Design of shear-friction reinforcement A_{vf} to resist shear V_u shall be in accordance with Section 1911.7.

1911.9.3.2.1 For normal-weight concrete, shear strength V_n shall not be taken greater than $0.2f'_c b_w d$ nor $800\,b_w d$ in pounds ($5.5\,b_w d$ in newtons).

1911.9.3.2.2 For all lightweight or sand-lightweight concrete, shear strength V_n shall not be taken greater than $(0.2 - 0.07\,a/d)\,f'_c b_w d$ or $(800 - 280\,a/d)\,b_w d$ in pounds [$(5.5 - 1.9\,a/d)\,b_w d$ in newtons].

1911.9.3.3 Reinforcement A_f to resist moment $[V_u a + N_{uc}(h–d)]$ shall be computed in accordance with Sections 1910.2 and 1910.3.

1911.9.3.4 Reinforcement A_n to resist tensile force N_{uc} shall be determined from $N_{uc} \le \phi A_n f_y$. Tensile force N_{uc} shall not be taken less than 0.2 V_u unless special provisions are made to avoid tensile forces. Tensile force N_{uc} shall be regarded as a live load even when tension results from creep, shrinkage or temperature change.

1911.9.3.5 Area of primary tension reinforcement A_s shall be made equal to the greater of $(A_f + A_n)$ or $(2A_{vf}/3 + A_n)$.

1911.9.4 Closed stirrups or ties parallel to A_s, with a total area A_n not less than $0.5\,(A_s–A_n)$, shall be uniformly distributed within two thirds of the effective depth adjacent to A_s.

1911.9.5 Ratio $\rho = A_s/bd$ shall not be less than $0.04\,(f'_c/f_y)$.

1911.9.6 At front face of bracket or corbel, primary tension reinforcement A_s shall be anchored by one of the following: (1) by a structural weld to a transverse bar of at least equal size; weld to be designed to develop specified yield strength f_y of A_s bars; (2) by bending primary tension bars A_s back to form a horizontal loop; or (3) by some other means of positive anchorage.

1911.9.7 Bearing area of load on bracket or corbel shall not project beyond straight portion of primary tension bar A_s, or project beyond interior face of transverse anchor bar (if one is provided).

1911.10 Special Provisions for Walls.

1911.10.1 Design for shear forces perpendicular to face of wall shall be in accordance with provisions for slabs in Section 1911.12. Design for horizontal shear forces in plane of wall shall be in accordance with Section 1911.10.2 through 1911.10.8.

1911.10.2 Design of horizontal section for shear in plane of wall shall be based on Formulas (11-1) and (11-2), where shear strength V_c shall be in accordance with Section 1911.10.5 or 1911.10.6 and shear strength V_s shall be in accordance with Section 1911.10.9.

1911.10.3 Shear strength V_n at any horizontal section for shear in plane of wall shall not be taken greater than $10\sqrt{f'_c}\,hd$ (For **SI:** $0.83\sqrt{f'_c}\,hd$).

1911.10.4 For design for horizontal shear forces in plane of wall, d shall be taken equal to 0.8 l_w. A larger value of d, equal to the distance from extreme compression fiber to center of force of all reinforcement in tension shall be permitted to be used when determined by a strain compatibility analysis.

1911.10.5 Unless a more detailed calculation is made in accordance with Section 1911.10.6, shear strength V_c shall not be taken greater than $2\sqrt{f'_c}\,hd$ (For **SI:** $0.166\sqrt{f'_c}\,hd$) for walls subject to N_u in compression, or V_c shall not be taken greater than the value given in Section 1911.3.2.3 for walls subject to N_u in tension.

1911.10.6 Shear strength V_c shall be permitted to be computed by *Formulas* (11-31) and (11-32), where V_c shall be the lesser of *Formula* (11-31) or (11-32).

$$V_c = 3.3\sqrt{f'_c}\,hd + \frac{N_u d}{4l_w} \qquad (11\text{-}31)$$

For **SI:**

$$V_c = 0.27\sqrt{f'_c}\,hd + \frac{N_u d}{4l_w}$$

or

$$V_c = \left[0.6\sqrt{f'_c} + \frac{l_w\left(1.25\sqrt{f'_c} + 0.2\frac{N_u}{l_w h}\right)}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right]hd \qquad (11\text{-}32)$$

For **SI:** $$V_c = \left[0.05\sqrt{f'_c} + \frac{l_w\left(0.10\sqrt{f'_c} + 0.2\frac{N_u}{l_w h}\right)}{\frac{M_u}{V_u} - \frac{l_w}{2}}\right] hd$$

where N_u is negative for tension. When $(M_u/V_u - l_w/2)$ is negative, Formula (11-32) shall not apply.

1911.10.7 Sections located closer to wall base than a distance $l_w/2$ or one half the wall height, whichever is less, shall be permitted to be designed for the same V_c as that computed at a distance $l_w/2$ or one half the height.

1911.10.8 When factored shear force V_u is less than $\phi V_c/2$, reinforcement shall be provided in accordance with Section 1911.10.9 or in accordance with Section 1914. When V_u exceeds $\phi V_c/2$, wall reinforcement for resisting shear shall be provided in accordance with Section 1911.10.9.

1911.10.9 Design of shear reinforcement for walls.

1911.10.9.1 Where factored shear force V_u exceeds shear strength ϕV_c, horizontal shear reinforcement shall be provided to satisfy Formulas (11-1) and (11-2), where shear strength V_s shall be computed by

$$V_s = \frac{A_v f_y d}{s_2} \qquad (11\text{-}33)$$

where A_v is area of horizontal shear reinforcement within a distance s_2 and distance d is in accordance with Section 1911.10.4. Vertical shear reinforcement shall be provided in accordance with Section 1911.10.9.4.

1911.10.9.2 Ratio ρ_h of horizontal shear reinforcement area to gross concrete area of vertical section shall not be less than 0.0025.

1911.10.9.3 Spacing of horizontal shear reinforcement s_2 shall not exceed $l_w/5$, $3h$ or 18 inches (457 mm).

1911.10.9.4 Ratio ρ_n of vertical shear reinforcement area to gross concrete area of horizontal section shall not be less than

$$\rho_n = 0.0025 + 0.5\left(2.5 - \frac{h_w}{l_w}\right)(\rho_h - 0.0025) \qquad (11\text{-}34)$$

or 0.0025, but need not be greater than the required horizontal shear reinforcement.

1911.10.9.5 Spacing of vertical shear reinforcement s_1 shall not exceed $l_w/3$, $3h$ or 18 inches (457 mm).

1911.11 Transfer of Moments to Columns.

1911.11.1 When gravity load, wind, earthquake or other lateral forces cause transfer of moment at connections of framing elements to columns, the shear resulting from moment transfer shall be considered in the design of lateral reinforcement in the columns.

1911.11.2 Except for connections not part of a primary seismic load-resisting system that are restrained on four sides by beams or slabs of approximately equal depth, connections shall have lateral reinforcement not less than that required by Formula (11-13) within the column for a depth not less than that of the deepest connection of framing elements to the columns. See also Section 1907.9.

1911.12 Special Provisions for Slabs and Footings.

1911.12.1 The shear strength of slabs and footings in the vicinity of columns, concentrated loads or reactions is governed by the more severe of two conditions:

1911.12.1.1 Beam action where each critical section to be investigated extends in a plane across the entire width. For beam action the slab or footing shall be designed in accordance with Sections 1911.1 through 1911.5.

1911.12.1.2 Two-way action where each of the critical sections to be investigated shall be located so that its perimeter, b_o, is a minimum, but need not approach closer than $d/2$ to:

1. Edges or corners of columns, concentrated loads or reaction areas, or
2. Changes in slab thickness such as edges of capitals or drop panels.

For two-way action, the slab of footing shall be designed in accordance with Sections 1911.12.2 through 1911.12.6.

1911.12.1.3 For square or rectangular columns, concentrated loads or reactions areas, the critical sections with four straight sides shall be permitted.

1911.12.2 The design of a slab or footing for two-way action is based on Formulas (11-1) and (11-2). V_c shall be computed in accordance with Section 1911.12.2.1, 1911.12.2.2 or 1911.12.3.1. V_s shall be computed in accordance with Section 1911.12.3. For slabs with shear heads, V_n shall be in accordance with Section 1911.12.4. When moment is transferred between a slab and a column, Section 1911.12.6 shall apply.

1911.12.2.1 For nonprestressed slabs and footings, V_c shall be the smallest of:

1. $$V_c = \left(2 + \frac{4}{\beta_c}\right)\sqrt{f'_c}\, b_o d \qquad (11\text{-}35)$$

For **SI:** $$V_c = 0.083\left(2 + \frac{4}{\beta_c}\right)\sqrt{f'_c}\, b_o d$$

where β_c is the ratio of long side to short side of the column, concentrated load or reaction area

2. $$V_c = \left(\frac{\alpha_s d}{b_o} + 2\right)\sqrt{f'_c}\, b_o d \qquad (11\text{-}36)$$

For **SI:** $$V_c = 0.083\left(\frac{\alpha_s d}{b_o} + 2\right)\sqrt{f'_c}\, b_o d$$

where α_s is 40 for interior columns, 30 for edge columns and 20 for corner columns, and

3. $$V_c = 4\sqrt{f'_c}\, b_o d \qquad (11\text{-}37)$$

For **SI:** $$V_c = 0.33\sqrt{f'_c}\, b_o d$$

1911.12.2.2 At columns of two-way prestressed slabs and footings that meet the requirements of Section 1918.9.3:

$$V_c = (\beta_p \sqrt{f'_c} + 0.3 f_{pc})\, b_o d + V_p \qquad (11\text{-}38)$$

For **SI:** $$V_c = (0.083\,\beta_p \sqrt{f'_c} + 0.3 f_{pc})\, b_o d + V_p$$

where β_p is the smaller of 3.5 or $(\alpha_s d/b_o + 1.5)$, α_s is 40 for interior columns, 30 for edge columns and 20 for corner columns, b_o is perimeter of critical section defined in Section 1911.12.1.2, f_{pc} is the average value of f_{pc} for the two directions, and V_p is the vertical component of all effective prestress forces crossing the critical section. V_c shall be permitted to be computed by Formula (11-38) if the following are satisfied; otherwise, Section 1911.12.2.1 shall apply:

1. No portion of the column cross section shall be closer to the discontinuous edge than four times the slab thickness, and

2. f'_c in Formula (11-38) shall not be taken greater than 5,000 psi (34.47 MPa), and
3. f_{pc} in each direction shall not be less than 125 psi (0.86 MPa), or be taken greater than 500 psi (3.45 MPa).

1911.12.3 Shear reinforcement consisting of bars or wires shall be permitted in slabs and footings in accordance with the following:

1911.12.3.1 V_n shall be computed by Formula (11-2), where V_c shall not be taken greater than $2\sqrt{f'_c}\,b_o d$ (For **SI:** $0.166\sqrt{f'_c}\,b_o d$), and the required area of shear reinforcement A_v and V_s shall be calculated in accordance with Section 1911.5 and anchored in accordance with Section 1912.13.

1911.12.3.2 V_n shall not be taken greater than $6\sqrt{f'_c}\,b_o d$ (For **SI:** $0.50\sqrt{f'_c}\,b_o d$).

1911.12.4 Shear reinforcement consisting of steel I- or channel-shaped sections (shearheads) shall be permitted in slabs. The provisions of Sections 1911.12.4.1 through 1911.12.4.9 shall apply where shear due to gravity load is transferred at interior column supports. Where moment is transferred to columns, Section 1911.12.6.3 shall apply.

1911.12.4.1 Each shearhead shall consist of steel shapes fabricated by welding with a full penetration weld into identical arms at right angles. Shearhead arms shall not be interrupted within the column section.

1911.12.4.2 A shearhead shall not be deeper than 70 times the web thickness of the steel shape.

1911.12.4.3 The ends of each shearhead arm shall be permitted to be cut at angles not less than 30 degrees with the horizontal, provided the plastic moment strength of the remaining tapered section is adequate to resist the shear force attributed to the arm of the shearhead.

1911.12.4.4 All compression flanges of steel shapes shall be located within 0.3d of compression surface of slab.

1911.12.4.5 The ratio α_v between the stiffness of each shearhead arm and that of the surrounding composite cracked slab section of width $(c_2 + d)$ shall not be less than 0.15.

1911.12.4.6 The plastic moment strength M_p required for each arm of the shearhead shall be computed by

$$\phi M_p = \frac{V_u}{2\eta}\left[h_v + \alpha_v\left(l_v - \frac{c_1}{2}\right)\right] \qquad (11\text{-}39)$$

where ϕ is the strength-reduction factor for flexure, η is the number of arms, and l_v is the minimum length of each shearhead arm required to comply with requirements of Section 1911.12.4.7 and 1911.12.4.8.

1911.12.4.7 The critical slab section for shear shall be perpendicular to the plane of the slab and shall cross each shearhead arm at three fourths the distance $[l_v - (c_1/2)]$ from the column face to the end of the shearhead arm. The critical section shall be located so that its perimeter b_o is a minimum, but need not be closer than the perimeter defined in Section 1911.12.1.2, Item 1.

1911.12.4.8 V_n shall not be taken greater than $4\sqrt{f'_c}\,b_o d$ (For **SI:** $0.33\sqrt{f'_c}\,b_o d$), on the critical section defined in Section 1911.12.4.7. When shearhead reinforcement is provided, V_n shall not be taken greater than $7\sqrt{f'_c}\,b_o d$ (For **SI:** $0.58\sqrt{f'_c}\,b_o d$), on the critical section defined in Section 1911.12.1.2, Item 1.

1911.12.4.9 The moment resistance M_v contributed to each slab column strip computed by a shearhead shall not be taken greater than

$$M_v = \frac{\phi\alpha_v V_u}{2\eta}\left(l_v - \frac{c_1}{2}\right) \qquad (11\text{-}40)$$

where ϕ is the strength-reduction factor for flexure, η is the number of arms, and l_v is the length of each shearhead arm actually provided. However, M_v shall not be taken larger than the smaller of:

1. Thirty percent of the total factored moment required for each slab column strip,
2. The change in column strip moment over the length l_v,
3. The value of M_p computed by Formula (11-39).

1911.12.4.10 When unbalanced moments are considered, the shearhead must have adequate anchorage to transmit M_p to column.

1911.12.5 Opening in slabs. When openings in slabs are located at a distance less than 10 times the slab thickness from a concentrated load or reaction area, or when openings in flat slabs are located within column strips as defined in Section 1913, the critical slab sections for shear defined in Section 1911.12.1.2 and Section 1911.12.4.7 shall be modified as follows:

1911.12.5.1 For slabs without shearheads, that part of the perimeter of the critical section that is enclosed by straight lines projecting from the centroid of the column, concentrated load or reaction area and tangent to the boundaries of the openings shall be considered ineffective.

1911.12.5.2 For slabs with shearheads, the ineffective portion of the perimeter shall be one half of that defined in Section 1911.12.5.1.

1911.12.6 Transfer of moment in slab-column connections.

1911.12.6.1 When gravity load, wind, earthquake or other lateral forces cause transfer of unbalanced moment, M_u, between a slab and a column, a fraction $\gamma f M_u$ of the unbalanced moment shall be transferred by flexure in accordance with Section 1913.5.3. The remainder of the unbalanced moment given by $\gamma_v M_u$ shall be considered to be transferred by eccentricity of shear about the centroid of the critical section defined in Section 1911.12.1.2 where:

$$\gamma_v = (1 - \gamma_f) \qquad (11\text{-}41)$$

1911.12.6.2 The shear stress resulting from moment transfer by eccentricity of shear shall be assumed to vary linearly about the centroid of the critical sections defined in Section 1911.12.1.2. The maximum shear stress due to the factored shear force and moment shall not exceed ϕv_n:

For members without shear reinforcement:

$$\phi v_n = \phi V_c/(b_o d) \qquad (11\text{-}42)$$

where V_c is as defined in Section 1911.12.2.1 and 1911.12.2.2.

For members with shear reinforcement other than shearheads:

$$\phi v_n = \phi(V_c + V_s)/(b_o d) \qquad (11\text{-}43)$$

where V_c and V_s are defined in Section 1911.12.3. If shear reinforcement is provided, the design shall take into account the variation of shear stress around the column.

1911.12.6.3 When shear reinforcement consisting of steel I- or channel-shaped sections (shearheads) is provided, the sum of the shear stresses due to vertical load acting on the critical section defined by Section 1911.12.4.7 and the shear stresses resulting from moment transferred by eccentricity of shear about the centroid of the critical section defined in Section 1911.12.1.2 shall not exceed $\phi 4\sqrt{f'_c}$ (For **SI:** $\phi 0.33\sqrt{f'_c}$).

SECTION 1912 — DEVELOPMENT AND SPLICES OF REINFORCEMENT

1912.0 Notations.

A_b = area of an individual bar, square inches (mm^2).

A_s = area of nonprestressed tension reinforcement, square inches (mm^2).

A_{tr} = total cross-sectional area of all transverse reinforcement which is within the spacing s and which crosses the potential plane of splitting through the reinforcement being developed, inches squared (mm^2).

A_v = area of shear reinforcement within a distance s, square inches (mm^2).

A_w = area of an individual wire to be developed or spliced, square inches (mm^2).

a = depth of equivalent rectangular stress block as defined in Section 1910.2.7.1.

b_w = web width, or diameter of circular section, inches (mm).

c = spacing or cover dimension, inches (mm). See Section 1912.2.4.

d = distance from extreme compression fiber to centroid of tension reinforcement, inches (mm).

d_b = nominal diameter of bar, wire or prestressing strand, inches (mm).

f'_c = specified compressive strength of concrete, pounds per square inch (MPa).

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, pounds per square inch (MPa).

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, pounds per square inch (MPa).

f_{ps} = stress in prestressed reinforcement at nominal strength, kips per square inch (MPa).

f_{se} = effective stress in prestressed reinforcement (after allowance for all prestress losses), kips per square inch (MPa).

f_y = specified yield strength of nonprestressed reinforcement, pounds per square inch (MPa).

f_{yt} = specified yield strength of transverse reinforcement, psi (MPa).

h = overall thickness of member, inches (mm).

K_{tr} = transverse reinforcement index.

= $\dfrac{A_{tr}\ f_{yt}}{1,500sn}$ (constant 1,500 carries the unit lb./in.).

l_a = additional embedment length at support or at point of inflection, inches (mm).

l_d = development length, inches (mm).

= $l_{db} \times$ applicable modification factors.

l_{db} = basic development length, inches (mm).

l_{dh} = development length of standard hook in tension, measured from critical section to outside end of hook [straight embedment length between critical section and start of hook (point of tangency) plus radius of bend and one bar diameter], inches (mm).

= $l_{hb} \times$ applicable modification factors.

l_{hb} = basic development length of standard hook in tension, inches (mm).

M_n = nominal moment strength at section, inch-pounds (N·m).

= $A_s f_y(d - a/2)$.

N = number of bars in a layer being spliced or developed at a critical section.

n = number of bars or wires being spliced or developed along the plane of splitting.

s = maximum center to center spacing of transverse reinforcement within l_d, inches (mm).

s_w = spacing of wire to be developed or spliced, inches (mm).

V_u = factored shear force at section.

α = reinforcement location factor. See Section 1912.2.4.

β = coating factor. See Section 1912.2.4.

β_b = ratio of area of reinforcement cut off to total area of tension reinforcement at section.

γ = reinforcement size factor. See Section 1912.2.4.

λ = lightweight aggregate concrete factor. See Section 1912.2.4.

1912.1 Development of Reinforcement—General.

1912.1.1 Calculated tension or compression in reinforcement at each section of structural concrete members shall be developed on each side of that section by embedment length, hook or mechanical device, or a combination thereof. Hooks shall not be used to develop bars in compression.

1912.1.2 The values of $\sqrt{f'_c}$ used in Section 1912 shall not exceed 100 psi (0.69 MPa).

1912.2 Development of Deformed Bars and Deformed Wire in Tension.

1912.2.1 Development length, l_d, in terms of diameter, d_b, for deformed bars and deformed wire in tension shall be determined from either Section 1912.2.2 or 1912.2.3, but l_d shall not be less than 12 inches (305 mm).

1912.2.2 For deformed bars or deformed wire, l_d/d_b shall be as follows:

	NO. 6 AND SMALLER BARS AND DEFORMED WIRES	NO. 7 AND LARGER BARS
Clear spacing of bars being developed or spliced not less than d_b, clear cover not less than d_b, and stirrups or ties throughout l_d not less than the prescribed minimum or Clear spacing of bars being developed or spliced not less than $2d_b$ and clear cover not less than d_b	$\dfrac{l_d}{d_b} = \dfrac{f_y\alpha\beta\lambda}{25\sqrt{f'_c}}$	$\dfrac{l_d}{d_b} = \dfrac{f_y\alpha\beta\lambda}{20\sqrt{f'_c}}$
Other cases	$\dfrac{l_d}{d_b} = \dfrac{3f_y\alpha\beta\lambda}{50\sqrt{f'_c}}$	$\dfrac{l_d}{d_b} = \dfrac{3f_y\alpha\beta\lambda}{40\sqrt{f'_c}}$

1912.2.3 For deformed bars or deformed wire, l_d/d_b shall be:

$$\frac{l_d}{d_b} = \frac{3}{40}\frac{f_y}{\sqrt{f'_c}}\frac{\alpha\beta\gamma\lambda}{\left(\frac{c\ +\ K_{tr}}{d_b}\right)} \qquad (12\text{-}1)$$

in which the term $\dfrac{c\ +\ K_{tr}}{d_b}$ shall not be taken greater than 2.5.

1912.2.4 The factors for use in the expressions for development of deformed bars and deformed wires in tension in Sections 1912.0 through 1912.19 are as follows:

α = reinforcement location factor

Horizontal reinforcement so placed that more than 12 inches (305 mm) of fresh concrete is cast in the member below the development length or splice 1.3

Other reinforcement 1.0

β = coating factor

Epoxy-coated bars or wires with cover less than $3d_b$, or clear spacing less than $6d_b$ 1.5

All other epoxy-coated bars or wires 1.2

Uncoated reinforcement 1.0

However, the product $\alpha\beta$ need not be taken greater than 1.7.

γ = reinforcement size factor

No. 6 and smaller bars and deformed wires 0.8

No. 7 and larger bars 1.0

λ = lightweight aggregate concrete factor.

When lightweight aggregate concrete is used 1.3

However, when f_{ct} is specified, λ shall be permitted to be taken as $6.7\sqrt{f'_c}/f_{ct}$ but not less than 1.0

when normal weight concrete is used 1.0

c = spacing or cover dimension, inches (mm).

Use the smaller of either the distance from the center of the bar to the nearest concrete surface or one-half the center-to-center spacing of the bars being developed.

K_{tr} = transverse reinforcement index

$$= \frac{A_{tr}\ f_{yt}}{1,500sn}$$

WHERE:

A_{tr} = total cross-sectional area of all transverse reinforcement which is within the spacing s and which crosses the potential plane of splitting through the reinforcement being developed, inches squared (mm^2).

f_{yt} = specified yield strength of transverse reinforcement, inches squared (mm^2).

s = maximum spacing of transverse reinforcement within l_d, center-to-center, inches (mm).

n = number of bars or wires being developed along the plane of splitting.

It shall be permitted to use $K_{tr} = 0$ as a design simplification even if transverse reinforcement is present.

1912.2.5 Excess reinforcement. Reduction in development length shall be permitted where reinforcement in a flexural member is in excess of that required by analysis except where anchorage or development for f_y is specifically required or the reinforcement is designed under provisions of Section 1921.2.1.4 . . . . [(A_s required)/(A_s provided)]

1912.3 Development of Deformed Bars in Compression.

1912.3.1 Development length l_d, in inches, for deformed bars in compression shall be computed as the product of the basic development length l_{db} and applicable modification factors as defined in this section, but l_d shall not be less than 8 inches (203 mm).

1912.3.2 Basic development length l_{db} shall be . $0.02 d_b f_y/\sqrt{f'_c}$
(For **SI:** $0.24 d_b f_y/\sqrt{f'_c}$)

but not less than . . . . $0.0003 d_b f_y$
(For **SI:** $0.044\ d_b f_y$)

1912.3.3 Basic development length l_{db} shall be permitted to be multiplied by applicable factors for:

1912.3.3.1 Excess reinforcement. Reinforcement in excess of that required by analysis . . . . (A_s required)/(A_s provided)

1912.3.3.2 Spirals and ties. Reinforcement enclosed within spiral reinforcement not less than $^1/_4$-inch (6.4 mm) diameter and not more than 4-inch (102 mm) pitch or within No. 4 ties in conformance with Section 1907.10.5 and spaced not more than 4 inches (102 mm) on center 0.75

1912.4 Development of Bundled Bars.

1912.4.1 Development length of individual bars within a bundle, in tension or compression, shall be that for the individual bar, increased 20 percent for 3-bar bundle, and 33 percent for 4-bar bundle.

1912.4.2 For determining the appropriate factors in Section 1912.2, a unit of bundled bars shall be treated as a single bar of a diameter derived from the equivalent total area.

1912.5 Development of Standard Hooks in Tension.

1912.5.1 Development length l_{dh} in inches (mm) for deformed bars in tension terminating in a standard hook shall be computed as the product of the basic development length l_{hb} of Section 1912.5.2 and the applicable modification factor or factors of Section 1912.5.3, but l_{dh} shall not be less than $8d_b$ or less than 6 inches (152 mm).

1912.5.2 Basic development length l_{hb} for a hooked bar with f_y equal to 60,000 psi (413.7 MPa) shall be . . . . . $1,200\ d_b/\sqrt{f'_c}$
(For **SI:** $99.7\ d_b/\sqrt{f'_c}$)

1912.5.3 Basic development length l_{hb} shall be multiplied by applicable factor or factors for:

1912.5.3.1 Bar yield strength. Bars with f_y other than 60,000 psi (413.7 MPa) . . . . f_y/60,000
(For **SI:** f_y/413.7)

1912.5.3.2 Concrete cover. For No. 11 bar and smaller, side cover (normal to plane of the hook) not less than $2^1/_2$ inches (64 mm), and for 90-degree hook, cover on bar extension beyond hook not less than 2 inches (51 mm) 0.7

1912.5.3.3 Ties or stirrups. For No. 11 bar and smaller, hook enclosed vertically or horizontally within ties or stirrup ties spaced along the full development length l_{dh} not greater than $3d_b$, where d_b is diameter of hooked bar 0.8

1912.5.3.4 Excessive reinforcement. Where anchorage or development for f_y is not specifically required, reinforcement in excess of that required by analysis . [(A_s required)/(A_s provided)]

1912.5.3.5 Lightweight aggregate concrete 1.3

1912.5.3.6 Epoxy-coated reinforcement. Hooked bars with epoxy coating 1.2

1912.5.4 For bars being developed by a standard hook at discontinuous ends of members with side cover and top (or bottom) cover over hook less than $2^1/_2$ inches (64 mm), hooked bar shall be enclosed within ties or stirrups spaced along the full development length l_{dh} not greater than $3d_b$, where d_b is diameter of hooked bar. For this case, factor of Section 1912.5.3.3 shall not apply.

1912.5.5 Hooks shall not be considered effective in developing bars in compression.

1912.6 Mechanical Anchorage.

1912.6.1 Any mechanical device capable of developing the strength of reinforcement without damage to concrete may be used as anchorage.

1912.6.2 Test results showing adequacy of such mechanical devices shall be presented to the building official.

1912.6.3 Development of reinforcement shall be permitted to consist of a combination of mechanical anchorage plus additional embedment length of reinforcement between the point of maximum bar stress and the mechanical anchorage.

1912.7 Development of Welded Deformed Wire Fabric in Tension.

1912.7.1 Development length l_d, in inches (mm), of welded deformed wire fabric measured from the point of critical section to the end of wire shall be computed as the product of the development length l_d, from Section 1912.2.2 or 1912.2.3 times a wire fabric factor from Section 1912.7.2 or 1912.7.3. It shall be permitted to reduce the development length in accordance with 1912.2.5 when applicable, but l_d shall not be less than 8 inches (203 mm) except in computation of lap splices by Section 1912.18. When using the wire fabric factor from Section 1912.7.2, it shall be permitted to use an epoxy-coating factor β of 1.0 for epoxy-coated welded wire fabric in Sections 1912.2.2 and 1912.2.3.

1912.7.2 For welded deformed wire fabric with at least one cross wire within the development length and not less than 2 inches (51 mm) from the point of the critical section, the wire fabric factor shall be the greater of:

$$\left(\frac{f_y - 35,000}{f_y}\right)$$

or

$$\left(\frac{5d_b}{s_w}\right)$$

but need not be taken greater than 1.

1912.7.3 For welded deformed wire fabric with no cross wires within the development length or with a single cross wire less than 2 inches (51 mm) from the point of the critical section, the wire fabric factor shall be taken as 1, and the development length shall be determined as for deformed wire.

1912.7.4 When any plain wires are present in the deformed wire fabric in the direction of the development length, the fabric shall be developed in accordance with Section 1912.8.

1912.8 Development of Welded Plain Wire Fabric in Tension. Yield strength of welded plain wire fabric shall be considered developed by embedment of two cross wires with the closer cross wire not less than 2 inches (51 mm) from the point of the critical section. However, the development length l_d, in inches (mm), measured from the point of the critical section to the outermost cross wire shall not be less than

$$0.27 \ \frac{A_w}{s_w} \left(\frac{f_y}{\sqrt{f'_c}}\right) \lambda$$

For **SI:** $$3.3 \ \frac{A_w}{s_w} \left(\frac{f_y}{\sqrt{f'_c}}\right) \lambda$$

except that when reinforcement provided is in excess of that required, this length may be reduced in accordance with Section 1912.2.5. l_d shall not be less than 6 inches (152 mm) except in computation of lap splices by Section 1912.19.

1912.9 Development of Prestressing Strand.

1912.9.1 Three- or seven-wire pretensioning strand shall be bonded beyond the critical section for a development length, in inches (mm), not less than

$$\left(f_{ps} - \frac{2}{3} f_{se}\right) d_b†$$

For **SI:** $$0.145\left(f_{ps} - \frac{2}{3} f_{se}\right) d_b$$

†Expression in parentheses used as a constant without units.

where d_b is strand diameter in inches (mm), and f_{ps} and f_{se} are expressed in kips per square inch (MPa).

1912.9.2 Limiting the investigation to cross sections nearest each end of the member that are required to develop full design strength under specified factored loads shall be permitted.

1912.9.3 Where bonding of a strand does not extend to end of member, and design includes tension at service load in precompressed tensile zone as permitted by Section 1918.4.2, development length specified in Section 1912.9.1 shall be doubled.

1912.10 Development of Flexural Reinforcement—General.

1912.10.1 Development of tension reinforcement by bending across the web to be anchored or made continuous with reinforcement on the opposite face of member shall be permitted.

1912.10.2 Critical sections for development of reinforcement in flexural members are at points of maximum stress and at points within the span where adjacent reinforcement terminates or is bent. Provisions of Section 1912.11.3 must be satisfied.

1912.10.3 Reinforcement shall extend beyond the point at which it is no longer required to resist flexure for a distance equal to the effective depth of member or $12d_b$, whichever is greater, except at supports of simple spans and at free end of cantilevers.

1912.10.4 Continuing reinforcement shall have an embedment length not less than the development length l_d beyond the point where bent or terminated tension reinforcement is no longer required to resist flexure.

1912.10.5 Flexural reinforcement shall not be terminated in a tension zone unless one of the following conditions is satisfied:

1912.10.5.1 Shear at the cutoff point does not exceed two thirds that permitted, including shear strength of shear reinforcement provided.

1912.10.5.2 Stirrup area in excess of that required for shear and torsion is provided along each terminated bar or wire over a distance from the termination point equal to three fourths the effective depth of member. Excess stirrup area A_v shall not be less than $60b_w s/f_y$ (For **SI:** $0.41b_w s/f_y$). Spacing s shall not exceed $d/8\beta_b$ where β_b is the ratio of area of reinforcement cut off to total area of tension reinforcement at the section.

1912.10.5.3 For No. 11 bar and smaller, continuing reinforcement provides double the area required for flexure at the cutoff point and shear does not exceed three fourths that permitted.

1912.10.6 Adequate anchorage shall be provided for tension reinforcement in flexural members where reinforcement stress is not directly proportional to moment, such as sloped, stepped or tapered footings, brackets, deep flexural members, or members in which tension reinforcement is not parallel to compression face. See Sections 1912.11.4 and 1912.12.4 for deep flexural members.

1912.11 Development of Positive Moment Reinforcement.

1912.11.1 At least one third the positive moment reinforcement in simple members and one fourth the positive moment reinforcement in continuous members shall extend along the same face of member into the support. In beams, such reinforcement shall extend into the support at least 6 inches (152 mm).

1912.11.2 When a flexural member is part of a primary lateral-load-resisting system, positive moment reinforcement required to be extended into the support by Section 1912.11.1 shall be anchored to develop the specified yield strength f_y in tension at the face of support.

1912.11.3 At simple supports and at points of inflection, positive moment tension reinforcement shall be limited to a diameter such that l_d computed for f_y by Section 1912.2 satisfies Formula (12-2), except Formula (12-2) need not be satisfied for reinforcement terminating beyond center line of simple supports by a standard hook or a mechanical anchorage at least equivalent to a standard hook.

$$l_d \leq \frac{M_n}{V_u} + l_a \qquad (12\text{-}2)$$

WHERE:

l_a = at a support shall be the embedment length beyond center of support.

l_a = at a point of inflection shall be limited to the effective depth of member or $12d_b$, whichever is greater.

M_n = nominal strength assuming all reinforcement at the section to be stressed to the specified yield strength f_y.

V_u = factored shear force at the section.

An increase of 30 percent in the value of M_n/V_u shall be permitted when the ends of reinforcement are confined by a compressive reaction.

1912.11.4 At simple supports of deep flexural members, positive moment tension reinforcement shall be anchored to develop the specified yield strength f_y in tension at the face of support. At interior supports of deep flexural members, positive moment tension reinforcement shall be continuous or be spliced with that of the adjacent spans.

1912.12 Development of Negative Moment Reinforcement.

1912.12.1 Negative moment reinforcement in a continuous, restrained or cantilever member, or in any member of a rigid frame, shall be anchored in or through the supporting member by embedment length, hooks or mechanical anchorage.

1912.12.2 Negative moment reinforcement shall have an embedment length into the span as required by Sections 1912.1 and 1912.10, Item 3.

1912.12.3 At least one third the total tension reinforcement provided for negative moment at a support shall have an embedment length beyond the point of inflection not less than effective depth of member, $12d_b$, or $^1/_{16}$ the clear span, whichever is greater.

1912.12.4 At interior supports of deep flexural members, negative moment tension reinforcement shall be continuous with that of the adjacent spans.

1912.13 Development of Web Reinforcement.

1912.13.1 Web reinforcement shall be carried as close to compression and tension surfaces of member as cover requirements and proximity of other reinforcement will permit.

1912.13.2 Ends of single leg, simple U- or multiple U-stirrups shall be anchored by one of the following means:

1912.13.2.1 For No. 5 bar and D31 wire, and smaller, and for Nos. 6, 7 and 8 bars with f_y of 40,000 psi (275.8 MPa) or less, a standard stirrup hook around longitudinal reinforcement.

1912.13.2.2 For Nos. 6, 7 and 8 stirrups with f_y greater than 40,000 psi (275.8 MPa), a standard stirrup hook around a longitudinal bar plus an embedment between midheight of the member and the outside end of the hook equal to or greater than 0.014 $d_b f_y / \sqrt{f'_c}$ (For **SI:** 0.169 $d_b f_y / \sqrt{f'_c}$).

1912.13.2.3 For each leg of welded smooth wire fabric forming simple U-stirrups, either:

1. Two longitudinal wires spaced at a 2-inch (51 mm) spacing along the member at the top of the U.
2. One longitudinal wire located not more than $d/4$ from the compression face and a second wire closer to the compression face and spaced not less than 2 inches (51 mm) from the first wire. The second wire shall be permitted to be located on the stirrup leg beyond a bend, or on a bend with an inside diameter of bend not less than $8d_b$.

1912.13.2.4 For each end of a single-leg stirrup of welded plain or deformed wire fabric, two longitudinal wires at a minimum spacing of 2 inches (51 mm) and with the inner wire at least the greater of $d/4$ or 2 inches (51 mm) from middepth of member $d/2$. Outer longitudinal wire at tension face shall not be farther from the face than the portion of primary flexural reinforcement closest to the face.

1912.13.2.5 In joist construction as defined in Section 1908.11, for No. 4 bar and D20 wire and smaller, a standard hook.

1912.13.3 Between anchored ends, each bend in the continuous portion of a simple U-stirrup or multiple U-stirrups shall enclose a longitudinal bar.

1912.13.4 Longitudinal bars bent to act as shear reinforcement, if extended into a region of tension, shall be continuous with longitudinal reinforcement and, if extended into a region of compression, shall be anchored beyond middepth $d/2$ as specified for development length in Section 1912.2 for that part of f_y required to satisfy Formula (11-19).

1912.13.5 Pairs of U-stirrups or ties so placed as to form a closed unit shall be considered properly spliced when lengths of laps are $1.3l_d$. In members at least 18 inches (457 mm) deep, such splices with $A_b f_y$ not more than 9,000 pounds (40 000 N) per leg may be considered adequate if stirrup legs extend the full available depth of member.

1912.14 Splices of Reinforcement.

1912.14.1 Splices of reinforcement shall be made only as required or permitted on design drawings or in specifications, or as authorized by the *building official.*

1912.14.2 Lap splices.

1912.14.2.1 Lap splices shall not be used for bars larger than No. 11, except as provided in Sections 1912.16.2 and 1915.8.2.3.

1912.14.2.2 Lap splices of bars in a bundle shall be based on the lap splice length required for individual bars within the bundle, increased in accordance with Section 1912.4. Individual bar splices within a bundle shall not overlap. Entire bundles shall not be lap spliced.

1912.14.2.3 Bars spliced by noncontact lap splices in flexural members shall not be spaced transversely farther apart than one fifth the required lap splice length, or 6 inches (152 mm).

1912.14.3 Welded splices and mechanical connections.

1912.14.3.1 Welded splices and other mechanical connections may be used.

1912.14.3.2 Except as provided in this code, all welding shall conform to UBC Standard 19-1.

1912.14.3.3 A full-welded splice shall develop at least 125 percent of specified yield strength, f_y, of the bar.

1912.14.3.4 A full mechanical connection shall develop in tension or compression, as required, at least 125 percent of specified yield strength f_y of the bar.

1912.14.3.5 Welded splices and mechanical connections not meeting requirements of Section 1912.14.3.3 or 1912.14.3.4 are allowed only for No. 5 bars and smaller and in accordance with Section 1912.15.4.

1912.14.3.6 *Welded splices and mechanical connections shall maintain the clearance and coverage requirements of Sections 1907.6 and 1907.7.*

1912.15 Splices of Deformed Bars and Deformed Wire in Tension.

1912.15.1 Minimum length of lap for tension lap splices shall be as required for Class A or B splice, but not less than 12 inches (305 mm), where:

Class A splice . . . . $1.0l_d$

Class B splice . . . . $1.3l_d$

where l_d is the tensile development length for the specified yield strength f_y in accordance with Section 1912.2 without the modification factor of Section 1912.2.5.

1912.15.2 Lap splices of deformed bars and deformed wire in tension shall be Class B splices except that Class A splices may be used when (1) the area of reinforcement provided is at least twice that required by analysis over the entire length of the splice, and (2) one half or less of the total reinforcement is spliced within the required lap length.

1912.15.3 Welded splices or mechanical connections used where area of reinforcement provided is less than twice that required by analysis shall meet requirements of Section 1912.14.3.3 and 1912.14.3.4.

1912.15.4 Welded splices or mechanical connections not meeting the requirements of Section 1912.14.3.3 or 1912.14.3.4 are allowed for No. 5 bars and smaller when the area of reinforcement provided is at least twice that required by analysis, and the following requirements are met:

1912.15.4.1 Splices shall be staggered at least 24 inches (610 mm) and in such manner as to develop at every section at least twice the calculated tensile force at that section but not less than 20,000 psi (137.9 MPa) for total area of reinforcement provided.

1912.15.4.2 In computing tensile forces developed at each section, rate the spliced reinforcement at the specified splice strength. Unspliced reinforcement shall be rated at that fraction of f_y defined by the ratio of the shorter actual development length to l_d required to develop the specified yield strength f_y.

1912.15.4.3 *Mechanical connections need not be staggered as required by Section 1912.15.4.1 or 1912.15.5 provided the clearance and coverage requirements of Sections 1907.6 and 1907.7 are maintained and, at 90 percent of the yield stress, the strain measured over the full length of the connector does not exceed 50 percent of the strain of an unspliced bar when the maximum computed design load stress does not exceed 50 percent of the yield stress.*

1912.15.5 Splices in ‘‘tension tie members’’ shall be made with a full-welded splice or full mechanical connection in accordance with Section 1912.14.3.3 and 1912.14.3.4, and splices in adjacent bar shall be staggered at least 30 inches (762 mm).

1912.16 Splices of Deformed Bars in Compression.

1912.16.1 Compression lap splice length shall be 0.0005 $f_y d_b$ (For **SI:** 0.073 $f_y d_b$) for f_y of 60,000 psi (413.7 MPa) or less, or (0.0009 f_y – 24) d_b [For **SI:** (0.13 f_y – 24) d_b] for f_y greater than 60,000 psi (413.7 MPa), but not less than 12 inches (305 mm). For f'_c less than 3,000 psi (20.68 MPa), length of lap shall be increased by one third.

1912.16.2 When bars of different size are lap spliced in compression, splice length shall be the larger of: development length of larger bar, or splice length of smaller bar. Lap splices of No. 14 and No. 18 bars to No. 11 and smaller bars shall be permitted.

1912.16.3 Welded splices or mechanical connections used in compression shall meet requirements of Sections 1912.14.3.3 and 1912.14.3.4.

1912.16.4 End-bearing splices.

1912.16.4.1 In bars required for compression only, transmission of compressive stress by bearing of square cut ends held in concentric contact by a suitable device shall be permitted.

1912.16.4.2 Bar ends shall terminate in flat surfaces within $1^1/_2$ degrees of a right angle to the axis of the bars and shall be fitted within 3 degrees of full bearing after assembly.

1912.16.4.3 End-bearing splices shall be used only in members containing closed ties, closed stirrups or spirals.

1912.17 Special Splice Requirements for Columns.

1912.17.1 Lap splices, butt welded splices, mechanical connections or end-bearing splices shall be used with the limitations of Sections 1912.17.2 through 1912.17.4. A splice shall satisfy requirements for all load combinations for the column.

1912.17.2 Lap splices in columns.

1912.17.2.1 Where the bar stress due to factored loads is compressive, lap splices shall conform to Sections 1912.16.1 and 1912.16.2, and where applicable, to Section 1912.17.2.4 or 1912.17.2.5.

1912.17.2.2 Where the bar stress due to factored loads is tensile and does not exceed $0.5f_y$ in tension, lap splices shall be Class B tension lap splices if more than one half of the bars are spliced at any section, or Class A tension lap splices if one half or fewer of the bars are spliced at any section and alternate lap splices are staggered by l_d.

1912.17.2.3 Where the bar stress due to factored loads is greater than 0.5 f_y in tension, lap splices shall be Class B tension lap splices.

1912.17.2.4 In tied reinforced compression members, where ties throughout the lap splice length have an effective area not less than $0.0015hs$, lap splice length shall be permitted to be multiplied by 0.83, but lap length shall not be less than 12 inches (305 mm).

Tie legs perpendicular to dimension h shall be used in determining effective area.

1912.17.2.5 In spirally reinforced compression members, lap splice length of bars within a spiral shall be permitted to be multiplied by 0.75, but lap length shall not be less than 12 inches (305 mm).

1912.17.3 Welded splices or mechanical connectors in columns. Welded splices or mechanical connectors in columns shall meet the requirements of Section 1912.14.3.3 or 1912.14.3.4.

1912.17.4 End-bearing splices in columns. End-bearing splices complying with Section 1912.16.4 shall be permitted to be used for column bars stressed in compression provided the splices are staggered or additional bars are provided at splice locations. The continuing bars in each face of the column shall have a tensile strength, based on the specified yield strength f_y, not less than $0.25f_y$ times the area of the vertical reinforcement in that face.

1912.18 Splices of Welded Deformed Wire Fabric in Tension.

1912.18.1 Minimum length of lap for lap splices of welded deformed wire fabric measured between the ends of each fabric sheet shall not be less than $1.3l_d$ or 8 inches (203 mm), and the overlap measured between outermost cross wires of each fabric sheet shall not be less than 2 inches (51 mm), l_d shall be the development length for the specified yield strength f_y in accordance with Section 1912.7.

1912.18.2 Lap splices of welded deformed wire fabric, with no cross wires within the lap splice length, shall be determined as for deformed wire.

1912.18.3 When any plain wires are present in the deformed wire fabric in the direction of the lap splice or when deformed wire fabric is lap spliced to plain wire fabric, the fabric shall be lap spliced in accordance with Section 1912.19.

1912.19 Splices of Welded Plain Wire Fabric in Tension. Minimum length of lap for lap splices of welded smooth wire fabric shall be in accordance with the following:

1912.19.1 When area of reinforcement provided is less than twice that required by analysis at splice location, length of overlap measured between outermost cross wires of each fabric sheet shall not be less than one spacing of cross wires plus 2 inches (51 mm), or less than 1.5 l_d, or 6 inches (152 mm), l_d shall be the development length for the specified yield strength f_y in accordance with Section 1912.8.

1912.19.2 When area of reinforcement provided is at least twice that required by analysis at splice location, length of overlap measured between outermost cross wires of each fabric sheet shall not be less than 1.5 l_d, or 2 inches (51 mm), l_d shall be the development length for the specified yield strength f_y in accordance with Section 1912.8.

SECTION 1913 — TWO-WAY SLAB SYSTEMS

1913.0 Notations.

b_1 = width of the critical section defined in Section 1911.12.1.2 measured in the direction of the span for which moments are determined, inches (mm).

b_2 = width of the critical section defined in Section 1911.12.1.2 measured in the direction perpendicular to b_1, inches (mm).

C = cross-sectional constant to define torsional properties.

$$\sum \left(1 - 0.63\ \frac{x}{y}\right)\ \frac{x^3y}{3}$$

The constant C for T- or L-sections shall be permitted to be evaluated by dividing the section into separate rectangular parts and summing the values of C for each part.

c_1 = size of rectangular or equivalent rectangular column, capital, or bracket measured in the direction of the span for which moments are being determined, inches (mm).

c_2 = size of rectangular or equivalent rectangular column, capital or bracket measured transverse to the direction of the span for which moments are being determined, inches (mm).

E_{cb} = modulus of elasticity of beam concrete.

E_{cs} = modulus of elasticity of slab concrete.

h = overall thickness of member, inches (mm).

I_b = moment of inertia about centroidal axis of gross section of beam as defined in Section 1913.3.

I_s = moment of inertia about centroidal axis of gross section of slab.

= $h^3/12$ times width of slab defined in notations α and β_t.

K_t = torsional stiffness of torsional member; moment per unit rotation.

l_n = length of clear span in direction that moments are being determined, measured face to face of supports.

l_1 = length of span in direction that moments are being determined, measured center to center of supports.

l_2 = length of span transverse to l_1, measured center to center of supports. See also Sections 1913.6.2.3 and 1913.6.2.4.

M_o = total factored static moment.

M_u = factored moment at section.

V_c = nominal shear strength provided by concrete. See Section 1911.12.2.1.

V_u = factored shear force at section.

w_d = factored dead load per unit area.

w_l = factored live load per unit area.

w_u = factored load per unit area.

x = shorter overall dimension of rectangular part of cross section.

y = longer overall dimension of rectangular part of cross section.

α = ratio of flexural stiffness of beam section to flexural stiffness of a width of slab bounded laterally by center lines of adjacent panels (if any) on each side of the beam.

= $\dfrac{E_{cb}I_b}{E_{cs}I_s}$

α_1 = α in direction of l_1.

α_2 = α in direction of l_2.

β_t = ratio of torsional stiffness of edge beam section to flexural stiffness of a width of slab equal to span length of beam, center to center of supports.

= $\dfrac{E_{cb}C}{2E_{cs}I_s}$

γ_f = fraction of unbalanced moment transferred by flexure at slab-column connections. See Section 1913.5.3.2.

γ_v = fraction of unbalanced moment transferred by eccentricity of shear at slab-column connections.

= $1 - \gamma_f$

ρ = ratio of nonprestressed tension reinforcement.

ρ_b = reinforcement ratio producing balanced strain conditions.

ϕ = strength reduction factor.

1913.1 Scope.

1913.1.1 The provisions of this section shall apply for design of slab systems reinforced for flexure in more than one direction, with or without beams between supports.

1913.1.2 For a slab system supported by columns or walls, the dimensions c_1 and c_2 and the clear span l_n shall be based on an effective support area defined by the intersection of the bottom surface of the slab, or the drop panel if there is one, with the largest right circular cone, right pyramid, or tapered wedge whose surfaces are located within the column and capital or bracket and are oriented no greater than 45 degrees to the axis of the column.

1913.1.3 Solid slabs and slabs with recesses or pockets made by permanent or removable fillers between ribs or joists in two directions are included within the scope of this section.

1913.1.4 Minimum thickness of slabs designed in accordance with this section shall be as required by Section 1909.5.3.

1913.2 Definitions.

1913.2.1 Column strip is a design strip with a width on each side of a column center line equal to $0.25l_2$ or $0.25l_1$, whichever is less. Column strip includes beams, if any.

1913.2.2 Middle strip is a design strip bounded by two column strips.

1913.2.3 A panel is bounded by column, beam or wall center lines on all sides.

1913.2.4 For monolithic or fully composite construction, a beam includes that portion of slab on each side of the beam extending a distance equal to the projection of the beam above or below the slab, whichever is greater, but not greater than four times the slab thickness.

1913.3 Slab Reinforcement.

1913.3.1 Area of reinforcement in each direction for two-way slab systems shall be determined from moments at critical sections, but shall not be less than required by Section 1907.12.

1913.3.2 Spacing of reinforcement at critical sections shall not exceed two times the slab thickness, except for portions of slab area of cellular or ribbed construction. In the slab over cellular spaces, reinforcement shall be provided as required by Section 1907.12.

1913.3.3 Positive moment reinforcement perpendicular to a discontinuous edge shall extend to the edge of slab and have embedment, straight or hooked, at least 6 inches (152 mm) in spandrel beams, columns or walls.

1913.3.4 Negative moment reinforcement perpendicular to a discontinuous edge shall be bent, hooked or otherwise anchored, in spandrel beams, columns or walls, to be developed at face of support according to provisions of Section 1912.

1913.3.5 Where a slab is not supported by a spandrel beam or wall at a discontinuous edge or where a slab cantilevers beyond the support, anchorage of reinforcement shall be permitted within the slab.

1913.3.6 In slabs with beams between supports with a value of α greater than 1.0, special top and bottom slab reinforcement shall be provided at exterior corners in accordance with the following:

1913.3.6.1 The special reinforcement in both top and bottom of slab shall be sufficient to resist a moment equal to the maximum positive moment (per foot of width) (per meter of width) in the slab.

1913.3.6.2 The moment shall be assumed to be about an axis perpendicular to the diagonal from the corner in the top of the slab and perpendicular to the diagonal in the bottom of the slab.

1913.3.6.3 The special reinforcement shall be provided for a distance in each direction from the corner equal to one fifth the longer span.

1913.3.6.4 The special reinforcement shall be placed in a band parallel to the diagonal in the top of the slab and a band perpendicular to the diagonal in the bottom of the slab. Alternatively, the special reinforcement shall be placed in two layers parallel to the sides of the slab in either the top or bottom of the slab.

1913.3.7 Where a drop panel is used to reduce amount of negative moment reinforcement over the column of a flat slab, size of drop panel shall be in accordance with the following:

1913.3.7.1 Drop panel shall extend in each direction from center line of support a distance not less than one sixth the span length measured from center to center of supports in that direction.

1913.3.7.2 Projection of drop panel below the slab shall be at least one fourth the slab thickness beyond the drop.

1913.3.7.3 In computing required slab reinforcement, thickness of drop panel below the slab shall not be assumed greater than one fourth the distance from edge of drop panel to edge of column or column capital.

1913.3.8 Details of reinforcement in slabs without beams.

1913.3.8.1 In addition to the other requirements of Section 1913.3, reinforcement in slabs without beams shall have minimum extensions as prescribed in Figure 19-1.

1913.3.8.2 Where adjacent spans are unequal, extension of negative moment reinforcement beyond the face of support as prescribed in Figure 19-1 shall be based on requirements of longer span.

1913.3.8.3 Bent bars shall be permitted only when depth-span ratio permits use of bends 45 degrees or less.

1913.3.8.4 For slabs in frames not braced against sidesway, lengths of reinforcement shall be determined by analysis but shall not be less than those prescribed in Figure 19-1.

1913.3.8.5 All bottom bars or wires within the column strip, in each direction, shall be continuous or spliced with Class A splices located as shown in Figure 19-1. At least two of the column strip bottom bars or wires in each direction shall pass within the column core and shall be anchored at exterior supports.

1913.3.8.6 In slabs with shearheads and in lift-slab construction, at least two bonded bottom bars or wires in each direction shall pass through the shearhead or lifting collar as close to the column as practicable and be continuous or spliced with a Class A splice. At exterior columns, the reinforcement shall be anchored at the shearhead or lifting collar.

1913.4 Openings in Slab Systems.

1913.4.1 Openings of any size shall be permitted in slab systems if shown by analysis that the design strength is at least equal to the required strength considering Sections 1909.2 and 1909.3, and that all serviceability conditions, including the specified limits on deflections, are met.

1913.4.2 In lieu of special analysis as required by Section 1913.4.1, openings shall be permitted in slab systems without beams only in accordance with the following:

1913.4.2.1 Openings of any size shall be permitted in the area common to intersecting middle strips, provided total amount of reinforcement required for the panel without the opening is maintained.

1913.4.2.2 In the area common to intersecting column strips, not more than one eighth the width of column strip in either span shall be interrupted by openings. An amount of reinforcement equivalent to that interrupted by an opening shall be added on the sides of the opening.

1913.4.2.3 In the area common to one column strip and one middle strip, not more than one fourth the reinforcement in either strip shall be interrupted by openings. An amount of reinforcement equivalent to that interrupted by an opening shall be added on the sides of the opening.

1913.4.2.4 Shear requirements of Section 1911.12.5 shall be satisfied.

1913.5 Design Procedures.

1913.5.1 A slab system shall be designed by any procedure satisfying conditions of equilibrium and geometric compatibility if shown that the design strength at every section is at least equal to the required strength considering Sections 1909.2 and 1909.3 and that all serviceability conditions, including specified limits on deflections, are met.

1913.5.1.1 Design of a slab system for gravity loads including the slab and beams (if any) between supports and supporting columns or walls forming orthogonal frames, by either the Direct Design Method of Section 1913.6 or the Equivalent Frame Method of Section 1913.7, shall be permitted.

1913.5.1.2 For lateral loads, analysis of unbraced frames shall take into account effects of cracking and reinforcement on stiffness of frame members.

1913.5.1.3 Combining the results of the gravity load analysis with the results of the lateral load analysis shall be permitted.

1913.5.2 The slab and beams (if any) between supports shall be proportioned for factored moments prevailing at every section.

1913.5.3 When gravity load, wind, earthquake or other lateral forces cause transfer of moment between slab and column, a fraction of the unbalanced moment shall be transferred by flexure in accordance with Sections 1913.5.3.2 and 1913.5.3.3.

1913.5.3.1 Fraction of unbalanced moment not transferred by flexure shall be transferred by eccentricity of shear in accordance with Section 1911.12.6.

1913.5.3.2 A fraction of the unbalanced moment given by $\gamma_f M_u$ shall be considered to be transferred by flexure within an effective slab width between lines that are one and one-half slab or drop panel thickness (1.5h) outside opposite faces of the column or capital, where M_u is the moment to be transferred and

$$\gamma_f = \frac{1}{1 + {}^2/_3 \sqrt{b_1/b_2}} \tag{13-1}$$

1913.5.3.3 For unbalanced moments about an axis parallel to the edge at exterior supports, the value of γ_f by Formula (13-1) shall be permitted to be increased up to 1.0 provided that V_u at an edge support does not exceed $0.75\phi V_c$ or at a corner support does not exceed $0.5\phi V_c$. For unbalanced moments at interior supports, and for unbalanced moments about an axis transverse to the edge at exterior supports, the value of γ_f in Formula (13-1) shall be permitted to be increased by up to 25 percent provided that V_u at the support does not exceed $0.4\phi V_c$. The reinforcement ratio ρ, within the effective slab width defined in Section 1913.5.3.2, shall not exceed 0.375 ρ_b. No adjustments to γ_f shall be permitted for prestressed slab systems.

1913.5.3.4 Concentration of reinforcement over the column by closer spacing or additional reinforcement shall be used to resist moment on the effective slab width defined in Section 1913.5.3.2.

1913.5.4 Design for transfer of load from slab to supporting columns or walls through shear and torsion shall be in accordance with Sections 1911.0 through 1911.12.

1913.6 Direct Design Method.

1913.6.1 Limitations. Design of slab systems within the following limitations by the Direct Design Method shall be permitted:

1913.6.1.1 There shall be a minimum of three continuous spans in each direction.

1913.6.1.2 Panels shall be rectangular, with a ratio of longer to shorter span center-to-center supports within a panel not greater than 2.

1913.6.1.3 Successive span lengths center-to-center supports in each direction shall not differ by more than one third the longer span.

1913.6.1.4 Offset of columns by a maximum of 10 percent of the span (in direction of offset) from either axis between center lines of successive columns shall be permitted.

1913.6.1.5 All loads shall be due to gravity only and uniformly distributed over an entire panel. Live load shall not exceed two times dead load.

1913.6.1.6 For a panel with beams between supports on all sides, the relative stiffness of beams in two perpendicular directions

$$\frac{\alpha_1 l_2^{\,2}}{\alpha_2 l_1^{\,2}} \tag{13-2}$$

shall not be less than 0.2 or greater than 5.0.

1913.6.1.7 Moment redistribution as permitted by Section 1908.4 shall not be applied for slab systems designed by the direct design method. See Section 1913.6.7.

1913.6.1.8 Variations from the limitations of Section 1913.6.1 shall be permitted if demonstrated by analysis that requirements of Section 1913.5.1 are satisfied.

1913.6.2 Total factored static moment for a span.

1913.6.2.1 Total factored static moment for a span shall be determined in a strip bounded laterally by center line of panel on each side of center line of supports.

1913.6.2.2 Absolute sum of positive and average negative factored moments in each direction shall not be less than

$$M_o = \frac{w_u l_2 l_n^{\,2}}{8} \tag{13-3}$$

1913.6.2.3 Where the transverse span of panels on either side of the center line of supports varies, l_2 in Formula (13-3) shall be taken as the average of adjacent transverse spans.

1913.6.2.4 When the span adjacent and parallel to an edge is being considered, the distance from edge to panel center line shall be substituted for l_2 in Formula (13-3).

1913.6.2.5 Clear span l_n shall extend from face to face of columns, capitals, brackets or walls. Value of l_n used in Formula (13-3) shall not be less than $0.65l_1$. Circular or regular polygon-shaped supports shall be treated as square supports with the same area.

1913.6.3 Negative and positive factored moments.

1913.6.3.1 Negative factored moments shall be located at face of rectangular supports. Circular or regular polygon-shaped supports shall be treated as square supports with the same area.

1913.6.3.2 In an interior span, total static moment M_o shall be distributed as follows:

Negative factored moment 0.65

Positive factored moment 0.35

1913.6.3.3 In an end span, total factored static moment M_o shall be distributed as follows:

	(1)	(2)	(3)	(4)	(5)
			Slab without Beams between Interior Supports		
	Exterior Edge Unrestrained	Slab with Beams between All Supports	Without Edge Beam	With Edge Beam	Exterior Edge Fully Restrained
Interior negative factored moment	0.75	0.70	0.70	0.70	0.65
Positive factored moment	0.63	0.57	0.52	0.50	0.35
Exterior negative factored moment	0	0.16	0.26	0.30	0.65

1913.6.3.4 Negative moment sections shall be designed to resist the larger of the two interior negative factored moments determined for spans framing into a common support unless an analysis is made to distribute the unbalanced moment in accordance with stiffness of adjoining elements.

1913.6.3.5 Edge beams or edges of slab shall be proportioned to resist in torsion their share of exterior negative factored moments.

1913.6.3.6 The gravity load moment to be transferred between slab and edge column in accordance with Section 1913.5.3.1 shall be $0.3M$.

1913.6.4 Factored moments in column strips.

1913.6.4.1 Column strips shall be proportioned to resist the following percentage of interior negative factored moments:

$l_2\ l_1$	0.5	1.0	2.0
$(\alpha_1 l_2/l_1) = 0$	75	75	75
$(\alpha_1 l_2/l_1) \geq 1.0$	90	75	45

Linear interpolations shall be made between values shown.

1913.6.4.2 Column strips shall be proportioned to resist the following percentage of exterior negative factored moments:

l_2/l_1		0.5	1.0	2.0
$(\alpha_1 l_2/l_1) = 0$	$\beta_t = 0$	100	100	100
	$\beta_t \geq 2.5$	75	75	75
$(\alpha_1 l_2/l_1) \geq 1.0$	$\beta_t = 0$	100	100	100
	$\beta_t \geq 2.5$	90	75	45

Linear interpolations shall be made between values shown.

1913.6.4.3 Where supports consist of columns or walls extending for a distance equal to or greater than three fourths the span length l_2 used to compute M_o, negative moments shall be considered to be uniformly distributed across l_2.

1913.6.4.4 Column strips shall be proportioned to resist the following percentage of positive factored moments:

$l_2\ l_1$	0.5	1.0	2.0
$(\alpha_1 l_2/l_1) = 0$	60	60	60
$(\alpha_1 l_2/l_1) \geq 1.0$	90	75	45

Linear interpolations shall be made between values shown:

1913.6.4.5 For slabs with beams between supports, the slab portion of column strips shall be proportioned to resist that portion of column strip moments not resisted by beams.

1913.6.5 Factored moments in beams.

1913.6.5.1 Beams between supports shall be proportioned to resist 85 percent of column strip moments if $(\alpha_1 l_2/l_1)$ is equal to or greater than 1.0.

1913.6.5.2 For values of $(\alpha_1 l_2/l_1)$ between 1.0 and zero, proportion of column strip moments resisted by beams shall be obtained by linear interpolation between 85 and zero percent.

1913.6.5.3 In addition to moments calculated for uniform loads according to Sections 1913.6.2.2, 1913.6.5.1 and 1913.6.5.2, beams shall be proportioned to resist all moments caused by concentrated or linear loads applied directly to beams, including weight of projecting beam stem above or below the slab.

1913.6.6 Factored moments in middle strips.

1913.6.6.1 That portion of negative and positive factored moments not resisted by column strips shall be proportionately assigned to corresponding half middle strips.

1913.6.6.2 Each middle strip shall be proportioned to resist the sum of the moments assigned to its two half middle strips.

1913.6.6.3 A middle strip adjacent to and parallel with an edge supported by a wall shall be proportioned to resist twice the moment assigned to the half middle strip corresponding to the first row of interior supports.

1913.6.7 Modification of factored moments. Modification of negative and positive factored moments by 10 percent shall be permitted provided the total static moment for a panel in the direction considered is not less than that required by Formula (13-3).

1913.6.8 Factored shear in slab systems with beams.

1913.6.8.1 Beams with $(\alpha_1 l_2/l_1)$ equal to or greater than 1.0 shall be proportioned to resist shear caused by factored loads on tributary areas bounded by 45-degree lines drawn from the corners of the panels and the center lines of the adjacent panels parallel to the long sides.

1913.6.8.2 In proportioning of beams with $(\alpha_1 l_2/l_1)$ less than 1.0 to resist shear, linear interpolation, assuming beams carry no load at $\alpha_1 = 0$, shall be permitted.

1913.6.8.3 In addition to shears calculated according to this section, beams shall be proportioned to resist shears caused by factored loads applied directly on beams.

1913.6.8.4 Computations of slab shear strength on the assumption that load is distributed to supporting beams in accordance with Section 1913.6.8.1 or 1913.6.8.2 shall be permitted. Resistance to total shear occurring on a panel shall be provided.

1913.6.8.5 Shear strength shall satisfy requirements of Section 1911.

1913.6.9 Factored moments in columns and walls.

1913.6.9.1 Columns and walls built integrally with a slab system shall resist moments caused by factored loads on the slab system.

1913.6.9.2 At an interior support, supporting elements above and below the slab shall resist the moment specified by Formula (13-4) in direct proportion to their stiffnesses unless a general analysis is made.

$$M = 0.07\,[(w_d + 0.5wl)l_2 l_n{}^2 - w'_d\,l'_2(l'_n)^2] \qquad (13\text{-}4)$$

where w'_d, l'_2 and l'_n refer to shorter span.

1913.7 Equivalent Frame Method.

1913.7.1 Design of slab systems by the equivalent frame method shall be based on assumptions given in Sections 1913.7.2 through 1913.7.6, and all sections of slabs and supporting members shall be proportioned for moments and shears thus obtained.

1913.7.1.1 Where metal column capitals are used, it shall be permitted to take account of their contributions to stiffness and resistance to moment and to shear.

1913.7.1.2 Neglecting the change in length of columns and slabs due to direct stress, and deflections due to shear, shall be permitted.

1913.7.2 Equivalent frame.

1913.7.2.1 The structure shall be considered to be made up of equivalent frames on column lines taken longitudinally and transversely through the building.

1913.7.2.2 Each frame shall consist of a row of columns or supports and slab-beam strips, bounded laterally by the center line of panel on each side of the center line of columns or supports.

1913.7.2.3 Columns or supports shall be assumed to be attached to slab-beam strips by torsional members (Section 1913.7.5) transverse to the direction of the span for which moments are being determined and extending to bounding lateral panel center lines on each side of a column.

1913.7.2.4 Frames adjacent and parallel to an edge shall be bounded by that edge and the center line of adjacent panel.

1913.7.2.5 Analysis of each equivalent frame in its entirety shall be permitted. Alternatively for gravity loading, a separate analysis of each floor or roof with far ends of columns considered fixed shall be permitted.

1913.7.2.6 Where slab-beams are analyzed separately, determination of moment at a given support assuming that the slab-beam is fixed at any support two panel distance therefrom shall be permitted, provided the slab continues beyond that point.

1913.7.3 Slab-beams.

1913.7.3.1 Determination of the moment of inertia of slab-beams at any cross section outside of joints or column capitals using the gross area of concrete shall be permitted.

1913.7.3.2 Variation in moment of inertia along axis of slab-beams shall be taken into account.

1913.7.3.3 Moment of inertia of slab-beams from center of column to face of column, bracket or capital shall be assumed equal to the moment of inertia of the slab-beam at face of column, bracket or capital divided by the quantity $(1 - c_2/l_2)^2$ where c_2 and l_2 are measured transverse to the direction of the span for which moments are being determined.

1913.7.4 Columns.

1913.7.4.1 Determination of the moment of inertia of columns at any cross section outside of joints or column capitals using the gross area of concrete shall be permitted.

1913.7.4.2 Variation in moment of inertia along axis of columns shall be taken into account.

1913.7.4.3 Moment of inertia of columns from top to bottom of the slab-beam at a joint shall be assumed infinite.

1913.7.5 Torsional members.

1913.7.5.1 Torsional members shall be assumed to have a constant cross section throughout their length consisting of the largest of:

1. A portion of slab having a width equal to that of the column, bracket or capital in the direction of the span for which moments are being determined, or

2. For monolithic or fully composite construction, the portion of slab specified in A above plus that part of the transverse beam above and below the slab, and

3. The transverse beam as defined in Section 1913.2.4.

1913.7.5.2 Where beams frame into columns in the direction of the span for which moments are being determined, the torsional stiffness shall be multiplied by the ratio of moment of inertia of slab with such beam to moment of inertia of slab without such beam.

1913.7.6 Arrangement of live load.

1913.7.6.1 When loading pattern is known, the equivalent frame shall be analyzed for that load.

1913.7.6.2 When live load is variable but does not exceed three-quarters of the dead load, or the nature of live load is such that all panels will be loaded simultaneously, it shall be permitted to assume that maximum factored moments occur at all sections with full factored live load on entire slab system.

1913.7.6.3 For loading conditions other than those defined in Section 1913.7.6.2, it shall be permitted to assume that maximum positive factored moment near midspan of a panel occurs with three-quarters of the full factored live load on the panel and on alternate panels; and it shall be permitted to assume that maximum negative factored moment in the slab at a support occurs with three-quarters of the full live load on adjacent panels only.

1913.7.6.4 Factored moments shall not be taken less than those occurring with full factored live load on all panels.

1913.7.7 Factored moments.

1913.7.7.1 At interior supports, critical section for negative factored moment (in both column and middle strips) shall be taken at face of rectilinear supports, but not greater than $0.175l_1$ from center of a column.

1913.7.7.2 At exterior supports provided with brackets or capitals, critical section for negative factored moment in the span perpendicular to an edge shall be taken at a distance from face of supporting element not greater than one half the projection of bracket or capital beyond face of supporting element.

1913.7.7.3 Circular or regular polygon-shaped supports shall be treated as square supports with the same area for location of critical section for negative design moment.

1913.7.7.4 When slab systems within limitations of Section 1913.6.1 are analyzed by the Equivalent Frame Method, it shall be permitted to reduce the resulting computed moments in such proportion that the absolute sum of the positive and average negative moments used in the design need not exceed the value obtained from Formula (13-3).

1913.7.7.5 Distribution of moments at critical sections across the slab-beam strip of each frame to column strips, beams and middle strips as provided in Sections 1913.6.4, 1913.6.5 and 1913.6.6 shall be permitted if the requirement of Section 1913.6.1.6 is satisfied.

SECTION 1914 — WALLS

1914.0 Notations.

A_g = gross area of section, square inches (mm^2).

f'_c = specified compressive strength of concrete, pounds per square inch (MPa).

h = overall thickness of member, inches (mm).

k = effective length factor.

l_c = vertical distance between supports, inches (mm).

M_{cr} = *cracking moment* $5\sqrt{f'_c}Ig/y_t$ (For **SI:** $0.42\sqrt{f'_c}Ig/y_t$) *for regular concrete.*

M_n = *nominal moment strength at section, inch-pound (N·m).*

M_u = *factored moment at section, inch-pound (N·m). See Section 1914.8.3.*

P_{nw} = nominal axial load strength of wall designed by Section 1914.4.

P_u = *factored axial load at midheight of wall, including tributary wall weight.*

ρ = *ratio of nonprestressed tension reinforcement.*

ρ_b = *reinforcement ratio producing balanced strain conditions. See Formula (8-1).*

ϕ = strength-reduction factor. See Section 1909.3.

1914.1 Scope.

1914.1.1 Provisions of Section 1914 shall apply for design of walls subjected to axial load, with or without flexure.

1914.1.2 Cantilever retaining walls are designed according to flexural design provisions of Section 1910 with minimum horizontal reinforcement according to Section 1914.3.3.

1914.2 General.

1914.2.1 Walls shall be designed for eccentric loads and any lateral or other loads to which they are subjected.

1914.2.2 Walls subject to axial loads shall be designed in accordance with Sections 1914.2, 1914.3 and either Section 1914.4 or 1914.5.

1914.2.3 Design for shear shall be in accordance with Section 1911.10.

1914.2.4 Unless demonstrated by a detailed analysis, horizontal length of wall to be considered as effective for each concentrated load shall not exceed center-to-center distance between loads, or width of bearing plus four times the wall thickness.

1914.2.5 Compression members built integrally with walls shall conform to Section 1910.8.2.

1914.2.6 Walls shall be anchored to intersecting elements such as floors or roofs or to columns, pilasters, buttresses, and intersecting walls and footings.

1914.2.7 Quantity of reinforcement and limits of thickness required by Sections 1914.3 and 1914.5 shall be permitted to be waived where structural analysis shows adequate strength and stability.

1914.2.8 Transfer of force to footing at base of wall shall be in accordance with Section 1915.8.

1914.3 Minimum Reinforcement.

1914.3.1 Minimum vertical and horizontal reinforcement shall be in accordance with Sections 1914.3.2 and 1914.3.3 unless a greater amount is required for shear by Sections 1911.10.8 and 1911.10.9.

1914.3.2 Minimum ratio of vertical reinforcement area to gross concrete area shall be:

1. 0.0012 for deformed bars not larger than No. 5 with a specified yield strength not less than 60,000 psi (413.7 MPa), or

2. 0.0015 for other deformed bars, or

3. 0.0012 for welded wire fabric (plain or deformed) not larger than W31 or D31.

1914.3.3 Minimum ratio of horizontal reinforcement area to gross concrete area shall be:

1. 0.0020 for deformed bars not larger than No. 5 with a specified yield strength not less than 60,000 psi (413.7 MPa), or

2. 0.0025 for other deformed bars, or

3. 0.0020 for welded wire fabric (plain or deformed) not larger than W31 or D31.

1914.3.4 Walls more than 10 inches (254 mm) thick, except basement walls, shall have reinforcement for each direction placed in two layers parallel with faces of wall in accordance with the following:

1. One layer consisting of not less than one half and not more than two thirds of total reinforcement required for each direction shall be placed not less than 2 inches (51 mm) or more than one third the thickness of wall from exterior surface.

2. The other layer, consisting of the balance of required reinforcement in that direction, shall be placed not less than $^3/_4$ inch (19 mm) or more than one third the thickness of wall from interior surface.

1914.3.5 Vertical and horizontal reinforcement shall not be spaced farther apart than three times the wall thickness, nor 18 inches (457 mm). *Unless otherwise required by the engineer, the upper- and lowermost horizontal reinforcement shall be placed within one half of the specified spacing at the top and bottom of the wall.*

1914.3.6 Vertical reinforcement need not be enclosed by lateral ties if vertical reinforcement area is not greater than 0.01 times gross concrete area, or where vertical reinforcement is not required as compression reinforcement.

1914.3.7 In addition to the minimum reinforcement required by Section 1914.3.1, not less than two No. 5 bars shall be provided around all window and door openings. Such bars shall be extended to develop the bar beyond the corners of the openings but not less than 24 inches (610 mm).

1914.3.8 *The minimum requirements for horizontal and vertical steel of Sections 1914.3.2 and 1914.3.3 may be interchanged for precast panels which are not restrained along vertical edges to inhibit temperature expansion or contraction.*

1914.4 Walls Designed as Compression Members. Except as provided in Section 1914.5, walls subject to axial load or combined flexure and axial load shall be designed as compression members in accordance with provisions of Sections 1910.2, 1910.3, 1910.10, 1910.11, 1910.12, 1910.13, 1910.14, 1910.17, 1914.2 and 1914.3.

1914.5 Empirical Design Method.

1914.5.1 Walls of solid rectangular cross section shall be permitted to be designed by the empirical provisions of Section 1914.5 if resultant of all factored loads is located within the middle third of the overall thickness of wall and all limits of Sections 1914.2, 1914.3 and 1914.5 are satisfied.

1914.5.2 Design axial load strength ϕP_{nw} of a wall satisfying limitations of Section 1914.5.1 shall be computed by Formula (14-1) unless designed in accordance with Section 1914.4.

$$\phi P_{nw} = 0.55 \phi f'_c A_g \left[1 - \left(\frac{kl_c}{32h}\right)^2\right] \qquad (14\text{-}1)$$

where $\phi = 0.70$ and effective length factor k shall be:

For walls braced top and bottom against lateral translation and

1. Restrained against rotation at one or both ends (top and/or bottom) 0.8

2. Unrestrained against rotation at both ends 1.0

For walls not braced against lateral translation 2.0

1914.5.3 Minimum thickness of walls designed by empirical design method.

1914.5.3.1 Thickness of bearing walls shall not be less than $^1/_{25}$ the supported height or length, whichever is shorter, or not less than 4 inches (102 mm).

1914.5.3.2 Thickness of exterior basement walls and foundation walls shall not be less than $7^1/_2$ inches (191 mm).

1914.6 Nonbearing Walls.

1914.6.1 Thickness of nonbearing walls shall not be less than 4 inches (102 mm), or not less than $^1/_{30}$ the least distance between members that provide lateral support.

1914.7 Walls as Grade Beams.

1914.7.1 Walls designed as grade beams shall have top and bottom reinforcement as required for moment in accordance with provisions of Sections 1910.2 through 1910.7. Design for shear shall be in accordance with provisions of Section 1911.

1914.7.2 Portions of grade beam walls exposed above grade shall also meet requirements of Section 1914.3.

1914.8 Alternate Design Slender Walls.

1914.8.1 *When flexural tension controls design of walls, the requirements of Section 1910.10 may be satisfied by complying with the limitations and procedures set forth in this section.*

1914.8.2 *The following limitations apply when this section is employed.*

1. Vertical service load stress at the location of maximum moment does not exceed 0.04 f'_c.

2. The reinforcement ratio ρ does not exceed 0.6 ρ_b.

3. Sufficient reinforcement is provided so that the nominal moment capacity times the ϕ factor is greater than M_{cr}.

4. Distribution of concentrated load does not exceed the width of bearing plus a width increasing at a slope of 2 vertical to 1 horizontal down to the design flexural section.

1914.8.3 *The required factored moment, M_u at the midheight cross section for combined axial and lateral factored loads, including the P Δ moments, shall be as set forth in Formula (14-2).*

$$M_u \le \phi M_n \qquad (14\text{-}2)$$

Unless a more comprehensive analysis is used, the P Δ moment shall be calculated using the maximum potential deflection, Δ_n, as defined in Section 1914.8.4.

1914.8.4 *The midheight deflection Δ_s, under service lateral and vertical loads (without load factors), shall be limited by the relation*

$$\Delta_s = \frac{l_c}{150} \qquad (14\text{-}3)$$

Unless a more comprehensive analysis is used, the midheight deflection shall be computed with the following formulas:

$$\Delta_s = \Delta_{cr} + \left(\frac{M_s - M_{cr}}{M_n - M_{cr}}\right)(\Delta_n - \Delta_{cr});\ \text{for } M_s > M_{cr} \qquad (14\text{-}4)$$

$$\Delta_s = \frac{5M_s l_c^{\,2}}{48E_c I_g};\ \text{for } M_s < M_{cr} \qquad (14\text{-}5)$$

WHERE:

$A_{se} = \dfrac{P_u + A_s f_y}{f_y}$

$I_{cr} = nA_{se}(d - c)^2 + \dfrac{bc^3}{3}$

M_s = *the maximum moment in the wall resulting from the application of the unfactored load combinations.*

$\Delta_{cr} = \dfrac{5M_{cr} l_c^{\,2}}{48E_c I_g}$

$\Delta_n = \dfrac{5M_n l_c^{\,2}}{48E_c I_{cr}}$

SECTION 1915 — FOOTINGS

1915.0 Notations.

A_g = gross area of section, square inches (mm^2).

d_p = diameter of pile at footing base.

β = ratio of long side to short side of footing.

1915.1 Scope.

1915.1.1 Provisions of this section shall apply for design of isolated footings and, where applicable, to combined footings and mats.

1915.1.2 Additional requirements for design of combined footings and mats are given in Section 1915.10.

1915.2 Loads and Reactions.

1915.2.1 Footings shall be proportioned to resist the factored loads and induced reactions, in accordance with the appropriate design requirements of this code and as provided in this section.

1915.2.2 Base area of footing or number and arrangement of piles shall be determined from the external forces and moments (transmitted by footing to soil or piles) and permissible soil pressure or permissible pile capacity selected through principles of soil mechanics. *External forces and moments are those resulting from unfactored loads (D, L, W and E) specified in Chapter 16.*

1915.2.3 For footings on piles, computations for moments and shears may be based on the assumption that the reaction from any pile is concentrated at pile center.

1915.2.4 *External forces and moments applied to footings shall be transferred to supporting soil without exceeding permissible soil pressures.*

1915.3 Footings Supporting Circular or Regular Polygon-shaped Columns or Pedestals. For location of critical sections for moment, shear and development of reinforcement in footings, it shall be permitted to treat circular or regular polygon-shaped concrete columns or pedestals as square members with the same area.

1915.4 Moment in Footings.

1915.4.1 External moment on any section of a footing shall be determined by passing a vertical plane through the footing and computing the moment of the forces acting over entire area of footing on one side of that vertical plane.

1915.4.2 Maximum factored moment for an isolated footing shall be computed as prescribed in Section 1915.4.1 at critical sections located as follows:

1. At face of column, pedestal or wall, for footings supporting a concrete column, pedestal or wall.

2. Halfway between middle and edge of wall, for footings supporting a masonry wall.

3. Halfway between face of column and edge of steel base, for footings supporting a column with steel base plates.

1915.4.3 In one-way footings, and two-way square footings, reinforcement shall be distributed uniformly across entire width of footing.

1915.4.4 In two-way rectangular footings, reinforcement shall be distributed as follows:

1915.4.4.1 Reinforcement in long direction shall be distributed uniformly across entire width of footing.

1915.4.4.2 For reinforcement in short direction, a portion of the total reinforcement given by Formula (15-1) shall be distributed uniformly over a band width (centered on center line of column or pedestal) equal to the length of short side of footing. Remainder of reinforcement required in short direction shall be distributed uniformly outside center band width of footing.

$$\frac{\text{Reinforcement in band width}}{\text{Total reinforcement in short direction}} = \frac{2}{(\beta + 1)} \qquad (15\text{-}1)$$

1915.5 Shear in Footings.

1915.5.1 Shear strength in footings shall be in accordance with Section 1911.12.

1915.5.2 Location of critical section for shear in accordance with Section 1911 shall be measured from face of column, pedestal or wall, for footings supporting a column, pedestal or wall. For footings supporting a column or pedestal with steel base plates, the critical section shall be measured from location defined in Section 1915.4.2, Item 3.

1915.5.3 Computation of shear on any section through a footing supported on piles shall be in accordance with the following:

1915.5.3.1 Entire reaction from any pile whose center is located $d_p/2$ or more outside the section shall be considered as producing shear on that section.

1915.5.3.2 Reaction from any pile whose center is located $d_p/2$ or more inside the section shall be considered as producing no shear in that section.

1915.5.3.3 For intermediate positions of pile center, the portion of the pile reaction to be considered as producing shear on the section shall be based on straight-line interpolation between full value at $d_p/2$ outside the section and zero value at $d_p/2$ inside the section.

1915.6 Development of Reinforcement in Footings.

1915.6.1 Development of reinforcement in footings shall be in accordance with Section 1912.

1915.6.2 Calculated tension or compression in reinforcement at each section shall be developed on each side of that section by embedment length, hooks (tension only), mechanical device or combinations thereof.

1915.6.3 Critical sections for development of reinforcement shall be assumed at the same locations as defined in Section 1915.4.2 for maximum factored moment, and at all other vertical planes where changes of section or reinforcement occur. See also Section 1912.10.6.

1915.7 Minimum Footing Depth. Depth of footing above bottom reinforcement shall not be less than 6 inches (152 mm) for footings on soil, or not less than 12 inches (305 mm) for footings on piles.

1915.8 Transfer of Force at Base of Column, Wall or Reinforced Pedestal.

1915.8.1 Forces and moments at base of column, wall, or pedestal shall be transferred to supporting pedestal or footing by bearing on concrete and by reinforcement, dowels and mechanical connectors.

1915.8.1.1 Bearing on concrete at contact surface between supported and supporting member shall not exceed concrete bearing strength for either surface as given by Section 1910.17.

1915.8.1.2 Reinforcement, dowels or mechanical connectors between supported and supporting members shall be adequate to transfer:

1. All compressive force that exceeds concrete bearing strength of either member.

2. Any computed tensile force across interface.

In addition, reinforcement, dowels or mechanical connectors shall satisfy Section 1915.8.2 or 1915.8.3.

1915.8.1.3 If calculated moments are transferred to supporting pedestal or footing, reinforcement, dowels or mechanical connectors shall be adequate to satisfy Section 1912.17.

1915.8.1.4 Lateral forces shall be transferred to supporting pedestal or footing in accordance with shear-friction provisions of Section 1911.7 or by other appropriate means.

1915.8.2 In cast-in-place construction, reinforcement required to satisfy Section 1915.8.1 shall be provided either by extending longitudinal bars into supporting pedestal or footing, or by dowels.

1915.8.2.1 For cast-in-place columns and pedestals, area of reinforcement across interface shall not be less than 0.005 times gross area of supported member.

1915.8.2.2 For cast-in-place walls, area of reinforcement across interface shall not be less than minimum vertical reinforcement given in Section 1914.3.2.

1915.8.2.3 At footings, No. 14 and No. 18 longitudinal bars, in compression only, may be lap spliced with dowels to provide reinforcement required to satisfy Section 1915.8.1. Dowels shall not be larger than No. 11 bar and shall extend into supported member a distance not less than the development length of No. 14 or No. 18 bars or the splice length of the dowels, whichever is greater, and into the footing a distance not less than the development length of the dowels.

1915.8.2.4 If a pinned or rocker connection is provided in cast-in-place construction, connection shall conform to Sections 1915.8.1 and 1915.8.3.

1915.8.3 In precast construction, reinforcement required to satisfy Section 1915.8.1 may be provided by anchor bolts or suitable mechanical connectors.

1915.8.3.1 Connection between precast columns or pedestals and supporting members shall meet the requirements of Section 1916.5.1.3, Item 1.

1915.8.3.2 Connection between precast walls and supporting members shall meet the requirements of Section 1916.5.1.3, Items 2 and 3.

> ***EXCEPTION:*** *In tilt-up construction, this connection may be to an adjacent floor slab. In no case shall the connection provided be less than that required by Section 1611.*

1915.8.3.3 Anchor bolts and mechanical connectors shall be designed to reach their design strength prior to anchorage failure or failure of surrounding concrete.

1915.9 Sloped or Stepped Footings.

1915.9.1 In sloped or stepped footings, angle of slope or depth and location of steps shall be such that design requirements are satisfied at every section.

1915.9.2 Sloped or stepped footings designed as a unit shall be constructed to assure action as a unit.

1915.10 Combined Footings and Mats.

1915.10.1 Footings supporting more than one column, pedestal or wall (combined footings or mats) shall be proportioned to resist the factored loads and induced reactions in accordance with appropriate design requirements of this code.

1915.10.2 The direct design method of Section 1913 shall not be used for design of combined footings and mats.

1915.10.3 Distribution of soil pressure under combined footings and mats shall be consistent with properties of the soil and the structure and with established principles of soil mechanics.

1915.11 Plain Concrete Pedestals and Footings. *See Section 1922.*

SECTION 1916 — PRECAST CONCRETE

1916.0 Notations.

A_g = gross area of column, inches squared (mm^2).

l = clear span, inches (mm).

1916.1 Scope.

1916.1.1 All provisions of this code, not specifically excluded and not in conflict with the provisions of Section 1916, shall apply to structures incorporating precast concrete structural members.

1916.2 General.

1916.2.1 Design of precast members and connections shall include loading and restraint conditions from initial fabrication to end use in the structure, including form removal, storage, transportation and erection.

1916.2.2 When precast members are incorporated into a structural system, the forces and deformations occurring in and adjacent to connections shall be included in the design.

1916.2.3 Tolerances for both precast members and interfacing members shall be specified. Design of precast members and connections shall include the effects of these tolerances.

1916.2.4 In addition to the requirements for drawings and specifications in Section *106.3.2,* the following shall be included in either the contract documents or shop drawings:

1. Details of reinforcement, inserts and lifting devices required to resist temporary loads from handling, storage, transportation and erection.

2. Required concrete strength at stated ages or stages of construction.

1916.3 Distribution of Forces among Members.

1916.3.1 Distribution of forces that are perpendicular to the plane of members shall be established by analysis or by test.

1916.3.2 Where the system behavior requires in-plane forces to be transferred between the members of a precast floor or wall system, the following shall apply:

1916.3.2.1 In-plane force paths shall be continuous through both connections and members.

1916.3.2.2 Where tension forces occur, a continuous path of steel or steel reinforcement shall be provided.

1916.4 Member Design.

1916.4.1 In one-way precast floor and roof slabs and in one-way precast, prestressed wall panels, all not wider than 12 feet (4 m), and where members are not mechanically connected to cause restraint in the transverse direction, the shrinkage and temperature reinforcement requirements of Section 1907.12 in the direction normal to the flexural reinforcement shall be permitted to be waived. This waiver shall not apply to members which require reinforcement to resist transverse flexural stresses.

1916.4.2 For precast, nonprestressed walls the reinforcement shall be designed in accordance with the provisions of Section 1910 or 1914 except that the area of horizontal and vertical reinforcement shall each be not less than 0.001 times the gross cross-sectional area of the wall panel. Spacing of reinforcement shall not exceed five times the wall thickness or 30 inches (762 mm) for interior walls or 18 inches (457 mm) for exterior walls.

1916.5 Structural Integrity.

1916.5.1 Except where the provisions of Section 1916.5.2 govern, the following minimum provisions for structural integrity shall apply to all precast concrete structures:

1916.5.1.1 Longitudinal and transverse ties required by Section 1907.13.3 shall connect members to a lateral-load-resisting system.

1916.5.1.2 Where precast elements form floor or roof diaphragms, the connections between diaphragm and those members being laterally supported shall have a nominal tensile strength capable of resisting not less than 300 pounds per linear foot (630 N/mm).

1916.5.1.3 Vertical tension tie requirements of Section 1907.13.3 shall apply to all vertical structural members, except cladding, and shall be achieved by providing connections at horizontal joints in accordance with the following:

1. Precast columns shall have a nominal strength in tension not less than 200 A_g in pounds (N). For columns with a larger cross section than required by consideration of loading, a reduced effective area A_g, based on cross section required but not less than one-half the total area, shall be permitted.

2. Precast wall panels shall have a minimum of two ties per panel, with a nominal tensile strength not less than 10,000 pounds (44 500 N) per tie.

3. When design forces result in no tension at the base, the ties required by Section 1916.5.1.3, Item 2, shall be permitted to be anchored into an appropriately reinforced concrete floor slab on grade.

1916.5.1.4 Connection details that rely solely on friction caused by gravity loads shall not be used.

1916.5.2 For precast concrete bearing wall structures three or more stories in height, the following minimum provisions shall apply:

1916.5.2.1 Longitudinal and transverse ties shall be provided in floor and roof systems to provide a nominal strength of 1,500 pounds per foot (315 N/mm) of width or length. Ties shall be provided over interior wall supports and between members and exterior walls. Ties shall be positioned in or within 2 feet (610 mm) of the plane of the floor or roof system.

1916.5.2.2 Longitudinal ties parallel to floor or roof slab spans shall be spaced not more than 10 feet (3048 mm) on centers. Provisions shall be made to transfer forces around openings.

1916.5.2.3 Transverse ties perpendicular to floor or roof slab spans shall be spaced not greater than the bearing wall spacing.

1916.5.2.4 Ties around the perimeter of each floor and roof, within 4 feet (1219 mm) of the edge, shall provide a nominal strength in tension not less than 16,000 pounds (71 200 N).

1916.5.2.5 Vertical tension ties shall be provided in all walls and shall be continuous over the height of the building. They shall provide a nominal tensile strength not less than 3,000 pounds per horizontal foot (6300 N/mm) of wall. Not less than two ties shall be provided for each precast panel.

1916.6 Connection and Bearing Design.

1916.6.1 Forces shall be permitted to be transferred between members by grouted joints, shear keys, mechanical connectors, reinforcing steel connections, reinforced topping or a combination of these means.

1916.6.1.1 The adequacy of connections to transfer forces between members shall be determined by analysis or by test. Where shear is the primary imposed loading, it shall be permitted to use the provisions of Section 1911.7 as applicable.

1916.6.1.2 When designing a connection using materials with different structural properties, their relative stiffnesses, strengths and ductilities shall be considered.

1916.6.2 Bearing for precast floor and roof members on simple supports shall satisfy the following:

1916.6.2.1 The allowable bearing stress at the contact surface between supported and supporting members and between any intermediate bearing elements shall not exceed the bearing strength for either surface and the bearing element. Concrete bearing strength shall be as given in Section 1910.17.

1916.6.2.2 Unless shown by test or analysis that performance will not be impaired, the following minimum requirements shall be met:

1. Each member and its supporting system shall have design dimensions selected so that, after consideration of tolerances, the distance from the edge of the support to the end of the precast member in the direction of the span is at least $^1/_{180}$ of the clear span, l, but not less than:

For solid or hollow-core slabs . . . . 2 inches (51 mm).

For beams or stemmed members . . . . 3 inches (76 mm).

2. Bearing pads at unarmored edges shall be set back a minimum of $^1/_2$ inch (12.7 mm) from the face of the support, or at least the chamfer dimension at chamfered edges.

1916.6.2.3 The requirements of Section 1912.11.1 shall not apply to the positive bending moment reinforcement for statically determinate precast members, but at least one-third of such reinforcement shall extend to the center of the bearing length.

1916.7 Items Embedded after Concrete Placement.

1916.7.1 When approved by the engineer, embedded items (such as dowels or inserts) that either protrude from the concrete or remain exposed for inspection shall be permitted to be embedded while the concrete is in a plastic state provided that:

1916.7.1.1 Embedded items are not required to be hooked or tied to reinforcement within the concrete.

1916.7.1.2 Embedded items are maintained in the correct position while the concrete remains plastic.

1916.7.1.3 The concrete is properly consolidated around the embedded item.

1916.8 Marking and Identification.

1916.8.1 Each precast member shall be marked to indicate its location and orientation in the structure and date of manufacture.

1916.8.2 Identification marks shall correspond to placing drawings.

1916.9 Handling.

1916.9.1 Member design shall consider forces and distortions during curing, stripping, storage, transportation and erection so that precast members are not overstressed or otherwise damaged.

1916.9.2 Precast members and structures shall be adequately supported and braced during erection to ensure proper alignment and structural integrity until permanent connections are completed.

1916.10 Strength Evaluation of Precast Construction.

1916.10.1 A precast element to be made composite with cast-in-place concrete shall be permitted to be tested in flexure as a precast element alone in accordance with the following:

1916.10.1.1 Test loads shall be applied only when calculations indicate the isolated precast element will not be critical in compression or buckling.

1916.10.1.2 The test load shall be that load which, when applied to the precast member alone, induces the same total force in the tension reinforcement as would be induced by loading the composite member with the test load required by Section 1920.3.2.

1916.10.2 The provisions of Sections 1920.5 shall be the basis for acceptance or rejection of the precast element.

SECTION 1917 — COMPOSITE CONCRETE FLEXURAL MEMBERS

1917.0 Notations.

A_c = area of contact surface being investigated for horizontal shear, square inches (mm^2).

A_v = area of ties within a distance s, square inches (mm^2).

b_v = width of cross section at contact surface being investigated for horizontal shear.

d = distance from extreme compression fiber to centroid of tension reinforcement for entire composite section, inches (mm).

h = overall thickness of composite members, inches (mm).

s = spacing of ties measured along the longitudinal axis of the member, inches (mm).

V_{nh} = nominal horizontal shear strength.

V_u = factored shear force at section.

λ = correction factor related to unit weight of concrete.

ρ_v = ratio of tie reinforcement area to area of contact surface.
= $A_v/b_v s$

ϕ = strength-reduction factor. See Section 1909.3.

1917.1 Scope.

1917.1.1 Provisions of this section shall apply for design of composite concrete flexural members defined as precast or cast-in-place concrete elements or both constructed in separate placements but so interconnected that all elements respond to loads as a unit.

1917.1.2 All provisions of this code shall apply to composite concrete flexural members, except as specifically modified in this section.

1917.2 General.

1917.2.1 The use of an entire composite member or portions thereof for resisting shear and moment shall be permitted.

1917.2.2 Individual elements shall be investigated for all critical stages of loading.

1917.2.3 If the specified strength, unit weight or other properties of the various elements are different, properties of the individual elements or the most critical values shall be used in design.

1917.2.4 In strength computations of composite members, no distinction shall be made between shored and unshored members.

1917.2.5 All elements shall be designed to support all loads introduced prior to full development of design strength of composite members.

1917.2.6 Reinforcement shall be provided as required to control cracking and to prevent separation of individual elements of composite members.

1917.2.7 Composite members shall meet requirements for control of deflections in accordance with Section 1909.5.5.

1917.3 Shoring. When used, shoring shall not be removed until supported elements have developed design properties required to support all loads and limit deflections and cracking at time of shoring removal.

1917.4 Vertical Shear Strength.

1917.4.1 When an entire composite member is assumed to resist vertical shear, design shall be in accordance with requirements of Section 1911 as for a monolithically cast member of the same cross-sectional shape.

1917.4.2 Shear reinforcement shall be fully anchored into interconnected elements in accordance with Section 1912.13.

1917.4.3 Extended and anchored shear reinforcement shall be permitted to be included as ties for horizontal shear.

1917.5 Horizontal Shear Strength.

1917.5.1 In a composite member, full transfer of horizontal shear forces shall be assured at contact surfaces of interconnected elements.

1917.5.1.1 *Full transfer of horizontal shear forces may be assumed when all of the following are satisfied:*

1. *Contact surfaces are clean, free of laitance, and intentionally roughened to a full amplitude of approximately* $^1/_4$ *inch (6.4 mm),*
2. *Minimum ties are provided in accordance with Section 1917.6,*
3. *Web members are designed to resist total vertical shear, and*
4. *All shear reinforcement is fully anchored into all interconnected elements.*

1917.5.1.2 *If all requirements of Section 1917.5.1.1 are not satisfied, horizontal shear shall be investigated in accordance with Section 1917.5.2 or 1917.5.3.*

1917.5.2 Unless calculated in accordance with Section 1917.5.3, design of cross sections subject to horizontal shear shall be based on

$$V_u \le \phi V_{nh} \qquad (17\text{-}1)$$

where V_u is factored shear force at section considered and V_{nh} is nominal horizontal shear strength in accordance with the following:

1917.5.2.1 When contact surfaces are clear, free of laitance and intentionally roughened, shear strength V_{nh} shall not be taken greater than $80 b_v d$, in pounds ($0.55\ b_v d$, in newtons).

1917.5.2.2 When minimum ties are provided in accordance with Section 1917.6 and contact surfaces are clean and free of laitance, but not intentionally roughened, shear strength V_{nh} shall not be taken greater than $80 b_v d$, in pounds ($0.55\ b_v d$, in newtons).

1917.5.2.3 When minimum ties are provided in accordance with Section 1917.6 and contact surfaces are clean, free of laitance, and intentionally roughened to a full amplitude of approximately $^1/_4$ inch (6.4 mm), shear strength V_{nh} shall be taken equal to $(260 + 0.6\rho_v f_y) b_v d$ in pounds [$(1.79 + 0.6\rho_v f_y) b_v d$, in newtons], but not greater than $500\ b_v d$ in pounds ($3.5\ b_v d$, in newtons). Values for λ in Section 1911.7.4.3 shall apply.

1917.5.2.4 When factored shear force V_u at section considered exceeds $\phi(500 b_v d)$ [For **SI:** $\phi(3.5 b_v d)$], design for horizontal shear shall be in accordance with Section 1911.7.4.

1917.5.2.5 When determining nominal horizontal shear strength over prestressed concrete elements, d shall be as defined or $0.8h$, whichever is greater.

1917.5.3 As an alternative to Section 1917.5.2, horizontal shear shall be determined by computing the actual compressive or tensile force in any segment, and provisions shall be made to transfer that force as horizontal shear to the supporting element. The factored horizontal shear force shall not exceed horizontal shear strength ϕV_{nh} as given in Sections 1917.5.2.1 through 1917.5.2.4 where area of contact surface A_c shall be substituted for $b_v d$.

1917.5.3.1 When ties provided to resist horizontal shear are designed to satisfy Section 1917.5.3, the tie-area-to-tie-spacing ratio along the member shall approximately reflect the distribution of shear forces in the member.

1917.5.4 When tension exists across any contact surface between interconnected elements, shear transfer by contact may be assumed only when minimum ties are provided in accordance with Section 1917.6.

1917.6 Ties for Horizontal Shear.

1917.6.1 When ties are provided to transfer horizontal shear, tie area shall not be less than that required by Section 1911.5.5.3 and tie spacing shall not exceed four times the least dimension of supported element, or 24 inches (610 mm).

1917.6.2 Ties for horizontal shear may consist of single bars or wire, multiple leg stirrups or vertical legs of welded wire fabric (plain or deformed).

1917.6.3 All ties shall be fully anchored into interconnected elements in accordance with Section 1912.13.

SECTION 1918 — PRESTRESSED CONCRETE

1918.0 Notations.

A = area of that part of cross section between flexural tension face and center of gravity of gross section, square inches (mm^2).

A_{ps} = area of prestressed reinforcement in tension zone, square inches (mm^2).

A_s = area of nonprestressed tension reinforcement, square inches (mm^2).

A'_s = area of compression reinforcement, square inches (mm^2).

b = width of compression face of member, inches (mm).

D = dead loads or related internal moments and forces.

d = distance from extreme compression fiber to centroid of nonprestressed tension reinforcement, inches (mm).

d' = distance from extreme compression fiber to centroid of compression reinforcement, inches (mm).

d_p = distance from extreme compression fiber to centroid of prestressed reinforcement.

e = base of Napierian logarithms.

f'_c = specified compressive strength of concrete, pounds per square inch (MPa).

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, pounds per square inch; or *square root of compressive strength of concrete at time of initial prestress, pounds per square inch (MPa)*.

f'_{ci} = compressive strength of concrete at time of initial prestress, pounds per square inch (MPa).

f_{pc} = average compressive stress in concrete due to effective prestress force only (after allowance for all prestress losses), pounds per square inch (MPa).

f_{ps} = stress in prestressed reinforcement at nominal strength, pounds per square inch (MPa).

f_{pu} = specified tensile strength of prestressing tendons, pounds per square inch (MPa).

f_{py} = specified yield strength of prestressing tendons, pounds per square inch (MPa).

f_r = modulus of rupture of concrete, pounds per square inch (MPa).

f_{se} = effective stress in prestressed reinforcement (after allowance for all prestress losses), pounds per square inch (MPa).

f_y = specified yield strength of nonprestressed reinforcement, pounds per square inch (MPa).

h = overall dimension of member in direction of action considered, inches (mm).

K = wobble friction coefficient per foot (per mm) of prestressing tendon.

L = live loads or related internal moments and forces.

l = length of span of two-way flat plates in direction parallel to that of the reinforcement being determined, inches (mm). See Formula (18-8).

l_x = length of prestressing tendon element from jacking end to any point x, feet (mm). See Formulas (18-1) and (18-2).

N_c = tensile force in concrete due to unfactored dead load plus live load ($D + L$).

P_s = prestressing tendon force at jacking end.

P_x = prestressing tendon force at any point x.

α = total angular change of prestressing tendon profile in radians from tendon jacking end to any point x.

β_1 = factor defined in Section 1910.2.7.1.

γ_p = factor for type of prestressing tendon.
= 0.55 for f_{py}/f_{pu} not less than 0.80.
= 0.40 for f_{py}/f_{pu} not less than 0.85.
= 0.28 for f_{py}/f_{pu} not less than 0.90.

μ = curvature friction coefficient.

ρ = ratio of nonprestressed tension reinforcement.
= A_s/bd.

ρ' = ratio of compression reinforcement.
= A'_s/bd.

ρ_p = ratio of prestressed reinforcement.
= A_{ps}/bd_p.

ϕ = strength-reduction factor. See Section 1909.3.

ω = $\rho f_y/f'_c$.

ω' = $\rho' f_y/f'_c$.

ω_p = $\rho_p f_{ps}/f'_c$.

ω_w, ω_{pw}, ω'_w
= reinforcement indices for flanged sections computed as for ω, ω_p, and ω' except that b shall be the web width, and reinforcement area shall be that required to develop compressive strength of web only.

1918.1 Scope.

1918.1.1 Provisions of this section shall apply to members prestressed with wire, strands or bars conforming to provisions for prestressing tendons.

1918.1.2 All provisions of this code not specifically excluded, and not in conflict with provisions of this section, shall apply to prestressed concrete.

1918.1.3 The following provisions of this code shall not apply to prestressed concrete, except as specifically noted: Sections

1907.6.5, 1908.4, 1908.10.2 through 1908.10.4, 1908.11, 1910.3.2 and 1910.3.3, 1910.5, 1910.6, 1910.9.1, 1910.9.2, 1913, 1914.3, 1914.5 and 1914.6.

1918.2 General.

1918.2.1 Prestressed members shall meet the strength requirements specified in this code.

1918.2.2 Design of prestressed members shall be based on strength and on behavior at service conditions at all load stages that may be critical during the life of the structure from the time prestress is first applied.

1918.2.3 Stress concentrations due to prestressing shall be considered in design.

1918.2.4 Provisions shall be made for effects on adjoining construction of elastic and plastic deformations, deflections, changes in length and rotations due to prestressing. Effects of temperature and shrinkage shall also be included.

1918.2.5 Possibility of buckling in a member between points where concrete and prestressing tendons are in contact and of buckling in thin webs and flanges shall be considered.

1918.2.6 In computing section properties prior to bonding of prestressing tendons, effect of loss of area due to open ducts shall be considered.

1918.3 Design Assumptions.

1918.3.1 Strength design of prestressed members for flexure and axial loads shall be based on assumptions given in Section 1910.2, except Section 1910.2.4, shall apply only to reinforcement conforming to Section 1903.5.3.

1918.3.2 For investigation of stresses at transfer of prestress, at service loads and at cracking loads, straight-line theory may be used with the following assumptions:

1918.3.2.1 Strains vary linearly with depth through entire load range.

1918.3.2.2 At cracked sections, concrete resists no tension.

1918.4 Permissible Stresses in Concrete—Flexural Members.

1918.4.1 Stresses in concrete immediately after prestress transfer (before time-dependent prestress losses) shall not exceed the following:

1. Extreme fiber stress in compression . . . . $0.60f'_c$
2. Extreme fiber stress in tension except as permitted in . . . . $3\sqrt{f'_{ci}}$
(For **SI:** $0.25\sqrt{f'_{ci}}$)
3. Extreme fiber stress in tension at ends of simply supported members . . . . $6\sqrt{f'_{ci}}$
(For **SI:** $0.50\sqrt{f'_{ci}}$)

Where computed tensile stresses exceed these values, bonded auxiliary reinforcement (nonprestressed or prestressed) shall be provided in the tensile zone to resist the total tensile force in concrete computed with the assumption of an uncracked section.

1918.4.2 Stresses in concrete at service loads (after allowance for all prestress losses) shall not exceed the following:

1. Extreme fiber stress in compression due to prestress plus sustained loads . . . . $0.45f'_c$
2. Extreme fiber stress in compression due to prestress plus total load . . . . $0.60f'_c$
3. Extreme fiber stress in tension in precompressed tensile zone . . . . $6\sqrt{f'_c}$
(For **SI:** $0.50\sqrt{f'_c}$)
4. Extreme fiber stress in tension in precompressed tensile zone of members (except two-way slab systems) where analysis based on transformed cracked sections and on bilinear moment-deflection relationships show that immediate and long-time deflections comply with requirements of Section 1909.5.4, and where cover requirements comply with Section 1907.7.3.2 . . . . $12\sqrt{f'_c}$
(For **SI:** $1.0\sqrt{f'_c}$)

1918.4.3 Permissible stresses in concrete of Sections 1918.4.1 and 1918.4.2 may be exceeded if shown by test or analysis that performance will not be impaired.

1918.5 Permissible Stress in Prestressing Tendons.

1918.5.1 Tensile stress in prestressing tendons shall not exceed the following:

1. Due to tendon jacking force . . . . $0.94f_{py}$ but not greater than the lesser of 0.80 f_{pu} and the maximum value recommended by manufacturer of prestressing tendons or anchorages.
2. Immediately after prestress transfer . . . . $0.82f_{py}$ but not greater than $0.74f_{pu}$.
3. Posttensioning tendons, at anchorages and couplers, immediately after tendon anchorage . . . . $0.70f_{pu}$

1918.6 Loss of Prestress.

1918.6.1 To determine effective prestress f_{se}, allowance for the following sources of loss of prestress shall be considered:

1. Anchorage seating loss.
2. Elastic shortening of concrete.
3. Creep of concrete.
4. Shrinkage of concrete.
5. Relaxation of tendon stress.
6. Friction loss due to intended or unintended curvature in posttensioning tendons.

1918.6.2 Friction loss in posttensioning tendons.

1918.6.2.1 Effect of friction loss in posttensioning tendons shall be computed by

$$P_s = P_x e^{(Kl_x + \mu\alpha)} \qquad (18\text{-}1)$$

When $(Kl \pm \mu\alpha)$ is not greater than 0.3, effect of friction loss shall be permitted to be computed by

$$P_s = P_x (1 + Kl_x + \mu\alpha) \qquad (18\text{-}2)$$

1918.6.2.2 Friction loss shall be based on experimentally determined wobble K and curvature μ friction coefficients and shall be verified during tendon stressing operations.

1918.6.2.3 Values of wobble and curvature coefficients used in design shall be shown on design drawings.

1918.6.3 Where loss of prestress in member may occur due to connection of member to adjoining construction, such loss of prestress shall be allowed for in design.

1918.7 Flexural Strength.

1918.7.1 Design moment strength of flexural members shall be computed by the strength design methods of this chapter. For prestressing tendons, f_{ps} shall be substituted for f_y in strength computations.

1918.7.2 As an alternative to a more accurate determination of f_{ps} based on strain compatibility, the following approximate values of f_{ps} shall be used if f_{se} is not less than 0.5 f_{pu}.

1. For members with bonded prestressing tendons:

$$f_{ps} = f_{pu}\left(1 - \frac{\gamma_p}{\beta_1}\left[\rho_p \frac{f_{pu}}{f'_c} + \frac{d}{d_p}(\omega - \omega')\right]\right) \quad (18\text{-}3)$$

If any compression reinforcement is taken into account when calculating f_{ps} by Formula (18-3), the term

$$\left[\rho_p \frac{f_{pu}}{f'_c} + \frac{d}{d_p}(\omega - \omega')\right]$$

shall be taken not less than 0.17 and d' shall be no greater than 0.15 d_p.

2. For members with unbonded prestressing tendons and with a span-to-depth ratio of 35 or less:

$$f_{ps} = f_{se} + 10,000 + \frac{f'_c}{100\rho_p} \quad (18\text{-}4)$$

For **SI:** $$f_{ps} = f_{se} + 69 + \frac{f'_c}{100\rho_p}$$

but f_{ps} in Formula (18-4) shall not be taken greater than f_{py}, or (f_{se} + 60,000) (For **SI:** f_{se} + 413.7).

3. For members with unbonded prestressing tendons and with a span-to-depth ratio greater than 35:

$$f_{ps} = f_{se} + 10,000 + \frac{f'_c}{300\rho_p} \quad (18\text{-}5)$$

For **SI:** $$f_{ps} = f_{se} + 69 + \frac{f'_c}{300\rho_p}$$

but f_{ps} in Formula (18-5) shall not be taken greater than f_{py}, or (f_{se} + 30,000) (For **SI:** f_{se} + 206.9).

1918.7.3 Nonprestressed reinforcement conforming to Section 1903.5.3, if used with prestressing tendons, shall be permitted to be considered to contribute to the tensile force and to be included in moment strength computations at a stress equal to the specified yield strength f_y. Other nonprestressed reinforcement shall be permitted to be included in strength computations only if a strain compatibility analysis is made to determine stresses in such reinforcement.

1918.8 Limits for Reinforcement of Flexural Members.

1918.8.1 Ratio of prestressed and nonprestressed reinforcement used for computation of moment strength of a member, except as provided in this section shall be such that ω_p, $[\omega_p + (d/d_p)(\omega - \omega')]$, or $[\omega_{pw} + (d/d_p)(\omega_w - \omega'_w)]$ is not greater than 0.36 β_1.

1918.8.2 When a reinforcement ratio in excess of that specified in this section is provided, design moment strength shall not exceed the moment strength based on the compression portion of the moment couple.

1918.8.3 Total amount of prestressed and nonprestressed reinforcement shall be adequate to develop a factored load at least 1.2 times the cracking load computed on the basis of the modulus of rupture f_r specified in Section 1909.5.2.3, except for flexural members with shear and flexural strength at least twice that required by Section 1909.2.

1918.9 Minimum Bonded Reinforcement.

1918.9.1 A minimum area of bonded reinforcement shall be provided in all flexural members with unbonded prestressing tendons as required by Sections 1918.9.2 and 1918.9.3.

1918.9.2 Except as provided in Section 1918.9.3, minimum area of bonded reinforcement shall be computed by

$$A_s = 0.004A \quad (18\text{-}6)$$

1918.9.2.1 Bonded reinforcement required by Formula (18-6) shall be uniformly distributed over precompressed tensile zone as close as practicable to extreme tension fiber.

1918.9.2.2 Bonded reinforcement shall be required regardless of service load stress conditions.

One-way, unbonded, posttensioned slabs and beams shall be designed to carry the dead load of the slab or beam plus 25 percent of the unreduced superimposed live load by some method other than the primary unbonded posttensioned reinforcement. Design shall be based on the strength method of design with a load factor and capacity reduction factor of one. All reinforcement other than the primary unbonded reinforcement provided to meet other requirements of this section may be used in the design.

1918.9.2.3 *Maximum spacing limitations of Sections 1907.6.1 and 1908.10.5.2, for bonded reinforcement in slabs are not applicable to spacing of bonded reinforcement in members with unbonded tendons.*

1918.9.3 For two-way flat plates, defined as solid slabs of uniform thickness, minimum area and distribution of bonded reinforcement shall be as follows:

1918.9.3.1 Bonded reinforcement shall not be required in positive moment areas where computed tensile stress in concrete at service load (after allowance for prestress losses) does not exceed $2\sqrt{f'_c}$ (For **SI:** $0.166\sqrt{f'_c}$).

1918.9.3.2 In positive moment areas where computed tensile stress in concrete at service load exceeds $2\sqrt{f'_c}$ (For **SI:** $0.166\sqrt{f'_c}$) minimum area of bonded reinforcement shall be computed by

$$A_s = \frac{N_c}{0.5f_y} \quad (18\text{-}7)$$

where design yield strength f_y shall not exceed 60,000 pounds per square inch (413.7 MPa). Bonded reinforcement shall be uniformly distributed over precompressed tensile zone as close as practicable to extreme tension fiber.

1918.9.3.3 In negative moment areas at column supports, minimum area of bonded reinforcement in each direction shall be computed by

$$A_s = 0.00075hl \quad (18\text{-}8)$$

where l is length of span in direction parallel to that of the reinforcement being determined. Bonded reinforcement required by Formula (18-8) shall be distributed within a slab width between lines that are 1.5h outside opposite faces of the column support. At least four bars or wires shall be provided in each direction. Spacing of bonded reinforcement shall not exceed 12 inches (305 mm).

1918.9.4 Minimum length of bonded reinforcement required by Sections 1918.9.2 and 1918.9.3 shall be as follows:

1918.9.4.1 In positive moment areas, minimum length of bonded reinforcement shall be one third the clear span length and centered in positive moment area.

1918.9.4.2 In negative moment areas, bonded reinforcement shall extend one sixth the clear span on each side of support.

1918.9.4.3 Where bonded reinforcement is provided for design moment strength in accordance with Section 1918.7.3, or for tensile stress conditions in accordance with Section 1918.9.3.2, minimum length also shall conform to provisions of Section 1912.

1918.10 Statically Indeterminate Structures.

1918.10.1 Frames and continuous construction of prestressed concrete shall be designed for satisfactory performance at service load conditions and for adequate strength.

1918.10.2 Performance at service load conditions shall be determined by elastic analysis, considering reactions, moments, shears, and axial forces produced by prestressing, creep, shrinkage, temperature change, axial deformation, restraint of attached structural elements and foundation settlement.

1918.10.3 Moments to be used to compute required strength shall be the sum of the moments due to reactions induced by prestressing (with a load factor of 1.0) and the moments due to factored loads. Adjustment of the sum of these moments shall be permitted as allowed in Section 1918.10.4.

1918.10.4 Redistribution of negative moments in continuous prestressed flexural members.

1918.10.4.1 Where bonded reinforcement is provided at supports in accordance with Section 1918.9.2, negative moments calculated by elastic theory for any assumed loading arrangement shall be permitted to be increased or decreased by not more than

$$20\left[1 - \frac{\omega_p + (d/d_p)(\omega - \omega')}{0.36\beta_1}\right] \text{percent}$$

1918.10.4.2 The modified negative moments shall be used for calculating moments at sections within spans for the same loading arrangement.

1918.10.4.3 Redistribution of negative moments shall be made only when the section at which moment is reduced is so designed that ω_p, $[\omega_p + (d/d_p)(\omega - \omega')]$, or $[\omega_{pw} + (d/d_p)(\omega_w - \omega'_w)]$, whichever is applicable, is not greater than 0.24 β_1.

1918.11 Compression Members—Combined Flexure and Axial Loads.

1918.11.1 Prestressed concrete members subject to combined flexure and axial load, with or without nonprestressed reinforcement, shall be proportioned by the strength design methods of this chapter for members without prestressing. Effects of prestress, creep, shrinkage and temperature change shall be included.

1918.11.2 Limits for reinforcement of prestressed compression members.

1918.11.2.1 Members with average prestress f_{pc} less than 225 psi (1.55 MPa) shall have minimum reinforcement in accordance with Sections 1907.10, 1910.9.1 and 1910.9.2 for columns, or Section 1914.3 for walls.

1918.11.2.2 Except for walls, members with average prestress f_{pc} equal to or greater than 225 psi (1.55 MPa) shall have all prestressing tendons enclosed by spirals or lateral ties in accordance with the following:

1. Spirals shall conform to Section 1907.10.4.
2. Lateral ties shall be at least No. 3 in size or welded wire fabric of equivalent area, and spaced vertically not to exceed 48 tie bar or wire diameters or least dimension of compression member.
3. Ties shall be located vertically not more than half a tie spacing above top of footing or slab in any story, and shall be spaced as provided herein to not more than half a tie spacing below lowest horizontal reinforcement in members supported above.
4. Where beams or brackets frame into all sides of a column, it shall be permitted to terminate ties not more than 3 inches (76 mm) below lowest reinforcement in such beams or brackets.

1918.11.2.3 For walls with average prestress f_{pc} equal to or greater than 225 pounds per square inch (1.55 MPa), minimum reinforcement required by Section 1914.3 may be waived where structural analysis shows adequate strength and stability.

1918.12 Slab Systems.

1918.12.1 Factored moments and shears in prestressed slab systems reinforced for flexure in more than one direction shall be determined in accordance with provisions of Section 1913.7, excluding Sections 1913.7.7.4 and 1913.7.7.5, or by more detailed design procedures.

1918.12.2 Moment strength of prestressed slabs at every section shall be at least equal to the required strength considering Sections 1909.2, 1909.3, 1918.10.3 and 1918.10.4. Shear strength of prestressed slabs at columns shall be at least equal to the required strength considering Sections 1909.2, 1909.3, 1911.1, 1911.12.2 and 1911.12.6.2.

1918.12.3 At service load conditions, all serviceability limitations, including specified limits on deflections, shall be met, with appropriate consideration of the factors listed in Section 1918.10.2.

1918.12.4 For normal live loads and load uniformly distributed, spacing of prestressing tendons or groups of tendons in one direction shall not exceed eight times the slab thickness, or 5 feet (1524 mm). Spacing of tendons also shall provide a minimum average prestress, after allowance for all prestress losses, of 125 psi (0.86 MPa) on the slab section tributary to the tendon or tendon group. A minimum of two tendons shall be provided in each direction through the critical shear section over columns. Special consideration of tendon spacing shall be provided for slabs with concentrated loads.

1918.12.5 In slabs with unbonded prestressing tendons, bonded reinforcement shall be provided in accordance with Sections 1918.9.3 and 1918.9.4.

1918.12.6 In lift slabs, bonded bottom reinforcement shall be detailed in accordance with the last paragraph of Section 1913.3.8.6.

1918.13 Tendon Anchorage Zones.

1918.13.1 Reinforcement shall be provided where required in tendon anchorage zones to resist bursting, splitting and spalling forces induced by tendon anchorages. Regions of abrupt change in section shall be adequately reinforced.

1918.13.2 End blocks shall be provided where required for support bearing or for distribution of concentrated prestressing forces.

1918.13.3 Posttensioning anchorages and supporting concrete shall be designed to resist maximum jacking force for strength of concrete at time of prestressing.

1918.13.4 Posttensioning anchorage zones shall be designed to develop the guaranteed ultimate tensile strength of prestressing tendons using a strength-reduction factor ϕ of 0.90 for concrete.

1918.14 Corrosion Protection for Unbonded Prestressing Tendons.

1918.14.1 Unbonded tendons shall be completely coated with suitable material to ensure corrosion protection.

1918.14.2 Tendon cover shall be continuous over entire length to be unbonded, and shall prevent intrusion of cement paste or loss of coating materials during concrete placement.

1918.14.3 Unbonded single strand tendons shall be protected against corrosion.

1918.15 Posttensioning Ducts.

1918.15.1 Ducts for grouted or unbonded tendons shall be mortar-tight and nonreactive with concrete, tendons or filler materials.

1918.15.2 Ducts for grouted single wire, strand or bar tendons shall have an inside diameter at least $^1/_4$ inch (6.4 mm) larger than tendon diameter.

1918.15.3 Ducts for grouted multiple wire, strand or bar tendons shall have an inside cross-sectional area at least two times the area of tendons.

1918.15.4 Ducts shall be maintained free of water if members to be grouted are exposed to temperatures below freezing prior to grouting.

1918.16 Grout for Bonded Prestressing Tendons.

1918.16.1 Grout shall consist of portland cement and water; or portland cement, sand and water.

1918.16.2 Materials for grout shall conform to the following:

1918.16.2.1 Portland cement shall conform to Section 1903.2.

1918.16.2.2 Water shall conform to Section 1903.4.

1918.16.2.3 The gradation of sand shall be permitted to be modified as necessary to obtain satisfactory workability.

1918.16.2.4 Admixtures conforming to Section 1903.6 and known to have no injurious effects on grout, steel or concrete may be used. Calcium chloride shall not be used.

1918.16.3 Selection of grout proportions.

1918.16.3.1 Proportions of materials for grout shall be based on either of the following:

1. Results of tests on fresh and hardened grout prior to beginning grouting operations, or

2. Prior documented experience with similar materials and equipment and under comparable field conditions.

1918.16.3.2 Cement used in the work shall correspond to that on which selection of grout proportions was based.

1918.16.3.3 Water content shall be the minimum necessary for proper pumping of grout; however, water-cementitous materials ratio shall not exceed 0.45 by weight.

1918.16.3.4 Water shall not be added to increase grout flowability that has been decreased by delayed use of grout.

1918.16.4 Mixing and pumping grout.

1918.16.4.1 Grout shall be mixed in equipment capable of continuous mechanical mixing and agitation that will produce uniform distribution of materials, passed through screens, and pumped in a manner that will completely fill tendon ducts.

1918.16.4.2 Temperature of members at time of grouting shall be above 35°F (1.7°C) and shall be maintained above 35°F (1.7°C) until field-cured 2-inch (51 mm) cubes of grout reach a minimum compressive strength of 800 pounds per square inch (5.52 MPa).

1918.16.4.3 Grout temperatures shall not be above 90°F (32.2°C) during mixing and pumping.

1918.17 Protection for Prestressing Tendons. Burning or welding operations in vicinity of prestressing tendons shall be carefully performed so that tendons are not subject to excessive temperatures, welding sparks or ground currents.

1918.18 Application and Measurement of Prestressing Force.

1918.18.1 Prestressing force shall be determined by both of the following methods:

1. Measurement of tendon elongation. Required elongation shall be determined from average load-elongation curves for the prestressing tendons used.

2. Observation of jacking force on a calibrated gauge or load cell or by use of a calibrated dynamometer.

Cause of any difference in force determination between 1 and 2 that exceeds 5 percent for pretensioned elements or 7 percent for post-tensioned construction shall be ascertained and corrected.

1918.18.2 Where transfer of force from bulkheads of pretensioning bed to concrete is accomplished by flame cutting prestressing tendons, cutting points and cutting sequence shall be predetermined to avoid undesired temporary stresses.

1918.18.3 Long lengths of exposed pretensioned strand shall be cut near the member to minimize shock to concrete.

1918.18.4 Total loss of prestress due to unreplaced broken tendons shall not exceed 2 percent of total prestress.

1918.19 Posttensioning Anchorages and Couplers.

1918.19.1 Anchorages and couplers for bonded and unbonded prestressed tendons shall develop at least 95 percent of the specified breaking strength of the tendons, when tested in an unbonded condition, without exceeding anticipated set. For bonded tendons, anchorages and couplers shall be located so that 100 percent of the specified breaking strength of the tendons shall be developed at critical sections after tendons are bonded in the member.

1918.19.2 Couplers shall be placed in areas approved by the *building official* and enclosed in housing long enough to permit necessary movements.

1918.19.3 In unbonded construction subject to repetitive loads, special attention shall be given to the possibility of fatigue in anchorages and couplers.

1918.19.4 Anchorages, couplers and end fittings shall be permanently protected against corrosion.

SECTION 1919 — SHELLS AND FOLDED PLATES

1919.0 Notations.

E_c = modulus of elasticity of concrete, pounds per square inch (MPa). See Section 1908.5.1.

f'_c = specified compressive strength of concrete, pounds per square inch (MPa).

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, pounds per square inch (MPa).

f_y = specified yield strength of nonprestressed reinforcement, pounds per square inch (MPa).

h = thickness of shell or folded plate, inches (mm).

l_d = development length, inches (mm).

ϕ = strength-reduction factor. See Section 1909.3.

1919.1 Scope and Definitions.

1919.1.1 Provisions of Section 1919 shall apply to thin-shell and folded-plate concrete structures, including ribs and edge members.

1919.1.2 All provisions of Chapter 19 not specifically excluded, and not in conflict with provisions of Section 1919, shall apply to thin-shell structures.

AUXILIARY MEMBERS are ribs or edge beams which serve to strengthen, stiffen and/or support the shell; usually, auxiliary members act jointly with the shell.

ELASTIC ANALYSIS is an analysis of deformations and internal forces based on equilibrium, compatibility of strains and assumed elastic behavior and representing to suitable approximation the three-dimensional action of the shell together with its auxiliary members.

EXPERIMENTAL ANALYSIS is an analysis procedure based on the measurement of deformations and/or strains of the structure or its model; experimental analysis may be based on either elastic or inelastic behavior.

FOLDED PLATES are a special class of shell structures formed by joining flat, thin slabs along their edges to create a three-dimensional spatial structure.

INELASTIC ANALYSIS is an analysis of deformations and internal forces based on equilibrium, nonlinear stress-strain relations for concrete and reinforcement, consideration of cracking and time-dependent effects and compatibility of strains. The analysis shall represent a suitable approximation of the three-dimensional action of the shell together with its auxiliary members.

RIBBED SHELLS are spatial structures with material placed primarily along certain preferred rib lines, with the area between the ribs filled with thin slabs or left open.

THIN SHELLS are three-dimensional spatial structures made up of one or more curved slabs or folded plates whose thicknesses are small compared to their other dimensions. Thin shells are characterized by their three-dimensional load-carrying behavior which is determined by the geometry of their forms, by the manner in which they are supported and by the nature of the applied load.

1919.2 Analysis and Design.

1919.2.1 Elastic behavior shall be an accepted basis for determining internal forces and displacements of thin shells. This behavior shall be permitted to be established by computations based on an analysis of the uncracked concrete structure in which the material is assumed linearly elastic, homogeneous and isotropic. Poisson's ratio of concrete shall be permitted to be taken equal to zero.

1919.2.2 Inelastic analysis shall be permitted to be used where it can be shown that such methods provide a safe basis for design.

1919.2.3 Equilibrium checks of internal resistances and external loads shall be made to ensure consistency of results.

1919.2.4 Experimental or numerical analysis procedures shall be permitted where it can be shown that such procedures provide a safe basis for design.

1919.2.5 Approximate methods of analysis shall be permitted where it can be shown that such methods provide a safe basis for design.

1919.2.6 In prestressed shells, the analysis shall also consider behavior under loads induced during prestressing, at cracking load and at factored load. Where prestressing tendons are draped within a shell, design shall take into account force components on the shell resulting from the tendon profile not lying in one plane.

1919.2.7 The thickness of a shell and its reinforcement shall be proportioned for the required strength and serviceability, using either the strength design method of Section 1908.1.1 or the alternate design method of Section *1926.*

1919.2.8 Shell instability shall be investigated and shown by design to be precluded.

1919.2.9 Auxiliary members shall be designed according to the applicable provisions of this code. It shall be permitted to assume that a portion of the shell equal to the flange width, as specified in Section 1908.10, acts with the auxiliary member. In such portions of the shell, the reinforcement perpendicular to the auxiliary member shall be at least equal to that required for the flange of a T-beam by Section 1908.10.5.

1919.2.10 Strength design of shell slabs for membrane and bending forces shall be based on the distribution of stresses and strains as determined from either an elastic or an inelastic analysis.

1919.2.11 In a region where membrane cracking is predicted, the nominal compressive strength parallel to the cracks shall be taken as $0.4f'_c$.

1919.3 Design Strength of Materials.

1919.3.1 Specified compressive strength of concrete f'_c at 28 days shall not be less than 3,000 psi (20.69 MPa).

1919.3.2 Specified yield strength of nonprestressed reinforcement f_y shall not exceed 60,000 psi (413.7 MPa).

1919.4 Shell Reinforcement.

1919.4.1 Shell reinforcement shall be provided to resist tensile stresses from internal membrane forces, to resist tension from bending and twisting moments, to control shrinkage and temperature cracking and as special reinforcement as shell boundaries, load attachments and shell openings.

1919.4.2 Tensile reinforcement shall be provided in two or more directions and shall be proportioned such that its resistance in any direction equals or exceeds the component of internal forces in that direction.

Alternatively, reinforcement for the membrane forces in the slab shall be calculated as the reinforcement required to resist axial tensile forces plus the tensile force due to shear friction required to transfer shear across any cross section of the membrane. The assumed coefficient of friction shall not exceed 1.0 where λ = 1.0 for normal-weight concrete, 0.85 for sand-lightweight concrete, and 0.75 for all lightweight concrete. Linear interpolation shall be permitted when partial sand replacement is used.

1919.4.3 The area of shell reinforcement at any section as measured in two orthogonal directions shall not be less than the slab shrinkage or temperature reinforcement required by Section 1907.12.

1919.4.4 Reinforcement for shear and bending moments about axes in the plane of the shell slab shall be calculated in accordance with Sections 1910, 1911 and 1913.

1919.4.5 The area of shell tension reinforcement shall be limited so that the reinforcement will yield before either crushing of concrete in compression or shell buckling can take place.

1919.4.6 In regions of high tension, membrane reinforcement shall, if practical, be placed in the general directions of the principal tensile membrane forces. Where this is not practical, it shall be permitted to place membrane reinforcement in two or more component directions.

1919.4.7 If the direction of reinforcement varies more than 10 degrees from the direction of principal tensile membrane force, the amount of reinforcement shall be reviewed in relation to cracking at service loads.

1919.4.8 Where the magnitude of the principal tensile membrane stress within the shell varies greatly over the area of the shell surface, reinforcement resisting the total tension may be concentrated in the regions of largest tensile stress where it can be shown that this provides a safe basis for design. However, the ratio of shell reinforcement in any portion of the tensile zone shall not be less than 0.0035 based on the overall thickness of the shell.

1919.4.9 Reinforcement required to resist shell bending moments shall be proportioned with due regard to the simultaneous action of membrane axial forces at the same location. Where shell reinforcement is required in only one face to resist bending moments, equal amounts shall be placed near both surfaces of the shell even though a reversal of bending moments is not indicated by the analysis.

1919.4.10 Shell reinforcement in any direction shall not be spaced farther apart than 18 inches (457 mm), or five times the shell thickness. Where the principal membrane tensile stress on the gross concrete area due to factored loads exceeds $4\phi\sqrt{f'_c}$ (For **SI:** $0.33\phi\sqrt{f'_c}$), reinforcement shall not be spaced farther apart than three times the shell thickness.

1919.4.11 Shell reinforcement at the junction of the shell and supporting members or edge members shall be anchored in or extended through such members in accordance with the requirements of Section 1912, except that the minimum development length shall be 1.2 d but not less than 18 inches (457 mm).

1919.4.12 Splice development lengths of shell reinforcement shall be governed by the provisions of Section 1912, except that the minimum splice length of tension bars shall be 1.2 times the value required by Section 1912 but not less than 18 inches (457 mm). The number of splices in principal tensile reinforcement shall be kept to a practical minimum. Where splices are necessary, they shall be staggered at least l_d with not more than one third of the reinforcement spliced at any section.

1919.5 Construction.

1919.5.1 When removal of formwork is based on a specific modulus of elasticity of concrete because of stability or deflection considerations, the value of the modulus of elasticity E_c shall be determined from flexural tests of field-cured beam specimens. The number of test specimens, the dimensions of test beam specimens and test procedures shall be specified.

1919.5.2 The tolerances for the shape of the shell shall be specified. If construction results in deviations from the shape greater than the specified tolerances, an analysis of the effect of the deviations shall be made and any required remedial actions shall be taken to ensure safe behavior.

SECTION 1920 — STRENGTH EVALUATION OF EXISTING STRUCTURES

1920.0 Notations.

D = dead loads, or related internal moments and forces.

f'_c = specified compressive strength concrete, psi (MPa).

h = overall thickness of member in direction of action considered, inches (mm).

L = live loads or related internal moments and forces.

l_t = span of member under load test, inches (mm). (The shorter span for two-way slab systems.) Span is the smaller of (1) distance between centers of supports and (2) clear distance between supports plus thickness, h, of member, inches (mm). In Formula (20-1), span for a cantilever shall be taken as twice the distance from support to cantilever end, inches (mm).

Δ_{max} = measured maximum deflection, inches (mm), see Formula (20-1).

$\Delta_{r\,max}$ = measured residual deflection, inches (mm), see Formulas (20-2) and (20-3).

$\Delta_{f\,max}$ = maximum deflection measured during the second test relative to the position of the structure at the beginning of the second test, inches (mm). See Formula (20-3).

1920.1 Strength Evaluation—General.

1920.1.1 If there is a doubt that a part or all of a structure meets the safety requirements of this code, a strength evaluation shall be carried out as required by the engineer or building official.

1920.1.2 If the effect of the strength deficiency is well understood and if it is feasible to measure the dimensions and materials properties required for analysis, analytical evaluations of strength based on those measurements shall suffice. Required data shall be determined in accordance with Section 1920.2.

1920.1.3 If the effect of the strength deficiency is not well understood or if it is not feasible to establish the required dimensions and material properties by measurement, a load test shall be required if the structure is to remain in service.

1920.1.4 If the doubt about safety of a part or all of a structure involves deterioration and if the observed response during the load test satisfies the acceptance criteria, the structure or part of the structure shall be permitted to remain in service for a specified time period. If deemed necessary by the engineer, periodic reevaluations shall be conducted.

1920.2 Determination of Required Dimensions and Material Properties.

1920.2.1 Dimensions of the structural elements shall be established at critical sections.

1920.2.2 Locations and sizes of the reinforcing bars, welded wire fabric or tendons shall be determined by measurement. It shall be permitted to base reinforcement locations on available drawings if spot checks are made confirming the information on the drawings.

1920.2.3 If required, concrete strength shall be based on results of cylinder tests or tests of cores removed from the part of the structure where the strength is in doubt. Concrete strength shall be determined as specified in Section 1905.6.4.

1920.2.4 If required, reinforcement or tendon strength shall be based on tensile tests of representative samples of the material in the structure in question.

1920.2.5 If the required dimensions and material properties are determined through measurements and testing, and if calculations can be made in accordance with Section 1920.1.2, it shall be permitted to increase the strength-reduction factor in Section 1909.3 but the strength-reduction factor shall not be more than:

Flexure without axial load 1.0

Axial tension and axial tension with flexure 1.0

Axial compression and axial compression with flexure:

Members with spiral reinforcement conforming to Section 1910.9.3 . . . . 0.9

Other members 0.85

Shear and/or torsion 0.9

Bearing on concrete 0.85

1920.3 Load Test Procedure.

1920.3.1 Load arrangement. The number and arrangement of spans or panels loaded shall be selected to maximize the deflection and stresses in the critical regions of the structural elements of which strength is in doubt. More than one test load arrangement shall be used if a single arrangement will not simultaneously result in maximum values of the effects (such as deflection, rotation or stress) necessary to demonstrate the adequacy of the structure.

1920.3.2 Load intensity. The total test load (including dead load already in place) shall not be less than 0.85 ($1.4D + 1.7L$). It shall be permitted to reduce L in accordance with the requirements of this code.

1920.3.3 A load test shall not be made until that portion of the structure to be subject to load is at least 56 days old. If the owner of the structure, the contractor and all involved parties agree, it shall be permitted to make the test at an earlier age.

1920.4 Loading Criteria.

1920.4.1 The initial value for all applicable response measurements (such as deflection, rotation, strain, slip, crack widths) shall be obtained not more than one hour before application of the first load increment. Measurements shall be made at locations where maximum response is expected. Additional measurements shall be made if required.

1920.4.2 Test load shall be applied in not less than four approximately equal increments.

1920.4.3 Uniform test load shall be applied in a manner to ensure uniform distribution of the load transmitted to the structure or portion of the structure being tested. Arching of the applied load shall be avoided.

1920.4.4 A set of response measurements shall be made after each load increment is applied and after the total load has been applied on the structure for at least 24 hours.

1920.4.5 Total test load shall be removed immediately after all response measurements defined in Section 1920.4.4 are made.

1920.4.6 A set of final response measurements shall be made 24 hours after the test load is removed.

1920.5 Acceptance Criteria.

1920.5.1 The portion of the structure tested shall show no evidence of failure. Spalling and crushing of compressed concrete shall be considered an indication of failure.

1920.5.2 Measured maximum deflections shall satisfy one of the following conditions:

$$\Delta_{max} \leq \frac{l_t^2}{20,000\,h} \qquad (20\text{-}1)$$

$$\Delta_{r\,max} \leq \frac{\Delta_{max}}{4} \qquad (20\text{-}2)$$

If the measured maximum and residual deflections do not satisfy Formula (20-1) or (20-2), it shall be permitted to repeat the load test.

The repeated test shall be conducted not earlier than 72 hours after removal of the first test load. The portion of the structure tested in the repeat test shall be considered acceptable if deflection recovery satisfied the condition:

$$\Delta_{r\,max} \leq \frac{\Delta_{f\,max}}{5} \qquad (20\text{-}3)$$

where $\Delta_{f\,max}$ is the maximum deflection measured during the second test relative to the position of the structure at the beginning of the second test.

1920.5.3 Structural members tested shall not have cracks indicating the imminence of shear failure.

1920.5.4 In regions of structural members without transverse reinforcement, appearance of structural cracks inclined to the longitudinal axis and having a horizontal projection longer than the depth of the member at mid-point of the crack shall be evaluated.

1920.5.5 In regions of anchorage and lap splices, the appearance along the line of reinforcement of a series of short inclined cracks or horizontal cracks shall be evaluated.

1920.6 Provisions for Lower Load Rating. If the structure under investigation does not satisfy conditions or criteria of Section 1920.1.2, 1920.5.2 or 1920.5.3, the structure may be permitted for use at a lower load rating based on the results of the load test or analysis, if approved by the building official.

1920.7 Safety.

1920.7.1 Load tests shall be conducted in such a manner as to provide for safety of life and structure during the test.

1920.7.2 No safety measures shall interfere with load test procedures or affect results.

SECTION 1921 — REINFORCED CONCRETE STRUCTURES RESISTING FORCES INDUCED BY EARTHQUAKE MOTIONS

1921.0 Notations.

A_{ch} = cross-sectional area of a structural member measured out-to-out of transverse reinforcement, square inches (mm^2).

A_{cp} = area of concrete section, resisting shear, of an individual pier or horizontal wall segment, square inches (mm^2).

A_{cv} = net area of concrete section bounded by web thickness and length of section in the direction of shear force considered, square inches (mm^2).

A_g = gross area of section, square inches (mm^2).

A_j = effective cross-sectional area within a joint (see Section 1921.5.3.1) in a plane parallel to plane of reinforcement generating shear in the joint. The joint depth shall be the overall depth of the column. Where a beam frames into a support of larger width, the effective width of the joint shall not exceed the smaller of:

1. beam width plus the joint depth
2. twice the smaller perpendicular distance from the

longitudinal axis of the beam to the column side. See Section 1921.5.3.1.

A_{sh} = total cross-sectional area of transverse reinforcement (including crossties) within spacing, s, and perpendicular to dimension, h_c.

b = effective compressive flange width of a structural member, inches (mm).

b_w = web width, or diameter of circular section, inches (mm).

d = effective depth of section.

d_b = bar diameter.

E = load effects of earthquake, or related internal moments and forces.

f'_c = specified compressive strength of concrete, psi (MPa).

f_y = specified yield strength of reinforcement, psi (MPa).

f_{yh} = specified yield strength of transverse reinforcement, psi (MPa).

h = overall dimension of member in the direction of action considered.

h_c = cross-sectional dimension of a column core or shear wall boundary zone measured center-to-center of confining reinforcement.

h_w = height of entire wall (diaphragm) or of the segment of wall (diaphragm) considered.

l_d = development length for a straight bar.

l_{dh} = development length for a bar with a standard hook as defined in Formula (21-5).

l_o = minimum length, measured from joint face along axis of structural member, over which transverse reinforcement must be provided, inches (mm).

l_u = unsupported length of compression member (see Section 1910.11.3.1).

l_w = length of entire wall (diaphragm) or of segment of wall (diaphragm) considered in direction of shear force.

M_{pr} = probable flexural strength of members, with or without axial load, determined using the properties of the member at the joint faces assuming a tensile strength in the longitudinal bars of at least 1.25 f_y and a strength-reduction factor ϕ of 1.0.

M_s = portion of slab moment balanced by support moment.

s = spacing of transverse reinforcement measured along the longitudinal axis of the structural member, inches (mm).

$S_{e\ CONNECTION}$ = *moment, shear or axial force at connection cross section other than the nonlinear action location corresponding to probable strength at the nonlinear action location, taking gravity load effects into consideration, per Section 1921.2.7.3.*

$S_{n\ CONNECTION}$ = *nominal strength of connection cross section in flexural, shear or axial action, per Section 1921.2.7.3.*

s_o = maximum spacing of transverse reinforcement, inches (mm).

V_c = nominal shear strength provided by concrete.

V_e = design shear force determined from Section 1921.3.4.1 or 1921.4.5.1.

V_n = nominal shear strength.

V_u = factored shear force at section.

α_c = coefficient defining the relative contribution of concrete strength to wall strength.

ρ = ratio of nonprestressed tension reinforcement = A_s/bd.

ρ_g = ratio of total reinforcement area to cross-sectional area of column.

ρ_n = ratio of distributed shear reinforcement on a plane perpendicular to plane of A_{cv}.

ρ_s = ratio of volume of spiral reinforcement to the core volume confined by the spiral reinforcement (measured out-to-out).

ρ_v = A_{sv}/A_{cv}; where A_{sv} is the projection on A_{cv} of area of distributed shear reinforcement crossing the plane of A_{cv}.

ϕ = strength-reduction factor.

Δ_m = 0.7 $R\Delta_s$.

Δ_s = *Design Level Response Displacement, which is the total drift or total story drift that occurs when the structure is subjected to the design seismic forces.*

ψ = *Dynamic Amplification Factor from Sections 1921.2.7.3 and 1921.2.7.4.*

1921.1 Definitions. For the purposes of this section, certain terms are defined as follows:

BASE OF STRUCTURE is the level at which earthquake motions are assumed to be imparted to a building. This level does not necessarily coincide with the ground level.

BOUNDARY ELEMENTS *(or ZONES)* are portions along wall and diaphragm edges strengthened by longitudinal and transeverse reinforcement. Boundary elements do not necessarily require an increase in the thickness of the wall or diaphragm. Edges of openings within walls and diaphragms shall be provided with boundary elements if required by Sections 1921.6.6.1 and 1921.6.7.1.

COLLECTOR ELEMENTS are elements that serve to transmit the inertial forces with the diaphragms to members of the lateral-force-resisting systems.

CONFINED CORE is the area within the core defined by h_c.

CONNECTION *is an element that joins two precast members or a precast member and a cast-in-place member.*

COUPLING BEAMS are a horizontal element in plane with and connecting two shear walls.

CROSSTIE is a continuous reinforcing bar having a seismic hook at one end and a hook of not less than 90 degrees with at least six diameters at the other end. The hooks shall engage peripheral longitudinal bars. The 90-degree hooks of two successive crossties engaging the same longitudinal bar shall be alternated end for end.

DESIGN LOAD COMBINATIONS are combinations of factored loads and forces specified in Sections *1612.2.1 and* 1909.2.

DEVELOPMENT LENGTH FOR A BAR WITH A STANDARD HOOK is the shortest distance between the critical section (where the strength of the bar is to be developed) and a tangent to the outer edge of the 90-degree hook.

DRY CONNECTION *is a connection used between precast members, which does not qualify as a wet connection.*

FACTORED LOADS AND FORCES are the specified loads and forces modified by the factors in Sections *1612.2.1 and 1909.2.*

HOOP is a closed tie or continuously wound tie. A closed tie can be made up of several reinforcing elements, each having seismic hooks at both ends. A continuously wound tie shall have a seismic hook at both ends.

JOINT *is the geometric volume common to intersecting members.*

LATERAL-FORCE-RESISTING SYSTEM is that portion of the structure composed of members proportioned to resist forces related to earthquake effects.

LIGHTWEIGHT-AGGREGATE CONCRETE is all lightweight or sanded lightweight aggregate concrete made with lightweight aggregates conforming to Section 1903.3.

NONLINEAR ACTION LOCATION *is the center of the region of yielding in flexure, shear or axial action.*

NONLINEAR ACTION REGION *is the member length over which nonlinear action takes place. It shall be taken as extending a distance of no less than* h*/2 on either side of the nonlinear action location.*

SEISMIC HOOK is a hook on a stirrup, hoop or crosstie having a bend not less than 135 degrees with a six-bar-diameter [but not less than 3 inches (76 mm)], extension that engages the longitudinal reinforcement and projects into the interior of the stirrup or hoop.

SHELL CONCRETE is concrete outside the transverse reinforcement confining the concrete.

SPECIFIED LATERAL FORCES are lateral forces corresponding to the appropriate distribution of the design base shear force prescribed by the governing code for earthquake-resistant design.

STRONG CONNECTION *is a connection that remains elastic, while the designated nonlinear action regions undergo inelastic response under the Design Basis Ground Motion.*

STRUCTURAL DIAPHRAGMS are structural members, such as floor and roof slabs, which transmit inertial forces to lateral-force-resisting members.

STRUCTURAL TRUSSES are assemblages of reinforced concrete members subjected primarily to axial forces.

STRUT is an element of a structural diaphragm used to provide continuity around an opening in the diaphragm.

TIE ELEMENTS are elements which serve to transmit inertia forces and prevent separation of such building components as footings and walls.

WALL PIER *is a wall segment with a horizontal length-to-thickness ratio between 2.5 and 6, and whose clear height is at least two times its horizontal length.*

WET CONNECTION *uses any of the splicing methods, per Section 1921.2.6.1 or 1921.3.2.3, to connect precast members and uses cast-in-place concrete or grout to fill the splicing closure.*

1921.2 General Requirements.

1921.2.1 Scope.

1921.2.1.1 *Section 1921* contains special requirements for design and construction of reinforced concrete members of a structure for which the design forces, related to earthquake motions, have been determined on the basis of energy dissipation in the nonlinear range of response.

1921.2.1.2 The provisions of Sections 1901 through 1918 shall apply except as modified by the provisions of Section 1921.

1921.2.1.3 *In Seismic Zones 0 and 1, the provisions of Section 1921 shall not apply.*

In Seismic Zone 2, reinforced concrete frames resisting forces induced by earthquake motions shall be intermediate moment-resisting frames proportioned to satisfy only Section 1921.8 in addition to the requirements of Sections 1901 through 1918. In Seismic Zone 2, frame members which are not designated to be part of the lateral-force-resisting system shall conform to Section 1921.7.

1921.2.1.4 *In Seismic Zones 3 and 4,* all reinforced concrete structural members that are part of the lateral-force-resisting system shall satisfy the requirements of Sections 1921.2 through 1921.7, in addition to the requirements of Sections 1901 through 1917.

1921.2.1.5 A reinforced concrete structural system not satisfying the requirements of this section may be used if it is demonstrated by experimental evidence and analysis that the proposed system will have strength and toughness equal to or exceeding those provided by a comparable monolithic reinforced concrete structure satisfying this section.

1921.2.1.6 *Precast lateral-force-resisting systems shall satisfy either of the following criteria:*

1. Emulate the behavior of monolithic reinforced concrete construction and satisfy Section 1921.2.2.5, or

2. Rely on the unique properties of a structural system composed of interconnected precast elements and conform to Section 1629.9.2.

1921.2.1.7 *In structures having precast gravity systems, the lateral-force-resisting system shall be one of the systems listed in Table 16-N and shall be well distributed using one of the following methods:*

1. The lateral-force-resisting systems shall be spaced such that the span of the diaphragm or diaphragm segment between lateral-force-resisting systems shall be no more than three times the width of the diaphragm or diaphragm segment.

Where the lateral-force-resisting system consists of moment-resisting frames, at least [(N_b/4) + 1] of the bays (rounded up to the nearest integer) along any frame line at any story shall be part of the lateral-force-resisting system, where N_b is the total number of bays along that line at that story. This requirement applies to only the lower two thirds of the stories of buildings three stories or taller.

2. All beam-to-column connections that are not part of the lateral-force-resisting system shall be designed in accordance with the following:

Connection design force. *The connection shall be designed to develop strength M. M is the moment developed at the connection when the frame is displaced by Δ_s assuming fixity at the connection and a beam flexural stiffness of no more than one-half of the gross section stiffness. M shall be sustained through a deformation of Δ_m.*

Connection characteristics. *The connection shall be permitted to resist moment in one direction only, positive or negative. The connection at the opposite end of the member shall resist moment with same positive or negative sign. The connection shall be permitted to have zero flexural stiffness up to a frame displacement of Δ_s.*

In addition, complete calculations for the deformation compatibility of the gravity load carrying system shall be made in accordance with Section 1633.2.4 using cracked section stiffnesses in the lateral-force-resisting system and the diaphragm.

Where gravity columns are not provided with lateral support on all sides, a positive connection shall be provided along each unsupported direction parallel to a principal plan axis of the structure. The connection shall be designed for a horizontal force equal to 4 percent of the axial load strength (P_0) of the column.

The bearing length shall be 2 inches (51 mm) more than that required for bearing strength.

1921.2.2 Analysis and proportioning of structural members.

1921.2.2.1 The interaction of all structural and nonstructural members which materially affect the linear and nonlinear response of the structure to earthquake motions shall be considered in the analysis.

1921.2.2.2 Rigid members assumed not to be a part of the lateral-force-resisting system shall be permitted, provided their effect on the response of the system is considered and accommodated in the structural design. Consequences of failure of structural and nonstructural members which are not a part of the lateral-force-resisting system shall also be considered.

1921.2.2.3 Structural members below base of structure required to transmit to the foundation forces resulting from earthquake effects shall also comply with the requirements of Section 1921.

1921.2.2.4 All structural members assumed not to be part of the lateral-force-resisting system shall conform to Section 1921.7.

1921.2.2.5 *Precast structural systems using frames and emulating the behavior of monolithic reinforced concrete construction shall satisfy either Section 1921.2.2.6 or 1921.2.2.7.*

1921.2.2.6 *Precast structural systems, utilizing wet connections, shall comply with all the applicable requirements of monolithic concrete construction for resisting seismic forces.*

1921.2.2.7 *Precast structural systems not meeting Section 1921.2.2.6 shall utilize strong connections resulting in nonlinear response away from connections. Design shall satisfy the requirements of Section 1921.2.7 in addition to all the applicable requirements of monolithic concrete construction for resisting seismic forces, except that provisions of Section 1921.3.1.2 shall apply to the segments between nonlinear action locations.*

1921.2.3 Strength-reduction factors. Strength-reduction factors shall be as given in Section 1909.3.4.

1921.2.4 Concrete in members resisting earthquake-induced forces.

1921.2.4.1 Compressive strength f'_c shall not be less than 3,000 psi (20.69 MPa).

> ***EXCEPTION:*** *Footings of buildings three stories or less may have concrete with f'_c of not less than 2,500 psi (17.24 MPa).*

1921.2.4.2 Compressive strength of lightweight-aggregate concrete used in design shall not exceed 4,000 psi (27.58 MPa). Lightweight aggregate concrete with higher design compressive strength shall be permitted if demonstrated by experimental evidence that structural members made with that lightweight aggregate concrete provide strength and toughness equal to or exceeding those of comparable members made with normal-weight aggregate concrete of the same strength. *In no case shall the compressive strength of lightweight concrete used in design exceed 6,000 psi (41.37 MPa).*

1921.2.5 Reinforcement in members resisting earthquake-induced forces.

1921.2.5.1 ***Alloy A 706 reinforcement.*** *Except as permitted in Sections 1921.2.5.2 through 1921.2.5.5,* reinforcement resisting earthquake-induced flexural and axial forces in frame members and in wall boundary elements shall comply with *low alloy* A 706 except as allowed in Section 1921.2.5.2.

1921.2.5.2 Billet steel A 615 reinforcement. *Billet steel A 615 Grades 40 and 60 reinforcement shall be permitted to be used in frame members and wall boundary elements* if (1) the actual yield strength based on mill tests does not exceed the specified yield strength by more than 18,000 psi (124.1 MPa) [retests shall not exceed this value by more than an additional 3,000 psi (20.69 MPa)], and (2) the ratio of the actual ultimate tensile stress to the actual yield strength is not less than 1.25.

1921.2.5.3 *The average prestress f_{pc}, calculated for an area equal to the member's shortest cross-sectional dimension multiplied by the perpendicular dimension, shall be the lesser of 350 psi (2.41 MPa) or $f'_c/12$ at locations of nonlinear action, where prestressing tendons are used in members of frames.*

1921.2.5.4 *For members in which prestressing tendons are used together with mild reinforcement to resist earthquake-induced forces, prestressing tendons shall not provide more than one-quarter of the strength for both positive and negative moments at the joint face and shall extend through exterior joints and be anchored at the exterior face of the joint or beyond.*

1921.2.5.5 *Shear strength provided by prestressing tendons shall not be considered in design.*

1921.2.6 Welded splices and mechanically connected reinforcement.

1921.2.6.1 Reinforcement resisting earthquake-induced flexural or axial forces in frame members or in wall boundary members shall be permitted to be spliced using welded splices or mechanical connectors conforming to Section 1912.14.3.3 or 1912.14.3.4.

Splice locations in frame members shall conform to Section 1921.2.6.1.1 or 1921.2.6.1.2.

1921.2.6.1.1 Welded splices. *In Seismic Zones 2, 3 and 4, welded splices on billet steel A 615 or low allow A 706 reinforcement shall not be used within an anticipated plastic hinge region nor within a distance of one beam depth on either side of the plastic hinge region or within a joint.*

1921.2.6.1.2 Mechanical connection splices. *Splices with mechanical connections shall be classified according to strength capacity as follows:*

Type 1 splice. *Mechanical connections meeting the requirements of Sections 1912.14.3.4 and 1912.14.3.5.*

Type 2 splice. *Mechanical connections that develop in tension the lesser of 95 percent of the ultimate tensile strength or 160 percent of specified yield strength,* f_y, *of the bar.*

Mechanical connection splices shall be permitted to be located as follows:

Type 1 splice. *In Seismic Zone 1, a Type 1 splice shall be permitted in any location within a member. In Seismic Zones 2, 3 and 4, a Type 1 splice shall not be used within an anticipated plastic hinge region or within a distance of one beam depth on either side of the plastic hinge region or within a joint.*

Type 2 splice. *A Type 2 splice shall be permitted in any location within a member.*

1921.2.6.2 Welding of stirrups, ties, inserts or other similar elements to longitudinal reinforcement required by design shall not be permitted.

1921.2.7 Emulation of monolithic construction using strong connections. *Members resisting earthquake-induced forces in precast frames using strong connections shall satisfy the following:*

1921.2.7.1 Location. *Nonlinear action location shall be selected so that there is a strong column/weak beam deformation mecha-*

nism under seismic effects. The nonlinear action location shall be no closer to the near face of strong connection than h/2. For column-to-footing connections, where nonlinear action may occur at the column base to complete the mechanism, the nonlinear action location shall be no closer to the near face of the connection than h/2.

1921.2.7.2 Anchorage and splices. *Reinforcement in the nonlinear action region shall be fully developed outside both the strong connection region and the nonlinear action region. Noncontinuous anchorage reinforcement of strong connection shall be fully developed between the connection and the beginning of nonlinear action region. Lap splices are prohibited within connections adjacent to a joint.*

1921.2.7.3 Design forces. *Design strength of strong connections shall be based on*

$$\phi S_{n\ CONNECTION} > \psi S_{e\ CONNECTION} \qquad (21\text{-}1)$$

Dynamic amplification factor ψ shall be taken as 1.0.

1921.2.7.4 Column-to-column connection. *The strength of such connections shall comply with Section 1921.2.7.3 with ψ taken as 1.4. Where column-to-column connections occur, the columns shall be provided with transverse reinforcement as specified in Sections 1921.4.4.1 through 1921.4.4.3 over their full height if the factored axial compressive force in these members, including seismic effects, exceeds $A_g f'_c/10$.*

> ***EXCEPTION:*** *Where column-to-column connection is located within the middle third of the column clear height, the following shall apply: (1) The design moment strength ϕM_n of the connection shall not be less than 0.4 times the maximum M_{pr} for the column within the story height, and (2) the design shear strength ϕV_n of the connection shall not be less than that determined per Section 1921.4.5.1.*

1921.2.7.5 Column-face connection. *Any strong connection located outside the middle half of a beam span shall be a wet connection, unless a dry connection can be substantiated by approved cyclic test results. Any mechanical connector located within such a column-face strong connection shall develop in tension or compression, as required, at least 140 percent of specified yield strength, f_y, of the bar.*

1921.3 Flexural Members of Frames.

1921.3.1 Scope. Requirements of this section apply to frame members (1) resisting earthquake-induced forces and (2) proportioned primarily to resist flexure. These frame members shall also satisfy the following conditions:

1921.3.1.1 Factored axial compressive force on the member shall not exceed ($A_g f'_c/10$).

1921.3.1.2 Clear span for the members shall not be less than four times its effective depth.

1921.3.1.3 The width-to-depth ratio shall not be less than 0.3.

1921.3.1.4 The width shall not be (1) less than 10 inches (254 mm) and (2) more than the width of the supporting member (measured on a plane perpendicular to the longitudinal axis of the flexural member) plus distances on each side of the supporting member not exceeding three fourths of the depth of the flexural member.

1921.3.2 Longitudinal reinforcement.

1921.3.2.1 At any section of a flexural member, except as provided in Section 1910.5.3, for top as well as for bottom reinforcement, the amount of reinforcement shall not be less than that given by Formula (10-3) but not less than $200\ b_w d/f_y$, (For **SI:** $1.38\ b_w d/f_y$) and the reinforcement ratio, ρ, shall not exceed 0.025. At least two bars shall be provided continuously, both top and bottom.

1921.3.2.2 Positive-moment strength at joint face shall not be less than one half of the negative-moment strength provided at that face of the joint. Neither the negative nor the positive-moment strength at any section along member length shall be less than one fourth the maximum moment strength provided at face of either joint.

1921.3.2.3 Lap splices of flexural reinforcement shall be permitted only if hoop or spiral reinforcement is provided over the lap length. Maximum spacing of the transverse reinforcement enclosing the lapped bars shall not exceed $d/4$ or 4 inches (102 mm). Lap splices shall not be used (1) within the joints, (2) within a distance of twice the member depth from the face of joint, and (3) at locations where analysis indicates flexural yielding caused by inelastic lateral displacements of the frame.

1921.3.2.4 Welded splices and mechanical connections shall conform to Section 1921.2.6.1.

1921.3.3 Transverse reinforcement.

1921.3.3.1 Hoops shall be provided in the following regions of frame members:

1. Over a length equal to twice the member depth measured from the face of the supporting member toward midspan, at both ends of the flexural members.

2. Over lengths equal to twice the member depth on both sides of a section where flexural yielding may occur in connection with inelastic lateral displacements of the frame.

1921.3.3.2 The first hoop shall be located not more than 2 inches (51 mm) from the face of a supporting member. Maximum spacing of the hoops shall not exceed (1) $d/4$, (2) eight times the diameter of the smallest longitudinal bars, (3) 24 times the diameter of the hoop bars, and (4) 12 inches (305 mm).

1921.3.3.3 Where hoops are required, longitudinal bars on the perimeter shall have lateral support conforming to Section 1907.10.5.3.

1921.3.3.4 Where hoops are not required, stirrups with seismic hooks at both ends shall be spaced at a distance not more than $d/2$ throughout the length of the member.

1921.3.3.5 Stirrups or ties required to resist shear shall be hoops over lengths of members as specified in Sections 1921.3.3, 1921.4.4 and 1921.5.2.

1921.3.3.6 Hoops in flexural members shall be permitted to be made up of two pieces of reinforcement: a stirrup having seismic hooks at both ends and closed by a crosstie. Consecutive crossties engaging the same longitudinal bar shall have their 90-degree hooks at opposite sides of the flexural member. If the longitudinal reinforcing bars secured by the crossties are confined by a slab on only one side of the flexural frame member, the 90-degree hooks of the crossties shall all be placed on that side.

1921.3.4 Shear strength.

1921.3.4.1 Design forces. The design shear forces V_e shall be determined from consideration of the static forces on the portion of the member between faces of the joint. It shall be assumed that moments of opposite sign corresponding to probable strength M_{pr} act at the joint faces and that the member is loaded with the tributary gravity load along its span.

1921.3.4.2 Transverse reinforcement. Transverse reinforcement over the lengths identified in Section 1921.3.3.1 shall be proportioned to resist shear assuming $V_c = 0$ when both of the following conditions occur:

1. The earthquake-induced shear force calculated in accordance with Section 1921.3.4.1 represents one-half or more of the maximum required shear strength within those lengths.

2. The factored axial compressive force including earthquake effects is less than $A_g f'_c/20$.

1921.4 Frame Members Subjected to Bending and Axial Load.

1921.4.1 Scope. The requirements of Section 1921.4 apply to frame members (1) resisting earthquake-induced forces and (2) having a factored axial force exceeding $A_g f'_c/10$. These frame members shall also satisfy the following conditions:

1921.4.1.1 The shortest cross-sectional dimension, measured on a straight line passing through the geometric centroid, shall not be less than 12 inches (305 mm).

1921.4.1.2 The ratio of the shortest cross-sectional dimension to the perpendicular dimension shall not be less than 0.4.

1921.4.2 Minimum flexural strength of columns.

1921.4.2.1 Flexural strength of any column proportioned to resist a factored axial compressive force exceeding $A_g f'_c/10$ shall satisfy Section 1921.4.2.2 or 1921.4.2.3.

Lateral strength and stiffness of columns not satisfying Section 1921.4.2.2 shall be ignored in determining the calculated strength and stiffness of the structure but shall conform to Section 1921.7.

1921.4.2.2 The flexural strengths of the columns shall satisfy Formula (21-1).

$$\Sigma M_e \geq (^6/_5)\Sigma M_g \qquad (21\text{-}1)$$

WHERE:

ΣM_e = sum of moments, at the center of the joint, corresponding to the design flexural strength of the columns framing into that joint. Column flexural strength shall be calculated for the factored axial force, consistent with the direction of the lateral forces considered, resulting in the lowest flexural strength.

ΣM_g = sum of moments, at the center of the joint, corresponding to the design flexural strengths of the girders framing into that joint.

Flexural strengths shall be summed such that the column moments oppose the beam moments. Formula (21-1) shall be satisfied for beam moments acting in both directions in the vertical plane of the frame considered.

1921.4.2.3 If Section 1921.4.2.2 is not satisfied at a joint, columns supporting reactions from that joint shall be provided with transverse reinforcement as specified in Section 1921.4.4 over their full height.

1921.4.3 Longitudinal reinforcement.

1921.4.3.1 The reinforcement ratio ρ_g shall not be less than 0.01 and shall not exceed 0.06.

1921.4.3.2 Welded splices and mechanical connections shall conform to Section 1921.2.6.1. Lap splices shall be permitted only within the center half of the member length and shall be proportioned as tension splices.

1921.4.4 Transverse reinforcement.

1921.4.4.1 Transverse reinforcement as specified below shall be provided unless a larger amount is required by Section 1921.4.5.

1. The volumetric ratio of spiral or circular hoop reinforcement, ρ_s, shall not be less than that indicated by Formula (21-2).

$$\rho_s = 0.12\, f'_c/f_{yh} \qquad (21\text{-}2)$$

and shall not be less than that required by Formula (10-6).

2. The total cross-sectional area of rectangular hoop reinforcement shall not be less than that given by Formulas (21-3) and (21-4).

$$A_{sh} = 0.3\,(sh_c f'_c/f_{yh})\left[(A_g/A_{ch}) - 1\right] \qquad (21\text{-}3)$$

$$A_{sh} = 0.09\,(sh_c f'_c/f_{yh}) \qquad (21\text{-}4)$$

3. Transverse reinforcement shall be provided by either single or overlapping hoops. Crossties of the same bar size and spacing as the hoops shall be permitted to be used. Each end of the crosstie shall engage a peripheral longitudinal reinforcing bar. Consecutive crossties shall be alternated end for end along the longitudinal reinforcement.

4. If the design strength of member core satisfies the requirement of the specified loading combinations including earthquake effect, Formulas (21-3) and (10-6) need not be satisfied.

5. Any area of a column which extends more than 4 inches (102 mm) beyond the confined core shall have minimum reinforcement as required for nonseismic columns as specified in Section 1921.7.

6. Where the calculated point of contraflexure is not within the middle half of the member clear height, provide transverse reinforcement as specified in Sections 1921.4.4.1, Items 1 through 3, over the full height of the member.

1921.4.4.2 Transverse reinforcement shall be spaced at distances not exceeding (1) one-quarter minimum member dimension and (2) 4 inches (102 mm). *Anchor bolts set in the top of a column shall be enclosed with ties as specified in Section 1921.4.4.8.*

1921.4.4.3 Crossties or legs of overlapping hoops shall not be spaced more than 14 inches (356 mm) on center in the direction perpendicular to the longitudinal axis of the structural member.

1921.4.4.4 Transverse reinforcement in amount specified in Sections 1921.4.4.1 through 1921.4.4.3 shall be provided over a length l_o from each joint face and on both sides of any section where flexural yielding may occur in connection with inelastic lateral displacements of the frame. The length l_o shall not be less than (1) the depth of the member at the joint face or at the section where flexural yielding may occur, (2) one sixth of the clear span of the member, and (3) 18 inches (457 mm).

1921.4.4.5 Columns supporting reactions from discontinued stiff members, such as walls, shall be provided with transverse reinforcement as specified in Sections 1921.4.4.1 through 1921.4.4.3 over their full height beneath the level at which the discontinuity occurs if the factored axial compressive force in these members, including earthquake effect, exceeds $A_g f'_c/10$. Transverse reinforcement as specified in Sections 1921.4.4.1 through 1921.4.4.3 shall extend into the discontinued member for at least the development length of the largest longitudinal reinforcement in the column in accordance with Section 1921.5.4. If the lower end of the column terminates on a wall, transverse reinforcement as specified in Sections 1921.4.4.1 through 1921.4.4.3 shall extend into the wall for at least the development length of the largest longitudinal reinforcement in the column at the point of termination. If the column terminates on a footing or mat, transverse reinforcement as specified in Sections 1921.4.4.1 through 1921.4.4.3 shall extend at least 12 inches (305 mm) into the footing or mat.

1921.4.4.6 Where transverse reinforcement as specified in Sections 1921.4.4.1 through 1921.4.4.3 is not provided throughout the full length of the column, the remainder of the column length shall contain spiral or hoop reinforcement with center-to-center spacing not exceeding the smaller of six times the diameter of the longitudinal column bars or 6 inches (152 mm).

1921.4.4.7 At any section where the design strength, ϕP_n, of the column is less than the sum of the shears V_e computed in accordance with Sections 1921.3.4.1 and 1921.4.5.1 for all the beams framing into the column above the level under consideration, transverse reinforcement as specified in Sections 1921.4.4.1 through 1921.4.4.3 shall be provided. For beams framing into opposite sides of the column, the moment components may be assumed to be of opposite sign. For the determination of the design strength, ϕP_n, of the column, these moments may be assumed to result from the deformation of the frame in any one principal axis.

1921.4.4.8 Ties at anchor bolts. *Anchor bolts which are set in the top of a column shall be provided with ties which enclose at least four vertical column bars. Such ties shall be in accordance with Section 1907.1.3, Item 3, shall be within 5 inches (127 mm) of the top of the column, and shall consist of at least two No. 4 or three No. 3 bars.*

1921.4.5 Shear strength requirements.

1921.4.5.1 Design forces. The design shear force V_e shall be determined from the consideration of the maximum forces that can be generated at the faces of the joints at each end of the member. These joint forces shall be determined using the maximum probable moment strengths, M_{pr}, of the member associated with the range of factored axial loads on the member. The member shear need not exceed those determined from joint strengths based on the probable moment strength, M_{pr}, of the transverse members framing in the joint. In no case shall V_e be less than the factored shear determined by analysis of the structure.

1921.4.5.2 Transverse reinforcement over the lengths l_o, identified in Section 1921.4.4.4, shall be proportioned to resist shear assuming $V_c = 0$ when both of the following conditions occur:

1. The earthquake-induced shear force calculated in accordance with Section 1921.4.5.1 represents one-half or more of the maximum required shear strength within those lengths.

2. The factored axial compressive force including earthquake effects is less than $A_g f'_c/20$.

1921.5 Joints of Frames.

1921.5.1 General requirements.

1921.5.1.1 Forces in longitudinal beam reinforcement at the joint face shall be determined by assuming that the stress in the flexural tensile reinforcement is 1.25 f_y.

1921.5.1.2 Strength of joint shall be governed by the appropriate strength-reduction factors specified in Section 1909.3.

1921.5.1.3 Beam longitudinal reinforcement terminated in a column shall be extended to the far face of the confined column core and anchored in tension according to Section 1921.5.4, and in compression according to Section 1912.

1921.5.1.4 Where longitudinal beam reinforcement extends through a beam-column joint, the column dimension parallel to the beam reinforcement shall not be less than 20 times the diameter of the largest longitudinal bar for normal-weight concrete. For lightweight concrete, the dimension shall not be less than 26 times the bar diameter.

1921.5.2 Transverse reinforcement.

1921.5.2.1 Transverse hoop reinforcement as specified in Section 1921.4.4 shall be provided within the joint, unless the joint is confined by structural members as specified in Section 1921.5.2.2.

1921.5.2.2 Within the depth of the shallowest framing member, transverse reinforcement equal to at least one half the amount required by Section 1921.4.4.1 shall be provided where members frame into all four sides of the joint and where each member width is at least three fourths the column width. At these locations, the spacing specified in Section 1921.4.4.2 shall be permitted to be increased to 6 inches (152 mm).

1921.5.2.3 Transverse reinforcement as required by Section 1921.4.4 shall be provided through the joint to provide confinement for longitudinal beam reinforcement outside the column core if such confinement is not provided by a beam framing into the joint.

1921.5.3 Shear strength.

1921.5.3.1 The nominal shear strength of the joint shall not be taken greater than the forces specified below for normal-weight aggregate concrete.

For joints confined on all four faces . . . . $20\sqrt{f'_c}A_j$
(For **SI:** $1.66\sqrt{f'_c}A_j$)

For joints confined on three faces or on two opposite faces . . . . $15\sqrt{f'_c}A_j$
(For **SI:** $1.25\sqrt{f'_c}A_j$)

For others . . . . $12\sqrt{f'_c}A_j$
(For **SI:** $1.00\sqrt{f'_c}A_j$)

A member that frames into a face is considered to provide confinement to the joint if at least three fourths of the face of the joint is covered by the framing member. A joint is considered to be confined is such confining members frame into all faces of the joint.

1921.5.3.2 For lightweight aggregate concrete, the nominal shear strength of the joint shall not exceed three fourths of the limits for normal-weight aggregate concrete.

1921.5.4 Development length for reinforcement in tension.

1921.5.4.1 The development length, l_{dh}, for a bar with a standard 90-degree hook in normal-weight aggregate concrete shall not be less than $8d_b$, 6 inches (152 mm), and the length required by Formula (21-5).

$$l_{dh} = f_y d_b / 65\sqrt{f'_c} \qquad (21\text{-}5)$$

For **SI:** $$l_{dh} = f_y d_b / 5.4\sqrt{f'_c}$$

for bar sizes No. 3 through No. 11.

For lightweight aggregate concrete, the development length for a bar with a standard 90-degree hook shall not be less than $10d_b$, 7.5 inches (191 mm), and 1.25 times that required by Formula (21-5).

The 90-degree hook shall be located within the confined core of a column or of a boundary member.

1921.5.4.2 For bar sizes No. 3 through No. 11, the development length, l_d, for a straight bar shall not be less than (1) 2.5 times the length required by Section 1921.5.4.1 if the depth of the concrete cast in one lift beneath the bar does not exceed 12 inches (305 mm), and (2) 3.5 times the length required by Section 1921.5.4.1 if the depth of the concrete cast in one lift beneath the bar exceeds 12 inches (305 mm).

1921.5.4.3 Straight bars terminated at a joint shall pass through the confined core of a column or of a boundary member. Any portion of the straight embedment length not within the confined core shall be increased by a factor of 1.6.

1921.5.4.4 If epoxy-coated reinforcement is used, the development lengths in Sections 1921.5.4.1 through Section 1921.5.4.3 shall be multiplied by the applicable factor specified in Section 1912.2.4 or 1912.5.3.6.

1921.6 ***Shear* Walls, Diaphragms and Trusses.**

1921.6.1 Scope. The requirements of this section apply to *shear* walls and trusses serving as parts of the earthquake-force-resisting systems as well as to diaphragms, struts, ties, chords and collector members which transmit forces induced by earthquake.

1921.6.2 Reinforcement.

1921.6.2.1 The reinforcement ratio, ρ_v, for *shear* walls shall not be less than 0.0025 along the longitudinal and transverse axes. If the design shear force does not exceed $A_{cv}\sqrt{f'_c}$ (For **SI:** $0.08A_{cv}\sqrt{f'_c}$), the minimum reinforcement for *shear* walls shall be in conformance with Section 1914.3. The minimum reinforcement ratio for structural diaphragms shall be in conformance with Section 1907.12. Reinforcement spacing each way in *shear* walls and diaphragms shall not exceed 18 inches (457 mm). Reinforcement provided for shear strength shall be continuous and shall be distributed across the shear plane.

1921.6.2.2 At least two curtains of reinforcement shall be used in a wall if the in-plane factored shear force assigned to the wall exceeds $2A_{cv}\sqrt{f'_c}$ (For **SI:** $0.166A_{cv}\sqrt{f'_c}$).

*When V_u in the plane of the wall exceeds $A_{cv}\sqrt{f'_c}$ (For **SI:** $0.08A_{cv}\sqrt{f'_c}$), horizontal reinforcement terminating at the edges of shear walls shall have a standard hook engaging the edge reinforcement, or the edge reinforcement shall be enclosed in "U" stirrups having the same size and spacing as, and spliced to, the horizontal reinforcement.*

1921.6.2.3 Structural-truss elements, struts, ties and collector elements with compressive stresses exceeding 0.2 f'_c shall have special transverse reinforcement, as specified in Section 1921.4.4, over the total length of the element. The special transverse reinforcement may be discontinued at a section where the calculated compressive stress is less than 0.15 f'_c. Stresses shall be calculated for the factored forces using a linearly elastic model and gross-section properties of the elements considered.

1921.6.2.4 All continuous reinforcement in *shear* walls, diaphragms, trusses, struts, ties, chords and collector elements shall be anchored or spliced in accordance with the provisions for reinforcement in tension as specified in Section 1921.5.4.

1921.6.3 Design forces. The design shear force V_u shall be obtained from the lateral load analysis in accordance with the factored loads and combinations specified in Section 1909.2 *and as modified in Section 1612.2.1.*

1921.6.4 Diaphragms. *See Sections 1921.6.11 and 1921.6.12.*

1921.6.5 Shear strength.

1921.6.5.1 Nominal shear strength of *shear* walls and diaphragms shall be determined using either Section 1921.6.5.2 or 1921.6.5.3.

1921.6.5.2 Nominal shear strength, V_n, of *shear* walls and diaphragms shall be assumed not to exceed the shear force calculated from

$$V_n = A_{cv}(2\sqrt{f'_c} + \rho_n f_y) \qquad (21\text{-}6)$$

For **SI:** $$V_n = A_{cv}(0.166\sqrt{f'_c} + \rho_n f_y)$$

1921.6.5.3 For walls (diaphragms) and wall (diaphragm) segments having a ratio of (h_w/l_w) less than 2.0, nominal shear strength of wall (diaphragm) shall be determined from Formula (21-7)

$$V_n = A_{cv}(\alpha_c\sqrt{f'_c} + \rho_n f_y) \qquad (21\text{-}7)$$

For **SI:** $$V_n = A_{cv}(0.08\alpha_c\sqrt{f'_c} + \rho_n f_y)$$

Where the coefficient α_c varies linearly from 3.0 for $h_w/l_w = 1.5$ to 2.0 for $h_w/l_w = 2.0$.

1921.6.5.4 In Section 1921.6.5.3 above, the value of ratio (h_w/l_w) used for determining V_n for segments of a wall or diaphragm shall be the largest of the ratios for the entire wall (diaphragm) and the segment of wall (diaphragm) considered.

1921.6.5.5 Walls (diaphragms) shall have distributed shear reinforcement providing resistance in two orthogonal directions in the plane of the wall (diaphragm). If the ratio (h_w/l_w) does not exceed 2.0, reinforcement ratio ρ_v shall not be less than reinforcement ratio ρ_n.

1921.6.5.6 Nominal shear strength of all wall piers sharing a common lateral force shall not be assumed to exceed $8A_{cv}\sqrt{f'_c}$ (For **SI:** $0.66A_{cv}\sqrt{f'_c}$) where A_{cv} is the total cross-sectional area and the nominal shear strength of any one of the individual wall piers shall not be assumed to exceed $10A_{cp}\sqrt{f'_c}$ (For **SI:** $0.83A_{cp}\sqrt{f'_c}$) where A_{cp} represents the cross-sectional area of the pier considered.

1921.6.5.7 Nominal shear strength of horizontal wall segments shall not be assumed to exceed $10A_{cp}\sqrt{f'_c}$ (For **SI:** $0.83A_{cp}\sqrt{f'_c}$) where A_{cp} represents the cross-sectional area of a horizontal wall segment.

1921.6.6 Design of shear walls for flexural and axial loads.

1921.6.6.1 *Shear walls and portions of shear walls subject to combined flexural and axial loads shall be designed in accordance with Sections 1910.2 and 1910.3, except Section 1910.3.6 and the nonlinear strain requirements of Section 1910.2.2 do not apply. The strength-reduction factor ϕ shall be in accordance with Section 1909.3.*

1921.6.6.2 *The effective flange widths to be used in the design of I-, L-, C- or T-shaped sections shall not be assumed to extend further from the face of the web than (1) one half the distance to an adjacent shear wall web, or (2) 15 percent of the total wall height for the flange in compression or 30 percent of the total wall height for the flange in tension, not to exceed the total projection of the flange.*

1921.6.6.3 *Walls and portions of walls with $P_u > 0.35P_o$ shall not be considered to contribute to the calculated strength of the structure for resisting earthquake-induced forces. Such walls shall conform to the requirements of Section 1631.2, Item 4.*

1921.6.6.4 *Shear wall boundary zone detail requirements as defined in Section 1921.6.6.6 need not be provided in shear walls or portions of shear walls meeting the following conditions:*

1. *$P_u \le 0.10A_g f'_c$ for geometrically symmetrical wall sections*
   $P_u \le 0.05A_g f'_c$ for geometrically unsymmetrical wall sections

and either

2. $\dfrac{M_u}{V_u l_w} \le 1.0$

or

3. $V_u \le 3A_{cv}\sqrt{f'_c}$ *and* $\frac{M_u}{V_u\, l_w} \le 3$ (For **SI:** $V_u \le 0.25A_{cv}\sqrt{f'_c}$)

Shear walls and portions of shear walls not meeting the conditions of Section 1921.6.6.4 and having $P_u < 0.35P_o$ shall have boundary zones at each end a distance varying linearly from 0.25 l_w to 0.15 l_w for P_u varying from 0.35 P_o to 0.15 P_o. The boundary zone shall have minimum length of 0.15 l_w and shall be detailed in accordance with Section 1921.6.6.6.

1921.6.6.5 *Alternatively, the requirements for boundary zones in shear walls or portions of shear walls not meeting the conditions of Section 1921.6.6.4 may be based on determination of the compressive strain levels at edges when the wall or portion of wall is subjected to displacement levels resulting from the ground motions specified in Section 1629.2 using cracked section properties and considering the response modification effects of possible nonlinear behavior of the building.*

Boundary zone detail requirements as defined in Section 1921.6.6.6 shall be provided over those portions of the wall where compressive strains exceed 0.003. In no instance shall designs be permitted in which compressive strains exceed ε_{max}.

WHERE:

$$\epsilon_{max} = 0.015 \qquad (21\text{-}8)$$

1. Using the displacement of Section 1921.6.6.5, determine the curvature of the wall cross section at each location of potential flexural yielding assuming the possible nonlinear response of the wall and its elements. Using a strain compatibility analysis of the wall cross section, determine the compressive strains resulting from these curvatures.

2. For shear walls in which the flexural limit state response is governed by yielding at the base of the wall, compressive strains at wall edges may be approximated as follows:

Determine the total curvature demand (ϕ_t) as given in Formula (21-9):

$$\phi_t = \frac{\Delta_i}{(h_w - l_p/2)l_p} + \phi_y \qquad (21\text{-}9)$$

WHERE:

c'_u = *neutral axis depth at P'_u and M'_n.*
l_p = *height of the plastic hinge above critical section and which shall be established on the basis of substantiated test data or may be alternatively taken at* $0.5l_w$.
$P'u$ = *1.2D + 0.5L + E_h.*
Δ_E = *elastic design displacement at the top of the wall using gross section properties and code-specified seismic forces.*
Δ_i = *inelastic deflection at top of wall.*
= $\Delta_t - \Delta_y$
Δ_t = *total deflection at the top of the wall equal to Δ_M, using cracked section properties, or may be taken as $2\Delta_M$, using gross section properties.*
Δ_y = *displacement at top of wall corresponding to yielding of the tension reinforcement at critical section, or may be taken as $(M'_n/M_E)\Delta_E$, where M_E equals unfactored moment at critical section when top of wall is displaced Δ_E. M'_n is nominal flexural strength of critical section at P'_u.*
ϕ_y = yield curvature which may be estimated as $0.003/l_w$.

If ϕ_t is less than or equal to $0.003/c'_u$, boundary zone details as defined in Section 1921.6.6.6 are not required. If ϕ_t exceeds $0.003/c'_u$, the compressive strains may be assumed to vary linearly over the depth c'_u and have maximum value equal to the product of c'_u and ϕ_t.

1921.6.6.6 Shear wall boundary zone detail requirements. *When required by Section 1921.6.6.1 through 1921.6.6.5, boundary zones shall meet the following:*

1. *Dimensional requirements.*

   1.1 *All portions of the boundary zones shall have a thickness of l_u/16 or greater.*

   1.2 *Boundary zones shall extend vertically a distance equal to the development length of the largest vertical bar within the boundary zone above the elevation where the requirements of Section 1921.6.6.4 or 1921.6.6.5 are met.*

   Extensions below the base of the boundary zone shall conform to Section 1921.4.4.6.

   EXCEPTION: *The boundary zone reinforcement need not extend above the base of the boundary zone a distance greater than the larger of l_w or $M_u/4V_u$.*

   1.3 *Boundary zones as determined by the requirements of Section 1921.6.6.5 shall have a minimum length of 18 inches (457 mm) at each end of the wall or portion of wall.*

   1.4 *In I-, L-, C- or T-shaped sections, the boundary zone at each end shall include the effective flange width and shall extend at least 12 inches (305 mm) into the web.*

2. *Confinement reinforcement.*

   2.1 *All vertical reinforcement within the boundary zone shall be confined by hoops or cross ties producing an area of steel not less than:*

   $$A_{sh} = 0.09sh_c\, f'_c/f_{yh} \qquad (21\text{-}10)$$

   2.2 *Hoops and cross ties shall have a vertical spacing not greater than the smaller of 6 inches (152 mm) or 6 diameters of the largest vertical bar within the boundary zone.*

   2.3 *The ratio of the length to the width of the hoops shall not exceed 3. All adjacent hoops shall be overlapping.*

   2.4 *Cross ties or legs of overlapping hoops shall not be spaced further apart than 12 inches (305 mm) along the wall.*

   2.5 *Alternate vertical bars shall be confined by the corner of a hoop or cross tie.*

3. *Horizontal reinforcement.*

   3.1 *All horizontal reinforcement terminating within a boundary zone shall be anchored in accordance with Section 1921.6.2.*

   3.2 *Horizontal reinforcement shall not be lap spliced within the boundary zone.*

4. *Vertical reinforcement.*

   4.1 *Vertical reinforcement shall be provided to satisfy all tension and compression requirements.*

   4.2 *Area of reinforcement shall not be less than 0.005 times the area of boundary zone or less than two No. 5 bars at each edge of boundary zone.*

   4.3 *Lap splices of vertical reinforcement within the boundary zone shall be confined by hoops or cross ties. Spacing of hoops and cross ties confining lap-spliced reinforcement shall not exceed 4 inches (102 mm).*

1921.6.6.7 Welded splices and mechanical connections of longitudinal reinforcement in the boundary *zone* shall conform to Section 1921.2.6.1.

1921.6.7 Boundaries of structural diaphragms.

1921.6.7.1 Boundary elements of structural diaphragms shall be proportioned to resist the sum of the factored axial force acting in the plane of the diaphragm and the force obtained from dividing the factored moment at the section by the distance between the edges of the diaphragm at that section.

1921.6.7.2 Splices of tensile reinforcement in the boundaries and collector elements of all diaphragms shall develop the yield strength of the reinforcement. Welded splices and mechanical connections shall conform to Section 1921.2.7.1.

1921.6.7.3 *Reinforcement for chords and collectors at splices and anchorage zones shall have a minimum spacing of three bar diameters, but not less than $1^1/_2$ inches (38 mm), and a minimum concrete cover of two and one-half bar diameters, but not less than 2 inches (51 mm), and shall have transverse reinforcement as specified by Section 1911.5.5.3, except as required in Section 1921.6.2.3.*

1921.6.8 Construction joints.

1921.6.8.1 All construction joints in walls and diaphragms shall conform to Section 1906.4, and contact surfaces shall be roughened as specified in Section 1911.7.9.

1921.6.9 Discontinuous walls. Columns supporting discontinuous walls shall be reinforced in accordance with Section 1921.4.4.5.

1921.6.10 Coupling beams.

1921.6.10.1 *For coupling beams with $1_n/d \geq 4$, the design shall conform to the requirements of Sections 1921.2 and 1921.3. It shall be permitted to waive the requirements of Sections 1921.3.1.3 and 1921.3.1.4 if it can be shown by analysis that lateral stability is adequate or if alternative means of maintaining lateral stability is provided.*

1921.6.10.2 *Coupling beams with $1_n/d < 4$ shall be permitted to be reinforced with two intersecting groups of symmetrical diagonal bars. Coupling beams with $1_n/d < 4$ and with factored shear force V_u exceeding $4\sqrt{f'_c}\, b_w d$ (For* ***SI:*** *$0.33\sqrt{f'_c}\, b_w d$) shall be reinforced with two intersecting groups of symmetrical diagonal bars. Each group shall consist of a minimum of four bars assembled in a core with a lateral dimension of each side not less than $b_w/2$ or 4 inches (102 mm). The design shear strength, ϕV_n, of these coupling beams shall be determined by:*

$$\phi V_n = 2\phi f_y \sin\alpha A_d \leq 10\phi\sqrt{f'_c}\, b_w d \qquad (21\text{-}11)$$

For ***SI:*** $$\phi V_n = 2\phi f_y \sin\alpha A_d \leq 0.83\phi\sqrt{f'_c}\, b_w d$$

WHERE:

α = *the angle between the diagonal reinforcement and the longitudinal axis.*

A_{vd} = *the total area of reinforcement of each group of diagonal bars.*

ϕ = *0.85.*

EXCEPTION: *The design of coupling beams need not comply with the requirements for diagonal reinforcement if it can be shown that failure of the coupling beams will not impair the vertical load carrying capacity of the structure, the egress from the structure, or the integrity of nonstructural components and connections. The analysis shall take into account the effects of the failure of the coupling beams on foundation rotation and overall system displacements. Design strength of coupling beams assumed to be part of the seismic force resisting system shall not be reduced below the values otherwise required.*

1921.6.10.3 *Each group of diagonally placed bars shall be enclosed in transverse reinforcement conforming to Sections 1921.4.4.1 through 1921.4.4.3. For the purpose of computing A_g, as per Formulas 10-6 and 21-3, the minimum cover, as specified in Section 1907.7, shall be assumed over each group of diagonally placed reinforcing bars.*

1921.6.10.4 *Reinforcement parallel and transverse to the longitudinal axis shall be provided and, as a minimum, shall conform to Sections 1910.5, 1911.8.9 and 1911.8.10.*

1921.6.10.5 *Contribution of the diagonal reinforcement to nominal flexural strength of the coupling beam shall be considered.*

1921.6.11 Floor topping. *A cast-in-place topping on a precast floor system may serve as the diaphragm, provided the cast-in-place topping acting alone is proportioned and detailed to resist the design forces.*

1921.6.12 Diaphragms. *Diaphragms used to resist prescribed lateral forces shall comply with the following:*

1. Thickness shall not be less than 2 inches (51 mm).

2. When mechanical connectors are used to transfer forces between the diaphragm and the lateral system, the anchorage shall be adequate to develop 1.4 $A_s f_y$, where A_s is the connector's cross-sectional area.

3. Collector and boundary elements in topping slabs placed over precast floor and roof elements shall not be less than 3 inches (76 mm) or 6 d_b thick, where d_b is the diameter of the largest reinforcement in the topping slab.

4. Prestressing tendons shall not be used as primary reinforcement in boundaries and collector elements of structural diaphragms. Precompression from unbonded tendons may be used to resist diaphragm forces.

1921.6.13 Wall piers.

1921.6.13.1 *Wall piers not designed as part of a special moment-resisting frame shall have transverse reinforcement designed to satisfy the requirements in Section 1921.6.13.2.*

EXCEPTIONS: *1. Wall piers that satisfy Section 1921.7.*

2. Wall piers along a wall line within a story where other shear wall segments provide lateral support to the wall piers, and such segments have a total stiffness of at least six times the sum of the stiffnesses of all the wall piers.

1921.6.13.2 *Transverse reinforcement shall be designed to resist the shear forces determined from Sections 1921.4.5.1 and 1921.3.4.2. When the axial compressive force, including earthquake effects, is less than $A_g f'_c/20$, transverse reinforcement in wall piers may have standard hooks at each end in lieu of hoops. Spacing of transverse reinforcement shall not exceed 6 inches (152 mm). Transverse reinforcement shall be extended beyond the pier clear height for at least the development length of the largest longitudinal reinforcement in the wall pier.*

1921.6.13.3 *Wall segments with horizontal length-to-thickness ratio less than $2^1/_2$ shall be designed as columns.*

1921.7 Frame Members Not Part of the Lateral-force-resisting System.

1921.7.1 Frame members assumed not to contribute to lateral resistance shall be detailed according to Section 1921.7.2 or 1921.7.3, depending on the magnitude of moments induced in those members when subjected to Δ_M. When induced moments under lateral displacements are not calculated, Section 1921.7.3 shall apply.

1921.7.2 When the induced moments and shears under lateral displacements of Section 1921.7.1 combined with the factored gravity moments and shear loads do not exceed the design moment and shear strength of the frame member, the following conditions shall be satisfied. For this purpose, the load combinations (*1.4*D + *1.4*L) and 0.9*D* shall be used.

1921.7.2.1 Members with factored gravity axial forces not exceeding ($A_g f'_c/10$), shall satisfy Section 1921.3.2.1. Stirrups shall be placed at not more than $d/2$ throughout the length of the member.

1921.7.2.2 Members with factored gravity axial forces exceeding ($A_g f'_c/10$), but not exceeding $0.3P_o$ shall satisfy Sections 1921.4.3, 1921.4.4.1, Item 3, and 1921.4.4.3. Design shear strength shall not be less than the shear associated with the development of nominal moment strengths of the member at each end of the clear span. The maximum longitudinal spacing of ties shall be s_o for the full column height. The spacing s_o shall not be more than (1) 6 diameters of the smallest longitudinal bar enclosed, (2) 16 tie-bar diameters, (3) one-half the least cross-sectional dimension of the column and (4) 6 inches (152 mm).

1921.7.2.3 Members with factored gravity axial forces exceeding $0.3P_o$ shall satisfy Sections 1921.4.4 and 1921.4.5.

1921.7.3 When the induced moments under lateral displacements of Section 1921.7.1 exceed the design moment strength of the frame member, or where induced moments are not calculated, the following conditions in Sections 1921.7.3.1 through 1921.7.3.3 shall be satisfied.

1921.7.3.1 Materials shall satisfy Sections 1921.2.4, 1921.2.5 and 1921.2.6.

1921.7.3.2 Members with factored gravity axial forces not exceeding ($A_g f'_c/10$) shall satisfy Sections 1921.3.2.1 and 1921.3.4. Stirrups shall be placed at not more than $d/2$ throughout the length of the member.

1921.7.3.3 Members with factored gravity axial forces exceeding ($Agf'_c/10$) shall satisfy Sections 1921.4.4, 1921.4.5 and 1921.5.2.1.

1921.7.4 Ties at anchor bolts. *Anchor bolts set in the top of a column shall be enclosed with ties as specified in Section 1921.4.4.8.*

1921.8 Requirements for Frames *in Seismic Zone 2.*

1921.8.1 *In Seismic Zone 2*, structural frames proportioned to resist forces induced by earthquake motions shall satisfy the requirements of Section 1921.8 in addition to those of Sections 1901 through 1918.

1921.8.2 Reinforcement details in a frame member shall satisfy Section 1921.8.4 if the factored compressive axial load for the member does not exceed ($A_g f'_c/10$). If the factored compressive axial load is larger, frame reinforcement details shall satisfy Section 1921.8.5 unless the member has spiral reinforcement according to Formula (10-5). If a two-way slab system without beams is treated as part of a frame-resisting earthquake effect, reinforcement details in any span resisting moments caused by lateral force shall satisfy Section 1921.8.6.

1921.8.3 Design shear strength of beams, columns and two-way slabs resisting earthquake effect shall not be less than either (1) the sum of the shear associated with development of nominal moment strengths of the member at each restrained end of the clear span and the shear calculated for gravity loads, or (2) the maximum shear obtained from design load combinations which include earthquake effect E, with E assumed to be twice that prescribed in Section 1626.

1921.8.4 Beams.

1921.8.4.1 The positive-moment strength at the face of the joint shall not be less than one third the negative-moment strength provided at that face of the joint. Neither the negative- nor the positive-moment strength at any section along the length of the member shall be less than one fifth the maximum moment strength provided at the face of either joint.

1921.8.4.2 At both ends of the member, stirrups shall be provided over lengths equal to twice the member depth measured from the face of the supporting member toward midspan. The first stirrup shall be located at not more than 2 inches (51 mm) from the face of the supporting member. Maximum stirrup spacing shall not exceed (1) $d/4$, (2) eight times the diameter of the smallest longitudinal bar enclosed, (3) 24 times the diameter of the stirrup bar, and (4) 12 inches (305 mm).

1921.8.4.3 Stirrups shall be placed at not more than $d/2$ throughout the length of the member.

1921.8.5 Columns.

1921.8.5.1 Maximum tie spacing shall not exceed s_o over a length l_o measured from the joint face. Spacing s_o shall not exceed (1) eight times the diameter of the smallest longitudinal bar enclosed, (2) 24 times the diameter of the tie bar, (3) one half of the smallest cross-sectional dimension of the frame member, and (4) 12 inches (305 mm). Length l_o shall not be less than (1) one sixth of the clear span of the member, (2) maximum cross-sectional dimension of the member, and (3) 18 inches (457 mm).

1921.8.5.2 The first tie shall be located at not more than $s_o/2$ from the joint face.

1921.8.5.3 Joint reinforcement shall conform to Section 1911.11.2.

1921.8.5.4 Tie spacing shall not exceed twice the spacings s_o.

1921.8.5.5 *Column lateral ties shall be as specified in Section 1907.1.3. Anchor bolts set in the top of a column shall be enclosed with ties as specified in Section 1921.4.4.8.*

1921.8.6 Two-way slabs without beams.

1921.8.6.1 Factored slab moment at support related to earthquake effect shall be determined for load combinations defined by Formulas (9-2) and (9-3). All reinforcement provided to resist M_s, the portion of slab moment balanced by support moment, shall be placed within the column strip defined in Section 1913.2.1.

1921.8.6.2 The fraction, defined by Formula (13-1), of moment M_s shall be resisted by reinforcement placed within the effective width specified in Section 1913.5.2.

1921.8.6.3 Not less than one half of the reinforcement in the column strip at support shall be placed within the effective slab width specified in Section 1913.5.2.

1921.8.6.4 Not less than one fourth of the top reinforcement at the support in the column strip shall be continuous throughout the span.

1921.8.6.5 Continuous bottom reinforcement in the column strip shall not be less than one third of the top reinforcement at the support in the column strip.

1921.8.6.6 Not less than one half of all bottom reinforcement at midspan shall be continuous and shall develop its yield strength at face of support as defined in Section 1913.6.2.5.

1921.8.6.7 At discontinuous edges of the slab, all top and bottom reinforcement at support shall be developed at the face of support as defined in Section 1913.6.2.5.

SECTION 1922 — STRUCTURAL PLAIN CONCRETE

1922.0 Notations.

A_g = gross area of section, inches squared (mm^2).

A_1 = loaded area, inches squared (mm^2).

A_2 = the area of the lower base of the largest frustum of a pyramid, cone or tapered wedge contained wholly within the support and having for its upper base the loaded area, and having side slopes of 1 unit vertical to 2 units horizontal, inches squared (mm^2).

b = width of member, inches (mm).

b_o = perimeter of critical section for shear in footings, inches (mm).

B_n = nominal bearing strength of loaded area.

f'_c = specified compressive strength of concrete, psi (MPa). See Section 1905.

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi (MPa).

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, psi (MPa). See Sections 1905.1.4 and 1905.1.5.

h = overall thickness of member, inches (mm).

l_c = vertical distance between supports, inches (mm).

M_n = nominal moment strength at section.

M_u = factored moment at section.

P_n = nominal strength of cross section subject to compression.

P_{nw} = nominal axial load strength of wall designed by Section 1922.6.5.

P_u = factored axial load at given eccentricity.

S = elastic section modulus of section.

V_n = nominal shear strength at section.

v_u = shear stress due to factored shear force at section.

V_u = factored shear force at section.

β_c = ratio of long side to short side of concentrated load or reaction area.

ϕ = strength reduction factor. See Section 1909.3.5.

1922.1 Scope.

1922.1.1 This section provides minimum requirements for design and construction of structural plain concrete members (cast-in-place or precast) except as specified in Sections 1922.1.1.1 and 1922.1.1.2.

> ***EXCEPTION:*** *The design is not required when the minimum foundation for stud walls is in accordance with Table 18-I-C.*

1922.1.1.1 Structural plain concrete basement walls shall be exempted from the requirements for special exposure conditions of Section 1904.2.2.

1922.1.1.2 Design and construction of soil-supported slabs, such as sidewalks and slabs on grade shall not be regulated by this code unless they transmit vertical loads from other parts of the structure to the soil.

1922.1.2 For special structures, such as arches, underground utility structures, gravity walls, and shielding walls, provisions of this section shall govern where applicable.

1922.2 Limitations.

1922.2.1 Provisions of this section shall apply for design of structural plain concrete members defined as either unreinforced or containing less reinforcement than the minimum amount specified in this code for reinforced concrete.

1922.2.2 Use of structural plain concrete shall be limited to (1) members that are continuously supported by soil or supported by other structural members capable of providing continuous vertical support, (2) members for which arch action provides compression under all conditions of loading, or (3) walls and pedestals. See Sections 1922.6 and 1922.8. The use of structural plain concrete columns is not permitted.

1922.2.3 This section does not govern design and installation of cast-in-place concrete piles and piers embedded in ground.

1922.2.4 Minimum strength. Specified compressive strength of concrete, f'_c, used in structural plain concrete elements shall not be less than 2,500 psi (17.2 MPa).

1922.2.5 Seismic Zones 2, 3 and 4. *Plain concrete shall not be used in Seismic Zone 2, 3 or 4 except where specifically permitted by Section 1922.10.3.*

1922.3 Joints.

1922.3.1 Contraction or isolation joints shall be provided to divide structural plain concrete members into flexurally discontinuous elements. Size of each element shall be limited to control buildup of excessive internal stresses within each element caused by restraint to movements from creep, shrinkage and temperature effects.

1922.3.2 In determining the number and location of contraction or isolation joints, consideration shall be given to: influence of climatic conditions; selection and proportioning of materials; mixing, placing and curing of concrete; degree of restraint to movement; stresses due to loads to which an element is subject; and construction techniques.

1922.4 Design Method.

1922.4.1 Structural plain concrete members shall be designed for adequate strength in accordance with provisions of this chapter, using load factors and design strength.

1922.4.2 Factored loads and forces shall be in such combinations as specified in Section 1909.2.

1922.4.3 Where required strength exceeds design strength, reinforcement shall be provided and the member designed as a reinforced concrete member in accordance with appropriate design requirements of this chapter.

1922.4.4 Strength design of structural plain concrete members for flexure and axial loads shall be based on a linear stress-strain relationship in both tension and compression.

1922.4.5 Tensile strength of concrete shall be permitted to be considered in design of plain concrete members when provisions of Section 1922.3 have been followed.

1922.4.6 No strength shall be assigned to steel reinforcement that may be present.

1922.4.7 Tension shall not be transmitted through outside edges, construction joints, contraction joints or isolation joints of an individual plain concrete element. No flexural continuity due to tension shall be assumed between adjacent structural plain concrete elements.

1922.4.8 In computing strength in flexure, combined flexure and axial load, and shear, the gross cross section of a member shall be considered in design, except for concrete cast against soil, overall thickness h shall be taken as 2 inches (51 mm) less than actual thickness.

1922.5 Strength Design.

1922.5.1 Design of cross sections subject to flexure shall be based on

$$\phi M_n \geq M_u \tag{22-1}$$

where M_u is factored moment and M_n is nominal moment strength* computed by

$$M_n = 5\sqrt{f'_c}\, S \tag{22-2}$$

where S is the elastic section modulus of the cross section.

1922.5.2 Design of cross sections subject to compression shall be based on

$$\phi P_N \geq P_u \tag{22-3}$$

where P_u is factored load and P_n is nominal compression strength computed by

$$P_n = 0.60 f'_c \left[1 - \left(\frac{l_c}{32h}\right)^2\right] A_1 \tag{22-4}$$

where A_1 is the loaded area.

1922.5.3 Members subject to combined flexure and axial load in compression shall be proportioned such that on the compression face:

$$P_u/\phi P_n + M_u/\phi M_n \leq 1 \tag{22-5}$$

and on the tension face:

$$M_u/S - P_u/A_g \leq 5\phi\sqrt{f'_c} \tag{22-6}$$

1922.5.4 Design of rectangular cross sections subject to shear* shall be based on

$$\phi V_n \geq V_u \tag{22-7}$$

where V_u is factored shear and V_n is nominal shear strength computed by

$$V_n = \frac{4}{3}\sqrt{f'_c}\, bh \tag{22-8}$$

for beam action and by

$$V_n = \left[\frac{4}{3} + \frac{8}{3\beta_c}\right]\sqrt{f'_c}\, b_o h \leq 2.66\sqrt{f'_c}\, b_o h \tag{22-9}$$

for two-way action but not greater than $2.66\sqrt{f'_c}\, b_o h$.

1922.5.5 Design of bearing areas subject to compression shall be based on

$$\phi B_n \geq P_u \tag{22-10}$$

where P_u is factored bearing load and B_n is the nominal bearing strength of loaded area A_1 computed by

$$B_n = 0.85 f'_c A_1 \tag{22-11}$$

except when the supporting surface is wider on all sides than the loaded area, design bearing strength on the loaded area shall be multiplied by $\sqrt{A_2/A_1}$ but not more than 2.

1922.6 Walls.

1922.6.1 Structural plain concrete walls shall be continuously supported by soil, footings, foundation walls, grade beams or other structural members capable of providing continuous vertical support.

1922.6.2 Structural plain concrete walls shall be designed for vertical, lateral and other loads to which they are subjected.

1922.6.3 Structural plain concrete walls shall be designed for an eccentricity corresponding to the maximum moment that can accompany the axial load but not less than 0.10h. If the resultant of all factored loads is located within the middle third of the overall wall thickness, the design shall be in accordance with Section 1922.5.3 or 1922.6.5. Otherwise, walls shall be designed in accordance with Section 1922.5.3.

1922.6.4 Design for shear shall be in accordance with Section 1922.5.4.

1922.6.5 Empirical design method.

1922.6.5.1 Structural plain concrete walls of solid rectangular cross section shall be permitted to be designed by Formula (22-13) if the resultant of all factored loads is located within the middle third of the overall thickness of wall.

1922.6.5.2 Design of walls subject to axial loads in compression shall be based on

$$\phi P_{nw} \geq P_u \tag{22-12}$$

where P_u is the factored axial load and P_{nw} is nominal axial load strength computed by

$$P_{nw} = 0.45 f'_c A_g \left[1 - \left(\frac{l_c}{32h}\right)^2\right] \tag{22-13}$$

1922.6.6 Limitations.

1922.6.6.1 Unless demonstrated by a detailed analysis, horizontal length of wall to be considered effective for each vertical concentrated load shall not exceed center-to-center distance between loads, nor width of bearing plus four times the wall thickness.

1922.6.6.2 Except as provided for in Section 1922.6.6.3, thickness of bearing walls shall not be less than $^1/_{24}$ the unsupported height or length, whichever is shorter, nor less than $5^1/_2$ inches (140 mm).

1922.6.6.3 Thickness of exterior basement walls and foundation walls shall not be less than $7^1/_2$ inches (191 mm).

1922.6.6.4 Walls shall be braced against lateral translation. See Sections 1924.3 and 1922.4.7.

*Equations for nominal flexural and shear strengths apply for normal concrete; for lightweight aggregate concrete, one of the following modifications shall apply:

1. When f_{ct} is specified and concrete is proportioned in accordance with Section 1905.2, $f_{ct}/6.7$ shall be substituted for f'_c but the value of $f_{ct}/6.7$ shall not exceed.

2. When f_{ct} is not specified, the value for nominal flexural and shear shall be multiplied by 0.75 for "all-lightweight" concrete and by 0.85 for "sand-lightweight" concrete. Linear interpolation is permitted when partial sand replacement is used.

1922.6.6.5 Not less than two No. 5 bars shall be provided around all window and door openings. Such bars shall extend at least 24 inches (610 mm) beyond the corners of openings.

1922.7 Footings.

1922.7.1 Structural plain concrete footings shall be designed for factored loads and induced reactions in accordance with appropriate design requirements of this code and as provided in Sections 1922.7.2 through 1922.7.8.

1922.7.2 Base area of footing shall be determined from unfactored forces and moments transmitted by footing to soil and permissible soil pressure selected through principles of soil mechanics.

1922.7.3 Plain concrete shall not be used for footings on piles.

1922.7.4 Thickness of structural plain concrete footings shall not be less than 8 inches (203 mm). See Section 1922.4.8.

1922.7.5 Maximum factored moment shall be computed at critical sections located as follows:

1. At face of column, pedestal or wall for footing supporting a concrete column, pedestal or wall.
2. Halfway between middle and edge of wall, for footing supporting a masonry wall.
3. Halfway between face of column and edge of steel base plate, for footing supporting a column with steel base plate.

1922.7.6 Shear in plain concrete footing.

1922.7.6.1 Maximum factored shear shall be computed in accordance with Section 1922.7.6.2, with location of critical section measured from face of column, pedestal or wall for footing supporting a column, pedestal or wall. For footing supporting a column with steel base plates, the critical section shall be measured from location defined in Section 1922.7.5, Item 3.

1922.7.6.2 Shear strength of structural plain concrete footings in the vicinity of concentrated loads or reactions shall be governed by the more severe of two conditions:

1. Beam action for footing, with a critical section extending in a plane across the entire footing width and located at a distance h from face of concentrated load or reaction area. For this condition, the footing shall be designed in accordance with Formula (22-8).
2. Two-way action for footing, with a critical section perpendicular to plane of footing and located so that its perimeter b_o is a minimum, but need not approach closer than $h/2$ to perimeter of concentrated load or reaction area. For this condition, the footing shall be designed in accordance with Formula (22-9).

1922.7.7 Circular or regular polygon shaped concrete columns or pedestals shall be permitted to be treated as square members with the same area for location of critical sections for moment and shear.

1922.7.8 Factored bearing load on concrete at contact surface between supporting and supported member shall not exceed design bearing strength for either surface as given in Section 1922.5.5.

1922.8 Pedestals.

1922.8.1 Plain concrete pedestals shall be designed for vertical, lateral and other loads to which they are subjected.

1922.8.2 Ratio of unsupported height to average least lateral dimension of plain concrete pedestals shall not exceed 3.

1922.8.3 Maximum factored axial load applied to plain concrete pedestals shall not exceed design bearing strength given in Section 1922.5.5.

1922.9 Precast Members.

1922.9.1 Design of precast plain concrete members shall consider all loading conditions from initial fabrication to completion of the structure, including form removal, storage, transportation and erection.

1922.9.2 Limitations of Section 1922.2 apply to precast members of plain concrete not only to the final condition but also during fabrication, transportation and erection.

1922.9.3 Precast members shall be connected securely to transfer all lateral forces into a structural system capable of resisting such forces.

1922.9.4 Precast members shall be adequately braced and supported during erection to ensure proper alignment and structural integrity until permanent connections are completed.

1922.10 Seismic Requirements for Plain Concrete.

1922.10.1 General*. The design and construction of plain concrete components that resist seismic forces shall conform to the requirements of Section 1922, except as modified by this section.*

1922.10.2 Seismic Zones 0 and 1. *Structural plain concrete members located in Seismic Zones 0 and 1 shall be designed in accordance with the provisions of Sections 1922.1 through 1922.9.*

1922.10.3 Seismic Zones 2, 3 and 4. *Structural plain concrete members are not permitted in buildings located in Seismic Zones 2, 3 and 4.*

EXCEPTIONS*: 1. Footings for buildings of Group R, Division 3 or Group U, Division 1 Occupancy constructed in accordance with Table 18-I-C.*

2. Nonstructural slabs supported directly on the ground or by approved structural systems.

Division III—DESIGN STANDARD FOR ANCHORAGE TO CONCRETE

SECTION 1923 — ANCHORAGE TO CONCRETE

1923.1 *Service Load Design.* *Bolts and headed stud anchors shall be solidly cast in concrete and the service load shear and tension shall not exceed the values set forth in Table 19-D.*

For combined tension and shear:

$$(P_s/P_t)^{5/3} + (V_s/V_t)^{5/3} \leq 1$$

WHERE:

P_s = *applied service tension load.*

P_t = *Table 19-D service tension load.*

V_s = *applied service shear load.*

V_t = *Table 19-D service shear load.*

1923.2 *Strength Design.* *The factored loads on embedded anchor bolts and headed studs shall not exceed the design strengths determined by Section 1923.3.*

In addition to the load factors in Section 1909.2, a multiplier of 2 shall be used if special inspection is not provided, or of 1.3 if it is provided. When anchors are embedded in the tension zone of a member, the load factors in Section 1909.2 shall have a multiplier of 3 if special inspection is not provided, or of 2 if it is provided.

1923.3 Strength of Anchors.

1923.3.1 General. *The strength of headed bolts and headed studs solidly cast in concrete shall be taken as the average of 10 tests approved by the building official for each concrete strength and anchor size. Alternatively, the strength of the anchor shall be calculated in accordance with Sections 1923.3.2 through 1923.3.4. The bearing area of headed anchors shall be at least one and one-half times the shank area.*

1923.3.2 Design strength in tension. *The design strength of anchors in tension shall be the minimum of P_{ss} or ϕP_c where:*

$$P_{ss} = 0.9 A_b f_{ut}$$

and for an anchor group where the distance between anchors is less than twice their embedment length or for a single anchor or anchor group where the distance between anchors is equal to or greater than twice their embedment length

$$\phi P_c = \phi\lambda\, 4 A_p \sqrt{f'_c}$$

For **SI:** $\phi P_c = 0.32\, \phi\lambda A_p \sqrt{f'_c}$

WHERE:

A_b = *area [in square inches (mm²)] of anchor. Must be used with the corresponding steel properties to determine the weakest part of the assembly in tension.*

A_p = *the effective area [in square inches (mm²)] of the projection of an assumed concrete failure surface upon the surface from which the anchor protrudes. For a single anchor or for an anchor group where the distance between anchors is equal to or greater than twice their embedment length, the surface is assumed to be that of a truncated cone radiating at a 45-degree slope from the bearing edge of the anchor toward the surface from which the anchor protrudes. The effective area is the projection of the cone on this surface. For an anchor which is perpendicular to the surface from which it protrudes, the effective area is a circle.*

For an anchor group where the distance between anchors is less than twice their embedment length, the failure surface is assumed to be that of a truncated pyramid radiating at a 45-degree slope from the bearing edge of the anchor group toward the surface from which the anchors protrudes. The effective area is the projection of this truncated pyramid on this surface. In addition, for thin sections with anchor groups, the failure surface shall be assumed to follow the extension of this slope through to the far side rather than be truncated, and the failure mode resulting in the lower value of ϕP_c shall control.

d_b = *anchor shank diameter.*

f'_c = *specified compression strength of concrete, which shall not be taken as greater than 6,000 psi (41.37 MPa) for design.*

f_{ut} = *minimum specified tensile strength [in psi (MPa)] of the anchor. May be assumed to be 60,000 psi (413.7 MPa) for A 307 bolts or A 108 studs.*

P_c = *design tensile strength [in pounds (MPa)].*

P_u = *required tensile strength from factored loads, pounds (N).*

V_c = *design shear strength [in pounds (MPa)].*

V_u = *required shear strength from factored loads, pounds (N).*

λ = *1 for normal-weight concrete, 0.75 for "all lightweight" concrete, and 0.85 for "sand-lightweight" concrete.*

ϕ = *strength reduction factor*

= *0.65.*

EXCEPTION: *When the anchor is attached to or hooked around reinforcing steel or otherwise terminated to effectively transfer forces to the reinforcing steel that is designed to distribute forces and avert sudden local failure, ϕ may be taken as 0.85.*

Where edge distance is less than embedment length, reduce ϕP_c proportionately. For multiple edge distances less than embedment length, use multiple reductions.

1923.3.3 Design strength in shear. *The design strength of anchors in shear shall be the minimum of V_{ss} or ϕV_c where:*

$$V_{ss} = 0.75 A_b f_{ut}$$

and where loaded toward an edge greater than 10 diameters away,

$$\phi V_c = \phi\, 800 A_b \lambda \sqrt{f'_c}$$

For **SI:** $\phi V_c = 66.4\, \phi A_b \lambda \sqrt{f'_c}$

or where loaded toward an edge equal to or less than 10 diameters away,

$$\phi V_c = \phi\, 2\pi d_e^2 \lambda \sqrt{f'_c}$$

For **SI:** $\phi V_c = 0.166\, \phi\pi d_e^2 \lambda \sqrt{f'_c}$

where d_e equals the edge distance from the anchor axis to the free edge.

For groups of anchors, the concrete design shear strength shall be taken as the smallest of:

1. The design strength of the weakest anchor times the number of anchors,

2. The design strength of the row of anchors nearest the free edge in the direction of shear times the number of rows or

3. The design strength of the row farthest from the free edge in the direction of shear.

For shear loading toward an edge equal to or less than 10 diameters away, or tension or shear not toward an edge less than five diameters away, reinforcing sufficient to carry the load shall be provided to prevent failure of the concrete in tension. In no case shall the edge distance be less than four diameters.

1923.3.4 Combined tension and shear. *When tension and shear act simultaneously, all of the following shall be met:*

$$\frac{1}{\phi}\left(\frac{P_u}{P_c}\right) \leq 1 \qquad \frac{1}{\phi}\left(\frac{V_u}{V_c}\right) \leq 1$$

$$\frac{1}{\phi}\left[\left(\frac{P_u}{P_c}\right)^{5/3} + \left(\frac{V_u}{V_c}\right)^{5/3}\right] \leq 1 \qquad \left(\frac{P_u}{P_{ss}}\right)^2 + \left(\frac{V_u}{V_{ss}}\right)^2 \leq 1$$

Division IV—DESIGN AND CONSTRUCTION STANDARD FOR SHOTCRETE

SECTION 1924 — SHOTCRETE

1924.1 General. *Shotcrete shall be defined as mortar or concrete pneumatically projected at high velocity onto a surface. Except as specified in this section, shotcrete shall conform to the regulations of this chapter for plain concrete or reinforced concrete.*

1924.2 Proportions and Materials. *Shotcrete proportions shall be selected that allow suitable placement procedures using the delivery equipment selected and shall result in finished in-place hardened shotcrete meeting the strength requirements of this code.*

1924.3 Aggregate. *Coarse aggregate, if used, shall not exceed $^3/_4$ inch (19 mm).*

1924.4 Reinforcement. *The maximum size of reinforcement shall be No. 5 bars unless it can be demonstrated by preconstruction tests that adequate encasement of larger bars can be achieved. When No. 5 or smaller bars are used, there shall be a minimum clearance between parallel reinforcement bars of $2^1/_2$ inches (64 mm). When bars larger than No. 5 are permitted, there shall be a minimum clearance between parallel bars equal to six diameters of the bars used. When two curtains of steel are provided, the curtain nearest the nozzle shall have a minimum spacing equal to 12 bar diameters and the remaining curtain shall have a minimum spacing of six bar diameters.*

> ***EXCEPTION:*** *Subject to the approval of the building official, reduced clearances may be used where it can be demonstrated by preconstruction tests that adequate encasement of the bars used in the design can be achieved.*

Lap splices in reinforcing bars shall be by the noncontact lap splice method with at least 2 inches (51 mm) clearance between bars. The building official may permit the use of contact lap splices when necessary for the support of the reinforcing provided it can be demonstrated by means of preconstruction testing, that adequate encasement of the bars at the splice can be achieved, and provided that the splices are placed so that a line through the center of the two spliced bars is perpendicular to the surface of the shotcrete work.

Shotcrete shall not be applied to spirally tied columns.

1924.5 Preconstruction Tests. *When required by the building official a test panel shall be shot, cured, cored or sawn, examined and tested prior to commencement of the project. The sample panel shall be representative of the project and simulate job conditions as closely as possible. The panel thickness and reinforcing shall reproduce the thickest and most congested area specified in the structural design. It shall be shot at the same angle, using the same nozzleman and with the same concrete mix design that will be used on the project.*

1924.6 Rebound. *Any rebound or accumulated loose aggregate shall be removed from the surfaces to be covered prior to placing the initial or any succeeding layers of shotcrete. Rebound shall not be reused as aggregate.*

1924.7 Joints. *Except where permitted herein, unfinished work shall not be allowed to stand for more than 30 minutes unless all edges are sloped to a thin edge. Before placing additional material adjacent to previously applied work, sloping and square edges shall be cleaned and wetted.*

1924.8 Damage. *In-place shotcrete which exhibits sags or sloughs, segregation, honeycombing, sand pockets or other obvious defects shall be removed and replaced. Shotcrete above sags and sloughs shall be removed and replaced while still plastic.*

1924.9 Curing*. During the curing periods specified herein, shotcrete shall be maintained above 40°F (4.4°C) and in moist condition. In initial curing, shotcrete shall be kept continuously moist for 24 hours after placement is complete. Final curing shall continue for seven days after shotcreting, for three days if high-early-strength cement is used, or until the specified strength is obtained. Final curing shall consist of a fog spray or an approved moisture-retaining cover or membrane. In sections of a depth in excess of 12 inches (305 mm), final curing shall be the same as that for initial curing.*

1924.10 Strength Test. *Strength test for shotcrete shall be made by an approved agency on specimens which are representative of work and which have been water soaked for at least 24 hours prior to testing. When the maximum size aggregate is larger than $^3/_8$ inch (9.5 mm), specimens shall consist of not less than three 3-inch-diameter (76 mm) cores or 3-inch (76 mm) cubes. When the maximum size aggregate is $^3/_8$ inch (9.5 mm) or smaller, specimens shall consist of not less than three 2-inch-diameter (51 mm) cores or 2-inch (51 mm) cubes. Specimens shall be taken in accordance with one of the following:*

1. From the in-place work: taken at least once each shift or less than one for each 50 cubic yards (38.2 m^3) of shotcrete; or

2. From test panels: made not less than once each shift or not less than one for each 50 cubic yards (38.2 m^3) of shotcrete placed. When the maximum size aggregate is larger than $^3/_8$ inch (9.5 mm), the test panels shall have a minimum dimension of 18 inches by 18 inches (457 mm by 457 mm). When the maximum size aggregate is $^3/_8$ inch (9.5 mm) or smaller, the test panels shall have a minimum dimension of 12 inches by 12 inches (305 mm by 305 mm). Panels shall be gunned in the same position as the work, during the course of the work and by nozzlepersons doing the work. The condition under which the panels are cured shall be the same as the work.

The average of three cores from a single panel shall be equal to or exceed 0.85 f'_c with no single core less than 0.75 f'_c. The average of three cubes taken from a single panel must equal or exceed f'_c with no individual cube less than 0.88 f'_c. To check testing accuracy, locations represented by erratic core strengths may be retested.

1924.11 Inspections.

1924.11.1 During placement. *When shotcrete is used for structural members, a special inspector is required by Section 1701.5, Item 12. The special inspector shall provide continuous inspection of the placement of the reinforcement and shotcreting and shall submit a statement indicating compliance with the plans and specifications.*

1924.11.2 Visual examination for structural soundness of in-place shotcrete. *Completed shotcrete work shall be checked visually for reinforcing bar embedment, voids, rock pockets, sand streaks and similar deficiencies by examining a minimum of three 3-inch (76 mm) cores taken from three areas chosen by the design engineer which represent the worst congestion of reinforcing bars occurring in the project. Extra reinforcing bars may be added to noncongested areas and cores may be taken from these areas. The cores shall be examined by the special inspector and a report submitted to the building official prior to final approval of the shotcrete.*

> ***EXCEPTION:*** *Shotcrete work fully supported on earth, minor repairs, and when, in the opinion of the building official, no special hazard exists.*

1924.12 Equipment. *The equipment used in preconstruction testing shall be the same equipment used in the work requiring such testing, unless substitute equipment is approved by the building official.*

Division V—DESIGN STANDARD FOR REINFORCED GYPSUM CONCRETE

SECTION 1925 — REINFORCED GYPSUM CONCRETE

1925.1 *General.* *Reinforced gypsum concrete shall conform to UBC Standard 19-2.*

Reinforced gypsum concrete shall develop the minimum ultimate compressive strength in pounds per square inch (MPa) set forth in Table 19-E when dried to constant weight, with tests made on cylinders 2 inches (51 mm) in diameter and 4 inches (102 mm) long or on 2-inch (51 mm) cubes.

For special inspection, see Section 1701.

1925.2 Design. *The minimum thickness of reinforced gypsum concrete shall be 2 inches (51 mm) except the thickness may be reduced to $1^1/_2$ inches (38 mm), provided all of the following conditions are satisfied:*

1. The overall thickness, including the formboard, is not less than 2 inches (51 mm).

2. The clear span of the gypsum concrete between supports does not exceed 2 feet 9 inches (838 mm).

3. Diaphragm action is not required.

4. The design live load does not exceed 40 pounds per square foot (195 kg/m^2).

1925.3 Stresses*. The maximum allowable unit working stresses in reinforced gypsum concrete shall not exceed the values set forth in Table 19-F except as specified in Chapter 16. Bolt values shall not exceed those set forth in Table 19-G.*

Allowable shear in poured-in-place reinforced gypsum concrete diaphragms using standard hot-rolled bulb tee subpurlins shall be determined by UBC Standard 19-2. (See Table 19-2-A in the standard for values for commonly used roof systems.)

Division VI—ALTERNATE DESIGN METHOD

SECTION 1926 — ALTERNATE DESIGN METHOD

1926.0 Notations. The following symbols and notations apply only to the provisions of this section:

A_g = gross area of section, square inches (mm^2).

A_1 = loaded area.

A_2 = maximum area of the portion of the supporting surface that is geometrically similar to and concentric with the loaded area.

A_v = area of shear reinforcement within a distance s, square inches (mm^2).

b = width of compression face of member, inches (mm).

b_o = perimeter of critical section for slabs and footings, inches (mm).

b_w = web width, or diameter of circular section, inches (mm).

d = distance from extreme compression fiber to centroid of tension reinforcement, inches (mm).

E_c = modulus of elasticity of concrete, psi (MPa). See Section 1908.5.1.

E_s = modulus of elasticity of reinforcement, psi (MPa). See Section 1908.5.2.

f'_c = specified compressive strength of concrete, psi (MPa). See Section 1905.

$\sqrt{f'_c}$ = square root of specified compressive strength of concrete, psi (MPa).

f_{ct} = average splitting tensile strength of lightweight aggregate concrete, psi (MPa). See Section 1905.1.4.

f_s = permissible tensile stress in reinforcement, psi (MPa).

f_y = specified yield strength of reinforcement, psi (MPa).

M = design moment.

N = design axial load normal to cross section occurring simultaneously with V; to be taken as positive for compression, negative for tension and to include effects of tension due to creep and shrinkage.

n = modular ratio of elasticity.
= E_s/E_c.

s = spacing of shear reinforcement in direction parallel to longitudinal reinforcement, inches (mm).

V = design shear force at section.

v = design shear stress.

v_c = permissible shear stress carried by concrete, psi (MPa).

v_h = permissible horizontal shear stress, psi (MPa).

α = angle between inclined stirrups and longitudinal axis of member.

β_c = ratio of long side to short side of concentrated load or reaction area.

ρ = ratio of tension reinforcement.
= A_s/bd.

ϕ = strength-reduction factor. See Section 1926.2.1.

1926.1 Scope.

1926.1.1 Nonprestressed reinforced concrete members shall be permitted to be designed using service loads (without load factors) and permissible service load stresses in accordance with provisions of this section.

1926.1.2 For design of members not covered by this section, appropriate provisions of this code shall apply.

1926.1.3 All applicable provisions of this code for nonprestressed concrete, except Section 1908.4, shall apply to members designed by the alternate design method.

1926.1.4 Flexural members shall meet requirements for deflection control in Section 1909.5 and requirements of Sections 1910.4 through 1910.7 of this code.

1926.2 General.

1926.2.1 Load factors and strength-reduction factors ϕ shall be taken as unity for members designed by the alternate design method.

1926.2.2 It shall be permitted to proportion members for 75 percent of capacities required by other parts of the section when considering wind or earthquake forces combined with other loads, provided the resulting section is not less than that required for the combination of dead and live load.

1926.2.3 When dead load reduces effects of other loads, members shall be designed for 85 percent of dead load in combination with the other loads.

1926.3 Permissible Service Load Stresses.

1926.3.1 Stresses in concrete shall not exceed the following:

1. Flexure.
   Extreme fiber stress in compression . . . . $0.45 f'_c$
2. Shear.†
   Beams and one-way slabs and footings:
   Shear carried by concrete, v_c . . . . $1.1 \sqrt{f'_c}$
   (For **SI:** $0.09 \sqrt{f'_c}$)
   Maximum shear carried by concrete plus shear reinforcement . . . . $v_c + 4.4 \sqrt{f'_c}$
   (For **SI:** $v_c + 0.37 \sqrt{f'_c}$)
   Joists.*
   Shear carried by concrete, v_c . . . . $1.2 \sqrt{f'_c}$
   (For **SI:** $0.10 \sqrt{f'_c}$)

†For more detailed calculation of shear stress carried by concrete v_c and shear values for lightweight aggregate concrete, see Section 1926.7.4.
*Designed in accordance with Section 1908.11.

   Two-way slabs and footings:
   Shear carried by concrete, v_c‡ . . . . $(1 + 2/\beta_c) \sqrt{f'_c}$
   [For **SI:** $(1 + 2/\beta_c) 0.08 \sqrt{f'_c}$]
   . . . . but not greater than $2 \sqrt{f'_c}$
   (For **SI:** $0.166 \sqrt{f'_c}$)
3. Bearing on loaded area** . . . . $0.3 f'_c$

‡If shear reinforcement is provided, see Sections 1926.7.7.4 and 1926.7.7.5.
**When the supporting surface is wider on all sides than the loaded area, permissible bearing stress on the loaded area shall be permitted to be increased by $\sqrt{A_2/A_1}$ but not more than 2. When the supporting surface is sloped or stepped, A_2 shall be permitted to be taken as the area of the lower base of the largest frustum of a right pyramid or cone contained wholly within the support and having for its upper base the loaded area and having side slopes of 1 vertical to 2 horizontal.

1926.3.2 Tensile stress in reinforcement f_s shall not exceed the following:

1. Grade 40 or Grade 50 reinforcement . . . . 20,000 psi (137.9 MPa)

2. Grade 60 reinforcement or greater and welded wire fabric (smoothed or deformed) . . . . 24,000 psi (165.5 MPa)
3. For flexural reinforcement, $^3/_8$ inch (9.5 mm) or less in diameter, in one-way slabs of not more than 12-foot (3658 mm) span, but not greater than 30,000 psi (206.8 MPa) . . . . 0.50 f_y

1926.4 Development and Splices of Reinforcement.

1926.4.1 Development and splices of reinforcement shall be as required in Section 1912.

1926.4.2 In satisfying requirements of Section 1912.11.3, M_n shall be taken as computed moment capacity assuming all positive moment tension reinforcement at the section to be stressed to the permissible tensile stress f_s, and V_u shall be taken as unfactored shear force at the section.

1926.5 Flexure. For investigation of stresses at service loads, straight-line theory (for flexure) shall be used with the following assumptions:

1926.5.1 Strains vary linearly as the distance from the neutral axis, except for deep flexural members with overall depth-span ratios greater than 2:5 for continuous spans and 4:5 for simple spans, a nonlinear distribution of strain shall be considered. (See Section 1910.7.)

1926.5.2 Stress-strain relationship of concrete is a straight line under service loads within permissible service load stresses.

1926.5.3 In reinforced concrete members, concrete resists no tension.

1926.5.4 It shall be permitted to take the modular ratio, $n = E_s/E_c$, as the nearest whole number (but not less than 6). Except in calculations for deflections, value of n for lightweight concrete shall be assumed to be the same as for normal-weight concrete of the same strength.

1926.5.5 In doubly reinforced flexural members, an effective modular ratio of 2 E_s/E_c shall be used to transform compression reinforcement for stress computations. Compressive stress in such reinforcement shall not exceed permissible tensile stress.

1926.6 Compression Members with or without Flexure.

1926.6.1 Combined flexure and axial load capacity of compression members shall be taken as 40 percent of that computed in accordance with provisions in Section 1910.

1926.6.2 Slenderness effects shall be included according to requirements of Sections 1910.10 and 1910.11. In Formulas (10-7) and (10-8), the term P_u shall be replaced by 2.5 times the design axial load, and ϕ shall be taken equal to 1.0.

1926.6.3 Walls shall be designed in accordance with Section 1914 with flexure and axial load capacities taken as 40 percent of that computed using Section 1914. In Formula (14-1), ϕ shall be taken equal to 1.0.

1926.7 Shear and Torsion.

1926.7.1 Design shear stress v shall be computed by:

$$v = \frac{V}{b_w d} \qquad (26\text{-}1)$$

where V is design shear force at section considered.

1926.7.2 When the reaction, in direction of applied shear, introduces compression into the end regions of a member, sections located less than a distance d from face of support shall be permitted to be designed for the same shear v as that computed at a distance d.

1926.7.3 Whenever applicable, effects of torsion, in accordance with provisions of Section 1911, shall be added. Shear and torsional moment strengths provided by concrete and limiting maximum strengths for torsion shall be taken as 55 percent of the values given in Section 1911.

1926.7.4 Shear stress carried by concrete.

1926.7.4.1 For members subject to shear and flexure only, shear stress carried by concrete v_c shall not exceed $1.1\sqrt{f'_c}$ (For **SI:** $0.09\sqrt{f'_c}$) unless a more detailed calculation is made in accordance with Section 1926.7.4.4.

1926.7.4.2 For members subject to axial compression, shear stress carried by concrete v_c shall not exceed $1.1\sqrt{f'_c}$ (For **SI:** $0.09\sqrt{f'_c}$) unless a more detailed calculation is made in accordance with Section 1926.7.4.5.

1926.7.4.3 For members subject to significant axial tension, shear reinforcement shall be designed to carry total shear, unless a more detailed calculation is made using

$$v_c = 1.1\left(1 + 0.004\frac{N}{A_g}\right)\sqrt{f'_c} \qquad (26\text{-}2)$$

For **SI:** $$v_c = 0.09\left(1 + 0.004\frac{N}{A_g}\right)\sqrt{f'_c}$$

where N is negative for tension. Quantity N/A_g shall be expressed in psi (MPa).

1926.7.4.4 For members subject to shear and flexure only, v_c it shall be permitted to compute by

$$v_c = \sqrt{f'_c} + 1,300\,\rho_w\frac{Vd}{M} \qquad (26\text{-}3)$$

For **SI:** $$v_c = 0.083\sqrt{f'_c} + 9\,\rho_w\frac{Vd}{M}$$

but v_c shall not exceed $1.9\sqrt{f'_c}$ (For **SI:** $0.16\sqrt{f'_c}$). Quantity Vd/M shall not be taken greater than 1.0 where M is design moment occurring simultaneously with V at section considered.

1926.7.4.5 For members subject to axial compression, v_c may be computed by

$$v_c = 1.1\left(1 + 0.0006\frac{N}{A_g}\right)\sqrt{f'_c} \qquad (26\text{-}4)$$

For **SI:** $$v_c = 0.09\left(1 + 0.0006\frac{N}{A_g}\right)\sqrt{f'_c}$$

Quantity N/A_g shall be expressed in psi (MPa).

1926.7.4.6 Shear stresses carried by concrete v_c apply to normal-weight concrete. When lightweight aggregate concrete is used, one of the following modifications shall apply:

1. When f_{ct} is specified and concrete is proportioned in accordance with Section 1904.2, $f_{ct}/6.7$ (For **SI:** 1.8 f_{ct}) shall be substituted for $\sqrt{f'_c}$, but the value of $f_{ct}/6.7$ (For **SI:** 1.8 f_{ct}) shall not exceed $\sqrt{f'_c}$.

2. When f_{ct} is not specified, the value of $\sqrt{f'_c}$ (For **SI:** $0.083\sqrt{f'_c}$) shall be multiplied by 0.75 for all-lightweight concrete and by 0.85 for sand-lightweight concrete. Linear interpolation may be applied when partial sand replacement is used.

1926.7.4.7 In determining shear stress by concrete v_c, whenever applicable, effects of axial tension due to creep and shrinkage in restrained members shall be included and it shall be permitted to include effects of inclined flexural compression in variable-depth members.

1926.7.5 Shear stress carried by shear reinforcement.

1926.7.5.1 Types of shear reinforcement. Shear reinforcement shall consist of the following:

1. Stirrups perpendicular to axis of member.

2. Welded wire fabric with wires located perpendicular to axis of member making an angle of 45 degrees or more with longitudinal tension reinforcement.

3. Longitudinal reinforcement with bent portion making an angle of 30 degrees or more with longitudinal tension reinforcement.

4. Combinations of stirrups and bent longitudinal reinforcement.

5. Spirals.

1926.7.5.2 Design yield strength of shear reinforcement shall not exceed 60,000 psi (413.7 MPa).

1926.7.5.3 Stirrups and other bars or wires used as shear reinforcement shall extend to a distance *d* from extreme compression fiber and shall be anchored at both ends according to Section 1912.13 to develop design yield strength of reinforcement.

1926.7.5.4 Spacing limits for shear reinforcement.

1926.7.5.4.1 Spacing of shear reinforcement placed perpendicular to axis of member shall not exceed *d*/2 or 24 inches (610 mm).

1926.7.5.4.2 Inclined stirrups and bent longitudinal reinforcement shall be so spaced that every 45-degree line, extending toward the reaction from middepth of member *d*/2 to longitudinal tension reinforcement, shall be crossed by at least one line of shear reinforcement.

1926.7.5.4.3 When $(v - v_c)$ exceeds $2\sqrt{f'_c}$ (For **SI:** $0.166\sqrt{f'_c}$) maximum spacing given by this subsection shall be reduced by one half.

1926.7.5.5 Minimum shear reinforcement.

1926.7.5.5.1 A minimum area of shear reinforcement shall be provided in all reinforced concrete flexural members where design shear stress *v* is greater than one half the permissible shear stress v_c carried by concrete, except the following:

1. Slab and footings.

2. Concrete joist construction defined by Section 1908.11 of this code.

3. Beams with total depth not greater than 10 inches (254 mm), two and one-half times thickness of flange or one half the width of web, whichever is greater.

1926.7.5.5.2 Minimum shear reinforcement requirements of this section may be waived if shown by test that required ultimate flexural and shear strength can be developed when shear reinforcement is omitted.

1926.7.5.5.3 Where shear reinforcement is required by this subsection or by analysis, minimum area of shear reinforcement shall be computed by

$$A_v = 50\frac{b_w s}{f_y} \qquad (26\text{-}5)$$

For **SI:**

$$A_v = 0.34\frac{b_w s}{f_y}$$

where b_w and *s* are in inches (mm).

1926.7.5.6 Design of shear reinforcement.

1926.7.5.6.1 Where design shear stress *v* exceeds shear stress carried by concrete v_c, shear reinforcement shall be provided in accordance with this subsection.

1926.7.5.6.2 When shear reinforcement perpendicular to axis of member is used,

$$A_v = \frac{(v - v_c)b_w s}{f_s} \qquad (26\text{-}6)$$

1926.7.5.6.3 When inclined stirrups are used as shear reinforcement,

$$A_v = \frac{(v - v_c)b_w s}{f_s(\sin\alpha + \cos\alpha)} \qquad (26\text{-}7)$$

1926.7.5.6.4 When shear reinforcement consists of a single bar or a single group of parallel bars, all bent up at the same distance from the support,

$$A_v = \frac{(v - v_c)b_w d}{f_s \sin\alpha} \qquad (26\text{-}8)$$

where $(v - v_c)$ shall not exceed $1.6\sqrt{f'_c}$ (For **SI:** $0.13\sqrt{f'_c}$).

1926.7.5.6.5 When shear reinforcement consists of a series of parallel bent-up bars or groups of parallel bent-up bars at different distances from the support, required area shall be computed by Formula (26-7).

1926.7.5.6.6 Only the center three fourths of the inclined portion of any longitudinal bent bar shall be considered effective for shear reinforcement.

1926.7.5.6.7 When more than one type of shear reinforcement is used to reinforce the same portion of a member, required area shall be computed as the sum of the various types separately. In such computations, v_c shall be included only once.

1926.7.5.6.8 Value of $(v - v_c)$ shall not exceed $4.4\sqrt{f'_c}$ (For **SI:** $0.37\sqrt{f'_c}$).

1926.7.6 Shear friction. Where it is appropriate to consider shear transfer across a given plane such as an existing or potential crack, an interface between dissimilar materials, or an interface between two concretes cast at different times, shear friction provisions of Section 1911.7 shall be permitted to be applied with limiting maximum stress for shear taken as 55 percent of that given in Section 1911.7.5. Permissible stress in shear friction reinforcement shall be that given in Section 1926.3.2.

1926.7.7 Special provisions for slabs and footings.

1926.7.7.1 Shear capacity of slabs and footings in the vicinity of concentrated loads or reactions is governed by the more severe of the following two conditions:

1926.7.7.1.1 Beam action for slab or footing with a critical section extending in a plane across the entire width and located at a distance *d* from face of concentrated load or reaction area. For this condition, the slab or footing shall be designed in accordance with Sections 1926.7.1 through 1926.7.5.

1926.7.7.1.2 Two-way action for slab or footing with a critical section perpendicular to plane of slab and located so that its perimeter is a minimum but need not approach closer than *d*/2 to perimeter of concentrated load or reaction area. For this condition, the slab or footing shall be designed in accordance with Sections 1926.7.7.2 and 1926.7.7.3.

1926.7.7.2 Design shear stress v shall be computed by

$$v = \frac{V}{b_o d} \qquad (26\text{-}9)$$

where V and b_o shall be taken at the critical section defined in Section 1926.7.7.1.2.

1926.7.7.3 Design shear stress v shall not exceed v_c given by Formula (26-10) unless shear reinforcement is provided.

$$v_c = \left(1 + \frac{2}{\beta_c}\right)\sqrt{f'_c} \qquad (26\text{-}10)$$

For **SI:** $$v_c = 0.083\left(1 + \frac{2}{\beta_c}\right)\sqrt{f'_c}$$

but v_c shall not exceed $2\sqrt{f'_c}$ (For **SI:** $0.166\sqrt{f'_c}$). β_c is the ratio of long side to short side of concentrated load or reaction area. When lightweight aggregate concrete is used, the modifications of Section 1926.7.4.6 shall apply.

1926.7.7.4 If shear reinforcement consisting of bars or wires is provided in accordance with Section 1911.12.3, v_c shall not exceed $\sqrt{f'_c}$ (For **SI:** $0.083\sqrt{f'_c}$), and v shall not exceed $3\sqrt{f'_c}$ (For **SI:** $0.25\sqrt{f'_c}$).

1926.7.7.5 If shear reinforcement consisting of steel I or channel shapes (shearheads) is provided in accordance with Section 1911.12.4 of this code, v on the critical section defined in Section 1926.7.7.1.2 shall not exceed $3.5\sqrt{f'_c}$ (For **SI:** $0.29\sqrt{f'_c}$) and v on the critical section defined in Section 1911.12.4.7 shall not exceed $2\sqrt{f'_c}$ (For **SI:** $0.166\sqrt{f'_c}$). In Formulas (11-38) and (11-39), design shear force V shall be multiplied by 2 and substituted for V_u.

1926.7.8 Special provisions for other members. For design of deep flexural members, brackets and corbels and walls, the special provisions of Section 1911 shall be used with shear strengths provided by concrete and limiting maximum strengths for shear taken as 55 percent of the values given in Section 1911. In Section 1911.10.6, the design axial load shall be multiplied by 1.2 if compression and 2.0 if tension and substituted for N_u.

1926.7.9 Composite concrete flexural members. For design of composite concrete flexural members, permissible horizontal shear stress v_h shall not exceed 55 percent of the horizontal shear strengths given in Section 1917.5.2.

Division VII—UNIFIED DESIGN PROVISIONS

NOTE: This is a new division.

SECTION 1927 — UNIFIED DESIGN PROVISIONS FOR REINFORCED AND PRESTRESSED CONCRETE FLEXURAL AND COMPRESSION MEMBERS

B.1927.0

B.1927.1 Scope. Design for flexure and axial load by provisions of Section 1927.0 shall be permitted. When Section 1927.0 is used in design, all numbered sections in Section 1927.0 shall be used in place of the corresponding numbered sections in Sections 1908, 1909, 1910 and 1918. If any section in Section 1927.0 is used, all sections in Section 1927.0 shall be substituted for the corresponding sections in Chapter 19.*

B.1908.4 Redistribution of Negative Moments in Continuous Flexural Members.

B.1908.4.1 Except where approximate values for moments are used, it shall be permitted to increase or decrease negative moments calculated by elastic theory at supports of continuous flexural members for any assumed loading arrangement by not more than 1,000 percent ε_t, with a maximum of 20 percent.

B.1908.4.2 The modified negative moments shall be used for calculating moments at sections within the spans.

B.1908.4.3 Redistribution of negative moments shall be made only when ε_t is equal to or greater than 0.0075 at the section at which moment is reduced.

B.1909.2 Required Strength.

B.1909.2.1 Required strength *U* to resist dead load *D* and live load *L* shall be at least equal to

$$U = 1.4D + 1.7L \qquad \text{(B.9-1)}$$

B.1909.2.2 If resistance to structural effects of a specified wind load *W* are included in design, the following combinations of *D*, *L* and *W* shall be investigated to determine the greatest required strength *U:*

$$U = 0.75\ (1.4D + 1.7L + 1.7W) \qquad \text{(B.9-2)}$$

where load combinations shall include both full value and zero value of *L* to determine the more severe condition, and

$$U = 0.9D + 1.3W \qquad \text{(B.9-3)}$$

but for any combination of *D*, *L* and *W*, required strength *U* shall not be less than Formula (B.9-1).

B.1909.2.3 If resistance to specified earthquake loads or forces *E* are included in design, load combinations of Section 1612.2.1 shall apply.

B.1909.2.4 If resistance to earth pressure *H* is included in design, required strength *U* shall be at least equal to

$$U = 1.4D + 1.7L + 1.7H \qquad \text{(B.9-4)}$$

except that where *D* or *L* reduce the effect of *H*, 0.9*D* shall be substituted for 1.4*D* and zero value of *L* shall be used to determine the greatest required *U*. For any combination of *D*, *L* and *H*, required strength *U* shall not be less than Formula (B.9-1).

B.1909.2.5 If resistance to loadings due to weight and pressure of fluids with well-defined densities and controllable maximum heights *F* is included in design, such loading shall have a load factor of 1.4, and be added to all loading combinations that include live load.

B.1909.2.6 If resistance to impact effects is taken into account in design, such effects shall be included with live load *L*.

B.1909.2.7 Where structural effects *T* of differential settlement, creep, shrinkage, expansion and shrinkage-compensating concrete, or temperature change are significant in design, required strength *U* shall be at least equal to

$$U = 0.75\ (1.4D + 1.4T + 1.7L) \qquad \text{(B.9-5)}$$

but required strength *U* shall not be less than

$$U = 1.4\ (D + T) \qquad \text{(B.9-6)}$$

Estimations of differential settlement, creep, shrinkage, expansion of shrinkage-compensating concrete, or temperature change shall be based on a realistic assessment of such effects occurring in service.

B.1909.3 Design Strength.

B.1909.3.1 Design strength provided by a member, its connections to other members, and its cross sections, in terms of flexure, axial load, shear, and torsion, shall be taken as the nominal strength calculated in accordance with requirements and assumptions of this code, multiplied by a strength reduction factor ϕ.

B.1909.3.2 Strength reduction factor ϕ shall be as follows:

B.1909.3.2.1 Tension-controlled sections 0.90

B.1909.3.2.2 Compression-controlled sections:

1. Members with spiral reinforcement conforming to Section 1910.9.3 . . . . 0.75
2. Other reinforced members 0.70

For sections in which the net tensile strain in the extreme tension steel at nominal strength is between the limits for compression-controlled and tension-controlled sections, ϕ shall be linearly increased from that for compression-controlled sections to 0.90 as the net tensile strain in the extreme tension steel at nominal strength increases from the compression-controlled strain limit to 0.005. Alternatively, it shall be permitted to take ϕ as that for compression-controlled sections.

B.1909.3.2.3 Shear and torsion 0.85

B.1909.3.2.4 Bearing on concrete. See also Section 1918.13. . . . . 0.70

B.1910.3.2 Balanced strain conditions exist at a cross section when tension reinforcement reaches the strain corresponding to its specified yield strength f_y just as concrete in compression reaches its assumed strain limit of 0.003.

The compression-controlled strain limit is the net tensile strain in the reinforcement at balanced strain conditions. For prestressed

*When Section 1927.0 is used, each section of Section 1927.0 must be substituted for the corresponding section in Chapter 19. For instance, Section B.1908.4 is substituted for Section 1908.4, etc., through Section B.1918.10.4 being substituted for Section 1918.10.4. The corresponding commentary sections should also be substituted.

Section 1927.0 introduces substantial changes in design for flexure and axial loads to Chapter 19. Reinforcement limits, strength reduction factor and moment redistribution are affected. Designs using the provisions of Section 1927.0 satisfy Chapter 19, and are equally acceptable.

sections, it shall be permitted to use the same compression-controlled strain limit as that for reinforcement with a design yield strength f_y of 60,000 psi (413.7 MPa).

B.1910.3.3 Sections are compression-controlled when the net tensile strain in the extreme tension steel is equal to or less than the compression-controlled strain limit at the time the concrete in compression reaches its assumed strain limit of 0.003. Sections are tension-controlled when the net tensile strain in the extreme tension steel is equal to or greater than 0.005 just as the concrete in compression reaches its assumed strain limit of 0.003. Sections with net tensile strain in the extreme tension steel between the compression-controlled strain limit and 0.005 constitute a transition region between compression-controlled and tension-controlled sections.

B.1918.1.3 The following provisions of this code shall not apply to prestressed concrete, except as specifically noted: Sections 1907.6.5, 1908.10.2, 1908.10.3, 1908.10.4, 1908.11, 1910.5, 1910.6, 1910.9.1 and 1910.9.2; Section 1913; and Sections 1914.3, 1914.5 and 1914.6.

B.1918.8 Limits for Reinforcement of Flexural Members.

B.1918.8.1 Prestressed concrete sections shall be classified as tension-controlled and compression-controlled sections in accordance with Section B.1910.3.3. The appropriate ϕ-factors from Section B.1909.3.2 shall apply.

B.1918.8.2 Total amount of prestressed and nonprestressed reinforcement shall be adequate to develop a factored load at least 1.2 times the cracking load computed on the basis of the modulus of rupture specified in Section 1909.5.2.3, except for flexural members with shear and flexural strength at least twice that required by Section 1909.2.

B.1918.8.3 Part or all of the bonded reinforcement consisting of bars or tendons shall be provided as close as practicable to the extreme tension fiber in all prestressed flexural members, except that in members prestressed with unbonded tendons, the minimum bonded reinforcement consisting of bars or tendons shall be as required by Section 1918.9.

B.1918.10.4 Redistribution of negative moments in continuous prestressed flexural members.

B.1918.10.4.1 Where bonded reinforcement is provided at supports in accordance with Section 1918.9.2, it shall be permitted to increase or decrease negative moments calculated by elastic theory for any assumed loading, in accordance with Section B.1908.4.

B.1918.10.4.2 The modified negative moments shall be used for calculating moments at sections within spans for the same loading arrangement.

Division VIII—ALTERNATIVE LOAD-FACTOR COMBINATION AND STRENGTH REDUCTION FACTORS

NOTE: This is a new division.

SECTION 1928 — ALTERNATIVE LOAD-FACTOR COMBINATION AND STRENGTH REDUCTION FACTORS

1928.1 General. It shall be permitted to proportion concrete structural elements using the alternate load-factor combinations in Section 1928.1.2 in conjunction with the alternate strength reduction factors in Section 1928.1.1 if the structural framing includes primary members of other materials proportioned to satisfy the alternate load-factor combinations in Section 1928.1.2. Loads shall be determined in accordance with Chapter 16 of this code.

1928.1.1 Alternate strength reduction factors.

1928.1.1.1 Flexure, without axial load 0.80

1928.1.1.2 Axial tension and axial tension with flexure . 0.80

1928.1.1.3 Axial compression and axial compression with flexure

1. Members with spiral reinforcement conforming to Section 1910.9.3 . . . . 0.70
2. Other reinforced members 0.65

except that for low values of axial compression, it shall be permitted to increase ϕ toward the value for flexure, 0.80, using the linear interpolation provided in either Section 1909.3.2.2 or B.1909.3.2.2.

3. In Seismic Zones 3 and 4, members resisting earthquake forces without transverse reinforcement conforming to 21.4.4 . . . . 0.50

1928.1.1.4 Shear and torsion 0.75

except that in Seismic Zones 3 and 4:

1. Shear in members resisting earthquake forces if the nominal shear strength of the member is less than the nominal shear corresponding to the development of the nominal flexural strength of the member 0.55
2. Shear in joints of building structures 0.80

1928.1.1.5 Bearing 0.65

1928.1.1.6 Plain concrete 0.55

1928.1.2 Alternate load-factor combinations.

1928.1.2.1 Symbols and notations.

D = dead load consisting of: (1) weight of the member, (2) weight of all materials of construction incorporated into the building to be permanently supported by the member, including built-in partitions, and (3) weight of permanent equipment.

E = earthquake load.

F = loads due to fluids with well-defined pressures and maximum heights.

H = loads due to the weight and lateral pressure of soil and water in soil.

L = live loads due to intended use and occupancy, including loads due to movable objects and movable partitions and loads temporarily supported by the structure during maintenance. L includes any permissible reduction. If resistance to impact loads is taken into account in design, such effects shall be included with the live load L.

L_r = roof live loads.

P = loads, forces and effects due to ponding.

R = rain loads, except ponding.

S = snow loads.

T = self-straining forces and effects arising from contraction or expansion resulting from temperature changes, shrinkage, moisture changes, creep in component materials, movement due to differential settlement or combinations thereof.

W = wind load.

1928.1.2.2 Combining loads using strength design.

1928.1.2.3 Basic combinations. When permitted by Section 1928.1, structures, components and foundations shall be designed so that their design strength exceeds the effects of the factored loads in the following combinations:

1. $1.4D$
2. $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (0.5L \text{ or } 0.8W)$
4. $1.2D + 1.3W + 0.5L + 0.5(L_r \text{ or } S \text{ or } R)$
5. $1.2D + 1.5E + (0.5L \text{ or } 0.2S)$
6. $0.9D - (1.3W \text{ or } 1.5E)$

EXCEPTIONS: 1. The load factor on L in combinations 3, 4 and 5 shall equal 1.0 for garages, areas occupied and places of public assembly, and all areas where the live load is greater than 100 lb./ft.^{2} (pounds-force per square foot) (4.79 kPa).

2. Each relevant strength limit state shall be considered. The most unfavorable effect may occur when one or more of the contributing loads are not acting.

1928.1.2.4 Other combinations. The structural effects of F, H, P or T shall be considered in design as the following factored loads: $1.3F$, $1.6H$, $1.2P$ and $1.2T$.

TABLE 19-A-1—TOTAL AIR CONTENT FOR FROST-RESISTANT CONCRETE

NOMINAL MAXIMUM AGGREGATE SIZE (inches)	AIR CONTENT, PERCENTAGE	
× 25.4 for mm	Severe Exposure	Moderate Exposure
$^3/_8$	$7^1/_2$	6
$^1/_2$	7	$5^1/_2$
$^3/_4$	6	5
1	6	$4^1/_2$
$1^1/_2$	$5^1/_2$	$4^1/_4$
2[1]	5	4
3[1]	$4^1/_2$	$3^1/_2$

[1]These air contents apply to total mix, as for the preceding aggregate sizes. When testing this concrete, however, aggregate larger than $1^1/_2$ inches (38 mm) is removed by hand picking or sieving, and air content is determined on the minus $1^1/_2$-inch (38 mm) fraction.

TABLE 19-A-2—REQUIREMENTS FOR SPECIAL EXPOSURE CONDITIONS

EXPOSURE CONDITION	MAXIMUM WATER-CEMENTITIOUS MATERIALS RATIO, BY WEIGHT, NORMAL-WEIGHT AGGREGATE CONCRETE	MINIMUM f'_c, NORMAL-WEIGHT AND LIGHTWEIGHT AGGREGATE CONCRETE, psi
		× 0.00689 for MPa
Concrete intended to have low permeability when exposed to water	0.50	4,000
Concrete exposed to freezing and thawing in a moist condition or to deicing chemicals	0.45	4,500
For corrosion protection for reinforced concrete exposed to chlorides from deicing chemicals, salt, saltwater, brackish water, seawater or spray from these sources	0.40	5,000

TABLE 19-A-3—REQUIREMENTS FOR CONCRETE EXPOSED TO DEICING CHEMICALS

CEMENTITIOUS MATERIALS	MAXIMUM PERCENT OF TOTAL CEMENTITIOUS MATERIALS BY WEIGHT[1]
Fly ash or other pozzolans conforming to ASTM C 618	25
Slag conforming to ASTM C 989	50
Silica fume conforming to ASTM C 1240	10
Total of fly ash or other pozzolans, slag and silica fume	50[2]
Total of fly ash or other pozzolans and silica fume	35[2]

[1]The total cementitious materials also includes ASTM C 150, C 595 and C 845 cement.

[2]Fly ash or other pozzolans and silica fume shall constitute no more than 25 and 10 percent, respectively, of the total weight of the cementitious materials.

The maximum percentages above shall include:

1. Fly ash or other pozzolans present in Type IP or I(PM) blended cement in accordance with ASTM C 595.
2. Slag used in the manufacture of a IS or I(SM) blended cement in accordance with ASTM C 595.
3. Silica fume, ASTM C 1240, present in a blended cement.

TABLE 19-A-4—REQUIREMENTS FOR CONCRETE EXPOSED TO SULFATE-CONTAINING SOLUTIONS

SULFATE EXPOSURE	WATER- SOLUBLE SULFATE (SO_4) IN SOIL, PERCENTAGE BY WEIGHT	SULFATE (SO_4) IN WATER, ppm	CEMENT TYPE	MAXIMUM WATER-CEMENTITIOUS MATERIALS RATIO, BY WEIGHT, NORMAL-WEIGHT AGGREGATE CONCRETE[1]	MINIMUM f'_c, NORMAL-WEIGHT AND LIGHTWEIGHT AGGREGATE CONCRETE, psi
					× 0.00689 for MPa
Negligible	0.00-0.10	0-150	—	—	—
Moderate[2]	0.10-0.20	150-1,500	II, IP(MS), IS (MS)	0.50	4,000
Severe	0.20-2.00	1,500-10,000	V	0.45	4,500
Very severe	Over 2.00	Over 10,000	V plus pozzolan[3]	0.45	4,500

[1]A lower water-cementitious materials ratio or higher strength may be required for low permeability or for protection against corrosion of embedded items or freezing and thawing (Table 19-A-2).

[2]Seawater.

[3]Pozzolan that has been determined by test or service record to improve sulfate resistance when used in concrete containing Type V cement.

TABLE 19-A-5—MAXIMUM CHLORIDE ION CONTENT FOR CORROSION PROTECTION REINFORCEMENT

TYPE OF MEMBER	MAXIMUM WATER-SOLUBLE CHLORIDE ION (Cl) IN CONCRETE, PERCENTAGE BY WEIGHT OF CEMENTITIOUS MATERIALS
Prestressed concrete	0.06
Reinforced concrete exposed to chloride in service	0.15
Reinforced concrete that will be dry or protected from moisture in service	1.00
Other reinforced concrete construction	0.30

TABLE 19-A-6—MODIFICATION FACTOR FOR STANDARD DEVIATION WHEN LESS THAN 30 TESTS ARE AVAILABLE

NUMBER OF TESTS[1]	MODIFICATION FACTOR FOR STANDARD DEVIATION[2]
Less than 15	Use Table 19-A-7
15	1.16
20	1.08
25	1.03
30 or more	1.00

[1]Interpolate for intermediate numbers of tests.
[2]Modified standard deviation to be used to determine required average strength f'_{cr} from Section 1905.3.2.1.

TABLE 19-A-7—REQUIRED AVERAGE COMPRESSIVE STRENGTH WHEN DATA ARE NOT AVAILABLE TO ESTABLISH A STANDARD DEVIATION

SPECIFIED COMPRESSIVE STRENGTH f'_c psi	REQUIRED AVERAGE COMPRESSIVE STRENGTH f'_{cr} psi
× 0.00689 for MPa	
Less than 3,000 psi	f'_c + 1,000
3,000 to 5,000	f'_c + 1,200
Over 5,000	f'_c + 1,400

TABLE 19-B—MINIMUM DIAMETERS OF BEND

BAR SIZE	MINIMUM DIAMETER
Nos. 3 through 8	$6d_b$
Nos. 9, 10 and 11	$8d_b$
Nos. 14 and 18	$10d_b$

TABLE 19-C-1—MINIMUM THICKNESS OF NONPRESTRESSED BEAMS OR ONE-WAY SLABS UNLESS DEFLECTIONS ARE COMPUTED[1]

	MINIMUM THICKNESS, *h*			
	Simply Supported	One End Continuous	Both Ends Continuous	Cantilever
MEMBER	Members not supporting or attached to partitions or other construction likely to be damaged by large deflections			
Solid one-way slabs	l/20	l/24	l/28	l/10
Beams or ribbed one-way slabs	l/16	l/18.5	l/21	l/8

[1]Span length l is in inches.
Values given shall be used directly for members with normal-weight concrete [w_c = 145 pcf (2323 kg/m^3)] and Grade 60 reinforcement. For other conditions, the values shall be modified as follows:
(a) For structural lightweight concrete having unit weights in the range 90 to 120 pounds per cubic foot (1442 to 1922 kg/m^3), the value shall be multiplied by (1.65 – 0.005 w_c) (For **SI:** 1.65 – 0.0003 w_c) but not less than 1.09, where w_c is the unit weight in pounds per cubic foot (kg/m^3).
(b) For f_y other than 60,000 psi (413.7 MPa), the values shall be multiplied by (0.4 + f_y/100,000) (For **SI:** 0.4 + f_y/689.5).

TABLE 19-C-2—MAXIMUM PERMISSIBLE COMPUTED DEFLECTIONS

TYPE OF MEMBER	DEFLECTION TO BE CONSIDERED	DEFLECTION LIMITATION
Flat roofs not supporting or attached to nonstructural elements likely to be damaged by large deflections	Immediate deflection due to live load L	$\frac{l}{180}$[1]
Floors not supporting or attached to nonstructural elements likely to be damaged by large deflections	Immediate deflection due to live load L	$\frac{l}{360}$
Roof or floor construction supporting or attached to nonstructural elements likely to be damaged by large deflections	That part of the total deflection occurring after attachment of nonstructural elements (sum of the long-time deflection due to all sustained loads and the immediate deflection due to any additional live loads)[3]	$\frac{l}{480}$[2]
Roof or floor construction supporting or attached to nonstructural elements likely to not be damaged by large deflections		$\frac{l}{240}$[4]

[1]The limit is not intended to safeguard against ponding. The member shall be checked for ponding by suitable calculations of deflection, including added deflections due to ponded water, and considering long-term effects of all sustained loads, camber, construction tolerances, and reliability of provisions for drainage.
[2]The limit may be exceeded if adequate measures are taken to prevent damage to supported or attached elements.
[3]Long-time deflection shall be determined in accordance with Section 1909.5.2.5 or 1909.5.4.2, but may be reduced by the amount of deflection calculated to occur before attachment of nonstructural elements. This amount shall be determined on basis of accepted engineering data relating to time-deflection characteristics of members similar to those being considered.
[4]But not greater than tolerance provided for nonstructural elements. The limits may be exceeded if camber is provided so that total deflection minus camber does not exceed limit.

TABLE 19-C-3—MINIMUM THICKNESS OF SLABS WITHOUT INTERIOR BEAMS

YIELD STRENGTH, f_y, psi*	WITHOUT DROP PANELS*			WITH DROP PANELS[1]		
	Exterior Panels			Exterior Panels		
× 0.00689 for MPa	Without edge beams	With edge beams[2]	Interior panels	Without edge beams	With edge beams[2]	Interior panels
40,000	$\frac{l_n}{33}$	$\frac{l_n}{36}$	$\frac{l_n}{36}$	$\frac{l_n}{36}$	$\frac{l_n}{40}$	$\frac{l_n}{40}$
60,000	$\frac{l_n}{30}$	$\frac{l_n}{33}$	$\frac{l_n}{33}$	$\frac{l_n}{33}$	$\frac{l_n}{36}$	$\frac{l_n}{36}$
75,000	$\frac{l_n}{28}$	$\frac{l_n}{31}$	$\frac{l_n}{31}$	$\frac{l_n}{31}$	$\frac{l_n}{34}$	$\frac{l_n}{34}$

*For values of reinforcement yield strength between the values given in the table, minimum thickness shall be determined by linear interpolation.
[1]Drop panel is defined in Section 1913.3.7.
[2]Slabs with beams between columns along exterior edges. The value of α for the edge beam shall not be less than 0.8.

TABLE 19-D—ALLOWABLE SERVICE LOAD ON EMBEDDED BOLTS (Pounds) (Newtons)[1,2,3]

BOLT DIAMETER (inches)	MINIMUM[4] EMBEDMENT (inches)	EDGE DISTANCE (inches)	SPACING (inches)	MINIMUM CONCRETE STRENGTH (psi)					
				× 0.00689 for MPa					
				f'_c = 2,000		f'_c = 3,000		f'_c = 4,000	
				Tension[5]	Shear[6]	Tension[5]	Shear[6]	Tension[5]	Shear[6]
× 25.4 for mm				× 4.5 for newtons					
$^1/_4$	$2^1/_2$	$1^1/_2$	3	200	500	200	500	200	500
$^3/_8$	3	$2^1/_4$	$4^1/_2$	500	1,100	500	1,100	500	1,100
$^1/_2$	4 4	3 5	6 6	950 1,400	1,250 1,550	950 1,500	1,250 1,650	950 1,550	1,250 1,750
$^5/_8$	$4^1/_2$ $4^1/_2$	$3^3/_4$ $6^1/_4$	$7^1/_2$ $7^1/_2$	1,500 2,050	2,750 2,900	1,500 2,200	2,750 3,000	1,500 2,400	2,750 3,050
$^3/_4$	5 5	$4^1/_2$ $7^1/_2$	9 9	2,250 2,700	2,940 4,250	2,250 2,950	3,560 4,300	2,250 3,200	3,560 4,400
$^7/_8$	6	$5^1/_4$	$10^1/_2$	2,550	3,350	2,550	4,050	2,550	4,050
1	7	6	12	2,850	3,750	3,250	4,500	3,650	5,300
$1^1/_8$	8	$6^3/_4$	$13^1/_2$	3,400	4,750	3,400	4,750	3,400	4,750
$1^1/_4$	9	$7^1/_2$	15	4,000	5,800	4,000	5,800	4,000	5,800

[1]Values are natural stone aggregate concrete and bolts of at least A 307 quality. Bolts shall have a standard head or an equal deformity in the embedded portion.
[2]The tabulated values are for anchors installed at the specified spacing and edge distances. Such spacing and edge distance may be reduced 50 percent with an equal reduction in value. Use linear interpolation for intermediate spacings and edge margins.
[3]The allowable values may be increased per Section 1612.3 for duration of loads such as wind or seismic forces.
[4]An additional 2 inches (51 mm) of embedment shall be provided for anchor bolts located in the top of columns located in Seismic Zones 2, 3 and 4.
[5]Values shown are for work without special inspection. Where special inspection is provided, values may be increased 100 percent.
[6]Values shown are for work with or without special inspection.

TABLE 19-E—MINIMUM COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY AND OF RIGIDITY OF REINFORCED GYPSUM CONCRETE

CLASS	COMPRESSIVE STRENGTH psi (f_g)	MODULUS OF ELASTICITY psi (E)	E_s/E_g (n)	MODULUS OF RIGIDITY (G)
	× 0.00689 for MPa			
A	500	200,000	150	.36E
B	1,000	600,000	50	.40E

TABLE 19-F—ALLOWABLE UNIT WORKING STRESS REINFORCED GYPSUM CONCRETE

TYPE OF STRESS	FACTOR	CLASS A	CLASS B
		(pounds per square inch)	
		× 0.00689 for MPa	
Flexural compression	$.25f_g$	125	250
Axial compression or bearing	$.20f_g$	100	200
Bond for plain bars and shear[1]	$.02f_g$	10	20
Bond for deformed bars and electrically welded wire mesh[1]	$.03f_g$	15	30

[1]Electrically welded wire mesh reinforcement shall be considered as meeting the bond and shear requirements of this section. In no case shall the area of principal reinforcement be less than 0.26 square inch per foot (550 mm^2/m) of slab width.

TABLE 19-G—SHEAR ON ANCHOR BOLTS AND DOWELS—REINFORCED GYPSUM CONCRETE[1]

BOLT OR DOWEL SIZE (inches)	EMBEDMENT (inches)	SHEAR[2] (inches)
× 25.4 for mm		
$^3/_8$ bolt	4	325
$^1/_2$ bolt	5	450
$^5/_8$ bolt	5	650
$^3/_8$ deformed dowel	6	325
$^1/_2$ deformed dowel	6	450

[1]The bolts or dowels shall be spaced not closer than 6 inches (152 mm) on center.
[2]The tabulated values may be increased one third for bolts or dowels resisting wind or seismic forces.

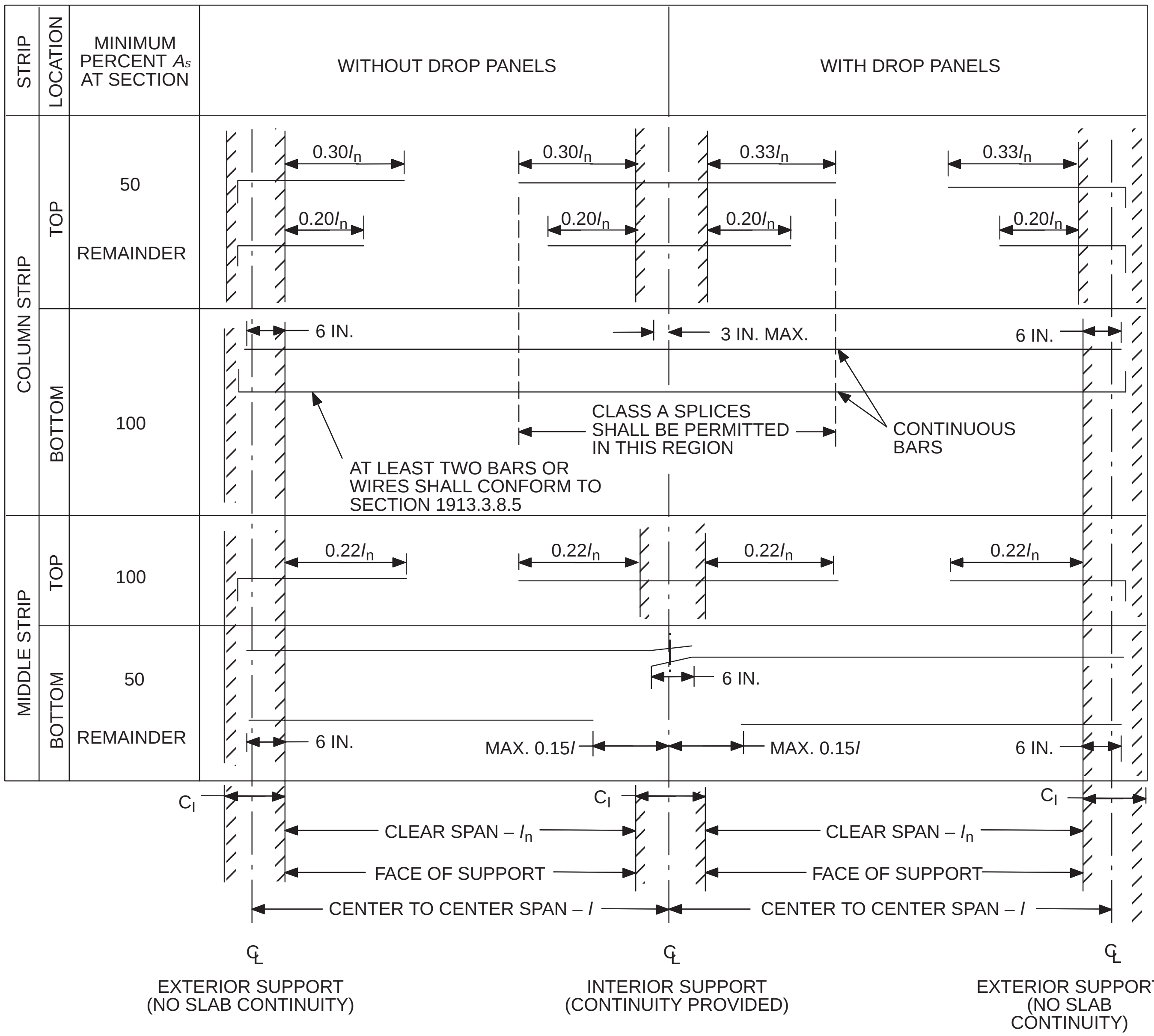


FIGURE 19-1—MINIMUM EXTENSIONS FOR REINFORCEMENT IN SLABS WITHOUT BEAMS
(See Section 1912.11.1 for reinforcement extension into supports.)

UNIFORM BUILDING CODE STANDARD 19-1

WELDING REINFORCING STEEL, METAL INSERTS AND CONNECTIONS IN REINFORCED CONCRETE CONSTRUCTION

See Sections 1903.5.2, 1903.10, and 1912.14,
Uniform Building Code

SECTION 19.101 — ADOPTION OF AWS CODE

19.101.1 Except for the limitations, deletions, modifications or amendments set forth in Section 19.102 of this standard, the welding of concrete reinforcing steel for splices (prestressing steel excepted), steel connection devices, inserts, anchors and anchorage details, as well as any other welding required in reinforced concrete construction, shall be in accordance with the *Structural Welding Code—Reinforcing Steel*, ANSI/AWS D1.4-92, published by the American Welding Society, Inc., Copyright 1992, 550 North LeJeune Road, Miami, Florida 33135, as if set out at length herein.

SECTION 19.102 — DELETIONS AND AMENDMENTS

19.102.1 General. The American Welding Society, Inc., code adopted by Section 19.101 applies to all materials, processes, design, workmanship and testing of welding performed as a part of reinforced concrete construction, except as set forth in this section.

19.102.2 Deletions. The following sections and chapters are deleted:

Section 1.6

Section 1.7

Section 3.7

Section 5.6.3

Chapter 7

19.102.3 Amendments

1. **Sec. 1.2.1** is amended by changing the last sentence to read as follows:

When reinforcing steel is welded to primary structural steel members, welding procedures, welder qualification requirements and welding electrodes shall be in accordance with Chapter 22, Divisions II, III and VI or VII, of this code and approved national standards.

2. **Sec. 1.2.3** is amended to read as follows:

1.2.3. All references to the need for approval shall be interpreted to mean approval by the building official.

3. **Sec. 1.2.4** is amended to read as follows:

1.2.4 When structural steel base metals make up the entire weld joint, the engineer may select the use of welding procedures and welder qualifications in accordance with Chapter 22, Divisions II, III and VI or VII, of this code and approved national standards to perform that weld, provided other relevant provisions of UBC Standard 19-1 are considered.

4. **Sec. 1.3.3** is amended to read as follows:

1.3.3 Base metal, other than those previously listed, shall be one of the structural steels listed in Chapter 22, Divisions II, III and VI or VII, of this code.

5. **Sec. 1.5** is amended to read as follows:

1.5 Definitions

The welding terms used in this code shall be interpreted in accordance with the definitions given in Chapter 22, Divisions V, VIII and IX or X, of this code and approved national standards.

6. **Sec. 2.1** is amended to read as follows:

2.1 Base Metal Stresses. The allowable base metal stresses shall be those specified in this code for reinforced concrete construction.

UNIFORM BUILDING CODE STANDARD 19-2

MILL-MIXED GYPSUM CONCRETE AND POURED GYPSUM ROOF DIAPHRAGMS

Based on Reports of Test Programs by S. B. Barnes and Associates dated February 1955, November 1956, January 1958, and February 1962, and Standard Specification C 317-70 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 1903.9 and 1925.3, *Uniform Building Code*

Part I—Mill-mixed Gypsum Concrete

SECTION 19.201 — SCOPE

This part covers mill-mixed gypsum concrete. Gypsum concrete supplied under this standard shall be mill-mixed gypsum concrete, consisting essentially of calcined gypsum and suitable aggregate, requiring the addition of water only at the job. Gypsum concrete is intended for use in construction of poured-in-place roof decks or slabs. Two classes, based on the compressive strength and density, are covered.

SECTION 19.202 — COMPOSITION

Gypsum concrete shall consist essentially of calcined gypsum and wood chips or wood shavings, proportioned to meet the applicable requirements of this standard. Calcined gypsum used in the mill mixed gypsum concrete shall conform to the requirements of ASTM C 28-76a. Wood chips or wood shavings shall be of dry wood, uniform and clean in appearance, shall pass a 1-inch (25 mm) sieve, and shall not be more than $^{1}/_{16}$ inch (1.6 mm) in thickness.

SECTION 19.203 — TIME OF SETTING

Gypsum concrete shall not set in less than 20 minutes nor more than 90 minutes.

SECTION 19.204 — COMPRESSIVE STRENGTH AND DENSITY

Gypsum concrete shall have the following compressive strength and density for the respective classes:

	COMPRESSIVE STRENGTH MINIMUM psi (MPa)	DENSITY POUNDS PER CUBIC FOOT (kg/m^3)
Class A	500 (3.5)	60 (960)
Class B	1,000 (6.9)	—

SECTION 19.205 — METHODS OF TESTING

The physical properties of gypsum concrete shall be determined in accordance with approved methods.

Part II—Poured-in-place Reinforced Gypsum Concrete

SECTION 19.206 — SCOPE

This part covers the design of poured-in-place reinforced gypsum concrete roof decks when used as a horizontal diaphragm.

SECTION 19.207 — DESIGN

19.207.1 General. The gypsum roof diaphragm shall consist of sub-purlins welded transversely to primary purlins. Formboard is then placed on the flanges of the subpurlins. Wire mesh reinforcement is then placed over the subpurlins and formboard and lapped at least 4 inches (102 mm) or one mesh on ends and edges, whichever is greater. Gypsum concrete meeting the requirements of Part I of this standard is then placed to a minimum thickness of 2 inches (51 mm) over the formboard and $^{5}/_{8}$ inch (16 mm) over the subpurlins and doweling elements. The bulb section or top flange of the subpurlin shall be fully embedded in the gypsum concrete.

19.207.2 Diaphragm Shear. Shear in poured gypsum concrete diaphragms shall be determined by the formula:

$$Q = .16 f_g\ t\ C_l + 1{,}000\ (k_1\ d_1 + k_2\ d_2)$$

For **SI:** $$Q = 1.36 f_g\ t\ C_l + 17.86\ (k_1\ d_1 + k_2\ d_2)$$

WHERE:

C_l = 1.0 for Class A gypsum; 1.5 for Class B gypsum.

d_1 = diameter of mesh wires passing over subpurlins, in inches (mm), except hexagonal mesh.

d_2 = diameter, in inches (mm), of mesh wires parallel to subpurlins or of hexagonal wires.

f_g = oven-dry compressive strength of gypsum in pounds per square inch (MPa) as determined by tests conforming to this standard.

k_1 = number of mesh wires per foot (m) passing over subpurlins.

k_2 = number of mesh wires per foot (m) parallel to subpurlins or .7 times the number of hexagonal wires. Note: k_2 = 8.5 (27.9) for 2-inch (51 mm) hexagonal mesh woven of No. 19 gage galvanized wire with additional longitudinal No. 16 gage galvanized wires spaced every 3 inches (76 mm) across the width of the mesh.

Q = allowable shear on diaphragm in pounds per linear foot (kg/m), which includes a one-third increase for short-time loading.

t = thickness of gypsum concrete between subpurlins, in inches (mm). For the purpose of computing diaphragm shear values, t shall not exceed 4 inches (102 mm).

The solution of the above equation for commonly used thickness and mesh types for each class of gypsum would give the values set forth in Table 19-2-A.

19.207.3 Shear Transfer. Bolts, dowels or other approved elements may be used to transfer diaphragm shears to perimeter or other structural members. Allowable bolt and dowel stresses shall comply with Table 19-G and Section 1603 of this code.

TABLE 19-2-A—ALLOWABLE SHEAR VALUES IN POUNDS PER FOOT USING BULB TEE SUBPURLINS[1]

CLASS OF GYPSUM CONCRETE	CONCRETE THICKNESS (inches)	MESH TYPE[2]		
		4″ × 8″ (102 mm × 203 mm) No. 12-No. 14 (Galvanized)	6″ × 6″ (152 mm × 152 mm) No. 10-No. 10	Hexagonal[3] (Galvanized)
× 6.89 for kPa	× 25.4 for mm	× 14.59 for N/m		
A (500 psi)	2 2 1/2	600 640	700 740	760 800
B (1,000 psi)	2 2 1/2	920 1,040	1,020 1,140	1,080 1,200

[1]The tabulated shear values are for short-time loads due to wind or earthquake forces and are not permitted a one-third increase for duration of load.

[2]Mesh shall be lapped at least 4 inches (102 mm) or one mesh on ends and edges, whichever is greater.

[3]Two-inch (51 mm) hexagonal mesh woven of No. 19 gage galvanized wire with additional longitudinal No. 16 gage galvanized wires spaced every 3 inches (76 mm) across the width of the mesh.

Chapter 20
LIGHTWEIGHT METALS
Division I—GENERAL

SECTION 2001 — MATERIAL STANDARDS AND SYMBOLS

2001.1 General. The quality, design, fabrication and erection of aluminum used structurally in buildings and structures shall conform to the requirements of this chapter, to other applicable requirements of this code and to Division II.

Allowable stresses and design formulas provided in this chapter shall be used with the allowable stress design load combinations specified in Section 1612.3.

2001.2 Alloys. The use of aluminum alloys and tempers other than those covered by this chapter and other lightweight metal alloys are allowed for structural members and assemblies, provided standards of performance not less than those required by this chapter are substantiated to the satisfaction of the building official. When required by the building official, certification that the alloys and tempers called for on the plans have been furnished shall be provided.

2001.3 Symbols and Notations. The symbols and notations used in this chapter are defined as follows:

A = area, square inches (mm^2).

A_c = area of compression element, square inches (mm^2) (compression flange plus one third of area of web between compression flange and neutral axis).

A_w = area of cross section lying within 1.0 inch of a weld, square inches (mm^2).

a_1 = shorter dimension of rectangular panel, inches (mm).

a_2 = longer dimension of rectangular panel, inches (mm).

a_e = equivalent width of rectangular panel, inches (mm).

B, D, C = buckling formula constants, with following subscript:
c—compression in columns
p—compression in flat plates
t—compression in round tubes
tb—bending in round tubes
b—bending in rectangular bars
s—shear in flat plates

b = width of sections, inches (mm).

b/t = width-to-thickness ratio or rectangular element of a cross section.

c = distance from neutral axis to extreme fiber, inches (mm).

D = diameter, inches (mm).

d = depth of section or beam, inches (mm).

E = compressive modulus of elasticity, kips per square inch (ksi) (MPa).

F = allowable stress, ksi (MPa).

F_a = allowable compressive stress for member considered as an axially loaded column, ksi (MPa).

F_b = allowable compressive stress for member considered as a beam, ksi (MPa).

F_{bu} = bearing ultimate strength, ksi (MPa).

F_{buw} = bearing ultimate strength within 1.0 inch (25.4 mm) of a weld, ksi (MPa).

F_{by} = bearing yield strength, ksi (MPa).

F_{byw} = bearing yield strength within 1.0 inch (25.4 mm) of a weld, ksi (MPa).

F_c = allowable compressive stress, ksi (MPa).

F_{cy} = compressive yield strength, ksi (MPa).

F_{cyw} = compressive yield strength across a butt weld [0.2 percent offset in 10-inch (254 mm) gage length], ksi (MPa).

F_{ec} = $\pi^2 E/[n_u(l/r)^2]$, where l/r is slenderness ratio for member considered as a column tending to fail in the plane of the applied bending moments, ksi (MPa).

F_n = allowable stress for cross section 1.0 inch (25.4 mm) or more from weld, ksi (MPa).

F_{pw} = allowable stress on cross section, part of whose area lies within 1.0 (25.4 mm) inch of a weld, ksi (MPa).

F_s = allowable shear stress for members subjected only to torsion or shear, ksi (MPa).

F_{su} = shear ultimate strength, ksi (MPa).

F_{suw} = shear ultimate strength within 1.0 inch (25.4 mm) of a weld, ksi (MPa).

F_{sy} = shear yield strength, ksi (MPa).

F_{syw} = shear yield strength within 1.0 inch (25.4 mm) of a weld, ksi (MPa).

F_{tu} = tensile ultimate strength, ksi (MPa).

F_{tuw} = tensile ultimate strength across a butt weld, ksi (MPa).

F_{ty} = tensile yield strength, ksi (MPa).

F_{tyw} = tensile yield strength across a butt weld [0.2 percent offset in 10-inch (254 mm) gage length], ksi (MPa).

F_y = either F_{ty} or F_{cy}, whichever is smaller, ksi (MPa).

f = calculated stress, ksi (MPa).

f_a = average compressive stress on cross section of member produced by axial compressive load, ksi (MPa).

f_b = maximum bending stress (compressive) caused by transverse loads or end moments, ksi (MPa).

f_s = shear stress caused by torsion or transverse shear, ksi (MPa).

G = modulus of elasticity in shear, ksi (MPa).

g = spacing of rivet or bolt holes perpendicular to direction of load, inches (mm).

h = clear height of shear web, inches (mm).

I = moment of inertia, inches^4 (mm^4).

I_h = moment of inertia of horizontal stiffener, inches^4 (mm^4).

I_s = moment of inertia of transverse stiffener to resist shear buckling, inches^4 (mm^4).

I_x = moment of inertia of a beam about axis perpendicular to web, inches^4 (mm^4).

I_y = moment of inertia of a beam about axis parallel to web, inches^4 (mm^4).

I_{yc} = moment of inertia of compression element about axis parallel to vertical web, inches^4 (mm^4).

J = torsion constant, inches^4 (mm^4).

k_1 = coefficient for determining slenderness limit S_2 for sections for which the allowable compressive stress is based on crippling strength.

k_2 = coefficient for determining allowable compressive stress in sections with slenderness ratio above S_2 for which the allowable compressive stress is based on crippling strength.

k_c = coefficient for compression members.

k_t = coefficient for tension members.

L = length of compression member between points of lateral support, or twice the length of a cantilever column (except where analysis shows that a shorter length can be used), inches (mm).

L_b = length of beam between points at which the compression flange is supported against lateral movement, or length of cantilever beam from free end to point at which the compression flange is supported against lateral movement, inches (mm).

L_h = total length of portion of column lying within 1.0 inch (25.4 mm) of a weld (excluding welds at ends of columns that are supported at both ends), inches (mm).

L_w = increased length to be substituted in column formula to determine allowable stress for welded column, inches (mm).

l/r = slenderness ratio for columns.

M = bending moment, inch-kips (kN·m).

M_1, M_2 = bending moments at two ends of a beam, inch-kips (kN·m).

M_c = bending moment at center of span resulting from applied bending loads, inch-kips (kN·m).

M_m = maximum bending moment in span resulting from applied bending loads, inch-kips (kN·m).

N = length of bearing at reaction or concentrated load, inches (mm).

n_a = factor of safety on appearance of buckling.

n_u = factor of safety on ultimate strength.

n_y = factor of safety on yield strength.

P = local load concentration on bearing stiffener, kips (kN).

P_c = allowable reaction or concentrated load per web, kips (kN).

P_t = allowable tensile load per fastener, sheet to purlin or girt, kips (kN).

R = outside radius of round tube or maximum outside radius for an oval tube, inches (mm).

R_b = radius of curvature of tubular members, inches (mm).

R_t = transition radius, the radius of an attachment of the weld detail.

r = least radius of gyration of a column, inches (mm).

r_L = radius of gyration of lip or bulb about face of flange from which lip projects, inches (mm).

r_y = radius of gyration of a beam (about axis parallel to web), inches (mm). (For beams that are unsymmetrical about the horizontal axis, r_y should be calculated as though both flanges were the same as the compression flange.)

S_1, S_2 = slenderness limits.

S_c = section modulus of a beam, compression side, inches^3 (mm^3).

SR = stress ratio, the ratio of minimum stress to maximum stress.

S_t = section modulus of a beam, tension side, inches^3 (mm^3).

s = spacing of transverse stiffeners (clear distance between stiffeners for stiffeners consisting of a pair of members, one on each side of the web, center-to-center distance between stiffeners consisting of a member on one side of the web only), inches (mm); spacing of rivet or bolt holes parallel to direction of load, inches (mm).

t = thickness of flange, plate, web or tube, inches (mm). (For tapered flanges, t is the average thickness.)

V = shear force on web at stiffener location, kips (kN).

α = a factor equal to unity for a stiffener consisting of equal members on both sides of the web and equal to 3.5 for a stiffener consisting of a member on one side only.

θ = angle between plane of web and plane of bearing surface (θ 90), degrees.

2001.4 Identification. Aluminum for structural elements shall at all times be segregated or otherwise handled in the fabricator's plant so that the separate alloys and tempers are positively identified and, after completion of fabrication, shall be marked to identify the alloy and temper. Such markings shall be affixed to complete members and assemblies or to boxed or bundled shipments of multiple units prior to shipment from the fabricator's plant.

SECTION 2002 — ALLOWABLE STRESSES FOR MEMBERS AND FASTENERS

2002.1 Allowable Unit Stresses. Except as modified by Division II, allowable unit stresses in aluminum alloy structural members shall be determined in accordance with the formulas of Table 20-I-C utilizing the safety factors listed in Table 20-I-D, and the constants and coefficients listed in Tables 20-I-E, 20-I-F and 20-I-G. Where two formulas are given, the smaller of the resulting stresses shall be used.

2002.2 Welded Structural Members. Allowable unit stresses for structural members whose entire cross-sectional area lies within 1 inch (25.4 mm) of the center line of a butt weld of the heel of a fillet weld shall be determined by means of the formulas of Table 20-I-C utilizing the applicable minimum expected mechanical properties for welded aluminum alloys listed in Division II. The tensile ultimate strength, F_{tuw}, shall be 90 percent of the American Society of Mechanical Engineers weld qualification test value of ultimate strength. Except as modified by Division II, buckling constants determined in accordance with the formulas of Tables 20-I-E and 20-I-G shall be calculated using the nonwelded mechanical properties of the respective aluminum alloys.

If less than 15 percent of the area of a given cross section lies within 1 inch (25.4 mm) of the center line of a butt weld or the heel of a fillet weld, the effect of the weld may be neglected and allowable stresses for nonwelded structural members may be used.

If the area of a cross section that lies within 1 inch (25.4 mm) of a weld is between 15 percent and 100 percent of the total area of the cross section, the allowable stress shall be calculated by the following formula:

$$F_{pw} = F_n \times \frac{A_w}{A} (F_n \times F_w)$$

WHERE:

A = net area of cross section of a tension member or tension flange of a beam, or gross area of cross section of a compression member or compression flange of a beam, square inches (mm^2). (A beam flange is considered to consist of that portion of the member further than $2c/3$ from the neutral axis, where c is the distance from the neutral axis to the extreme fiber.)

A_w = area of cross section lying within 1.0 inch (25.4 mm) of a weld.

F_n = allowable stress for cross section 1.0 inch (25.4 mm) or more from weld.

F_{pw} = allowable stress on cross section part of whose area lies within 1.0 inch (25.4 mm) of a weld.

F_w = allowable stress on cross section if entire area were to lie within 1.0 inch (25.4 mm) of a weld.

For columns and beams with welds at locations other than at their supported ends (not farther from the supports than 0.05 L from the ends), and for cantilever columns and single web beams with transverse welds at or near the supported end, the effect of welding on allowable stresses shall be determined in accordance with the provisions of Division II.

2002.3 Rivets and Bolts. Allowable stresses in aluminum rivets and bolts shall be as set forth in Table 20-I-A.

2002.4 Fillet Welds. Allowable shear stresses in fillet welds shall be as set forth in Table 20-I-B.

SECTION 2003 — DESIGN

2003.1 Combined Stresses. Members subjected to combinations of compression and bending or shear, compression and bending shall be proportioned in accordance with the provisions of Division II.

2003.2 Light Gage Members. Where the design of light gage structural members is involved, the special provisions of Division II shall be applied.

2003.3 Structural Roofing and Siding. The live load deflection of structural roofing and siding made of formed sheet shall not exceed $^1/_{60}$ of the span length.

2003.4 Connections. The design of mechanical and welded connections shall be in accordance with this chapter and the provisions of Division II.

SECTION 2004 — FABRICATION AND ERECTION

2004.1 Cutting. Oxygen cutting of aluminum alloys shall not be permitted.

2004.2 Fasteners. Bolts and other fasteners shall be aluminum, stainless steel or aluminized, hot-dip galvanized or electrogalvanized steel. Double cadmium-plated AN steel bolts may also be used. Steel rivets shall not be used except where aluminum is to be joined to steel or where corrosion resistance of the structure is not a requirement or where the structure is to be protected against corrosion.

2004.3 Dissimilar Materials. Where aluminum alloy parts are in contact with dissimilar metals, other than stainless, aluminized or galvanized steel or absorbent building materials likely to be continuously or intermittently wet, the faying surfaces shall be painted or otherwise separated in accordance with Division II.

2004.4 Painting. Except as prescribed in Section 2004.3, painting or coating of aluminum alloy parts shall be required only when called for on the plans.

2004.5 Welding. Aluminum parts shall be welded with an inert gas shielded arc or resistance welding process. No welding process that requires a welding flux shall be used. Filler alloys complying with the requirements of Division II shall be used.

2004.6 Welder Qualification. All welds of structural members shall be performed by welders qualified in accordance with the procedures of Division II.

2004.7 Erection. During erection, structural aluminum shall be adequately braced and fastened to resist dead, wind and erection loads.

TABLE 20-I-A—ALLOWABLE STRESSES FOR RIVETS

DESIGNATION BEFORE DRIVING	DRIVING PROCEDURE	DESIGNATION AFTER DRIVING	MINIMUM EXPECTED SHEAR STRENGTH (ksi)	ALLOWABLE SHEAR STRESS ON EFFECTIVE AREA (ksi)
			× 6.89 for MPa	
1100-H14	Cold, as received	1100-F	9.5	4
2017-T4	Cold, as received	2017-T3	34	14.5
2117-T4	Cold, as received	2117-T3	29	12
5056-H32	Cold, as received	5056-H321	26	11
6053-T61	Cold, as received	6053-T61	20	8.5
6061-T4	Hot, 990°F to 1050°F	6061-T43	21	9
6061-T6	Cold, as received	6061-T6	26	11[1]

ALLOWABLE STRESSES FOR BOLTS

ALLOY AND TEMPER	MINIMUM EXPECTED SHEAR STRENGTH (ksi)	ALLOWABLE[2] SHEAR STRESS ON EFFECTIVE AREA (ksi)	ALLOWABLE TENSILE STRESS ON ROOT AREA (ksi)
	× 6.89 for MPa		
2024-T4	37	16	26
6061-T6	27	12	18
7075-T73	40	17	28

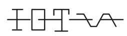
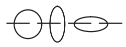
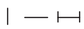
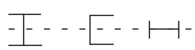
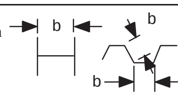
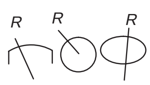
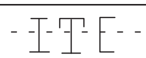
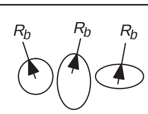
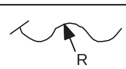
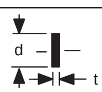
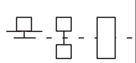
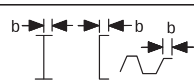
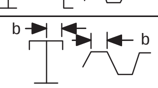
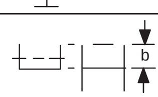
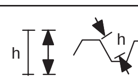
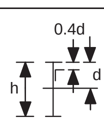
[1]Also applies to 6061-T6 pins.
[2]Values apply to either turned bolts or unfinished bolts in holes not more than $^1/_{16}$ inch (1.6 mm) oversized.

TABLE 20-I-B—ALLOWABLE SHEAR STRESSES IN FILLET WELDS (ksi)
(Shear stress is considered equal to the load divided by the throat area.)

FILLER ALLOY	1100	4043	5356 5554	5556
	× 6.89 for MPa			
Parent Alloy				
1100	3.2	4.8	*	*
3003	3.2	5	*	*
Alclad 3004	*	5	7	8
5052	*	5	7	*
5083	*	*	*	8.5
5086	*	*	7	8.5
5454	*	*	7	8.5
5456	*	*	*	8.5
6061	*	5	7	8.5
6063	*	5	6.5	6.5

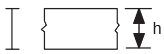
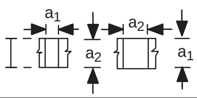
* Not permitted.

TABLE 20-I-C—GENERAL FORMULAS FOR DETERMINING ALLOWABLE STRESSES

TYPE OF STRESS	TYPE OF MEMBER OR COMPONENT	SPEC. NO.	ALLOWABLE STRESS (ksi)				
Tension, axial, net section	Any tension member:	1	F_{ty}/n_y or $F_{tu}/(k_t n_u)$				$\times$ 6890 for kN/m^2
Tension in beams, extreme fiber, net section	Rectangular tubes, structural shapes bent about strong axis 	2	F_{ty}/n_y or $F_{tu}/(k_t n_u)$				
	Round or oval tubes 	3	$1.17F_{ty}/n_y$ or $1.24F_{tu}/(k_t n_u)$				
	Rectangular bars, plates, shapes bent about weak axis 	4	$1.30F_{ty}/n_y$ or $1.42F_{tu}/(k_t n_u)$				
Bearing	On rivets and bolts	5	F_{by}/n_y or $F_{bu}/(1.2n_u)$				
	On flat surfaces and pins and on bolts in slotted holes	6	$F_{by}/(1.5n_y)$ or $F_{bu}/(1.8n_u)$				
			ALLOWABLE STRESS, KSI, SLENDERNESS $< S_1$	SLENDERNESS LIMIT, S_1	ALLOWABLE STRESS, KSI SLENDERNESS BETWEEN S_1 AND S_2	SLENDERNESS LIMIT, S_2	ALLOWABLE STRESS, KSI SLENDERNESS $\geq S_2$
Compression in columns, axial, gross section	All columns	7	$\frac{F_{cy}}{k_c n_y}$	$\frac{kL}{r} = \frac{B_c - \frac{n_u F_{cy}}{k_c n_y}}{D_c}$	$\frac{1}{n_u}\left(B_c - D_c \frac{kL}{r}\right)$	$\frac{kL}{r} = C_c$	$\frac{\pi^2 E}{n_u (kL/r)^2}$
Compression in components of columns, gross section	Outstanding flanges and legs 	8	$\frac{F_{cy}}{k_c n_y}$	$\frac{b}{t} = \frac{B_p - \frac{n_u F_{cy}}{k_c n_y}}{5.1D_p}$	$\frac{1}{n_u}\left(B_p - 5.1D_p \frac{b}{t}\right)$	$\frac{b}{t} = \frac{C_p}{5.1}$	$\frac{\pi^2 E}{n_u (5.1b/t)^2}$
	Flat plates with both edges supported 	9	$\frac{F_{cy}}{k_c n_y}$	$\frac{b}{t} = \frac{B_p - \frac{n_u F_{cy}}{k_c n_y}}{1.6D_p}$	$\frac{1}{n_u}\left(B_p - 1.6D_p \frac{b}{t}\right)$	$\frac{b}{t} = \frac{k_1 B_p}{1.6D_p}$	$\frac{k_2\sqrt{B_p E}}{n_u (1.6b/t)}$
	Curved plates supported on both edges, walls of round or oval tubes 	10	$\frac{F_{cy}}{k_c n_y}$	$\frac{R}{t} = \left[\frac{B_t - \frac{n_u F_{cy}}{k_c n_y}}{D_t}\right]^2$	$\frac{1}{n_u}\left(B_t - D_t \sqrt{\frac{R}{t}}\right)$	$\frac{R}{t} = C_t$	$\frac{\pi^2 E}{16 n_u \left(\frac{R}{t}\right)\left(1 + \frac{\sqrt{R/t}}{35}\right)^2}$
Compression in beams, extreme fiber, gross section	Single web beams bent about strong axis 	11	$\frac{F_{cy}}{n_y}$	$\frac{L_b}{r_y} = \frac{1.2(B_c - F_{cy})}{D_c}$	$\frac{1}{n_y}\left(B_c - \frac{D_c L_b}{1.2r_y}\right)$	$\frac{L_b}{r_y} = 1.2C_c$	$\frac{\pi^2 E}{n_y (L_b/1.2r_y)^2}$
	Round or oval tubes 	12	$\frac{1.17F_{cy}}{n_y}$	$\frac{R_b}{t} = \left(\frac{B_{tb} - 1.17F_{cy}}{D_{tb}}\right)^2$	$\frac{1}{n_y}\left(B_{tb} - D_{tb}\sqrt{\frac{R_b}{t}}\right)$	$\frac{R_b}{t} = \left(\frac{\frac{n_u}{n_y}B_{tb} - B_t}{\frac{n_u}{n_y}D_{tb} - D_t}\right)^2$	Same as Specification 10[1]
	Curved sections 	12	$\frac{1.17F_{cy}}{n_y}$	$\frac{R}{t} = \left(\frac{B_t - 1.17F_{cy}}{D_t}\right)^2$	$\frac{1}{n_y}\left(B_t - D_t\sqrt{\frac{R}{t}}\right)$	$\frac{R}{t} = C_c$	$\frac{\pi^2 E}{16 n_y \left(\frac{R}{t}\right)\left(1 + \frac{\sqrt{R/t}}{35}\right)^2}$
	Solid rectangular beams 	13	$\frac{1.3F_{cy}}{n_y}$	$\frac{d}{t}\sqrt{\frac{L_{br}}{d}} = \frac{B_{br} - 1.3F_{cy}}{2.3D_{br}}$	$\frac{1}{n_y}\left(B_{br} - 2.3D_{br}\frac{d}{t}\sqrt{\frac{L_b}{d}}\right)$	$\frac{d}{t}\sqrt{\frac{L_b}{d}} = \frac{C_{br}}{2.3}$	$\frac{\pi^2 E}{5.29 n_y (d/t)^2 (L_b/d)}$
	Rectangular tubes and box sections 	14	$\frac{F_{cy}}{n_y}$	$\frac{L_b S_c}{0.5\sqrt{I_y J}} = \left(\frac{B_c - F_{cy}}{1.6D_c}\right)^2$	$\frac{1}{n_y}\left(B_c - 1.6D_c\sqrt{\frac{L_b S_c}{0.5\sqrt{I_y J}}}\right)$	$\frac{L_b S_c}{0.5\sqrt{I_y J}} = \left(\frac{C_c}{1.6}\right)^2$	$\frac{\pi^2 E}{2.56 n_y (L_b S_c / 0.5\sqrt{I_y J})}$
Compression in components of beams (component under uniform compression), gross section	Outstanding flanges 	15	$\frac{F_{cy}}{n_y}$	$\frac{b}{t} = \frac{B_p - F_{cy}}{5.1D_p}$	$\frac{1}{n_y}\left(B_p - 5.1D_p\frac{b}{t}\right)$	$\frac{b}{t} = \frac{k_1 B_p}{5.1D_p}$	$\frac{k_2\sqrt{B_p E}}{n_y (5.1b/t)}$
	Flat plates with both edges supported 	16	$\frac{F_{cy}}{n_y}$	$\frac{b}{t} = \frac{B_p - F_{cy}}{1.6D_p}$	$\frac{1}{n_y}\left(B_p - 1.6D_p\frac{b}{t}\right)$	$\frac{b}{t} = \frac{k_1 B_p}{1.6D_p}$	$\frac{k_2\sqrt{B_p E}}{n_y (1.6b/t)}$
Compression in components of beams (component under bending in own plane), gross section	Flat plates with compressed edge free tension edge supported 	17	$\frac{1.3F_{cy}}{n_y}$	$\frac{b}{t} = \frac{B_{br} - 1.3F_{cy}}{3.5D_{br}}$	$\frac{1}{n_y}\left(B_{br} - 3.5D_{br}\frac{b}{t}\right)$	$\frac{b}{t} = \frac{C_{br}}{3.5}$	$\frac{\pi^2 E}{n_y (3.5b/t)^2}$
	Flat plates with both edges supported 	18	$\frac{1.3F_{cy}}{n_y}$	$\frac{h}{t} = \frac{B_{br} - 1.3F_{cy}}{0.67D_{br}}$	$\frac{1}{n_y}\left(B_{br} - 0.67D_{br}\frac{h}{t}\right)$	$\frac{h}{t} = \frac{k_1 B_{br}}{0.67D_{br}}$	$\frac{k_2\sqrt{B_{br} E}}{n_y (0.67h/t)}$
	Flat plates with horizontal stiffener, both edges supported 	19	$\frac{1.3F_{cy}}{n_y}$	$\frac{h}{t} = \frac{B_{br} - 1.3F_{cy}}{0.29D_{br}}$	$\frac{1}{n_y}\left(B_{br} - 0.29D_{br}\frac{h}{t}\right)$	$\frac{h}{t} = \frac{k_1 B_{br}}{0.29D_{br}}$	$\frac{k_2\sqrt{B_{br} E}}{n_y (0.29h/t)}$

(Continued)

TABLE 20-I-C—GENERAL FORMULAS FOR DETERMINING ALLOWABLE STRESSES—(Continued)

TYPE OF STRESS	TYPE OF MEMBER OR COMPONENT	SPEC. NO.	ALLOWABLE STRESS, KSI, SLENDERNESS < S_1	SLENDERNESS LIMIT, S_1	ALLOWABLE STRESS, KSI SLENDERNESS BETWEEN S_1 AND S_2	SLENDERNESS LIMIT, S_2	ALLOWABLE STRESS, KSI SLENDERNESS ≥ S_2
Shear in webs, gross section	Unstiffened flat webs 	**20**	$\frac{F_{sy}}{n_y}$	$\frac{h}{t} = \frac{B_s - F_{sy}}{1.25D_s}$	$\frac{1}{n_y}\left(B_s - 1.25D_s\frac{h}{t}\right)$	$\frac{h}{t} = \frac{C_s}{1.25}$	$\frac{\pi^2 E}{n_y(1.25h/t)^2}$
	Stiffened flat webs 	**21**	$\frac{F_{sy}}{n_y}$	$\frac{a_e}{t} = \frac{B_s - \frac{n_a F_{sy}}{n_y}}{1.25D_s}$	$\frac{1}{n_a}\left(B_s - 1.25D_s\frac{a_e}{t}\right)$	$\frac{a_e}{t} = \frac{C_s}{1.25}$	$\frac{\pi^2 E}{n_a(1.25a_e/t)^2}$

[1]For R_b/t values greater than S_2, the allowable bending shall be determined from the formula for tubes in compression, Specification 10, using the formula that is appropriate for the particular value of R_b/t. Note that in this case, R_b/t may be either less than or greater than the value of S_2 for tubes in compression.

TABLE 20-I-D—FACTORS OF SAFETY FOR USE WITH ALUMINUM ALLOWABLE STRESS SPECIFICATIONS

	BUILDING AND SIMILAR TYPE STRUCTURES
1. Tension members	
F.S. on tensile strength, n_u	1.95
F.S. on yield strength, n_y	1.65
2. Columns	
F.S. on buckling strength, n_u	1.95
F.S. on crippling strength of thin sections, n_u	1.95
F.S. on yield strength for short columns, n_y	1.65
3. Beams	
F.S. on tensile strength, n_u	1.95
F.S. on tensile yield strength, n_y	1.65
F.S. on compressive yield strength for short beams, n_y	1.65
F.S. on buckling strength, n_y	1.65
F.S. on crippling strength of thin sections, n_y	1.65
F.S. on shear buckling of webs, n_a	1.20
4. Connections	
F.S. on bearing strength	1.2 × 1.95 = 2.34
F.S. on bearing yield strength, n_y	1.65
F.S. on shear strength of rivets and bolts	1.2 × 1.95 = 2.34
F.S. on shear strength of fillet welds	1.2 × 1.95 = 2.34
F.S. on tensile strength of butt welds, n_u	1.95
F.S. on tensile yield strength of butt welds, n_y	1.65

TABLE 20-I-E—FORMULAS FOR BUCKLING CONSTANTS
For All Products Whose Temper Designation begins with -O, -H, -T1, -T2, -T3 or -T4

TYPE OF MEMBER AND STRESS	INTERCEPT (ksi)	SLOPE (ksi)	INTERSECTION
	× 6.89 for MPa		
1. Compression in columns and beam flanges	$B_c = F_{cy}\left[1 + \left(\frac{F_{cy}}{1000}\right)^{1/2}\right]$	$D_c = \frac{B_c}{20}\left(\frac{6B_c}{E}\right)^{1/2}$	$C_c = \frac{2B_c}{3D_c}$
2. Compression in flat plates	$B_p = F_{cy}\left[1 + \frac{(F_{cy})^{1/3}}{7.6}\right]$	$D_p = \frac{B_p}{20}\left(\frac{6B_p}{E}\right)^{1/2}$	$C_p = \frac{2B_p}{3D_p}$
3. Compression in round tubes under axial end load	$B_t = F_{cy}\left[1 + \frac{(F_{cy})^{1/5}}{5.8}\right]$	$D_t = \frac{B_t}{3.7}\left(\frac{B_t}{E}\right)^{1/3}$	C_t *
4. Compressive bending stress in solid rectangular bars	$B_b = 1.3F_{cy}\left[1 + \frac{(F_{cy})^{1/3}}{7}\right]$	$D_b = \frac{B_b}{20}\left(\frac{6B_b}{E}\right)^{1/2}$	$C_b = \frac{2B_b}{3D_b}$
5. Compressive bending stress in round tubes	$B_{tb} = 1.5F_y\left[1 + \frac{(F_y)^{1/5}}{5.8}\right]$	$D_{tb} = \frac{B_{tb}}{2.7}\left(\frac{B_{tb}}{E}\right)^{1/3}$	$C_{tb} = \left(\frac{B_{tb} - B_t}{D_{tb} - D_t}\right)^2$
6. Shear stress in flat plates	$B_s = F_{sy}\left[1 + \frac{(F_{sy})^{1/3}}{6.2}\right]$	$D_s = \frac{B_s}{20}\left(\frac{6B_s}{E}\right)^{1/2}$	$C_s = \frac{2B_s}{3D_s}$
7. Crippling of flat plates in compression or bending	$k_1 = 0.50$	$k_2 = 2.04$	

*C_t can be found from a plot of the curves of allowable stress based on elastic and inelastic buckling or by a trial-and-error solution.

TABLE 20-I-F—VALUES OF COEFFICIENTS k_t and k_c

ALLOY AND TEMPER	NONWELDED OR REGIONS FARTHER THAN 1.0 INCH (25.4 mm) FROM A WELD		REGIONS WITHIN 1.0 INCH (25.4 mm) OF A WELD	
	k_t	k_c	k_t	k_c[1]
2014-T6, -T651	1.25	1.12	—	—
Alclad 2014-T6, -T651	1.25	1.12	—	—
6061-T6, -T651	1.0	1.12	1.0	1.0
6063-T5, -T6, -T83	1.0	1.12	1.0	1.0
6351-T5	1.0	1.12	1.0	1.0
All others listed in Division II	1.0	1.10	1.0	1.0

[1]If the weld yield strength exceeds 0.9 of the parent metal yield strength, the allowable compressive stress within 1.0 inch (25.4 mm) of a weld should be taken equal to the allowable stress for nonwelded material.

TABLE 20-I-G—FORMULAS FOR BUCKLING CONSTANTS
For all products whose temper designation begins with -T5, -T6, -T7, -T8 or -T9

TYPE OF MEMBER AND STRESS	INTERCEPT (ksi)	SLOPE (ksi)	INTERSECTION
	× 6.89 for MPa		
1. Compression in columns and beam flanges	$B_c = F_{cy}\left[1 + \left(\frac{F_{cy}}{2250}\right)^{1/2}\right]$	$D_c = \frac{B_c}{10}\left(\frac{B_c}{E}\right)^{1/2}$	$C_c = 0.41\frac{B_c}{D_c}$
2. Compression in flat plates	$B_p = F_{cy}\left[1 + \frac{(F_{cy})^{1/3}}{11.4}\right]$	$D_p = \frac{B_p}{10}\left(\frac{B_p}{E}\right)^{1/2}$	$C_p = 0.41\frac{B_p}{D_p}$
3. Compression in round tubes under axial end load	$B_t = F_{cy}\left[1 + \frac{(F_{cy})^{1/5}}{8.7}\right]$	$D_t = \frac{B_t}{4.5}\left(\frac{B_t}{E}\right)^{1/3}$	C_t *
4. Compressive bending stress in solid rectangular bars	$B_b = 1.3F_{cy}\left[1 + \frac{(F_{cy})^{1/3}}{7}\right]$	$D_b = \frac{B_b}{20}\left(\frac{6B_b}{E}\right)^{1/2}$	$C_b = \frac{2B_b}{3D_b}$
5. Compressive bending stress in round tubes	$B_{tb} = 1.5F_y\left[1 + \frac{(F_y)^{1/5}}{8.7}\right]$	$D_{tb} = \frac{B_{tb}}{2.7}\left(\frac{B_{tb}}{E}\right)^{1/3}$	$C_{tb} = \left(\frac{B_{tb} - B_t}{D_{tb} - D_t}\right)^2$
6. Shear stress in flat plates	$B_s = F_{sy}\left[1 + \frac{(F_{sy})^{1/3}}{9.3}\right]$	$D_s = \frac{B_s}{10}\left(\frac{B_s}{E}\right)^{1/2}$	$C_s = 0.41\frac{B_s}{D_s}$
7. Crippling of flat plates in compression	$k_1 = 0.35$	$k_2 = 2.27$	
8. Crippling of flat plates in bending	$k_1 = 0.50$	$k_2 = 2.04$	

*C_t can be found from a plot of the curves of allowable stress based on elastic and inelastic buckling or by a trial-and-error solution.

Division II—DESIGN STANDARD FOR ALUMINUM STRUCTURES
Based on Specifications for Aluminum Structures of The Aluminum Association (December, 1986)

SECTION 2005 — SCOPE

This standard covers design of aluminum alloy load-carrying members.

SECTION 2006 — MATERIALS

The principal materials to which this standard applies are aluminum alloys registered with The Aluminum Association. Those frequently used for structural members are listed in Table 20-II-A. Applicable American Society for Testing and Materials (ASTM) specifications are designations B 209, B 210, B 211, B 221, B 241, B 247, B 308 and B 429.

SECTION 2007 — DESIGN

Design shall be in accordance with Division I and other applicable provisions of this code.

Properties of section, such as cross-sectional area, moment of inertia, section modulus, radius of gyration, etc., shall be determined by accepted methods of engineering design. Computations of forces, moments, stresses and deflection shall be in accordance with accepted principles of elastic structural analyses.

SECTION 2008 — ALLOWABLE STRESSES

Allowable stresses shall be determined in accordance with the provisions of Division I.

SECTION 2009 — SPECIAL DESIGN RULES

2009.1 Combined Compression and Bending. A member subjected to axial compression and carrying a bending moment due to lateral or eccentric loads shall be proportioned in accordance with the following formulas:

1. Bending moment at center equal to or greater than 0.9 of maximum bending moment in span:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b(1 - f_a/F_{ec})} \le 1$$

2. Bending moment at center equal to or less than 0.5 of maximum bending moment in span:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \le 1$$

3. Bending moment at center between 0.5 and 0.9 maximum bending moment in span:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b\left[1 - \left(\frac{2M_c}{M_m} - 1\right)\frac{f_a}{F_{ec}}\right]} \le 1$$

WHERE:

M_c = bending moment at center of span.

M_m = maximum bending moment in span.

2009.2 Torsion and Shear in Tubes. Allowable shear stresses in round or oval tubes due to torsion or transverse shear loads shall be determined from Specification 20 in Table 20-I-C with the ratio *h/t* replaced by an equivalent *h/t* given by the following:

$$\text{Equivalent } \frac{h}{t} = 2.9\left(\frac{R}{t}\right)^{5/8}\left(\frac{L_t}{R}\right)^{1/4}$$

WHERE:

L_t = length of tube between circumferential stiffeners, inches (mm). Equivalent (*h/t*) = value to be substituted for *h/t* in Specification 20 in Table 20-I-C.

2009.3 Combined Shear, Compression and Bending. Allowable combinations of shear, compression and bending, as in the web of a beam column or the wall of a tube, shall be determined from the following formula:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} + \left(\frac{f_s}{F_s}\right)^2 \le 1.0$$

2009.4 Stiffeners for Outstanding Flanges. Outstanding flanges stiffened by lips or bulbs at the free edge shall be considered as supported on both edges if the radius of gyration of the lip or bulb meets the following requirement:

$$r_L = \frac{b}{5}$$

For simple rectangular lips having the same thickness as the flange, as in the case of formed sheet construction, the preceding requirement can be expressed as:

$$b_L = b/3$$

WHERE:

b_L = clear width of lip, inches (mm).

Allowable stresses for flanges with lips or bulbs meeting the foregoing requirements shall be determined from Specifications 15 and 16 in Table 20-I-C. The area of stiffening lips or bulbs may be included with the area of the rest of the section in calculating the stresses caused by the loads.

2009.5 Horizontal Stiffeners for Shear Webs. If a horizontal stiffener is used on a beam web, it shall be located so that the distance from the toe of the compression flange to the centroid of the stiffener is 0.4 of the distance from the toe of the compression flange to the toe of the tension flange. The horizontal stiffener shall have a moment of inertia about the web of the beam not less than that given by the expression:

$$I_h = 2_\alpha f th^3\left[\left(1 + \frac{6A_h}{ht}\right)\left(\frac{s}{h}\right)^2 + 0.4\right]10^{-6}$$

For **SI:** 1 inch^4 = 416 231 mm^4.

WHERE:

A_h = gross area of cross section of horizontal stiffener, inches^2.

α = 1, for stiffener consisting of equal members on both sides of the web.

α = 3.5, for stiffener consisting of member on only one side of web.

For stiffener consisting of equal members on both sides of the web, the moment of inertia, I_h, shall be the sum of the moments of inertia about the center line of the web. For a stiffener consisting of a member on one side only, the moment of inertia shall be taken about the face of the web in contact with the stiffener.

2009.6 Vertical Stiffeners for Shear Webs. Stiffeners applied to beam webs to resist shear buckling shall have a moment of inertia not less than the value given by the following expressions:

$$\frac{s}{h} \le 0.4, \quad I_s = \frac{n_a Vh^2}{22,400}\left(\frac{s}{h}\right)$$

For **SI:** 1 inch^4 = 416 231 mm^4.

$$\frac{s}{h} \geq 0.4, \quad I_s = \frac{n_a Vh^2}{140,000}\left(\frac{h}{s}\right)$$

For **SI:** 1 inch^4 = 416 231 mm^4.

When a stiffener is composed of a pair of members, one on each side of the web, the stiffener spacing, *s,* shall be the clear distance between the pairs of stiffeners. When a stiffener is composed of a member on one side only of the web, the stiffener spacing, *s,* shall be the distance between rivet lines or other connecting lines.

For a stiffener composed of members of equal size on each side of the web, the moment of inertia of the stiffener shall be computed about the center line of the web. For a stiffener composed of a member on one side only of the web, the moment of inertia of the stiffener shall be computed about the face of the web in contact with the stiffener.

In the determination of the required moment of inertia of stiffeners, the distance, *h,* shall always be taken as the full clear height of the web regardless of whether or not a horizontal stiffener is present.

Stiffeners shall extend from flange to flange but need not be connected to either flange.

Unless the outer edge of a stiffener is continuously stiffened, its thickness shall not be less than one twelfth the clear width of the outstanding leg.

Vertical stiffeners shall, where possible, be placed in pairs at end bearings and at points of support of concentrated loads. They shall be connected to the web by enough rivets, or other means, to transmit the load. Such stiffeners shall be fitted to form a tight and uniform bearing against the loaded flanges unless welds, designed to transmit the full reaction or load, are provided between flange and stiffener.

Only that part of a stiffener cross section which lies outside the fillet of the flange angle shall be considered as effective in bearing. Bearing stiffeners shall not be joggled.

The moment of inertia of the bearing stiffener shall not be less than that given by the following expression:

$$I_b = I_s + \frac{Ph^2 n_u}{\pi^2 E}$$

For **SI:** 1 inch^4 = 416 231 mm^4.

WHERE:

I_b = required moment of inertia of bearing stiffener, inches^4 (mm^4).

2009.7 Special Provisions for Thin Sections.

2009.7.1 Appearance of buckling. For very thin sections the allowable compressive stresses given in Specifications 9, 15, 16, 18 and 19 of Table 20-I-C may result in visible local buckling, even though an adequate margin of safety is provided against ultimate failure. In applications where any appearance of buckling must be avoided, the allowable stresses for thin sections shall not exceed the value of F_{ab} given by the following formulas:

SPECIFICATION	ALLOWABLE STRESS, F_{ab} ksi (MPa)
9, 16	$F_{ab} = \frac{\pi^2 E}{n_a(1.6b/t)^2}$
15	$F_{ab} = \frac{\pi^2 E}{n_a(5.1b/t)^2}$
18	$F_{ab} = \frac{\pi^2 E}{n_a(0.67h/t)^2}$
19	$F_{ab} = \frac{\pi^2 E}{n_a(0.29h/t)^2}$

2009.7.2 Weighted average allowable compressive stress. The cross section of a compression member may be composed of several thin elements, for which allowable stresses are determined by Specification 8, 9 or 10 of Table 20-I-C. The allowable compressive stress for the section as a whole may be considered to be the weighted average allowable stress for the individual elements, where the allowable stress for each element is weighted in accordance with the ratio of the area of the element to the total area of the section. The allowable compressive stress for the section as a whole used as a column must not exceed that given by Specification 7 of Table 20-I-C.

Weighted average allowable compressive stresses for beam flanges may be calculated in the same way, where the allowable stresses for individual elements are determined from Specifications 15 through 19 of Table 20-I-C. The beam flange may be considered to consist of the flange proper plus one sixth of the area of the web or webs.

2009.7.3 Trapezoidal-formed sheet beams. The weighted average allowable compressive stress for a trapezoidal-formed sheet beam, calculated according to paragraph 2, is:

$$F_{ba} = \frac{F_{bf} + F_{bh}\left(\frac{h}{3b}\right)}{1 + \frac{h}{3b}}$$

WHERE:

F_{ba} = weighted average allowable compressive stress for beam flange, ksi (MPa).

F_{bf} = allowable stress for flange proper based on Specification 16 of Table 20-I-C.

F_{bh} = allowable stress for webs based on Specification 18 or 19 of Table 20-I-C.

The foregoing formula may also be applied to the allowable tensile stress in trapezoidal-formed sheet beams, if the designer wishes to take full advantage of the strength of the section. In this case, F_{ba} is the weighted average allowable tensile stress, F_{bf} is determined from Specification 2 in Table 20-I-C, and F_{bh} is given by Specification 4 in Table 20-I-C.

In regions of negative bending moment (for example, at interior supports of multiple-span beams) the allowable tensile stress on the tension flange of a formed sheet beam shall not exceed the compressive stress that would be allowed on the same flange if it were in compression.

2009.7.4 Effect of local buckling on column strength. An additional limitation must be placed on the allowable stress for very thin-walled columns whose cross section is a rectangular tube or a formed sheet shape such that the flanges consist of flat elements supported on both edges. If the *b/t* for the flange of such a column is less than the value of S_2 in Specification 9 of Table 20-I-C, or less than 0.6 of the maximum slenderness ratio (*L/r*) for the column, no additional reduction in allowable stress is necessary. However, if the maximum *b/t* for the flange is greater than the value of S_2 from Specification 9 of Table 20-I-C, and also greater than 0.6 of the maximum slenderness ratio for the column, the allowable column stress shall not exceed the value given by

$$F_{rc} = \frac{\pi^2 E}{n_u (L/r)^{2/3} (1.6b/t)^{4/3}}$$

WHERE:

F_{rc} = reduced allowable stress on column, ksi.

The allowable stress shall also not exceed the value given by Specification 9 of Table 20-I-C.

2009.7.5 Effect of local buckling on beam strength. The allowable compressive bending stress for single web beams whose flanges consist of thin, flat elements supported on one edge shall also be reduced in the case where the value of *b/t* for the flange is greater than the value of S_2 from Specification 15 of Table 20-I-C, and also greater than 0.16 (L_b/r_y). In this case, the allowable beam stress shall not exceed

$$F_{rb} = \frac{\pi^2 E}{n_u\,(L_b/1.2r_y)^{2/3}\,(5.1b/t)^{4/3}}$$

WHERE:

F_{rb} = reduced allowable compressive bending stress in beam flange, ksi.

L_b/r_y = slenderness ratio for beam.

2009.7.6 Effective width for calculation of deflection of thin gage sections. As noted in paragraph 1, the allowable compressive stresses given in Specifications 9, 15, 16, 18 and 19 of Table 20-I-C may result in some local buckling at design loads for very thin sections even though an adequate margin of safety is provided against ultimate failure. This local buckling may result in increased deflections for sections containing thin elements with *b/t* value exceeding 1.65 S_2, where the value of S_2 is obtained for the element in question from Specifications 9, 15, 16, 18 and 19 of Table 20-I-C.

Where deflection at design loads is critical, the effective width concept may be used to determine an effective section to be used in deflection calculations. The effective width, b_e, of a thin element subjected to direct compression stresses is:

$$\text{If } f_a \le n_a F_{ab}, \quad b_e = b$$

$$\text{If } f_a > n_a F_{ab}, \quad b_e = b\sqrt{n_a F_{ab}/f_a}$$

WHERE:

b_e = effective width of flat plate element to be used in deflection calculations, inches (mm).

F_{ab} = allowable stress for element from Subsection (g), ksi (MPa).

The same expression may be used to calculate the effective width on the compression side of a web in bending, with the compressive bending stress due to the applied loads, f_b, replacing f_a.

2009.7.7 Web crippling. For structural formed sheet roofing and siding, allowable interior reactions and concentrated loads for flat webs shall not exceed

$$P_c = 600\frac{F_{cy}\,dt^2}{w}\left(6 + 0.04\frac{N}{t}\right)$$

$$\left[1.1 - 0.1\left(\frac{\theta}{90}\right)\sqrt{\frac{r}{t}}\right] \text{ for } \frac{w}{t} \le C_p$$

$$\text{and } P_c = 1{,}500\,Ed\,(N + w)\left(\frac{t}{w}\right)^3 \text{ for } \frac{w}{t} > C_p$$

$$\text{in which } C_p = \frac{2.5E\left(\frac{N}{w} + 1\right)}{F_{cy}\left(6 + 0.04\,\frac{N}{t}\right)\left[1.1 - 0.1\left(\frac{\theta}{90}\right)\sqrt{\frac{r}{t}}\right]}$$

Allowable end reactions shall not exceed

$$P_c = 600\frac{F_{cy}\,dt^2}{w}\left(3 + 0.04\frac{N}{t}\right)$$

$$\left[1.1 - 0.1\left(\frac{\theta}{90}\right)\sqrt{\frac{r}{t}}\right] \text{for } \frac{w}{t} \le C_p$$

$$\text{and } P_c = 1{,}500\,Ed\,(N + \frac{w}{2})\left(\frac{t}{w}\right)^3 \text{ for } \frac{w}{t} > C_p$$

$$\text{in which } C_p = \frac{1.25E\left(\frac{2N}{w} + 1\right)}{F_{cy}\left(3 + 0.04\,\frac{N}{t}\right)\left[1.1 - 0.1\left(\frac{\theta}{90}\right)\sqrt{\frac{r}{t}}\right]}$$

WHERE:

d = depth (vertical projection), inches (mm).

F_{cy} = minimum compressive yield strength of sheet, in kips per square inch (MPa).

N = length of bearing at reaction or concentrated load, inches (mm).

P_c = allowable reaction or concentrated load per web, pounds (N).

r = bend radius at juncture of flange and web of trapezoidal section, measured to inside surface of bend, inches (mm).

t = sheet thickness, inches (mm).

w = slope width of web (shear element spanning between flats) of trapezoidal section, inches (mm).

θ = angle between plane of web of trapezoidal section and plane of bearing surface ($\theta \le 90$), degrees.

2009.8 Fatigue. For up to 100,000 repetitions of maximum live load, if nonwelded, and 20,000 repetitions of maximum live load if welded, allowable stresses shall be determined in accordance with Table 20-I-C and Section 2010.1 provided that the structural members are free of re-entrant corners and other unusual stress raisers. For repetitions of loads in excess of these values, allowable stresses shall be determined by a special analysis.

2009.9 Compression in Single-web Beams. The formulas of Specification 11 of Table 20-I-C for single-web beams and girders, are based on an approximation in which the term L_b/r_y replaces a more complicated expression involving several different properties of the beam cross section. Because of this approximation, the formulas give very conservative results for certain conditions, namely for values of L_b/r_y exceeding about 50; for load distributions such that the bending moment near the center of the beam is appreciably less than the maximum bending moment in the beam; and for beams with transverse loads applied to the bottom flange. If the designer wishes to compute more precise values of allowable compressive stress for these cases, the value of r_y in Specification 11 of Table 20-I-C may be replaced by an "effective r_y" given by one of the following formulas:

Beam spans subjected to end moment only or to transverse loads applied at the neutral axis of the beam:

$$\text{Effective } r_y = \frac{k_b}{1.7}\sqrt{\frac{I_y d}{S_c}\sqrt{1 + 0.152\,\frac{J}{I_y}\left(\frac{L_b}{d}\right)^2}}$$

For **SI:** 1 inch = 25.4 mm.

Beams subjected to transverse loads applied on the top or bottom flange (where the load is free to move laterally with the beam if the beam should buckle):

Effective r_y =

$$\frac{k_b}{1.7}\sqrt{\frac{I_y d}{S_c}\left[\pm\,0.5 + \sqrt{1.25 + 0.152\,\frac{J}{I_y}\left(\frac{L_b}{d}\right)^2}\right]}$$

For **SI:** 1 inch = 25.4 mm.

The plus sign in front of the term “0.5” applies if the load is on the bottom flange, the minus sign if the load is on the top flange.

Effective r_y = value to be substituted for r_y in Specification 11 of Table 20-I-C.

The terms appearing in the above formulas are defined in this code.

Values of the coefficient, k_b, follow:

BEAMS RESTRAINED AGAINST LATERAL DISPLACEMENT AT BOTH ENDS OF SPAN	VALUE OF COEFFCIENT k_b
Uniform bending moment, uniform transverse load, or two equal concentrated loads equidistant from the center of the span	1.00
Bending moment varying uniformly from a value of M_1 at one end to M_2 at the other end	
M_1/M_2 = 0.5	1.14
M_1/M_2 = 0	1.33
M_1/M_2 = – 0.5	1.53
M_1/M_2 = – 1.0	1.60
Concentrated load at center of span	1.16
CANTILEVER BEAMS	
Concentrated load at end of span	1.13
Uniform transverse load	1.43

2009.10 Compression in Elastically Supported Flanges. Allowable compressive stresses in elastically supported flanges, such as the compression flange of a standing seam roof or of a hat-shaped beam loaded with the two flanges in compression, shall be determined from Specification No. 11 with the following effective value of L_b/r_y substituted in the formulas for allowable stress.

$$\text{Effective } \frac{L_b}{r_y} = 2.7\sqrt[4]{\frac{EA_c^2}{\beta I_{yc}}}$$

WHERE:

β = spring constant [transverse force in kips applied to a 1-inch (25.4 mm) length of the member at the compression flange to cause a 1-inch (25.4 mm) deflection of the flange], ksi (MPa).

SECTION 2010 — MECHANICAL CONNECTIONS

2010.1 Riveted and Bolted Connections. Aluminum alloys used for rivets and bolts shall be those listed in Table 20-I-A. Nuts for $^1/_4$-inch (6.4 mm) bolts and smaller shall be 2024-T4. Nuts for larger diameter bolts shall be alloy 6061-T6 or 6262-T9. Flat washers shall be Alclad 2024-T4. Spring lock washers shall be alloy 7075-T6. For improved corrosion resistance, a 0.0002-inch (0.005 mm) minimum thickness anodic coating may be applied to alloy 2024 bolts.

2010.1.1 Allowable loads. The allowable loads on rivets and bolts shall be calculated using the allowable bearing stresses in Table 20-I-C and the allowable shear stresses in Table 20-I-A. The allowable bearing stress depends on the ratio of edge distance to rivet or bolt diameter where the edge distance is the distance from the center of the rivet or bolt to the edge of the load-carrying member toward which the pressure of the rivet or bolt is directed.

Allowable bearing stresses on bolts apply to either threaded or unthreaded surfaces.

2010.1.2 Effective diameter. The effective diameter of rivets shall be taken as the hole diameter, but shall not exceed the nominal diameter of the rivet by 4 percent for cold driven rivets and 7 percent for hot driven rivets. The effective diameter of bolts shall be taken as the nominal diameter of the bolt.

2010.1.3 Shear area. The effective area of a rivet or bolt in any shear plane shall be based on the effective diameter except that for bolts with threads included in the shear plane, the effective shear area shall be based on the root diameter.

2010.1.4 Bearing area. The effective bearing area of rivets or bolts shall be the effective diameter multiplied by the length in bearing except that for countersunk rivets, half of the depth of the countersink shall be deducted from the length.

2010.1.5 Arrangements and strength of connections. Insofar as possible, connections shall be arranged so that the center of resistance of the connection shall coincide with the resultant line of action of the load. Where eccentricity exists, members and connections shall be proportioned to take into account any eccentricity of loading at the connections.

2010.1.6 Net section. The net section of a riveted or bolted tension member shall be determined as the sum of the net sections of its component parts. The net section of a part is the product of the thickness of the part multiplied by its least net width. The net width for a chain of holes extending across the part in any straight or broken line shall be obtained by deducting from the gross width the sum of the diameters of all the holes in the chain and adding $s^2/4g$ for each gage space in the chain. In the correction quantity $s^2/4g$, s denotes spacing parallel to the direction of the load (pitch) of any two successive holes in the chain, in inches, and g refers to gage, the spacing perpendicular to the direction of the load of the same holes, in inches (mm).

The net section of the part shall be obtained from that chain which gives the least net width. The hole diameter to be deducted shall be the actual hole diameter for drilled or reamed holes and the hole diameter plus $^1/_{32}$ inch (0.794 mm) for punched holes.

For angles, the gross width shall be the sum of the widths of the legs less the thickness. The gage for holes in opposite legs shall be the sum of the gages from the back of the angles less the thickness.

For splice members, the thickness shall be only that part of the thickness of the member that has been developed by rivets or bolts, beyond the section considered.

2010.1.7 Effective sections of angles. If a discontinuous angle (single or paired) in tension is connected to one side of a gusset plate, the effective net section shall be the net section of the connected leg plus one third of the section of the outstanding leg unless the outstanding leg is connected by a lug angle. In the latter case, the effective net section shall be the entire net section of the angle. The lug angle shall be designed to develop at least one half the total load in the member and shall be connected to the main member by at least two fasteners.

For double angles placed back to back and connected to both sides of a gusset plate, the effective net section shall be the net section of the connected legs plus two thirds of the section of the outstanding legs.

For intermediate joints of continuous angles, the effective net area shall be the gross sectional area less deductions for holes.

2010.1.8 Grip of rivets and bolts. If the grip (total thickness of metal being fastened) of rivets or bolts carrying calculated stress exceeds four and one-half times the diameter, the allowable load per rivet or bolt shall be reduced. The reduced allowable load shall be the normal allowable load divided by [$^1/_2 + G/(9D)$] in which G is the grip and D is the nominal diameter of the rivet or bolt. If the grip of the rivet exceeds six times the diameter, special care shall be taken to ensure that holes will be filled completely.

2010.1.9 Spacing of rivets and bolts. Minimum distance of rivet centers shall be three times the nominal rivet diameter; minimum distance of bolt centers shall be two and one-half times the nominal bolt diameter. In built-up compression members, the pitch in the direction of stress shall be such that the allowable stress on the individual outside sheets and shapes treated as columns having a length equal to the rivet or bolt pitch exceeds the calculated stress. The gage at right angles to the direction of stress shall be such that the allowable stress in the outside sheets, calculated from Specification 9 of Table 20-I-C exceeds the calculated stress. In this case the width, *b*, may be taken as 0.8*s* where *s* is the gage in inches (mm).

2010.1.10 Stitch rivets and bolts. Where two or more web plates are in contact, there shall be stitch rivets or bolts to make them act in unison. In compression members, the pitch and gage of such rivets or bolts shall be determined as outlined in paragraph 9. In tension members, the maximum pitch or gage of such rivets or bolts shall not exceed a distance, in inches, equal to $(3 + 20t)$ in which t is the thickness of the outside plates, in inches (mm).

2010.1.11 Edge distance of rivets or bolts. The distance from the center of rivet or bolt under computed stress to the edge of the sheet or shape toward which the pressure is directed shall be twice the nominal diameter of the rivet or bolt. When a shorter edge distance is used, the allowable bearing stress as determined by Table 20-I-C shall be reduced by the ratio: actual edge distance/twice rivet or bolt diameter. The edge distance shall not be less than 1.5 times the rivet or bolt diameter to sheared, sawed, rolled or planed edges.

2010.1.12 Blind rivets. Blind rivets may be used only when the grip lengths and rivethole tolerances are as recommended by the respective manufacturers.

2010.1.13 Hollow-end rivets. If hollow-end rivets with solid cross sections for a portion of the length are used, the strength of these rivets may be taken equal to the strength of solid rivets of the same material, provided that the bottom of the cavity is at least 25 percent of the rivet diameter from the plane of shear as measured toward the hollow end; and, further, provided that they are used in locations where they will not be subjected to appreciable tensile stresses.

2010.1.14 Lock bolts. Lock bolts may be used when installed in conformance with the lock bolt manufacturer's recommended practices and provided the body diameter and bearing areas under the head and nut, or their equivalent, are not less than those of a conventional nut and bolt.

2010.2 Thread Forming (Tapping) Screws and Metal Stitching Staples. If joints carrying calculated loads are to be made with thread-forming screws or metal stitches, allowable strength values for these connections shall be established on the basis of specific acceptable tests.

2010.3 Fasteners for Structural Formed Sheet Roofing and Siding.

2010.3.1 General. Fasteners shall have tensile and tensile anchorage strengths in resisting back loads, or uplift, in excess of the strength of the connection between fastener and sheet.

2010.3.2 Allowable loads for fasteners. The allowable tensile load per fastener shall be:

P_t = (1/2.2) × (minimum strength of connection between fastener and sheet).

2010.3.3 Allowable loads for specific fasteners. The allowable loads for the specific fasteners listed, expressed in pounds (N), shall be used unless other allowable loads can be justified. Allowable loads for fasteners not listed shall be based on the results of tests and shall comply with the provisions of Sections 2010.3.1 and 2010.3.2 above.

1. No. 14 stainless steel alloy self-tapping screws, hex head, cadmium plated, with composite aluminum-neoprene washer, the aluminum portion of which has minimum dimensions of 0.050-inch (1.27 mm) thickness and $^5/_8$-inch (16 mm) OD, or with a stainless steel neoprene washer, the stainless steel portion of which has minimum dimensions of 0.038-inch (0.965 mm) (No. 20 gage) thickness and $^5/_8$-inch (16 mm) OD. In crowns,

$$P_t = 140t\,F_{ty}$$

For **SI:** $$P_t = 3.56t\,F_{ty}$$

and in valleys,

$$P_t = 170t\,F_{ty}$$

For **SI:** $$P_t = 4.32t\,F_{ty}$$

For steel supporting members, screw holes should be made with a No. 8 drill for No. 14-gage through No. 11-gage material, a No. 4 drill for No. 10-gage up to $^3/_{16}$ inch (4.76 mm) and a No. 1 drill for $^3/_{16}$ inch (4.76 mm) and thicker.

2. Stainless steel alloy welded studs, $^5/_{16}$-inch-diameter (7.9 mm) base, $^3/_{16}$-inch-diameter (4.76 mm) serrated top, with field-installed swaged aluminum cap of $^1/_2$-inch (13 mm) diameter,

$$P_t = 230$$

For **SI:** $$P_t = 1023\ N$$

SECTION 2011 — FABRICATION

2011.1 Laying Out. Hole centers may be center punched and cutoff lines may be punched or scribed. Center punching and scribing shall not be used where such marks would remain on fabricated material.

A temperature correction shall be applied where necessary in the layout of critical dimensions. The coefficient of expansion shall be taken as 0.000013 per °F (0.0000072 per °C).

2011.2 Cutting. Material may be sheared, sawed, cut with a router or arc cut. All edges which have been cut by the arc process shall be planed to remove edge cracks.

Cut edges shall be true, smooth and free from excessive burrs or ragged breaks.

Re-entrant cuts shall be avoided wherever possible. If used, they shall be filleted by drilling prior to cutting.

Oxygen cutting of aluminum alloys shall not be permitted.

2011.3 Heating. Structural material shall not be heated.

> **EXCEPTION:** Material may be heated to a temperature not exceeding 400°F (204°C) for a period not exceeding 30 minutes in order to facilitate bending. Such heating shall be done only when proper temperature controls and supervision are provided to ensure that the limitations on temperature and time are carefully observed.

2011.4 Punching, Drilling and Reaming. The following rules for punching, drilling and reaming shall be observed:

1. Rivet or bolt holes may be either punched or drilled. Punching shall not be used if the metal thickness is greater than the diameter of the hole. The amount by which the diameter of a sub-punched hole is less than that of the finished hole shall be at least one fourth the thickness of the piece and in no case less than $^1/_{32}$ inch (0.8 mm).

2. The finished diameter of holes for cold-driven rivets shall not be more than 4 percent greater than the nominal diameter of the rivet.

3. The finished diameter of holes for hot-driven rivets shall not be more than 7 percent greater than the nominal diameter of the rivet.

4. The finished diameter of holes for bolts shall not be more than $^1/_{16}$ inch (1.6 mm) larger than the nominal bolt diameter.

5. If any holes must be enlarged to admit the rivets or bolts, they shall be reamed. Poor matching of holes shall be cause for rejection. Holes shall not be drifted in such a manner as to distort the metal. All chips lodged between contacting surfaces shall be removed before assembly.

2011.5 Riveting.

2011.5.1 Driven head. The driven head of aluminum alloy rivets shall be of the flat or the cone-point type with dimensions as follows:

1. Flat heads shall have a diameter not less than 1.4 times the nominal rivet diameter and a height not less than 0.4 times the nominal rivet diameter.

2. Cone-point heads shall have a diameter not less than 1.4 times the nominal rivet diameter and a height to the apex of the cone not less than 0.65 times the nominal rivet diameter. The included angle at the apex of the cone shall be approximately 127 degrees.

2011.5.2 Hole filling. Rivets shall fill holes completely. Rivet heads shall be concentric with the rivet holes and shall be in proper contact with the surface of the metal.

2011.5.3 Defective rivets. Defective rivets shall be removed by drilling.

2011.6 Painting.

2011.6.1 General. Structures of the alloys covered by these standards are not ordinarily painted (with the exception of 2014-T6 when exposed to corrosive environments). Surfaces shall be painted where:

1. The aluminum alloy parts are in contact with, or are fastened to, steel members or other dissimilar materials.

2. The structures are to be exposed to extremely corrosive conditions, or for reason of appearance. Painting procedure is covered in the following paragraphs and methods of cleaning and preparation are found in Section 2011.7. (Treatment and painting of the structure in accordance with United States Military Specification MIL-T-704 is also acceptable.)

2011.6.2 Contact with dissimilar materials. Where the aluminum alloy parts are in contact with, or are fastened to, steel members or other dissimilar materials, the aluminum shall be kept from direct contact with the steel or other dissimilar material by painting as follows:

1. Aluminum surfaces to be placed in contact with steel shall be given one coat of zinc chromate primer in accordance with Federal Specification TT-P-645 or the equivalent, or one coat of a suitable nonhardening joint compound capable of excluding moisture from the joint during prolonged service. Where severe corrosion conditions are expected, additional protection can be obtained by applying the joint compound in addition to the zinc chromate primer. Zinc chromate paint shall be allowed to dry hard (air dry 24 hours) before assembly of the parts. The steel surfaces to be placed in contact with aluminum shall be painted with good quality priming paint, such as zinc chromate primer in accordance with Federal Specification TT-P-645, followed by one coat of paint consisting of 2 pounds of aluminum paste pigment (ASTM Specification D 96266, Type 2, Class B) per gallon (0.24 kg/L) of varnish meeting Federal Specification TT-V-81d, Type II, or the equivalent. Stainless steel, or aluminized, hot-dip galvanized or electrogalvanized steel placed in contact with aluminum need not be painted.

2. When aluminum is in direct contact with wood, fiberboard or other porous material that may absorb water, an insulating barrier shall be installed between the aluminum and the porous material. Such aluminum surfaces shall be given a heavy coat of alkali-resistant bituminous paint or other coating providing equivalent protection before installation. Aluminum in contact with concrete or masonry shall be similarly protected in cases where moisture is present and corrodents can be entrapped between the surfaces.

3. Aluminum surfaces to be embedded in concrete ordinarily need not be painted, unless corrosive components are added to the concrete or unless the concrete is subjected for extended periods to extremely corrosive conditions. In such cases, aluminum surfaces shall be given one coat of suitable quality paint, such as zinc chromate primer conforming to Federal Specification TT-P-645 or equivalent, or shall be wrapped with a suitable plastic tape applied in such a manner as to provide adequate protection at the overlap.

4. Water that comes in contact with aluminum after first running over a heavy metal such as copper may contain trace quantities of the dissimilar metal or its corrosion product, which will cause corrosion of the aluminum. Protection shall be obtained by painting or plastic coating the dissimilar metal or by designing the structure so that the drainage from the dissimilar metal is diverted away from the aluminum.

2011.6.3 Overall painting. Structures of the alloys covered by this standard are either not ordinarily painted for surface protection (with the exception of 2014-T6 when exposed to corrosive environments) or are made of prepainted aluminum components. There may be applications where the structures are to be exposed to extremely corrosive conditions. In these cases overall painting shall be specified.

2011.7 Cleaning and Treatment of Metal Surfaces. Prior to field painting of structures, all surfaces to be painted shall be cleaned immediately before painting by a method that will remove all dirt, oil, grease, chips and other foreign substances.

Exposed metal surfaces shall be cleaned with a suitable chemical cleaner such as a solution of phosphoric acid and organic solvents meeting United States Military Specification MIL-M-10578. If the metal is more than $^1/_8$ inch (3.2 mm) thick, sandblasting may be used.

SECTION 2012 — WELDED CONSTRUCTION

2012.1 Filler Wire. Verification shall be provided to show that the choice of filler metal for general purpose welding is appropriate.

2012.2 Columns and Single-web Beams with Welds at Locations Other than Ends and Cantilever Columns and Single-web Beams. The allowable stresses determined in accordance with the provisions of Division I apply to members supported at both ends with welds at the ends only (not farther from the supports than 0.05 L from the ends).

For columns with transverse welds at locations other than the supports, cantilever columns with transverse welds at or near the supported end and columns with longitudinal welds having A_w equal to or greater than 15 percent of A, the effect of welding on column strength shall be taken into account by using an increased slenderness ratio, L_w/r, in the column formula, as follows:

$$\text{If } \frac{L}{r} > \sqrt{\frac{250,000}{F_{cyw}}}\ ; \ \frac{L_w}{r} = \frac{L}{r}$$

For **SI:** If $\frac{L}{r} > \sqrt{\frac{24.4E}{F_{cyw}}}$; $\frac{L_w}{r} = \frac{L}{r}$

If $\frac{L}{r} \leq \sqrt{\frac{250,000}{F_{cyw}}}$;

For **SI:** If $\frac{L}{r} \leq \sqrt{\frac{24.4E}{F_{cyw}}}$;

$$\frac{L_w}{r} = \frac{L}{r}\sqrt{\frac{1 + 100\frac{L_h}{L}}{1 + \left(\frac{L_h}{L}\right)\left(\frac{L}{r}\right)^2\left(\frac{F_{cyw}}{2500}\right)}}$$

For **SI:**
$$\frac{L_w}{r} = \frac{L}{r}\sqrt{\frac{1 + 100\frac{L_h}{L}}{1 + \left(\frac{L_h}{L}\right)\left(\frac{L}{r}\right)^2\left(\frac{4.1F_{cyw}}{E}\right)}}$$

The above formulas assume that the entire cross section within the length, L_h, is affected by the heat of welding. If only part of the cross section is so affected, the allowable stress based on L_w/r shall be substituted for F_w in the formula in Section 2002.2.

2012.3 Welding Fabrication. Welding of aluminum shall be in accordance with approved nationally recognized standards.

SECTION 2013 — TESTING

2013.1 General. Testing shall be considered an acceptable method for substantiating the design of aluminum alloy load-carrying members. Tests shall be conducted by an independent testing laboratory or by a manufacturer's testing laboratory.

2013.2 Test Loading and Behavior. In order to test a structure or load-carrying member adequately, the loading shall be applied in a fashion that reasonably approximates the application of the loading during service. Further, the structure or member shall be supported in a manner that is no more sustaining to the structure than the supports available will be when the structure is in service.

Determination of allowable load-carrying capacity shall be made on the basis that the member, assembly or connection shall be capable of sustaining during the test without failure a total load, including the weight of the test specimen, equal to twice the live load plus one and one-half the dead load. Furthermore, harmful local distortions shall not develop during the test at a total load, including the weight of the test specimen, equal to the dead load plus one and one-half times the live load.

The factors by which the design live and dead loads are multiplied to determine the test loads are reduced to three fourths of the values given in the preceding paragraph when wind or seismic forces represent all or a portion of the live load, provided the structure or member meets the test requirements with the full load factors applied to the dead load and to that portion of the live load not attributable to wind or seismic forces.

Differences that may exist between nominal section properties and those of tested sections shall be considered.

TABLE 20-II-A—MINIMUM MECHANICAL PROPERTIES FOR ALUMINUM ALLOYS
Values Are Given in Units of ksi (1,000 lb/in^2)

ALLOY AND TEMPER	PRODUCT[1]	THICKNESS RANGE[1] (inch)	TENSION[2]		COMPRESSION	SHEAR		BEARING		COMPRESSIVE MODULUS OF ELASTICITY[3]
			F_{tu} ksi	F_{ty} ksi	F_{cy} ksi	F_{su} ksi	F_{sy} ksi	F_{bu} ksi	F_{by} ksi	E ksi
		× 25.4 for mm	× 6.89 for MPa							
1100-H12	Sheet, plate	All	14	11	10	9	6.5	28	18	10,100
-H14	Rolled rod and bar	All	16	14	13	10	8	32	21	10,100
	Drawn tube									
2014-T6	Sheet	0.040-0.249	66	58	59	40	33	125	93	10,900
-T651	Plate	0.250-2.000	67	59	58	40	34	127	94	10,900
-T6, -T6510[1]	Extrusions	All	60	53	55	35	31	114	85	10,900
-T6, -T651	Rolled rod and bar Drawn tube	All	65	55	53	38	32	124	88	10,900
Alclad										
2014-T6	Sheet	0.020-0.039	63	55	56	38	32	120	88	10,800
-T6	Sheet	0.040-0.249	64	57	58	39	33	122	91	10,800
-T651	Plate	0.250-0.499	64	57	56	39	33	122	91	10,800
3003-H12	Sheet and plate	0.017-2.000	17	12	10	11	7	34	19	10,100
-H14	Sheet and plate	0.009-1.000	20	17	14	12	10	40	25	10,100
-H16	Sheet	0.006-0.162	24	21	18	14	12	46	31	10,100
-H18	Sheet	0.006-0.128	27	24	20	15	14	49	34	10,100
3003-H12	Drawn tube	All	17	12	11	11	7	34	19	10,100
-H14	Drawn tube	All	20	17	16	12	10	40	25	10,100
-H16	Drawn tube	All	24	21	19	14	12	46	31	10,100
-H18	Drawn tube	All	27	24	21	15	14	49	34	10,100
Alclad										
3003-H12	Sheet and plate	0.017-2.000	16	11	9	10	6.5	32	18	10,100
-H14	Sheet and plate	0.009-1.000	19	16	13	12	9	38	24	10,100
-H16	Sheet	0.006-0.162	23	20	17	14	12	44	30	10,100
-H18	Sheet	0.006-0.128	26	23	19	15	13	47	32	10,100
Alclad										
3003-H14	Drawn tube	0.010-0.500	19	16	15	12	9	38	24	10,100
-H18	Drawn Tube	0.010-0.500	26	23	20	15	13	47	32	10,100
3004-H32	Sheet and plate	0.017-2.000	28	21	18	17	12	56	36	10,100
-H34	Sheet and plate	0.009-1.000	32	25	22	19	14	64	40	10,100
-H36	Sheet	0.006-0.162	35	28	25	20	16	70	45	10,100
3004-H34	Drawn tube	0.018-0.450	32	25	24	19	14	64	40	10,100
-H36	Drawn tube	0.018-0.450	35	28	27	20	16	70	45	10,100
Alclad										
3004-H32	Sheet	0.017-0.249	27	20	17	16	12	54	34	10,100
-H34	Sheet	0.009-0.249	31	24	21	18	14	62	38	10,100
-H36	Sheet	0.006-0.162	34	27	24	19	16	68	43	10,100
-H14	Sheet	0.009-0.249	32	26	22	19	15	64	39	10,100
-H16	Sheet	0.006-0.050	35	30	28	20	17	66	45	10,100
-H16	Sheet	0.051-0.162	35	30	26	20	17	66	45	10,100
-H131, -H241, -H341	Sheet	0.024-0.050	31	26	22	18	15	62	39	10,100
-H151, -H261, -H361	Sheet	0.024-0.050	34	30	28	19	17	66	45	10,100
3005-H25	Sheet	0.013-0.050	26	22	20	15	13	49	35	10,100
3006-H391	Sheet	0.010-0.050	31	27	27	20	16	60	44	10,100
3105-H25	Sheet	0.013-0.080	23	19	17	14	11	44	28	10,100
5005-H12	Sheet and plate	0.018-2.000	18	14	13	11	8	34	22	10,100
-H14	Sheet and plate	0.009-1.000	21	17	15	12	10	40	25	10,100
-H16	Sheet	0.006-0.162	24	20	18	14	12	48	30	10,100
-H32	Sheet and plate	0.017-2.000	17	12	11	11	7	34	20	10,100
-H34	Sheet and plate	0.009-1.000	20	15	14	12	8.5	40	24	10,100
-H36	Sheet	0.006-0.162	23	18	16	13	11	48	29	10,100
5050-H32	Sheet	0.017-0.249	22	16	14	14	9	44	27	10,100
-H34	Sheet	0.009-0.249	25	20	18	15	12	50	32	10,100
-H32	Rolled rod and bar Drawn tube	All	22	16	15	13	9	44	27	10,100
-H34	Rolled rod and bar Drawn tube	All	25	20	19	15	12	50	32	10,100
5052-H32	Sheet and plate	All	31	23	21	19	13	60	39	10,200
-H34	Rolled rod and bar	All	34	26	24	20	15	65	44	10,200
	Drawn tube									
-H36	Sheet	0.006-0.162	37	29	26	22	17	70	46	10,200

(Continued)

TABLE 20-II-A—MINIMUM MECHANICAL PROPERTIES FOR ALUMINUM ALLOYS—(Continued)
Values Are Given in Units of ksi (1,000 lb/in^2)

ALLOY AND TEMPER	PRODUCT[1]	THICKNESS RANGE[1] (inch)	TENSION[2]		COMPRESSION	SHEAR		BEARING		COMPRESSIVE MODULUS OF ELASTICITY[3]
			F_{tu} ksi	F_{ty} ksi	F_{cy} ksi	F_{su} ksi	F_{sy} ksi	F_{bu} ksi	F_{by} ksi	E ksi
		× 25.4 for mm	× 6.89 for MPa							
5083-H111	Extrusions	up to 0.500	40	24	21	24	14	78	41	10,400
-H111	Extrusions	0.501 and over	40	24	21	23	14	78	38	10,400
-H321	Sheet and plate	0.188-1.500	44	31	26	26	18	84	53	10,400
-H323	Sheet	0.051-0.249	45	34	32	26	20	88	58	10,400
-H343	Sheet	0.051-0.249	50	39	37	29	23	95	66	10,400
-H321	Plate	1.501-3.000	41	29	24	24	17	78	49	10,400
5086-H111	Extrusions	up to 0.500	36	21	18	21	12	70	36	10,400
-H111	Extrusions	0.501 and over	36	21	18	21	12	70	34	10,400
-H112	Plate	0.250-0.499	36	18	17	22	10	72	31	10,400
-H112	Plate	0.500-1.000	35	16	16	21	9	70	28	10,400
-H112	Plate	1.001-2.000	35	14	15	21	8	70	28	10,400
-H112	Plate	2.001-3.000	34	14	15	21	8	68	28	10,400
-H32	Sheet and plate	All	40	28	26	24	16	78	48	10,400
-H34	Drawn tube	All	44	34	32	26	20	84	58	10,400
5154-H38	Sheet	0.006-0.128	45	35	33	24	20	81	56	10,300
5454-H111	Extrusions	up to 0.500	33	19	16	20	11	64	32	10,400
-H111	Extrusions	0.501 and over	33	19	16	19	11	64	30	10,400
-H112	Extrusions	up to 5.000	31	12	13	19	7	62	24	10,400
-H32	Sheet and plate	0.020-2.000	36	26	24	21	15	70	44	10,400
-H34	Sheet and plate	0.020-1.000	39	29	27	23	17	74	49	10,400
5456-H111	Extrusions	up to 0.500	42	26	22	25	15	82	44	10,400
-H111	Extrusions	0.501 and over	42	26	22	24	15	82	42	10,400
-H112	Extrusions	up to 5.000	41	19	20	24	11	82	38	10,400
-H321	Sheet and plate	0.188-1.250	46	33	27	27	19	87	56	10,400
-H321	Plate	1.251-1.500	44	31	25	25	18	84	53	10,400
-H321	Plate	1.501-3.000	41	29	25	25	17	82	49	10,400
-H323	Sheet	0.051-0.249	48	36	34	28	21	94	61	10,400
-H343	Sheet	0.051-0.249	53	41	39	31	24	101	70	10,400
6005-T5	Extrusions	up to 0.500	38	35	35	24	20	80	56	10,100
6061-T6, -T651	Sheet and plate	0.010-4.000	42	35	35	27	20	88	58	10,100
-T6, -T6510[1]	Extrusions	up to 3.000	38	35	35	24	20	80	56	10,100
-T6, -T651	Rolled rod and bar	up to 8.000	42	35	35	27	20	88	56	10,100
-T6	Drawn tube	0.025-0.500	42	35	35	27	20	88	56	10,100
-T6	Pipe	up to 0.999	42	35	35	27	20	88	56	10,100
-T6	Pipe	over 0.999	38	35	35	24	20	80	56	10,100
6063-T5	Extrusions	up to 0.500	22	16	16	13	9	46	26	10,100
-T5	Extrusions	over 0.500	21	15	15	12	8.5	44	24	10,100
-T6	Extrusions Pipe	All	30	25	25	19	14	63	40	10,100
6351-T5	Extrusions	up to 1.00	38	35	35	24	20	80	56	10,100

[1]Values also apply to -T6511 temper.

[2]F_{tu} and F_{ty} are minimum specified values (except for Alclad 3004-H14, -H16 and F_{ty} for Alclad 3003-H18). Other strength properties are corresponding minimum expected values.

[3]For deflection calculations an average modulus of elasticity is used; numerically this is 100 ksi (689 MPa) lower than the values in this column.

TABLE 20-II-B—MINIMUM MECHANICAL PROPERTIES FOR WELDED ALUMINUM ALLOYS[1]
(Gas Tungsten Arc or Gas Metal Arc Welding with No Postweld Heat Treatment)

ALLOY AND TEMPER	PRODUCT AND THICKNESS RANGE (inch)	TENSION		COMPRES-SION	SHEAR		BEARING	
		F_{tuw}[1] ksi	F_{tyw}[2] ksi	F_{cyw}[2] ksi	F_{suw} ksi	F_{syw} ksi	F_{buw} ksi	F_{byw} ksi
	× 25.4 for mm	× 6.89 for MPa						
1100-H12, -H14	All	11	4.5	4.5	8	2.5	23	8
3003-H12, -H14, -H16, -H18	All	14	7	7	10	4	30	12
Alclad 3003-H12, -H14, -H16, -H18	All	13	6	6	10	3.5	30	11
3004-H32, -H34, -H36	All	22	11	11	14	6.5	46	20
Alclad 3004-H32, -H34, -H14, -H16	All	21	11	11	13	6.5	44	19
3005-H25	Sheet 0.013-0.050	17	9	9	12	5	36	15
5005-H12, -H14, -H32, -H34	All	14	7	7	9	4	28	10
5050-H32, -H34	All	18	8	8	12	4.5	36	12
5052-H32, -H34	All	25	13	13	16	7.5	50	19
5083-H111	Extrusions	39	21	20	23	12	78	32
-H321	Sheet and plate 0.188-1.500	40	24	24	24	14	80	36
-H321	Plate 1.501-3.000	39	23	23	24	13	78	34
-H323, -H343	Sheet	40	24	24	24	14	80	36
5086-H111	Extrusions	35	18	17	21	10	70	28
-H112	Plate 0.250-0.499	35	17	17	21	9.5	70	28
-H112	Plate 0.500-1.000	35	16	16	21	9	70	28
-H112	Plate 1.001-2.000	35	14	14	21	8	70	28
-H32, -H34	Sheet and plate	35	19	19	21	11	70	28
5086-H111	Extrusions	35	18	17	21	10	70	28
-H112	Plate 0.250-0.499	35	17	17	21	9.5	70	28
-H112	Plate 0.500-1.000	35	16	16	21	9	70	28
-H112	Plate 1.001-2.000	35	14	14	21	8	70	28
-H32, -H34	Sheet and plate	35	19	19	21	11	70	28
5154-H38	Sheet	30	15	15	19	8.5	60	23
5454-H111	Extrusions	31	16	15	19	9.5	62	24
-H112	Extrusions	31	12	12	19	7	62	24
-H32, -H34	Sheet and plate	31	16	16	19	9.5	62	24
5456-H111	Extrusions	41	24	22	24	14	82	38
-H112	Extrusions	41	19	19	24	11	82	38
-H321	Sheet and plate 0.188-1.500	42	26	24	25	15	84	38
-H321	Plate 1.501-3.000	41	24	23	25	14	82	36
-H323, -H343	Sheet	42	26	26	25	15	84	38
6005-T5	Extrusions Up to 0.250	24	17	17	15	10	50	30
6061-T6, -T651[3]	All	24	20	20	15	12	50	30
-T6, -T651[4]	Over 0.375	24	15	15	15	9	50	30
6063-T5, -T6	All	17	11	11	11	6.5	34	22
6351-T5[1]	Extrusions	24	20	20	15	12	50	30
-T5[4]	Over 0.375	24	15	15	15	9	50	30

[1]Values of F_{tuw} are ASME weld qualification test values.
[2]0.2 percent offset in 10-inch (254 mm) gauge length across a butt weld.
[3]Values when welded with 5183, 5356 or 5556 alloy filler wire regardless of thickness. Values also apply to thicknesses less than 0.375 inch (9.5 mm) when welded with 4043, 5154, 5254 or 5554 alloy filler wire.
[4]Values when welded with 4043, 5154, 5254 or 5554 alloy filler wire.

Chapter 21
MASONRY

SECTION 2101 — GENERAL

2101.1 Scope. The materials, design, construction and quality assurance of masonry shall be in accordance with this chapter.

2101.2 Design Methods. Masonry shall comply with the provisions of one of the following design methods in this chapter as well as the requirements of Sections 2101 through 2105.

2101.2.1 Working stress design. Masonry designed by the working stress design method shall comply with the provisions of Sections 2106 and 2107.

2101.2.2 Strength design. Masonry designed by the strength design method shall comply with the provisions of Sections 2106 and 2108.

2101.2.3 Empirical design. Masonry designed by the empirical design method shall comply with the provisions of Sections 2106.1 and 2109.

2101.2.4 Glass masonry. Glass masonry shall comply with the provisions of Section 2110.

2101.3 Definitions. For the purpose of this chapter, certain terms are defined as follows:

AREAS:

Bedded Area is the area of the surface of a masonry unit which is in contact with mortar in the plane of the joint.

Effective Area of Reinforcement is the cross-sectional area of reinforcement multiplied by the cosine of the angle between the reinforcement and the direction for which effective area is to be determined.

Gross Area is the total cross-sectional area of a specified section.

Net Area is the gross cross-sectional area minus the area of ungrouted cores, notches, cells and unbedded areas. Net area is the actual surface area of a cross section of masonry.

Transformed Area is the equivalent area of one material to a second based on the ratio of moduli of elasticity of the first material to the second.

BOND:

Adhesion Bond is the adhesion between masonry units and mortar or grout.

Reinforcing Bond is the adhesion between steel reinforcement and mortar or grout.

BOND BEAM is a horizontal grouted element within masonry in which reinforcement is embedded.

CELL is a void space having a gross cross-sectional area greater than $1^1/_2$ square inches (967 mm^2).

CLEANOUT is an opening to the bottom of a grout space of sufficient size and spacing to allow the removal of debris.

COLLAR JOINT is the mortared or grouted space between wythes of masonry.

COLUMN, REINFORCED, is a vertical structural member in which both the reinforcement and masonry resist compression.

COLUMN, UNREINFORCED, is a vertical structural member whose horizontal dimension measured at right angles to the thickness does not exceed three times the thickness.

DIMENSIONS:

Actual Dimensions are the measured dimensions of a designated item. The actual dimension shall not vary from the specified dimension by more than the amount allowed in the appropriate standard of quality in Section 2102.

Nominal Dimensions of masonry units are equal to its specified dimensions plus the thickness of the joint with which the unit is laid.

Specified Dimensions are the dimensions specified for the manufacture or construction of masonry, masonry units, joints or any other component of a structure.

GROUT LIFT is an increment of grout height within the total grout pour.

GROUT POUR is the total height of masonry wall to be grouted prior to the erection of additional masonry. A grout pour will consist of one or more grout lifts.

GROUTED MASONRY:

Grouted Hollow-unit Masonry is that form of grouted masonry construction in which certain designated cells of hollow units are continuously filled with grout.

Grouted Multiwythe Masonry is that form of grouted masonry construction in which the space between the wythes is solidly or periodically filled with grout.

JOINTS:

Bed Joint is the mortar joint that is horizontal at the time the masonry units are placed.

Head Joint is the mortar joint having a vertical transverse plane.

MASONRY UNIT is brick, tile, stone, glass block or concrete block conforming to the requirements specified in Section 2102.

Hollow-masonry Unit is a masonry unit whose net cross-sectional areas (solid area) in any plane parallel to the surface containing cores, cells or deep frogs is less than 75 percent of its gross cross-sectional area measured in the same plane.

Solid-masonry Unit is a masonry unit whose net cross-sectional area in any plane parallel to the surface containing the cores or cells is at least 75 percent of the gross cross-sectional area measured in the same plane.

PRISM is an assemblage of masonry units and mortar with or without grout used as a test specimen for determining properties of the masonry.

REINFORCED MASONRY is that form of masonry construction in which reinforcement acting in conjunction with the masonry is used to resist forces.

SHELL is the outer portion of a hollow masonry unit as placed in masonry.

WALLS

Bonded Wall is a masonry wall in which two or more wythes are bonded to act as a structural unit.

Cavity Wall is a wall containing continuous air space with a minimum width of 2 inches (51 mm) and a maximum width of

$4^1/_2$ inches (114 mm) between wythes which are tied with metal ties.

WALL TIE is a mechanical metal fastener which connects wythes of masonry to each other or to other materials.

WEB is an interior solid portion of a hollow-masonry unit as placed in masonry.

WYTHE is the portion of a wall which is one masonry unit in thickness. A collar joint is not considered a wythe.

2101.4 Notations.

A_b = cross-sectional area of anchor bolt, square inches (mm^2).

A_e = effective area of masonry, square inches (mm^2).

A_g = gross area of wall, square inches (mm^2).

A_{jh} = total area of special horizontal reinforcement through wall frame joint, square inches (mm^2).

A_{mv} = net area of masonry section bounded by wall thickness and length of section in direction of shear force considered, square inches (mm^2).

A_p = area of tension (pullout) cone of embedded anchor bolt projected onto surface of masonry, square inches (mm^2).

A_s = effective cross-sectional area of reinforcement in column or flexural member, square inches (mm^2).

A_{se} = effective area of reinforcement, square inches (mm^2).

A_{sh} = total cross-sectional area of rectangular tie reinforcement for confined core, square inches (mm^2).

A_v = area of reinforcement required for shear reinforcement perpendicular to longitudinal reinforcement, square inches (mm^2).

A'_s = effective cross-sectional area of compression reinforcement in flexural member, square inches (mm^2).

a = depth of equivalent rectangular stress block, inches (mm).

B_{sn} = nominal shear strength of anchor bolt, pounds (N).

B_t = allowable tensile force on anchor bolt, pounds (N).

B_{tn} = nominal tensile strength of anchor bolt, pounds (N).

B_v = allowable shear force on anchor bolt, pounds (N).

b = effective width of rectangular member or width of flange for T and I sections, inches (mm).

b_{su} = factored shear force supported by anchor bolt, pounds (N).

b_t = computed tensile force on anchor bolt, pounds (N).

b_{tu} = factored tensile force supported by anchor bolt, pounds (N).

b_v = computed shear force on anchor bolt, pounds (N).

b' = width of web in T or I section, inches (mm).

C_d = nominal shear strength coefficient as obtained from Table 21-K.

c = distance from neutral axis to extreme fiber, inches (mm).

D = dead loads, or related internal moments and forces.

d = distance from compression face of flexural member to centroid of longitudinal tensile reinforcement, inches (mm).

d_b = diameter of reinforcing bar, inches (mm).

d_{bb} = diameter of largest beam longitudinal reinforcing bar passing through, or anchored in, a joint, inches (mm).

d_{bp} = diameter of largest pier longitudinal reinforcing bar passing through a joint, inches (mm).

E = load effects of earthquake, or related internal moments and forces.

E_m = modulus of elasticity of masonry, pounds per square inch (MPa).

e = eccentricity of P_{uf}, inches (mm).

e_{mu} = maximum usable compressive strain of masonry.

F = loads due to weight and pressure of fluids or related moments and forces.

F_a = allowable average axial compressive stress in columns for centroidally applied axial load only, pounds per square inch (MPa).

F_b = allowable flexural compressive stress in members subjected to bending load only, pounds per square inch (MPa).

F_{br} = allowable bearing stress in masonry, pounds per square inch (MPa).

F_s = allowable stress in reinforcement, pounds per square inch (MPa).

F_{sc} = allowable compressive stress in column reinforcement, pounds per square inch (MPa).

F_t = allowable flexural tensile stress in masonry, pounds per square inch (MPa).

F_v = allowable shear stress in masonry, pounds per square inch (MPa).

f_a = computed axial compressive stress due to design axial load, pounds per square inch (MPa).

f_b = computed flexural stress in extreme fiber due to design bending loads only, pounds per square inch (MPa).

f_{md} = computed compressive stress due to dead load only, pounds per square inch (MPa).

f_r = modulus of rupture, pounds per square inch (MPa).

f_s = computed stress in reinforcement due to design loads, pounds per square inch (MPa).

f_v = computed shear stress due to design load, pounds per square inch (MPa).

f_y = tensile yield stress of reinforcement, pounds per square inch (MPa).

fyh = tensile yield stress of horizontal reinforcement, pounds per square inch (MPa).

f'_g = specified compressive strength of grout at age of 28 days, pounds per square inch (MPa).

f'_m = specified compressive strength of masonry at age of 28 days, pounds per square inch (MPa).

G = shear modulus of masonry, pounds per square inch (MPa).

H = loads due to weight and pressure of soil, water in soil or related internal moments and forces.

h = height of wall between points of support, inches (mm).

h_b = beam depth, inches (mm).

h_c = cross-sectional dimension of grouted core measured center to center of confining reinforcement, inches (mm).

h_p = pier depth in plane of wall frame, inches (mm).

h' = effective height of wall or column, inches (mm).

I = moment of inertia about neutral axis of cross-sectional area, $inches^4$ (mm^4).

I_e = effective moment of inertia, $inches^4$ (mm^4).

I_g, I_{cr} = gross, cracked moment of inertia of wall cross section, $inches^4$ (mm^4).

j = ratio or distance between centroid of flexural compressive forces and centroid of tensile forces of depth, d.

K = reinforcement cover or clear spacing, whichever is less, inches (mm).

k = ratio of depth of compressive stress in flexural member to depth, d.

L = live loads, or related internal moments and forces.

L_w = length of wall, inches (mm).

l = length of wall or segment, inches (mm).

l_b = embedment depth of anchor bolt, inches (mm).

l_{be} = anchor bolt edge distance, the least distance measured from edge of masonry to surface of anchor bolt, inches (mm).

l_d = required development length of reinforcement, inches (mm).

M = design moment, inch-pounds (N·mm).

M_a = maximum moment in member at stage deflection is computed, inch-pounds (N·mm).

M_c = moment capacity of compression reinforcement in flexural member about centroid of tensile force, inch-pounds (N·mm).

M_{cr} = nominal cracking moment strength in masonry, inch-pounds (N·mm).

M_m = moment of compressive force in masonry about centroid of tensile force in reinforcement, inch-pounds (N·mm).

M_n = nominal moment strength, inch-pounds (N·mm).

M_s = moment of tensile force in reinforcement about centroid of compressive force in masonry, inch-pounds (N·mm).

M_{ser} = service moment at midheight of panel, including $P\Delta$ effects, inch-pounds (N·mm).

M_u = factored moment, inch-pounds (N·mm).

n = modular ratio.

= E_s/E_m.

P = design axial load, pounds (N).

P_a = allowable centroidal axial load for reinforced masonry columns, pounds (N).

P_b = nominal balanced design axial strength, pounds (N).

P_f = load from tributary floor or roof area, pounds (N).

P_n = nominal axial strength in masonry, pounds (N).

P_o = nominal axial load strength in masonry without flexure, pounds (N).

P_u = factored axial load, pounds (N).

P_{uf} = factored load from tributary floor or roof loads, pounds (N).

P_{uw} = factored weight of wall tributary to section under consideration, pounds (N).

P_w = weight of wall tributary to section under consideration, pounds (N).

r = radius of gyration (based on specified unit dimensions or Tables 21-H-1, 21-H-2 and 21-H-3), inches (mm).

r_b = ratio of area of reinforcing bars cut off to total area of reinforcing bars at the section.

S = section modulus, inches^3 (mm^3).

s = spacing of stirrups or of bent bars in direction parallel to that of main reinforcement, inches (mm).

T = effects of temperature, creep, shrinkage and differential settlement.

t = effective thickness of wythe, wall or column, inches (mm).

U = required strength to resist factored loads, or related internal moments and forces.

u = bond stress per unit of surface area of reinforcing bar, pounds per square inch (MPa).

V = total design shear force, pounds (N).

V_{jh} = total horizontal joint shear, pounds (N).

V_m = nominal shear strength of masonry, pounds (N).

V_n = nominal shear strength, pounds (N).

V_s = nominal shear strength of shear reinforcement, pounds (N).

V_u = required shear strength in masonry, pounds (N).

W = wind load, or related internal moments in forces.

w_u = factored distributed lateral load.

Δ_s = horizontal deflection at midheight under factored load, inches (mm).

Δ_u = deflection due to factored loads, inches (mm).

ρ = ratio of area of flexural tensile reinforcement, A_s, to area bd.

ρ_b = reinforcement ratio producing balanced strain conditions.

ρ_n = ratio of distributed shear reinforcement on plane perpendicular to plane of A_{mv}.

Σ_o = sum of perimeters of all longitudinal reinforcement, inches (mm).

$\sqrt{f'_m}$ = square root of specified strength of masonry at the age of 28 days, pounds per square inch (MPa).

ϕ = strength-reduction factor.

SECTION 2102 — MATERIAL STANDARDS

2102.1 Quality. Materials used in masonry shall conform to the requirements stated herein. If no requirements are specified in this section for a material, quality shall be based on generally accepted good practice, subject to the approval of the building official.

Reclaimed or previously used masonry units shall meet the applicable requirements as for new masonry units of the same material for their intended use.

2102.2 Standards of Quality. The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards. See Sections 3503 and 3504.

1. **Aggregates.**
   - 1.1 ASTM C 144, Aggregates for Masonry Mortar
   - 1.2 ASTM C 404, Aggregates for Grout
2. **Cement.**
   - 2.1 UBC Standard 21-11, Cement, Masonry. (Plastic cement conforming to the requirements of UBC Standard 25-1 may be used in lieu of masonry cement when it also conforms to UBC Standard 21-11.)
   - 2.2 ASTM C 150, Portland Cement
   - 2.3 UBC Standard 21-14, Mortar Cement
3. **Lime.**
   - 3.1 UBC Standard 21-12, Quicklime for Structural Purposes
   - 3.2 UBC Standard 21-13, Hydrated Lime for Masonry Purposes. When Types N and NA hydrated lime are used in

masonry mortar, they shall comply with the provisions of UBC Standard 21-15, Section 21.1506.7, excluding the plasticity requirement.

4. **Masonry units of clay or shale.**

4.1 ASTM C 34, Structural Clay Load-bearing Wall Tile

4.2 ASTM C 56, Structural Clay Nonload-bearing Tile

4.3 UBC Standard 21-1, Section 21.101, Building Brick (solid units)

4.4 ASTM C 126, Ceramic Glazed Structural Clay Facing Tile, Facing Brick and Solid Masonry Units. Load-bearing glazed brick shall conform to the weathering and structural requirements of UBC Standard 21-1, Section 21.106, Facing Brick

4.5 UBC Standard 21-1, Section 21.106, Facing Brick (solid units)

4.6 UBC Standard 21-1, Section 21.107, Hollow Brick

4.7 ASTM C 67, Sampling and Testing Brick and Structural Clay Tile

4.8 ASTM C 212, Structural Clay Facing Tile

4.9 ASTM C 530, Structural Clay Non-Loadbearing Screen Tile

5. **Masonry units of concrete.**

5.1 UBC Standard 21-3, Concrete Building Brick

5.2 UBC Standard 21-4, Hollow and Solid Load-bearing Concrete Masonry Units

5.3 UBC Standard 21-5, Nonload-bearing Concrete Masonry Units

5.4 ASTM C 140, Sampling and Testing Concrete Masonry Units

5.5 ASTM C 426, Standard Test Method for Drying Shrinkage of Concrete Block

6. **Masonry units of other materials.**

6.1 **Calcium silicate.**

UBC Standard 21-2, Calcium Silicate Face Brick (Sand-lime Brick)

6.2 UBC Standard 21-9, Unburned Clay Masonry Units and Standard Methods of Sampling and Testing Unburned Clay Masonry Units

6.3 ACI-704, Cast Stone

6.4 UBC Standard 21-17, Test Method for Compressive Strength of Masonry Prisms

7. **Connectors.**

7.1 Wall ties and anchors made from steel wire shall conform to UBC Standard 21-10, Part II, and other steel wall ties and anchors shall conform to A 36 in accordance with UBC Standard 22-1. Wall ties and anchors made from copper, brass or other nonferrous metal shall have a minimum tensile yield strength of 30,000 psi (207 MPa).

7.2 All such items not fully embedded in mortar or grout shall either be corrosion resistant or shall be coated after fabrication with copper, zinc or a metal having at least equivalent corrosion-resistant properties.

8. **Mortar.**

8.1 UBC Standard 21-15, Mortar for Unit Masonry and Reinforced Masonry other than Gypsum

8.2 UBC Standard 21-16, Field Tests Specimens for Mortar

8.3 UBC Standard 21-20, Standard Test Method for Flexural Bond Strength of Mortar Cement

9. **Grout.**

9.1 UBC Standard 21-18, Method of Sampling and Testing Grout

9.2 UBC Standard 21-19, Grout for Masonry

10. **Reinforcement.**

10.1 UBC Standard 21-10, Part I, Joint Reinforcement for Masonry

10.2 ASTM A 615, A 616, A 617, A 706, A 767, and A 775, Deformed and Plain Billet-steel Bars, Rail-steel Deformed and Plain Bars, Axle-steel Deformed and Plain Bars, and Deformed Low-alloy Bars for Concrete Reinforcement

10.3 UBC Standard 21-10, Part II, Cold-drawn Steel Wire for Concrete Reinforcement

SECTION 2103 — MORTAR AND GROUT

2103.1 General. Mortar and grout shall comply with the provisions of this section. Special mortars, grouts or bonding systems may be used, subject to satisfactory evidence of their capabilities when approved by the building official.

2103.2 Materials. Materials used as ingredients in mortar and grout shall conform to the applicable requirements in Section 2102. Cementitious materials for grout shall be one or both of the following: lime and portland cement. Cementitious materials for mortar shall be one or more of the following: lime, masonry cement, portland cement and mortar cement. Cementitious materials or additives shall not contain epoxy resins and derivatives, phenols, asbestos fibers or fireclays.

Water used in mortar or grout shall be clean and free of deleterious amounts of acid, alkalies or organic material or other harmful substances.

2103.3 Mortar.

2103.3.1 General. Mortar shall consist of a mixture of cementitious materials and aggregate to which sufficient water and approved additives, if any, have been added to achieve a workable, plastic consistency.

2103.3.2 Selecting proportions. Mortar with specified proportions of ingredients that differ from the mortar proportions of Table 21-A may be approved for use when it is demonstrated by laboratory or field experience that this mortar with the specified proportions of ingredients, when combined with the masonry units to be used in the structure, will achieve the specified compressive strength f'_m. Water content shall be adjusted to provide proper workability under existing field conditions. When the proportion of ingredients is not specified, the proportions by mortar type shall be used as given in Table 21-A.

2103.4 Grout.

2103.4.1 General. Grout shall consist of a mixture of cementitious materials and aggregate to which water has been added such that the mixture will flow without segregation of the constituents. The specified compressive strength of grout, f'_g, shall not be less than 2,000 psi (13.8 MPa).

2103.4.2 Selecting proportions. Water content shall be adjusted to provide proper workability and to enable proper placement under existing field conditions, without segregation. Grout shall be specified by one of the following methods:

1. Proportions of ingredients and any additives shall be based on laboratory or field experience with the grout ingredients and the masonry units to be used. The grout shall be specified by the proportion of its constituents in terms of parts by volume, or

2. Minimum compressive strength which will produce the required prism strength, or

3. Proportions by grout type shall be used as given in Table 21-B.

2103.5 Additives and Admixtures.

2103.5.1 General. Additives and admixtures to mortar or grout shall not be used unless approved by the building official.

2103.5.2 Antifreeze compounds. Antifreeze liquids, chloride salts or other such substances shall not be used in mortar or grout.

2103.5.3 Air entrainment. Air-entraining substances shall not be used in mortar or grout unless tests are conducted to determine compliance with the requirements of this code.

2103.5.4 Colors. Only pure mineral oxide, carbon black or synthetic colors may be used. Carbon black shall be limited to a maximum of 3 percent of the weight of the cement.

SECTION 2104 — CONSTRUCTION

2104.1 General. Masonry shall be constructed according to the provisions of this section.

2104.2 Materials: Handling, Storage and Preparation. All materials shall comply with applicable requirements of Section 2102. Storage, handling and preparation at the site shall conform also to the following:

1. Masonry materials shall be stored so that at the time of use the materials are clean and structurally suitable for the intended use.

2. All metal reinforcement shall be free from loose rust and other coatings that would inhibit reinforcing bond.

3. At the time of laying, burned clay units and sand lime units shall have an initial rate of absorption not exceeding 0.035 ounce per square inch (1.6 L/m^2) during a period of one minute. In the absorption test, the surface of the unit shall be held $^1/_8$ inch (3 mm) below the surface of the water.

4. Concrete masonry units shall not be wetted unless otherwise approved.

5. Materials shall be stored in a manner such that deterioration or intrusion of foreign materials is prevented and that the material will be capable of meeting applicable requirements at the time of mixing or placement.

6. The method of measuring materials for mortar and grout shall be such that proportions of the materials can be controlled.

7. Mortar or grout mixed at the jobsite shall be mixed for a period of time not less than three minutes or more than 10 minutes in a mechanical mixer with the amount of water required to provide the desired workability. Hand mixing of small amounts of mortar is permitted. Mortar may be retempered. Mortar or grout which has hardened or stiffened due to hydration of the cement shall not be used. In no case shall mortar be used two and one-half hours, nor grout used one and one-half hours, after the initial mixing water has been added to the dry ingredients at the jobsite.

EXCEPTION: Dry mixes for mortar and grout which are blended in the factory and mixed at the jobsite shall be mixed in mechanical mixers until workable, but not to exceed 10 minute

2104.3 Cold-weather Construction.

2104.3.1 General. All materials shall be delivered in a usable condition and stored to prevent wetting by capillary action, rain and snow.

The tops of all walls not enclosed or sheltered shall be covered with a strong weather-resistive material at the end of each day or shutdown.

Partially completed walls shall be covered at all times when work is not in progress. Covers shall be draped over the wall and extend a minimum of 2 feet (600 mm) down both sides and shall be securely held in place, except when additional protection is required in Section 2104.3.4.

2104.3.2 Preparation. If ice or snow has inadvertently formed on a masonry bed, it shall be thawed by application of heat carefully applied until top surface of the masonry is dry to the touch.

A section of masonry deemed frozen and damaged shall be removed before continuing construction of that section.

2104.3.3 Construction. Masonry units shall be dry at time of placement. Wet or frozen masonry units shall not be laid.

Special requirements for various temperature ranges are as follows:

1. Air temperature 40°F to 32°F (4.5°C to 0°C): Sand or mixing water shall be heated to produce mortar temperatures between 40°F and 120°F (4.5°C and 49°C).

2. Air temperature 32°F to 25°F (0°C to –4°C): Sand and mixing water shall be heated to produce mortar temperatures between 40°F and 120°F (4.5°C and 49°C). Maintain temperatures of mortar on boards above freezing.

3. Air temperature 25°F to 20°F (–4°C to –7°C): Sand and mixing water shall be heated to produce mortar temperatures between 40°F and 120°F (4.5°C and 49°C). Maintain mortar temperatures on boards above freezing. Salamanders or other sources of heat shall be used on both sides of walls under construction. Windbreaks shall be employed when wind is in excess of 15 miles per hour (24 km/h).

4. Air temperature 20°F (–7°C) and below: Sand and mixing water shall be heated to produce mortar temperatures between 40°F and 120°F (4.5°C and 49°C). Enclosure and auxiliary heat shall be provided to maintain air temperature above freezing. Temperature of units when laid shall not be less than 20°F (–7°C).

2104.3.4 Protection. When the mean daily air temperature is 40°F to 32°F (4.5°C to 0°C), masonry shall be protected from rain or snow for 24 hours by covering with a weather-resistive membrane.

When the mean daily air temperature is 32°F to 25°F (0°C to –4°C), masonry shall be completely covered with a weather-resistive membrane for 24 hours.

When the mean daily air temperature is 25°F to 20°F (–4°C to –7°C), masonry shall be completely covered with insulating blankets or equally protected for 24 hours.

When the mean daily air temperature is 20°F (–7°C) or below, masonry temperature shall be maintained above freezing for 24 hours by enclosure and supplementary heat, by electric heating blankets, infrared heat lamps or other approved methods.

2104.3.5 Placing grout and protection of grouted masonry. When air temperatures fall below 40°F (4.5°C), grout mixing water and aggregate shall be heated to produce grout temperatures between 40°F and 120°F (4.5°C and 49°C).

Masonry to be grouted shall be maintained above freezing during grout placement and for at least 24 hours after placement.

When atmospheric temperatures fall below 20°F (–7°C), enclosures shall be provided around the masonry during grout placement and for at least 24 hours after placement.

2104.4 Placing Masonry Units.

2104.4.1 Mortar. The mortar shall be sufficiently plastic and units shall be placed with sufficient pressure to extrude mortar from the joint and produce a tight joint. Deep furrowing which produces voids shall not be used.

The initial bed joint thickness shall not be less than $^1/_4$ inch (6 mm) or more than 1 inch (25 mm); subsequent bed joints shall not be less than $^1/_4$ inch (6 mm) or more than $^5/_8$ inch (16 mm) in thickness.

2104.4.2 Surfaces. Surfaces to be in contact with mortar or grout shall be clean and free of deleterious materials.

2104.4.3 Solid masonry units. Solid masonry units shall have full head and bed joints.

2104.4.4 Hollow-masonry units. All head and bed joints shall be filled solidly with mortar for a distance in from the face of the unit not less than the thickness of the shell.

Head joints of open-end units with beveled ends that are to be fully grouted need not be mortared. The beveled ends shall form a grout key which permits grout within $^5/_8$ inch (16 mm) of the face of the unit. The units shall be tightly butted to prevent leakage of grout.

2104.5 Reinforcement Placing. Reinforcement details shall conform to the requirements of this chapter. Metal reinforcement shall be located in accordance with the plans and specifications. Reinforcement shall be secured against displacement prior to grouting by wire positioners or other suitable devices at intervals not exceeding 200 bar diameters.

Tolerances for the placement of reinforcement in walls and flexural elements shall be plus or minus $^1/_2$ inch (12.7 mm) for *d* equal to 8 inches (200 mm) or less, ± 1 inch (± 25 mm) for *d* equal to 24 inches (600 mm) or less but greater than 8 inches (200 mm), and ± $1^1/_4$ inches (32 mm) for *d* greater than 24 inches (600 mm).

Tolerance for longitudinal location of reinforcement shall be ± 2 inches (51 mm).

2104.6 Grouted Masonry.

2104.6.1 General conditions. Grouted masonry shall be constructed in such a manner that all elements of the masonry act together as a structural element.

Prior to grouting, the grout space shall be clean so that all spaces to be filled with grout do not contain mortar projections greater than $^1/_2$ inch (12.7 mm), mortar droppings or other foreign material. Grout shall be placed so that all spaces designated to be grouted shall be filled with grout and the grout shall be confined to those specific spaces.

Grout materials and water content shall be controlled to provide adequate fluidity for placement without segregation of the constituents, and shall be mixed thoroughly.

The grouting of any section of wall shall be completed in one day with no interruptions greater than one hour.

Between grout pours, a horizontal construction joint shall be formed by stopping all wythes at the same elevation and with the grout stopping a minimum of $1^1/_2$ inches (38 mm) below a mortar joint, except at the top of the wall. Where bond beams occur, the grout pour shall be stopped a minimum of $^1/_2$ inch (12.7 mm) below the top of the masonry.

Size and height limitations of the grout space or cell shall not be less than shown in Table 21-C. Higher grout pours or smaller cavity widths or cell size than shown in Table 21-C may be used when approved, if it is demonstrated that grout spaces will be properly filled.

Cleanouts shall be provided for all grout pours over 5 feet (1524 mm) in height.

Where required, cleanouts shall be provided in the bottom course at every vertical bar but shall not be spaced more than 32 inches (813 mm) on center for solidly grouted masonry. When cleanouts are required, they shall be sealed after inspection and before grouting.

Where cleanouts are not provided, special provisions must be made to keep the bottom and sides of the grout spaces, as well as the minimum total clear area as required by Table 21-C, clean and clear prior to grouting.

Units may be laid to the full height of the grout pour and grout shall be placed in a continuous pour in grout lifts not exceeding 6 feet (1830 mm). When approved, grout lifts may be greater than 6 feet (1830 mm) if it can be demonstrated the grout spaces can be properly filled.

All cells and spaces containing reinforcement shall be filled with grout.

2104.6.2 Construction requirements. Reinforcement shall be placed prior to grouting. Bolts shall be accurately set with templates or by approved equivalent means and held in place to prevent dislocation during grouting.

Segregation of the grout materials and damage to the masonry shall be avoided during the grouting process.

Grout shall be consolidated by mechanical vibration during placement before loss of plasticity in a manner to fill the grout space. Grout pours greater than 12 inches (300 mm) in height shall be reconsolidated by mechanical vibration to minimize voids due to water loss. Grout pours 12 inches (300 mm) or less in height shall be mechanically vibrated or puddled.

In one-story buildings having wood-frame exterior walls, foundations not over 24 inches (600 mm) high measured from the top of the footing may be constructed of hollow-masonry units laid in running bond without mortared head joints. Any standard shape unit may be used, provided the masonry units permit horizontal flow of grout to adjacent units. Grout shall be solidly poured to the full height in one lift and shall be puddled or mechanically vibrated.

In nonstructural elements which do not exceed 8 feet (2440 mm) in height above the highest point of lateral support, including fireplaces and residential chimneys, mortar of pouring consistency may be substituted for grout when the masonry is constructed and grouted in pours of 12 inches (300 mm) or less in height.

In multiwythe grouted masonry, vertical barriers of masonry shall be built across the grout space the entire height of the grout pour and spaced not more than 30 feet (9144 mm) horizontally. The grouting of any section of wall between barriers shall be completed in one day with no interruption longer than one hour.

2104.7 Aluminum Equipment. Grout shall not be handled nor pumped utilizing aluminum equipment unless it can be demonstrated with the materials and equipment to be used that there will be no deleterious effect on the strength of the grout.

2104.8 Joint Reinforcement. Wire joint reinforcement used in the design as principal reinforcement in hollow-unit construction shall be continuous between supports unless splices are made by lapping:

1. Fifty-four wire diameters in a grouted cell, or

2. Seventy-five wire diameters in the mortared bed joint, or

3. In alternate bed joints of running bond masonry a distance not less than 54 diameters plus twice the spacing of the bed joints, or

4. As required by calculation and specific location in areas of minimum stress, such as points of inflection.

Side wires shall be deformed and shall conform to UBC Standard 21-10, Part I, Joint Reinforcement for Masonry.

SECTION 2105 — QUALITY ASSURANCE

2105.1 General. Quality assurance shall be provided to ensure that materials, construction and workmanship are in compliance with the plans and specifications, and the applicable requirements of this chapter. When required, inspection records shall be maintained and made available to the building official.

2105.2 Scope. Quality assurance shall include, but is not limited to, assurance that:

1. Masonry units, reinforcement, cement, lime, aggregate and all other materials meet the requirements of the applicable standards of quality and that they are properly stored and prepared for use.

2. Mortar and grout are properly mixed using specified proportions of ingredients. The method of measuring materials for mortar and grout shall be such that proportions of materials are controlled.

3. Construction details, procedures and workmanship are in accordance with the plans and specifications.

4. Placement, splices and reinforcement sizes are in accordance with the provisions of this chapter and the plans and specifications.

2105.3 Compliance with f'_m.

2105.3.1 General. Compliance with the requirements for the specified compressive strength of masonry f'_m shall be in accordance with one of the sections in this subsection.

2105.3.2 Masonry prism testing. The compressive strength of masonry determined in accordance with UBC Standard 21-17 for each set of prisms shall equal or exceed f'_m. Compressive strength of prisms shall be based on tests at 28 days. Compressive strength at seven days or three days may be used provided a relationship between seven-day and three-day and 28-day strength has been established for the project prior to the start of construction. Verification by masonry prism testing shall meet the following:

1. A set of five masonry prisms shall be built and tested in accordance with UBC Standard 21-17 prior to the start of construction. Materials used for the construction of the prisms shall be taken from those specified to be used in the project. Prisms shall be constructed under the observation of the engineer or special inspector or an approved agency and tested by an approved agency.

2. When full allowable stresses are used in design, a set of three prisms shall be built and tested during construction in accordance with UBC Standard 21-17 for each 5,000 square feet (465 m^2) of wall area, but not less than one set of three masonry prisms for the project.

3. When one half the allowable masonry stresses are used in design, testing during construction is not required. A letter of certification from the supplier of the materials used to verify the f'_m in accordance with Section 2105.3.2, Item 1, shall be provided at the time of, or prior to, delivery of the materials to the jobsite to ensure the materials used in construction are representative of the materials used to construct the prisms prior to construction.

2105.3.3 Masonry prism test record. Compressive strength verification by masonry prism test records shall meet the following:

1. A masonry prism test record approved by the building official of at least 30 masonry prisms which were built and tested in accordance with UBC Standard 21-17. Prisms shall have been constructed under the observation of an engineer or special inspector or an approved agency and shall have been tested by an approved agency.

2. Masonry prisms shall be representative of the corresponding construction.

3. The average compressive strength of the test record shall equal or exceed 1.33 f'_m.

4. When full allowable stresses are used in design, a set of three masonry prisms shall be built during construction in accordance with UBC Standard 21-17 for each 5,000 square feet (465 m^2) of wall area, but not less than one set of three prisms for the project.

5. When one half the allowable masonry stresses are used in design, field testing during construction is not required. A letter of certification from the supplier of the materials to the jobsite shall be provided at the time of, or prior to, delivery of the materials to assure the materials used in construction are representative of the materials used to develop the prism test record in accordance with Section 2105.3.3, Item 1.

2105.3.4 Unit strength method. Verification by the unit strength method shall meet the following:

1. When full allowable stresses are used in design, units shall be tested prior to construction and test units during construction for each 5,000 square feet (465 m^2) of wall area for compressive strength to show compliance with the compressive strength required in Table 21-D; and

> **EXCEPTION:** Prior to the start of construction, prism testing may be used in lieu of testing the unit strength. During construction, prism testing may also be used in lieu of testing the unit strength and the grout as required by Section 2105.3.4, Item 4.

2. When one half the allowable masonry stresses are used in design, testing is not required for the units. A letter of certification from the manufacturer of the units shall be provided at the time of, or prior to, delivery of the units to the jobsite to assure the units comply with the compressive strength required in Table 21-D; and

3. Mortar shall comply with the mortar type required in Table 21-D; and

4. When full stresses are used in design for concrete masonry, grout shall be tested for each 5,000 square feet (465 m^2) of wall area, but not less than one test per project, to show compliance with the compressive strength required in Table 21-D, Footnote 4.

5. When one half the allowable stresses are used in design for concrete masonry, testing is not required for the grout. A letter of certification from the supplier of the grout shall be provided at the time of, or prior to, delivery of the grout to the jobsite to assure the grout complies with the compressive strength required in Table 21-D, Footnote 4; or

6. When full allowable stresses are used in design for clay masonry, grout proportions shall be verified by the engineer or special inspector or an approved agency to conform with Table 21-B.

7. When one half the allowable masonry stresses are used in design for clay masonry, a letter of certification from the supplier of the grout shall be provided at the time of, or prior to, delivery of the grout to the jobsite to assure the grout conforms to the proportions of Table 21-B.

2105.3.5 Testing prisms from constructed masonry. When approved by the building official, acceptance of masonry which does not meet the requirements of Section 2105.3.2, 2105.3.3 or 2105.3.4 shall be permitted to be based on tests of prisms cut from the masonry construction in accordance with the following:

1. A set of three masonry prisms that are at least 28 days old shall be saw cut from the masonry for each 5,000 square feet (465 m^2) of the wall area that is in question but not less than one set of three masonry prisms for the project. The length, width and height dimensions of the prisms shall comply with the requirements of UBC Standard 21-17. Transporting, preparation and testing of prisms shall be in accordance with UBC Standard 21-17.

2. The compressive strength of prisms shall be the value calculated in accordance with UBC Standard 21-17, Section 21.1707.2, except that the net cross-sectional area of the prism shall be based on the net mortar bedded area.

3. Compliance with the requirement for the specified compressive strength of masonry, f'_m, shall be considered satisfied provided the modified compressive strength equals or exceeds the specified f'_m. Additional testing of specimens cut from locations in question shall be permitted.

2105.4 Mortar Testing. When required, mortar shall be tested in accordance with UBC Standard 21-16.

2105.5 Grout Testing. When required, grout shall be tested in accordance with UBC Standard 21-18.

SECTION 2106 — GENERAL DESIGN REQUIREMENTS

2106.1 General.

2106.1.1 Scope. The design of masonry structures shall comply with the working stress design provisions of Section 2107, or the strength design provisions of Section 2108 or the empirical design provisions of Section 2109, and with the provisions of this section. Unless otherwise stated, all calculations shall be made using or based on specified dimensions.

2106.1.2 Plans. Plans submitted for approval shall describe the required design strengths of masonry materials and inspection requirements for which all parts of the structure were designed, and any load test requirements.

2106.1.3 Design loads. See Chapter 16 for design loads.

2106.1.4 Stack bond. In bearing and nonbearing walls, except veneer walls, if less than 75 percent of the units in any transverse vertical plane lap the ends of the units below a distance less than one half the height of the unit, or less than one fourth the length of the unit, the wall shall be considered laid in stack bond.

2106.1.5 Multiwythe walls.

2106.1.5.1 General. All wythes of multiwythe walls shall be bonded by grout or tied together by corrosion-resistant wall ties or joint reinforcement conforming to the requirements of Section 2102, and as set forth in this section.

2106.1.5.2 Wall ties in cavity wall construction. Wall ties shall be of sufficient length to engage all wythes. The portion of the wall ties within the wythe shall be completely embedded in mortar or grout. The ends of the wall ties shall be bent to 90-degree angles with an extension not less than 2 inches (51 mm) long. Wall ties not completely embedded in mortar or grout between wythes shall be a single piece with each end engaged in each wythe.

There shall be at least one $^3/_{16}$-inch-diameter (9.5 mm) wall tie for each $4^1/_2$ square feet (0.42 m^2) of wall area. For cavity walls in which the width of the cavity is greater than 3 inches (75 mm), but not more than $4^1/_2$ inches (115 mm), at least one $^3/_{16}$-inch-diameter (9.5 mm) wall tie for each 3 square feet (0.28 m^2) of wall area shall be provided.

Ties in alternate courses shall be staggered. The maximum vertical distance between ties shall not exceed 24 inches (610 mm) and the maximum horizontal distance between ties shall not exceed 36 inches (914 mm).

Additional ties spaced not more than 36 inches (914 mm) apart shall be provided around openings within a distance of 12 inches (305 mm) from the edge of the opening.

Adjustable wall ties shall meet the following requirements:

1. One tie shall be provided for each 1.77 square feet (0.16 m^2) of wall area. Horizontal and vertical spacing shall not exceed 16 inches (406 mm). Maximum misalignment of bed joints from one wythe to the other shall be $1^1/_4$ inches (32 mm).

2. Maximum clearance between the connecting parts of the tie shall be $^1/_{16}$ inch (1.6 mm). When used, pintle ties shall have at least two $^3/_{16}$-inch-diameter (4.8 mm) pintle legs.

Wall ties of different size and spacing that provide equivalent strength between wythes may be used.

2106.1.5.3 Wall ties for grouted multiwythe construction. Wythes of multiwythe walls shall be bonded together with at least $^3/_{16}$-inch-diameter (4.8 mm) steel wall tie for each 2 square feet (0.19 m^2) of area. Wall ties of different size and spacing that provide equivalent strength between wythes may be used.

2106.1.5.4 Joint reinforcement. Prefabricated joint reinforcement for masonry walls shall have at least one cross wire of at least No. 9 gage steel for each 2 square feet (0.19 m^2) of wall area. The vertical spacing of the joint reinforcement shall not exceed 16 inches (406 mm). The longitudinal wires shall be thoroughly embedded in the bed joint mortar. The joint reinforcement shall engage all wythes.

Where the space between tied wythes is solidly filled with grout or mortar, the allowable stresses and other provisions for masonry bonded walls shall apply. Where the space is not filled, tied walls shall conform to the allowable stress, lateral support, thickness (excluding cavity), height and tie requirements for cavity walls.

2106.1.6 Vertical support. Structural members providing vertical support of masonry shall provide a bearing surface on which the initial bed joint shall not be less than $^1/_4$ inch (6 mm) or more than 1 inch (25 mm) in thickness and shall be of noncombustible material, except where masonry is a nonstructural decorative feature or wearing surface.

2106.1.7 Lateral support. Lateral support of masonry may be provided by cross walls, columns, pilasters, counterforts or buttresses where spanning horizontally or by floors, beams, girts or roofs where spanning vertically.

The clear distance between lateral supports of a beam shall not exceed 32 times the least width of the compression area.

2106.1.8 Protection of ties and joint reinforcement. A minimum of $^5/_8$-inch (16 mm) mortar cover shall be provided between ties or joint reinforcement and any exposed face. The thickness of grout or mortar between masonry units and joint reinforcement shall not be less than $^1/_4$ inch (6 mm), except that $^1/_4$ inch (6 mm) or smaller diameter reinforcement or bolts may be placed in bed joints which are at least twice the thickness of the reinforcement or bolts.

2106.1.9 Pipes and conduits embedded in masonry. Pipes or conduit shall not be embedded in any masonry in a manner that will reduce the capacity of the masonry to less than that necessary for required strength or required fire protection.

Placement of pipes or conduits in unfilled cores of hollow-unit masonry shall not be considered as embedment.

EXCEPTIONS: 1. Rigid electric conduits may be embedded in structural masonry when their locations have been detailed on the approved plan.

2. Any pipe or conduit may pass vertically or horizontally through any masonry by means of a sleeve at least large enough to pass any hub or coupling on the pipeline. Such sleeves shall not be placed closer than three diameters, center to center, nor shall they unduly impair the strength of construction.

2106.1.10 Load tests. When a load test is required, the member or portion of the structure under consideration shall be subjected to a superimposed load equal to twice the design live load plus one half of the dead load. This load shall be left in position for a period of 24 hours before removal. If, during the test or upon removal of the load, the member or portion of the structure shows evidence of failure, such changes or modifications as are necessary to make the structure adequate for the rated capacity shall be made; or where approved, a lower rating shall be established. A flexural member shall be considered to have passed the test if the maximum deflection D at the end of the 24-hour period does not exceed the value of Formulas (6-1) or (6-2) and the beams and slabs show a recovery of at least 75 percent of the observed deflection within 24 hours after removal of the load.

$$D = \frac{l}{200} \tag{6-1}$$

$$D = \frac{l^2}{4,000t} \tag{6-2}$$

2106.1.11 Reuse of masonry units. Masonry units may be reused when clean, whole and conforming to the other requirements of this section. All structural properties of masonry of reclaimed units shall be determined by approved test.

2106.1.12 Special provisions in areas of seismic risk.

2106.1.12.1 General. Masonry structures constructed in the seismic zones shown in Figure 16-2 shall be designed in accordance with the design requirements of this chapter and the special provisions for each seismic zone given in this section.

2106.1.12.2 Special provisions for Seismic Zones 0 and 1. There are no special design and construction provisions in this section for structures built in Seismic Zones 0 and 1.

2106.1.12.3 Special provisions for Seismic Zone 2. Masonry structures in Seismic Zone 2 shall comply with the following special provisions:

1. Columns shall be reinforced as specified in Sections 2106.3.6, 2106.3.7 and 2107.2.13.

2. Vertical wall reinforcement of at least 0.20 square inch (130 mm^2) in cross-sectional area shall be provided continuously from support to support at each corner, at each side of each opening, at the ends of walls and at maximum spacing of 4 feet (1219 mm) apart horizontally throughout walls.

3. Horizontal wall reinforcement not less than 0.2 square inch (130 mm^2) in cross-sectional area shall be provided (1) at the bottom and top of wall openings and shall extend not less than 24 inches (610 mm) or less than 40 bar diameters past the opening, (2) continuously at structurally connected roof and floor levels and at the top of walls, (3) at the bottom of walls or in the top of foundations when doweled in walls, and (4) at maximum spacing of 10 feet (3048 mm) unless uniformly distributed joint reinforcement is provided. Reinforcement at the top and bottom of openings when continuous in walls may be used in determining the maximum spacing specified in Item 1 of this paragraph.

4. Where stack bond is used, the minimum horizontal reinforcement ratio shall be 0.0007bt. This ratio shall be satisfied by uniformly distributed joint reinforcement or by horizontal reinforcement spaced not over 4 feet (1219 mm) and fully embedded in grout or mortar.

5. The following materials shall not be used as part of the vertical or lateral load-resisting systems: Type O mortar, masonry cement, plastic cement, nonloadbearing masonry units and glass block.

2106.1.12.4 Special provisions for Seismic Zones 3 and 4. All masonry structures built in Seismic Zones 3 and 4 shall be designed and constructed in accordance with requirements for Seismic Zone 2 and with the following additional requirements and limitations:

EXCEPTION: One- and two-story masonry buildings of Group R, Division 3 and Group U Occupancies located in Seismic Zone 3 having masonry wall h'/t ratios not greater than 27 and using running bond construction when provisions of Section 2106.1.12.3 are met.

1. **Column reinforcement ties.** In columns that are stressed by tensile or compressive axial overturning forces from seismic loading, the spacing of column ties shall not exceed 8 inches (203 mm) for the full height of such columns. In all other columns, ties shall be spaced a maximum of 8 inches (203 mm) in the tops and bottoms of the columns for a distance of one sixth of the clear column height, 18 inches (457 mm), or the maximum column cross-sectional dimension, whichever is greater. Tie spacing for the remaining column height shall not exceed the lessor of 16 bar diameters, 48 tie diameters, the least column cross-sectional dimension, or 18 inches (457 mm).

Column ties shall terminate with a minimum 135-degree hook with extensions not less than six bar diameters or 4 inches (102 mm). Such extensions shall engage the longitudinal column reinforcement and project into the interior of the column. Hooks shall comply with Section 2107.2.2.5, Item 3.

EXCEPTION: Where ties are placed in horizontal bed joints, hooks shall consist of a 90-degree bend having an inside radius of not less than four tie diameters plus an extension of 32 tie diameters.

2. **Shear Walls.**

2.1 **Reinforcement.** The portion of the reinforcement required to resist shear shall be uniformly distributed and shall be joint reinforcement, deformed bars or a combination thereof. The spacing of reinforcement in each direction shall not exceed one half the length of the element, nor one half the height of the element, nor 48 inches (1219 mm).

Joint reinforcement used in exterior walls and considered in the determination of the shear strength of the member shall be hot-dipped galvanized in accordance with UBC Standard 21-10.

Reinforcement required to resist in-plane shear shall be terminated with a standard hook as defined in Section 2107.2.2.5 or with an extension of proper embedment length beyond the reinforcement at the end of the wall section. The hook or extension may be turned up, down or horizontally. Provisions shall be made not to obstruct grout placement. Wall reinforcement terminating in columns or beams shall be fully anchored into these elements.

2.2 **Bond.** Multiwythe grouted masonry shear walls shall be designed with consideration of the adhesion bond strength between the grout and masonry units. When bond strengths are not known from previous tests, the bond strength shall be determined by tests.

2.3 **Wall reinforcement.** All walls shall be reinforced with both vertical and horizontal reinforcement. The sum of the areas of horizontal and vertical reinforcement shall be at least 0.002 times the gross cross-sectional area of the wall, and the minimum area of reinforcement in either direction shall not be less than 0.0007 times the gross cross-sectional area of the wall. The minimum steel requirements for Seismic Zone 2 in Section 2106.1.12.3, Items 2 and 3, may be included in the sum. The spacing of reinforcement shall not exceed 4 feet (1219 mm). The diameter of reinforcement shall not be less than $^3/_8$ inch (9.5 mm) except that joint reinforcement may be considered as a part or all of the requirement for minimum reinforcement. Reinforcement shall be continuous around wall corners and through intersections. Only reinforcement which is continuous in the wall or element shall be considered in computing the minimum area of reinforcement. Reinforcement with splices conforming to Section 2107.2.2.6 shall be considered as continuous reinforcement.

2.4 **Stack bond.** Where stack bond is used, the minimum horizontal reinforcement ratio shall be 0.0015*bt*. Where open-end units are used and grouted solid, the minimum horizontal reinforcement ratio shall be 0.0007*bt*.

Reinforced hollow-unit stacked bond construction which is part of the seismic-resisting system shall use open-end units so that all head joints are made solid, shall use bond beam units to facilitate the flow of grout and shall be grouted solid.

3. **Type N mortar.** Type N mortar shall not be used as part of the vertical- or lateral-load-resisting system.

4. **Concrete abutting structural masonry.** Concrete abutting structural masonry, such as at starter courses or at wall intersections not designed as true separation joints, shall be roughened to a full amplitude of $^1/_{16}$ inch (1.6 mm) and shall be bonded to the masonry in accordance with the requirements of this chapter as if it were masonry. Unless keys or proper reinforcement is provided, vertical joints as specified in Section 2106.1.4 shall be considered to be stack bond and the reinforcement as required for stack bond shall extend through the joint and be anchored into the concrete.

2106.2 Working Stress Design and Strength Design Requirements for Unreinforced and Reinforced Masonry.

2106.2.1 General. In addition to the requirements of Section 2106.1, the design of masonry structures by the working stress design method and strength design method shall comply with the requirements of this section. Additionally, the design of reinforced masonry structures by these design methods shall comply with the requirements of Section 2106.3.

2106.2.2 Specified compressive strength of masonry. The allowable stresses for the design of masonry shall be based on a value of f'_m selected for the construction.

Verification of the value of f'_m shall be based on compliance with Section 2105.3. Unless otherwise specified, f'_m shall be based on 28-day tests. If other than a 28-day test age is used, the value of f'_m shall be as indicated in design drawings or specifications. Design drawings shall show the value of f'_m for which each part of the structure is designed.

2106.2.3 Effective thickness.

2106.2.3.1 Single-wythe walls. The effective thickness of single-wythe walls of either solid or hollow units is the specified thickness of the wall.

2106.2.3.2 Multiwythe walls. The effective thickness of multiwythe walls is the specified thickness of the wall if the space between wythes is filled with mortar or grout. For walls with an open space between wythes, the effective thickness shall be determined as for cavity walls.

2106.2.3.3 Cavity walls. Where both wythes of a cavity wall are axially loaded, each wythe shall be considered to act independently and the effective thickness of each wythe is as defined in Section 2106.2.3.1. Where only one wythe is axially loaded, the effective thickness of the cavity wall is taken as the square root of the sum of the squares of the specified thicknesses of the wythes.

Where a cavity wall is composed of a single wythe and a multiwythe, and both sides are axially loaded, each side of the cavity wall shall be considered to act independently and the effective thickness of each side is as defined in Sections 2106.2.3.1 and 2106.2.3.2. Where only one side is axially loaded, the effective thickness of the cavity wall is the square root of the sum of the squares of the specified thicknesses of the sides.

2106.2.3.4 Columns. The effective thickness for rectangular columns in the direction considered is the specified thickness. The effective thickness for nonrectangular columns is the thickness of the square column with the same moment of inertia about its axis as that about the axis considered in the actual column.

2106.2.4 Effective height. The effective height of columns and walls shall be taken as the clear height of members laterally supported at the top and bottom in a direction normal to the member axis considered. For members not supported at the top normal to the axis considered, the effective height is twice the height of the member above the support. Effective height less than clear height may be used if justified.

2106.2.5 Effective area. The effective cross-sectional area shall be based on the minimum bedded area of hollow units, or the gross area of solid units plus any grouted area. Where hollow units are used with cells perpendicular to the direction of stress, the effective area shall be the lesser of the minimum bedded area or the minimum cross-sectional area. Where bed joints are raked, the effective area shall be correspondingly reduced. Effective areas for cavity walls shall be that of the loaded wythes.

2106.2.6 Effective width of intersecting walls. Where a shear wall is anchored to an intersecting wall or walls, the width of the overhanging flange formed by the intersected wall on either side of the shear wall, which may be assumed working with the shear wall for purposes of flexural stiffness calculations, shall not exceed six times the thickness of the intersected wall. Limits of the effective flange may be waived if justified. Only the effective area of the wall parallel to the shear forces may be assumed to carry horizontal shear.

2106.2.7 Distribution of concentrated vertical loads in walls. The length of wall laid up in running bond which may be considered capable of working at the maximum allowable compressive stress to resist vertical concentrated loads shall not exceed the center-to-center distance between such loads, nor the width of bearing area plus four times the wall thickness. Concentrated vertical loads shall not be assumed to be distributed across continuous vertical mortar or control joints unless elements designed to distribute the concentrated vertical loads are employed.

2106.2.8 Loads on nonbearing walls. Masonry walls used as interior partitions or as exterior surfaces of a building which do not carry vertical loads imposed by other elements of the building shall be designed to carry their own weight plus any superimposed finish and lateral forces. Bonding or anchorage of nonbearing walls shall be adequate to support the walls and to transfer lateral forces to the supporting elements.

2106.2.9 Vertical deflection. Elements supporting masonry shall be designed so that their vertical deflection will not exceed $^{1}/_{600}$ of the clear span under total loads. Lintels shall bear on supporting masonry on each end such that allowable stresses in the supporting masonry are not exceeded. A minimum bearing length of 4 inches (102 mm) shall be provided for lintels bearing on masonry.

2106.2.10 Structural continuity. Intersecting structural elements intended to act as a unit shall be anchored together to resist the design forces.

2106.2.11 Walls intersecting with floors and roofs. Walls shall be anchored to all floors, roofs or other elements which provide lateral support for the wall. Where floors or roofs are designed to transmit horizontal forces to walls, the anchorage to such walls shall be designed to resist the horizontal force.

2106.2.12 Modulus of elasticity of materials.

2106.2.12.1 Modulus of elasticity of masonry. The moduli for masonry may be estimated as provided below. Actual values, where required, shall be established by test. The modulus of elasticity of masonry shall be determined by the secant method in which the slope of the line for the modulus of elasticity is taken from 0.05 f'_m to a point on the curve at 0.33 f'_m. These values are not to be reduced by one half as set forth in Section 2107.1.2.

Modulus of elasticity of clay or shale unit masonry.

$$E_m = 750\ f'_m,\ 3{,}000{,}000 \text{ psi (20.5 GPa) maximum} \qquad (6\text{-}3)$$

Modulus of elasticity of concrete unit masonry.

$$E_m = 750\ f'_m,\ 3{,}000{,}000 \text{ psi (20.5 GPa) maximum} \qquad (6\text{-}4)$$

2106.2.12.2 Modulus of elasticity of steel.

$$E_s = 29{,}000{,}000 \text{ psi (200 GPa)} \qquad (6\text{-}5)$$

2106.2.13 Shear modulus of masonry.

$$G = 0.4\ E_m \qquad (6\text{-}6)$$

2106.2.14 Placement of embedded anchor bolts.

2106.2.14.1 General. Placement requirements for plate anchor bolts, headed anchor bolts and bent bar anchor bolts shall be determined in accordance with this subsection. Bent bar anchor bolts shall have a hook with a 90-degree bend with an inside diameter of three bolt diameters, plus an extension of one and one half bolt diameters at the free end. Plate anchor bolts shall have a plate welded to the shank to provide anchorage equivalent to headed anchor bolts.

The effective embedment depth l_b for plate or headed anchor bolts shall be the length of embedment measured perpendicular from the surface of the masonry to the bearing surface of the plate or head of the anchorage, and l_b for bent bar anchors shall be the length of embedment measured perpendicular from the surface of the masonry to the bearing surface of the bent end minus one anchor bolt diameter. All bolts shall be grouted in place with at least 1 inch (25 mm) of grout between the bolt and the masonry, except that $^{1}/_{4}$-inch-diameter (6.4 mm) bolts may be placed in bed joints which are at least $^{1}/_{2}$ inch (12.7 mm) in thickness.

2106.2.14.2 Minimum edge distance. The minimum anchor bolt edge distance l_{be} measured from the edge of the masonry parallel with the anchor bolt to the surface of the anchor bolt shall be $1^{1}/_{2}$ inches (38 mm).

2106.2.14.3 Minimum embedment depth. The minimum embedment depth of anchor bolts l_b shall be four bolt diameters but not less than 2 inches (51 mm).

2106.2.14.4 Minimum spacing between bolts. The minimum center-to-center distance between anchor bolts shall be four bolt diameters.

2106.2.15 Flexural resistance of cavity walls. For computing the flexural resistance of cavity walls, lateral loads perpendicular to the plane of the wall shall be distributed to the wythes according to their respective flexural rigidities.

2106.3 Working Stress Design and Strength Design Requirements for Reinforced Masonry.

2106.3.1 General. In addition to the requirements of Sections 2106.1 and 2106.2, the design of reinforced masonry structures by the working stress design method or the strength design method shall comply with the requirements of this section.

2106.3.2 Plain bars. The use of plain bars larger than $^{1}/_{4}$ inch (6.4 mm) in diameter is not permitted.

2106.3.3 Spacing of longitudinal reinforcement. The clear distance between parallel bars, except in columns, shall not be less than the nominal diameter of the bars or 1 inch (25 mm), except that bars in a splice may be in contact. This clear distance requirement applies to the clear distance between a contact splice and adjacent splices or bars.

The clear distance between the surface of a bar and any surface of a masonry unit shall not be less than $^{1}/_{4}$ inch (6.4 mm) for fine grout and $^{1}/_{2}$ inch (12.7 mm) for coarse grout. Cross webs of hollow units may be used as support for horizontal reinforcement.

2106.3.4 Anchorage of flexural reinforcement. The tension or compression in any bar at any section shall be developed on each side of that section by the required development length. The development length of the bar may be achieved by a combination of an embedment length, anchorage or, for tension only, hooks.

Except at supports or at the free end of cantilevers, every reinforcing bar shall be extended beyond the point at which it is no longer needed to resist tensile stress for a distance equal to 12 bar diameters or the depth of the beam, whichever is greater. No flexural bar shall be terminated in a tensile zone unless at least one of the following conditions is satisfied:

1. The shear is not over one half that permitted, including allowance for shear reinforcement where provided.

2. Additional shear reinforcement in excess of that required is provided each way from the cutoff a distance equal to the depth of the beam. The shear reinforcement spacing shall not exceed $d/8r_b$.

3. The continuing bars provide double the area required for flexure at that point or double the perimeter required for reinforcing bond.

At least one third of the total reinforcement provided for negative moment at the support shall be extended beyond the extreme position of the point of inflection a distance sufficient to develop one half the allowable stress in the bar, not less than $^1/_{16}$ of the clear span, or the depth *d* of the member, whichever is greater.

Tensile reinforcement for negative moment in any span of a continuous restrained or cantilever beam, or in any member of a rigid frame, shall be adequately anchored by reinforcement bond, hooks or mechanical anchors in or through the supporting member.

At least one third of the required positive moment reinforcement in simple beams or at the freely supported end of continuous beams shall extend along the same face of the beam into the support at least 6 inches (153 mm). At least one fourth of the required positive moment reinforcement at the continuous end of continuous beams shall extend along the same face of the beam into the support at least 6 inches (153 mm).

Compression reinforcement in flexural members shall be anchored by ties or stirrups not less than $^1/_4$ inch (6.4 mm) in diameter, spaced not farther apart than 16 bar diameters or 48 tie diameters, whichever is less. Such ties or stirrups shall be used throughout the distance where compression reinforcement is required.

2106.3.5 Anchorage of shear reinforcement. Single, separate bars used as shear reinforcement shall be anchored at each end by one of the following methods:

1. Hooking tightly around the longitudinal reinforcement through 180 degrees.

2. Embedment above or below the mid-depth of the beam on the compression side a distance sufficient to develop the stress in the bar for plain or deformed bars.

3. By a standard hook, as defined in Section 2107.2.2.5, considered as developing 7,500 psi (52 MPa), plus embedment sufficient to develop the remainder of the stress to which the bar is subjected. The effective embedded length shall not be assumed to exceed the distance between the mid-depth of the beam and the tangent of the hook.

The ends of bars forming a single U or multiple U stirrup shall be anchored by one of the methods set forth in Items 1 through 3 above or shall be bent through an angle of at least 90 degrees tightly around a longitudinal reinforcing bar not less in diameter than the stirrup bar, and shall project beyond the bend at least 12 stirrup diameters.

The loops or closed ends of simple U or multiple U stirrups shall be anchored by bending around the longitudinal reinforcement through an angle of at least 90 degrees and project beyond the end of the bend at least 12 stirrup diameters.

2106.3.6 Lateral ties. All longitudinal bars for columns shall be enclosed by lateral ties. Lateral support shall be provided to the longitudinal bars by the corner of a complete tie having an included angle of not more than 135 degrees or by a standard hook at the end of a tie. The corner bars shall have such support provided by a complete tie enclosing the longitudinal bars. Alternate longitudinal bars shall have such lateral support provided by ties and no bar shall be farther than 6 inches (152 mm) from such laterally supported bar.

Lateral ties and longitudinal bars shall be placed not less than $1^1/_2$ inches (38 mm) and not more than 5 inches (127 mm) from the surface of the column. Lateral ties may be placed against the longitudinal bars or placed in the horizontal bed joints where the requirements of Section 2106.1.8 are met. Spacing of ties shall not exceed 16 longitudinal bar diameters, 48 tie diameters or the least dimension of the column but not more than 18 inches (457 mm).

Ties shall be at least $^1/_4$ inch (6.4 mm) in diameter for No. 7 or smaller longitudinal bars and at least No. 3 for longitudinal bars larger than No. 7. Ties smaller than No. 3 may be used for longitudinal bars larger than No. 7, provided the total cross-sectional area of such smaller ties crossing a longitudinal plane is equal to that of the larger ties at their required spacing.

2106.3.7 Column anchor bolt ties. Additional ties shall be provided around anchor bolts which are set in the top of columns. Such ties shall engage at least four bolts or, alternately, at least four vertical column bars or a combination of bolts and bars totaling at least four. Such ties shall be located within the top 5 inches (127 mm) of the column and shall provide a total of 0.4 square inch (260 mm^2) or more in cross-sectional area. The uppermost tie shall be within 2 inches (51 mm) of the top of the column.

2106.3.8 Effective width *b* of compression area. In computing flexural stresses in walls where reinforcement occurs, the effective width assumed for running bond masonry shall not exceed six times the nominal wall thickness or the center-to-center distance between reinforcement. Where stack bond is used, the effective width shall not exceed three times the nominal wall thickness or the center-to-center distance between reinforcement or the length of one unit, unless solid grouted open-end units are used.

SECTION 2107 — WORKING STRESS DESIGN OF MASONRY

2107.1 General.

2107.1.1 Scope. The design of masonry structures using working stress design shall comply with the provisions of Section 2106 and this section. Stresses in clay or concrete masonry under service loads shall not exceed the values given in this section.

2107.1.2 Allowable masonry stresses. When quality assurance provisions do not include requirements for special inspection as prescribed in Section 1701, the allowable stresses for masonry in Section 2107 shall be reduced by one half.

When one half allowable masonry stresses are used in Seismic Zones 3 and 4, the value of f'_m from Table 21-D shall be limited to a maximum of 1,500 psi (10 MPa) for concrete masonry and 2,600 psi (18 MPa) for clay masonry unless the value of f'_m is verified by tests in accordance with Section 2105.3.4, Items 1 and 4 or 6. A letter of certification is not required.

When one half allowable masonry stresses are used for design in Seismic Zones 3 and 4, the value of f'_m shall be limited to 1,500 psi (10 MPa) for concrete masonry and 2,600 psi (18 MPa) for clay masonry for Section 2105.3.2, Item 3, and Section 2105.3.3, Item 5, unless the value of f'_m is verified during construction by the testing requirements of Section 2105.3.2, Item 2. A letter of certification is not required.

2107.1.3 Minimum dimensions for masonry structures located in Seismic Zones 3 and 4. Elements of masonry structures located in Seismic Zones 3 and 4 shall be in accordance with this section.

2107.1.3.1 Bearing walls. The nominal thickness of reinforced masonry bearing walls shall not be less than 6 inches (152 mm) except that nominal 4-inch-thick (102 mm) load-bearing reinforced hollow-clay unit masonry walls may be used, provided net area unit strength exceeds 8,000 psi (55 MPa), units are laid in running bond, bar sizes do not exceed $^1/_2$ inch (12.7 mm) with no more than two bars or one splice in a cell, and joints are flush cut, concave or a protruding V section.

2107.1.3.2 Columns. The least nominal dimension of a reinforced masonry column shall be 12 inches (305 mm) except that, for working stress design, if the allowable stresses are reduced by one half, the minimum nominal dimension shall be 8 inches (203 mm).

2107.1.4 Design assumptions. The working stress design procedure is based on working stresses and linear stress-strain distribution assumptions with all stresses in the elastic range as follows:

1. Plane sections before bending remain plane after bending.
2. Stress is proportional to strain.
3. Masonry elements combine to form a homogenous member.

2107.1.5 Embedded anchor bolts.

2107.1.5.1 General. Allowable loads for plate anchor bolts, headed anchor bolts and bent bar anchor bolts shall be determined in accordance with this section.

2107.1.5.2 Tension. Allowable loads in tension shall be the lesser value selected from Tables 21-E-1 and 21-E-2 or shall be determined from the lesser of Formula (7-1) or Formula (7-2).

$$B_t = 0.5\, A_p \sqrt{f'_m} \qquad (7\text{-}1)$$

For **SI:**

$$B_t = 0.042\, A_p \sqrt{f'_m}$$

$$B_t = 0.2\, A_b f_y \qquad (7\text{-}2)$$

The area A_p shall be the lesser of Formula (7-3) or Formula (7-4) and where the projected areas of adjacent anchor bolts overlap, A_p of each anchor bolt shall be reduced by one half of the overlapping area.

$$A_p = \pi l_b^{\,2} \qquad (7\text{-}3)$$

$$A_p = \pi l_{b_e}^{\,2} \qquad (7\text{-}4)$$

2107.1.5.3 Shear. Allowable loads in shear shall be the value selected from Table 21-F or shall be determined from the lesser of Formula (7-5) or Formula (7-6).

$$B_v = 350 \sqrt[4]{f'_m A_b} \qquad (7\text{-}5)$$

For **SI:**

$$B_v = 1070 \sqrt[4]{f'_m A_b}$$

$$B_v = 0.12\, A_b f_y \qquad (7\text{-}6)$$

Where the anchor bolt edge distance l_{be} in the direction of load is less than 12 bolt diameters, the value of B_v in Formula (7-5) shall be reduced by linear interpolation to zero at an l_{be} distance of $1^1/_2$ inches (38 mm). Where adjacent anchors are spaced closer than $8d_b$, the allowable shear of the adjacent anchors determined by Formula (7-5) shall be reduced by linear interpolation to 0.75 times the allowable shear value at a center-to-center spacing of four bolt diameters.

2107.1.5.4 Combined shear and tension. Anchor bolts subjected to combined shear and tension shall be designed in accordance with Formula (7-7).

$$\frac{b_t}{B_t} + \frac{b_v}{B_v} \leq 1.0 \qquad (7\text{-}7)$$

2107.1.6 Compression in walls and columns.

2107.1.6.1 Walls, axial loads. Stresses due to compressive forces applied at the centroid of wall may be computed by Formula (7-8) assuming uniform distribution over the effective area.

$$f_a = P / A_e \qquad (7\text{-}8)$$

2107.1.6.2 Columns, axial loads. Stresses due to compressive forces applied at the centroid of columns may be computed by Formula (7-8) assuming uniform distribution over the effective area.

2107.1.6.3 Columns, bending or combined bending and axial loads. Stresses in columns due to combined bending and axial loads shall satisfy the requirements of Section 2107.2.7 where f_a/F_a is replaced by P/P_a. Columns subjected to bending shall meet all applicable requirements for flexural design.

2107.1.7 Shear walls, design loads. When calculating shear or diagonal tension stresses, shear walls which resist seismic forces in Seismic Zones 3 and 4 shall be designed to resist 1.5 times the forces required by Section 1630.

2107.1.8 Design, composite construction.

2107.1.8.1 General. The requirements of this section govern multiwythe masonry in which at least one wythe has strength or composition characteristics different from the other wythe or wythes and is adequately bonded to act as a single structural element.

The following assumptions shall apply to the design of composite masonry:

1. Analysis shall be based on elastic transformed section of the net area.

2. The maximum computed stress in any portion of composite masonry shall not exceed the allowable stress for the material of that portion.

2107.1.8.2 Determination of moduli of elasticity. The modulus of elasticity of each type of masonry in composite construction shall be measured by tests if the modular ratio of the respective types of masonry exceeds 2 to 1 as determined by Section 2106.2.12.

2107.1.8.3 Structural continuity.

2107.1.8.3.1 Bonding of wythes. All wythes of composite masonry elements shall be tied together as specified in Section 2106.1.5.2 as a minimum requirement. Additional ties or the combination of grout and metal ties shall be provided to transfer the calculated stress.

2107.1.8.3.2 Material properties. The effect of dimensional changes of the various materials and different boundary conditions of various wythes shall be included in the design.

2107.1.8.4 Design procedure, transformed sections. In the design of transformed sections, one material is chosen as the reference material, and the other materials are transformed to an equivalent area of the reference material by multiplying the areas of the other materials by the respective ratios of the moduli of elasticity of the other materials to that of the reference material. Thickness of the transformed area and its distance perpendicular to a given bending axis remain unchanged. Effective height or length of the element remains unchanged.

2107.1.9 Reuse of masonry units. The allowable working stresses for reused masonry units shall not exceed 50 percent of those permitted for new masonry units of the same properties.

2107.2 Design of Reinforced Masonry.

2107.2.1 Scope. The requirements of this section are in addition to the requirements of Sections 2106 and 2107.1, and govern masonry in which reinforcement is used to resist forces.

Walls with openings used to resist lateral loads whose pier and beam elements are within the dimensional limits of Section 2108.2.6.1.2 may be designed in accordance with Section 2108.2.6. Walls used to resist lateral loads not meeting the dimensional limits of Section 2108.2.6.1.2 may be designed as walls in accordance with this section or Section 2108.2.5.

2107.2.2 Reinforcement.

2107.2.2.1 Maximum reinforcement size. The maximum size of reinforcement shall be No. 11 bars. Maximum reinforcement area in cells shall be 6 percent of the cell area without splices and 12 percent of the cell area with splices.

2107.2.2.2 Cover. All reinforcing bars, except joint reinforcement, shall be completely embedded in mortar or grout and have a minimum cover, including the masonry unit, of at least $^3/_4$ inch (19 mm), $1^1/_2$ inches (38 mm) of cover when the masonry is exposed to weather and 2 inches (51 mm) of cover when the masonry is exposed to soil.

2107.2.2.3 Development length. The required development length l_d for deformed bars or deformed wire shall be calculated by:

$$l_d = 0.002\, d_b\, f_s \text{ for bars in tension} \qquad (7\text{-}9)$$

For **SI:** $l_d = 0.29\, d_b\, f_s$ for bars in tension

$$l_d = 0.0015\, d_b\, f_s \text{ for bars in compression} \qquad (7\text{-}10)$$

For **SI:** $l_d = 0.22\, d_b\, f_s$ for bars in compression

Development length for smooth bars shall be twice the length determined by Formula (7-9).

2107.2.2.4 Reinforcement bond stress. Bond stress u in reinforcing bars shall not exceed the following:

Plain Bars	60 psi (413 kPa)
Deformed Bars	200 psi (1378 kPa)
Deformed Bars without Special Inspection	100 psi (689 kPa)

2107.2.2.5 Hooks.

1. The term "standard hook" shall mean one of the following:

   1.1 A 180-degree turn plus extension of at least four bar diameters, but not less than $2^1/_2$ inches (63 mm) at free end of bar.

   1.2 A 90-degree turn plus extension of at least 12 bar diameters at free end of bar.

   1.3 For stirrup and tie anchorage only, either a 90-degree or a 135-degree turn, plus an extension of at least six bar diameters, but not less than $2^1/_2$ inches (63 mm) at the free end of the bar.

2. Inside diameter of bend of the bars, other than for stirrups and ties, shall not be less than that set forth in Table 21-G.

3. Inside diameter of bend for No. 5 or smaller stirrups and ties shall not be less than four bar diameters. Inside diameter of bend for No. 5 or larger stirrups and ties shall not be less than that set forth in Table 21-G.

4. Hooks shall not be permitted in the tension portion of any beam, except at the ends of simple or cantilever beams or at the freely supported end of continuous or restrained beams.

5. Hooks shall not be assumed to carry a load which would produce a tensile stress in the bar greater than 7,500 psi (52 MPa).

6. Hooks shall not be considered effective in adding to the compressive resistance of bars.

7. Any mechanical device capable of developing the strength of the bar without damage to the masonry may be used in lieu of a hook. Data must be presented to show the adequacy of such devices.

2107.2.2.6 Splices. The amount of lap of lapped splices shall be sufficient to transfer the allowable stress of the reinforcement as specified in Sections 2106.3.4, 2107.2.2.3 and 2107.2.12. In no case shall the length of the lapped splice be less than 30 bar diameters for compression or 40 bar diameters for tension.

Welded or mechanical connections shall develop 125 percent of the specified yield strength of the bar in tension.

> **EXCEPTION:** For compression bars in columns that are not part of the seismic-resisting system and are not subject to flexure, only the compressive strength need be developed.

When adjacent splices in grouted masonry are separated by 3 inches (76 mm) or less, the required lap length shall be increased 30 percent.

> **EXCEPTION:** Where lap splices are staggered at least 24 bar diameters, no increase in lap length is required.

See Section 2107.2.12 for lap splice increases.

2107.2.3 Design assumptions. The following assumptions are in addition to those stated in Section 2107.1.4:

1. Masonry carries no tensile stress.

2. Reinforcement is completely surrounded by and bonded to masonry material so that they work together as a homogenous material within the range of allowable working stresses.

2107.2.4 Nonrectangular flexural elements. Flexural elements of nonrectangular cross section shall be designed in accordance with the assumptions given in Sections 2107.1.4 and 2107.2.3.

2107.2.5 Allowable axial compressive stress and force. For members other than reinforced masonry columns, the allowable axial compressive stress F_a shall be determined as follows:

$$F_a = 0.25 f'_m \left[1 - \left(\frac{h'}{140r}\right)^2\right] \text{ for } h'/r \le 99 \qquad (7\text{-}11)$$

$$F_a = 0.25 f'_m \left(\frac{70r}{h'}\right)^2 \text{ for } h'/r > 99 \qquad (7\text{-}12)$$

For reinforced masonry columns, the allowable axial compressive force P_a shall be determined as follows:

$$P_a = [0.25 f'_m A_e + 0.65 A_s F_{sc}]\left[1 - \left(\frac{h'}{140r}\right)^2\right]$$

$$345h'/M\le \qquad (7\text{-}13)$$

$$P_a = [0.25 f'_m A_e + 0.65 A_s F_{sc}]\left(\frac{70r}{h'}\right)^2$$

$$345h'/M> \qquad (7\text{-}14)$$

2107.2.6 Allowable flexural compressive stress. The allowable flexural compressive stress F_b is:

$$F_b = 0.33\, f'_m,\ 2{,}000 \text{ psi (13.8 MPa) maximum} \qquad (7\text{-}15)$$

2107.2.7 Combined compressive stresses, unity formula. Elements subjected to combined axial and flexural stresses shall be designed in accordance with accepted principles of mechanics or in accordance with Formula (7-16):

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \le 1 \qquad (7\text{-}16)$$

2107.2.8 Allowable shear stress in flexural members. Where no shear reinforcement is provided, the allowable shear stress F_v in flexural members is:

$$F_v = 1.0\sqrt{f'_m},\ 50 \text{ psi maximum} \qquad (7\text{-}17)$$

For **SI:** $F_v = 0.083\sqrt{f'_m}$, 345 kPa maximum

EXCEPTION: For a distance of $^1/_{16}$ the clear span beyond the point of inflection, the maximum stress shall be 20 psi (140 kPa).

Where shear reinforcement designed to take entire shear force is provided, the allowable shear stress F_v in flexural members is:

$$F_v = 3.0\sqrt{f'_m}\text{, 150 psi maximum} \qquad (7\text{-}18)$$

For **SI:** $F_v = 0.25\sqrt{f'_m}$, 1.0 MPa maximum

2107.2.9 Allowable shear stress in shear walls. Where in-plane flexural reinforcement is provided and masonry is used to resist all shear, the allowable shear stress F_v in shear walls is:

For $M/Vd < 1$,

$$F_v = {}^1/_3\left(4 - \frac{M}{Vd}\right)\sqrt{f'_m},\ \left(80 - 45\frac{M}{Vd}\right)\text{ maximum} \qquad (7\text{-}19)$$

For **SI:** $F_v = {}^1/_{36}\left(4 - \frac{M}{Vd}\right)\sqrt{f'_m},\ \left(80 - 45\frac{M}{Vd}\right)$ maximum

For $M/Vd \geq 1$, $F_v = 1.0\sqrt{f'_m}$, 35 psi maximum (7-20)

For **SI:** $F_v = {}^1/_{12}\sqrt{f'_m}$, 240 kPa maximum

Where shear reinforcement designed to take all the shear is provided, the allowable shear stress F_v in shear walls is:

For $M/Vd < 1$,

$$F_v = {}^1/_2\left(4 - \frac{M}{Vd}\right)\sqrt{f'_m},\ \left(120 - 45\frac{M}{Vd}\right)\text{ maximum} \qquad (7\text{-}21)$$

For **SI:** For $M/Vd < 1$,

$$F_v = {}^1/_{24}\left(4 - \frac{M}{Vd}\right)\sqrt{f'_m},\ \left(120 - 45\frac{M}{Vd}\right)\text{ maximum}$$

For $M/Vd \geq 1$, $F_v = 1.5\sqrt{f'_m}$, 75 psi maximum (7-22)

For **SI:** For $M/Vd \geq 1$, $F_v = 0.12\sqrt{f'_m}$, 520 kPa maximum

2107.2.10 Allowable bearing stress. When a member bears on the full area of a masonry element, the allowable bearing stress F_{br} is:

$$F_{br} = 0.26 f'_m \qquad (7\text{-}23)$$

When a member bears on one third or less of a masonry element, the allowable bearing stress F_{br} is:

$$F_{br} = 0.38 f'_m \qquad (7\text{-}24)$$

Formula (7-24) applies only when the least dimension between the edges of the loaded and unloaded areas is a minimum of one fourth of the parallel side dimension of the loaded area. The allowable bearing stress on a reasonably concentric area greater than one third but less than the full area shall be interpolated between the values of Formulas (7-23) and (7-24).

2107.2.11 Allowable stresses in reinforcement. The allowable stresses in reinforcement shall be as follows:

1. **Tensile stress.**

1.1 Deformed bars,

$$F_s = 0.5 f_y\text{, 24,000 psi (165 MPa) maximum} \qquad (7\text{-}25)$$

1.2 Wire reinforcement,

$$F_s = 0.5 f_y\text{, 30,000 psi (207 MPa) maximum} \qquad (7\text{-}26)$$

1.3 Ties, anchors and smooth bars,

$$F_s = 0.4 f_y\text{, 20,000 psi (138 MPa) maximum} \qquad (7\text{-}27)$$

2. **Compressive stress.**

2.1 Deformed bars in columns,

$$F_{sc} = 0.4 f_y\text{, 24,000 psi (165 MPa) maximum} \qquad (7\text{-}28)$$

2.2 Deformed bars in flexural members,

$$F_s = 0.5 f_y\text{, 24,000 psi (165 MPa) maximum} \qquad (7\text{-}29)$$

2.3 Deformed bars in shear walls which are confined by lateral ties throughout the distance where compression reinforcement is required and where such lateral ties are not less than $^1/_4$ inch in diameter and spaced not farther apart than 16 bar diameters or 48 tie diameters,

$$F_{sc} = 0.4 f_y\text{, 24,000 psi (165 MPa) maximum} \qquad (7\text{-}30)$$

2107.2.12 Lap splice increases. In regions of moment where the design tensile stresses in the reinforcement are greater than 80 percent of the allowable steel tensile stress F_s, the lap length of splices shall be increased not less than 50 percent of the minimum required length. Other equivalent means of stress transfer to accomplish the same 50 percent increase may be used.

2107.2.13 Reinforcement for columns. Columns shall be provided with reinforcement as specified in this section.

2107.2.13.1 Vertical reinforcement. The area of vertical reinforcement shall not be less than 0.005 A_e and not more than 0.04 A_e. At least four No. 3 bars shall be provided. The minimum clear distance between parallel bars in columns shall be two and one half times the bar diameter.

2107.2.14 Compression in walls and columns.

2107.2.14.1 General. Stresses due to compressive forces in walls and columns shall be calculated in accordance with Section 2107.2.5.

2107.2.14.2 Walls, bending or combined bending and axial loads. Stresses in walls due to combined bending and axial loads shall satisfy the requirements of Section 2107.2.7 where f_a is given by Formula (7-8). Walls subjected to bending with or without axial loads shall meet all applicable requirements for flexural design.

The design of walls with an h'/t ratio larger than 30 shall be based on forces and moments determined from an analysis of the structure. Such analysis shall consider the influence of axial loads and variable moment of inertia on member stiffness and fixed-end moments, effect of deflections on moments and forces and the effects of duration of loads.

2107.2.15 Flexural design, rectangular flexural elements. Rectangular flexural elements shall be designed in accordance with the following formulas or other methods based on the assumptions given in Sections 2107.1.4, 2107.2.3 and this section.

1. Compressive stress in the masonry:

$$f_b = \frac{M}{bd^2}\left(\frac{2}{jk}\right) \qquad (7\text{-}31)$$

2. Tensile stress in the longitudinal reinforcement:

$$f_s = \frac{M}{A_s jd} \qquad (7\text{-}32)$$

3. Design coefficients:

$$k = \sqrt{(n\rho)^2 + 2n\rho} - n\rho \qquad (7\text{-}33)$$

or

$$k = \frac{1}{1 + \frac{f_s}{n f_b}} \qquad (7\text{-}34)$$

$$j = 1 - \frac{k}{3} \qquad (7\text{-}35)$$

2107.2.16 Bond of flexural reinforcement. In flexural members in which tensile reinforcement is parallel to the compressive face, the bond stress shall be computed by the formula:

$$u = \frac{V}{\Sigma_o jd} \qquad (7\text{-}36)$$

2107.2.17 Shear in flexural members and shear walls. The shear stress in flexural members and shear walls shall be computed by:

$$f_v = \frac{V}{bjd} \qquad (7\text{-}37)$$

For members of T or I section, b' shall be substituted for b. Where f_v as computed by Formula (7-37) exceeds the allowable shear stress in masonry, F_v, web reinforcement shall be provided and designed to carry the total shear force. Both vertical and horizontal shear stresses shall be considered.

The area required for shear reinforcement placed perpendicular to the longitudinal reinforcement shall be computed by:

$$A_v = \frac{sV}{F_s d} \qquad (7\text{-}38)$$

Where web reinforcement is required, it shall be so spaced that every 45-degree line extending from a point at $d/2$ of the beam to the longitudinal tension bars shall be crossed by at least one line of web reinforcement.

2107.3 Design of Unreinforced Masonry.

2107.3.1 General. The requirements of this section govern masonry in which reinforcement is not used to resist design forces and are in addition to the requirements of Sections 2106 and 2107.1.

2107.3.2 Allowable axial compressive stress. The allowable axial compressive stress F_a is:

$$F_a = 0.25 f'_m \left[1 - \left(\frac{h'}{140r} \right)^2 \right] \text{ for } h'/r \leq 99 \qquad (7\text{-}39)$$

$$F_a = 0.25 f'_m \left(\frac{70r}{h'} \right)^2 \text{ for } h'/r > 99 \qquad (7\text{-}40)$$

2107.3.3 Allowable flexural compressive stress. The allowable flexural compressive stress F_b is:

$$F_b = 0.33 f'_m, \text{ 2,000 psi (13.8 MPa) maximum} \qquad (7\text{-}41)$$

2107.3.4 Combined compressive stresses, unity formula. Elements subjected to combined axial and flexural stresses shall be designed in accordance with accepted principles of mechanics or in accordance with the Formula (7-42):

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1 \qquad (7\text{-}42)$$

2107.3.5 Allowable tensile stress. Resultant tensile stress due to combined bending and axial load shall not exceed the allowable flexural tensile stress, F_t.

The allowable tensile stress for walls in flexure without tensile reinforcement using portland cement and hydrated lime, or using mortar cement Type M or S mortar, shall not exceed the values in Table 21-I.

Values in Table 21-I for tension normal to head joints are for running bond; no tension is allowed across head joints in stack bond masonry. These values shall not be used for horizontal flexural members.

2107.3.6 Allowable shear stress in flexural members. The allowable shear stress F_v in flexural members is:

$$F_v = 1.0 \sqrt{f'_m}, \text{ 50 psi maximum} \qquad (7\text{-}43)$$

For **SI:** $F_v = 0.083 \sqrt{f'_m}$, 345 kPa maximum

EXCEPTION: For a distance of $^1/_{16}$th the clear span beyond the point of inflection, the maximum stress shall be 20 psi (138 kPa).

2107.3.7 Allowable shear stress in shear walls. The allowable shear stress F_v in shear walls is as follows:

1. Clay units $F_v = 0.3 \sqrt{f'_m}$, 80 psi maximum (7-44)

For **SI:** $F_v = 0.025 \sqrt{f'_m}$, 551 kPa maximum

2. Concrete units with Type M or S mortar, F_v = 34 psi (234 kPa) maximum.

3. Concrete units with Type N mortar, F_v = 23 psi (158 kPa) maximum.

4. The allowable shear stress in unreinforced masonry may be increased by 0.2 f_{md}.

2107.3.8 Allowable bearing stress. When a member bears on the full area of a masonry element, the allowable bearing stress F_{br} shall be:

$$F_{br} = 0.26 f'_m \qquad (7\text{-}45)$$

When a member bears on one-third or less of a masonry element, the allowable bearing stress F_{br} shall be:

$$F_{br} = 0.38 f'_m \qquad (7\text{-}46)$$

Formula (7-46) applies only when the least dimension between the edges of the loaded and unloaded areas is a minimum of one fourth of the parallel side dimension of the loaded area. The allowable bearing stress on a reasonably concentric area greater than one third but less than the full area shall be interpolated between the values of Formulas (7-45) and (7-46).

2107.3.9 Combined bending and axial loads, compressive stresses. Compressive stresses due to combined bending and axial loads shall satisfy the requirements of Section 2107.3.4.

2107.3.10 Compression in walls and columns. Stresses due to compressive forces in walls and columns shall be calculated in accordance with Section 2107.2.5.

2107.3.11 Flexural design. Stresses due to flexure shall not exceed the values given in Sections 2107.1.2, 2107.3.3 and 2107.3.5, where:

$$f_b = Mc/I \qquad (7\text{-}47)$$

2107.3.12 Shear in flexural members and shear walls. Shear calculations for flexural members and shear walls shall be based on Formula (7-48).

$$f_v = V / A_e \qquad (7\text{-}48)$$

2107.3.13 Corbels. The slope of corbelling (angle measured from the horizontal to the face of the corbelled surface) of unreinforced masonry shall not be less than 60 degrees.

The maximum horizontal projection of corbelling from the plane of the wall shall be such that allowable stresses are not exceeded.

2107.3.14 Stack bond. Masonry units laid in stack bond shall have longitudinal reinforcement of at least 0.00027 times the vertical cross-sectional area of the wall placed horizontally in the bed joints or in bond beams spaced vertically not more than 48 inches (1219 mm) apart.

SECTION 2108 — STRENGTH DESIGN OF MASONRY

2108.1 General.

2108.1.1 General provisions. The design of hollow-unit clay and concrete masonry structures using strength design shall comply with the provisions of Section 2106 and this section.

EXCEPTION: Two-wythe solid-unit masonry may be used under Sections 2108.2.1 and 2108.2.4.

2108.1.2 Quality assurance provisions. Special inspection during construction shall be provided as set forth in Section 1701.5, Item 7.

2108.1.3 Required strength. The required strength shall be determined in accordance with the factored load combinations of Section 1612.2.

2108.1.4 Design strength. Design strength is the nominal strength, multiplied by the strength-reduction factor, ϕ, as specified in this section. Masonry members shall be proportioned such that the design strength exceeds the required strength.

2108.1.4.1 Beams, piers and columns.

2108.1.4.1.1 Flexure. Flexure with or without axial load, the value of ϕ shall be determined from Formula (8-1):

$$\phi = 0.8 - \frac{P_u}{A_e f'_m} \qquad (8\text{-}1)$$

$$\text{and } 0.60 \le \phi \le 0.80$$

2108.1.4.1.2 Shear. Shear: $\phi = 0.60$

2108.1.4.2 Wall design for out-of-plane loads.

2108.1.4.2.1 Walls with unfactored axial load of 0.04 f'_m or less. Flexure: $\phi = 0.80$.

2108.1.4.2.2 Walls with unfactored axial load greater than 0.04 f'_m. Axial load and axial load with flexure: $\phi = 0.80$. Shear: $\phi = 0.60$.

2108.1.4.3 Wall design for in-plane loads.

2108.1.4.3.1 Axial load. Axial load and axial load with flexure: $\phi = 0.65$.

For walls with symmetrical reinforcement in which f_y does not exceed 60,000 psi (413 MPa), the value of ϕ may be increased linearly to 0.85 as the value of ϕP_n decreases from $0.10 f'_m A_e$ or $0.25 P_b$ to zero.

For solid grouted walls, the value of P_b may be calculated by Formula (8-2)

$$P_b = 0.85 f'_m b a_b \qquad (8\text{-}2)$$

WHERE:

$$a_b = 0.85d \{e_{mu} / [e_{mu} + (f_y / E_s)]\} \qquad (8\text{-}3)$$

2108.1.4.3.2 Shear. Shear: $\phi = 0.60$.

The value of ϕ may be 0.80 for any shear wall when its nominal shear strength exceeds the shear corresponding to development of its nominal flexural strength for the factored-load combination.

2108.1.4.4 Moment-resisting wall frames.

2108.1.4.4.1 Flexure with or without axial load. The value of ϕ shall be as determined from Formula (8-4); however, the value of ϕ shall not be less than 0.65 nor greater than 0.85.

$$\phi = 0.85 - 2\left(\frac{P_u}{A_e f'_m}\right) \qquad (8\text{-}4)$$

2108.1.4.4.2 Shear. Shear: $\phi = 0.80$.

2108.1.4.5 Anchor. Anchor bolts: $\phi = 0.80$.

2108.1.4.6 Reinforcement.

2108.1.4.6.1 Development. Development: $\phi = 0.80$.

2108.1.4.6.2 Splices. Splices: $\phi = 0.80$.

2108.1.5 Anchor bolts.

2108.1.5.1 Required strength. The required strength of embedded anchor bolts shall be determined from factored loads as specified in Section 2108.1.3.

2108.1.5.2 Nominal anchor bolt strength. The nominal strength of anchor bolts times the strength-reduction factor shall equal or exceed the required strength.

The nominal tensile capacity of anchor bolts shall be determined from the lesser of Formula (8-5) or (8-6).

$$B_{tn} = 1.0 A_p \sqrt{f'_m} \qquad (8\text{-}5)$$

For **SI:** $$B_{tn} = 0.084 A_p \sqrt{f'_m}$$

$$B_{tn} = 0.4 A_b f_y \qquad (8\text{-}6)$$

The area A_p shall be the lesser of Formula (8-7) or (8-8) and where the projected areas of adjacent anchor bolts overlap, the value of A_p of each anchor bolt shall be reduced by one half of the overlapping area.

$$A_p = \pi l_b^2 \qquad (8\text{-}7)$$

$$A_p = \pi l_{be}^2 \qquad (8\text{-}8)$$

The nominal shear capacity of anchor bolts shall be determined from the lesser of Formula (8-9) or (8-10).

$$B_{sn} = 900 \sqrt[4]{f'_m A_b} \qquad (8\text{-}9)$$

For **SI:** $$B_{sn} = 2750 \sqrt[4]{f'_m A_b}$$

$$B_{sn} = 0.25 A_b f_y \qquad (8\text{-}10)$$

Where the anchor bolt edge distance, l_{be}, in the direction of load is less than 12 bolt diameters, the value of B_{tn} in Formula (8-9) shall be reduced by linear interpolation to zero at an l_{be} distance of $1^1/_2$ inches (38 mm). Where adjacent anchor bolts are spaced closer than $8d_b$, the nominal shear strength of the adjacent anchors determined by Formula (8-9) shall be reduced by linear interpolation to 0.75 times the nominal shear strength at a center-to-center spacing of four bolt diameters.

Anchor bolts subjected to combined shear and tension shall be designed in accordance with Formula (8-11).

$$\frac{b_{tu}}{\phi B_{tn}} + \frac{b_{su}}{\phi B_{sn}} \le 1.0 \qquad (8\text{-}11)$$

2108.1.5.3 Anchor bolt placement. Anchor bolts shall be placed so as to meet the edge distance, embedment depth and spacing requirements of Sections 2106.2.14.2, 2106.2.14.3 and 2106.2.14.4.

2108.2 Reinforced Masonry.

2108.2.1 General.

2108.2.1.1 Scope. The requirements of this section are in addition to the requirements of Sections 2106 and 2108.1 and govern masonry in which reinforcement is used to resist forces.

2108.2.1.2 Design assumptions. The following assumptions apply:

Masonry carries no tensile stress greater than the modulus of rupture.

Reinforcement is completely surrounded by and bonded to masonry material so that they work together as a homogeneous material.

Nominal strength of singly reinforced masonry wall cross sections for combined flexure and axial load shall be based on applicable conditions of equilibrium and compatibility of strains. Strain in reinforcement and masonry walls shall be assumed to be directly proportional to the distance from the neutral axis.

Maximum usable strain, e_{mu}, at the extreme masonry compression fiber shall:

1. Be 0.003 for the design of beams, piers, columns and walls.

2. Not exceed 0.003 for moment-resisting wall frames, unless lateral reinforcement as defined in Section 2108.2.6.2.6 is utilized.

Strain in reinforcement and masonry shall be assumed to be directly proportional to the distance from the neutral axis.

Stress in reinforcement below specified yield strength f_y for grade of reinforcement used shall be taken as E_s times steel strain. For strains greater than that corresponding to f_y, stress in reinforcement shall be considered independent of strain and equal to f_y.

Tensile strength of masonry walls shall be neglected in flexural calculations of strength, except when computing requirements for deflection.

Relationship between masonry compressive stress and masonry strain may be assumed to be rectangular as defined by the following:

Masonry stress of 0.85 f'_m shall be assumed uniformly distributed over an equivalent compression zone bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance $a = 0.85c$ from the fiber of maximum compressive strain. Distance c from fiber of maximum strain to the neutral axis shall be measured in a direction perpendicular to that axis.

2108.2.2 Reinforcement requirements and details.

2108.2.2.1 Maximum reinforcement. The maximum size of reinforcement shall be No. 9. The diameter of a bar shall not exceed one fourth the least dimension of a cell. No more than two bars shall be placed in a cell of a wall or a wall frame.

2108.2.2.2 Placement. The placement of reinforcement shall comply with the following:

In columns and piers, the clear distance between vertical reinforcing bars shall not be less than one and one-half times the nominal bar diameter, nor less than $1^1/_2$ inches (38 mm).

2108.2.2.3 Cover. All reinforcing bars shall be completely embedded in mortar or grout and shall have a cover of not less than $1^1/_2$ inches (38 mm) nor less than 2.5 d_b.

2108.2.2.4 Standard hooks. A standard hook shall be one of the following:

1. A 180-degree turn plus an extension of at least four bar diameters, but not less than $2^1/_2$ inches (63 mm) at the free end of the bar.

2. A 135-degree turn plus an extension of at least six bar diameters at the free end of the bar.

3. A 90-degree turn plus an extension of at least 12 bar diameters at the free end of the bar.

2108.2.2.5 Minimum bend diameter for reinforcing bars. Diameter of bend measured on the inside of a bar other than for stirrups and ties in sizes No. 3 through No. 5 shall not be less than the values in Table 21-G.

Inside diameter of bends for stirrups and ties shall not be less than $4d_b$ for No. 5 bars and smaller. For bars larger than No. 5, diameter of bend shall be in accordance with Table 21-G.

2108.2.2.6 Development. The calculated tension or compression reinforcement shall be developed in accordance with the following provisions:

The embedment length of reinforcement shall be determined by Formula (8-12).

$$l_d = l_{de} / \phi \qquad (8\text{-}12)$$

WHERE:

$$l_{de} = \frac{0.15 d_b^{\,2} f_y}{K\sqrt{f'_m}} \le 52 d_b \qquad (8\text{-}13)$$

For **SI:** $$l_{de} = \frac{1.8 d_b^{\,2} f_y}{K\sqrt{f'_m}} \le 52 d_b$$

K shall not exceed $3d_b$.

The minimum embedment length of reinforcement shall be 12 inches (305 mm).

2108.2.2.7 Splices. Reinforcement splices shall comply with one of the following:

1. The minimum length of lap for bars shall be 12 inches (305 mm) or the length determined by Formula (8-14).

$$l_d = l_{de} / \phi \qquad (8\text{-}14)$$

Bars spliced by noncontact lap splices shall be spaced transversely a distance not greater than one fifth the required length of lap or more than 8 inches (203 mm).

2. A welded splice shall have the bars butted and welded to develop in tension 125 percent of the yield strength of the bar, f_y.

3. Mechanical splices shall have the bars connected to develop in tension or compression, as required, at least 125 percent of the yield strength of the bar, f_y.

2108.2.3 Design of beams, piers and columns.

2108.2.3.1 General. The requirements of this section are for the design of masonry beams, piers and columns.

The value of f'_m shall not be less than 1,500 psi (10.3 MPa). For computational purposes, the value of f'_m shall not exceed 4,000 psi (27.6 MPa).

2108.2.3.2 Design assumptions.

Member design forces shall be based on an analysis which considers the relative stiffness of structural members. The calculation of lateral stiffness shall include the contribution of all beams, piers and columns.

The effects of cracking on member stiffness shall be considered.

The drift ratio of piers and columns shall satisfy the limits specified in Chapter 16.

2108.2.3.3 Balanced reinforcement ratio for compression limit state. Calculation of the balanced reinforcement ratio, ρ_b, shall be based on the following assumptions:

1. The distribution of strain across the section shall be assumed to vary linearly from the maximum usable strain, e_{mu}, at the extreme compression fiber of the element, to a yield strain of f_y/E_s at the extreme tension fiber of the element.

2. Compression forces shall be in equilibrium with the sum of tension forces in the reinforcement and the maximum axial load associated with a loading combination 1.0*D* + 1.0*L* + (1.4*E* or 1.3*W*).

3. The reinforcement shall be assumed to be uniformly distributed over the depth of the element and the balanced reinforcement ratio shall be calculated as the area of this reinforcement divided by the net area of the element.

4. All longitudinal reinforcement shall be included in calculating the balanced reinforcement ratio except that the contribution of compression reinforcement to resistance of compressive loads shall not be considered.

2108.2.3.4 Required strength. Except as required by Sections 2108.2.3.6 through 2108.2.3.12, the required strength shall be determined in accordance with Section 2108.1.3.

2108.2.3.5 Design strength. Design strength provided by beam, pier or column cross sections in terms of axial force, sheer and moment shall be computed as the nominal strength multiplied by the applicable strength-reduction factor, ϕ, specified in Section 2108.1.4.

2108.2.3.6 Nominal strength.

2108.2.3.6.1 Nominal axial and flexural strength. The nominal axial strength, P_n, and the nominal flexural strength, M_n, of a cross section shall be determined in accordance with the design assumptions of Section 2108.2.1.2 and 2108.2.3.2.

The maximum nominal axial compressive strength shall be determined in accordance with Formula (8-15).

$$P_n = 0.80[0.85f'_m(A_e - A_s) + f_y A_s] \qquad (8\text{-}15)$$

2108.2.3.6.2 Nominal shear strength. The nominal shear strength shall be determined in accordance with Formula (8-16).

$$V_n = V_m + V_s \qquad (8\text{-}16)$$

WHERE:

$$V_m = C_d A_e \sqrt{f'_m},\ 63 C_d A_e \text{ maximum} \qquad (8\text{-}17)$$

For **SI:** $V_m = 0.083\ C_d A_e \sqrt{f'_m},\ 63 C_d A_e$ maximum

and

$$V_s = A_e \rho_n f_y \qquad (8\text{-}18)$$

1. The nominal shear strength shall not exceed the value given in Table 21-J.

2. The value of V_m shall be assumed to be zero within any region subjected to net tension factored loads.

3. The value of V_m shall be assumed to be 25 psi (172 kPa) where M_u is greater than 0.7 M_n. The required moment, M_u, for seismic design for comparison with the 0.7 M_n value of this section shall be based on an *R* of 2.

2108.2.3.7 Reinforcement.

1. Where transverse reinforcement is required, the maximum spacing shall not exceed one half the depth of the member nor 48 inches (1219 mm).

2. Flexural reinforcement shall be uniformly distributed throughout the depth of the element.

3. Flexural elements subjected to load reversals shall be symmetrically reinforced.

4. The nominal moment strength at any section along a member shall not be less than one fourth of the maximum moment strength.

5. The flexural reinforcement ratio, ρ, shall not exceed 0.5 ρ_b.

6. Lap splices shall comply with the provisions of Section 2108.2.2.7.

7. Welded splices and mechanical splices which develop at least 125 percent of the specified yield strength of a bar may be used for splicing the reinforcement. Not more than two longitudinal bars shall be spliced at a section. The distance between splices of adjacent bars shall be at least 30 inches (762 mm) along the longitudinal axis.

8. Specified yield strength of reinforcement shall not exceed 60,000 psi (413 MPa). The actual yield strength based on mill tests shall not exceed 1.3 times the specified yield strength.

2108.2.3.8 Seismic design provisions. The lateral seismic load resistance in any line or story level shall be provided by shear walls or wall frames, or a combination of shear walls and wall frames. Shear walls and wall frames shall provide at least 80 percent of the lateral stiffness in any line or story level.

EXCEPTION: Where seismic loads are determined based on *R* not greater than 2 and where all joints satisfy the provisions of Section 2108.2.6.2.9, the piers may be used to provide seismic load resistance.

2108.2.3.9 Dimensional limits. Dimensions shall be in accordance with the following:

1. **Beams.**

1.1 The nominal width of a beam shall not be less than 6 inches (153 mm).

1.2 The clear distance between locations of lateral bracing of the compression side of the beam shall not exceed 32 times the least width of the compression area.

1.3 The nominal depth of a beam shall not be less than 8 inches (203 mm).

2. **Piers.**

2.1 The nominal width of a pier shall not be less than 6 inches (153 mm) and shall not exceed 16 inches (406 mm).

2.2 The distance between lateral supports of a pier shall not exceed 30 times the nominal width of the piers except as provided for in Section 2108.2.3.9, Item 2.3.

2.3 When the distance between lateral supports of a pier exceeds 30 times the nominal width of the pier, the provisions of Section 2108.2.4 shall be used for design.

2.4 The nominal length of a pier shall not be less than three times the nominal width of the pier. The nominal length of a pier shall not be greater than six times the nominal width of the pier. The clear height of a pier shall not exceed five times the nominal length of the pier.

EXCEPTION: The length of a pier may be equal to the width of the pier when the axial force at the location of maximum moment is less than 0.04 $f'_m A_g$.

3. **Columns.**

3.1 The nominal width of a column shall not be less than 12 inches (305 mm).

3.2 The distance between lateral supports of a column shall not exceed 30 times the nominal width of the column.

3.3 The nominal length of a column shall not be less than 12 inches (305 mm) and not greater than three times the nominal width of the column.

2108.2.3.10 Beams.

2108.2.3.10.1 Scope. Members designed primarily to resist flexure shall comply with the requirements of this section. The factored axial compressive force on a beam shall not exceed 0.05 $A_e f'_m$.

2108.2.3.10.2 Longitudinal reinforcement.

1. The variation in the longitudinal reinforcing bars shall not be greater than one bar size. Not more than two bar sizes shall be used in a beam.

2. The nominal flexural strength of a beam shall not be less than 1.3 times the nominal cracking moment strength of the beam. The modulus of rupture, f_r, for this calculation shall be assumed to be 235 psi (1.6 MPa).

2108.2.3.10.3 Transverse reinforcement. Transverse reinforcement shall be provided where V_u exceeds V_m. Required shear, V_u, shall include the effects of drift. The value of V_u shall be based on Δ_M. When transverse shear reinforcement is required, the following provisions shall apply:

1. Shear reinforcement shall be a single bar with a 180-degree hook at each end.

2. Shear reinforcement shall be hooked around the longitudinal reinforcement.

3. The minimum transverse shear reinforcement ratio shall be 0.0007.

4. The first transverse bar shall not be more than one fourth of the beam depth from the end of the beam.

2108.2.3.10.4 Construction. Beams shall be solid grouted.

2108.2.3.11 Piers.

2108.2.3.11.1 Scope. Piers proportioned to resist flexure and shear in conjunction with axial load shall comply with the requirements of this section. The factored axial compression on the piers shall not exceed 0.3 $A_e f'_m$.

2108.2.3.11.2 Longitudinal reinforcement. A pier subjected to in-plane stress reversals shall be longitudinally reinforced symmetrically on both sides of the neutral axis of the pier.

1. One bar shall be provided in the end cells.

2. The minimum longitudinal reinforcement ratio shall be 0.0007.

2108.2.3.11.3 Transverse reinforcement. Transverse reinforcement shall be provided where V_u exceeds V_m. Required shear, V_u, shall include the effects of drift. The value of V_u shall be based on Δ_M. When transverse shear reinforcement is required, the following provisions shall apply:

1. Shear reinforcement shall be hooked around the extreme longitudinal bars with a 180-degree hook. Alternatively, at wall intersections, transverse reinforcement with a 90-degree standard hook around a vertical bar in the intersecting wall shall be permitted.

2. The minimum transverse reinforcement ratio shall be 0.0015.

2108.2.3.12 Columns.

2108.2.3.12.1 Scope. Columns shall comply with the requirements of this section.

2108.2.3.12.2 Longitudinal reinforcement. Longitudinal reinforcement shall be a minimum of four bars, one in each corner of the column.

1. Maximum reinforcement area shall be 0.03 A_e.

2. Minimum reinforcement area shall be 0.005 A_e.

2108.2.3.12.3 Lateral ties.

1. Lateral ties shall be provided in accordance with Section 2106.3.6.

2. Minimum lateral reinforcement area shall be 0.0018 A_g.

2108.2.3.12.4 Construction. Columns shall be solid grouted.

2108.2.4 Wall design for out-of-plane loads.

2108.2.4.1 General. The requirements of this section are for the design of walls for out-of-plane loads.

2108.2.4.2 Maximum reinforcement. The reinforcement ratio shall not exceed $0.5\rho_b$.

2108.2.4.3 Moment and deflection calculations. All moment and deflection calculations in Section 2108.2.4 are based on simple support conditions top and bottom. Other support and fixity conditions, moments and deflections shall be calculated using established principles of mechanics.

2108.2.4.4 Walls with axial load of 0.04f'_m or less. The procedures set forth in this section, which consider the slenderness of walls by representing effects of axial forces and deflection in calculation of moments, shall be used when the vertical load stress at the location of maximum moment does not exceed 0.04f'_m as computed by Formula (8-19). The value of f'_m shall not exceed 6,000 psi (41.3 MPa).

$$\frac{P_w + P_f}{A_g} \leq 0.04 f'_m \qquad (8\text{-}19)$$

Walls shall have a minimum nominal thickness of 6 inches (153 mm).

Required moment and axial force shall be determined at the midheight of the wall and shall be used for design. The factored moment, M_u, at the midheight of the wall shall be determined by Formula (8-20).

$$M_u = \frac{w_u h^2}{8} + P_{uf}\frac{e}{2} + P_u \Delta_u \qquad (8\text{-}20)$$

WHERE:

Δ_u = deflection at midheight of wall due to factored loads

$$P_u = P_{uw} + P_{uf} \qquad (8\text{-}21)$$

The design strength for out-of-plane wall loading shall be determined by Formula (8-22).

$$M_u \leq \phi M_n \qquad (8\text{-}22)$$

WHERE:

$$M_n = A_{se} f_y (d - a/2) \qquad (8\text{-}23)$$

$A_{se} = (A_s f_y + P_u) / f_y$, effective area of steel (8-24)

$a = (P_u + A_s f_y) / 0.85 f'_m b$, depth of stress block due to factored loads (8-25)

2108.2.4.5 Wall with axial load greater than 0.04f'_m. The procedures set forth in this section shall be used for the design of masonry walls when the vertical load stresses at the location of maximum moment exceed 0.04f'_m but are less than 0.2f'_m and the slenderness ratio h'/t does not exceed 30.

Design strength provided by the wall cross section in terms of axial force, shear and moment shall be computed as the nominal strength multiplied by the applicable strength-reduction factor, ϕ, specified in Section 2108.1.4. Walls shall be proportioned such that the design strength exceeds the required strength.

The nominal shear strength shall be determined by Formula (8-26).

$$V_n = 2A_{mv}\sqrt{f'_m} \qquad (8\text{-}26)$$

For **SI:** $V_n = 0.166 A_{mv} \sqrt{f'_m}$

2108.2.4.6 Deflection design. The midheight deflection, Δ_s, under service lateral and vertical loads (without load factors) shall be limited by the relation:

$$\Delta_s = 0.007h \qquad (8\text{-}27)$$

$P\Delta$ effects shall be included in deflection calculation. The midheight deflection shall be computed with the following formula:

$$\Delta_s = \frac{5 M_s h^2}{48 E_m I_g} \text{ for } M_{ser} \leq M_{cr} \qquad (8\text{-}28)$$

$$\Delta_s = \frac{5 M_{cr} h^2}{48 E_m I_g} + \frac{5 (M_{ser} - M_{cr}) h^2}{48 E_m I_{cr}} \text{ for } M_{cr} < M_{ser} < M_n \qquad (8\text{-}29)$$

The cracking moment strength of the wall shall be determined from the formula:

$$M_{cr} = S f_r \qquad (8\text{-}30)$$

The modulus of rupture, f_r, shall be as follows:

1. For fully grouted hollow-unit masonry,

$$f_r = 4.0 \sqrt{f'_m}, \text{ 235 psi maximum} \qquad (8\text{–}31)$$

For **SI:** $f_r = 0.33 \sqrt{f'_m}$, 1.6 MPa maximum

2. For partially grouted hollow-unit masonry,

$$f_r = 2.5 \sqrt{f'_m}, \text{ 125 psi maximum} \qquad (8\text{-}32)$$

For **SI:** $f_r = 0.21 \sqrt{f'_m}$, 861 kPa maximum

3. For two-wythe brick masonry,

$$f_r = 2.0 \sqrt{f'_m}, \text{ 125 psi maximum} \qquad (8\text{-}33)$$

For **SI:** $f_r = 0.166 \sqrt{f'_m}$, 861 kPa maximum

2108.2.5 Wall design for in-plane loads.

2108.2.5.1 General. The requirements of this section are for the design of walls for in-plane loads.

The value of f'_m shall not be less than 1,500 psi (10.3 MPa) nor greater than 4,000 psi (27.6 MPa).

2108.2.5.2 Reinforcement. Reinforcement shall be in accordance with the following:

1. Minimum reinforcement shall be provided in accordance with Section 2106.1.12.4, Item 2.3, for all seismic areas using this method of analysis.

2. When the shear wall failure mode is in flexure, the nominal flexural strength of the shear wall shall be at least 1.8 times the cracking moment strength of a fully grouted wall or 3.0 times the cracking moment strength of a partially grouted wall from Formula (8-30).

3. The amount of vertical reinforcement shall not be less than one half the horizontal reinforcement.

4. Spacing of horizontal reinforcement within the region defined in Section 2108.2.5.5, Item 3, shall not exceed three times the nominal wall thickness nor 24 inches (610 mm).

2108.2.5.3 Design strength. Design strength provided by the shear wall cross section in terms of axial force, shear and moment shall be computed as the nominal strength multiplied by the applicable strength-reduction factor, ϕ, specified in Section 2108.1.4.3.

2108.2.5.4 Axial strength. The nominal axial strength of the shear wall supporting axial loads only shall be calculated by Formula (8-34).

$$P_o = 0.85 f'_m (A_e - A_s) + f_y A_s \qquad (8\text{-}34)$$

Axial design strength provided by the shear wall cross section shall satisfy Formula (8-35).

$$P_u \leq 0.80 \phi P_o \qquad (8\text{-}35)$$

2108.2.5.5 Shear strength. Shear strength shall be as follows:

1. The nominal shear strength shall be determined using either Item 2 or 3 below. Maximum nominal shear strength values are determined from Table 21-J.

2. The nominal shear strength of the shear wall shall be determined from Formula (8-36), except as provided in Item 3 below

$$V_n = V_m + V_s \qquad (8\text{-}36)$$

WHERE:

$$V_m = C_d A_{mv} \sqrt{f'_m} \qquad (8\text{-}37)$$

For **SI:** $V_m = 0.083 C_d A_{mv} \sqrt{f'_m}$

and

$$V_s = A_{mv} \rho_n f_y \qquad (8\text{-}38)$$

3. For a shear wall whose nominal shear strength exceeds the shear corresponding to development of its nominal flexural strength, two shear regions exist.

For all cross sections within the region defined by the base of the shear wall and a plane at a distance L_w above the base of the shear wall, the nominal shear strength shall be determined from Formula (8-39).

$$V_n = A_{mv} \rho_n f_y \qquad (8\text{-}39)$$

The required shear strength for this region shall be calculated at a distance $L_w/2$ above the base of the shear wall, but not to exceed one half story height.

For the other region, the nominal shear strength of the shear wall shall be determined from Formula (8-36).

2108.2.5.6 Boundary members. Boundary members shall be as follows:

1. Boundary members shall be provided at the boundaries of shear walls when the compressive strains in the wall exceed 0.0015. The strain shall be determined using factored forces and R equal to 1.1.

2. The minimum length of the boundary member shall be three times the thickness of the wall, but shall include all areas where the compressive strain per Section 2108.2.6.2.7 is greater than 0.0015.

3. Lateral reinforcement shall be provided for the boundary elements. The lateral reinforcement shall be a minimum of No. 3 bars at a maximum of 8-inch (203 mm) spacing within the grouted core or equivalent confinement which can develop an ultimate compressive masonry strain of at least 0.006.

2108.2.6 Design of moment-resisting wall frames.

2108.2.6.1 General requirements.

2108.2.6.1.1 Scope. The requirements of this section are for the design of fully grouted moment-resisting wall frames constructed of reinforced open-end hollow-unit concrete or hollow-unit clay masonry.

2108.2.6.1.2 Dimensional limits. Dimensions shall be in accordance with the following.

Beams. Clear span for the beam shall not be less than two times its depth.

The nominal depth of the beam shall not be less than two units or 16 inches (406 mm), whichever is greater. The nominal beam depth to nominal beam width ratio shall not exceed 6.

The nominal width of the beam shall be the greater of 8 inches (203 mm) or $^1/_{26}$ of the clear span between pier faces.

Piers. The nominal depth of piers shall not exceed 96 inches (2438 mm). Nominal depth shall not be less than two full units or 32 inches (813 mm), whichever is greater.

The nominal width of piers shall not be less than the nominal width of the beam, nor less than 8 inches (203 mm) or $^1/_{14}$ of the clear height between beam faces, whichever is greater.

The clear height-to-depth ratio of piers shall not exceed 5.

2108.2.6.1.3 Analysis. Member design forces shall be based on an analysis which considers the relative stiffness of pier and beam members, including the stiffening influence of joints.

The calculation of beam moment capacity for the determination of pier design shall include any contribution of floor slab reinforcement.

The out-of-plane drift ratio of all piers shall satisfy the drift-ratio limits specified in Section 1630.10.2.

2108.2.6.2 Design procedure.

2108.2.6.2.1 Required strength. Except as required by Sections 2108.2.6.2.7 and 2108.2.6.2.8, the required strength shall be determined in accordance with Section 2108.1.3.

2108.2.6.2.2 Design strength. Design strength provided by frame member cross sections in terms of axial force, shear and moment shall be computed as the nominal strength multiplied by the applicable strength-reduction factor, ϕ, specified in Section 2108.1.4.4.

Members shall be proportioned such that the design strength exceeds the required strength.

2108.2.6.2.3 Design assumptions for nominal strength. The nominal strength of member cross sections shall be based on assumptions prescribed in Section 2108.2.1.2.

The value of f'_m shall not be less than 1,500 psi (10.3 MPa) or greater than 4,000 psi (27.6 MPa).

2108.2.6.2.4 Reinforcement. The nominal moment strength at any section along a member shall not be less than one fourth of the higher moment strength provided at the two ends of the member.

Lap splices shall be as defined in Section 2108.2.2.7. The center of the lap splice shall be at the center of the member clear length.

Welded splices and mechanical connections conforming to Section 1912.14.3, Items 1 through 4, may be used for splicing the reinforcement at any section provided not more than alternate longitudinal bars are spliced at a section, and the distance between splices of alternate bars is at least 24 inches (610 mm) along the longitudinal axis.

Reinforcement shall not have a specified yield strength greater than 60,000 psi (413 MPa). The actual yield strength based on mill tests shall not exceed the specified yield strength times 1.3.

2108.2.6.2.5 Flexural members (beams). Requirements of this section apply to beams proportioned primarily to resist flexure as follows:

The axial compressive force on beams due to factored loads shall not exceed 0.10 $A_n f'_m$.

1. **Longitudinal reinforcement.** At any section of a beam, each masonry unit through the beam depth shall contain longitudinal reinforcement.

The variation in the longitudinal reinforcement area between units at any section shall not be greater than 50 percent, except multiple No. 4 bars shall not be greater than 100 percent of the minimum area of longitudinal reinforcement contained by any one unit, except where splices occur.

Minimum reinforcement ratio calculated over the gross cross section shall be 0.002.

Maximum reinforcement ratio calculated over the gross cross section shall be $0.15f'_m / f_y$.

2. **Transverse reinforcement.** Transverse reinforcement shall be hooked around top and bottom longitudinal bars with a standard 180-degree hook, as defined in Section 2108.2.2.4, and shall be single pieces.

Within an end region extending one beam depth from pier faces and at any region at which beam flexural yielding may occur during seismic or wind loading, maximum spacing of transverse reinforcement shall not exceed one fourth the nominal depth of the beam.

The maximum spacing of transverse reinforcement shall not exceed one half the nominal depth of the beam.

Minimum reinforcement ratio shall be 0.0015.

The first transverse bar shall not be more than 4 inches (102 mm) from the face of the pier.

2108.2.6.2.6 Members subjected to axial force and flexure.

The requirements set forth in this subsection apply to piers proportioned to resist flexure in conjunction with axial loads.

1. **Longitudinal reinforcement.** A minimum of four longitudinal bars shall be provided at all sections of every pier.

Flexural reinforcement shall be distributed across the member depth. Variation in reinforcement area between reinforced cells shall not exceed 50 percent.

Minimum reinforcement ratio calculated over the gross cross section shall be 0.002.

Maximum reinforcement ratio calculated over the gross cross section shall be $0.15f'_m / f_y$.

Maximum bar diameter shall be one eighth nominal width of the pier.

2. **Transverse reinforcement.** Transverse reinforcement shall be hooked around the extreme longitudinal bars with standard 180-degree hook as defined in Section 2108.2.2.4.

Within an end region extending one pier depth from the end of the beam, and at any region at which flexural yielding may occur during seismic or wind loading, the maximum spacing of transverse reinforcement shall not exceed one fourth the nominal depth of the pier.

The maximum spacing of transverse reinforcement shall not exceed one half the nominal depth of the pier.

The minimum transverse reinforcement ratio shall be 0.0015.

3. **Lateral reinforcement.** Lateral reinforcement shall be provided to confine the grouted core when compressive strains due to axial and bending forces exceed 0.0015, corresponding to factored forces with R_w equal to 1.5. The unconfined portion of the cross section with strain exceeding 0.0015 shall be neglected in computing the nominal strength of the section.

The total cross-sectional area of rectangular tie reinforcement for the confined core shall not be less than:

$$A_{sh} = 0.09 s h_c \, f'_m / f_{yh} \tag{8-40}$$

Alternatively, equivalent confinement which can develop an ultimate compressive strain of at least 0.006 may be substituted for rectangular tie reinforcement.

2108.2.6.2.7 Pier design forces. Pier nominal moment strength shall not be less than 1.6 times the pier moment corresponding to the development of beam plastic hinges, except at the foundation level.

Pier axial load based on the development of beam plastic hinges in accordance with the paragraph above and including factored dead and live loads shall not exceed 0.15 $A_n \, f'_m$.

The drift ratio of piers shall satisfy the limits specified in Chapter 16.

The effects of cracking on member stiffness shall be considered.

The base plastic hinge of the pier must form immediately adjacent to the level of lateral support provided at the base or foundation.

2108.2.6.2.8 Shear design.

1. **General.** Beam and pier nominal shear strength shall not be less than 1.4 times the shears corresponding to the development of beam flexural yielding.

It shall be assumed in the calculation of member shear force that moments of opposite sign act at the joint faces and that the member is loaded with the tributary gravity load along its span.

2. **Vertical member shear strength.** The nominal shear strength shall be determined from Formula (8-41):

$$V_n = V_m + V_s \tag{8-41}$$

WHERE:

$$V_m = C_d \, A_{mv} \sqrt{f'_m} \tag{8-42}$$

For **SI:** $V_m = 0.083 \, C_d \, A_{mv} \sqrt{f'_m}$

and

$$V_s = A_{mv} \, \rho_n \, f_y \tag{8-43}$$

The value of V_m shall be zero within an end region extending one pier depth from beam faces and at any region where pier flexural yielding may occur during seismic loading, and at piers subjected to net tension factored loads.

The nominal pier shear strength, V_n, shall not exceed the value determined from Table 21-J.

3. **Beam shear strength.** The nominal shear strength shall be determined from Formula (8-44),

WHERE:

$$V_m = 1.2 \, A_{mv} \sqrt{f'_m} \tag{8-44}$$

For **SI:** $V_m = 0.01 \, A_{mv} \sqrt{f'_m}$

The value of V_m shall be zero within an end region extending one beam depth from pier faces and at any region at which beam flexural yielding may occur during seismic loading.

The nominal beam shear strength, V_n, shall be determined from Formula (8-45).

$$V_n \le 4 \, A_{mv} \sqrt{f'_m} \tag{8-45}$$

For **SI:** $V_n \le 0.33 \, A_{mv} \sqrt{f'_m}$

2108.2.6.2.9 Joints.

1. **General requirements.** Where reinforcing bars extend through a joint, the joint dimensions shall be proportioned such that

$$h_p > 4800 \, d_{bb} / \sqrt{f'_g} \tag{8-46}$$

For **SI:** $h_p > 400 \, d_{bb} / \sqrt{f'_g}$

and

$$h_b > 1800 \, d_{bp} / \sqrt{f'_g} \tag{8-47}$$

For **SI:** $h_b > 150 \, d_{bp} / \sqrt{f'_g}$

The grout strength shall not exceed 5,000 psi (34.4 MPa) for the purposes of Formulas (8-46) and (8-47).

Joint shear forces shall be calculated on the assumption that the stress in all flexural tension reinforcement of the beams at the pier faces is 1.4 f_y.

Strength of joint shall be governed by the appropriate strength-reduction factors specified in Section 2108.1.4.4.

Beam longitudinal reinforcement terminating in a pier shall be extended to the far face of the pier and anchored by a standard 90- or 180-degree hook, as defined in Section 2108.2.2.4, bent back to the beam.

Pier longitudinal reinforcement terminating in a beam shall be extended to the far face of the beam and anchored by a standard 90- or 180-degree hook, as defined in Section 2108.2.2.4, bent back to the beam.

2. **Transverse reinforcement.** Special horizontal joint shear reinforcement crossing a potential corner-to-corner diagonal joint shear crack, and anchored by standard hooks, as defined in Section 2108.2.2.4, around the extreme pier reinforcing bars shall be provided such that

$$A_{jh} = 0.5 \, V_{jh} / f_y \tag{8-48}$$

Vertical shear forces may be considered to be carried by a combination of masonry shear-resisting mechanisms and truss mechanisms involving intermediate pier reinforcing bars.

3. **Shear strength.** The nominal horizontal shear strength of the joint shall not exceed 7 $\sqrt{f'_m}$ (For **SI:** 0.58 $\sqrt{f'_m}$) or 350 psi (2.4 MPa), whichever is less.

SECTION 2109 — EMPIRICAL DESIGN OF MASONRY

2109.1 General. The design of masonry structures using empirical design located in those portions of Seismic Zones 0 and 1 as defined in Part III of Chapter 16 where the basic wind speed is less than 80 miles per hour as defined in Part II of Chapter 16 shall comply with the provisions of Section 2106 and this section, subject to approval of the building official.

2109.2 Height. Buildings relying on masonry walls for lateral load resistance shall not exceed 35 feet (10 668 mm) in height.

2109.3 Lateral Stability. Where the structure depends on masonry walls for lateral stability, shear walls shall be provided parallel to the direction of the lateral forces resisted.

Minimum nominal thickness of masonry shear walls shall be 8 inches (203 mm).

In each direction in which shear walls are required for lateral stability, the minimum cumulative length of shear walls provided shall be 0.4 times the long dimension of the building. The cumulative length of shear walls shall not include openings.

The maximum spacing of shear walls shall not exceed the ratio listed in Table 21-L.

2109.4 Compressive Stresses.

2109.4.1 General. Compressive stresses in masonry due to vertical dead loads plus live loads, excluding wind or seismic loads, shall be determined in accordance with Section 2109.4.3. Dead and live loads shall be in accordance with this code with permitted live load reductions.

2109.4.2 Allowable stresses. The compressive stresses in masonry shall not exceed the values set forth in Table 21-M. The allowable stresses given in Table 21-M for the weakest combination of the units and mortar used in any load wythe shall be used for all loaded wythes of multiwythe walls.

2109.4.3 Stress calculations. Stresses shall be calculated based on specified rather than nominal dimensions. Calculated compressive stresses shall be determined by dividing the design load by the gross cross-sectional area of the member. The area of openings, chases or recesses in walls shall not be included in the gross cross-sectional area of the wall.

2109.4.4 Anchor bolts. Bolt values shall not exceed those set forth in Table 21-N.

2109.5 Lateral Support. Masonry walls shall be laterally supported in either the horizontal or vertical direction not exceeding the intervals set forth in Table 21-O.

Lateral support shall be provided by cross walls, pilasters, buttresses or structural framing members horizontally or by floors, roof or structural framing members vertically.

Except for parapet walls, the ratio of height to nominal thickness for cantilever walls shall not exceed 6 for solid masonry or 4 for hollow masonry.

In computing the ratio for cavity walls, the value of thickness shall be the sums of the nominal thickness of the inner and outer wythes of the masonry. In walls composed of different classes of units and mortars, the ratio of height or length to thickness shall not exceed that allowed for the weakest of the combinations of units and mortar of which the member is composed.

2109.6 Minimum Thickness.

2109.6.1 General. The nominal thickness of masonry bearing walls in buildings more than one story in height shall not be less than 8 inches (203 mm). Solid masonry walls in one-story buildings may be of 6-inch nominal thickness when not over 9 feet (2743 mm) in height, provided that when gable construction is used, an additional 6 feet (1829 mm) is permitted to the peak of the gable.

> **EXCEPTION:** The thickness of unreinforced grouted brick masonry walls may be 2 inches (51 mm) less than required by this section, but in no case less than 6 inches (152 mm).

2109.6.2 Variation in thickness. Where a change in thickness due to minimum thickness occurs between floor levels, the greater thickness shall be carried up to the higher floor level.

2109.6.3 Decrease in thickness. Where walls of masonry of hollow units or masonry-bonded hollow walls are decreased in thickness, a course or courses of solid masonry shall be constructed between the walls below and the thinner wall above, or special units or construction shall be used to transmit the loads from face shells or wythes to the walls below.

2109.6.4 Parapets. Parapet walls shall be at least 8 inches (203 mm) in thickness and their height shall not exceed three times their thickness. The parapet wall shall not be thinner than the wall below.

2109.6.5 Foundation walls. Mortar used in masonry foundation walls shall be either Type M or S.

Where the height of unbalanced fill (height of finished grade above basement floor or inside grade) and the height of the wall between lateral support does not exceed 8 feet (2438 mm), and when the equivalent fluid weight of unbalanced fill does not exceed 30 pounds per cubic foot (480 kg/m^2), the minimum thickness of foundation walls shall be as set forth in Table 21-P. Maximum depths of unbalanced fill permitted in Table 21-P may be increased with the approval of the building official when local soil conditions warrant such an increase.

Where the height of unbalanced fill, height between lateral supports or equivalent fluid weight of unbalanced fill exceeds that set forth above, foundation walls shall be designed in accordance with Chapter 18.

2109.7 Bond.

2109.7.1 General. The facing and backing of multiwythe masonry walls shall be bonded in accordance with this section.

2109.7.2 Masonry headers. Where the facing and backing of solid masonry construction are bonded by masonry headers, not less than 4 percent of the wall surface of each face shall be composed of headers extending not less than 3 inches (76 mm) into the backing. The distance between adjacent full-length headers shall not exceed 24 inches (610 mm) either vertically or horizontally. In walls in which a single header does not extend through the wall, headers from opposite sides shall overlap at least 3 inches (76 mm), or headers from opposite sides shall be covered with another header course overlapping the header below at least 3 inches (76 mm).

Where two or more hollow units are used to make up the thickness of the wall, the stretcher courses shall be bonded at vertical intervals not exceeding 34 inches (864 mm) by lapping at least 3 inches (76 mm) over the unit below, or by lapping at vertical intervals not exceeding 17 inches (432 mm) with units which are at least 50 percent greater in thickness than the units below.

2109.7.3 Wall ties. Where the facing and backing of masonry walls are bonded with $^3/_{16}$-inch-diameter (4.8 mm) wall ties or metal ties of equivalent stiffness embedded in the horizontal mortar joints, there shall be at least one metal tie for each $4^1/_2$ square feet (0.42 m^2) of wall area. Ties in alternate courses shall be staggered, the maximum vertical distance between ties shall not exceed 24 inches (610 mm), and the maximum horizontal distance shall not exceed 36 inches (914 mm). Rods bent to rectangular shape shall be used with hollow-masonry units laid with the cells vertical. In other walls, the ends of ties shall be bent to 90-degree angles to provide hooks not less than 2 inches (51 mm) long. Additional ties shall be provided at all openings, spaced not more than 3 feet (914 mm) apart around the perimeter and within 12 inches (305 mm) of the opening.

The facing and backing of masonry walls may be bonded with prefabricated joint reinforcement. There shall be at least one cross wire serving as a tie for each $2^2/_3$ square feet (0.25 m^2) of wall area. The vertical spacing of the joint reinforcement shall not exceed 16 inches (406 mm). Cross wires of prefabricated joint reinforcement shall be at least No. 9 gage wire. The longitudinal wire shall be embedded in mortar.

2109.7.4 Longitudinal bond. In each wythe of masonry, head joints in successive courses shall be offset at least one fourth of the unit length or the walls shall be reinforced longitudinally as required in Section 2106.1.12.3, Item 4.

2109.8 Anchorage.

2109.8.1 Intersecting walls. Masonry walls depending on one another for lateral support shall be anchored or bonded at locations where they meet or intersect by one of the following methods:

1. Fifty percent of the units at the intersection shall be laid in an overlapping pattern, with alternating units having a bearing of not less than 3 inches (76 mm) on the unit below.

2. Walls shall be anchored by steel connectors having a minimum section of $^1/_4$ inch by $1^1/_2$ inches (6.4 mm by 38 mm) with ends bent up at least 2 inches (51 mm), or with cross pins to form anchorage. Such anchors shall be at least 24 inches (610 mm) long and the maximum spacing shall be 4 feet (1219 mm) vertically.

3. Walls shall be anchored by joint reinforcement spaced at a maximum distance of 8 inches (203 mm) vertically. Longitudinal rods of such reinforcement shall be at least No. 9 gage and shall extend at least 30 inches (762 mm) in each direction at the intersection.

4. Interior nonbearing walls may be anchored at their intersection, at vertical spacing of not more than 16 inches (406 mm) with joint reinforcement or $^1/_4$-inch (6.4 mm) mesh galvanized hardware cloth.

5. Other metal ties, joint reinforcement or anchors may be used, provided they are spaced to provide equivalent area of anchorage to that required by this section.

2109.8.2 Floor and roof anchorage. Floor and roof diaphragms providing lateral support to masonry walls shall be connected to the masonry walls by one of the following methods:

1. Wood floor joists bearing on masonry walls shall be anchored to the wall by approved metal strap anchors at intervals not exceeding 6 feet (1829 mm). Joists parallel to the wall shall be anchored with metal straps spaced not more than 6 feet (1829 mm) on center extending over and under and secured to at least three joists. Blocking shall be provided between joists at each strap anchor.

2. Steel floor joists shall be anchored to masonry walls with No. 3 bars, or their equivalent, spaced not more than 6 feet (1829 mm) on center. Where joists are parallel to the wall, anchors shall be located at joist cross bridging.

3. Roof structures shall be anchored to masonry walls with $^1/_2$-inch-diameter (12.7 mm) bolts at 6 feet (1829 mm) on center or their equivalent. Bolts shall extend and be embedded at least 15 inches (381 mm) into the masonry, or be hooked or welded to not less than 0.2 square inch (129 mm^2) of bond beam reinforcement placed not less than 6 inches (152 mm) from the top of the wall.

2109.8.3 Walls adjoining structural framing. Where walls are dependent on the structural frame for lateral support, they shall be anchored to the structural members with metal anchors or keyed to the structural members. Metal anchors shall consist of $^1/_2$-inch-diameter (12.7 mm) bolts spaced at a maximum of 4 feet (1219 mm) on center and embedded at least 4 inches (102 mm) into the masonry, or their equivalent area.

2109.9 Unburned Clay Masonry.

2109.9.1 General. Masonry of stabilized unburned clay units shall not be used in any building more than one story in height. The unsupported height of every wall of unburned clay units shall not be more than 10 times the thickness of such walls. Bearing walls shall in no case be less than 16 inches (406 mm) in thickness. All footing walls which support masonry of unburned clay units shall extend to an elevation not less than 6 inches (152 mm) above the adjacent ground at all points.

2109.9.2 Bolts. Bolt values shall not exceed those set forth in Table 21-Q.

2109.10 Stone Masonry.

2109.10.1 General. Stone masonry is that form of construction made with natural or cast stone in which the units are laid and set in mortar with all joints filled.

2109.10.2 Construction. In ashlar masonry, bond stones uniformly distributed shall be provided to the extent of not less than 10 percent of the area of exposed facets. Rubble stone masonry 24 inches (610 mm) or less in thickness shall have bond stones with a maximum spacing of 3 feet (914 mm) vertically and 3 feet (914 mm) horizontally and, if the masonry is of greater thickness than 24 inches (610 mm), shall have one bond stone for each 6 square feet (0.56 m^2) of wall surface on both sides.

2109.10.3 Minimum thickness. The thickness of stone masonry bearing walls shall not be less than 16 inches (406 mm).

SECTION 2110 — GLASS MASONRY

2110.1 General. Masonry of glass blocks may be used in nonload-bearing exterior or interior walls and in openings which might otherwise be filled with windows, either isolated or in continuous bands, provided the glass block panels have a minimum thickness of 3 inches (76 mm) at the mortar joint and the mortared surfaces of the blocks are treated for mortar bonding. Glass block may be solid or hollow and may contain inserts.

2110.2 Mortar Joints. Glass block shall be laid in Type S or N mortar. Both vertical and horizontal mortar joints shall be at least $^1/_4$ inch (6 mm) and not more than $^3/_8$ inch (9.5 mm) thick and shall be completely filled. All mortar contact surfaces shall be treated to ensure adhesion between mortar and glass.

2110.3 Lateral Support. Glass panels shall be laterally supported along each end of the panel.

Lateral support shall be provided by panel anchors spaced not more than 16 inches (406 mm) on center or by channels. The lateral support shall be capable of resisting the horizontal design forces determined in Chapter 16 or a minimum of 200 pounds per lineal foot (2920 N per linear meter) of wall, whichever is greater. The connection shall accommodate movement requirements of Section 2110.6.

2110.4 Reinforcement. Glass block panels shall have joint reinforcement spaced not more than 16 inches (406 mm) on center and located in the mortar bed joint extending the entire length of the panel. A lapping of longitudinal wires for a minimum of 6 inches (152 mm) is required for joint reinforcement splices. Joint reinforcement shall also be placed in the bed joint immediately below and above openings in the panel. Joint reinforcement shall conform to UBC Standard 21-10, Part I. Joint reinforcement in exterior panels shall be hot-dip galvanized in accordance with UBC Standard 21-10, Part I.

2110.5 Size of Panels. Glass block panels for exterior walls shall not exceed 144 square feet (13.4 m^2) of unsupported wall surface or 15 feet (4572 mm) in any dimension. For interior walls, glass block panels shall not exceed 250 square feet (23.2 m^2) of unsupported area or 25 feet (7620 mm) in any dimension.

2110.6 Expansion Joints. Glass block shall be provided with expansion joints along the sides and top, and these joints shall have sufficient thickness to accommodate displacements of the supporting structure, but not less than $^{3}/_{8}$ inch (9.5 mm). Expansion joints shall be entirely free of mortar and shall be filled with resilient material.

2110.7 Reuse of Units. Glass block units shall not be reused after being removed from an existing panel.

SECTION 2111 — CHIMNEYS, FIREPLACES AND BARBECUES

Chimneys, flues, fireplaces and barbecues and their connections carrying products of combustion shall be designed, anchored, supported and reinforced as set forth in Chapter 31 and any applicable provisions of this chapter.

TABLE 21-A—MORTAR PROPORTIONS FOR UNIT MASONRY

MORTAR	TYPE	PROPORTIONS BY VOLUME (CEMENTITIOUS MATERIALS): Portland Cement or Blended Cement	Masonry Cement[1] M	Masonry Cement[1] S	Masonry Cement[1] N	Mortar Cement[2] M	Mortar Cement[2] S	Mortar Cement[2] N	Hydrated Lime or Lime Putty	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
Cement-lime	M	1	—	—	—	—	—	—	$\frac{1}{4}$	Not less than $2\frac{1}{4}$ and not more than 3 times the sum of the separate volumes of cementitious materials.
	S	1	—	—	—	—	—	—	over $\frac{1}{4}$ to $\frac{1}{2}$	
	N	1	—	—	—	—	—	—	over $\frac{1}{2}$ to $1\frac{1}{4}$	
	O	1	—	—	—	—	—	—	over $1\frac{1}{4}$ to $2\frac{1}{2}$	
Mortar cement	M	1	—	—	—	—	—	1	—	
	M	—	—	—	—	1	—	—	—	
	S	$\frac{1}{2}$	—	—	—	—	—	1	—	
	S	—	—	—	—	—	1	—	—	
	N	—	—	—	—	—	—	1	—	
Masonry cement	M	1	—	—	1	—	—	—	—	
	M	—	1	—	—	—	—	—	—	
	S	$\frac{1}{2}$	—	—	1	—	—	—	—	
	S	—	—	1	—	—	—	—	—	
	N	—	—	—	1	—	—	—	—	
	O	—	—	—	1	—	—	—	—	

[1]Masonry cement conforming to the requirements of UBC Standard 21-11.

[2]Mortar cement conforming to the requirements of UBC Standard 21-14.

TABLE 21-B—GROUT PROPORTIONS BY VOLUME[1]

TYPE	PARTS BY VOLUME OF PORTLAND CEMENT OR BLENDED CEMENT	PARTS BY VOLUME OF HYDRATED LIME OR LIME PUTTY	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION: Fine	Coarse
Fine grout	1	0 to $\frac{1}{10}$	$2\frac{1}{4}$ to 3 times the sum of the volumes of the cementitious materials	
Coarse grout	1	0 to $\frac{1}{10}$	$2\frac{1}{4}$ to 3 times the sum of the volumes of the cementitious materials	1 to 2 times the sum of the volumes of the cementitious materials

[1]Grout shall attain a minimum compressive strength at 28 days of 2,000 psi (13.8 MPa). The building official may require a compressive field strength test of grout made in accordance with UBC Standard 21-18.

TABLE 21-C—GROUTING LIMITATIONS

GROUT TYPE	GROUT POUR MAXIMUM HEIGHT (feet)[1]	MINIMUM DIMENSIONS OF THE TOTAL CLEAR AREAS WITHIN GROUT SPACES AND CELLS[2,3] (× 25.4 for mm): Multiwythe Masonry	Hollow-unit Masonry
	× 304.8 for mm		
Fine	1	$\frac{3}{4}$	$1\frac{1}{2} \times 2$
Fine	5	$1\frac{1}{2}$	$1\frac{1}{2} \times 2$
Fine	8	$1\frac{1}{2}$	$1\frac{1}{2} \times 3$
Fine	12	$1\frac{1}{2}$	$1\frac{3}{4} \times 3$
Fine	24	2	3×3
Coarse	1	$1\frac{1}{2}$	$1\frac{1}{2} \times 3$
Coarse	5	2	$2\frac{1}{2} \times 3$
Coarse	8	2	3×3
Coarse	12	$2\frac{1}{2}$	3×3
Coarse	24	3	3×4

[1]See also Section 2104.6.

[2]The actual grout space or grout cell dimensions must be larger than the sum of the following items: (1) The required minimum dimensions of total clear areas in Table 21-C; (2) The width of any mortar projections within the space; and (3) The horizontal projections of the diameters of the horizontal reinforcing bars within a cross section of the grout space or cell.

[3]The minimum dimensions of the total clear areas shall be made up of one or more open areas, with at least one area being $\frac{3}{4}$ inch (19 mm) or greater in width.

TABLE 21-D—SPECIFIED COMPRESSIVE STRENGTH OF MASONRY, f'_m (psi) BASED ON SPECIFYING THE COMPRESSIVE STRENGTH OF MASONRY UNITS

COMPRESSIVE STRENGTH OF CLAY MASONRY UNITS[1, 2] (psi)	SPECIFIED COMPRESSIVE STRENGTH OF MASONRY, f'_m	
	Type M or S Mortar[3] (psi)	Type N Mortar[3] (psi)
× 6.89 for kPa		
14,000 or more	5,300	4,400
12,000	4,700	3,800
10,000	4,000	3,300
8,000	3,350	2,700
6,000	2,700	2,200
4,000	2,000	1,600
COMPRESSIVE STRENGTH OF CONCRETE MASONRY UNITS[2, 4] (psi)	**SPECIFIED COMPRESSIVE STRENGTH OF MASONRY, f'_m**	
	Type M or S Mortar[3] (psi)	**Type N Mortar[3] (psi)**
× 6.89 for kPa		
4,800 or more	3,000	2,800
3,750	2,500	2,350
2,800	2,000	1,850
1,900	1,500	1,350
1,250	1,000	950

[1]Compressive strength of solid clay masonry units is based on gross area. Compressive strength of hollow clay masonry units is based on minimum net area. Values may be interpolated. When hollow clay masonry units are grouted, the grout shall conform to the proportions in Table 21-B.
[2]Assumed assemblage. The specified compressive strength of masonry f'_m is based on gross area strength when using solid units or solid grouted masonry and net area strength when using ungrouted hollow units.
[3]Mortar for unit masonry, proportion specification, as specified in Table 21-A. These values apply to portland cement-lime mortars without added air-entraining materials.
[4]Values may be interpolated. In grouted concrete masonry, the compressive strength of grout shall be equal to or greater than the compressive strength of the concrete masonry units.

TABLE 21-E-1—ALLOWABLE TENSION, B_t, FOR EMBEDDED ANCHOR BOLTS FOR CLAY AND CONCRETE MASONRY, pounds[1,2,3]

	EMBEDMENT LENGTH, l_b, or EDGE DISTANCE, l_{be} (inches)						
f'_m (psi)	2	3	4	5	6	8	10
× 6.89 for kPa	× 25.4 for mm × 4.45 for N						
1,500	240	550	970	1,520	2,190	3,890	6,080
1,800	270	600	1,070	1,670	2,400	4,260	6,660
2,000	280	630	1,120	1,760	2,520	4,500	7,020
2,500	310	710	1,260	1,960	2,830	5,030	7,850
3,000	340	770	1,380	2,150	3,100	5,510	8,600
4,000	400	890	1,590	2,480	3,580	6,360	9,930
5,000	440	1,000	1,780	2,780	4,000	7,110	11,100
6,000	480	1,090	1,950	3,040	4,380	7,790	12,200

[1]The allowable tension values in Table 21-E-1 are based on compressive strength of masonry assemblages. Where yield strength of anchor bolt steel governs, the allowable tension in pounds is given in Table 21-E-2.
[2]Values are for bolts of at least A 307 quality. Bolts shall be those specified in Section 2106.2.14.1.
[3]Values shown are for work with or without special inspection.

TABLE 21-E-2—ALLOWABLE TENSION, B_t, FOR EMBEDDED ANCHOR BOLTS FOR CLAY AND CONCRETE MASONRY, pounds[1,2]

ANCHOR BOLT DIAMETER (inches) × 25.4 for mm							
1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8
× 4.45 for N							
350	790	1,410	2,210	3,180	4,330	5,650	7,160

[1]Values are for bolts of at least A 307 quality. Bolts shall be those specified in Section 2106.2.14.1.
[2]Values shown are for work with or without special inspection.

TABLE 21-F—ALLOWABLE SHEAR, B_v, FOR EMBEDDED ANCHOR BOLTS FOR CLAY AND CONCRETE MASONRY, pounds[1,2]

f'_m (psi)	ANCHOR BOLT DIAMETER (inches) × 25.4 for mm						
	3/8	1/2	5/8	3/4	7/8	1	1 1/8
× 4.45 for N							
1,500	480	850	1,330	1,780	1,920	2,050	2,170
1,800	480	850	1,330	1,860	2,010	2,150	2,280
2,000	480	850	1,330	1,900	2,060	2,200	2,340
2,500	480	850	1,330	1,900	2,180	2,330	2,470
3,000	480	850	1,330	1,900	2,280	2,440	2,590
4,000	480	850	1,330	1,900	2,450	2,620	2,780
5,000	480	850	1,330	1,900	2,590	2,770	2,940
6,000	480	850	1,330	1,900	2,600	2,900	3,080

[1]Values are for bolts of at least A 307 quality. Bolts shall be those specified in Section 2106.2.14.1.
[2]Values shown are for work with or without special inspection.

TABLE 21-G—MINIMUM DIAMETERS OF BEND

BAR SIZE	MINIMUM DIAMETER
No. 3 through No. 8	6 bar diameters
No. 9 through No. 11	8 bar diameters

TABLE 21-H-1—RADIUS OF GYRATION[1] FOR CONCRETE MASONRY UNITS[2]

GROUT SPACING (inches) × 25.4 for mm	NOMINAL WIDTH OF WALL (inches) × 25.4 for mm				
	4	6	8	10	12
Solid grouted	1.04	1.62	2.19	2.77	3.34
16	1.16	1.79	2.43	3.04	3.67
24	1.21	1.87	2.53	3.17	3.82
32	1.24	1.91	2.59	3.25	3.91
40	1.26	1.94	2.63	3.30	3.97
48	1.27	1.96	2.66	3.33	4.02
56	1.28	1.98	2.68	3.36	4.05
64	1.29	1.99	2.70	3.38	4.08
72	1.30	2.00	2.71	3.40	4.10
No grout	1.35	2.08	2.84	3.55	4.29

[1]For single-wythe masonry or for an individual wythe of a cavity wall.

$$r = \sqrt{I/A_e}$$

[2]The radius of gyration shall be based on the specified dimensions of the masonry units or shall be in accordance with the values shown which are based on the minimum dimensions of hollow concrete masonry unit face shells and webs in accordance with UBC Standard 21-4 for two cell units.

TABLE 21-H-2—RADIUS OF GYRATION[1] FOR CLAY MASONRY UNIT LENGTH, 16 INCHES[2]

GROUT SPACING (inches) × 25.4 for mm	NOMINAL WIDTH OF WALL (inches) × 25.4 for mm				
	4	6	8	10	12
Solid grouted	1.06	1.64	2.23	2.81	3.39
16	1.16	1.78	2.42	3.03	3.65
24	1.20	1.85	2.51	3.13	3.77
32	1.23	1.88	2.56	3.19	3.85
40	1.25	1.91	2.59	3.23	3.90
48	1.26	1.93	2.61	3.26	3.93
56	1.27	1.94	2.63	3.28	3.95
64	1.27	1.95	2.64	3.30	3.97
72	1.28	1.95	2.65	3.31	3.99
No grout	1.32	2.02	2.75	3.42	4.13

[1]For single-wythe masonry or for an individual wythe of a cavity wall.

$$r = \sqrt{I/A_e}$$

[2]The radius of gyration shall be based on the specified dimensions of the masonry units or shall be in accordance with the values shown which are based on the minimum dimensions of hollow clay masonry face shells and webs in accordance with UBC Standard 21-1 for two cell units.

TABLE 21-H-3—RADIUS OF GYRATION[1] FOR CLAY MASONRY UNIT LENGTH, 12 INCHES[2]

GROUT SPACING (inches) × 25.4 for mm	NOMINAL WIDTH OF WALL (inches) × 25.4 for mm				
	4	6	8	10	12
Solid grouted	1.06	1.65	2.24	2.82	3.41
12	1.15	1.77	2.40	3.00	3.61
18	1.19	1.82	2.47	3.08	3.71
24	1.21	1.85	2.51	3.12	3.76
30	1.23	1.87	2.53	3.15	3.80
36	1.24	1.88	2.55	3.17	3.82
42	1.24	1.89	2.56	3.19	3.84
48	1.25	1.90	2.57	3.20	3.85
54	1.25	1.90	2.58	3.21	3.86
60	1.26	1.91	2.59	3.21	3.87
66	1.26	1.91	2.59	3.22	3.88
72	1.26	1.91	2.59	3.22	3.88
No grout	1.29	1.95	2.65	3.28	3.95

[1]For single-wythe masonry or for an individual wythe of a cavity wall.

$$r = \sqrt{I/A_e}$$

[2]The radius of gyration shall be based on the specified dimensions of the masonry units or shall be in accordance with the values shown which are based on the minimum dimensions of hollow clay masonry face shells and webs in accordance with UBC Standard 21-1 for two cell units.

TABLE 21-I—ALLOWABLE FLEXURAL TENSION (psi)

UNIT TYPE	MORTAR TYPE			
	Cement-lime and Mortar Cement		Masonry Cement	
	M or S	N	M or S	N
	× 6.89 for kPa			
Normal to bed joints				
Solid	40	30	24	15
Hollow	25	19	15	9
Normal to head joints				
Solid	80	60	48	30
Hollow	50	38	30	18

TABLE 21-J—MAXIMUM NOMINAL SHEAR STRENGTH VALUES[1,2]

M/Vd	V_n MAXIMUM
≤ 0.25	$6.0\, A_e \sqrt{f'_m} \le 380\, A_e$ $(322\, A_e \sqrt{f'_m} \le 1691\, A_e)$
≥ 1.00	$4.0\, A_e \sqrt{f'_m} \le 250\, A_e$ $(214\, A_e \sqrt{f'_m} \le 1113\, A_e)$

[1]*M* is the maximum bending moment that occurs simultaneously with the shear load *V* at the section under consideration. Interpolation may be by straight line for *M/Vd* values between 0.25 and 1.00.
[2]V_n is in pounds (N), and f'_m is in pounds per square inches (kPa).

TABLE 21-K—NOMINAL SHEAR STRENGTH COEFFICIENT

M/Vd[1]	C_d
≤ 0.25	2.4
≥ 1.00	1.2

[1]*M* is the maximum bending moment that occurs simultaneously with the shear load *V* at the section under consideration. Interpolation may be by straight line for *M/Vd* values between 0.25 and 1.00.

TABLE 21-L—SHEAR WALL SPACING REQUIREMENTS FOR EMPIRICAL DESIGN OF MASONRY

FLOOR OR ROOF CONSTRUCTION	MAXIMUM RATIO Shear Wall Spacing to Shear Wall Length
Cast-in-place concrete	5:1
Precast concrete	4:1
Metal deck with concrete fill	3:1
Metal deck with no fill	2:1
Wood diaphragm	2:1

TABLE 21-M—ALLOWABLE COMPRESSIVE STRESSES FOR EMPIRICAL DESIGN OF MASONRY

CONSTRUCTION: COMPRESSIVE STRENGTH OF UNIT, GROSS AREA	ALLOWABLE COMPRESSIVE STRESSES[1] GROSS CROSS-SECTIONAL AREA (psi) × 6.89 for kPa	
× 6.89 for kPa	Type M or S Mortar	Type N Mortar
Solid masonry of brick and other solid units of clay or shale; sand-lime or concrete brick:		
8,000 plus, psi	350	300
4,500 psi	225	200
2,500 psi	160	140
1,500 psi	115	100
Grouted masonry, of clay or shale; sand-lime or concrete:		
4,500 plus, psi	275	200
2,500 psi	215	140
1,500 psi	175	100
Solid masonry of solid concrete masonry units:		
3,000 plus, psi	225	200
2,000 psi	160	140
1,200 psi	115	100
Masonry of hollow load-bearing units:		
2,000 plus, psi	140	120
1,500 psi	115	100
1,000 psi	75	70
700 psi	60	55
Hollow walls (cavity or masonry bonded)[2] solid units:		
2,500 plus, psi	160	140
1,500 psi	115	100
Hollow units	75	70
Stone ashlar masonry:		
Granite	720	640
Limestone or marble	450	400
Sandstone or cast stone	360	320
Rubble stone masonry Coarse, rough or random	120	100
Unburned clay masonry	30	—

[1]Linear interpolation may be used for determining allowable stresses for masonry units having compressive strengths which are intermediate between those given in the table.
[2]Where floor and roof loads are carried upon one wythe, the gross cross-sectional area is that of the wythe under load. If both wythes are loaded, the gross cross-sectional area is that of the wall minus the area of the cavity between the wythes.

TABLE 21-N—ALLOWABLE SHEAR ON BOLTS FOR EMPIRICALLY DESIGNED MASONRY EXCEPT UNBURNED CLAY UNITS

DIAMETER BOLT (inches)	EMBEDMENT[1] (inches)	SOLID MASONRY (shear in pounds)	GROUTED MASONRY (shear in pounds)
× 25.4 for mm		× 4.45 for N	
$^{1}/_{2}$	4	350	550
$^{5}/_{8}$	4	500	750
$^{3}/_{4}$	5	750	1,100
$^{7}/_{8}$	6	1,000	1,500
1	7	1,250	1,850[2]
$1^{1}/_{8}$	8	1,500	2,250[2]

[1]An additional 2 inches of embedment shall be provided for anchor bolts located in the top of columns for buildings located in Seismic Zones 2, 3 and 4.
[2]Permitted only with not less than 2,500 pounds per square inch (17.24 MPa) units.

TABLE 21-O—WALL LATERAL SUPPORT REQUIREMENTS FOR EMPIRICAL DESIGN OF MASONRY

CONSTRUCTION	MAXIMUM *l/t* or *h/t*
Bearing walls Solid or solid grouted All other	 20 18
Nonbearing walls Exterior Interior	 18 36

TABLE 21-P—THICKNESS OF FOUNDATION WALLS FOR EMPIRICAL DESIGN OF MASONRY

FOUNDATION WALL CONSTRUCTION	NOMINAL THICKNESS (inches)	MAXIMUM DEPTH OF UNBALANCED FILL (feet)
	× 25.4 for mm	× 304.8 for mm
Masonry of hollow units, ungrouted	8 10 12	4 5 6
Masonry of solid units	8 10 12	5 6 7
Masonry of hollow or solid units, fully grouted	8 10 12	7 8 8
Masonry of hollow units reinforced vertically with No. 4 bars and grout at 24″ o.c. Bars located not less than $4^1/_2$″ from pressure side of wall.	8	7

TABLE 21-Q—ALLOWABLE SHEAR ON BOLTS FOR MASONRY OF UNBURNED CLAY UNITS

DIAMETER OF BOLTS (inches)	EMBEDMENTS (inches)	SHEAR (pounds)
× 25.4 for mm		× 4.45 for N
$^1/_2$	—	—
$^5/_8$	12	200
$^3/_4$	15	300
$^7/_8$	18	400
1	21	500
$1^1/_8$	24	600

UNIFORM BUILDING CODE STANDARD 21-1

BUILDING BRICK, FACING BRICK AND HOLLOW BRICK (MADE FROM CLAY OR SHALE)

See Section 2102.2, Item 4, *Uniform Building Code*

SECTION 21.101 — SCOPE

21.101.1 General. This standard covers brick made from clay or shale and subjected to heat treatment at elevated temperatures (firing), and intended for use in brick masonry. In addition, this standard covers dimension and distortion tolerances for facing brick and hollow brick to be used in masonry construction.

21.101.2 Definition.

BRICK is a solid clay masonry unit whose net cross-sectional area in any plane parallel to the surface containing the cores or cells is at least 75 percent of the gross cross-sectional area measured in the same plane.

21.101.3 Grades. Three grades of brick are covered.

Grade SW. Brick intended for use where a high and uniform resistance to damage caused by cyclic freezing is desired and the exposure is such that the brick may be frozen when saturated with water.

Grade MW. Brick intended for use where moderate resistance to cyclic freezing damage is permissible or where brick may be damp but not saturated with water when freezing occurs.

Grade NW. Brick with little resistance to cyclic freezing damage but which may be acceptable for applications protected from water absorption and freezing.

21.101.4 Grade Requirements for Face Exposure. The selection of the grade of brick for face exposure of vertical or horizontal surfaces shall conform to Table 21-1-A and Figure 21-1-1.

SECTION 21.102 — PHYSICAL PROPERTIES

21.102.1 Durability. The brick shall conform to the physical requirements for the grade specified, as prescribed in Table 21-1-B.

21.102.2 Substitution of Grades. Grades SW and MW may be used in lieu of Grade NW, and Grade SW in lieu of Grade MW.

21.102.3 Waiver of Saturation Coefficient. The saturation coefficient shall be waived provided the average cold-water absorption of a random sample of five bricks does not exceed 8 percent, no more than one brick of the sample exceeds 8 percent and its cold-water absorption must be less than 10 percent.

21.102.4 Freezing and Thawing. The requirements specified in this standard for water absorption (five-hour boiling) and saturation coefficient shall be waived, provided a sample of five bricks, meeting all other requirements, complies with the following requirements when subjected to 50 cycles of the freezing-and-thawing test:

Grade SW	No breakage and not greater than 0.5 percent loss in dry weight of any individual brick.

Brick is not required to conform to the provisions of this section, and these do not apply unless the sample fails to conform to the requirements for absorption and saturation coefficient prescribed in Table 21-1-B or the absorption requirements in Section 21.102.3.

A particular lot or shipment shall be given the same grading as a previously tested lot, without repeating the freezing-and-thawing test, provided the brick is made by the same manufacturer from similar raw materials and by the same method of forming; and provided also that a sample of five bricks selected from the particular lot has an average and individual minimum strength not less than a previously graded sample, and has average and individual maximum water absorption and saturation coefficient not greater than those of the previously tested sample graded according to the freezing-and-thawing test.

21.102.5 Waiver of Durability Requirements. If brick is intended for use exposed to weather where the weathering index is less than 50 (see Figure 21-1-1), unless otherwise specified, the requirements given in Section 21.102.1 for water absorption (five-hour boiling) and for saturation coefficient shall be waived and a minimum average strength of 2,500 pounds per square inch (17 200 kPa) shall apply.

SECTION 21.103 — SIZE, CORING AND FROGGING

21.103.1 Tolerances on Dimensions. The maximum permissible variation in dimensions of individual units shall not exceed those given in Table 21-1-C.

21.103.2 Coring. The net cross-sectional area of cored brick in any plane parallel to the surface containing the cores or cells shall be at least 75 percent of the gross cross-sectional area measured in the same plane. No part of any hole shall be less than $^3/_4$ inch (19.1 mm) from any edge of the brick.

21.103.3 Frogging. One bearing face of each brick may have a recess or panel frog and deep frogs. The recess or panel frog shall not exceed $^3/_8$ inch (9.5 mm) in depth and no part of the recess or panel frog shall be less than $^3/_4$ inch (19.1 mm) from any edge of the brick. In brick containing deep frogs, frogs deeper than $^3/_8$ inch (9.5 mm), any cross section through the deep frogs parallel to the surface containing the deep frogs shall conform to the requirements of Section 21.103.2.

SECTION 21.104 — VISUAL INSPECTION

21.104.1 General. The brick shall be free of defects, deficiencies and surface treatments, including coatings, that would interfere with the proper setting of the brick or significantly impair the strength or performance of the construction.

Minor indentations or surface cracks incidental to the usual method of manufacture, or the chipping resulting from the customary methods of handling in shipment and delivery should not be deemed grounds for rejection.

SECTION 21.105 — SAMPLING AND TESTING

21.105.1 Sampling and Testing. Brick shall be sampled and tested in accordance with ASTM C 67.

SECTION 21.106 — FACING BRICK

21.106.1 General. Facing brick shall be of Grade SW or MW and shall comply with the degree of mechanical perfection and size variations specified in this section. Grade SW may be used in lieu of Grade MW.

21.106.2 Types. Three types of facing brick are covered:

Type FBS. Brick for general use in exposed exterior and interior masonry walls and partitions where greater variation in sizes are permitted than are specified for Type FBX.

Type FBX. Brick for general use in exposed exterior and interior masonry walls and partitions where a high degree of mechanical perfection and minimum permissible variation in size are required.

Type FBA. Brick manufactured and selected to produce characteristic architectural effects resulting from nonuniformity in size and texture of individual units.

When the type is not specified, the requirements for Type FBS shall govern.

21.106.3 Tolerances on Dimensions. The brick shall not depart from the specified size to be used by more than the individual tolerance for the type specified set forth in Table 21-1-D. Tolerances on dimensions for Type FBA shall be as specified by the purchaser, but not more restrictive than Type FBS.

21.106.4 Warpage. Tolerances for distortion or warpage of face or edges of indivi-dual brick from a plane surface and from a straight line, respectively, shall not exceed the maximum for the type specified as set forth in Table 21-1-E. Tolerances on distortion for Type FBA shall be as specified by the purchaser.

21.106.5 Coring. Brick may be cored. The net cross-sectional area of cored brick in any plane parallel to the surface containing the cores or cells shall be at least 75 percent of the gross cross-sectional area measured in the same plane. No part of any hole shall be less than $^3/_4$ inch (19.1 mm) from any edge of the brick.

21.106.6 Frogging. One bearing face of each brick may have a recess or panel frog and deep frogs. The recess or panel frog shall not exceed $^3/_8$ inch (9.5 mm) in depth and no part of the recess or panel frog shall be less than $^3/_4$ inch (19.1 mm) from any edge of the brick. In brick containing deep frogs, frogs deeper than $^3/_8$ inch (9.5 mm), any cross section through the deep frogs parallel to the surface containing the deep frogs shall conform to the requirements of Section 21.106.5.

21.106.7 Visual Inspection. In addition to the requirements of Section 21.104, brick used in exposed wall construction shall have faces which are free of cracks or other imperfections detracting from the appearance of the designated sample when viewed from a distance of 15 feet (4600 mm) for Type FBX and a distance of 20 feet (6100 mm) for Types FBS and FBA.

SECTION 21.107 — HOLLOW BRICK

21.107.1 General. Hollow brick shall be of Grade SW or MW and comply with the physical requirements in Table 21-1-B and other requirements of this section. Grade SW may be used in lieu of Grade MW.

21.107.2 Definitions.

HOLLOW BRICK is a clay masonry unit whose net cross-sectional area (solid area) in any plane parallel to the surface, containing the cores, cells or deep frogs is less than 75 percent of its gross cross-sectional area measured in the same plane.

CORES are void spaces having a gross cross-sectional area equal to or less than $1^1/_2$ square inches (968 mm^2).

CELLS are void spaces having a gross cross-sectional area greater than $1^1/_2$ square inches (968 mm^2).

21.107.3 Types. Four types of hollow brick are covered:

Type HBS. Hollow brick for general use in exposed exterior and interior masonry walls and partitions greater variation in size are permitted than is specified for Type HBX.

Type HBX. Hollow brick for general use in exposed exterior and interior masonry walls and partitions where a high degree of mechanical perfection and minimum permissible variation in size are required.

Type HBA. Hollow brick manufactured and selected to produce characteristic architectural effects resulting from nonuniformity in size and texture of the individual units.

Type HBB. Hollow brick for general use in masonry walls and partitions where a particular color, texture, finish, uniformity, or limits on cracks, warpage, or other imperfections detracting from the appearance are not a consideration.

When the type is not specified, the requirements for Type HBS shall govern.

21.107.4 Class. Two classes of hollow brick are covered:

Class H40V. Hollow brick intended for use where void areas or hollow spaces greater than 25 percent, but not greater than 40 percent, of the gross cross-sectional area of the unit measured in any plane parallel to the surface containing the cores, cells or deep frogs are desired. The void spaces, web thicknesses and shell thicknesses shall comply with the requirements of Sections 21.107.5, 21.107.6 and 21.107.7.

Class H60V. Hollow brick intended for use where larger void areas are desired. The sum of these void areas shall be greater than 40 percent, but not greater than 60 percent, of the gross cross-sectional area of the unit measured in any plane parallel to the surface containing the cores, cells or deep frogs. The void spaces, web thicknesses and shell thicknesses shall comply with the requirements of Sections 21.107.5, 21.107.6 and 21.107.7 and to the minimum requirements of Table 21-1-F.

When the class is not specified, the requirements for Class H40V shall govern.

21.107.5 Hollow Spaces. Core holes shall not be less than $^5/_8$ inch (15.9 mm) from any edge of the brick, except for cored-shell hollow brick. Cored-shell hollow brick shall have a minimum shell thickness of $1^1/_2$ inches (38 mm). Cores greater than 1 square inch (645 mm^2) in cored shells shall not be less than $^1/_2$ inch (13 mm) from any edge. Cores not greater than 1 inch square (645 mm^2) in shells cored not more than 35 percent shall not be less than $^3/_8$ inch (9.5 mm) from any edge.

Cells shall not be less than $^3/_4$ inch (19.1 mm) from any edge of the brick except for double-shell hollow brick.

Double-shell hollow brick with inner and outer shells not less than $^1/_2$ inch (13 mm) thick may not have cells greater than $^5/_8$ inch (15.9 mm) in width or 5 inches (127 mm) in length between the inner and outer shell.

21.107.6 Webs. The thickness for webs between cells shall not be less than $^1/_2$ inch (13 mm), $^3/_8$ inch (9.5 mm) between cells and cores or $^1/_4$ inch (6 mm) between cores. The distance of voids from unexposed edges, which are recessed not less than $^1/_2$ inch (13 mm), shall not be less than $^1/_2$ inch (13 mm).

21.107.7 Frogging. One bearing face of each brick may have a recess or panel frog and deep frogs. The recess or panel frog shall not exceed $^3/_8$ inch (9.5 mm) in depth and no part of the recess or panel frog shall be less than $^5/_8$ inch (15.9 mm) from any edge of the brick. In brick containing deep frogs, frogs deeper than $^3/_8$ inch (9.5 mm), any cross section through the deep frogs parallel to the bearing surface shall conform to other requirements of Sections 21.107.2 and 21.107.4 for void area and Section 21.107.5 for hollow spaces.

21.107.8 Tolerances on Dimensions. The hollow brick shall not depart from the specified size by more than the individual tolerance for specified size by more than individual tolerances for the type specified as set forth in Table 21-1-G. Tolerances and dimensions for Type HBA shall be as specified by the purchaser.

21.107.9 Warpage. Tolerances for distortion or warpage of face or edges of individual hollow brick from a plane surface and from a straight line, respectively, shall not exceed the maximum for the type specified in Table 21-1-H. Tolerances on distortion for Type HBA shall be as specified by the purchaser.

21.107.10 Visual Inspection. In addition to the requirements of Section 21.104, brick used in exposed wall construction shall have faces which are free of cracks or other imperfections detracting from the appearance of a sample wall when viewed from a distance of 15 feet (4600 mm) for Type HBX and a distance of 20 feet (6100 mm) for Types HBS and HBA.

TABLE 21-1-A—GRADE REQUIREMENTS FOR FACE EXPOSURE

EXPOSURE	WEATHERING INDEX		
	Less than 50	50 to 500	500 and greater
In vertical surfaces:			
In contact with earth	MW	SW	SW
Not in contact with earth	MW	SW	SW
In other than vertical surfaces:			
In contact with earth	SW	SW	SW
Not in contact with earth	MW	SW	SW

TABLE 21-1-B—PHYSICAL REQUIREMENTS FOR TYPES OF UNIT MASONRY[5]

TYPE OF MASONRY	GRADE	MINIMUM FACE SHELL THICKNESS (inches)	MINIMUM[1] COMPRESSIVE STRENGTH PSI AVERAGE GROSS AREA × 6.89 for kPa		MAXIMUM WATER ABSORPTION By Five-hour Boiling (percent)		MAXIMUM SATURATION COEFFICIENT[2]		WATER ABSORPTION Maximum Pounds per Cubic Foot × 16 for kg/m³	MOISTURE CONTENT Maximum Percentage of Total Absorption	MINIMUM MODULUS OF RUPTURE	
			Average of Five Tests	Individual	Average of Five Tests	Individual	Average of Five Test	Individual			Average of Five Tests	Individual
			(brick flatwise)								(brick flatwise) psi Average Gross Area × 6.89 for kPa	
24-1. Building brick made from clay or shale[3]	SW		3,000	2,500	17	20	.78	.80				
	MW		2,500	2,200	22	25	.88	.90				
	NW		1,500	1,250	no limit							
			(net area)[4]									
Hollow Brick[3]	SW	See Table 21-1-F	3,000	2,500	17	20	.78	.80				
	MW		2,500	2,000	22	25	.88	.90				
24-2. Sand-lime building brick	SW		4,500	3,500							600	400
	MW		2,500	2,000							450	300
			Based on Net Area (psi)[4] × 6.89 for kPa						Based on % of Dry Wt.			
24-14. Unburned clay masonry units			300	250					2.5%	4.0%	50	35

[1]Gross area of a unit shall be determined by multiplying the horizontal face dimension of the unit as placed in the wall by its thickness.

[2]The saturation coefficient is the ratio of absorption by 24-hour submersion in cold water to that after five-hour submersion in boiling water.

[3]If the average cold-water absorption of a random sample of five bricks does not exceed 8.0 percent, when no more than one brick unit of the sample exceeds 8.0 percent and its cold-water absorption must be less than 10.0 percent, the saturation coefficient shall be waived.

[4]Based on net area of a unit which shall be taken as the area of solid material in shells and webs actually carrying stresses in a direction parallel to the direction of loading.

[5]For the compressive strength requirements, test the unit with the compressive force perpendicular to the bed surface of the unit, with the unit in the stretcher position.

TABLE 21-1-C—TOLERANCES ON DIMENSIONS

SPECIFIED DIMENSION (inches)	MAXIMUM PERMISSIBLE VARIATION FROM SPECIFIED DIMENSION, PLUS OR MINUS (inch)
× 25.4 for mm	
Up to 3, incl.	$\frac{3}{32}$
Over 3 to 4, incl.	$\frac{1}{8}$
Over 4 to 6, incl.	$\frac{3}{16}$
Over 6 to 8, incl.	$\frac{1}{4}$
Over 8 to 12, incl.	$\frac{5}{16}$
Over 12 to 16, incl.	$\frac{3}{8}$

TABLE 21-1-D—TOLERANCES ON DIMENSIONS

SPECIFIED DIMENSION (inches)	MAXIMUM PERMISSIBLE VARIATION FROM SPECIFIED DIMENSION, PLUS OR MINUS (inch)	
	Type FBX	Type FBS
× 25.4 for mm		
3 and under	$\frac{1}{16}$	$\frac{3}{32}$
Over 3 to 4, incl.	$\frac{3}{32}$	$\frac{1}{8}$
Over 4 to 6, incl.	$\frac{1}{8}$	$\frac{3}{16}$
Over 6 to 8, incl.	$\frac{5}{32}$	$\frac{1}{4}$
Over 8 to 12, incl.	$\frac{7}{32}$	$\frac{5}{16}$
Over 12 to 16, incl.	$\frac{9}{32}$	$\frac{3}{8}$

TABLE 21-1-E—TOLERANCES ON DISTORTION

MAXIMUM FACE DIMENSION (inches)	MAXIMUM PERMISSIBLE DISTORTION (inch)	
	Type FBX	Type FBS
× 25.4 for mm		
8 and under	$\frac{1}{16}$	$\frac{3}{32}$
Over 8 to 12, incl.	$\frac{3}{32}$	$\frac{1}{8}$
Over 12 to 16, incl.	$\frac{1}{8}$	$\frac{5}{32}$

TABLE 21-1-F—HOLLOW BRICK (Class H60V) MINIMUM THICKNESS OF FACE SHELLS AND WEBS

NOMINAL WIDTH OF UNIT (inches)	FACE SHELL THICKNESS (inches)		END SHELLS OR WEBS (inches)	WEB THICKNESS PER FOOT, TOTAL (inches per foot)[1]
	Solid	Cored or Double Shell		
× 25.4 for mm				× 83 for mm per m
3 and 4	$\frac{3}{4}$	—	$\frac{3}{4}$	$1\frac{5}{8}$
6	1	$1\frac{1}{2}$	1	$2\frac{1}{4}$
8	$1\frac{1}{4}$	$1\frac{1}{2}$	1	$2\frac{1}{4}$
10	$1\frac{3}{8}$	$1\frac{5}{8}$	$1\frac{1}{8}$	$2\frac{1}{2}$
12	$1\frac{1}{2}$	2	$1\frac{1}{8}$	$2\frac{1}{2}$

[1]The sum of the measured thickness of all webs in the unit, multiplied by 12 (305 when using metric), and divided by the length of the unit. In the case of open-ended units where the open-end portion is solid grouted, the length of that open-ended portion shall be deducted from the overall length of the unit.

TABLE 21-1-G—TOLERANCES ON DIMENSIONS

SPECIFIED DIMENSION (inches)	MAXIMUM PERMISSIBLE VARIATION FROM SPECIFIED DIMENSION, PLUS OR MINUS (inch)	
	Type HBX	Types HBS and HBB
× 25.4 for mm		
3 and under	1/16	3/32
Over 3 to 4, incl.	3/32	1/8
Over 4 to 6, incl.	1/8	3/16
Over 6 to 8, incl.	5/32	1/4
Over 8 to 12, incl.	7/32	5/16
Over 12 to 16, incl.	9/32	3/8

TABLE 21-1-H—TOLERANCES ON DISTORTION

MAXIMUM FACE DIMENSION (inches)	MAXIMUM PERMISSIBLE DISTORTION (inch)	
	Type HBX	Types HBS and HBB
× 25.4 for mm		
8 and under	1/16	3/32
Over 8 to 12, incl.	3/32	1/8
Over 12 to 16, incl.	1/8	5/32

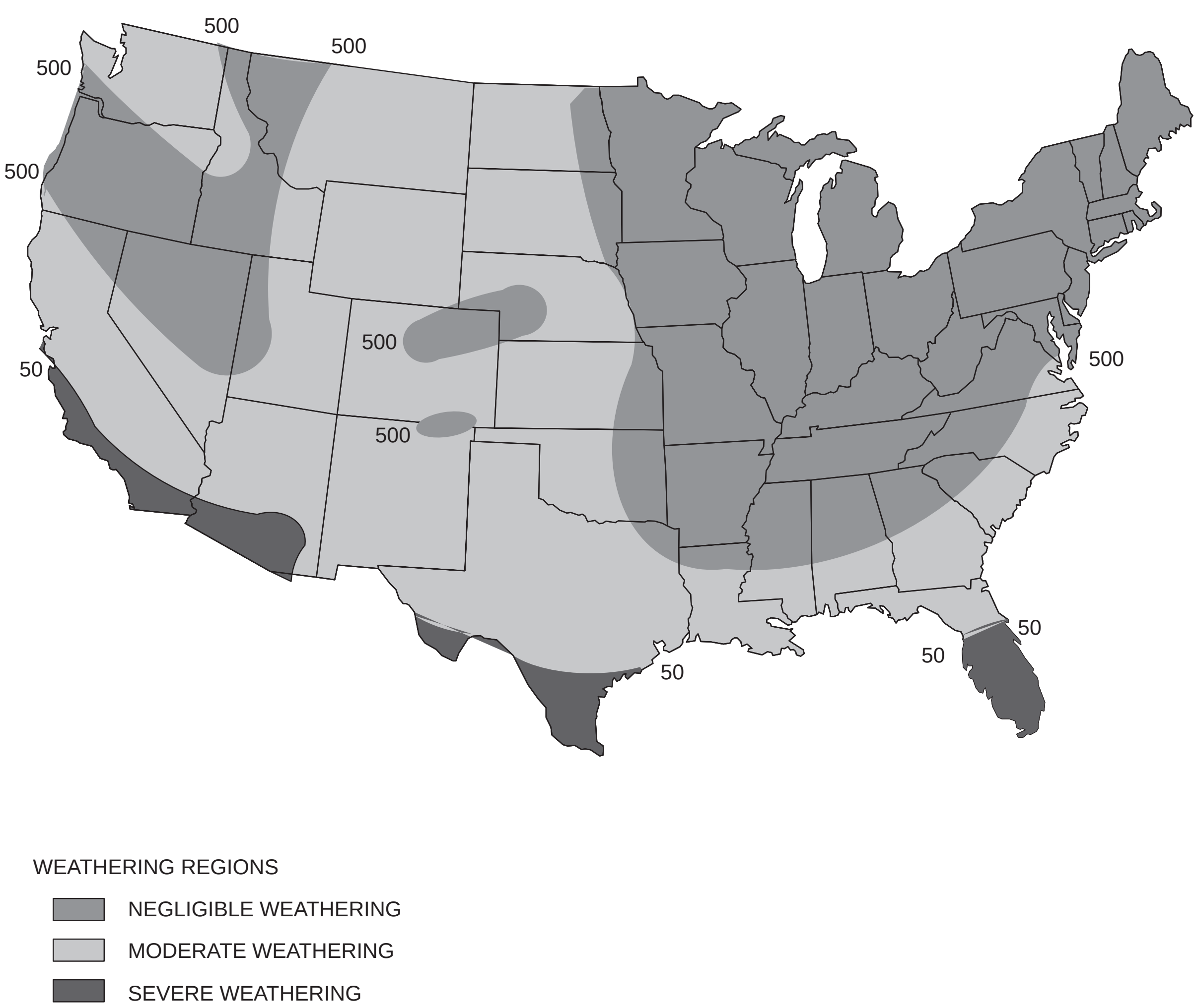


FIGURE 21-1-1—WEATHERING INDEXES IN THE UNITED STATES

UNIFORM BUILDING CODE STANDARD 21-2

CALCIUM SILICATE FACE BRICK (SAND-LIME BRICK)

Based on Standard Specification C 73-95 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 6, *Uniform Building Code*

SECTION 21.201 — SCOPE

21.201.1 Grades. This standard covers brick made from sand and lime and intended for use in brick masonry. Two grades of brick are covered:

21.201.1.1 Grade SW. Brick intended for use where exposed to temperatures below freezing in the presence of moisture.

21.201.1.2 Grade MW. Brick intended for use where exposed to temperature below freezing but unlikely to be saturated with water.

21.201.2 Definition. The term “brick” used in this standard shall mean brick or a solid sand-lime masonry unit.

SECTION 21.202 — PHYSICAL PROPERTIES

21.202.1 Durability. The brick shall conform to the physical requirements for the grade specified as prescribed in Table 21-2-A.

21.202.2 Substitution of Grades. Unless otherwise specified, brick of Grade SW shall be accepted in lieu of Grade MW.

SECTION 21.203 — SIZE

The size of the brick shall be as specified by the purchaser, and the average size of brick furnished shall approximate the size specified in the invitation for bids.

No overall dimension (width, height and length) shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimension. Standard dimensions of units are the manufacturer’s designated dimensions.

SECTION 21.204 — VISUAL INSPECTION

Brick shall pass a visual inspection for soundness, compact structure, reasonably uniform shape, and freedom from the following: cracks, warpage, large pebbles, balls of clay, or particles of lime that would affect the serviceability or strength of the brick.

SECTION 21.205 — METHODS OF SAMPLING AND TESTING

The purchaser or the purchaser’s authorized representative shall be accorded proper facilities to inspect and sample the units at the place of manufacture from the lots ready for delivery. At least 10 days should be allowed for completion of the tests.

Sample and test units in accordance with ASTM C 140.

TABLE 21-2-A—PHYSICAL REQUIREMENTS FOR SAND-LIME BUILDING BRICK

TYPE OF MASONRY	GRADE	MINIMUM COMPRESSIVE STRENGTH PSI AVERAGE GROSS AREA		MINIMUM MODULUS OF RUPTURE		WATER ABSORPTION MAX. lb./ft.^{3} (kg/m^3)
				Average of Five Tests	Individual	
		Average of Five Tests	Individual	(Brick Flatwise) psi Average Gross Area		
		× 6.89 for kPa				
Sand-lime	SW	4500	3500	600	400	10 (160)
Building brick	MW	2500	2000	450	300	13 (208)

Gross area of a unit shall be determined by multiplying the horizontal face dimension of the unit as placed in the wall by its thickness.

UNIFORM BUILDING CODE STANDARD 21-3
CONCRETE BUILDING BRICK

Based on Standard Specification C 55-95 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 5, *Uniform Building Code*

SECTION 21.301 — SCOPE

This standard covers concrete building brick and similar solid units made from portland cement, water and suitable mineral aggregates with or without the inclusion of other materials.

SECTION 21.302 — CLASSIFICATION

21.302.1 Types. Two types of concrete brick in each of two grades are covered, as follows:

21.302.1.1 Type I, moisture-controlled units. Concrete brick designated as Type I (Grades N-I and S-I) shall conform to all requirements of this standard, including the requirements of Table 21-3-A.

21.302.1.2 Type II, nonmoisture-controlled units. Concrete brick designated as Type II (Grades N-II and S-II) shall conform to all requirements of this standard except the requirements of Table 21-3-A.

21.302.2 Grades. Concrete brick manufactured in accordance with this standard shall conform to two grades as follows:

21.302.2.1 Grade N. For use as architectural veneer and facing units in exterior walls and for use where high strength and resistance to moisture penetration and severe frost action are desired.

21.302.2.2 Grade S. For general use where moderate strength and resistance to frost action and moisture penetration are required.

SECTION 21.303 — MATERIALS

21.303.1 Cementitious Materials. Materials shall conform to the following applicable standards:

1. Portland Cement—ASTM C 150 modified as follows:

   Limitation on insoluble residue—1.5 percent.
   Limitation on air content of mortar,
   Volume percent—22 percent maximum.
   Limitation on loss on ignition—7 percent maximum.
   Limestone with a minimum 85 percent calcium carbonate ($CaCO_3$) content may be added to the cement, provided the requirements of ASTM C 150 as modified above are met.

2. Blended Cements—ASTM C 595.

3. Hydrated Lime, Type S—UBC Standard 21-13.

21.303.2 Other Constituents. Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, etc., shall be previously established as suitable for use in concrete or shall be shown by test or experience not to be detrimental to the durability of the concrete.

SECTION 21.304 — PHYSICAL REQUIREMENTS

At the time of delivery to the work site, the concrete brick shall conform to the physical requirements prescribed in Table 21-3-B.

At the time of delivery to the purchaser, the total linear drying shrinkage of Type II units shall not exceed 0.065 percent when tested in accordance with ASTM C 426.

The moisture content of Type I concrete brick at the time of delivery shall conform to the requirements prescribed in Table 21-3-A.

SECTION 21.305 — DIMENSIONS AND PERMISSIBLE VARIATIONS

Overall dimensions (width, height, or length) shall not differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimensions.

> **NOTE:** Standard dimensions of concrete brick are the manufacturer's designated dimensions. Nominal dimensions of modular-size concrete brick are equal to the standard dimensions plus $^3/_8$ inch (9.5 mm), the thickness of one standard mortar joint. Nominal dimensions of nonmodular size concrete brick usually exceed the standard dimensions by $^1/_8$ inch to $^1/_4$ inch (3.2 mm to 6.4 mm).

Variations in thickness of architectural units such as split-faced or slumped units will usually vary from the specified tolerances.

SECTION 21.306 — VISUAL INSPECTION

21.306.1 General. All concrete brick shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or impair the strength or permanence of the construction. Minor cracks incidental to the usual method of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery, shall not be deemed grounds for rejection.

21.306.2 Brick in Exposed Walls. Where concrete brick is to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks or other imperfections when viewed from 20 feet (6100 mm), except that if not more than 5 percent of a shipment contains slight cracks or small chips not larger than $^1/_2$ inch (13 mm), this shall not be deemed grounds for rejection.

SECTION 21.307 — METHODS OF SAMPLING AND TESTING

The purchaser or authorized representative shall be accorded proper facilities to inspect and sample the concrete brick at the place of manufacture from the lots ready for delivery. At least 10 days shall be allowed for completion of the test.

Sample and test concrete brick in accordance with ASTM C 140 and C 426, when applicable.

Total linear drying shrinkage shall be based on tests of concrete brick made with the same materials, concrete mix design, manufacturing process and curing method, conducted in accordance with ASTM C 426 not more than 24 months prior to delivery.

SECTION 21.308 — REJECTION

If the shipment fails to conform to the specific requirements, the manufacturer may sort it, and new specimens shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. If the second set of specimens fails to conform to the test requirements, the entire lot shall be rejected.

TABLE 21-3-A—MOISTURE CONTENT REQUIREMENTS FOR TYPE I CONCRETE BRICK

	MOISTURE CONTENT, MAX. PERCENT OF TOTAL ABSORPTION (Average of 3 Concrete Brick)		
	Humidity[1] Conditions at Jobsite or Point of Use		
LINEAR SHRINKAGE, PERCENT	Humid	Intermediate	Arid
0.03 or less	45	40	35
From 0.03 to 0.045	40	35	30
0.045 to 0.065, max.	35	30	25

[1]Arid—Average annual relative humidity less than 50 percent.
Intermediate—Average annual relative humidity 50 to 75 percent.
Humid—Average annual relative humidity above 75 percent.

TABLE 21-3-B—STRENGTH AND ABSORPTION REQUIREMENTS

COMPRESSIVE STRENGTH, MIN., psi (Concrete Brick Tested Flatwise)			WATER ABSORPTION, MAX., (Avg. of 3 Brick) WITH OVEN-DRY WEIGHT OF CONCRETE Lb./Ft.^{3}		
× 6.89 for kPa			× 16 for kg/m^3		
Average Gross Area			Weight Classification		
Grade	Avg. of 3 Concrete Brick	Individual Concrete Brick	Lightweight Less Than 105	Medium Weight Less Than 125 to 105	Normal Weight 125 or More
N-I	3,500	3,000	15	13	10
N-II	3,500	3,000	15	13	10
S-I	2,500	2,000	18	15	13
S-II	2,500	2,000	18	15	13

UNIFORM BUILDING CODE STANDARD 21-4

HOLLOW AND SOLID LOAD-BEARING CONCRETE MASONRY UNITS

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SECTION 21.401 — SCOPE

This standard covers solid (units with 75 percent or more net area) and hollow load-bearing concrete masonry units made from portland cement, water and mineral aggregates with or without the inclusion of other materials.

SECTION 21.402 — CLASSIFICATION

21.402.1 Types. Two types of concrete masonry units in each of two grades are covered as follows:

21.402.1.1 Type I, moisture-controlled units. Units designated as Type I shall conform to all requirements of this standard including the moisture content requirements of Table 21-4-A.

21.402.1.2 Type II, nonmoisture-controlled units. Units designated as Type II shall conform to all requirements of this standard except the moisture content requirements of Table 21-4-A.

21.402.2 Grades. Concrete masonry units manufactured in accordance with this standard shall conform to two grades as follows:

21.402.2.1 Grade N. Units having a weight classification of 85 pcf (1360 kg/m^3) or greater, for general use such as in exterior walls below and above grade that may or may not be exposed to moisture penetration or the weather and for interior walls and backup.

21.402.2.2 Grade S. Units having a weight classification of less than 85 pcf (1360 kg/m^3), for uses limited to above-grade installation in exterior walls with weather-protective coatings and in walls not exposed to the weather.

SECTION 21.403 — MATERIALS

21.403.1 Cementitious Materials. Materials shall conform to the following applicable standards:

1. Portland Cement—ASTM C 150 modified as follows:

   Limitation on insoluble residue—1.5 percent maximum.
   Limitation on air content of mortar,
   Volume percent—22 percent maximum.
   Limitation on loss on ignition—7 percent maximum.
   Limestone with a minimum 85 percent calcium carbonate (C_aCO_3) content may be added to the cement, provided the requirements of ASTM C 150 as modified above are met.
2. Blended Cements—ASTM C 595.
3. Hydrated Lime, Type S—UBC Standard 21-13.

21.403.2 Other Constituents and Aggregates. Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, aggregates, and other constituents, shall be previously established as suitable for use in concrete or shall be shown by test or experience to not be detrimental to the durability of the concrete.

SECTION 21.404 — PHYSICAL REQUIREMENTS

At the time of delivery to the work site, the units shall conform to the physical requirements prescribed in Table 21-4-B. The moisture content of Type I concrete masonry units at time of delivery shall conform to the requirements prescribed in Table 21-4-A.

At the time of delivery to the purchaser, the linear shrinkage of Type II units shall not exceed 0.065 percent.

SECTION 21.405 — MINIMUM FACE-SHELL AND WEB THICKNESSES

Face-shell (FST) and web (WT) thicknesses shall conform to the requirements listed in Table 21-4-C.

SECTION 21.406 — PERMISSIBLE VARIATIONS IN DIMENSIONS

21.406.1 Precision Units. For precision units, no overall dimension (width, height and length) shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimensions.

21.406.2 Particular Feature Units. For particular feature units, dimensions shall be in accordance with the following:

1. For molded face units, no overall dimension (width, height and length) shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimension. Dimensions of molded features (ribs, scores, hex-shapes, patterns, etc.) shall be within $^1/_{16}$ inch (1.6 mm) of the specified standard dimensions and shall be within $^1/_{16}$ inch (1.6 mm) of the specified placement of the unit.

2. For split-faced units, all non-split overall dimensions (width, height and length) shall differ by no more than $^1/_8$ inch (3.2 mm) from the specified standard dimensions. On faces that are split, overall dimensions will vary. Local suppliers should be consulted to determine dimensional tolerances achievable.

3. For slumped units, no overall height dimension shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimension. On faces that are slumped, overall dimensions will vary. Local suppliers should be consulted to determine dimension tolerances achievable.

NOTE: Standard dimensions of units are the manufacturer's designated dimensions. Nominal dimensions of modular size units, except slumped units, are equal to the standard dimensions plus $^3/_8$ inch (9.5 mm), the thickness of one standard mortar joint. Slumped units are equal to the standard dimensions plus $^1/_2$ inch (13 mm), the thickness of one standard mortar joint. Nominal dimensions of nonmodular size units usually exceed the standard dimensions by $^1/_8$ inch to $^1/_4$ inch (3.2 mm to 6.4 mm).

SECTION 21.407 — VISUAL INSPECTION

All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or impair the strength or perm-anence of the construction. Units may have minor cracks incidental to the usual method of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery.

Units that are intended to serve as a base for plaster or stucco shall have a sufficiently rough surface to afford a good bond.

Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks or other imperfections when viewed from 20 feet (6100 mm), except that not more than 5 percent of a shipment may have slight cracks or small chips not larger than 1 inch (25.4 mm).

SECTION 21.408 — METHODS OF SAMPLING AND TESTING

The purchaser or authorized representative shall be accorded proper facilities to inspect and sample the units at the place of manufacture from the lots ready for delivery.

Sample and test units in accordance with ASTM C 140.

Total linear drying shrinkage shall be based on tests of concrete masonry units made with the same materials, concrete mix design, manufacturing process and curing method, conducted in accordance with ASTM C 426 and not more than 24 months prior to delivery.

SECTION 21.409 — REJECTION

If the samples tested from a shipment fail to conform to the specified requirements, the manufacturer may sort it, and new specimens shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. If the second set of specimens fails to conform to the specified requirements, the entire lot shall be rejected.

TABLE 21-4-A—MOISTURE CONTENT REQUIREMENTS FOR TYPE I UNITS

LINEAR SHRINKAGE, PERCENT	MOISTURE CONTENT, MAX. PERCENT OF TOTAL ABSORPTION (Average of 3 Units)		
	Humidity Conditions at Jobsite or Point of Use		
	Humid[1]	Intermediate[2]	Arid[3]
0.03 or less	45	40	35
From 0.03 to 0.045	40	35	30
0.045 to 0.065, max.	35	30	25

[1]Average annual relative humidity above 75 percent.
[2]Average annual relative humidity 50 to 75 percent.
[3]Average annual relative humidity less than 50 percent.

TABLE 21-4-B—STRENGTH AND ABSORPTION REQUIREMENTS

COMPRESSIVE STRENGTH, MIN, psi (MPa)		WATER ABSORPTION, MAX, lb./ft. (kg/m) (Average of 3 Units)		
Average Net Area		Weight Classification—Oven-dry Weight of Concrete, lb./ft. (kg/m)		
Average of 3 Units	Individual Unit	Lightweight, Less than 105 (1680)	Medium Weight, 105 to less than 125 (1680-2000)	Normal Weight, 125 (2000) or more
1900 (13.1)	1700 (11.7)	18 (288)	15 (240)	13 (208)

TABLE 21-4-C—MINIMUM THICKNESS OF FACE-SHELLS AND WEBS

NOMINAL WIDTH (W) OF UNIT (inches)	FACE-SHELL THICKNESS (FST) MIN., (inches)[1, 4]	WEB THICKNESS (WT)	
		Webs[1] Min., (inches)	Equivalent Web Thickness, Min., In./Lin. Ft.[2]
× 25.4 for mm			× 83 for mm/lin. m
3 and 4	$^3/_4$	$^3/_4$	$1^5/_8$
6	1	1	$2^1/_4$
8	$1^1/_4$	1	$2^1/_4$
10	$1^3/_8$ $1^1/_4$[3]	$1^1/_8$	$2^1/_2$
12	$1^1/_2$ $1^1/_4$[3]	$1^1/_8$	$2^1/_2$

[1]Average of measurements on three units taken at the thinnest point.
[2]Sum of the measured thickness of all webs in the unit, multiplied by 12 (305 when using metric), and divided by the length of the unit. In the case of open-ended units where the open-ended portion is solid grouted, the length of that open-ended portion shall be deducted from the overall length of the unit.
[3]This face-shell thickness (FST) is applicable where allowable design load is reduced in proportion to the reduction in thicknesses shown, except that allowable design load on solid-grouted units shall not be reduced.
[4]For split-faced units, a maximum of 10 percent of a shipment may have face-shell thicknesses less than those shown, but in no case less than $^3/_4$ inch (19 mm).

UNIFORM BUILDING CODE STANDARD 21-5
NONLOAD-BEARING CONCRETE MASONRY UNITS

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See Section 2102.2, Item 5, *Uniform Building Code*

SECTION 21.501 — SCOPE

This standard covers hollow and solid nonload-bearing concrete masonry units made from portland cement, water, and mineral aggregates with or without the inclusion of other materials. Such units are intended for use in nonload-bearing partitions but under certain conditions may be suitable for use in nonload-bearing exterior walls above grade, where effectively protected from the weather.

SECTION 21.502 — CLASSIFICATION

21.502.1 Weight Classifications. Nonload-bearing concrete masonry units manufactured in accordance with this standard shall conform to one of three weight classifications and two types as follows:

WEIGHT CLASSIFICATION	OVEN-DRY WEIGHT OF CONCRETE lb./cu.ft.
Lightweight	105 (1680 kg/m^3) max.
Medium weight	105 - 125 (1680 - 2000 kg/m^3)
Normal weight	125 (2000 kg/m^3) min.

21.502.2 Types. Nonload-bearing concrete masonry units shall be of two types as follows:

21.502.2.1 Type I, moisture-controlled units. Type I units shall conform to all requirements of this standard, including the requirements of Table 21-5-A.

21.502.2.2 Type II, nonmoisture-controlled units. Type II units shall conform to all requirements of this standard, except the requirements listed in Table 21-5-A.

SECTION 21.503 — MATERIALS

21.503.1 Cementitious Materials. Cementitious materials shall conform to the following applicable standards:

1. Portland Cement—ASTM C 150 modified as follows:

   Limitation on insoluble residue—1.5 percent.
   Limitation on air content of mortar,
   Volume percent—22 percent maximum.
   Limitation on loss on ignition—7 percent maximum.
   Limestone with a minimum 85 percent calcium carbonate ($CaCO_3$) content may be added to the cement, provided the requirements of ASTM C 150 as modified above are met.

2. Blended Cements—ASTM C 595.
3. Hydrated Lime, Type S—UBC Standard 21-13.

21.503.2 Other Constituents. Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, etc., shall be previously established as suitable for use in concrete or shall be shown by test or experience not to be detrimental to the durability of the concrete.

SECTION 21.504 — PHYSICAL REQUIREMENTS

At the time of delivery to the work site, the units shall conform to the strength requirements prescribed in Table 21-5-B.

The moisture content of Type I concrete masonry units at the time of delivery shall conform to the requirements prescribed in Table 21-5-A.

At the time of delivery to the purchaser, the total linear drying of Type II units shall not exceed 0.065 percent.

SECTION 21.505 — DIMENSIONS AND PERMISSIBLE VARIATIONS

Minimum face-shell thickness shall not be less than $^1/_2$ inch (13 mm).

No overall dimension (width, height or length) shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimensions.

NOTE: Standard dimensions of units are the manufacturer's designated dimensions. Nominal dimensions of modular-size units are equal to the standard dimensions plus $^3/_8$ inch (9.5 mm), the thickness of one standard mortar joint. Nominal dimensions of nonmodular size units usually exceed the standard dimensions by $^1/_8$ inch to $^1/_4$ inch (3.2 mm to 6.4 mm).

Variations in thickness of architectural units such as split-faced or slumped units will usually exceed the specified tolerances.

SECTION 21.506 — VISUAL INSPECTION

21.506.1 General. All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the units or impair the strength or permanence of the construction. Units may have minor cracks incidental to the usual method of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery.

21.506.2 Exposed Units. Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks or other imperfections when viewed from 20 feet (6100 mm), except that not more than 5 percent of a shipment may have slight cracks or small chips not larger than 1 inch (25 mm).

21.506.3 Identification. Nonloading concrete masonry units shall be clearly marked in a manner to preclude their use as load-bearing units.

SECTION 21.507 — METHODS OF SAMPLING AND TESTING

The purchaser or authorized representative shall be accorded proper facilities to inspect and sample the units at the place of manufacture from the lots ready for delivery. At least 10 days shall be allowed for the completion of the tests.

Sample and test units in accordance with ASTM C 140 and ASTM C 426 when applicable.

Total linear drying shrinkage shall be based on tests of concrete masonry units made with the same materials, concrete mix design, manufacturing process and curing method, conducted in accordance with ASTM C 426 and not more than 24 months prior to delivery.

SECTION 21.508 — REJECTION

If the shipment fails to conform to the specified requirements, the manufacturer may sort it, and new specimens shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. If the second set of specimens fails to conform to the specified requirements, the entire lot shall be rejected.

TABLE 21-5-A—MOISTURE CONTENT REQUIREMENTS FOR TYPE I UNITS

LINEAR SHRINKAGE, PERCENT	MOISTURE CONTENT, MAX. PERCENT OF TOTAL ABSORPTION (Average of 3 Units)		
	Humidity[1] Conditions at Jobsite or Point of Use		
	Humid	Intermediate	Arid
0.03 or less	45	40	35
From 0.03 to 0.045	40	35	30
0.045 to 0.065, max.	35	30	25

[1]Arid—Average annual relative humidity less than 50 percent.
Intermediate—Average annual relative humidity 50 to 75 percent.
Humid—Average annual relative humidity above 75 percent.

TABLE 21-5-B—STRENGTH REQUIREMENTS

	COMPRESSIVE STRENGTH (Average Net Area) Min., psi
	× 6.89 for kPa
Average of 3 units	600
Individual units	500

UNIFORM BUILDING CODE STANDARD 21-6
IN-PLACE MASONRY SHEAR TESTS

Test Standard of the International Conference of Building Officials

See Appendix Chapter 1, Sections A106.3.3 and A107.2, *Uniform Code for Building Conservation*

SECTION 21.601 — SCOPE

This standard applies when the *Uniform Code for Building Conservation* requires in-place testing of the quality of masonry mortar.

SECTION 21.602 — PREPARATION OF SAMPLE

The bed joints of the outer wythe of the masonry shall be tested in shear by laterally displacing a single brick relative to the adjacent bricks in the same wythe. The head joint opposite the loaded end of the test brick shall be carefully excavated and cleared. The brick adjacent to the loaded end of the test brick shall be carefully removed by sawing or drilling and excavating to provide space for a hydraulic ram and steel loading blocks.

SECTION 21.603 — APPLICATION OF LOAD AND DETERMINATION OF RESULTS

Steel blocks, the size of the end of the brick, shall be used on each end of the ram to distribute the load to the brick. The blocks shall not contact the mortar joints. The load shall be applied horizontally, in the plane of the wythe, until either a crack can be seen or slip occurs. The strength of the mortar shall be calculated by dividing the load at the first cracking or movement of the test brick by the nominal gross area of the sum of the two bed joints.

UNIFORM BUILDING CODE STANDARD 21-7
TESTS OF ANCHORS IN UNREINFORCED MASONRY WALLS

Test Standard of the International Conference of Building Officials

See Appendix Chapter 1, Section A107.3 and A107.4,
Uniform Code for Building Conservation

SECTION 21.701 — SCOPE

Shear and tension anchors in existing masonry construction shall be tested in accordance with this standard when required by the *Uniform Code for Building Conservation*.

SECTION 21.702 — DIRECT TENSION TESTING OF EXISTING ANCHORS AND NEW BOLTS

The test apparatus shall be supported by the masonry wall. The distance between the anchor and the test apparatus support shall not be less than one half the wall thickness for existing anchors and 75 percent of the embedment for new embedded bolts. Existing wall anchors shall be given a preload of 300 pounds (1335 N) prior to establishing a datum for recording elongation. The tension test load reported shall be recorded at $^1/_8$ inch (3.2 mm) relative movement of the existing anchor and the adjacent masonry surface. New embedded tension bolts shall be subject to a direct tension load of not less than 2.5 times the design load but not less than 1,500 pounds (6672 N) for five minutes (10 percent deviation).

SECTION 21.703 — TORQUE TESTING OF NEW BOLTS

Bolts embedded in unreinforced masonry walls shall be tested using a torque-calibrated wrench to the following minimum torques:

$^1/_2$-inch-diameter (13 mm) bolts—40 foot pounds (54.2 N·m)

$^5/_8$-inch-diameter (16 mm) bolts—50 foot pounds (67.8 N·m)

$^3/_4$-inch-diameter (19 mm) bolts—60 foot pounds (81.3 N·m)

SECTION 21.704 — PREQUALIFICATION TEST FOR BOLTS AND OTHER TYPES OF ANCHORS

This section is applicable when it is desired to use tension or shear values for anchors greater than those permitted by Table A-1-E of the *Uniform Code for Building Conservation*. The direct-tension test procedure set forth in Section 21.702 for existing anchors may be used to determine the allowable tension values for new embedded or through bolts, except that no preload is required. Bolts shall be installed in the same manner and using the same materials as will be used in the actual construction. A minimum of five tests for each bolt size and type shall be performed for each class of masonry in which they are proposed to be used. The allowable tension values for such anchors shall be the lesser of the average ultimate load divided by a factor of safety of 5.0 or the average load of which $^1/_8$ inch (3.2 mm) elongation occurs for each size and type of bolt and class of masonry.

Shear bolts may be similarly prequalified. The test procedure shall comply with ASTM E 488-90 or another approved procedure.

The allowable values determined in this manner may exceed those set forth in Table A-1-E of the *Uniform Code for Building Conservation.*

SECTION 21.705 — REPORTS

Results of all tests shall be reported. The report shall include the test results as related to anchor size and type, orientation of loading, details of the anchor installation and embedment, wall thickness, and joist orientation.

UNIFORM BUILDING CODE STANDARD 21-8
POINTING OF UNREINFORCED MASONRY WALLS

Construction Specification of the International Conference of Building Officials

See Appendix Chapter 1, Section A106.3.3.2,
Uniform Code for Building Conservation

SECTION 21.801 — SCOPE

Pointing of deteriorated mortar joints when required by the *Uniform Code for Building Conservation* shall be in accordance with this standard.

SECTION 21.802 — JOINT PREPARATION

The old or deteriorated mortar joint shall be cut out, by means of a toothing chisel or nonimpact power tool, to a uniform depth of $^{3}/_{4}$ inch (19 mm) until sound mortar is reached. Care shall be taken not to damage the brick edges. After cutting is complete, all loose material shall be removed with a brush, air or water stream.

SECTION 21.803 — MORTAR PREPARATION

The mortar mix shall be Type N or Type S proportioned as required by the construction specifications. The pointing mortar shall be prehydrated by first thoroughly mixing all ingredients dry and then mixing again, adding only enough water to produce a damp unworkable mix which will retain its form when pressed into a ball. The mortar shall be kept in a damp condition for one and one-half hours; then sufficient water shall be added to bring it to a consistency that is somewhat drier than conventional masonry mortar.

SECTION 21.804 — PACKING

The joint into which the mortar is to be packed shall be damp but without freestanding water. The mortar shall be tightly packed into the joint in layers not exceeding $^{1}/_{4}$ inch (6.4 mm) in depth until it is filled; then it shall be tooled to a smooth surface to match the original profile.

UNIFORM BUILDING CODE STANDARD 21-9

UNBURNED CLAY MASONRY UNITS AND STANDARD METHODS OF SAMPLING AND TESTING UNBURNED CLAY MASONRY UNITS

Test Standard of the International Conference of Building Officials

See Section 2102.2, Item 6, *Uniform Building Code*

Part I—Unburned Clay Masonry

SECTION 21.901 — SCOPE

This standard covers unburned clay masonry units made from a suitable mixture of soil, clay and stabilizing agent, and intended for use in brick masonry.

SECTION 21.902 — COMPOSITION OF UNITS

21.902.1 Soil. The soil used shall contain not less than 25 percent and not more than 45 percent of material passing a No. 200 mesh (75 μm) sieve. The soil shall contain sufficient clay to bind the particles together, but shall contain not more than 0.2 percent of water-soluble salts.

21.902.2 Stabilizer. The stabilizing agent shall be emulsified asphalt. The stabilizing agent shall be uniformly mixed with the soil in amounts sufficient to provide the required resistance to absorption.

SECTION 21.903 — PHYSICAL REQUIREMENTS

The units shall conform to the physical requirements prescribed in Table 21-1-B of UBC Standard 21-1.

SECTION 21.904 — SHRINKAGE CRACKS

No units shall contain more than three shrinkage cracks, and no shrinkage crack shall exceed 3 inches (76 mm) in length or $^1/_8$ inch (3.2 mm) in width.

Part II—Sampling and Testing of Unburned Clay Masonry Units

SECTION 21.905 — SCOPE

These methods cover procedures for the sampling and testing of unburned clay masonry units for compressive strength, modulus of rupture, absorption and moisture content.

Sampling

SECTION 21.906 — TEST SPECIMENS

For each of the tests prescribed in this standard, five sample units shall be selected at random from each lot of 5,000 units or fraction thereof.

SECTION 21.907 — IDENTIFICATION

Each specimen shall be marked so that it may be identified at any time. Markings shall not cover more than 5 percent of the superficial area of the specimen.

Compressive Strength

SECTION 21.908 — PROCEDURE

Five full-size specimens shall be tested for compressive strength according to the following procedure:

1. Dry the specimens at a temperature of 85°F ± 15°F (29°C ± 9°C) in an atmosphere having a relative humidity of not more than 50 percent. Weigh the specimens at one-day intervals until constant weight is attained.

2. Test the specimens in the position in which the unburned clay masonry unit is designed to be used, and bed on and cap with a felt pad not less than $^1/_8$ inch (3.2 mm) nor more than $^1/_4$ inch (6.4 mm) in thickness.

3. The specimens may be suitably capped with calcined gypsum mortar or the bearing surfaces of the tile may be planed or rubbed smooth and true. When calcined gypsum is used for capping, conduct the test after the capping has set and the specimen has been dried to constant weight in accordance with Item 1 of this section.

4. The loading head shall completely cover the bearing area of the specimen and the applied load shall be transmitted through a spherical bearing block of proper design. The speed of the moving head of the testing machine shall not be more than 0.05 inch (1.27 mm) per minute.

5. Calculate the average compressive strength of the specimens tested and report this as the compressive strength of the block.

Modulus of Rupture

SECTION 21.909 — PROCEDURE

Five full-size specimens shall be tested for modulus of rupture according to the following procedure:

1. Cured specimen shall be positioned on cylindrical supports 2 inches (51 mm) in diameter, located 2 inches (51 mm) from each end, and extending across the full width of the specimen.

2. A cylinder 2 inches (51 mm) in diameter shall be positioned on the specimen midway between and parallel to the cylindrical supports.

3. Load shall be applied to the cylinder at the rate of 500 pounds (2224 N) per minute until failure occurs.

4. Calculate modulus of rupture from the formula $S = \dfrac{3WL}{2Bd^2}$

WHERE:

B = width of specimen.
d = thickness of specimen.
L = distance between supports.
S = modulus of rupture, psi (kPa).
W = load at failure.

Absorption

SECTION 21.910 — PROCEDURE

A 4-inch (102 mm) cube cut from a sample unit shall be tested for absorption according to the following procedure:

1. Dry specimen to a constant weight in a ventilated oven at 212°F to 239°F (100°C to 115°C).

2. Place specimen on a constantly water-saturated porous surface for seven days. Weigh specimen.

3. Calculate absorption as a percentage of the initial dry weight.

Moisture Content

SECTION 21.911 — PROCEDURE

Five representative specimens shall be tested for moisture content according to the following procedure:

1. Obtain weight of each specimen immediately upon receiving.

2. Dry all specimens to constant weight in a ventilated oven at 212°F to 239°F (100°C to 115°C) and obtain dry weight.

3. Calculate moisture content as a percentage of the initial dry weight.

UNIFORM BUILDING CODE STANDARD 21-10
JOINT REINFORCEMENT FOR MASONRY

Specification Standard of the International Conference of Building Officials

See Sections 2102.2; 2104 and 2106.1.12.4, Item 2, *Uniform Building Code*

Part I—Joint Reinforcement for Masonry

SECTION 21.1001 — SCOPE

This standard covers joint reinforcement fabricated from cold-drawn steel wire for reinforcing masonry.

SECTION 21.1002 — DESCRIPTION

Joint reinforcement consists of deformed longitudinal wires welded to cross wires (Figure 21-10-1) in sizes suitable for placing in mortar joints between masonry courses.

SECTION 21.1003 — CONFIGURATION AND SIZE OF LONGITUDINAL AND CROSS WIRES

21.1003.1 General. The distance between longitudinal wires and the configuration of cross wires connecting the longitudinal wires shall conform to the design and the requirements of Figure 21-10-1.

21.1003.2 Longitudinal Wires. The diameter of longitudinal wires shall not be less than 0.148 inch (3.76 mm) or more than one half the mortar joint thickness.

21.1003.3 Cross Wires. The diameter of cross wires shall not be less than (No. 9 gage) 0.148-inch (3.76 mm) diameter nor more than the diameter of the longitudinal wires. Cross wires shall not project beyond the outside longitudinal wires by more than $^1/_8$ inch (3.2 mm).

21.1003.4 Width. The width of joint reinforcement shall be the out-to-out distance between outside longitudinal wires. Variation in the width shall not exceed $^1/_8$ inch (3.2 mm).

21.1003.5 Length. The length of pieces of joint reinforcement shall not vary more than $^1/_2$ inch (13 mm) or 1.0 percent of the specified length, whichever is less.

SECTION 21.1004 — MATERIAL REQUIREMENTS

21.1004.1 Tensile Properties. Wire of the finished product shall meet the following requirements:

Tensile strength, minimum	75,000 psi (517 MPa)
Yield strength, minimum	60,000 psi (414 MPa)
Reduction of area, minimum	30 percent

For wire testing over 100,000 psi (689 MPa), the reduction of area shall not be less than 25 percent.

21.1004.2 Bend Properties. Wire shall not break or crack along the outside diameter of the bend when tested in accordance with Section 21.1008.

21.1004.3 Weld Shear Properties. The least weld shear strength in pounds shall not be less than 25,000 (11.3 Mg) multiplied by the specified area of the smaller wire in square inches.

SECTION 21.1005 — FABRICATION

Wire shall be fabricated and finished in a workmanlike manner, shall be free from injurious imperfections and shall conform to this standard.

The wires shall be assembled by automatic machines or by other suitable mechanical means which will assure accurate spacing and alignment of all members of the finished product.

Longitudinal and cross wires shall be securely connected at every intersection by a process of electric-resistance welding.

Longitudinal wires shall be deformed. One set of four deformations shall occur around the perimeter of the wire at a maximum spacing of 0.7 times the diameter of the wire but not less than eight sets per inch (25.4 mm) of length. The overall length of each deformation within the set shall be such that the summation of gaps between the ends of the deformations shall not exceed 25 percent of the perimeter of the wire. The height or depth of the deformations shall be 0.012 inch (0.305 mm) for $^3/_{16}$ inch (4.76 mm) diameter or larger wire, 0.011 (0.28 mm) for 0.162-inch (4.11 mm) diameter wire and 0.009 inch (0.23 mm) for 0.148-inch (3.76 mm) diameter wire.

SECTION 21.1006 — TENSION TESTS

Tension tests shall be made on individual wires cut from the finished product across the welds.

Tension tests across a weld shall have the welded joint located approximately at the center of the wire being tested.

Tensile strength shall be the average of four test values determined by dividing the maximum test load by the specified cross-sectional area of the wire.

Reduction of area shall be determined by measuring the ruptured section of a specimen which has been tested.

SECTION 21.1007 — WELD SHEAR STRENGTH TESTS

Test specimens shall be obtained from the finished product by cutting a section of wire which includes one weld.

Weld shear strength tests shall be conducted using a fixture of such design as to prevent rotation of the cross wire. The cross wire shall be placed in the anvil of the testing device which is secured in the tensile machine and the load then applied to the longitudinal wire.

Weld shear strength shall be the average test load in pounds of four tests.

SECTION 21.1008 — BEND TESTS

Test specimens shall be obtained from the finished product by cutting a section of wire without welds.

The test specimens shall be bent cold through 180 degrees around a pin, the diameter of which is equal to the diameter of the specimen.

The specimen shall not break nor shall there be visual cracks on the outside diameter of the bend.

SECTION 21.1009 — FREQUENCY OF TESTS

One set of tension tests, weld strength shear tests and bend tests shall be performed for each 2,000,000 lineal feet (610 000 m) of joint reinforcement, but not less than monthly.

SECTION 21.1010 — CORROSION PROTECTION

When corrosion protection of joint reinforcement is provided, it shall be in accordance with one of the following:

21.1010.1 Brite Basic. No coating.

21.1010.2 Mill Galvanized. Zinc coated, by the hot-dipped method, with no minimum thickness of zinc coating. The coating may be applied before fabrication.

21.1010.3 Class I Mill Galvanized. Zinc coated, by the hot-dipped method, with a minimum of 0.40 ounce of zinc per square foot (0.12 kg/m^2) of surface area. The coating may be applied before fabrication.

21.1010.4 Class III Mill Galvanized. Zinc coated, by the hot-dipped method, with a minimum of 0.80 ounce of zinc per square foot (0.24 kg/m^2) of surface area. The coating may be applied before fabrication.

21.1010.5 Hot-dipped Galvanized. Zinc coated, by the hot-dipped method, with a minimum of 1.50 ounces of zinc per square foot (0.45 kg/m^2) of surface area. The coating shall be applied after fabrication.

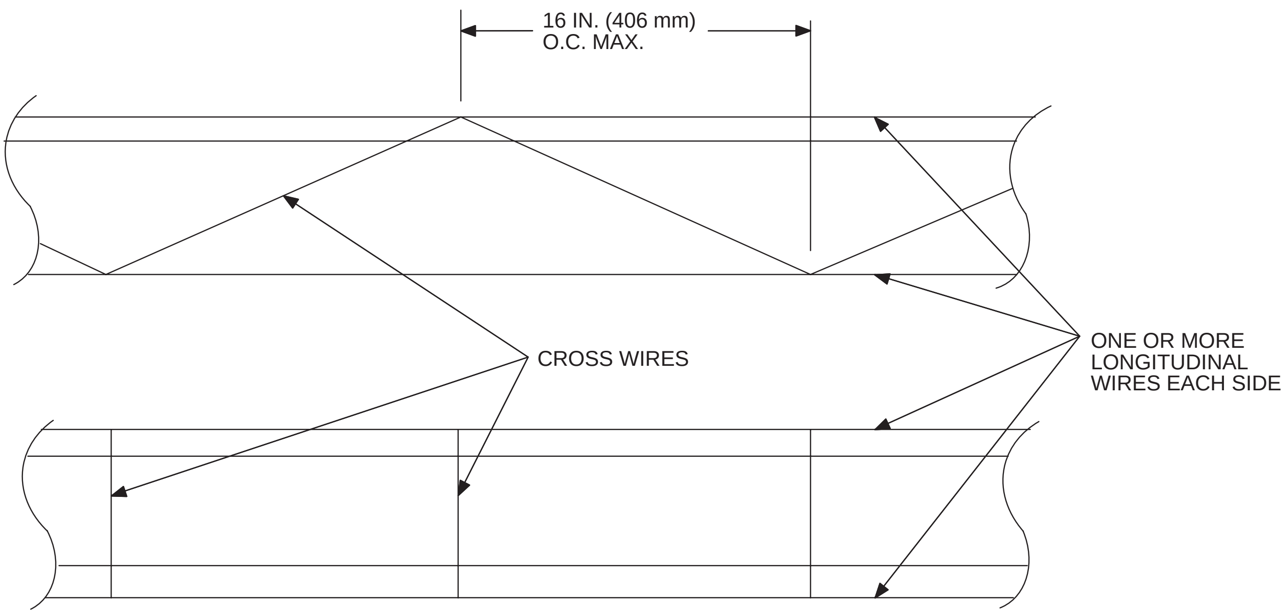

FIGURE 21-10-1—JOINT REINFORCEMENT

Part II—Cold-drawn Steel Wire for Concrete Reinforcement

Based on Standard Specification A 82-90a of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 2101.3; 2104 and 2106.1.12.4, Item 2, *Uniform Building Code*

SECTION 21.1011 — SCOPE

This standard covers cold-drawn steel wire to be used as such or in fabricated form, for the reinforcement as follows:

SIZE NUMBER	NOMINAL DIAMETER (inch) (× 25.4 for mm)	NOMINAL AREA (square inch) (× 645 for mm^2)
W 31	0.628	0.310
W 30	0.618	0.300
W 28	0.597	0.280
W 26	0.575	0.260
W 24	0.553	0.240
W 22	0.529	0.220
W 20	0.505	0.200
W 18	0.479	0.180
W 16	0.451	0.160
W 14	0.422	0.140
W 12	0.391	0.120
W 10	0.357	0.100
W 8	0.319	0.080
W 6	0.276	0.060
W 5.5	0.265	0.055
W 5	0.252	0.050
W 4.5	0.239	0.045
W 4	0.226	0.040
W 3.5	0.211	0.035
W 2.9	0.192	0.029
W 2.5	0.178	0.025
W 2	0.160	0.020
W 1.4	0.134	0.014
W 1.2	0.124	0.012
W 0.5	0.080	0.005

SECTION 21.1012 — PROCESS

The steel shall be made by one or more of the following processes: open hearth, electric furnace or basic oxygen.

The wire shall be cold drawn from rods that have been hot rolled from billets.

Unless otherwise specified, the wire shall be "as cold drawn," except wire smaller than size number W 1.2 for welded fabric, which shall be galvanized at finish size.

SECTION 21.1013 — TENSILE PROPERTIES

The material, except as specified in this section, shall conform to the following tensile property requirements based on nominal area of wire:

Tensile strength, minimum, psi	80,000 (552 MPa)
Yield strength, minimum, psi	70,000 (483 MPa)
Reduction of area, minimum, percent	30

For material testing over 100,000 pounds per square inch (689 MPa) tensile strength, the reduction of area shall not be less than 25 percent.

For material to be used in the fabrication of welded fabric, the following tensile and yield strength properties based on nominal area of wire shall apply:

	SIZE W. 1.2 AND LARGER	SMALLER THAN SIZE W 1.2
Tensile strength, minimum, psi	75,000 (517 MPa)	70,000 (483 MPa)
Yield strength, minimum, psi	65,000 (448 MPa)	56,000 (386 MPa)

The yield strength shall be determined at an extension of 0.005 inch per inch (0.005 mm per mm) of gage length.

The material shall not exhibit a definite yield point as evidenced by a distinct drop of the beam or halt in the gage of the testing machine prior to reaching ultimate tensile load.

SECTION 21.1014 — BENDING PROPERTIES

The bend test specimen shall stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as follows:

SIZE NUMBER OF WIRE	BEND TEST
W 7 and smaller	Bend around a pin, the diameter of which is equal to the diameter of the specimen.
Larger than W 7	Bend around a pin, the diameter of which is equal to twice the diameter of the specimen.

SECTION 21.1015 — TEST SPECIMENS

Tension and bend test specimens shall be of the full section of the wire and shall be obtained from ends of wire coils.

SECTION 21.1016 — NUMBER OF TESTS

One tension test and one bend test shall be made from each 10 tons (89 kN) or less of each size of wire or fraction thereof in a lot, or a total of seven samples, whichever is less. A lot shall consist of all the coils of a single size offered for delivery at the same time.

If any test specimen shows imperfections or develops flaws, it may be discarded and another specimen substituted.

SECTION 21.1017 — PERMISSIBLE VARIATIONS IN WIRE DIAMETER

The permissible variation in the diameter of the wire shall conform to the following:

SIZE NUMBER	PERMISSIBLE VARIATION PLUS AND MINUS (inch) (× 25.4 for mm)
Smaller than W 5	0.003
W 5 to W 12, inclusive	0.004
Over W 12 to W 20, inclusive	0.006
Over W 20	0.008

The difference between the maximum and minimum diameter, as measured on any given cross section of the wire, shall be more than the tolerances shown above for the given wire size.

SECTION 21.1018 — FINISH

The wire shall be free from injurious imperfections and shall have a workmanlike finish with smooth surface.

Galvanized wire shall be completely covered in a workmanlike manner with a zinc coating.

UNIFORM BUILDING CODE STANDARD 21-11
CEMENT, MASONRY

Based on Standard Specification C 91-93 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 2 and Table 21-A, *Uniform Building Code*

SECTION 21.1101 — SCOPE

This standard covers three types of masonry cement for use in masonry mortars.

SECTION 21.1102 — CLASSIFICATIONS

21.1102.1 General. Masonry cement complying with this standard shall be classified as one of the types set forth in this section.

21.1102.2 Type N. Type N cement is for use as the cementitious material in the prep-aration of UBC Standard 21-15 Type N and Type O mortars. It is for use in combination with portland or blended hydraulic cements in the preparation of Type S or Type M mortars.

21.1102.3 Type S. Type S cement is for use as the cementitious material in the preparation of UBC Standard 21-15 Type S mortar.

21.1102.4 Type M. Type M cement is for use as the cementitious material in the preparation of UBC Standard 21-15 Type M mortar.

SECTION 21.1103 — PHYSICAL REQUIREMENTS

Masonry cement shall conform to the requirements set forth in Table 21-11-A for its classifications.

SECTION 21.1104 — PACKAGE LABELING

Masonry cement packages shall carry a statement indicating that the product conforms to requirements of this standard and shall include the brand, name of manufacturer, type of masonry cement and net weight of the package in pounds.

SECTION 21.1105 — CERTIFICATION

Certification shall be submitted upon request of the building official and shall certify compliance with the requirements of this standard.

SECTION 21.1106 — SAMPLING AND TESTING

Every 90 days, each masonry cement producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the masonry cement for compliance with the physical requirements of Table 21-11-A.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

SECTION 21.1107 — TEMPERATURE AND HUMIDITY

The temperature of the air in the vicinity of the mixing slab and dry materials, molds, base plates and mixing bowl shall be maintained between 68°F and 81.5°F (20°C and 27.5°C). The temperature of the mixing water, moist cabinet or moist room, and water in the storage tank shall not vary from 73.4°F (23°C) by more than 3°F (1.7°C).

The relative humidity of the laboratory air shall not be less than 50 percent. The moist cabinet or moist room atmosphere shall have a relative humidity of not less than 90 percent.

The moist cabinet or moist room shall conform to applicable standards.

SECTION 21.1108 — FINENESS

The fineness of the cement shall be determined from the residue on the No. 325 (45 μm) sieve.

SECTION 21.1109 — NORMAL CONSISTENCY

Determine normal consistency by the Vicat apparatus.

SECTION 21.1110 — AUTOCLAVE EXPANSION

The autoclave expansion shall be determined. After molding, store the bars in the moist cabinet or room for 48 hours ± 30 minutes before removal from the molds for measurement and test in the autoclave. Calculate the difference in the lengths of the test specimen before and after autoclaving to the nearest 0.01 percent of the effective gage length and report as the autoclave expansion of the masonry cement.

SECTION 21.1111 — TIME OF SETTING

The time of setting shall be determined by the Gillmore needle method.

SECTION 21.1112 — DENSITY

The density of the masonry cement shall be determined by using kerosene as the liquid. Use the density so determined in the calculation of the air content of the mortars.

SECTION 21.1113 — APPARATUS FOR MORTAR TESTS

The apparatus for mortar tests shall be in accordance with applicable standards.

SECTION 21.1114 — BLENDED SAND

The sand shall be a blend of equal parts by weight of graded standard sand and Standard 20-30 sand.

SECTION 21.1115 — PREPARATION OF MORTAR

21.1115.1 Proportions for Mortar. Mortar for air entrainment, compressive strength and water-retention tests shall be proportioned to contain the weight of cement, in grams, equal to six times the printed bag weight in pounds (13.228 times the printed bag weight in kilograms) and 1,440 grams of sand. The sand shall consist of 720 grams of graded Ottawa sand and 720 grams of Standard 20-30 sand. The quantity of water, measured in milliliters, shall be such as to produce a flow of 110 ± 5 as determined by the flow table.

21.1115.2 Mixing of Mortars. The mortar shall be mixed in accordance with the applicable standards.

21.1115.3 Determination of Flow. The flow shall be determined in accordance with applicable standards.

SECTION 21.1116 — AIR ENTRAINMENT

21.1116.1 Procedure. If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the mass of 400 ml of the mortar.

21.1116.2 Calculation. Calculate the air content of the mortar and report it to the nearest 0.1 percent as follows:

$$D = (W_1 + W_2 + V_w)\,[(W_1/S_1) + (W_2/S_2) + V_w]$$

$$A = 100 - (w_m/4D)$$

WHERE:

A = volume percent of entrained air.

D = density of air-free mortar, g/ml.

S_1 = density of cement, g/ml.

S_2 = density of standard sand, 2.65 g/ml.

V_w = milliliters-grams of water used.

W_m = mass of 400 ml.

W_1 = mass of cement, g.

W_2 = mass of sand, g.

SECTION 21.1117 — COMPRESSIVE STRENGTH

21.1117.1 Test Specimens.

21.1117.1.1 Molding. Immediately after determining the flow and the mass of 400 ml of mortar, return all the mortar to the mixing bowl and remix for 15 seconds at the medium speed. Then mold test specimens in accordance with applicable standards, except that elapsed time for mixing mortar, determining flow, determining air entrainment and starting the molding of cubes shall be within eight minutes.

21.1117.1.2 Storage. Store all test specimens immediately after molding in the molds on plane plates in a moist cabinet or moist room for 48 to 52 hours, in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds and place in the moist cabinet or moist room for five days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of seven days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrodible materials.

21.1117.2 Procedure. Test the cube specimens immediately after their removal from the moist cabinet or moist room for seven-day specimens, and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist cabinet or moist room for seven-day tests, cover these cubes with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, place these cubes in a pan of water at a temperature of 73.4°F ± 3°F (23°C ± 1.7°C), and of sufficient depth to completely immerse each cube until time of testing.

The remainder of the testing procedure shall conform to applicable standards.

SECTION 21.1118 — WATER RETENTION

21.1118.1 Apparatus. The water-retention test shall conform to applicable standards.

21.1118.2 Procedure. Adjust the mercury relief column to maintain a vacuum of 51 ± 3 mm as indicated by the manometer. Seat the perforated dish on the greased gasket or greased rim of the funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum to the funnel and check the apparatus for leaks and to determine that the required vacuum is obtained. Then turn the stopcock to shut off the vacuum from the funnel.

Mix the mortar to a flow of 110 ± 5 percent in accordance with applicable standards. Immediately after making the flow test, return the mortar on the flow table to the mixing bowl and remix the entire batch for 15 seconds at medium speed. Immediately after remixing the mortar, fill the perforated dish with the mortar to slightly above the rim. Tamp the mortar 15 times with the tamper. Apply 10 of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish and with the long axis of the tamping face held at right angles to the radius of the dish. Apply the remaining five tamping strokes at random points distributed over the central area of the dish. The tamping pressure shall be just sufficient to ensure filling of the dish. On completion of the tamping, the top of the mortar will extend slightly above the rim of the dish. Smooth off the mortar by drawing the flat side of the straightedge (with the leading edge slightly raised) across the top of the dish. Then cut off the mortar to a plane surface flush with the rim of the dish by drawing the straightedge with a sawing motion across the top of the dish in two cutting strokes, starting each cut from near the center of the dish. If the mortar is pulled away from the side of the dish during the process of drawing the straightedge across the dish, gently press the mortar back into contact with the side of the dish using the tamper.

Turn the stopcock to apply the vacuum to the funnel. The time elapsed from the start of mixing the cement and water to the time of applying the vacuum shall not exceed eight minutes. After suction for 60 seconds, quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off from the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then, using the bowl scraper, plow and mix the mortar in the dish for 15 seconds. Upon completion of mixing, place the mortar in the flow mold and determine the flow. The entire operation shall be carried out without interruption and as quickly as possible, and shall be completed within an elapsed time of 11 minutes after the start of mixing the cement and water for the first flow determination. Both flow determinations shall be made in accordance with applicable standards.

21.1118.3 Calculation. Calculate the water-retention value for the mortar as follows:

$$\text{Water-retention value} = (A/B) \times 100$$

WHERE:

A = flow after suction.

B = flow immediately after mixing.

TABLE 21-11-A—PHYSICAL REQUIREMENTS

MASONRY CEMENT TYPE	N	S	M
Fineness, residue on a No. 325 (45 μm) sieve, maximum percent	24	24	24
Soundness: Autoclave expansion, maximum, percent	1.0	1.0	1.0
Time of setting, Gilmore method:			
Initial set, minimum, hour	2	$1^1/_2$	$1^1/_2$
Final set, maximum, hour	24	24	24
Compressive strength (average of 3 cubes): Initial compressive strength of mortar cubes, composed of 1 part cement and 3 parts blended sand (half Graded Ottawa sand, and half Standard 20-30 Ottawa sand) by volume, prepared and tested in accordance with this specification shall be equal to or higher than the values specified for the ages indicated below:			
7 days, psi	500 (3445 kPa)	1,300 (8957 kPa)	1,800 (12 402 kPa)
28 days, psi	900 (6201 kPa)	2,100 (14 469 kPa)	2,900 (19 981 kPa)
Air content of mortar:			
Minimum percent by volume	8	8	8
Maximum percent by volume	21	19	19
Water retention, flow after suction, minimum, percent of original flow	70	70	70

UNIFORM BUILDING CODE STANDARD 21-12
QUICKLIME FOR STRUCTURAL PURPOSES

Based on Standard Specification C 5-79 (Reapproved 1992) of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 3, *Uniform Building Code*

SECTION 21.1201 — SCOPE

This standard covers all classes of quicklime, such as crushed lime, granular lime, ground lime, lump lime, pebble lime and pulverized lime, used for structural purposes.

SECTION 21.1202 — GENERAL REQUIREMENTS

Quicklime shall be slaked and aged in accordance with the printed directions of the manufacturer. The resulting lime putty shall be stored until cool.

SECTION 21.1203 — CHEMICAL COMPOSITION

The quicklime shall conform to the following requirements as to chemical composition, calculated to the nonvolatile basis:

	CALCIUM LIME	MAGNESIUM LIME
Calcium oxide, minimum, percent	75	—
Magnesium oxide, minimum, percent	—	20
Calcium and magnesium oxides, minimum, percent	95	95
Silica, alumina, and oxide of iron, maximum, percent	5	5
Carbon dioxide, maximum, percent:		
If sample is taken at the place of manufacture	3	3
If sample is taken at any other place	10	10

SECTION 21.1204 — RESIDUE

The quicklime shall not contain more than 15 percent by weight of residue.

SECTION 21.1205 — QUALITY CONTROL

Every 90 days, each lime producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the lime for compliance with the physical requirements of Section 21.1204.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

UNIFORM BUILDING CODE STANDARD 21-13
HYDRATED LIME FOR MASONRY PURPOSES

Based on Standard Specification C 207-91 (Reapproved 1992) of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 3, *Uniform Building Code*

SECTION 21.1301 — SCOPE

This standard covers four types of hydrated lime. Types N and S are suitable for use in mortar, in the scratch and brown coats of cement plaster, for stucco, and for addition to portland-cement concrete. Types NA and SA are air-entrained hydrated limes that are suitable for use in any of the above uses where the inherent properties of lime and air entrainment are desired. The four types of lime sold under this specification shall be designated as follows:

Type N—Normal hydrated lime for masonry purposes.

Type S—Special hydrated lime for masonry purposes.

Type NA—Normal air-entraining hydrated lime for masonry purposes.

Type SA—Special air-entraining hydrated lime for masonry purposes.

NOTE: Type S, special hydrated lime, and Type SA, special air-entraining hydrated lime, are differentiated from Type N, normal hydrated lime, and Type NA, normal air-entraining hydrated lime, principally by their ability to develop high, early plasticity and higher water retentivity and by a limitation on their unhydrated oxide content.

SECTION 21.1302 — DEFINITION

HYDRATED LIME. The hydrated lime covered by Type N or S in this standard shall contain no additives for the purpose of entraining air. The air content of cement-lime mortars made with Type N or S shall not exceed 7 percent. Types NA and SA shall contain an air-entraining additive as specified by Section 21.1305. The air content of cement-lime mortars made with Type NA or SA shall have a minimum of 7 percent and a maximum of 14 percent.

SECTION 21.1303 — ADDITIONS

Types NA and SA hydrated lime covered by this standard shall contain additives for the purpose of entraining air.

SECTION 21.1304 — MANUFACTURER'S STATEMENT

Where required, the nature, amount and identity of the air-entraining agent used and of any processing addition that may have been used shall be provided, as well as test data showing compliance of such air-entraining addition.

SECTION 21.1305 — CHEMICAL REQUIREMENTS COMPOSITION

Hydrated lime for masonry purposes shall conform to the requirements as to chemical composition set forth in Table 21-13-A.

SECTION 21.1306 — RESIDUE, POPPING AND PITTING

The four types of hydrated lime for masonry purposes shall conform to one of the following requirements:

1. The residue retained on a No. 30 (600 µm) sieve shall not be more than 0.5 percent, or

2. If the residue retained on a No. 30 (600 µm) sieve is over 0.5 percent, the lime shall show no pops and pits when tested.

SECTION 21.1307 — PLASTICITY

The putty made from Type S, special hydrate, or Type SA, special air-entraining hydrate, shall have a plasticity figure of not less than 200 within 30 minutes after mixing with water, when tested.

SECTION 21.1308 — WATER RETENTION

Hydrated lime mortar made with Type N, normal hydrated lime, or Type NA, normal air-entraining hydrated lime, after suction for 60 seconds, shall have a water-retention value of not less than 75 percent when tested in a standard mortar made from the dry hydrate or from putty made from the hydrate which has been soaked for a period of 16 to 24 hours.

Hydrated lime mortar made with Type S, special hydrated lime, or Type SA, special air-entraining hydrated lime, after suction for 60 seconds, shall have a water-retention value of not less than 85 percent when tested in a standard mortar made from the dry hydrate.

SECTION 21.1309 — SPECIAL MARKING

When Type NA or SA air-entraining hydrated lime is delivered in packages, the type under this standard and the words "air-entraining" shall be plainly indicated thereon or, in case of bulk shipments, so indicated on shipping notices.

SECTION 21.1310 — QUALITY CONTROL

Every 90 days, each lime producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the lime for compliance with the physical requirements of Sections 21.1306, 21.1307 and 21.1308.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

TABLE 21-13-A—CHEMICAL REQUIREMENTS

	HYDRATE TYPES			
	N	NA	S	SA
Calcium and magnesium oxides (nonvolatile basis), min. percent	95	95	95	95
Carbon dioxide (as-received basis), max. percent				
If sample is taken at place of manufacture	5	5	5	5
If sample is taken at any other place	7	7	7	7
Unhydrated oxides (as-received basis), max. percent	—	—	8	8

UNIFORM BUILDING CODE STANDARD 21-14
MORTAR CEMENT

Test Standard of the International Conference of Building Officials

See Section 2102.2, Item 2, *Uniform Building Code*

SECTION 21.1401 — SCOPE

This standard covers mortar cement for use in masonry mortars.

SECTION 21.1402 — CLASSIFICATIONS

There are three types of mortar cement:

1. **Type N.** For use as the cementitious material in the preparation of UBC Standard 21-15 Type N and Type O mortars. For use in combination with portland or blended hydraulic cements in the preparation of Type S or Type M mortars.

2. **Type S.** For use as the cementitious material in the preparation of UBC Standard 21-15 Type S mortar.

3. **Type M.** For use as the cementitious material in the preparation of UBC Standard 21-15 Type M mortar.

SECTION 21.1403 — PHYSICAL REQUIREMENTS

Mortar cement shall conform to the requirements set forth in Table 21-14-A for its classifications.

SECTION 21.1404 — CONSTITUENT MATERIALS

Upon request of the building official, the constituent materials shall be provided to the building official and engineer of record.

SECTION 21.1405 — RESTRICTED MATERIALS

Materials used in mortar cement shall conform to the requirements set forth in Table 21-14-B.

SECTION 21.1406 — DELETERIOUS MATERIAL

Materials listed in Table 21-14-C shall not be used in mortar cement.

SECTION 21.1407 — PACKAGE LABELING

Mortar cement packages shall carry a statement indicating that the product conforms to requirements of this standard and shall include the brand, name of manufacturer, type of mortar cement and net weight of the package in pounds.

SECTION 21.1408 — CERTIFICATION

Certification shall be submitted upon request of the building official and shall certify compliance with the requirements of this standard.

SECTION 21.1409 — SAMPLING AND TESTING

Every 90 days, each mortar cement producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the mortar cement for compliance with the physical requirements of Table 21-14-A.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

SECTION 21.1410 — TEMPERATURE AND HUMIDITY

The temperature of the air in the vicinity of the mixing slab and dry materials, molds, base plates and mixing bowl shall be maintained between 68°F and 81.5°F (20°C and 27.5°C). The temperature of the mixing water, moist cabinet or moist room, and water in the storage tank shall not vary from 73.4°F (23°C) by more than 3°F (1.7°C).

The relative humidity of the laboratory air shall not be less than 50 percent. The moist cabinet or moist room atmosphere shall have a relative humidity of not less than 90 percent.

The moist cabinet or moist room shall conform to applicable standards.

SECTION 21.1411 — FINENESS

Determine the residue on the No. 325 (45 μm) sieve.

SECTION 21.1412 — NORMAL CONSISTENCY

Determine normal consistency by the Vicat apparatus.

SECTION 21.1413 — AUTOCLAVE EXPANSION

Determine autoclave expansion. After molding, store bars in the moist cabinet or room for 48 hours, plus or minus 30 minutes, before removal from the molds for measurement and test in the autoclave. Calculate the difference in length of the test specimen before and after autoclaving to the nearest 0.01 percent of the effective gauge length and report as the autoclave expansion of the mortar cement.

SECTION 21.1414 — TIME OF SETTING

Determine the time of setting by the Gillmore needle method.

SECTION 21.1415 — DENSITY

Determine the density of the mortar cement using kerosene as the liquid. Use the density so determined in the calculation of the air content of the mortars.

SECTION 21.1416 — APPARATUS FOR MORTAR TESTS

Apparatus shall be in accordance with applicable standards.

SECTION 21.1417 — BLENDED SAND

The sand shall be a blend of equal parts by weight of graded Ottawa sand and Standard 20-30 Ottawa sand.

SECTION 21.1418 — PREPARATION OF MORTAR

21.1418.1 Proportions for Mortar. Mortar for air entrainment, compressive strength and water-retention tests shall be proportioned to contain the weight of cement, in grams, equal to six times the printed bag weight in pounds (13.228 times the printed bag weight in kilograms) and 1,440 grams of sand. The sand shall consist of 720 grams of graded Ottawa sand and 720 grams of Standard 20-30 sand. The quantity of water, measured in milliliters, shall be such as to produce a flow of 110 ± 5 as determined by the flow table.

21.1418.2 Mixing of Mortars. Mix the mortar in accordance with applicable standards.

21.1418.3 Determination of Flow. Determine the flow in accordance with applicable standards.

SECTION 21.1419 — AIR ENTRAINMENT

21.1419.1 Procedure. If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the weight of 400 cm^3 of mortar.

21.1419.2 Calculation. Calculate the air content of the mortar and report it to the nearest 0.1 percent as follows:

$$D = (W_1 + W_2 + V_w)/[(W_1/S_1) + (W_2/S_2) + V_w]$$

$$A = 100 - (W_m/4D)$$

WHERE:

A = volume percent of entrained air.

D = density of air-free mortar, g/cm^3.

S_1 = density of cement, g/cm^3.

S_2 = density of standard sand, 2.65 g/cm^3.

V_w = milliliters-grams of water used.

W_m = mass of 400 ml of mortar, g.

W_1 = weight of cement, g.

W_2 = weight of sand, g.

SECTION 21.1420 — COMPRESSIVE STRENGTH OF TEST SPECIMENS

21.1420.1 Molding. Immediately after determining the flow and the weight of 400 cm^3 or mortar, return all the mortar to the mixing bowl and remix for 15 seconds at the medium speed. Then mold test specimens in accordance with applicable standards, except that the elapsed time for mixing mortar, determining flow, determining air entrainment and starting the molding of cubes shall be within eight minutes.

21.1420.2 Storage. Store all test specimens immediately after molding in the molds on plane plates in a moist cabinet maintained at a relative humidity of 90 percent or more for 48 to 52 hours in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds and place in the moist cabinet for five days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of seven days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrodible materials.

SECTION 21.1421 — PROCEDURE

Test the cube specimens immediately after their removal from the moist cabinet for seven-day specimens, and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist closet for seven-day tests, cover these cubes with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, place these cubes in a pan of water at a temperature of 73.4°F ± 3°F (23°C ± 1.7°C), and of sufficient depth to completely immerse each cube until time of testing.

The remainder of the testing procedure shall conform to applicable standards.

SECTION 21.1422 — WATER RETENTION

21.1422.1 Water-retention Apparatus. For the water-retention test, and apparatus essentially the same as that shown in Figure 21-14-1 shall be used. This apparatus consists of a water aspirator or other source of vacuum controlled by a mercury-relief column and connected by way of a three-way stopcock to a funnel upon which rests a perforated dish. The perforated dish shall be made of metal not attacked by masonry mortar. The metal in the base of the dish shall have a thickness of 1.7 to 1.9 mm and shall conform to the requirements given in Figure 21-14-1. The bore of the stopcock shall have a 4 mm plus or minus 0.5 mm diameter, and the connecting glass tubing shall have a minimum inside diameter of 4 mm. A mercury manometer, connected as shown in Figure 21-14-1, indicates the vacuum. The contact surface of the funnel and perforated dish shall be plane and shall be lapped to ensure intimate contact. An airtight seal shall be maintained between the funnel and the dish during a test. This shall be accomplished by either of the following procedures: (1) a synthetic (grease-resistant) rubber gasket may be permanently sealed to the top of the funnel, using petrolatum or light grease to ensure a seal between the funnel and dish, or (2) the top of the funnel may be lightly coated with petrolatum or light grease to ensure a seal between the funnel and dish. Care should be taken to ensure that none of the holes in the perforated dish are clogged from the grease. Hardened, very smooth, not rapid filter paper shall be used. It shall be of such diameter that it will lie flat and completely cover the bottom of the dish.

A steel straightedge not less than 8 inches (203 mm) long and not less than $^1/_{16}$ inch (1.6 mm) nor more than $^1/_8$-inch (3.2 mm) thickness shall be used.

Other apparatus required for the water-retention tests shall conform to the applicable requirements of Section 21.1416.

21.1422.2 Procedure. Adjust the mercury-relief column to maintain a vacuum of 50.8 mm as measured on the manometer. Seat the perforated dish on the greased gasket of the funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum to the funnel and check the apparatus for leaks and to determine that the required vacuum is obtained. Then turn the stopcock to shut off the vacuum from the funnel.

Mix the mortar to a flow of 110 plus or minus 5 percent in accordance with applicable standards. Immediately after making the flow test, return the mortar on the flow table to the mixing bowl and remix the entire batch for 15 seconds at medium speed. Immediately after remixing the mortar, fill the perforated dish with the mortar to slightly above the rim. Tamp the mortar 15 times with the tamper. Apply 10 of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish and with the long axis of the tamping face held at right angles to the radius of the dish. Apply the remaining five tamping strokes at random points distributed over the central area of the dish. The tamping pressure shall be just sufficient to ensure filling of the dish. On completion of the tamping, the top of the mortar should extend slightly above the rim of the dish. Smooth off the mortar by drawing the flat side of the straightedge (with the leading edge slightly raised) across the top of the dish. Then cut off the mortar to a plane surface flush with the rim of the dish by drawing the straightedge with a sawing motion across the top of the dish in two cutting strokes, starting each cut from near the center of the dish. If the mortar is pulled away from the side of the dish during the process of drawing the straightedge across the dish, gently press the mortar back into contact with the side of the dish using the tamper.

Turn the stopcock to apply the vacuum to the funnel. The time elapsed from the start of mixing the cement and water to the time of applying the vacuum shall not exceed eight minutes. After suction for 60 seconds, quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off from the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then, using the bowl scraper, in accordance with applicable standards, plow and mix the mortar in the dish for 15 seconds. Upon completion of mixing, place the mortar in the flow mold and determine the flow. The entire operation shall be carried out without interruption and as quickly as possible, and shall be completed within an elapsed time of 11 minutes after the start of mixing the cement and water for the first flow determination. Both flow determinations shall be made in accordance with applicable standards.

21.1422.3 Calculation. Calculate the water-retention value for the mortar as follows:

$$\text{Water-retention value} = (a/b) \times 100$$

WHERE:

a = flow after suction.

b = flow immediately after mixing.

TABLE 21-14-A—PHYSICAL REQUIREMENTS

MORTAR CEMENT TYPE	N	S	M
Fineness, residue on a No. 325 (45 μm) sieve Maximum percent	24	24	24
Autoclave expansion Maximum, percent	1.0	1.0	1.0
Time of setting, Gillmore method: Initial set, minimum, hour Final set, maximum, hour	2 24	$1^1/_2$ 24	$1^1/_2$ 24
Compressive strength[1] 7 days, minimum psi 28 days, minimum psi	500 (3445 kPa) 900 (6201 kPa)	1300 (8957 kPa) 2100 (14 469 kPa)	1800 (12 402 kPa) 2900 (19 981 kPa)
Flexural bond strength[2] 28 days, minimum psi	71 (489 kPa)	104 (717 kPa)	116 (799 kPa)
Air content of mortar Minimum percent by volume Maximum percent by volume	8 16	8 14	8 14
Water retention Minimum, percent	70	70	70

[1]Compressive strength shall be based on the average of three mortar cubes composed of one part mortar cement and three parts blended sand (one half graded Ottawa sand, and one half Standard 20-30 Ottawa sand) by volume and tested in accordance with this standard.

[2]Flexural bond strength shall be determined in accordance with UBC Standard 21-20.

TABLE 21-14-B—RESTRICTED MATERIALS

MATERIAL	MAXIMUM LIMIT (percentage)
Chloride salts	0.06
Carboxylic acids	0.25
Sugars	1.00
Glycols	1.00
Lignin and derivatives	0.50
Stearates	0.50
Fly ash	No limit
Clay (except fireclay)	5.00

TABLE 21-14-C—DELETERIOUS MATERIALS NOT PERMITTED IN MORTAR CEMENT

Epoxy resins and derivatives
Phenols
Asbestos fiber
Fireclays

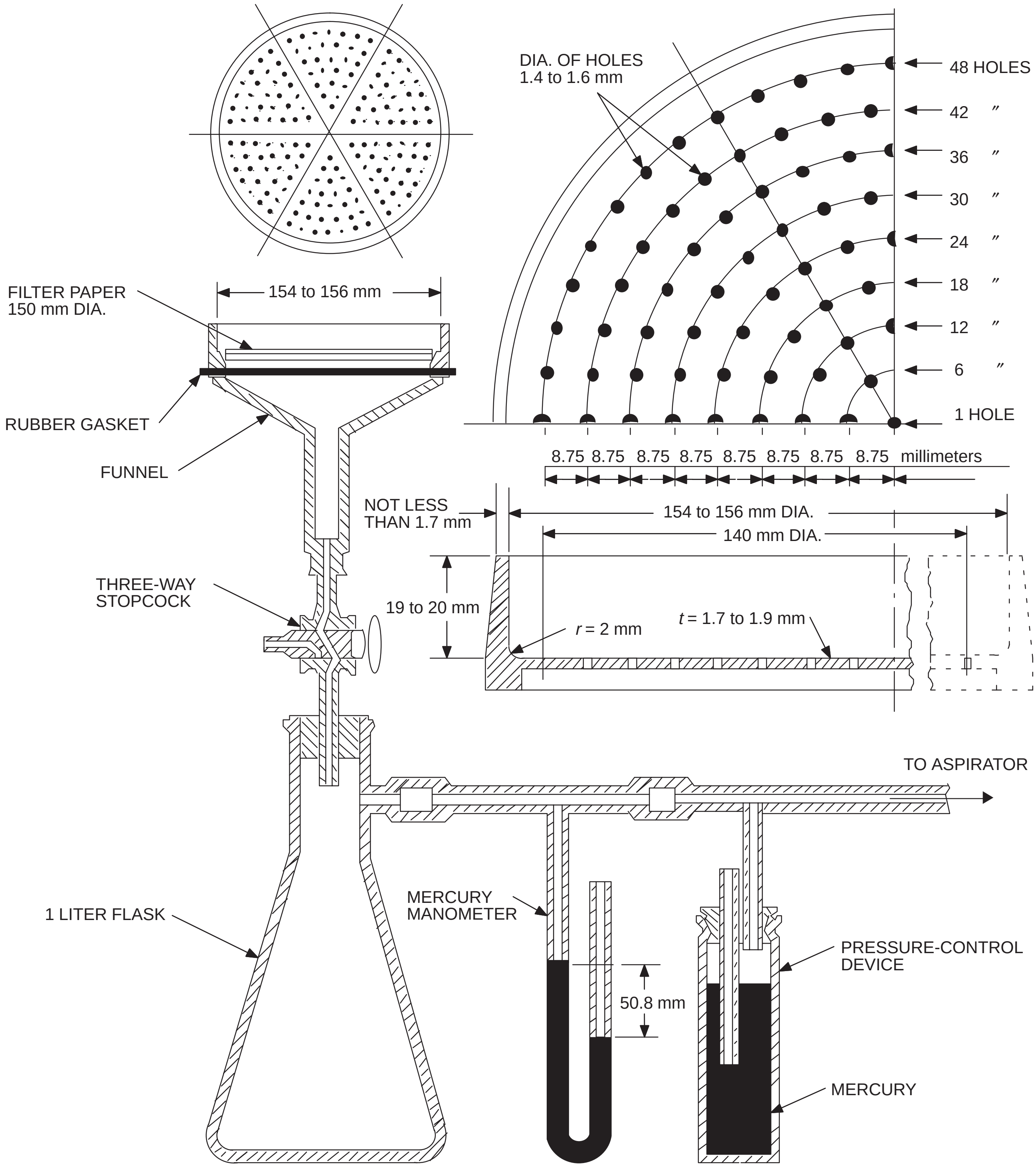

FIGURE 21-14-1—APPARATUS ASSEMBLY FOR THE WATER-RETENTION TEST

UNIFORM BUILDING CODE STANDARD 21-15

MORTAR FOR UNIT MASONRY AND REINFORCED MASONRY OTHER THAN GYPSUM

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See Section 2102.2, Item 8, *Uniform Building Code*

SECTION 21.1501 — SCOPE

These specifications cover the required properties of mortars determined by laboratory tests for use in the construction of reinforced brick masonry structures and unit masonry structures. Two alternative specifications are covered as follows:

21.1501.1 Property specifications. Property specifications are those in which the acceptability of the mortar is based on the properties of the ingredients (materials) and the properties (water retention and compressive strength) of samples of the mortar mixed and tested in the laboratory.

21.1501.2 Proportion specifications. Proportion specifications are those in which the acceptability of the mortar is based on the properties of the ingredients (materials) and a definite composition of the mortar consisting of fixed proportions of these ingredients.

Unless data are presented to show that the mortar meets the requirements of the physical property specifications, the proportion specifications shall govern. For field tests of grout and mortars see UBC Standard 21-16.

Property Specifications

SECTION 21.1502 — MATERIALS

21.1502.1 General. Materials used as ingredients in the mortar shall conform to the requirements specified in the pertinent UBC Standards.

21.1502.2 Cementitious Materials. Cementitious materials shall conform to the following specifications:

1. **Portland cement.** Type I, IA, II, IIA, III or IIIA of ASTM C 150.
2. **Blended hydraulic cement.** Type IS, IS-A, S, S-A, IP, IP-A, I(PM) or I(PM)-A of ASTM C 1157.
3. **Plastic cement.** Plastic cement conforming to the requirements of UBC Standard 25-1 and UBC Standard 21-11, when used in lieu of masonry cement.
4. **Mortar cement.** UBC Standard 21-14.
5. **Masonry cements.** UBC Standard 21-11.
6. **Quicklime.** UBC Standard 21-12.
7. **Hydrated lime.** UBC Standard 21-13.

21.1502.3 Water. Water shall be clean and free of deleterious amounts of acids, alkalies or organic materials.

21.1502.4 Admixtures or Mortar Colors. Admixtures or mortar colors shall not be added to the mortar at the time of mixing unless provided for in the contract specifications and, after the material is so added, the mortar shall conform to the requirements of the property specifications.

Only pure mineral mortar colors shall be used.

21.1502.5 Antifreeze Compounds. No antifreeze liquid, salts or other substances shall be used in the mortar to lower the freezing point.

21.1502.6 Storage of Materials. Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material. Any material that has become unsuitable for good construction shall not be used.

SECTION 21.1503 — MIXING MORTAR

Mortar blended on the jobsite shall be mixed for a minimum period of three minutes, with the amount of water required to produce the desired workability, in a drum-type batch mixer. Factory-dry blended mortar shall be mixed with water in a mechanical mixer until workable but not to exceed 10 minutes.

SECTION 21.1504 — MORTAR

21.1504.1 Mortar for Unit Masonry. Mortar conforming to the proportion specifications shall consist of a mixture of cementitious material and aggregate conforming to the requirements of Section 21.1502, and the measurement and mixing requirements of Section 21.1503, and shall be proportioned within the limits given in Table 21-15-B for each mortar type specified.

21.1504.2 Mortar for Reinforced Masonry. In mortar used for reinforced masonry the following special requirements shall be met: Sufficient water has been added to bring the mixture to a plastic state. The volume of aggregate in mortar shall be at least two and one-fourth times but not more than three times the volume of cementitious materials.

21.1504.3 Aggregate Ratio. The volume of damp, loose aggregate in mortar used in brick masonry shall be not less than two and one-fourth times or more than three times the total separate volumes of cementitious materials used.

21.1504.4 Water Retention. Mortar shall conform to the water retention requirements of Table 21-15-A.

21.1504.5 Air Content. Mortar shall conform to the air content requirements of Table 21-15-A.

SECTION 21.1505 — COMPRESSIVE STRENGTH

The average compressive strength of three 2-inch (51 mm) cubes of mortar (before thinning) shall not be less than the strength given in Table 21-15-A for the mortar type specified.

Proportion Specifications

SECTION 21.1506 — MATERIALS

21.1506.1 General. Materials used as ingredients in the mortar shall conform to the requirements of Section 21.1502 and to the requirements of this section.

21.1506.2 Portland Cement. Portland cement shall conform to the requirements of ASTM C 150.

21.1506.3 Blended Hydraulic Cements. Blended hydraulic cements of Type IS, IS-A, IP, IP-A, I(PM) or I(PM)-A shall conform to the requirements of ASTM C 595, when used in lieu of masonry cement.

21.1506.4 Plastic Cement. Plastic cement conforming to the requirements of UBC Standard 25-1 and UBC Standard 21-11.

21.1506.5 Mortar Cement. Mortar cement shall conform to the requirements of UBC Standard 21-14.

21.1506.6 Masonry Cement. Masonry cement shall conform to the requirements of UBC Standard 21-11.

21.1506.7 Hydrated Lime. Hydrated lime shall conform to either of the two following requirements:

1. The total free (unhydrated) calcium oxide (CaO) and magnesium oxide (MgO) shall not be more than 8 percent by weight (calculated on the as-received basis for hydrates).

2. When the hydrated lime is mixed with portland cement in the proportion set forth in Table 21-15-B, the mixture shall give an autoclave expansion of not more than 0.50 percent.

Hydrated lime intended for use when mixed dry with other mortar ingredients shall have a plasticity figure of not less than 200 when tested 15 minutes after adding water.

21.1506.8 Lime Putty. Lime putty made from either quicklime or hydrated lime shall be soaked for a period sufficient to produce a plasticity figure of not less than 200 and shall conform to either the requirements for limitation on total free oxides of calcium and magnesium or the autoclave test specified for hydrated lime in Section 21.1506.5.

SECTION 21.1507 — MORTAR

Mortar shall consist of a mixture of cementitious materials and aggregate conforming to the requirements specified in Section 21.1504, mixed in one of the proportions shown in Table 21-15-B, to which sufficient water has been added to reduce the mixture to a plastic state.

TABLE 21-15-A—PROPERTY SPECIFICATIONS FOR MORTAR[1]

MORTAR	TYPE	AVERAGE COMPRESSIVE STRENGTH OF 2-INCH (51 mm) CUBES AT 28 DAYS (Min., psi) × 6.89 for kPa	WATER RETENTION (Min., percent)	AIR CONTENT (Max., percent)[2]	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
Cement-lime or mortar cement	M	2,500	75	12	Not less than $2\frac{1}{4}$ and not more than $3\frac{1}{2}$ times the sum of the separate volumes of cementitious materials
	S	1,800	75	12	
	N	750	75	14[3]	
	O	350	75	14[3]	
Masonry cement	M	2,500	75	18	
	S	1,800	75	18	
	N	750	75	18	
	O	350	75	18	

[1]Laboratory-prepared mortar only.

[2]Determined in accordance with applicable standards.

[3]When structural reinforcement is incorporated in cement-lime mortar or mortar-cement mortar, the maximum air content shall be 12 percent.

TABLE 21-15-B—MORTAR PROPORTIONS FOR UNIT MASONRY

MORTAR	TYPE	PROPORTIONS BY VOLUME (CEMENTITIOUS MATERIALS): Portland Cement or Blended Cement[1]	Masonry Cement[2] M	Masonry Cement[2] S	Masonry Cement[2] N	Mortar Cement[3] M	Mortar Cement[3] S	Mortar Cement[3] N	Hydrated Lime or Lime Putty[1]	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
Cement-lime	M	1	—	—	—	—	—	—	$\frac{1}{4}$	Not less than $2\frac{1}{4}$ and not more than 3 times the sum of the separate volumes of cementitious materials
	S	1	—	—	—	—	—	—	over $\frac{1}{4}$ to $\frac{1}{2}$	
	N	1	—	—	—	—	—	—	over $\frac{1}{2}$ to $1\frac{1}{4}$	
	O	1	—	—	—	—	—	—	over $1\frac{1}{4}$ to $2\frac{1}{2}$	
Mortar cement	M	1	—	—	—	—	—	1	—	
	M	—	—	—	—	1	—	—	—	
	S	$\frac{1}{2}$	—	—	—	—	—	1	—	
	S	—	—	—	—	—	1	—	—	
	N	—	—	—	—	—	—	1	—	
Masonry cement	M	1	—	—	1	—	—	—	—	
	M	—	1	—	—	—	—	—	—	
	S	$\frac{1}{2}$	—	—	1	—	—	—	—	
	S	—	—	1	—	—	—	—	—	
	N	—	—	—	1	—	—	—	—	
	O	—	—	—	1	—	—	—	—	

[1]When plastic cement is used in lieu of portland cement, hydrated lime or putty may be added, but not in excess of one tenth of the volume of cement.

[2]Masonry cement conforming to the requirements of UBC Standard 21-11.

[3]Mortar cement conforming to the requirements of UBC Standard 21-14.

UNIFORM BUILDING CODE STANDARD 21-16
FIELD TESTS SPECIMENS FOR MORTAR

Test Standard of the International Conference of Building Officials

See Section 2102.2, Item 8, *Uniform Building Code*

SECTION 21.1601 — FIELD COMPRESSIVE TEST SPECIMEN FOR MORTAR

Spread mortar on the masonry units $^1/_2$ inch to $^5/_8$ inch (13 mm to 16 mm) thick, and allow to stand for one minute, then remove mortar and place in a 2-inch by 4-inch (51 mm by 102 mm) cylinder in two layers, compressing the mortar into the cylinder using a flat-end stick or fingers. Lightly tap mold on opposite sides, level off and immediately cover molds and keep them damp until taken to the laboratory. After 48 hours' set, have the laboratory remove molds and place them in the fog room until tested in damp condition.

SECTION 21.1602 — REQUIREMENTS

Each such mortar test specimen shall exhibit a minimum ultimate compressive strength of 1,500 pounds per square inch (10 304 kPa).

UNIFORM BUILDING CODE STANDARD 21-17

TEST METHOD FOR COMPRESSIVE STRENGTH OF MASONRY PRISMS

See Sections 2102.2, Item 6.4; 2105.3.2; and 2105.3.3, *Uniform Building Code*

SECTION 21.1701 — SCOPE

This standard covers procedures for masonry prism construction, testing and procedures for determining the compressive strength of masonry.

SECTION 21.1702 — CONSTRUCTION OF PRISMS

Prisms shall be constructed on a flat, level base. Masonry units used in the prism shall be representative of the units used in the corresponding construction. Each prism shall be built in an opened moisture-tight bag which is large enough to enclose and seal the completed prism. The orientation of units, where top and bottom cross sections vary due to taper of the cells, or where the architectural surface of either side of the unit varies, shall be the same orientation as used in the corresponding construction. Prisms shall be a single wythe in thickness and laid up in stack bond (see Figure 21-17-1).

The length of masonry prisms may be reduced by saw cutting; however, prisms composed of regular shaped hollow units shall have at least one complete cell with one full-width cross web on either end. Prisms composed of irregular-shaped units shall be cut to obtain as symmetrical a cross section as possible. The minimum length of saw-cut prisms shall be 4 inches (102 mm).

Masonry prisms shall be laid in a full mortar bed (mortar bed both webs and face shells). Mortar shall be representative of that used in the corresponding construction. Mortar joint thickness, the tooling of joints and the method of positioning and aligning units shall be representative of the corresponding construction.

Prisms shall be a minimum of two units in height, but the total height shall not be less than 1.3 times the least actual thickness or more than 5.0 times the least actual thickness. Immediately following the construction of the prism, the moisture-tight bag shall be drawn around the prism and sealed.

Where the corresponding construction is to be solid grouted, prisms shall be solid grouted. Grout shall be representative of that used in the corresponding construction. Grout shall be placed not less than one day nor more than two days following the construction of the prism. Grout consolidation shall be representative of that used in the construction. Additional grout shall be placed in the prism after reconsolidation and settlement due to water loss, but prior to the grout setting. Excess grout shall be screeded off level with the top of the prism. Where open-end units are used, additional masonry units shall be used as forms to confine the grout during placement. Masonry unit forms shall be sufficiently braced to prevent displacement during grouting. Immediately following the grouting operation, the moisture-tight bag shall be drawn around the prism and resealed.

Where the corresponding construction is to be partially grouted, two sets of prisms shall be constructed; one set shall be grouted solid and the other set shall not be grouted.

Where the corresponding construction is of multiwythe composite masonry, masonry prisms representative of each wythe shall be built and tested separately.

Prisms shall be left undisturbed for at least two days after construction.

SECTION 21.1703 — TRANSPORTING MASONRY PRISMS

Prior to transporting each prism, strap or clamp the prism together to prevent damage during handling and transportation. Secure prism to prevent jarring, bouncing or falling over during transporting.

SECTION 21.1704 — CURING

Prisms shall remain sealed in the moisture-tight bag until two days prior to testing; the moisture-tight bag shall then be removed and curing continued in laboratory air maintained at a temperature of 75°F ± 15°F (24°C ± 8°C). Prisms shall be tested at 28 days after constructing the prism or at test age designated.

SECTION 21.1705 — PREPARATION FOR TESTING

21.1705.1 Capping the Prism. Cap top and bottom of the prism prior to testing with sulfur-filled capping or with high-strength gypsum plaster capping (such as “Hydrostone” or “Hyprocal White”). Sulfur-filled capping material shall be 40 to 60 percent by weight sulfur, the remainder being ground fireclay or other suitable inert material passing a No. 100 (150 µm) sieve, with or without a plasticizer. Spread the capping material over a level surface which is plane within 0.003 inch (0.076 mm) in 16 inches (406 mm). Bring the surface to be capped into contact with the capping paste; firmly press down the specimen, holding it so that its axis is at right angles to the capping surfaces. The average thickness of the cap shall not exceed $^1/_8$ inch (3.2 mm). Allow caps to age at least two hours before testing.

21.1705.2 Measurement of the Prism. Measure the length and thickness of the prism to the nearest 0.01 inch (0.25 mm) by averaging three measurements taken at the center and quarter points of the height of the specimen. Measure the height of the prism, including caps, to the nearest 0.1 inch (2.54 mm).

SECTION 21.1706 — TEST PROCEDURE

21.1706.1 Test Apparatus. The test machine shall have an accuracy of plus or minus 1.0 percent over the load range. The upper bearing shall be spherically seated, hardened metal block firmly attached at the center of the upper head of the machine. The center of the sphere shall lie at the center of the surface held in its spherical seat, but shall be free to turn in any direction, and its perimeter shall have at least $^1/_4$-inch (6.4 mm) clearance from the head to allow for specimens whose bearing surfaces are not exactly parallel. The diameter of the bearing surface shall be at least 5 inches (127 mm). A hardened metal bearing block may be used beneath the specimen to minimize wear of the lower platen of the machine. The bearing block surfaces intended for contact with the specimen shall have a hardness not less than 60 HRC (620 HB). These surfaces shall not depart from plane surfaces by more than

0.001 inch (0.0254 mm) in any 6-inch (153 mm) dimension. When the bearing area of the spherical bearing block is not sufficient to cover the area of the specimen, a steel plate with surfaces machined to true planes within plus or minus 0.001 inch (0.0254 mm) in any 6-inch (153 mm) dimension, and with a thickness equal to at least the distance from the edge of the spherical bearings to the most distant corner, shall be placed between the spherical bearing block and the capped specimen.

21.1706.2 Installing the Prism in the Test Machine. Wipe clean the bearing faces of the upper and lower platens or bearing blocks and of the test specimen and place the test specimen on the lower platen or bearing block. Align both centroidal axes of the specimen with the center of thrust of the test machine. As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

21.1706.3 Loading. Apply the load, up one half of the expected minimum load, at any convenient rate, after which adjust the controls of the machine so that the remaining load is applied at a uniform rate in not less than one or more than two minutes.

21.1706.4 Observations. Describe the mode of failure as fully as possible or illustrate crack patterns, spalling, etc., on a sketch, or both. Note whether failure occurred on one side or one end of the prism prior to failure of the opposing side or end of the prism.

SECTION 21.1707 — CALCULATIONS

Calculations of test results shall be as follows:

21.1707.1 Net cross-sectional area. Determine the net cross-sectional area [square inches (mm^2)] of solid grouted prisms by multiplying the average measured width dimension [inches (mm)] by the average measured length dimension [inches (mm)]. The net cross-sectional area of ungrouted prisms shall be taken as the net cross-sectional area of masonry units determined from a representative sample of units.

21.1707.2 Masonry prism strength. Determine the compressive strength of each prism [psi (kPa)] by dividing the maximum compressive load sustained [pounds (N)] by the net cross-sectional area of the prism [square inches ($mm^2 \times 1{,}000{,}000$)].

21.1707.3 Compressive strength of masonry. The compressive strength of masonry [psi (kPa)] for each set of prisms shall be the lesser of the average strength of the prisms in the set, or 1.25 times the least prism strength multiplied by the prism height-to-thickness correction factor from Table 21-17-A. Where a set of grouted and nongrouted prisms are tested, the compressive strength of masonry shall be determined for the grouted set and for the nongrouted set separately. Where a set of prisms is tested for each wythe of a multiwythe wall, the compressive strength of masonry shall be determined for each wythe separately.

SECTION 21.1708 — MASONRY PRISM TEST REPORT

The test report shall include the following:

1. Name of testing laboratory and name of professional engineer responsible for the tests.

2. Designation of each prism tested and description of prism, including width, height and length dimensions, mortar type, grout and masonry unit used in the construction.

3. Age of prism at time of test.

4. Maximum compressive load sustained by each prism, net cross-sectional area of each prism and net area compressive strength of each prism.

5. Test observations for each prism in accordance with Section 21.1706.

6. Compressive strength of masonry for each set of prisms.

TABLE 21-17-A—PRISM HEIGHT-TO-THICKNESS CORRECTION FACTORS

Prisms h/t_p[1]	1.30	1.50	2.00	2.50	3.00	4.00	5.00
Correction factor	0.75	0.86	1.00	1.04	1.07	1.15	1.22

[1]h/t_p—ratio of prism height to least actual lateral dimension of prism.

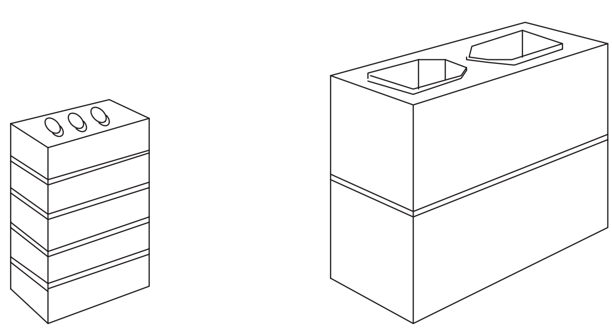


FIGURE 21-17-1—CONSTRUCTION OF PRISMS

UNIFORM BUILDING CODE STANDARD 21-18

METHOD OF SAMPLING AND TESTING GROUT

Based on Standard Method C 1019-89a (93) of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 9; and Table 21-B, *Uniform Building Code*

SECTION 21.1801 — SCOPE

This method covers procedures for both field and laboratory sampling and compression testing of grout used in masonry construction.

SECTION 21.1802 — APPARATUS

21.1802.1 Maximum-Minimum Thermometer.

21.1802.2 Straightedge. A steel straightedge not less than 6 inches (152.4 mm) long and not less than $^{1}/_{16}$ inch (1.6 mm) in thickness.

21.1802.3 Tamping Rod. A nonabsorbent smooth rod, either round or square in cross section nominally $^{5}/_{8}$ inch (15.9 mm) in dimension with ends rounded to hemispherical tips of the same diameter. The rod shall be a minimum length of 12 inches (304.8 mm).

21.1802.4 Wooden Blocks. Wooden squares with side dimensions equal to one-half the desired grout specimen height, within a tolerance of 5 percent, and of sufficient quantity or thickness to yield the desired grout specimen height, as shown in Figures 21-18-1 and 21-18-2.

Wooden blocks shall be soaked in limewater for 24 hours, sealed with varnish or wax, or covered with an impermeable material prior to use.

SECTION 21.1803 — SAMPLING

21.1803.1 Size of Sample. Grout samples to be used for slump and compressive strength tests shall be a minimum of $^{1}/_{2}$ ft.^{3} (0.014 m^3).

21.1803.2 Field Sample. Take grout samples as the grout is being placed into the wall. Field samples may be taken at any time except for the first and last 10 percent of the batch volume.

SECTION 21.1804 — TEST SPECIMEN AND SAMPLE

21.1804.1 Each grout specimen shall be a square prism, nominally 3 inches (76.2 mm) or larger on the sides and twice as high as its width. Dimensional tolerances shall be within 5 percent of the nominal width selected.

21.1804.2 Three specimens constitute one sample.

SECTION 21.1805 — PROCEDURE

21.1805.1 Select a level location where the molds can remain undisturbed for 48 hours.

21.1805.2 Mold Construction.

21.1805.2.1 The mold space should simulate the grout location in the wall. If the grout is placed between two different types of masonry units, both types should be used to construct the mold.

21.1805.2.2 Form a square prism space, nominally 3 inches (76.2 mm) or larger on each side and twice as high as its width, by stacking masonry units of the same type and moisture condition as those being used in the construction. Place wooden blocks, cut to proper size and of the proper thickness or quantity, at the bottom of the space to achieve the necessary height of specimen. Tolerance on space and specimen dimensions shall be within 5 percent of the specimen width. See Figures 21-18-1 and 21-18-2.

21.1805.2.3 Line the masonry surfaces that will be in contact with the grout specimen with a permeable material, such as paper towel, to prevent bond to the masonry units.

21.1805.3 Measure and record the slump of the grout.

21.1805.4 Fill the mold with grout in two layers. Rod each layer 15 times with the tamping rod penetrating $^{1}/_{2}$ inch (12.7 mm) into the lower layer. Distribute the strokes uniformly over the cross section of the mold.

21.1805.5 Level the top surface of the specimen with a straightedge and cover immediately with a damp absorbent material such as cloth or paper towel. Keep the top surface of the sample damp by wetting the absorbent material and do not disturb the specimen for 48 hours.

21.1805.6 Protect the sample from freezing and variations in temperature. Store an indicating maximum-minimum thermometer with the sample and record the maximum and minimum temperatures experienced prior to the time the specimens are placed in the moist room.

21.1805.7 Remove the masonry units after 48 hours. Transport field specimens to the laboratory, keeping the specimens damp and in a protective container.

21.1805.8 Store in a moist room conforming to nationally recognized standards.

21.1805.9 Cap the specimens in accordance with the applicable requirements of UBC Standard 21-17.

21.1805.10 Measure and record the width of each face at midheight. Measure and record the height of each face at midwidth. Measure and record the amount out of plumb at midwidth of each face.

21.1805.11 Test the specimens in a damp condition in accordance with applicable requirements of UBC Standard 21-17.

SECTION 21.1806 — CALCULATIONS

The report shall include the following:

1. Mix design.
2. Slump of the grout.
3. Type and number of units used to form mold for specimens.
4. Description of the specimens—dimensions, amount out of plumb—in percent.

5. Curing history, including maximum and minimum temperatures and age of specimen, when transported to laboratory and when tested.

6. Maximum load and compressive strength of the sample.

7. Description of failure.

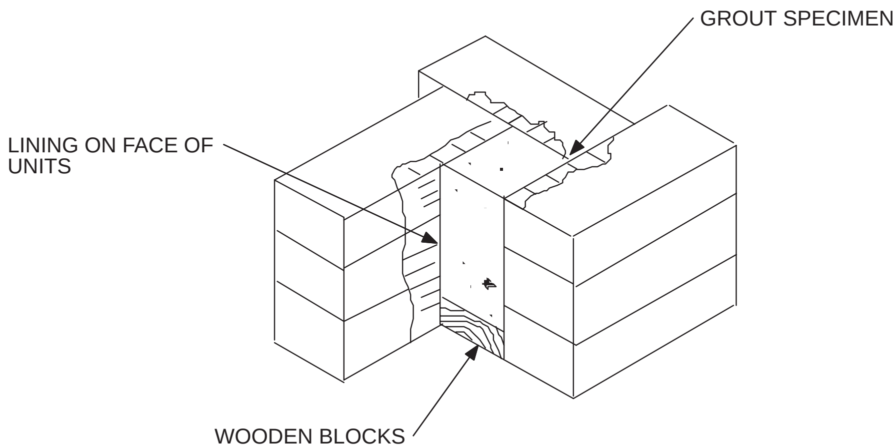


FIGURE 21-18-1—GROUT MOLD [UNITS 6 INCHES (152 mm) OR LESS IN HEIGHT, $2^1/_2$-INCH-HIGH (63.5 mm) BRICK SHOWN]

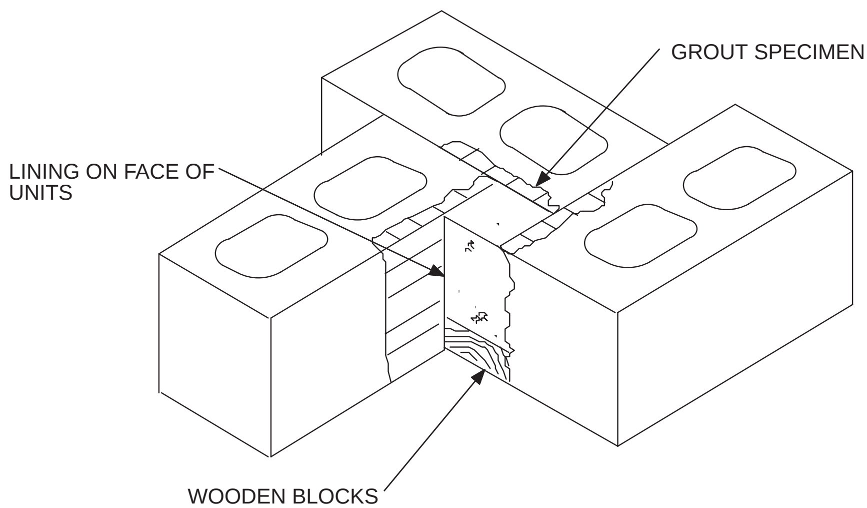


FIGURE 21-18-2—GROUT MOLD [UNITS GREATER THAN 6 INCHES (152 mm) IN HEIGHT, 8-INCH-HIGH (203 mm) CONCRETE MASONRY UNIT SHOWN]

UNIFORM BUILDING CODE STANDARD 21-19
GROUT FOR MASONRY

Based on Standard Specification C 476-91 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 9, *Uniform Building Code*

SECTION 21.1901 — SCOPE

This standard covers grout for use in the construction of reinforced and nonreinforced masonry structures.

SECTION 21.1902 — MATERIALS

Materials used as ingredients in grout shall conform to the following:

21.1902.1 Cementitious Materials. Cementitious materials shall conform to one of the following standards:

A. Portland Cement—Types I, II and III of ASTM C 150.

B. Blended Cement—Type IS, IS(MS) or IP of ASTM C 595.

C. Quicklime—UBC Standard 21-12.

D. Hydrated lime—Type S of UBC Standard 21-13.

21.1902.2 Water. Water shall be clean and potable.

21.1902.3 Admixtures. Additives and admixtures to grout shall not be used unless approved by the building official.

21.1902.4 Antifreeze Compounds. No antifreeze liquids, chloride salts or other substances shall be used in grout.

21.1902.5 Storage of Materials. Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material or moisture. Any material that has become unsuitable for good construction shall not be used.

SECTION 21.1903 — MEASUREMENT OF MATERIALS

The method of measuring materials for the grout used in construction shall be such that the specified proportions of the grout materials can be controlled and accurately maintained.

SECTION 21.1904 — GROUT

Grout shall consist of cementitious material and aggregate that have been mixed thoroughly for a minimum of five minutes in a mechanical mixer with sufficient water to bring the mixture to the desired consistency. The grout proportions and any additives shall be based on laboratory or field experience considering the grout ingredients and the masonry units to be used, or the grout shall be proportioned within the limits given in Table 21-B of this code, or the grout shall have a minimum compressive strength when tested in accordance with UBC Standard 21-18 equal to its specified strength, but not less than 2,000 psi (13 800 kPa).

> **EXCEPTION:** Dry mixes for grout which are blended in the factory and mixed at the jobsite shall be mixed in mechanical mixers until workable, but not to exceed 10 minutes.

UNIFORM BUILDING CODE STANDARD 21-20

STANDARD TEST METHOD FOR FLEXURAL BOND STRENGTH OF MORTAR CEMENT

Test Standard of the International Conference of Building Officials

See Section 2102.2, Item 8, *Uniform Building Code*, and UBC Standard 21-14, Table 21-14-A

SECTION 21.2001 — SCOPE

This method covers the laboratory evaluation of the flexural bond strength of a standardized mortar and a standardized masonry unit.

SECTION 21.2002 — APPARATUS

The test apparatus consists of a metal frame designed to support a prism as shown in Figures 21-20-1 and 21-20-2. The prism support system shall be adjustable to support prisms ranging in height from two to seven masonry units. The upper clamping bracket that is clamped to the top masonry unit of the prism shall not come into contact with the lower clamping bracket during the test. An alignment jig, mortar template, and drop hammer as shown in Figures 21-20-3, 21-20-4 and 21-20-5 are used in the fabrication of prism specimens for testing.

SECTION 21.2003 — MATERIALS

21.2003.1 Masonry units used shall be standard masonry units selected for the purpose of determining the flexural bond strength properties of mortar cement mortars. The standard unit shall be in accordance with the following requirements:

1. Dimensions of units shall be $3^5/_8$ inches (92 mm) wide by $2^1/_4$ inches (57 mm) high by $7^5/_8$ inches (194 mm) long within a tolerance of plus or minus $^1/_8$ inch (3.2 mm) and shall be 100 percent solid.

2. The unit material shall be concrete masonry manufactured with the following material proportions by volume:

   One part portland cement to eight parts aggregate

3. Aggregate used in the manufacture of the unit shall be as follows:

Bulk Specific Gravity	2.6 to 2.7
Gradation	Percent Retained by Weight
$^3/_8$-inch (9.5 mm) sieve	0
No. 4 (4.75 mm) sieve	0 to 5
No. 8 (2.36 mm) sieve	20 to 30
No. 16 (1.18 mm) sieve	20 to 30
No. 30 (600 μm) sieve	15 to 25
No. 50 (300 μm) sieve	5 to 15
No. 100 (150 μm) sieve	5 to 10
Pan	5 to 10

4. Density of the unit shall be 125 to 135 pounds per cubic foot (2000 to 2160 kg/m^3).

5. Unit shall be cured in a 100 percent relative humidity environment at 140°F ± 10°F (60°C ± 5.6°C) at atmospheric pressure for 10 to 20 hours. Additional curing, under covered atmospheric conditions, shall continue for at least 28 days. Unit shall be loose stacked in the cube (separated by a $^1/_4$-inch (6.4 mm) gap) to allow air to circulate during drying.

6. At the time of fabricating the prisms, units shall have a moisture content in the range of 25 percent to 35 percent.

7. Upon delivery units shall be stored in the laboratory at normal temperature and humidity. Units shall not be wetted or surface treated prior to or during prism fabrication.

21.2003.2 Mortar. Mortar shall be prepared in accordance with the following:

1. Mortar proportions shall be in accordance with Table 21-20-A. The aggregate shall consist of a blend of one-half graded Ottawa sand and one-half Standard 20-30 Ottawa sand.

2. Mortar materials shall be mixed in a drum-type batch mixer for five minutes.

3. Determine mortar flow in accordance with applicable standards and adjust water until a flow of 125 ± 5 is achieved.

4. Determine mortar density, air content and initial cone penetration immediately after mixing the mortar in accordance with applicable standards. Mortar shall not be used when cone penetration is less than 80 percent of the initial cone penetration value.

SECTION 21.2004 — TEST SPECIMENS

21.2004.1 Number. Test specimens shall consist of one set of six prisms constructed with the mortar cement mortar. Each prism shall be six units in height.

21.2004.2 Prism Construction. (1) Each prism shall be built in an opened moisture-tight bag which is large enough to enclose and seal the completed prism. Set the first unit on a $^1/_2$-inch (13 mm) plywood pallet in an alignment jig as shown in Figure 21-20-3. (2) Place the mortar template shown in Figure 21-20-4 on the unit such that the mortar bed depth prior to compaction is $^1/_2$ inch (13 mm). Place mortar in template and strike off excess mortar with straight edge. (3) Remove template and immediately place the next unit on the mortar bed in contact with the three alignment bolts for that course using a bulls-eye level to assure uniform initial contact of the unit surface and bed mortar. Carefully position drop hammer apparatus shown in Figure 21-20-5 on top of unit and drop its 4-pound (1.81 kg) weight, round end down, once from a height of 1.5 inches (38 mm). (4) Repeat (2) and (3) until the prisms are complete. (5) Joints shall be cut flush after the prism is completely built. Joints shall not be tooled. (6) One hour, ± 15 minutes after completion of construction, place two masonry units of the type used to construct the prism upon the top course. (7) Identify all prisms using a water-resistant marker. (8) Draw and seal the moisture-tight bag around the prism. (9) All prisms should be cured for 28 days. Two days prior to testing remove the moisture-tight bag and continue curing in the laboratory air, maintained at a temperature of 75°F ± 15°F (23.9°C ± 8.3°C), with a relative humidity between 30 to 70 percent.

SECTION 21.2005 — TEST PROCEDURE

Place the prism vertically in the support frame as shown in Figure 21-20-1 and clamp firmly into a locked position using the lower clamping bracket. Orient the prism so that the face of the joint intended to be subjected to flexural tension is on the same side of the specimen as the clamping screws. The prism shall be positioned at the required elevation that results in a single unit projecting above the lower clamping bracket. A soft bearing material (for example, polystyrene) at least $^1/_2$-inch (13 mm) thick shall be placed between the bottom of the prism and the adjustable prism base support.

Attach the upper clamping bracket to the top unit as shown in Figure 21-20-1. Tighten each clamping bolt using a torque not greater than 20 inch-pounds (2.26 N·m).

Apply the load at a uniform rate so that the total load is applied in not less than one minute or more than three minutes. Measure load to an accuracy of ± 2 percent with maximum error of five pounds (22.2 N).

SECTION 21.2006 — CALCULATIONS

Calculate the modulus of rupture of each mortar joint as follows:

$$f_r \quad \frac{6(PL \times P_1 L_1)}{bd^2} = \frac{(P \times P_1)}{bd}$$

For **SI:** $$f_r \quad \frac{6(PL \times P_1 L_1)}{1000\, bd^2} = \frac{(P \times P_1)}{1000\, bd}$$

WHERE:

b = average width of cross section of failure surface, inches (mm).

d = average thickness of cross section of failure surface, inches (mm).

f_r = modulus of rupture, psi (kPa).

L = distance from center of prism to loading point, inches (mm).

L_1 = distance from center of prism to centroid of loading arm, inches (mm).

P = maximum applied load, pounds (N).

P_1 = weight of loading arm, pounds (N).

The flexural bond strength of mortar shall be determined as the average modulus of rupture of 30 joints minus 1.28 times the standard deviation of the sample which yields a value that a mortar joint's modulus of rupture will equal or exceed nine out of 10 times.

SECTION 21.2007 — REPORT

The report shall include the manufacturer of the mortar cement being evaluated, the source of manufacture, type of mortar cement, date of testing, laboratory name and laboratory personnel.

Report mortar density, air content, flow and cone penetration test data. Report the following data for the mortar cement mortar being evaluated:

PRISM NO.	PRISM WEIGHT (lbs.) (kg)	JOINT NO.	TEST LOAD (lbs.) (N)	MOMENT (in.-lbs.) (N·m)	MODULUS OF RUPTURE			
					f_r psi (kPa)	Mean psi (kPa)	Std. Dev. psi[1] (kPa)	COV %
1	—	1	—	—	—	—	—	—
		2	—	—	—			
		3	—	—	—			
		4	—	—	—			
		5	—	—	—			

[1]Also, report the standard deviation for all six prisms (30 joints).

Report the flexural bond strength (determined in accordance with Section 21.2006) of the mortar cement mortar.

TABLE 21-20-A—MORTAR PROPORTIONS BY VOLUME FOR EVALUATING FLEXURAL BOND

MORTAR	MORTAR CEMENT TYPE	PROPORTIONS	
		Mortar Cement	Aggregate
Type N	N	1	3
Type S	S	1	3
Type M	M	1	3

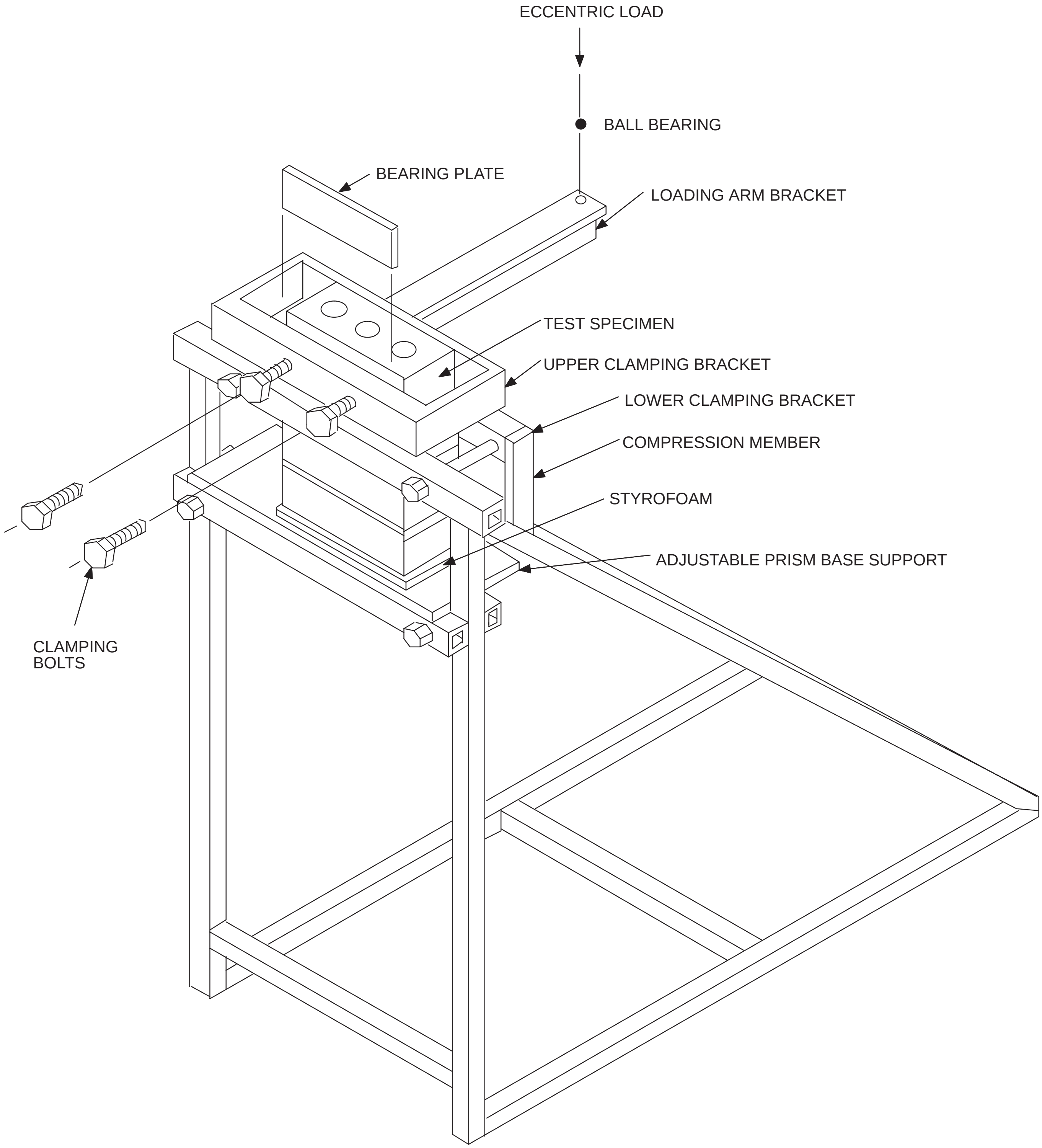
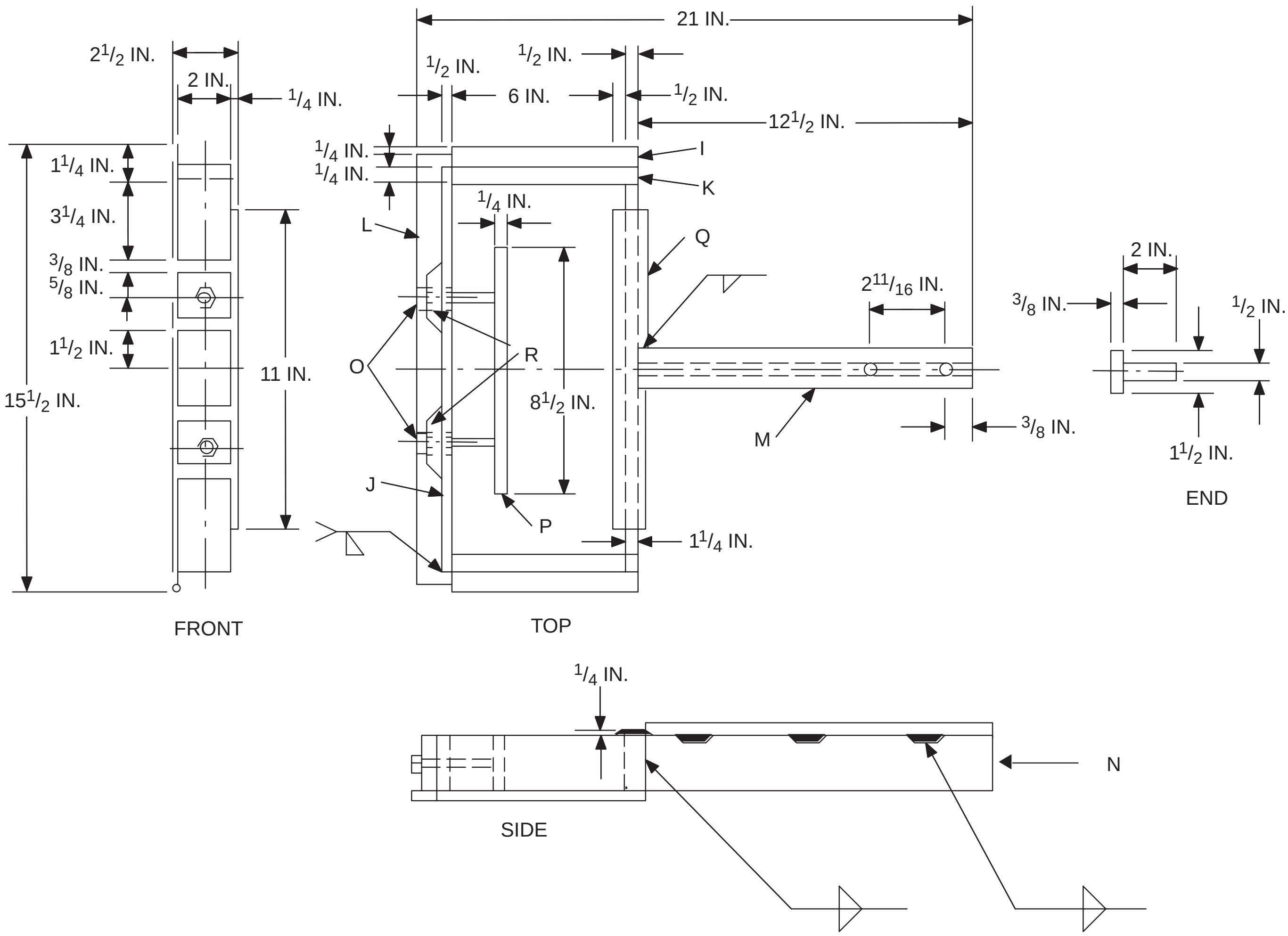
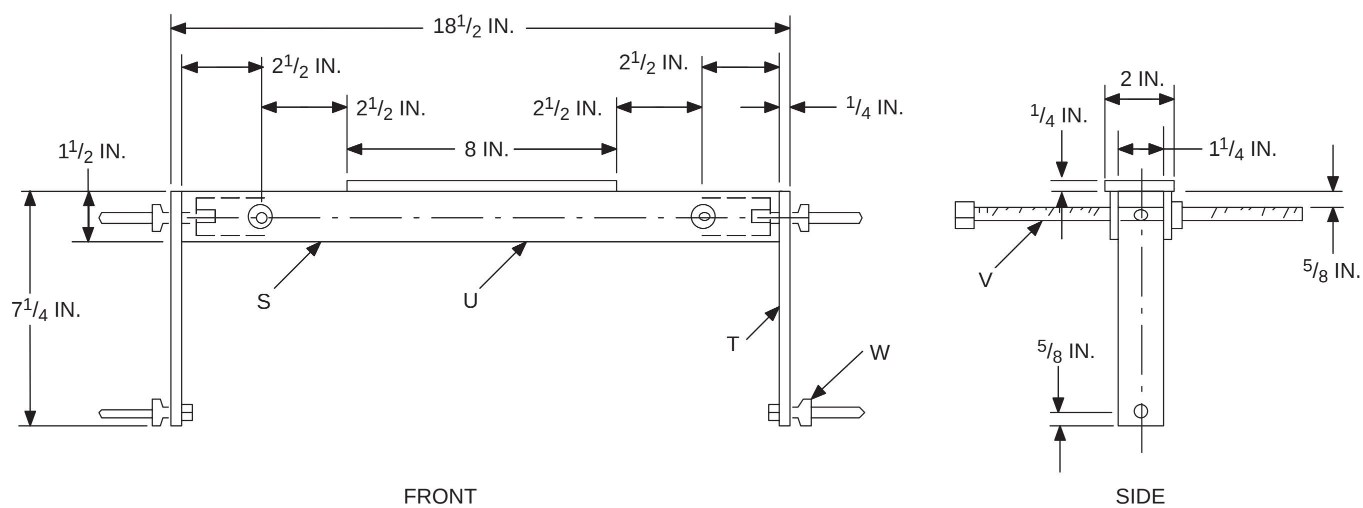


FIGURE 21-20-1—BOND WRENCH TEST APPARATUS



UPPER CLAMPING BRACKET

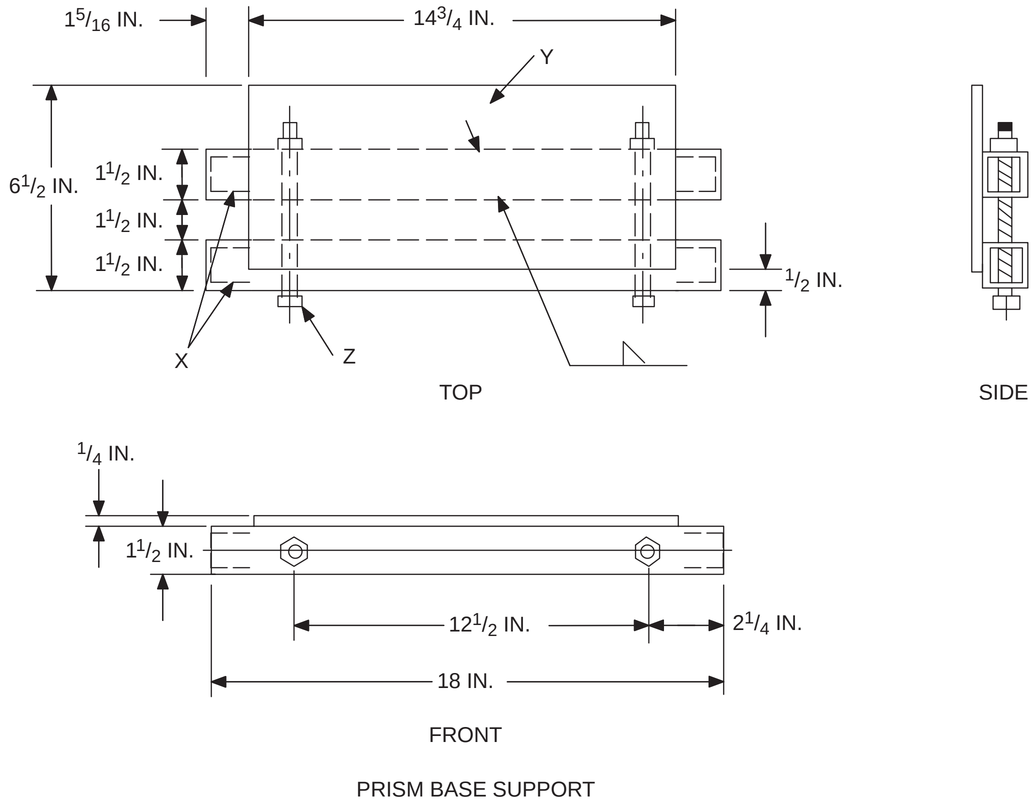


For **SI**: 1 inch = 25.4 mm.

LOWER CLAMPING BRACKET

FIGURE 21-20-2—DETAIL DRAWINGS OF BOND WRENCH

(Continued)



For **SI**: 1 inch = 25.4 mm.

FIGURE 21-20-2—DETAIL DRAWINGS OF BOND WRENCH—(Continued)

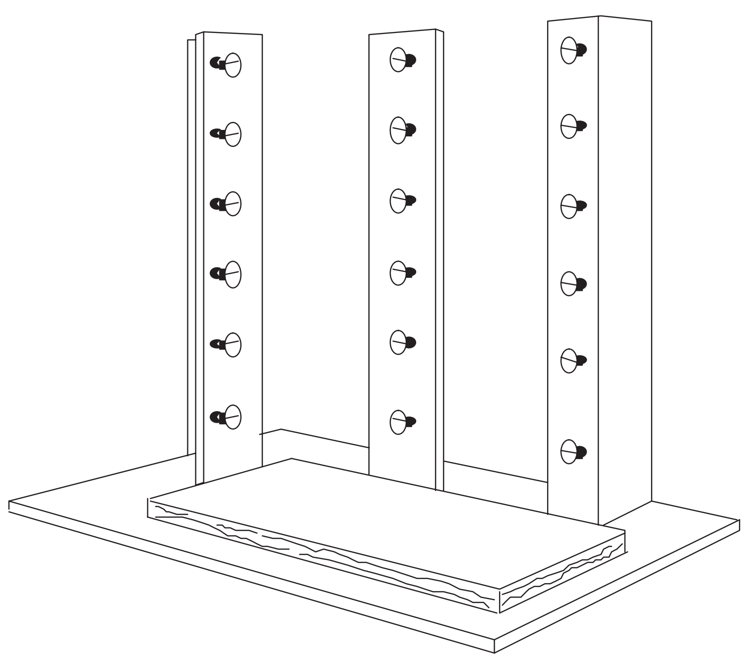


FIGURE 21-20-3—BOND WRENCH JIG WITH PALLET

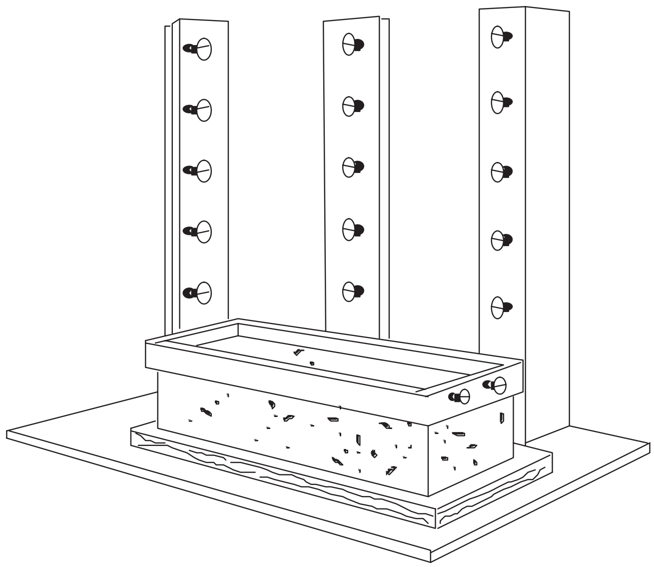


FIGURE 21-20-4—FIRST BRICK WITH MORTAR TEMPLATE

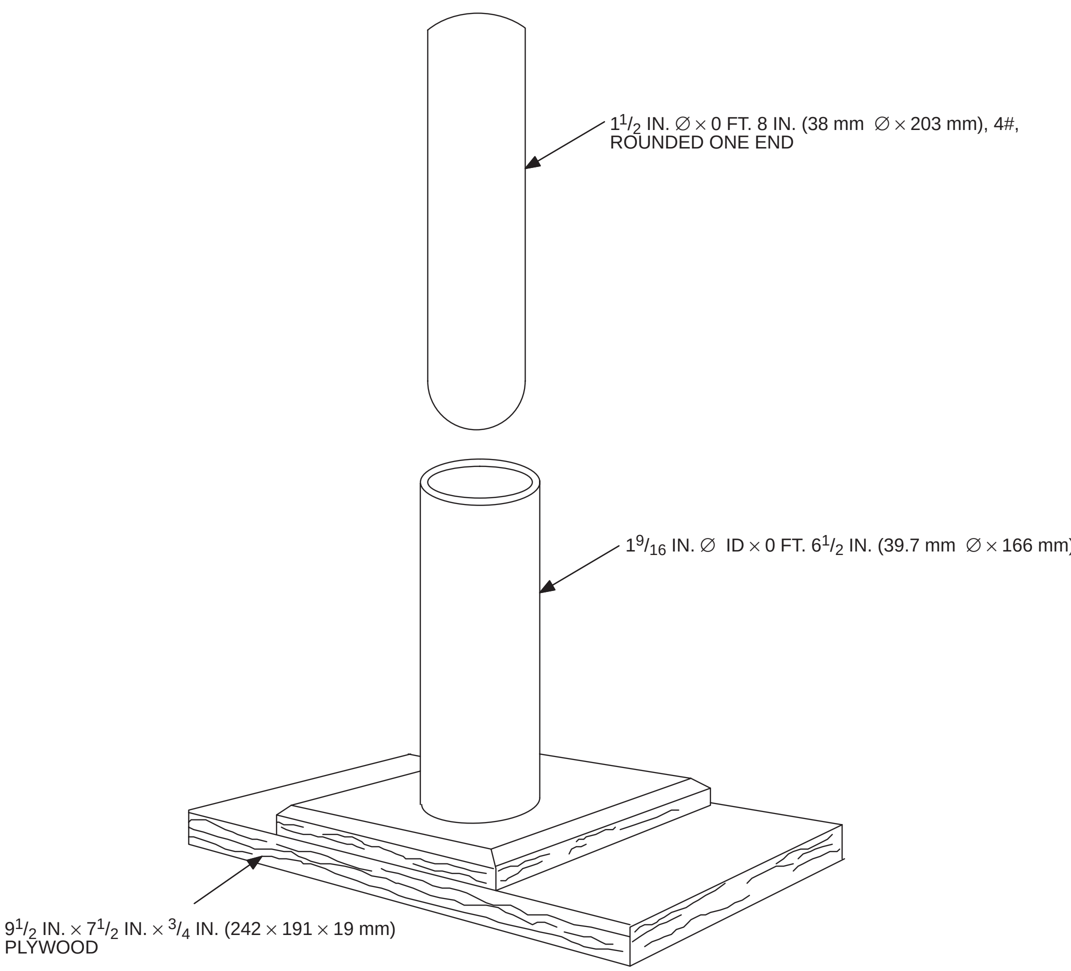


FIGURE 21-20-5—DROP HAMMER AND GUIDE

Chapter 22

STEEL

Division I—GENERAL

SECTION 2201 — SCOPE

The quality, testing and design of steel used structurally in buildings or structures shall conform to the requirements specified in this chapter.

SECTION 2202 — STANDARDS OF QUALITY

The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards. (See Sections 3503 and 3504.)

2202.1 Material Standards.

UBC Standard 22-1, Material Specifications for Structural Steel

2202.2 Design Standards.

ANSI/ASCE 8, Specification for the Design of Cold-formed Stainless Steel Structural Members, American Society of Civil Engineers

2202.3 Connectors.

ASTM A 502, Structural Rivet Steel

SECTION 2203 — MATERIAL IDENTIFICATION

2203.1 General. Steel furnished for structural load-carrying purposes shall be properly identified for conformity to the ordered grade in accordance with approved national standards, the provisions of this chapter and the appropriate UBC standards. Steel which is not readily identifiable as to grade from marking and test records shall be tested to determine conformity to such standards.

2203.2 Structural Steel. structural steel shall be identified by the mill in accordance with approved national standards. When such steel is furnished to a specified minimum yield point greater than 36,000 pounds per square inch (psi) (248 MPa), the American Society for Testing and Materials (ASTM) or other specification designation shall be so indicated.

The fabricator shall maintain identity of the material and shall maintain suitable procedures and records attesting that the specified grade has been furnished in conformity with the applicable standard. The fabricator's identification mark system shall be established and on record prior to fabrication.

When structural steel is furnished to a specified minimum yield point greater than 36,000 psi (248 MPa), the ASTM or other specification designation shall be included near the erection mark on each shipping assembly or important construction component over any shop coat of paint prior to shipment from the fabricator's plant. Pieces of such steel which are to be cut to smaller sizes shall, before cutting, be legibly marked with the fabricator's identification mark on each of the smaller-sized pieces to provide continuity of identification. When subject to fabrication operations, prior to assembling into members, which might obliterate paint marking, such as blast cleaning, galvanizing or heating for forming, such pieces of steel shall be marked by steel die stamping or by a substantial tag firmly attached.

Individual pieces of steel having a minimum specified yield point in excess of 36,000 psi (248 MPa), which are received by the fabricator in a tagged bundle or lift or which have only the top shape or plate in the bundle or lift marked by the mill shall be marked by the fabricator prior to use in accordance with the fabricator's established identification marking system.

2203.3 Cold-formed Carbon and Low-alloy Steel. Cold-formed carbon and low-alloy steel used for structural purposes shall be identified by the mill in accordance with approved national standards. When such steel is furnished to a specified minimum yield point greater than 33,000 psi (228 MPa), the fabricator shall indicate the ASTM or other specification designation, by painting, decal, tagging or other suitable means, on each lift or bundle of fabricated elements.

When cold-formed carbon and low-alloy steel used for structural purposes has a specified yield point equal to or greater than 33,000 psi (228 MPa), which was obtained through additional treatment, the resulting minimum yield point shall be identified in addition to the specification designation.

2203.4 Cold-formed Stainless Steel. Cold-formed stainless steel structural members designed in accordance with recognized standards shall be identified as to grade through mill test reports. (See reference to ANSI/ASCE 8 in Chapter 35.) A certification shall be furnished that the chemical and mechanical properties of the material supplied equals or exceeds that considered in the design. Each lift or bundle of fabricated elements shall be identified by painting, decal, tagging or other suitable means.

2203.5 Open-web Steel Joists. Open-web steel joists and similar fabricated light steel load-carrying members shall be identified in accordance with Division II as to type, size and manufacturer by tagging or other suitable means at the time of manufacture or fabrication. Such identification shall be maintained continuously to the point of their installation in a structure.

SECTION 2204 — DESIGN METHODS

Design shall be by one of the following methods.

2204.1 Load and Resistance Factor Design. Steel design based on load and resistance factor design methods shall resist the factored load combinations of Section 1612.2 in accordance with the applicable requirements of Section 2205. Seismic design of structures, where required, shall comply with Division IV for structures designed in accordance with Division II (LRFD).

2204.2 Allowable Stress Design. Steel design based on allowable stress design methods shall resist the load combinations of Section 1612.3 in accordance with the applicable requirements of Section 2205. Seismic design of structures, where required, shall comply with Division V for structures designed in accordance with Division III (ASD).

SECTION 2205 — DESIGN AND CONSTRUCTION PROVISIONS

2205.1 General. The following design standards shall apply.

2205.2 Structural Steel Construction. The design, fabrication and erection of structural steel shall be in accordance with the requirements of Division II for Load and Resistance Factor Design or Division III for Allowable Stress Design.

2205.3 Seismic Design Provisions for Structural Steel. Steel structural elements that resist seismic forces shall, in addition to the requirements of Section 2205.2, be designed in accordance with Division IV or V.

2205.4 Cold-formed Steel Construction. The design of cold-formed carbon or low-alloy steel structural members shall be in accordance with the requirements of Division VI for Load and Resistance Factor Design or Division VII for Allowable Stress Design.

2205.5 Cold-formed Stainless Steel Construction. The design of cold-formed stainless steel structural members shall be in accordance with approved national standards (see Section 2202).

2205.6 Design Provisions for Stud Wall Systems. Cold-formed steel stud wall systems that serve as part of the lateral-force-resisting system shall, in addition to the requirements of Section 2205.4 or 2205.5, be designed and constructed in accordance with Division VIII.

2205.7 Open-web Steel Joists and Joist Girders. The design, manufacture and use of steel joist, K, LH, and KLH series and joist girders shall be in accordance with Division IX.

2205.8 Steel Storage Racks. Steel storage racks may be designed in accordance with the provisions of Division X, except that in Seismic Zones 3 and 4 wholesale and retail sales areas, the W used in the design of racks over 8 feet (2438 mm) in height shall be equal to the weight of the rack structure and contents with no reductions.

2205.9 Steel Cables. Structural applications of steel cables for buildings shall be in accordance with the provisions of Division XI.

2205.10 Welding. Welding procedures, welder qualification requirements and welding electrodes shall be in accordance with Division II, III, VI or VII and approved national standards.

2205.11 Bolts. The use of high-strength A 325 and A 490 bolts shall be in accordance with the requirements of Divisions II and III.

Anchor bolts shall be set accurately to the pattern and dimensions called for on the plans. The protrusion of the threaded ends through the connected material shall be sufficient to fully engage the threads of the nuts, but shall not be greater than the length of threads on the bolts. Base plate holes for anchor bolts may be oversized as follows:

Bolt Size, inches (mm)	Hole Size, inches (mm)
$^3/_4$ (19.1)	$^5/_{16}$ (7.9) oversized
$^7/_8$ (22.2)	$^5/_{16}$ (7.9) oversized
1 < 2 (25.4 < 50.8)	$^1/_2$ (12.7) oversized
> 2 (> 50.8)	1 (25.4) > bolt diameter

Division II—DESIGN STANDARD FOR LOAD AND RESISTANCE FACTOR DESIGN SPECIFICATION FOR STRUCTURAL STEEL BUILDINGS

American Institute of Steel Construction
(December 1, 1993)

See Section 1602, *Uniform Building Code*

SECTION 2206 — ADOPTION

Except for the modifications as set forth in Section 2207 of this division and the requirements of the *Uniform Building Code*, the design, fabrication, erection and quality control of structural steel shall be in accordance with the *Load and Resistance Factor Design Specifications for Structural Steel Buildings*, December 1, 1993, published by the American Institute of Steel Construction, 1 East Wacker Drive, Suite 3100, Chicago, Illinois 60601, as if set out at length herein.

SECTION 2207 — AMENDMENTS

The *Load and Resistance Factory Design Specification for Structural Steel Buildings* (hereinafter referred to as LRFD) adopted by this division applies to the design, fabrication, erection and quality control of structural steel, except as modified by this section. Where other codes, standards or specifications are referred to in LRFD they are considered as supplemental standards and only considered guidelines subject to the approval of the building official.

1. Appendices. Appendices Sections B Design Requirements; E Columns and Other Compression Members; F Beams and Other Flexural Members; G Plate Girders; H Members Under Combined Forces and Torsion; J Connections, Joints and Fasteners; and K Concentrated Forces, Ponding and Fatigue are specifically adopted and made a part of this division.

2. Glossary. The glossary is specifically adopted and made a part of this division.

3. Sec. A4 is amended as follows:

The nominal loads shall be the minimum design loads required by the code, and the load combinations shall be as specified in Section A4.1, as amended.

4. Sec. A4.1 is amended as follows:

E: earthquake load

Division III—DESIGN STANDARD FOR SPECIFICATION FOR STRUCTURAL STEEL BUILDINGS ALLOWABLE STRESS DESIGN AND PLASTIC DESIGN

SECTION 2208 — ADOPTION

Except for the modifications as set forth in Section 2209 of this division and the requirements of the building code, the design, fabrication and erection of structural steel shall be in accordance with the *Specification for Structural Steel Buildings Allowable Stress Design and Plastic Design,* June 1, 1989, published by the American Institute of Steel Construction, 1 East Wacker Drive, Suite 3100, Chicago, IL 60601, as if set out at length herein. The adoption of the Specification for Structural Steel Buildings Allowable Stress Design and Plastic Design hereinafter referred to as AISC-ASD shall include the following appendices: B5, F7 and K4.

Where other codes, standards or specifications are referred to in this specification, they are to be considered as only an indication of an acceptable method or material that can be used with the approval of the building official.

SECTION 2209 — AMENDMENTS

The following amendments shall be made to the AISC ASD specification, as adopted in Section 2208:

1. Sec. A4. Revise as follows:

The nominal loads shall be the minimum design loads required by the code.

2. Secs. A4.1, A4.4 and A4.5. Delete in their entirety without replacement.

3. Replace Sec. A5.2 as follows:

Wind and Seismic Stresses. Allowable stresses may be increased for load combinations, including wind and seismic, as permitted by Section 1612.3.2. No increase in allowable stress is permitted for Section 1612.3.1 load combinations.

Division IV—SEISMIC PROVISIONS FOR STRUCTURAL STEEL BUILDINGS

Based on Seismic Provisions for Structural Steel Buildings, of the American Institute of Steel Construction (June 15, 1992)

Section 2210 of this division contains the exceptions to the referenced specification. Section 2211 of this division, "Seismic Provisions for Structural Steel Buildings" is reproduced with permission of the publisher.

SECTION 2210 — AMENDMENTS

The American Institute of Steel Construction Specification transcribed in this division applies to the seismic design of structural steel members and is to be used in conjunction with Division II (LRFD). Where other codes, standards or specifications are referred to in this division, they are to be considered as only an indication of an acceptable method or material that can be used with the approval of the building official.

1. Part I, Sec. 1. Revise as follows:

1. SCOPE

These special seismic requirements are to be applied in conjunction with the building code and Chapter 22, Division II (AISC-LRFD) hereinafter referred to as the *Specification.* They are intended for the design and construction of structural steel members and connections in buildings for which the design forces resulting from earthquake motions have been determined on the basis of energy dissipation in the nonlinear range of response.

2. Part I, Sec. 2. Revise as follows:

2. REQUIREMENTS IN SEISMIC ZONES

2.1 Seismic Zone 0 and 1 and Zone 2 (I = 1.0).

Buildings in Seismic Zones 0 and 1 and buildings in Seismic Zone 2 having an importance factor equal to 1.0 shall be designed in accordance with solely the *Specification* or in accordance with the *Specification* and these provisions.

2.2 Seismic Zone 2 (I > 1.0).

Buildings in Seismic Zone 2 having an importance factor I greater than 1.0 shall be designed in accordance with the *Specification* as modified by the additional provisions of this section.

2.2.a. Steel used in seismic-resisting systems shall be limited by the provisions of Section 5.

2.2.b. Columns in seismic-resisting systems shall be designed in accordance with Section 6.

2.2.c. Ordinary Moment Frames (OMF) shall be designed in accordance with the provisions of Section 7.

2.2.d. Special Moment Frames (SMF) are required to conform only to the requirements of Sections 8.2, 8.7 and 8.8.

2.2.e. Braced framed systems shall conform to the requirements of Section 9 or 10 when used alone or in combination with the moment frames of the seismic-resisting system.

2.3 Seismic Zones 3 and 4.

Buildings in Seismic Zones 3 and 4 shall be designed in accordance with the *Specification* as modified by the additional provisions of this section.

2.3.a. Steel used in seismic-resisting systems shall be limited by the provisions of Section 5.

2.3.b. Columns in seismic-resisting systems shall be designed in accordance with Section 6.

2.3.c. Ordinary Moment Frames (OMF) shall be designed in accordance with the provisions of Section 7.

2.3.d. Special Moment Frames (SMF) shall be designed in accordance with the provisions of Section 8.

2.3.e. Braced framed systems shall conform to the requirements of Section 9 (CBF) or 10 (EBF) when used alone or in combination with the moment frames of the seismic-resisting system.

The use of K-bracing systems shall not be permitted as part of the seismic resisting system except as permitted by Section 9.5 (Low Buildings).

2.3.f. A quality assurance plan shall be submitted to the regulatory agency for the seismic-force-resisting system of the building.

3. Part I, Sec. 3. Revise as follows:

3. LOADS, LOAD COMBINATIONS AND NOMINAL STRENGTHS

3.1 Loads and Load Combinations

The required strength of the structure and its elements shall be determined from the appropriate critical combination of factored loads, as determined by the load combinations in accordance with Section 1612.2. Wherever load combinations 3-1 through 3-6 are used in these provisions, they shall be taken as combinations 12-1 through 12-6 in Section 1612.2.1 of this code.

Orthogonal earthquake effects shall be included in the analysis unless noted specifically otherwise in Chapter 16.

Where required by these provisions, an amplified horizontal earthquake load of Ω_o as defined in Section 1630.3.1 shall be applied in load combinations 3-7 through 3-8 below.

The additional load combinations using the amplified horizontal earthquake are:

$$1.2\ D + f_1 L + \Omega_o\ E$$

$$0.9\ D \pm \Omega_o\ E$$

WHERE:

f_1 = 1.0 for floors in places of public assembly, for live loads in excess of 100 pounds per square foot (4.79 kN/m^2), and for garage live load.

= 0.5 for other live loads.

Where the amplified load is required, orthogonal effects are not required to be included.

3.2 Nominal Strengths

The nominal strengths shall be as provided in the *Specification.*

4. Sec. 5. Modify the second sentence by adding A 913 at the end of the sentence.

5. Sec. 6.1. Revise as follows:

6.1 Column Strength

When $P_u/\phi P_n > 0.5$, columns in seismic resisting frames, in addition to complying with the *Specification,* shall be limited by the following requirements.

6.1.a. The required axial compression strength shall be determined from Load Combination 3-7.

6.1.b. The required axial tension strength shall be determined from Load Combination 3-8.

6.1.c. The axial load combinations 3-7 and 3-8 are not required to exceed either of the following:

1. The maximum loads transferred to the column, considering 1.25 times the design strength of the connecting beams or brace elements of the structure.

2. The limit as determined by the foundation capacity to resist overturning uplift.

6. Part I, Sec. 6.2.a. Delete.

7. Sec. 7.2.c.2. Revise as follows:

2. The connections have been demonstrated by cyclic tests to have adequate rotation capacity at a design story drift Δ_m, as defined in Section 1630.9.

8. Part I, Sec. 8. Revise as follows:

8.2.c. Connection Strength. Connection configurations utilizing welds or high-strength bolts shall demonstrate, by approved cyclic testing results or calculation, the ability to sustain inelastic rotation and to develop the strength criteria in Section 8.2.a considering the expected value of yield strength and strain hardening.

8.2.d. Delete.

Sec. 8.4.b. Add the following to the end of the section:

The outside wall width thickness ratio of rectangular tubes used for columns shall not exceed $110/\sqrt{F_y}$ (For **SI:** $0.65\sqrt{E/F_y}$), unless otherwise stiffened.

Sec. 8.7.b.1. Revise as follows:

1. The required column strength shall be determined as the lesser of:

a. The loads resulting from the application of Load Combination No. 12.5 in Section 1612.2.1 except $\Omega_o\ E$ shall be substituted for *E*, or

b. 125 percent of the frame design strength based on either beam or panel zone design strengths.

8.9 Add section as follows:

8.9 Moment Frame Drift Calculations.

Moment frame drift calculations shall include bending and shear contributions from the clear girder and column spans, column axial deformation and the rotation and distortion of the panel zone.

8.9.a. Drift calculations may be based on column and girder center lines where either of the following conditions is met:

1. Where it can be demonstrated that drift so computed for frames of similar configuration is typically within 15 percent of that determined above, or

2. The nominal panel zone strength is equal to or greater than 0.8 ΣM_p of girders framing into the column flanges at the connection.

8.9.b. Column axial deformations may be neglected if they contribute less than 10 percent to the total drift.

9. Part I, Sec. 10.5. Add the following to the end of the section:

Intermediate bracing shall be provided at the top and bottom flanges of the link at intervals not exceeding $76/\sqrt{F_y}$ times the beam flange width. Such intermediate bracing shall have a design strength of 1.0 percent of the link flange nominal strength computed as $F_y b_f t_f$.

10. Part I. Add new requirements for Special Concentrically Braced Frames Requirements for Special Concentrically Braced Frames (SCBF) in Section 12:

Special CBFs shall be designed in accordance with the requirements of Section 9 except as modified herein. The following modifications shall apply to SCBFs and shall not modify the requirements for ordinary CBFs in Section 9.

a. Sec. 9.2.a. Revise as follows:

Slenderness: Bracing members shall have an $L/r < 1,000/\sqrt{F_y}$ (For **SI:** $5.87\sqrt{E/F_y}$).

b. Sec. 9.2.b. Revise as follows:

9.2.b. Compressive Design Strength. The design strength of a bracing member in axial compression shall not exceed $\phi_c P_n$.

c. Sec. 9.2.d. Revise as follows:

9.2.d. Width-thickness Ratio. Width-thickness ratios of stiffened and unstiffened compression elements of braces shall comply with Section B5 of the *Specification.* Braces shall be compact (i.e., $\lambda < \lambda p$). The width-thickness ratio of angle sections shall not exceed $52/\sqrt{F_y}$. Circular sections shall have an outside diameter to wall thickness ratio not exceeding $1,300/\sqrt{F_y}$; rectangular tubes shall have an outside wall width-thickness ratio not exceeding $100/\sqrt{F_y}$ unless the circular section or tube walls are stiffened.

d. Sec. 9.2.e. Revise as follows:

9.2.e. Built-up Member Stitches. For all built-up braces, the spacing of stitches shall be uniform and not less than two stitches shall be used:

1. For a brace in which stitches can be subjected to postbuckling shear, the spacing of the stitches shall be such that the slenderness ratio, *L/r*, of individual elements between the stitches does not exceed 0.4 times the governing slenderness ratio of the built-up member. The total shear strength of the stitches shall be at least equal to the tensile strength of each element. Bolted stitches shall not be located within the middle one-fourth of the clear brace length.
2. For braces that can buckle without causing shear in the stitches, the spacing of the stitches shall be such that the slenderness ratio, *L/r*, of the individual elements between the stitches does not exceed 0.75 times the governing slenderness ratio of the built-up member.

e. Sec. 9.4.a. Revise as follows:

9.4.a. V and Inverted V Type Bracing. V braced and inverted V braced frames shall comply with the following:

1. A beam intersected by braces shall be continuous between columns.
2. A beam intersected by braces shall be capable of supporting all tributary dead and live loads assuming the bracing is not present.
3. A beam intersected by braces shall be capable of resisting the combination of load effects caused by the application of the load combinations in Section 2213.5.1, Items 1 and 2,

except that the term Q_b shall be substituted for the term $3 (R_w/8)P_E$ where Q_b = the maximum unbalanced load effect applied to the beam by the braces. This load effect shall be permitted to be calculated using a minimum P_y for the brace in tension and a maximum $0.3 \phi_c P_n$ for the brace in compression.

4. The top and bottom flanges of the beam at the point of intersection of V braces shall be designed to support a lateral force equal to 1.5 percent of the nominal beam flange strength, $F_y b_f t_f$.

f. Sec. 9.4.b. Delete.

g. Sec. 9.5. Delete and substitute as follows:

9.5 Column.

9.5.a. Compactness. Columns used in SCBFs shall be compact according to Section B5 of the *Specification.* The outside wall width-thickness ratio of rectangular tube used for columns shall not exceed $110/\sqrt{F_y}$ unless otherwise stiffened.

9.5.b. Splices. In addition to meeting the requirements of Section 6.2, column splices in SBCFs also shall be designed to develop the nominal shear strength and 50 percent of the nominal moment strength of the section. Splices shall not be located in the middle one-third of the column clear height.

11. Sec. 10.2.g. Revise as follows:

The link rotation angle is the plastic angle between the link and the beam outside of the link determined at a design story drift, Δ_m, as defined in Section 1630.9.

12. Part II. Delete.

SECTION 2211 — ADOPTION

Seismic Provisions for Structural Steel Buildings
June 15, 1992

2211.1 Table of Contents.

2211.2 Symbols.

The section numbers in parentheses after the definition of a symbol refers to the section where the symbol is first used.

A_e Effective net area, in.^{2} (9)
A_f Flange area of member, in.^{2} (6)
A_g Gross area, in.^{2} (8)
A_{st} Area of link stiffener, in.^{2} (10)
A_v Seismic coefficient representing the effective peak velocity-related acceleration. (2)
A_w Effective area of weld, in.^{2} (6)
A_w Link web area, in.^{2} (10)
C_s Response factor related to the fundamental period of the building. (3)
D Dead load due to the self-weight of the structure and the permanent elements on the structure, kips. (3)
E Earthquake load. (3)
F_{BM} Nominal strength of the base material to be welded, ksi. (6)
F_{EXX} Classification strength of weld metal, ksi. (6)
F_w Nominal strength of the weld electrode material, ksi. (6)
F_y Specified minimum yield strength of the type of steel being used, ksi. (8)
F_{yb} F_y of a beam, ksi. (8)
F_{yc} F_y of a column, ksi. (6)
H Average story height above and below a beam-to-column connection, in. (8)
L Live load due to occupancy and moveable equipment, kips. (3)
L Unbraced length of compression or bracing member, in. (8)
L_r Roof live load, kips. (3)
M_n Nominal moment strength of a member or joint, kip-in. (8)
M_p Plastic bending moment, kip-in. (8)
M_{pa} Plastic bending moment modified by axial load ratio, kip-in. (10)
M_u Required flexural strength on a member or joint, kip-in. (8)
P_D Required axial strength on a column resulting from application of dead load, D, kips. (6)
P_E Required axial strength on a column resulting from application of the specified earthquake load, E, kips.
P_L Required axial strength on a column resulting from application of live load, L, kips. (6)
P_u Required axial strength on a column or a link, kips. (10)
P_n Nominal axial strength of a column, kips. (6)
P_u* Required axial strength on a brace, kips. (9)
P_{uc} Required axial strength on a column based on load combination with seismic loads, kips. (8)
P_y Nominal yield axial strength of a member = F_yA_g, kips. (10)
R Response modification factor. (3)
R' Load due to initial rainwater or ice exclusive of the ponding contribution, kips. (Symbol R is used in the *Specification*). (3)
R_n Nominal strength of a member. (8)
S Snow load, kips. (3)
V Base shear due to earthquake load, kips. (3)
V_n Nominal shear strength of a member, kips. (8)
V_u Required shear strength on a member, kips. (8)
V_p Nominal shear strength of an active link, kips. (10)
V_{pa} Nominal shear strength of an active link modified by the axial load magnitude, kips. (10)
W Wind load, kips. (3)
W_g Total weight of the building, kips. (3)
Z_b Plastic section modulus of a beam, in.^{3} (8)
Z_c Plastic section modulus of a column, in.^{3} (8)
b Width of compression element, in. (Table 8-1)
b_f Flange width, in. (8)
b_{cf} Column flange width, in. (8)
d_b Overall beam depth, in. (8)
d_c Overall column depth, in. (8)
d_z Overall panel zone depth between continuity plates, in. (8)
e EBF link length, in. (10)
h Assumed web depth for stability, in. (Table 8-1)
r Governing radius of gyration, in. (9)
r_y Radius of gyration about y axis, in. (8)
t_{bf} Thickness of beam flange, in. (8)

t_{cf} Thickness of column flange, in. (8)

t_f Thickness of flange, in. (8)

t_p Thickness of panel zone including doubler plates, in. (8)

t_w Thickness of web, in. (8)

t_z Thickness of panel zone (doubler plates not necessarily included), in. (8)

w_z Width of panel zone between column flanges, in. (8)

α Fraction of member force transferred across a particular net section. (9)

ρ Ratio of required axial force P_u to required shear strength V_u of a link. (10)

k Slenderness parameter. (9)

k_p Limiting slenderness parameter for compact element. (8)

k_r Limiting slenderness parameter for non-compact element. (9)

ϕ Resistance factor. (6,10)

ϕ_b Resistance factor for beams. (6)

ϕc Resistance factor for columns in compression. (6,10)

ϕ_t Resistance factor for columns in tension. (6)

ϕ_v Resistance factor for shear strength of panel zone of beam-to-column connections. (8)

ϕ_w Resistance factor for welds. (6)

2211.3 Glossary.

Beam. A structural member whose primary function is to carry loads transverse to its longitudinal axis, usually a horizontal member in a seismic frame system.

Braced Frame. An essentially vertical truss system of concentric or eccentric type that resists lateral forces on the structural system.

Concentrically Braced Frame (CBF). A braced frame in which all members of the bracing system are subjected primarily to axial forces. The CBF shall meet the requirements of Sect. 9.

Connection. Combination of joints used to transmit forces between two or more members. Categorized by the type and amount of force transferred (moment, shear, end reaction).

Continuity Plates. Column stiffeners at top and bottom of the panel zone.

Design strength. Resistance (force, moment, stress, as appropriate) provided by element or connection; the product of the nominal strength and the resistance factor.

Diagonal Bracing. Inclined structural members carrying primarily axial load employed to enable a structural frame to act as a truss to resist horizontal loads.

Dual System. A dual system is a structural system with the following features:

- An essentially complete space frame which provides support for gravity loads.
- Resistance to lateral load is provided by moment resisting frames (SMF) or (OMF) which is capable of resisting at least 25 percent of the base shear and concrete or steel shear walls, steel eccentrically (EBF) or concentrically (CBF) braced frames.
- Each system shall be also designed to resist the total lateral load in proportion to its relative rigidity.

Eccentrically Braced Frame (EBF). A diagonal braced frame in which at least one end of each bracing member connects to a beam a short distance from a beam-to-column connection or from another beam-to-brace connection. The EBF shall meet the requirements of Sect. 10.

Essential Facilities. Those facilities defined as essential in the applicable code under which the structure is designed. In the absence of such a code, see ASCE 7-92.

Joint. Area where two or more ends, surfaces, or edges are attached. Categorized by type of fastener or weld used and method of force transfer.

K Braced Frame. A concentric braced frame (CBF) in which a pair of diagonal braces located on one side of a column is connected to a single point within the clear column height.

Lateral Support Member. Member designed to inhibit lateral buckling or lateral-torsional buckling of primary frame members.

Link. In EBF, the segment of a beam which extends from column to column, located between the end of a diagonal brace and a column or between the ends of two diagonal braces of the EBF. The length of the link is defined as the clear distance between the diagonal brace and the column face or between the ends of two diagonal braces.

Link Intermediate Web Stiffeners. Vertical web stiffeners placed within the link.

Link Rotation Angle. The link rotation angle is the plastic angle between the link and the beam outside of the link when the total story drift is E'/E times the drift derived using the specified base shear, V.

Link Shear Design Strength. The lesser of ϕV_p or $2\phi M_p/_e$, where $\phi = 0.9$, $V_p = 0.55F_y d t_w$ and e = the link length except as modified by Sect. S9.2.f.

LRFD. (Load and Resistance Factor Design). A method of proportioning structural components (members, connectors, connecting elements, and assemblages) such that no applicable limit state is exceeded when the structure is subjected to all design load combinations.

Moment Frame. A building frame system in which seismic shear forces are resisted by shear and flexure in members and joints of the frame.

Nominal loads. The magnitudes of the loads specified by the applicable code.

Nominal strength. The capacity of a structure or component to resist the effects of loads, as determined by computations using specified material strengths and dimensions and formulas derived from accepted principles of structural mechanics or by field tests or laboratory tests of scaled models, allowing for modeling effects, and differences between laboratory and field conditions.

Ordinary Moment Frame (OMF). A moment frame system which meets the requirements of Sect. 7.

P - Delta effect. Secondary effect of column axial loads and lateral deflection on the shears and moments in members.

Panel Zone. Area of beam-to column connection delineated by beam and column flanges.

Required Strength. Load effect (force, moment, stress, as appropriate) acting on element of connection determined by structural analysis from the factored loads (using most appropriate critical load combinations).

Resistance Factor. A factor that accounts for unavoidable deviations of the actual strength from the nominal value and the manner and consequences of failure.

Slip-Critical Joint. A bolted joint in which slip resistance of the connection is required.

Special Moment Frame (SMF). A moment frame system which meets the requirements of Sect. 8.

Structural System. An assemblage of load carrying components which are joined together to provide regular interaction or interdependence.

V Braced Frame. A concentrically braced frame (CBF) in which a pair of diagonal braces located either above or below a beam is connected to a single point within the clear beam span. Where the diagonal braces are below the beam, the system is also referred to as an Inverted V Braced Frame.

X Braced Frame. A concentrically braced frame (CBF) in which a pair of diagonal braces crosses near midlength of the braces.

Y Braced Frame. An eccentrically braced frame (EBF) in which the stem of the Y is the link of the EBF system.

2211.4 Part I—Load and Resistance Factor Design (LRFD).

1. SCOPE

These special seismic requirements are to be applied in conjunction with the AISC *Load and Resistance Factor Design Specification for Structural Steel Buildings* (LRFD), 1986; hereinafter referred to as the *Specification.* They are intended for the design and construction of structural steel members and connections in buildings for which the design forces resulting from earthquake motions have been determined on the basis of energy dissipation in the non-linear range of response.

Seismic provisions and the nominal loads for each Seismic Performance Category, Seismic Hazard Exposure Group, or Seismic Zone shall be as specified by the applicable code under which the structure is designed or where no code applies, as dictated by the conditions involved. In the absence of a code, the Performance Categories, Seismic Hazard Exposure Groups, loads and load combinations shall be as given herein.

2. SEISMIC PERFORMANCE CATEGORIES

Seismic Performance Categories vary with the Seismic Hazard Exposure Group shown in Table 2-1, the Effective Peak Velocity Related Acceleration, A_v, and the Seismic Hazard Exposure Group shown in Table 2-2.

In addition to the general requirements assigned to the various Seismic Performance Categories in the applicable building code for all types of construction, the following requirements apply to fabricated steel construction for buildings and structures with similar structural characteristics.

2.1. Seismic Performance Categories A, B, and C

Buildings assigned to Categories A, B, and C, except Category C in Seismic Hazard Exposure Group III where the value of $A_v \geq 0.10$, shall be designed either in accordance with solely the *Specification* or in accordance with the *Specification* and these provisions.

TABLE 2-1

Seismic Hazard Exposure Groups

Group III	Buildings having essential facilities that are necessary for post-earthquake recovery and requiring special requirements for access and functionality.
Group II	Buildings that constitute a substantial public hazard because of occupancy or use.
Group I	All buildings not classified in Groups II and III.

2.2. Seismic Performance Category C

Buildings assigned to Category C in Seismic Hazard Exposure Group III where the value of $A_v \geq 0.10$ shall be designed in accordance with the *Specification* as modified by the additional provisions of this section.

2.2.a. Steel used in seismic resisting systems shall be limited by the provisions of Sect. 5.

2.2.b. Columns in seismic resisting systems shall be designed in accordance with Sect. 6.

2.2.c. Ordinary Moment Frames (OMF) shall be designed in accordance with the provisions of Sect. 7.

2.2.d. Special Moment Frames (SMF) are required to conform only to the requirements of Sects. 8.2, 8.7, and 8.8.

2.2.e. Braced framed systems shall conform to the requirements of Sects. 9 or 10 when used alone or in combination with the moment frames of the seismic resisting system.

2.2.f. A quality assurance plan shall be submitted to the regulatory agency for the seismic force resisting system of the building.

2.3. Seismic Performance Categories D and E

Buildings assigned to Categories D and E shall be designed in accordance with the *Specification* as modified by the additional provisions of this section.

2.3.a. Steel used in seismic resisting systems shall be limited by the provisions of Sect. 5.

2.3.b. Columns in seismic resisting systems shall be designed in accordance with Sect. 6.

2.3.c. Ordinary Moment Frames (OMF) shall be designed in accordance with the provisions of Sect. 7.

2.3.d. Special Moment Frames (SMF) shall be designed in accordance with the provisions of Sect. 8.

2.3.e. Braced framed systems shall conform to the requirements of Sects. 9. (CBF) or 10. (EBF) when used alone or in combination with the moment frames of the seismic resisting system.

The use of K-bracing systems shall not be permitted as part of the seismic resisting system except as permitted by Sect. 9.5. (Low Buildings)

TABLE 2-2
Seismic Performance Categories

Value of A_V	Seismic Hazard Exposure Group		
	I	II	III
$0.20 \le A_V$	D	D	E
$0.15 \le A_V < 0.20$	C	D	D
$0.10 \le A_V < 0.15$	C	C	C
$0.05 \le A_V < 0.10$	B	B	C
$A_V < 0.05$	A	A	A

2.3.f. A quality assurance plan shall be submitted to the regulatory agency for the seismic force resisting system of the building.

3. LOADS, LOAD COMBINATIONS, AND NOMINAL STRENGTHS

3.1. Loads and Load Combinations

The following specified loads and their effects on the structure shall be taken into account:

D: dead load due to the weight of the structural elements and the permanent features on the structure.

L: live load due to occupancy and moveable equipment.

L_r: roof live load.

W: wind load.

S: snow load.

E: earthquake load (where the horizontal component is derived from base shear Formula $V = C_S W_g$).

R': load due to initial rainwater or ice exclusive of the ponding contribution.

In the Formula $V = C_S W_g$ for base shear:

C_S = Seismic design coefficient

W_g = Total weight of the building, see the applicable code.

For the nominal loads as defined above, see the applicable code.

The required strength of the structure and its elements shall be determined from the appropriate critical combination of factored loads. The following Load Combinations and corresponding load factors shall be investigated:

$$1.4D \quad (3\text{-}1)$$

$$1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R') \quad (3\text{-}2)$$

$$1.2D + 1.6(L_r \text{ or } S \text{ or } R') + (0.5L \text{ or } 0.8W) \quad (3\text{-}3)$$

$$1.2D + 1.3W + 0.5L + 0.5(L_r \text{ or } S \text{ or } R') \quad (3\text{-}4)$$

$$1.2D \pm 1.0E + 0.5L + 0.2S \quad (3\text{-}5)$$

$$0.9D \pm (1.0E \text{ or } 1.3W) \quad (3\text{-}6)$$

Exception: The load factor on L in Load Combinations 3-3, 3-4, and 3-5 shall equal 1.0 for garages, areas occupied as places of public assembly, and all areas where the live load is greater than 100 psf.

Other special load combinations are included with specific design requirements throughout these provisions.

Orthogonal earthquake effects shall be included in the analysis unless noted specifically otherwise in the governing building code.

Where required by these provisions, an amplified horizontal earthquake load of $0.4R \times E$ (where the term $0.4R$ is greater or equal to 1.0) shall be applied in lieu of the horizontal component of earthquake load E in the load combinations above. The term R is the earthquake response modification coefficient contained in the applicable code. The additional load combinations using the amplified horizontal earthquake load are:

$$1.2D + 0.5L + 0.2S \pm 0.4R \times E \quad (3\text{-}7)$$

$$0.9D \pm 0.4R \times E \quad (3\text{-}8)$$

Exception: The load factor on L in Load Combinations 3-7 shall equal 1.0 for garages, areas occupied as places of public assembly and all areas where the live load is greater than 100 psf.

The term $0.4R$ in Load Combinations 3-7 and 3-8 shall be greater or equal to 1.0.

Where the amplified load is required, orthogonal effects are not required to be included.

3.2. Nominal Strengths

The nominal strengths shall be as provided in the *Specification.*

4. STORY DRIFT

Story drift shall be calculated using the appropriate load effects consistent with the structural system and the method of analysis. Limits on story drift shall be in accordance with the governing code and shall not impair the stability of the structure.

5. MATERIAL SPECIFICATIONS

Steel used in seismic force resisting systems shall be as listed in Sect. A3.1 of the *Specification,* except for buildings over one story in height. The steel used in seismic resisting systems described in Sections 8, 9, and 10 shall be limited to the following ASTM Specifications: A36, A500 (Grades B and C), A501, A572 (Grades 42 and 50), and A588. The steel used for base plates shall meet one of the preceding ASTM Specifications or ASTM A283 Grade D.

6. COLUMN REQUIREMENTS

6.1. Column Strength

When $P_u / \phi P_n > 0.5$, columns in seismic resisting frames, in addition to complying with the *Specification,* shall be limited by the following requirements:

6.1.a. Axial compression loads:

$$1.2P_D + 0.5P_L + 0.2P_S + 0.4R \times P_E \le \phi_c P_n \quad (6\text{-}1)$$

where the term $0.4R$ is greater or equal to 1.0.

Exception: The load factor on P_L in Load Combination 6-1 shall equal 1.0 for garages, areas occupied as places of public assembly, and all areas where the live load is greater than 100 psf.

6.1.b. Axial tension loads:

$$0.9P_D - 0.4R \times P_E \le \phi_t P_n \quad (6\text{-}2)$$

where the term $0.4R$ is greater or equal to 1.0.

6.1.c. The axial Load Combinations 6-1 and 6-2 are not required to exceed either of the following:

1. The maximum loads transferred to the column, considering 1.25 times the design strengths of the connecting beam or brace elements of the structure.

2. The limit as determined by the foundation capacity to resist overturning uplift.

6.2. Column Splices

Column splices shall have a design strength to develop the column axial loads given in Sect. 6.1.a, b, and c as well as the Load Combinations 3-1 to 3-6.

6.2.a. In column splices using either complete or partial penetration welded joints, beveled transitions are not required when changes in thickness and width of flanges and webs occur.

6.2.b. Splices using partial penetration welded joints shall not be within 3 ft of the beam-to-column connection. Column splices that are subject to net tension forces shall comply with the more critical of the following:

1. The design strength of partial penetration welded joints, the lesser of $\phi_w F_w A_w$ or $\phi_w F_{BM} A_w$ shall be at least 150 percent of the required strength, where ϕ_w = 0.8 and F_w = $0.6F_{EXX}$.
2. The design strength of welds shall not be less than $0.5F_{yc}A_f$, where F_{yc} is the yield strength of the column material and A_f is the flange area of the smaller column connected.

7. REQUIREMENTS FOR ORDINARY MOMENT FRAMES (OMF)

7.1. Scope

Ordinary Moment Frames (OMF) shall have a design strength as provided in the *Specification* to resist the Load Combinations 3-1 through 3-6 as modified by the following added provisions:

7.2. Joint Requirements

All beam-to-column and column to beam connections in OMF which resist seismic forces shall meet one of the following requirements:

7.2.a. FR (fully restrained) connections conforming with Sect. 8.2, except that the required flexural strength, M_u, of a column-to-beam joint is not required to exceed the nominal plastic flexural strength of the connection.

7.2.b. FR connections with design strengths of the connections meeting the requirements of Sect. 7.1 using the Load Combinations 3-7 and 3-8.

7.2.c. Either FR or PR (partially restrained) connections shall meet the following:

1. The design strengths of the members and connections meet the requirements of Sect. 7.1.
2. The connections have been demonstrated by cyclic tests to have adequate rotation capacity at a story drift calculated at a horizontal load of $0.4R \times E$, (where the term $0.4R$ is equal to or greater than 1.0).
3. The additional drift due to PR connections shall be considered in design.

FR and PR connections are described in detail in Sect. A2 of the *Specification*.

8. REQUIREMENTS FOR SPECIAL MOMENT FRAMES (SMF)

8.1. Scope

Special Moment Frames (SMF) shall have a design strength as provided in the *Specification* to resist the Load Combinations 3-1 through 3-6 as modified by the following added provisions:

8.2. Beam-to-Column Joints

8.2.a. The required flexural strength, M_u, of each beam-to-column joint shall be the lesser of the following quantities:

1. The plastic bending moment, M_p, of the beam.
2. The moment resulting from the panel zone nominal shear strength, V_n, as determined using Equation 8-1.

The joint is not required to develop either of the strengths defined above if it is shown that under an amplified frame deformation produced by Load Combinations 3-7 and 3-8, the design strength of the members at the connection is adequate to support the vertical loads, and the required lateral force resistance is provided by other means.

8.2.b. The required shear strength, V_u, of a beam-to-column joint shall be determined using the Load Combination $1.2D + 0.5L + 0.2S$ plus the shear resulting from M_u, as defined in Sect. 8.2.a., on each end of the beam. Alternatively, V_u shall be justified by a rational analysis. The required shear strength is not required to exceed the shear resulting from Load Combination 3-7.

8.2.c. The design strength, ϕR_n, of a beam-to-column joint shall be considered adequate to develop the required flexural strength, M_u, of the beam if it conforms to the following:

1. The beam flanges are welded to the column using complete penetration welded joints.
2. The beam web joint has a design shear strength ϕV_n greater than the required shear, V_u, and conforms to either:

a. Where the nominal flexural strength of the beam, M_n, considering only the flanges is greater than 70 percent of the nominal flexural strength of the entire beam section [i.e., $b_f t_f (d - t_f) F_{yf} \geq 0.7M_p$]; the web joint shall be made by means of welding or slip-critical high strength bolting, or;

b. Where $b_f t_f (d - t_f) F_{yf} < 0.7M_p$, the web joint shall be made by means of welding the web to the column directly or through shear tabs. That welding shall have a design strength of at least 20 percent of the nominal flexural strength of the beam web. The required beam shear, V_u, shall be resisted by further welding or by slip-critical high-strength bolting or both.

8.2.d. Alternate Joint Configurations: For joint configurations utilizing welds or high-strength bolts, but not conforming to Sect. 8.2.c, the design strength shall be determined by test or calculations to meet the criteria of Sect. 8.2.a. Where conformance is shown by calculation, the design strength of the joint shall be 125 percent of the design strengths of the connected elements.

8.3. Panel Zone of Beam-to-Column Connections (Beam web parallel to column web)

8.3.a. Shear Strength: The required shear strength, V_u, of the panel zone shall be based on beam bending moments determined from the Load Combinations 3-5 and 3-6. However, V_u is not required to exceed the shear forces determined from $0.9\Sigma\phi_b M_p$ of the beams framing into the column flanges at the connection. The design shear strength, $\phi_v V_n$, of the panel zone shall be determined by the following formula:

$$\phi_v V_n = 0.6\phi_v F_y d_c t_p \left[1 + \frac{3b_{cf} t_{cf}^2}{d_b d_c t_p}\right] \text{ where for this case } \phi_v = 0.75. \tag{8-1}$$

where:

t_p = Total thickness of panel zone including doubler plates, in.

d_c = Overall column section depth, in.

b_{cf} = Width of the column flange, in.

t_{cf} = Thickness of the column flange, in.

d_b = Overall beam depth, in.

F_y = Specified yield strength of the panel zone steel, ksi.

8.3.b. Panel Zone Thickness: The panel zone thickness, t_z, shall conform to the following:

$$t_z \geq (d_z + w_z) / 90 \tag{8-2}$$

where:

d_z = the panel zone depth between continuity plates, in.

w_z = the panel zone width between column flanges, in.

For this purpose, t_z shall not include any doubler plate thickness unless the doubler plate is connected to the web with plug welds adequate to prevent local buckling of the plate.

Where a doubler plate is used without plug welds to the column web, the doubler plate shall conform to Eq. 8-2.

8.3.c. Panel Zone Doubler Plates: Doubler plates provided to increase the design strength of the panel zone or to reduce the web depth thickness ratio shall be placed next to the column web and welded across the plate width along the top and bottom with at least a minimum fillet weld. The doubler plates shall be fastened to the column flanges using either butt or fillet welded joints to develop the design shear strength of the doubler plate.

8.4. Beam and Column Limitations

8.4.a. Beam Flange Area: There shall be no abrupt changes in beam flange areas in plastic hinge regions.

8.4.b. Width-Thickness Ratios: Beams and columns shall comply with λ_p in Table 8-1 in lieu of those in Table B5. 1 of the *Specification*.

8.5. Continuity Plates

Continuity plates shall be provided if required by the provisions in the *Specification* for webs and flanges with concentrated forces and if the nominal column local flange bending strength R_n is less than $1.8F_{yb} b_f t_{bf}$, where:

$R_n = 6.25(t_{cf})^2 F_{yf}$, and

F_{yb} = Specified minimum yield strength of beam, ksi.

F_{yf} = Specified minimum yield strength of column flange, ksi.

b_f = Beam flange width, in.

t_{bf} = Beam flange thickness, in.

t_{cf} = Column flange thickness, in.

Continuity plates shall be fastened by welds to both the column flanges and either the column webs or doubler plates.

8.6. Column-Beam Moment Ratio

At any beam-to-column connection, one of the following relationships shall be satisfied:

TABLE 8-1
Limiting Width Thickness Ratios λ_p for Compression Elements

Description of Element	Width-Thickness Ratio	Limiting Width-Thickness Ratios λ_p
Flanges of I-shaped nonhybrid sections and channels in flexure.	b/t	$52 / \sqrt{F_y}$
Flanges of I-shaped hybrid beams in flexure.		For $P_u/\phi_b P_y \leq 0.125$
Webs in combined flexural and axial compression	h/t_w	$\frac{520}{\sqrt{F_y}}\left[1 - \frac{1.54P_u}{\phi_b P_y}\right]$
		For $P_u/\phi_b P_y > 0.125$
		$\frac{191}{\sqrt{F_y}}\left[2.33 - \frac{P_u}{\phi_b P_y}\right] \geq \frac{253}{\sqrt{F_y}}$

$$\frac{\Sigma Z_c(F_{yc} - P_{uc}/A_{g})}{\Sigma Z_b F_{yb}} \geq 1.0, \tag{8–3}$$

$$\frac{\Sigma Z_c(F_{yc} - P_{uc}/A_{g})}{V_n d_b H/(H - d_{b})} \geq 1.0, \tag{8–4}$$

where:

A_g = Gross area of a column, in.^{2}

F_{yb} = Specified minimum yield strength of a beam, ksi.

F_{yc} = Specified minimum yield strength of a column, ksi.

H = Average of the story heights above and below the joint, in.

P_{uc} = Required axial strength in the column (in compression) ≥ 0

V_n = Nominal strength of the panel zone as determined from Equation 8-1, ksi.

Z_b = Plastic section modulus of a beam, in.^{3}

Z_c = Plastic section modulus of a column, in.^{3}

d_b = Average overall depth of beams framing into the connection, in.

These requirements do not apply in any of the following cases, provided the columns conform to the requirements of Sect. 8.4:

8.6.a. Columns with $P_{uc} < 0.3F_{yc}A_g$.

8.6.b. Columns in any story that has a ratio of design shear strength to design force 50 percent greater than the story above.

8.6.c. Any column not included in the design to resist the required seismic shears, but included in the design to resist axial overturning forces.

8.7. Beam-to-Column Connection Restraint

8.7.a. Restrained Connection:

1. Column flanges at a beam-to-column connection require lateral support only at the level of the top flanges of the beams when a column is shown to remain elastic outside of the panel zone, using one of the following conditions:

   a. Ratios calculated using Eqs. 8-3 or 8A are greater than 1.25.

   b. Column remains elastic when loaded with Load Combination 3-7.

2. When a column cannot be shown to remain elastic outside of the panel zone, the following provisions apply:

   a. The column flanges shall be laterally supported at the levels of both top and bottom beam flanges.

   b. Each column flange lateral support shall be designed for a required strength equal to 2.0 percent of the nominal beam flange strength ($F_y b_f t_f$).

   c. Column flanges shall be laterally supported either directly, or indirectly, by means of the column web or beam flanges.

8.7.b. Unrestrained Connections: A column containing a beam-to-column connection with no lateral support transverse to the seismic frame at the connection shall be designed using the distance between adjacent lateral supports as the column height for buckling transverse to the seismic frame and conform to Sect. H of the *Specification* except that:

1. The required column strength shall be determined from the Load Combination 3-5 where E is the least of:

   a. The amplified earthquake force $0.4R \times E$ (where the term $0.4R$ shall be equal to or greater than 1.0).

   b. 125 percent of the frame design strength based on either beam or panel zone design strengths.

2. The L/r for these columns shall not exceed 60.

3. The required column moment transverse to the seismic frame shall include that caused by the beam flange force specified in Sect. 8.7.a.2.b plus the added second order moment due to the resulting column displacement in this direction.

8.8. Lateral Support of Beams

Both flanges of beams shall be laterally supported directly or indirectly. The unbraced length between lateral supports shall not exceed 2,500 r_y/F_y. In addition, lateral supports shall be placed at concentrated loads where an analysis indicates a hinge will be formed during inelastic deformations of the SMF.

9. REQUIREMENTS FOR CONCENTRICALLY BRACED (CBF) BUILDINGS

9.1. Scope

Concentrically Braced Frames (CBF) are braced systems whose worklines essentially intersect at points. Minor eccentricities, where the worklines intersect within the width of the bracing members, are acceptable if accounted for in the design. CBF shall have a design strength as provided in the *Specification* to resist the Load Combinations 3-1 through 3-6 as modified by the following added provisions:

9.2. Bracing Members

9.2.a. Slenderness: Bracing members shall have an

$$\frac{L}{r} \leq \frac{720}{\sqrt{F_y}} \qquad \text{except as permitted in Sect. 9.5.}$$

9.2.b. Compressive Design Strength: The design strength of a bracing member in axial compression shall not exceed $0.8\phi_c P_n$.

9.2.c. Lateral Force Distribution: Along any line of bracing, braces shall be deployed in alternate directions such that, for either direction of force parallel to the bracing, at least 30 percent but no more than 70 percent of the total horizontal force shall be resisted by tension braces, unless the nominal strength, P_n, of each brace in compression is larger than the required strength, P_u, resulting from the application of the Load Combinations 3-7 or 3-8. A line of bracing, for the purpose of this provision, is defined as a single line or parallel lines whose plan offset is 10 percent or less of the building dimension perpendicular to the line of bracing.

9.2.d. Width-Thickness Ratios: Width-thickness ratios of stiffened and unstiffened compression elements in braces shall comply with Sect. B5 in the *Specification.* Braces shall be compact or non-compact, but not slender (i.e., $\lambda < \lambda_r$). Circular sections shall have an outside diameter to wall thickness ratio not exceeding 1,300/F_y, rectangular tubes shall have a flat-width to wall thickness not exceeding $110/\sqrt{F_y}$, unless the circular section or tube walls are stiffened.

9.2.e. Built-up Member Stitches: For all built-up braces, the first bolted or welded stitch on each side of the midlength of a built up member shall be designed to transmit a force equal to 50 percent of the nominal strength of one element to the adjacent element. Not less than two stitches shall be equally spaced about the member centerline.

9.3. Bracing Connections

9.3.a. Forces: The required strength of bracing joints (including beam-to-column joints if part of the bracing system) shall be the least of the following:

1. The design axial tension strength of the bracing member.
2. The force in the brace resulting from the Load Combinations 3-7 or 3-8.
3. The maximum force, indicated by an analysis, that is transferred to the brace by the system.

9.3.b. Net Area: In bolted brace joints, the minimum ratio of effective net section area to gross section area shall be limited by:

$$\frac{A_e}{A_g} \geq \frac{1.2\alpha P_u{}^*}{\phi_t P_n} \qquad (9\text{–}1)$$

where:

A_e = Effective net area as defined in Equation B3-1 of the *Specification*.

P_u* = Required strength on the brace as determined in Sect. 9.3.a.

P_n = Nominal tension strength as specified in Chapter D of the *Specification*.

ϕ_t = Special resistance factor for tension = 0.75.

α = Fraction of the member force from Sect. 9.3.a that is transferred across a particular net section.

9.3.c. Gusset Plates:

1. Where analysis indicates that braces buckle in the plane of the gusset plates, the gusset and other parts of the connection shall have a design strength equal to or greater than the in-plane nominal bending strength of the brace.
2. Where the critical buckling strength is out-of-plane of the gusset plate, the brace shall terminate on the gusset a minimum of two times the gusset thickness from the theoretical line of bending which is unrestrained by the column or beam joints. The gusset plate shall have a required compressive strength to resist the compressive design strength of the brace member without local buckling of the gusset plate. For braces designed for axial load only, the bolts or welds shall be designed to transmit the brace forces along the centroids of the brace elements.

9.4. Special Bracing Configuration Requirements

9.4.a. V and Inverted V Type Bracing:

1. The design strength of the brace members shall be at least 1.5 times the required strength using Load Combinations 3-5 and 3-6.
2. The beam intersected by braces shall be continuous between columns.
3. A beam intersected by V braces shall be capable of supporting all tributary dead and live loads assuming the bracing is not present.
4. The top and bottom flanges of the beam at the point of intersection of V braces shall be designed to support a lateral force equal to 1.5 percent of the nominal beam flange strength ($F_y b_f t_f$).

9.4.b. K bracing, where permitted:

1. The design strength of K brace members shall be at least 1.5 times the required strength using Load Combinations 3-5 and 3-6.
2. A column intersected by K braces shall be continuous between beams.
3. A column intersected by K braces shall be capable of supporting all dead and live loads assuming the bracing is not present.
4. Both flanges of the column at the point of intersection of K braces shall be designed to support a lateral force equal to 1.5 percent of the nominal column flange strength ($F_y b_f t_f$).

9.5. Low Buildings

Braced frames not meeting the requirements of Sect. 9.2 through 9.4 shall only be used in buildings not over two stories and in roof structures if Load Combinations 3-7 and 3-8 are used for determining the required strength of the members and connections.

10. REQUIREMENTS FOR ECCENTRICALLY BRACED FRAMES (EBF)

10.1. Scope

Eccentrically braced frames shall be designed so that under inelastic earthquake deformations, yielding will occur in the links. The diagonal braces, the columns, and the beam segments outside of the links shall be designed to remain elastic under the maximum forces that will be generated by the fully yielded and strain hardened links, except where permitted by this section.

10.2. Links

10.2.a. Beams with links shall comply with the width-thickness ratios in Table 8-1.

10.2.b. The specified minimum yield stress of steel used for links shall not exceed F_y = 50 ksi.

10.2.c. The web of a link shall be single thickness without doubler plate reinforcement and without openings.

10.2.d. Except as limited by Sect. 10.2.f., the requircd shear strength of the link, V_u, shall not exceed the design shear strength of the link, ϕV_n, where:

ϕV_n = Link design shear strength of the link = the lesser of ϕV_p or $2\phi M_p / e$, kips.

$V_p = 0.6F_y(d - 2t_f)t_w$, kips.

ϕ = 0.9.

e = link length, in.

10.2.e. If the required axial strength, P_u, in a link is equal to or less than $0.15P_y$, where $P_y = A_g F_y$, the effect of axial force on the link design shear strength need not be considered.

10.2.f. If the required axial strength, P_u, in a link exceeds $0.15P_y$, the following additional limitations shall be required:

1. The link design shear strength shall be the lesser of ϕV_{pa} or $2\phi M_{pa} / e$, where:

$$V_{pa} = V_p \sqrt{1 - (P_u/P_y)^2}$$

$M_{pa} = 1.18\ M_p\ [\ 1 - (P_u / P_y)]$

$\phi = 0.9$

2. The length of the link shall not exceed:

$[1.15 - 0.5\rho(A_w/A_g)]\ 1.6\ M_p / V_p$ for $\rho(A_w/A_g) \geq 0.3$ and

$1.6M_p / V_p$ for $\rho(A_w/A_g) < 0.3$, where:

$A_w = (d\text{-}2t_f)t_w$

$P = P_u / V_u$

10.2.g. The link rotation angle is the plastic angle between the link and the beam outside of the link when the total story drift is $0.4R$ times the drift determined using the specified base shear V. The term $0.4R$ shall be equal to or greater than 1.0. Except as noted in Sect. 10.4.d, the link rotation angle shall not exceed the following values:

1. 0.09 radians for links of length $1.6M_p / V_p$ or less.
2. 0.03 radians for links of length $2.6M_p / Vp$ or greater.
3. Linear interpolation shall be used for links of length between $1.6Mp / V_p$ and $2.6M_p / V_p$.

10.2.h. Alternatively, the top story of an EBF building having over five stories shall be a CBF.

10.3. Link Stiffeners

10.3.a. Full depth web stiffeners shall be provided on both sides of the link web at the diagonal brace ends of the link. These stiffeners shall have a combined width not less than $(b_f - 2t_w)$ and a thickness not less than $0.75t_w$ or $^3/_8$-in., whichever is larger, where b_f and t_w are the link flange width and link web thickness, respectively.

10.3.b. Links shall be provided with intermediate web stiffeners as follows:

1. Links of lengths $1.6M_p / V_p$ or less shall be provided with intermediate web stiffeners spaced at intervals not exceeding $(30t_w - d/5)$ for a link rotation angle of 0.09 radians or $(52t_w - d/5)$ for link rotation angles of 0.03 radians or less. Linear interpolation shall be used for values between 0.03 and 0.09 radians.
2. Links of length greater than $2.6M_p / V_p$ and less than $5M_p / V_p$ shall be provided with intermediate web stiffeners placed at a distance of $1.5b_f$ from each end of the link.
3. Links of length between $1.6M_p / V_p$ and $2.6M_p/V_p$ shall be provided with intermediate web stiffeners meeting the requirements of 1 and 2 above.
4. No intermediate web stiffeners are required in links of lengths greater than $5M_p / V_p$.
5. Intermediate link web stiffeners shall be full depth. For links less than 25 inches in depth, stiffeners are required on oniy one side of the link web. The thickness of one-sided stiffeners shall not be less than t_w or $^3/_8$-in., whichever is larger, and the width shall be not less than $(b_f/2) - t_w$. For links 25 inches in depth or greater, similar intermediate stiffeners are required on both sides of the web.

10.3.c. Fillet welds connecting link stiffener to the link web shall have a design strength adequate to resist a force of $A_{st}F_y$, in which A_{st} = area of the stiffener. The design strength of fillet welds fastening the stiffener to the flanges shall be adequate to resist a force of $A_{st}F_y / 4$.

10.4. Link-to-Column Connections

Where a link is connected to a column, the following additional requirements shall be met:

10.4.a. The length of links connected to columns shall not exceed $1.6M_p / V_p$ unless it is demonstrated that the link-to-column connection is adequate to develop the required inelastic rotation of the link.

10.4.b. The link flanges shall have complete penetration welded joints to the column. The joint of the link web to the column shall be welded. The required strength of the welded joint shall be at least the nominal axial, shear, and flexural strengths of the link web.

10.4.c. The need for continuity plates shall be determined according to the requirements of Sect. 8.5.

10.4.d. Where the link is connected to the column web, the link flanges shall have complete penetration welded joints to plates and the web joint shall be welded. The required strength of the link web shall be at least the nominal axial, shear, and flexural strength of the link web. The link rotation angle shall not exceed 0.015 radians for any link length.

10.5. Lateral Support of Link

Lateral supports shall be provided at both the top and bottom flanges of link at the ends of the link. End lateral supports of links shall have a design strength of 6 percent of the link flange nominal strength computed as $F_y b_f t_f$.

10.6. Diagonal Brace and Beam Outside of Link

10.6.a. The required combined axial and moment strength of the diagonal brace shall be the axial forces and moments generated by 1.25 times the nominal shear strength of the link as defined in Sect. 10.2. The design strengths of the diagonal brace, as determined by Sect. H (including Appendix H) of the *Specification*, shall exceed the required strengths as defined above.

10.6.b. The required strength of the beam outside of the link shall be the forces generated by at least 1.25 times the nominal shear strength of the link and shall be provided with lateral support to maintain the stability of the beam. Lateral supports shall be provided at both top and bottom flanges of the beam and each shall have a design strength to resist at least 1.5 percent of the beam flange nominal strength computed as $F_y b_f t_f$.

10.6.c. At the connection between the diagonal brace and the beam at the link end of the brace, the intersection of the brace and beam centerlines shall be at the end of the link or in the link. The beam shall not be spliced within or adjacent to the connection between the beam and the brace.

10.6.d. The required strength of the diagonal brace-to-beam connection at the link end of the brace shall be at least the nominal strength of the brace. No part of this connection shall extend over the link length. If the brace resists a portion of the link end moment, the connection shall be designed as Type FR (Fully Restrained).

10.6.e. The width-thickness ratio of brace shall satisfy λ_p of Table B5.1 of the *Specification*.

10.7. Beam-to-Column Connections

Beam-to-column connections away from links are permitted to be designed as a pin in the plane of the web. The connection shall have a design strength to resist torsion about the longitudinal axis of the beam based on two equal and opposite forces of at least 1.5 percent of the beam flange nominal strength computed as $F_y b_f t_f$ acting laterally on the beam flanges.

10.8. Required Column Strength

The required strength of columns shall be determined by Load Combinations 3-5 and 3-6 except that the moments and axial loads introduced into the column at the connection of a link or brace shall not be less than those generated by 1.25 times the nominal strength of the link.

11. QUALITY ASSURANCE

The general requirements and responsibilities for performance of a quality assurance plan shall be in accordance with the requirements of the regulatory agency and specifications by the design engineer.

The special inspections and special tests needed to establish that the construction is in conformance with these provisions shall be included in a quality assurance plan.

The minimum special inspection and testing contained in the quality assurance plan beyond that required by the *Specification* shall be as follows:

Groove welded joints subjected to net tensile forces which are part of the seismic force resisting systems of Sects. 8, 9, and 10 shall be tested 100 percent either by ultrasonic testing or by other approved equivalent methods conforming to AWS D1.1.

Exception: The nondestructive testing rate for an individual welder shall be reduced to 25 percent with the concurrence of the person responsible for structural design, provided the reject rate is demonstrated to be 5 percent or less of the welds tested for the welder.

2211.5 Part II—Allowable Stress Design (ASD) Alternative.

As an alternative to the LRFD seismic design procedures for structural steel design given in PART I, the design procedures in the *Specification for Structural Steel Buildings—Allowable Stress Design and Plastic Design*, AISC 1989 are permitted as modified by PART II of these provisions. When using ASD, the provisions of PART I of these seismic provisions shall apply except the following sections shall be substituted for, or added to, the appropriate sections as indicated:

1. SCOPE

Revise the first paragraph of Part I, Sect. 1 to read as follows:

These special requirements are to be applied in conjunction with the AISC *Specification for Structural Steel Buildings— Allowable Stress Design and Plastic Design* hereinafter referred to as *Specification*. They are intended for the design and construction of structural steel members and connections in buildings for which the design forces resulting from earthquake motions have been determined on the basis of energy dissipation in the nonlinear range of response.

3. LOADS, LOAD COMBINATIONS AND NOMINAL STRENGTHS

Substitute the following for Section 3.2 in Part I:

3.2. Nominal Strengths

The nominal strengths of members shall be determined as follows:

3.2.a. Replace Sect. A5.2 of the *Specification* to read: "The nominal strength of structural steel members for resisting seismic forces acting alone or in combination with dead and live loads shall be determined by multiplying 1.7 times the allowable stresses in Sect. D, E, F, G, J, and K."

3.2.b. Amend the first paragraph of Sect. N1 of the *Specification* by deleting "or earthquake" and adding: "The nominal strength of members shall be determined by the requirements contained herein. Except as modified by these rules, all pertinent provisions of Chapters A through M shall govern."

3.2.c. In Sect H1 of the *Specification* the definition of F_e' shall read as follows:

$$F_e' = \frac{\pi^2 E}{(Kl_b/r_b)^2}$$

where:

l_b = the actual length in the plane of bending.

r_b = the corresponding radius of gyration.

K = the effective length factor in the plane of bending.

Add the following section to Part I:

3.3. Design Strengths

3.3.a. The design strengths of structural steel members and connections subjected to seismic forces in combination with other prescribed loads shall be determined by converting allowable stresses into nominal strengths and multiplying such nominal strengths by the resistance factors herein.

3.3.b. Resistance factors, ϕ, for use in Part II shall be as follows:

Flexure $\phi_b = 0.90$

Compression and axially loaded composite members $\phi_c = 0.85$

Eyebars and pin connected members:

Shear of the effective area $\phi_{sf} = 0.75$

Tension on net effective area $\phi_t = 0.75$

Bearing on the project area of pin $\phi_t = 1.0$

Tension members:

Yielding on gross section $\phi_t = 0.90$

Fracture in the net section $\phi_t = 0.75$

Shear $\phi_v = 0.90$

Connections:

Base plates that develop the strength of the members or structural systems $\phi = 0.90$

Welded connections that do not develop the strength of the member or structural system, including connection of base plates and anchor bolts $\phi = 0.67$

Partial Penetration welds in columns when subjected to tension stresses $\phi = 0.80$

High strength bolts (A325 and A490) and rivets:

Tensile strength $\phi = 0.75$

Shear strength in hearing-type joints $\phi = 0.65$

Slip-critical joints $\phi = 1.0$

A307 bolts:

Tensile strength $\phi = 0.75$

Shear strength in bearing-type joints $\phi = 0.60$

Substitute the following for Section 7 in Part I in its entirety:

7. REQUIREMENTS FOR ORDINARY MOMENT FRAMES (OMF)

7.1. Scope

Ordinary Moment Frames (OMF) shall have a design strength as provided in the *Specification* to resist the Load Combinations 3-5 and 3-6 as modified by the following added provisions:

7.2. Joint Requirements

All beam-to-column and column to beam connections in OMF which resist seismic forces shall meet one of the following requirements:

7.2.a. Type 1 connections conforming with Sect. 8.2, except that the required flexural strength, M_u, of a column-to-beam joint are not required to exceed that required to develop the nominal plastic flexural strength of the connection.

7.2.b. Type 1 connections capable of inelastic deformation and the design strengths of the connections meeting the requirements of Sect. 7.1 using the Load Combinations 3-7 and 3-8.

7.2.c. Either Type 1 or Type 3 connections are permitted provided:

1. The design strengths of the members and connections meet the requirements of Sect. 7.1.
2. The connections have been demonstrated by cyclic tests to have adequate rotation capacity at a story drift calculated at a horizontal load of $0.4R \times E$ (where the term $0.4R$ is equal to or greater than 1.0).
3. The additional drift due to Type 3 connections shall be considered in design.

Type 1 and Type 3 connections are described in detail in Sect. A2 of the *Specification*.

Substitute the following in Sections 10.6.a and 10. 6.d in Part I:

10.6.a. Delete reference to Appendix H.

10.6.d. The last sentence shall read: “If the brace resists a portion of the link end moment as described above, the connection shall be designed as a Type 1 connection.”

Division V—SEISMIC PROVISIONS FOR STRUCTURAL STEEL BUILDINGS FOR USE WITH ALLOWABLE STRESS DESIGN

SECTION 2212 — GENERAL

When the load combinations of Section 1612.3 for Allowable Stress Design are used, structural steel buildings shall be designed in accordance with the provisions of Chapter 22, Division III (AISC-ASD), and this division where applicable.

SECTION 2213 — SEISMIC PROVISIONS FOR STRUCTURAL STEEL BUILDINGS IN SEISMIC ZONES 3 AND 4

2213.1 General. Design and construction of steel framing in lateral-force-resisting systems in Seismic Zones 3 and 4 shall conform to the requirements of the code and to the requirements of this section.

2213.2 Definitions.

ALLOWABLE STRESSES are prescribed in Divisons III and VII.

CHEVRON BRACING is that form of bracing where a pair of braces located either above or below a beam terminates at a single point within the clear beam span.

CONNECTION is the group of elements that connect the member to the joint.

DIAGONAL BRACING is that form of bracing that diagonally connects joints at different levels.

ECCENTRICALLY BRACED FRAME (EBF) is a diagonal braced frame in which at least one end of each bracing member connects to a beam a short distance from a beam-to-column connection or from another beam-to-brace connection.

GIRDER is the horizontal member in a seismic frame. The words beam and girder may be used interchangeably.

JOINT is the entire assemblage at the intersections of the members.

K BRACING is that form of bracing where a pair of braces located on one side of a column terminates at a single point within the clear column height.

LINK BEAM is that part of a beam in an eccentrically braced frame which is designed to yield in shear and/or bending so that buckling of the bracing members is prevented.

STRENGTH is the strength as prescribed in Section 2213.4.2.

V BRACING is that form of chevron bracing that intersects a beam from above and inverted V bracing is that form of chevron bracing that intersects a beam from below.

X BRACING is that form of bracing where a pair of diagonal braces cross near midlength of the bracing members.

2213.3 Symbols and Notations. The symbols and notations unique to this section are as follows:

M_s = flexural strength.
P_{DL} = axial dead load.
P_E = axial load on member due to earthquake.
P_{LL} = axial live load.
P_{sc} = compressive axial strength of member.
P_{st} = tensile axial strength of member.
V_s = shear strength of member.
Z = plastic section modulus.

2213.4 Materials.

2213.4.1 Quality. Structural steel used in lateral-force-resisting systems shall conform to A 36, A 500, A 501, A 572 (Grades 42 and 50), A 913 (Grades 50 and 65) and A 588. Structural steel conforming to A 283 (Grade D) may be used for base plates and anchor bolts.

EXCEPTION: Other steels permitted in this code may be used for the following:

1. One-story buildings.
2. Light-framed wall systems in accordance with Division VIII.

2213.4.2 Member strength. Where this section requires the strength of the member to be developed, the following shall be used:

	Strength
Moment	$M_s = ZF_y$
Shear	$V_s = 0.55\ F_y dt$
Axial compression	$P_{sc} = 1.7\ F_a A$
Axial tension	$P_{st} = F_y A$
Connectors	
Full-penetration welds	$F_y A$
Partial penetration welds	$1.7\ F_s$
Bolts and fillet welds	$1.7\ F_s$

Where F_s is the allowable stress value defined in the applicable chapter of Division III. For the purpose of determining member or connection strengths, the allowable stress values specified in Division III shall not be increased by the one-third allowable stress increase per Section 1612.3.2.

Members need not be compact unless otherwise required by this section.

2213.5 Column Requirements.

2213.5.1 Column strength. Columns shall satisfy the load combinations required by Section 1612.2 at load and resistance factor limits or Section 1612.3 at allowable stress limits with stress increases allowed by Section 1612.3.2. In addition, in Seismic Zones 3 and 4, columns in frames shall have the strength to resist the axial loads resulting from the load combinations in Items 1 and 2.

1. **Axial compression**

$$1.0\ P_{DL} + 0.7\ P_{LL} + \Omega_o\ P_E$$

2. **Axial tension**

$$0.85\ P_{DL} \pm \Omega_o\ P_E$$

EXCEPTION: The axial load combination as outlined in Items 1 and 2 above:

1. Need not exceed either the maximum force that can be transferred to the column, by elements of the structure, or the limit as determined by the overturning uplift which the foundation is capable of resisting.

2. Need not apply to columns in moment-resisting frames complying with Formula (13-3-1) or (13-3-2) where f_a is equal to or less than 0.3 F_y for all load combinations.

The load combinations from Items 1 and 2 need be used only when specifically referred to.

2213.5.2 Column splices. Column splices shall have sufficient strength to develop the column forces determined from Section 2213.5.1. Welded column splices subject to net tensile forces shall comply with the more critical of the following:

1. Partial penetration welds shall be designed to resist 150 percent of the force determined from Section 2213.5.1, Item 2.

2. Welding shall develop not less than 50 percent of the flange area strength of the smaller column.

Splices employing partial penetration welds shall be located at least three feet (914 mm) from girder flanges.

2213.5.3 Slenderness evaluation. This paragraph is applicable when the provisions are applied to the effective length determination of columns of moment frames resisting earthquake forces. In the plane of the earthquake forces the factor K may be taken as unity when all of the following conditions are met:

1. The column is either continuous or is fixed at each joint.

2. The maximum axial compressive stress, f_a, does not exceed 0.4 F_y under design loads.

3. The calculated drift ratios are less than the values given in Section 1630.8.

2213.6 Ordinary Moment Frame Requirements. Ordinary moment frames (OMF) shall be designed to resist the load combinations in Section 1612.3.

All beam-to-column connections in OMFs which resist earthquake forces shall meet one of the following requirements:

1. Fully restrained (Type F.R. or Type 1) conforming with Section 2213.7.1.

2. Fully restrained (Type F.R. or Type 1) connections with the design strengths of the connections capable of resisting a combination of gravity loads and Ω_o times the design seismic forces.

3. Partially restrained (Type P.R. or Type 3) connections are permitted provided:

3.1 The connections are designed to resist the load combinations in Section 1612.2 or 1612.3, and

3.2 The connections have been demonstrated by cyclic tests to have adequate rotation capacity to accommodate a story drift due to Ω_o times the design seismic forces.

3.3 The moment frame drift calculations shall include the contribution due to the rotation and distortion of the connection.

See Divisions II and III for definitions of fully restrained and partially restrained connections.

2213.7 Special Moment-resisting Frame (SMRF) Requirements.

2213.7.1 Girder-to-column connection.

2213.7.1.1 Required strength. The girder-to-column connection shall be adequate to develop the lesser of the following:

1. The strength of the girder in flexure.

2. The moment corresponding to development of the panel zone shear strength as determined from Formula (13-1).

EXCEPTION: Where a connection is not designed to contribute flexural resistance at the joint, it need not develop the required strength if it can be shown to meet the deformation compatibility requirements of Section 1633.2.4.

2213.7.1.2 Connection strength. Connection configurations utilizing welds or high-strength bolts shall demonstrate, by approved cyclic test results or calculation, the ability to sustain inelastic rotation and develop the strength criteria in Section 2213.7.1.1 considering the effect of steel overstrength and strain hardening.

2213.7.1.3 Flange detail limitations. For steel whose specified ultimate strength is less than 1.5 times the specified yield strength, plastic hinges shall not form at locations in which the beam flange area has been reduced, such as for bolt holes. Bolted connections of flange plates of beam-column joints shall have the net-to-gross area ratio A_e/A_g equal to or greater than 1.2 F_y/F_u.

2213.7.2 Panel zone.

2213.7.2.1 Strength. The panel zone of the joint shall be capable of resisting the shear induced by beam bending moments due to gravity loads plus 1.85 times the prescribed seismic forces, but the shear strength need not exceed that required to develop $0.8\Sigma M_s$ of the girders framing into the column flanges at the joint. The joint panel zone shear strength may be obtained from the following formula:

$$V = 0.55\,F_y d_c t\left[1 + \frac{3b_c t_{cf}^{\;2}}{d_b d_c t}\right] \qquad (13\text{-}1)$$

WHERE:

b_c = the width of the column flange.

d_b = the depth of the beam.

d_c = the column depth.

t = the total thickness of the joint panel zone including doubler plates.

t_{cf} = the thickness of the column flange.

2213.7.2.2 Thickness. The panel zone thickness, t_z, shall conform to the following formula:

$$t_z \geq (d_z + w_z)/90 \qquad (13\text{-}2)$$

WHERE:

d_z = the panel zone depth between continuity plates.

w_z = the panel zone width between column flanges.

For this purpose, t_z, shall not include any double plate thickness unless the doubler plate is connected to the column web with plug welds adequate to prevent local buckling of the plate.

2213.7.2.3 Doubler plates. Doubler plates provided to reduce panel zone shear stress or to reduce the web depth thickness ratio shall be placed not more than $^1/_{16}$ inch (1.6 mm) from the column web and shall be welded across the plate width top and bottom with at least a $^3/_{16}$-inch (4.7 mm) fillet weld. They shall be either butt or fillet welded to the column flanges to develop the shear strength of the doubler plate. Weld strength shall be as given in Section 2213.4.2.

2213.7.3 Width-thickness ratio. Girders shall comply with Division III, except that the flange width-thickness ratio, $b_f / 2t_f$, shall not exceed $52/\sqrt{F_y}$ (For **SI:** $0.31\sqrt{E/F_y}$). The width-thickness ratio of column sections shall meet the requirements of Division III, Section 2251N7. The outside wall width-thickness ratio of rectangular tubes used for columns shall not exceed $110/\sqrt{F_y}$ (For **SI:** $0.65\sqrt{E/F_y}$), unless otherwise stiffened.

2213.7.4 Continuity plates. When determining the need for girder tension flange continuity plates, the value of P_{bf} in Division III shall be taken as 1.8 $(bt_f)F_{yb}$.

2213.7.5 Strength ratio. At any moment frame joint, the following relationships shall be satisfied:

$$\Sigma Z_c\,(F_{yc} - f_a) / \Sigma M_c > 1.0 \qquad (13\text{-}3\text{-}1)$$

or

$$\Sigma Z_c \ (F_{yc} - f_a) \ / \ 1.25 \Sigma M_{pz} > 1.0 \qquad (13\text{-}3\text{-}2)$$

WHERE:

$f_a > 0$

M_c = the moment at column center line due to the development of plastic hinging in the beam accounting for overstrength and strain hardening.

M_{pz} = the sum of beam moments when panel zone shear strength reaches the value specified in Formula (13-1).

EXCEPTION: Columns meeting the compactness limitations for beams given in Section 2213.7.3 need not comply with this requirement provided they conform to one of the following conditions:

1. Columns with f_a less than 0.4 F_y for all load combinations other than loads specified in Section 2213.5.1, and

1.1 Which are used in the top story of a multistory building with building period greater than 0.7 second

1.2 Where the sum of their resistance is less than 20 percent of the shear in a story, and is less than 33 percent of the shear on each of the column lines within that story. A column line is defined for the purpose of this exception as a single line of columns, or parallel lines of columns located within 10 percent of the plan dimension perpendicular to the line of columns; or

1.3 When the design for combined axial compression and bending is proportioned to satisfy Division III without the one-third permissible stress increase.

2. Columns in any story which have lateral shear strength 50 percent greater than that of the story above.

3. Columns which lateral shear strengths are not included in the design to resist code-required shears.

2213.7.6 Trusses in SMRF. Trusses may be used as horizontal members in SMRF if the sum of the truss seismic force flexural strength exceeds the sum of the column seismic force flexural strength immediately above and below the truss by a factor of at least 1.25. For this determination the strengths of the members shall be reduced by the gravity load effects. In buildings of more than one story, the column axial stress shall not exceed $0.4F_y$ and the ratio of the unbraced column height to the least radius of gyration shall not exceed 60. Columns shall have allowable stresses reduced 25 percent when one end frames into a truss, and 50 percent when both ends frame into trusses. The connection of the truss chords to the column shall develop the lesser of the following:

1. The strength of the truss chord.

2. The chord force necessary to develop 125 percent of the flexural strength of the column.

2213.7.7 Girder-column joint restraint.

2213.7.7.1 Restrained joint. Where it can be shown that the columns of SMRF remain elastic, the flanges of the columns need be laterally supported only at the level of the girder top flange.

Columns may be assumed to remain elastic if one of the following conditions is satisfied:

1. The ratio in Formula (13-3-1) or (13-3-2) is greater than 1.25.

2. The flexural strength of the column is at least 1.25 times the moment that corresponds to the panel zone shear strength.

3. Girder flexural strength or panel zone strength will limit column stress $(f_a + f_{bx} + f_{by})$ to F_y of the column.

4. The column will remain elastic under gravity loads plus Ω_o times the design seismic forces.

Where the column cannot be shown to remain elastic, the column flanges shall be laterally supported at the levels of the girder top and bottom flanges. The column flange lateral support shall be capable of resisting a force equal to one percent of the girder flange capacity at allowable stresses and at a limiting displacement perpendicular to the frame of 0.2 inch (5.1 mm). Required bracing members may brace the column flanges directly or indirectly through the column web or the girder flanges.

2213.7.7.2 Unrestrained joint. Columns without lateral support transverse to a joint shall conform to the requirements of Division III, with the column considered as pin ended and the length taken as the distance between lateral supports conforming with Section 2213.7.7.1. The column stress, f_a, shall be determined from gravity loads plus the lesser of the following:

1. Ω_o times the design seismic forces.

2. The forces corresponding to either 125 percent of the girder flexural strength or the panel zone shear strength.

The stress, f_{by}, shall include the effects of the bracing force specified in Section 2213.7.7.1 and $P\Delta$ effects.

l/r for such columns shall not exceed 60.

At truss frames the column shall be braced at each truss chord for a lateral force equal to one percent of the compression yield strength of the chord.

2213.7.8 Beam bracing. Both flanges of beams shall be braced directly or indirectly. The beam bracing between column center lines shall not exceed $96r_y$. In addition, braces shall be placed at concentrated loads where a hinge may form.

2213.7.9 Changes in beam flange area. Abrupt changes in beam flange area are not permitted within possible plastic hinge regions of special moment-resistant frames.

2213.7.10 Moment frame drift calculations. Moment frame drift calculations shall include bending and shear contributions from the clear girder and column spans, column axial deformation and the rotation and distortion of the panel zone.

EXCEPTIONS: 1. Drift calculations may be based on column and girder center lines where either of the following conditions is met:

1.1 It can be demonstrated that the drift so computed for frames of similar configuration is typically within 15 percent of that determined above.

1.2 The column panel zone strength can develop $0.8\Sigma M_s$ of girders framing to the column flanges at the joint.

2. Column axial deformations may be neglected if they contribute less than 10 percent to the total drift.

2213.8 Requirements for Braced Frames.

2213.8.1 General. The provisions of this section apply to all braced frames except special concentrically braced frames designed in accordance with Section 2213.9 or eccentrically braced frames (EBF) designed in accordance with Section 2213.10. Those members which resist seismic forces totally or partially by shear or flexure shall be designed in accordance with Section 2213.7 except Section 2213.7.3.

2213.8.2 Bracing members.

2213.8.2.1 Slenderness. In Seismic Zones 3 and 4, the l/r ratio for bracing members shall not exceed $720/\sqrt{F_y}$ (For **SI:** $4.23\sqrt{E/F_y}$), except as permitted in Sections 2213.8.5 and 2213.8.6.

2213.8.2.2 Stress reduction. The allowable stress, F_{as}, for bracing members resisting seismic forces in compression shall be determined from the following formula:

$$F_{as} = BF_a \qquad (13\text{-}4)$$

WHERE:

B = the stress-reduction factor determined from the following formula:

$$B = 1/\{1 + [(Kl/r)/2C_c]\} \quad (13\text{-}5)$$

F_a = the allowable axial compressive stress allowed in Division III.

EXCEPTION: Bracing members carrying gravity loads may be designed using the column strength requirement and load combinations of Section 2213.5.1, Item 1.

2213.8.2.3 Lateral-force distribution. The seismic lateral force along any line of bracing shall be distributed to the various members so that neither the sum of the horizontal components of the forces in members acting in tension nor the sum of the horizontal components of forces in members acting in compression exceed 70 percent of the total force.

EXCEPTION: Where compression bracing acting alone has the strength, neglecting the stress-reduction factor B, to resist Ω_o times the design seismic force such distribution is not required.

A line of bracing is defined, for the purpose of this provision, as a single line or parallel lines within 10 percent of the dimension of the structure perpendicular to the line of bracing.

2213.8.2.4 Built-up members. The l/r of individual parts of built-up bracing members between stitches, when computed about a line perpendicular to the axis through the parts, shall not be greater than 75 percent of the l/r of the member as a whole.

2213.8.2.5 Compression elements in braces. The width-thickness ratio of stiffened and unstiffened compression elements used in braces shall be as shown in Division III, Table B5.1, for compact sections.

The width-thickness ratio of angle sections shall be limited to $52/\sqrt{f_y}$ (For **SI:** $0.31\sqrt{E/f_y}$). Circular sections shall have outside diameter-wall thickness ratio not exceeding $1{,}300/F_y$ (For **SI:** $7.63\ E/f_y$). Rectangular tubes shall have outside width-thickness ratio not exceeding $110/\sqrt{F_y}$ (For **SI:** $0.65\sqrt{E/F_y}$).

EXCEPTION: Compression elements stiffened to resist local buckling.

2213.8.3 Bracing connection.

2213.8.3.1 Forces. Bracing connections shall have the strength to resist the least of the following:

1. The strength of the bracing in axial tension, P_{st}.

2. Ω_o times the force in the brace due to the design seismic forces, in combination with gravity loads.

3. The maximum force that can be transferred to the brace by the system.

Bracing connections shall, as a minimum, satisfy the load combinations required by Section 1612.2 at load and resistance factor design limits or Section 1612.3 at allowable stress design limits with stress increases allowed by Section 1612.3.2. These combinations shall include the provisions for Sections 2213.8.2.2 and 2213.8.4.1.

Beam-to-column connections for beams that are part of the bracing system shall have the capacity to transfer the force determined above. Where eccentricities in the frame geometry or connection load path exist, the affected members and connections shall have the strength to resist all secondary forces resulting from the eccentricities in combination with all primary forces using the lesser of the forces determined above.

2213.8.3.2 Net area. In bolted brace connections, the ratio of effective net section area to gross section area shall satisfy the formula:

$$\frac{A_e}{A_g} \geq \frac{1.2\,\alpha F^*}{F_u} \quad (13\text{-}6)$$

WHERE:

A_e = effective net area as defined in Division III.

F_u = minimum tensile strength.

F^* = stress in brace as determined in Section 2213.8.3.1.

α = fraction of the member force from Section 2213.8.3.1 that is transferred across a particular net section.

2213.8.4 Bracing configuration.

2213.8.4.1 Chevron bracing. Chevron bracing shall conform with the following:

1. Bracing members shall be designed for 1.5 times the otherwise prescribed seismic forces, in addition to the requirements of Section 2213.8.2.2.

2. The beam intersected by chevron braces shall be continuous between columns.

3. Where chevron braces intersect a beam from below, i.e., inverted V brace, the beam shall be capable of supporting all tributary gravity loads presuming the bracing not to exist.

EXCEPTION: This limitation need not apply to penthouses, one-story buildings or the top story of buildings.

2213.8.4.2 K bracing. K bracing is prohibited except as permitted in Section 2213.8.5.

2213.8.4.3 Nonconcentric bracing. Nonconcentric bracing shall conform with the following:

1. Any member intersected by the brace shall be continuous through the connection.

2. When the eccentricity of the brace is greater than the depth of the intersected member at the eccentric location, the affected member shall have the strength to resist the forces prescribed in Section 2213.8.3.1, including the effects of all secondary forces resulting from the eccentricities.

2213.8.5 One- and two-story buildings. Braced frames not meeting the requirements of Sections 2213.8.2 and 2213.8.4 may be used in buildings not over two stories in height and in roof structures as defined in Chapter 15 if the braces have the strength to resist Ω_o times the design seismic forces.

2213.8.6 Nonbuilding structures. Nonbuilding structures with R values defined by Table 16-P need comply only with the provisions of Section 2213.8.3.

2213.9 Requirements for Special Concentrically Braced Frames.

2213.9.1 General. The provisions of this section apply to special concentrically braced frame structures as defined in Section 1625. All members and connections in special braced frames shall be designed and detailed to resist shear and flexure caused by eccentricities in the geometry of the members comprising the frame in accordance with Section 2213.9. Any member intersected by a brace shall be continuous through the connection. Horizontal bracing that transfers forces between horizontally offset bracing in the vertical plane shall be subject to the requirements of Section 2213.9, except Sections 2213.9.2.3; 2213.9.4.1, Item 3; and 2213.9.4.2. Horizontal bracing other than the above is not subjected to the requirements of Section 2213.9.

2213.9.2 Bracing members.

2213.9.2.1 Slenderness. The kl/r ratio for bracing members shall not exceed $1{,}000/\sqrt{F_y}$ (For **SI:** $5.87\sqrt{E/F_y}$), except as permitted in Section 2213.9.6.

2213.9.2.2 Lateral-force distribution. The seismic lateral force along any line of bracing shall be distributed to the various members so that neither the sum of the horizontal components of forces in members acting in compression or tension exceed 70 percent of the total force.

> **EXCEPTION:** Where compression bracing acting alone has the strength to resist Ω_o times the design seismic force, such distribution is not required.

A line of bracing is defined, for the purposes of this provision, as a single line or parallel lines within 10 percent of the dimension of the structure perpendicular to the line of bracing.

2213.9.2.3 Built-up members. The spacing of stitches shall be such that the slenderness ratio (l/r) of individual elements between the stitches does not exceed 0.4 times the governing slenderness ratio of the built-up member. The total shear strength of the stitches shall be at least equal to the tensile strength of each element. The spacing of the stitches shall be uniform and not less than two stitches shall be used. Bolted stitches shall not be located within the middle one fourth of the clear brace length.

> **EXCEPTION:** Where it can be shown that braces can buckle without causing shear in the stitches, the spacing of the stitches shall be such that the slenderness ration (l/r) of the individual element between the stitches does not exceed 0.75 times the governing slenderness ratio of the built-up member.

2213.9.2.4 Compression elements in braces. The width-thickness ratio of compression elements used in braces shall meet the requirements of Division III, Table B5.1, for compact sections. The width-thickness ratio of angle section shall be limited to $52/\sqrt{F_y}$ (For **SI:** $0.31\sqrt{E/F_y}$). Circular sections shall have outside diameter-wall thickness ratio not exceeding $1,300/F_y$ (For **SI:** $7.63\,E/F_y$), rectangular tubes shall have outside wall width-thickness ratio not exceeding $110/\sqrt{F_y}$ (For **SI:** $0.65\sqrt{E/F_y}$).

> **EXCEPTION:** Compression elements stiffened to resist local buckling.

2213.9.3 Bracing connections.

2213.9.3.1 Forces. Bracing connections shall have the strength to resist the lesser of the following:

1. The strength of the brace in axial tension, P_{st}.

2. Ω_o times the force in the brace due to the design seismic forces, in combination with gravity loads.

3. The maximum force that can be transferred to the brace by the system.

Bracing connections shall, as a minimum, satisfy the load combinations required by Section 1612.3 at allowable stress limits with stress increases allowed by Section 1612.3.2. Beam-to-column connections for beams that are part of the bracing system shall have the capacity to transfer the force determined above. Where eccentricities in the frame geometry or connection load path exist, the affected members and connections shall have the strength to resist all secondary forces resulting from the eccentricities in combination with all primary forces using the lesser of the forces determined above.

2213.9.3.2 Net area. In bolted brace connections, the ratio of effective net section area to gross section shall satisfy Formula (13-6) of Section 2213.8.3.2.

2213.9.3.3 Gusset plates. End connections of braces shall provide a flexural strength in excess of that of the brace gross section about the critical buckling axis.

> **EXCEPTION:** Where the out-of-plane buckling strength of the brace is less than the in-plane buckling strength, the brace is permitted to terminate on a single gusset plate connection with a setback of two times the gusset thickness from a line about which the gusset plate may bend unrestrained by the column or beam joints. The gusset plate shall be designed to carry the compressive strength of the brace without buckling.

2213.9.4 Bracing configuration.

2213.9.4.1 Chevron bracing. Chevron bracing shall conform with the following:

1. The beam intersected by chevron braces shall be continuous between columns.

2. Where chevron braces intersect a beam from below, i.e., inverted V brace, the beam shall be capable of supporting all tributary gravity loads presuming the bracing not to exist.

3. A beam intersected by chevron braces shall have the strength to support the following tributary gravity loads and unbalanced brace force combinations:

$$1.2D + 0.5L + P_b$$

$$0.9D - P_b$$

WHERE:

D = tributary dead load.

L = tributary live load.

P_b = the maximum unbalanced post-buckling force that can be applied to the beam by the braces. For this purpose, the maximum unbalanced force may be computed using a minimum of P_{st} for the tension and a maximum of 0.3 P_{sc} for the compression brace.

4. Both flanges of beams at the point of intersection of chevron braces shall be laterally supported directly or indirectly.

> **EXCEPTION:** Limitations 2 and 3 need not apply to penthouses, one-story buildings or the top story of buildings.

2213.9.4.2 K bracing. K bracing is prohibited.

2213.9.5 Columns. Columns in braced frames shall meet the requirements of Section 2213.7.3. In addition to meeting the requirements of Sections 2213.5.1 and 2213.5.2, column splices shall be designed to develop the full shear strength and 50 percent of the full moment strength of the section. Splices shall be located in the middle one third of the column clear height.

2213.9.6 Nonbuilding structures. Nonbuilding structures with R_w values defined by Table 16-P need comply only with the provisions of Sections 2213.9.3.1 and 2213.9.3.2.

2213.10 Eccentrically Braced Frame (EBF) Requirements.

2213.10.1 General. Eccentrically braced frames shall be designed in accordance with this section.

2213.10.2 Link beam. There shall be a link beam provided at least at one end of each brace. Beams in EBFs shall comply with the requirements of Division III, except that the flange width-thickness ratio, $b_f/2t_f$, shall not exceed $52/\sqrt{F_y}$. (For **SI:** $0.31\sqrt{E/F_y}$.)

2213.10.3 Link beam strength. Link beam shear strength, V_s, and flexural strength, M_s, are the strengths as defined in Section 2213.4.2. Where link beam strength is governed by shear, the flexural and axial capacities within the link shall be calculated using the beam flanges only.

A reduced flexural strength, M_{rs}, for use in Sections 2213.10.8 and 2213.10.13 is defined as $Z(F_y - f_a)$. Where f_a is less than $0.15F_y$, f_a may be neglected.

2213.10.4 Link beam rotation. The rotation of the link segment relative to the rest of the beam, at a total frame drift of Δ_M, shall not exceed the following:

1. 0.090 radian for link segments having clear lengths of 1.6 M_s/V_s or less.

2. 0.030 radian for link segments having clear lengths of 3.0 M_s/V_s or greater.

3. A value obtained by linear interpolation for clear lengths between the above limits.

2213.10.5 Link beam web. The web of the link beam shall be single thickness without doubler plate reinforcement. No openings shall be placed in the web of a link beam. The web shear shall not exceed $0.8V_s$ under prescribed lateral forces.

2213.10.6 Beam connection braces. Brace-to-beam connections shall develop the compression strength of the brace and transfer this force to the beam web. No part of the brace-to-beam connection shall extend into the web area of a link beam.

2213.10.7 Link beam stiffeners. Link beams shall have full-depth web stiffeners on both sides of the beam web at the brace end of the link beam. In addition, for link beams with clear lengths within the limits in Section 2213.10.4, Item 3, full-depth stiffeners shall be placed at a distance b_f from each end of the link. The stiffeners shall have a combined width not less than $b–2\,t_w$ and a thickness not less than 0.75 t_w or less than $^3/_8$ inch (9.5 mm).

2213.10.8 Intermediate stiffeners. Intermediate full-depth web stiffeners shall be provided in either of the following conditions:

1. Where the link beam strength is controlled by V_s.

2. Where the link beam strength is controlled by flexure and the shear determined by applying the reduced flexural strength, M_{rs}, exceeds 0.45 $F_y dt$.

2213.10.9 Web stiffener spacing. Where intermediate web stiffeners are required, the spacing shall conform to the requirements given below.

1. For link beams with rotation angle of 0.09 radian, the spacing shall not exceed $38t_w – d/5$.

2. For link beams with a rotation angle of 0.03 radian or less, the spacing shall not exceed $56t_w – d/5$. Interpolation may be used for rotation angles between 0.03 and 0.09 radian.

2213.10.10 Web stiffener location. For beams 24 inches (610 mm) in depth and greater, intermediate full-depth web stiffeners are required on both sides of the web. Such web stiffeners are required only on one side of the beam web for beams less than 24 inches (610 mm) in depth. The stiffener thickness, t_w, of one side stiffeners shall not be less than $^3/_8$ inch (9.5 mm) and the width shall not be less than $(b_f/2) – t_w$.

2213.10.11 Stiffener welds. Fillet welds connecting the stiffener to the beam web shall develop a stiffener force of $A_{st}F_y$. Fillet welds connecting the stiffener to the flanges shall develop a stiffener force of $A_{st}F_y/4$.

WHERE:

A_{st} = bt of stiffener.
b = width of stiffener plate.

2213.10.12 Link beam-column connections. Length of link beam connected to columns shall not exceed 1.6 M_s/V_s.

1. Where a link beam is connected to the column flange, the following requirements shall be met:

1.1 The beam flanges shall have full-penetration welds to the column.

1.2 Where the link beam strength is controlled by shear in conformance with Section 2213.10.8, the web connection shall be welded to develop the full link beam web shear strength.

2. Where the link beam is connected to the column web, the beam flanges shall have full-penetration welds to the connection plates and the web connection shall be welded to develop the link beam web shear strength. Rotation between the link beam and the column shall not exceed 0.015 radian at a total frame drift of Δ_M.

2213.10.13 Brace and beam strengths. The controlling link beam strength is either the shear strength, V_s, or the reduced flexural strength, M_{rs}, whichever results in the lesser axial force in the brace.

Each brace and beam outside the link shall have the axial strength or reduced flexural strength, M_{rs}, at least 1.5 times the forces corresponding to the controlling link beam strength. Each brace and beam assembly outside the link shall have combined reduced flexural strengths, M_{rs}, at least 1.3 times the forces corresponding to the controlling link beam strength.

2213.10.14 Column strength. Columns shall be designed to remain elastic at 1.25 times the strength of the EBF bay, as defined in Section 2213.10.13. Column strength need not exceed the requirements of Section 2213.5.

2213.10.15 Roof link beam. A link beam is not required in roof beams for EBF over five stories.

2213.10.16 Concentric brace in combination. The first story of an EBF bay over five stories in height may be concentrically braced if this story can be shown to have an elastic capacity 50 percent greater than the yield capacity of the story frames above the first story.

2213.10.17 Axial forces. Axial forces in beams of EBF frames due to braces and due to transfer of seismic force to the end of the frames shall be included in the frame calculations.

2213.10.18 Beam flanges. Top and bottom flanges of EBF beams shall be laterally braced at the ends of link beams and at intervals not exceeding $76/\sqrt{F_y}$ (For **SI:** $0.45\sqrt{E/F_y}$) times the beam flange width. End bracing shall be designed to resist 6.0 percent of the beam flange strength, defined as $F_y b_f t_f$. Intermediate bracing shall be designed to resist 1.0 percent of the beam flange force at the brace point using the link beam strength determined in Section 2213.10.13.

2213.10.19 Beam-column connection. Beam connections to columns may be designed as pins in the plane of the beam web if the link beam is not adjacent to the column. Such connection shall have the capacity to resist a torsional moment of $0.01F_y\, b_f t_f d$.

2213.11 Requirements for Special Truss Moment Frames.

2213.11.1 General. Special truss moment frames of steel shall be designed in accordance with this section.

2213.11.2 Special segment. Each horizontal truss which is part of the moment frame shall have a special segment located within the middle one-half length of the truss. Such trusses shall be limited to span lengths between columns not to exceed 50 feet (15 240 mm) and overall depth not to exceed 6 feet (1829 mm). The length of the special segment shall range from 0.1 to 0.5 times the truss span length. The length-to-depth ratio of any panel in the special segment shall be limited to a maximum of 1.5 and a minimum of 0.67. All panels within the special segment shall be either Vierendeel or X braced, not a combination thereof. Where diagonal members are used in the special segment, they shall be arranged in an X pattern separated by vertical members. Such diagonal members shall be interconnected at points of crossing. The interconnection shall have the strength to resist a force at least equal to 0.25 times the diagonal member tension strength. Bolted connections shall not be used for web members within the special segment. Splicing of chord members shall not be permitted within the special segment or within a one-half panel length from the ends of the special segment. Axial stresses in diagonal web members due to concentrated dead plus live loads acting within the special segment shall not exceed $0.03F_y$.

2213.11.3 Special segment members strength. In the fully yielded state, the special segment shall develop vertical shear strength through flexural strength of the chord members and through axial tension and compression strength of diagonal web members. The top and bottom chord members in the special segment shall be made of identical sections and shall provide at least 25 percent of the required vertical shear strength. The maximum axial stress in the chord members shall not exceed $0.4F_y$. Diagonal members in any panel of the special segment shall be made of identical sections. The end connections of diagonal web members in the special segment shall have strength to resist a minimum force equal to P_{st} of the member.

2213.11.4 Nonspecial segment member strength. All members and connections of special truss moment frames, except those in Section 2213.11.3, shall have strength to resist the forces due to combination of specified gravity loads and lateral forces necessary to develop maximum amplified vertical shear force in all special segments, V_{ss}, given by the following formula:

$$V_{ss} = \frac{3.4\ M_s}{L_s} + 0.11\ EI\ \frac{(L - L_s)}{L_s^3} + 1.25\ (P_{st} + 0.3\ P_{sc})\ \sin\ \alpha \qquad (13\text{-}7)$$

WHERE:

EI = flexural stiffness of the chord members.

L = span length of the truss.

L_s = 0.9 times the length of the special segment.

M_s = flexural strength of the chord members.

P_{sc} = axial compression strength of diagonal members.

P_{st} = axial tension strength of diagonal members.

α = angle that the diagonal members make with the horizontal.

2213.11.5 Connections. Connections of all elements in the truss frames, including those within the truss, shall conform to the requirements of Section 1633.2.3.

2213.11.6 Compactness. Diagonal web members of the special segment shall be made of flat bars. The width-thickness ratio of such flat bars shall not exceed 2.5. The width-thickness ratio of angles, and flanges and webs of T sections used for chord members in the special segment shall not exceed $52/\sqrt{F_y}$ (For **SI:** $0.31\sqrt{E/F_y}$).

2213.11.7 Lateral bracing. Top and bottom chords of the trusses shall be laterally braced at the ends of the special segment, and at intervals not to exceed L_p according to Chapter 22, Division II, Section F1.1, along the entire length of the truss. Each lateral brace at the ends of and within the special segment shall have strength to resist at least 5 percent of P_{st} of the chord member. Lateral braces outside of the special segment shall have strength to resist at least 2.5 percent of P_{st} of the chord member.

2213.11.8 Materials. The material specifications of Division III are superseded by the requirements of Section 2213.4.1 for all elements in the special trusses.

SECTION 2214 — SEISMIC PROVISIONS FOR STRUCTURAL STEEL BUILDINGS IN SEISMIC ZONES 1 AND 2

2214.1 General. Design and construction of steel framing in lateral-force-resisting systems in Seismic Zones 1 and 2 shall conform to the requirements of this code. Additionally, in Seismic Zone 2, such framing shall conform to the requirements of this section. Ordinary moment frames in Seismic Zone 1, meeting the requirements of Section 2214.4, may use an R value of 8.5. Other framing in Seismic Zone 1 need not comply with this section.

2214.2 Definitions. Definitions shall be as prescribed in Section 2213.2.

2214.3 Materials. Materials shall be as prescribed in Section 2213.4.

EXCEPTION: Ordinary moment frames in accordance with Section 2214.4.

2214.4 Ordinary Moment Frame Requirements. Ordinary moment frames (OMF) shall be designed to resist the load combinations of Section 1612.2 for Load and Resistance Factor Design or Section 1612.3 for Allowable Stress Design. Ordinary moment frames in Seismic Zone 1 meeting these requirements may use an R value of 8.5.

All beam-to-column connections in OMFs that resist earthquake forces shall meet one of the following requirements:

1. Fully restrained (Type F.R. or Type 1) conforming to Section 2214.5.1.

2. Fully restrained (Type F.R. or Type 1) connections with the design strengths of the connections capable of resisting a combination of gravity loads and Ω_o times the design seismic forces.

3. Partially restrained (Type P.R. or Type 3) connections are permitted provided:

3.1 The connections are designed to resist the load combinations in Section 1612.2 for Load and Resistance Factor Design or Section 1612.3 for Allowable Stress Design, and

3.2 The connections have been demonstrated by cyclic tests to have adequate rotation capacity to accommodate a story drift due to Ω_o times the design seismic forces.

3.3 The moment frame drift calculations shall include the contribution due to the rotation and distortion of the connection.

See Divisions II and III for definitions of fully restrained and partially restrained connections.

2214.5 Special Moment-resisting Frame (SMRF) Requirements.

2214.5.1 Girder-to-column connection.

2214.5.1.1 Required strength. The girder-to-column connection shall be adequate to develop the lesser of the following:

1. The strength of the girder in flexure.

2. The moment corresponding to development of the panel zone shear strength as determined from Formula (13-1).

EXCEPTION: Where a connection is not designed to contribute flexural resistance at the joint, it need not develop the required strength if it can be shown to meet the deformation compatibility requirements of Section 1633.2.4.

2214.5.1.2 Connection strength. The girder-to-column connection may be considered to be adequate to develop the flexural strength of the girder if it conforms to the following:

1. The flanges have full-penetration butt welds to the columns.

2. The girder web-to-column connection shall be capable of resisting the girder shear determined for the combination of gravity loads and the seismic shear forces which result from compliance with Section 2214.5.1.1. This connection strength need not exceed that required to develop gravity loads plus Ω_o times the girder shear resulting from the design seismic forces.

Where the flexural strength of the girder flanges is greater than 70 percent of the flexural strength of the entire section [i.e., $bt_f(d-t_f)F_y>0.7Z_xF_y$] the web connection may be made by means of welding or high-strength bolting.

For girders not meeting the criteria in the paragraph above, the girder web-to-column connection shall be made by means of welding the web directly or through shear tabs to the column. That welding shall have a strength capable of development at least 20 percent of the flexural strength of the girder web. The girder shear shall be resisted by means of additional welds or friction-type high-strength bolts or both.

2214.5.1.3 Alternate connection. Connection configurations utilizing welds or high-strength bolts not conforming with Section 2214.5.1.2 may be used if they are shown by test or calculation to meet the criteria in Section 2214.5.1.1. Where conformance is shown by calculation, 125 percent of the strengths of the connecting elements may be used.

2214.5.1.4 Flange detail limitations. For steel whose specified strength is less than 1.5 times the specified yield strength, plastic hinges shall not form at locations in which the beam flange area has been reduced, such as for bolt holes. Bolted connections of flange plates of beam-column joints shall have the net-to-gross area ratio A_e/A_g equal to or greater than $1.2F_y/F_u$.

2214.5.2 Trusses in SMRF. Trusses may be used as horizontal members in SMRF if the sum of the truss seismic force flexural strength exceeds the sum of the column seismic force flexural strength immediately above and below the truss by a factor of at least 1.25. For this determination, the strengths of the members shall be reduced by the gravity load effects. In buildings of more than one story, the column axial stress shall not exceed $0.4F_y$ and the ratio of the unbraced column height to the least radius of gyration shall not exceed 60. The connection of the truss chords to the column shall develop the lesser of the following:

1. The strength of the truss chord.

2. The chord force necessary to develop 125 percent of the flexural strength of the column.

2214.5.3 Girder-column joint restraint.

2214.5.3.1 Restrained joint. Where it can be shown that the columns of SMRF remain elastic, the flanges of the columns need be laterally supported only at the level of the girder top flange.

Columns may be assumed to remain elastic if one of the following conditions is satisfied:

1. The ratio in Formula (13-3-1) or (13-3-2) is greater than 1.25.

2. The flexural strength of the column is at least 1.25 times the moment that corresponds to the panel zone shear strength.

3. Girder flexural strength or panel zone strength will limit column stress ($f_a + f_{bx} + f_{by}$) to F_y of the column.

4. The column will remain elastic under gravity loads plus Ω_o times the design seismic forces.

Where the column cannot be shown to remain elastic, the column flanges shall be laterally supported at the levels of the girder top and bottom flanges. The column flange lateral support shall be capable of resisting a force equal to one percent of the girder flange capacity at allowable stresses [and at a limiting displacement perpendicular to the frame of 0.2 inch (5.08 mm)]. Required bracing members may brace the column flanges directly or indirectly through the column web or the girder flanges.

2214.5.3.2 Unrestrained joint. Columns without lateral support transverse to a joint shall conform to the requirements of Division III, with the column considered as a pin ended and the length taken as the distance between lateral supports conforming with Section 2214.5.3.1. The column stress, F_a, shall be determined from gravity loads plus the lesser of the following:

1. Ω_o times the design seismic forces.

2. The forces corresponding to either 125 percent of the girder flexural strength or the panel zone shear strength.

The stress, f_{by}, shall include the effects of the bracing force specified in Section 2214.5.3.1 and $P\,\Delta$ effects.

l/r for such columns shall not exceed 60.

At truss frames, the column shall be braced at each truss chord for a lateral force equal to one percent of the compression yield strength of the chord.

2214.5.4 Changes in beam flange area. Abrupt changes in beam flange area are not permitted within possible plastic hinge regions of special moment-resistant frames.

2214.6 Requirements for Braced Frames.

2214.6.1 General. The provisions of this section apply to all braced frames, except special concentrically braced frames designed in accordance with Section 2213.9 and eccentrically braced frames designed in accordance with Section 2213.9. Those members which resist seismic forces totally or partially by shear or flexure shall be designed in accordance with Section 2214.5.

2214.6.2 Bracing members.

2214.6.2.1 Stress reduction. The allowable stress, F_{as}, for bracing members resisting seismic forces in compression shall be determined from the following formula:

$$F_{as} = BF_a \qquad (14\text{-}1)$$

WHERE:

B = the stress-reduction factor determined from the following formula:

$$B = 1/\{1 + [(Kl/r)/2C_c]\} \geq 0.8 \qquad (14\text{-}2)$$

F_a = the allowable axial compressive stress allowed in Division III.

EXCEPTION: Bracing members carrying gravity loads may be designed using the column strength requirement and load combinations of Section 2213.5.1, Item 1.

2214.6.2.2 Built-up members. The *l/r* of individual parts of built-up bracing members between stitches, when computed about a line perpendicular to the axis through the parts, shall not be greater than 75 percent of the *l/r* of the member as a whole.

2214.6.2.3 Compression elements in braces. The width-to-thickness ratio of stiffened and unstiffened compression elements used in braces shall be shown in Division III.

2214.6.3 Bracing connections.

2214.6.3.1 Forces. Bracing connections shall be designed for the lesser of the following:

1. The tensile strength of the bracing.
2. Ω_o times the force in the brace due to design seismic forces.
3. The maximum force that can be transferred to the brace by the system.

Beam-to-column connections for beams that are part of the bracing system shall have the capacity to transfer the force determined above.

2214.6.3.2 Net area. In bolted brace connections, the ratio of effective net section area to gross section area shall satisfy the formula:

$$\frac{A_e}{A_g} = \frac{1.2\alpha F^*}{F_u} \qquad (14\text{-}3)$$

WHERE:

A_e = effective net area as defined in Division III.

A_g = gross area of the member.

F_u = minimum tensile strength.

F^* = stress in brace due to the forces determined in Section 2213.8.3.1.

α = fraction of the member force from Section 2213.8.3.1 that is transferred across a particular net section.

2214.6.4 Bracing configuration for chevron and K bracing. Bracing members shall be designed for 1.5 times the otherwise prescribed forces.

The beam intersected by chevron braces shall be continuous between columns.

Where chevron braces intersect a beam from below, i.e., inverted V brace, the beam shall be capable of supporting all tributary gravity loads presuming the bracing not to exist.

EXCEPTION: This limitation need not apply to penthouses, one-story buildings or the top story of buildings.

2214.6.5 One- and two-story buildings. Braced frames not meeting the requirements of Sections 2214.6.2 and 2214.6.4 may be used in buildings not over two stories in height and in roof structures as defined in Chapter 15 if the braces have the strength to resist Ω_o times the design seismic forces.

2214.6.6 Nonbuilding structures. Nonbuilding structures with *R* values defined by Table 16-P, need comply only with the provisions of Section 2214.6.3.

2214.7 Special Concentrically Braced Frames. Special concentrically braced frames shall comply with the requirements of Section 2213.9.

2214.8 Eccentrically Braced Frames. Eccentrically braced frames shall comply with the requirements of Section 2213.10.

2214.9 Nondestructive Testing. Nondestructive testing shall comply with the provisions of Section 1703.

2214.10 Special Truss Moment Frames. Special truss moment frames shall comply with the requirements of Section 2213.11.

Division VI—LOAD AND RESISTANCE FACTOR DESIGN SPECIFICATION FOR COLD-FORMED STEEL STRUCTURAL MEMBERS

SECTION 2215 — ADOPTION

Except for the modifications as set forth in Section 2216 of this division and the requirements of the building code, the design of cold-formed steel structural members shall be in accordance with the *Load and Resistance Factor Design Specification for Cold-Formed Steel Structural Members,* March 16, 1991, published by the American Iron and Steel Institute, 1101 17th Street, NW, Suite 1300, Washington, DC, as if set out at length herein. The adoption of Load and Resistance Factor Design Specification for Cold-Formed Steel Structural Members, hereinafter referred to as the AISI-LRFD.

Where other codes, standards or specifications are referred to in this specification, they are to be considered as only an indication of an acceptable method or material that can be used with the approval of the building official.

SECTION 2216 — AMENDMENTS

The following amendments shall be made to the AISI-LRFD specifications, as adopted in Section 2215:

1. Sec. A4.1 is deleted in its entirety.

2. Sec. A4.2 is deleted in its entirety.

3. Sec. A4.4 is deleted in its entirety.

4. Sec. A5.1.4 is deleted and substituted as follows:

The nominal loads shall be the minimum design loads required by the code.

Division VII—SPECIFICATION FOR DESIGN OF COLD-FORMED STEEL STRUCTURAL MEMBERS

SECTION 2217 — ADOPTION

Except for the modifications as set forth in Section 2218 of this division and the requirements of the building code, the design of cold-formed steel structural members shall be in accordance with the *Specification for Design of Cold-Formed Steel Structural Members,* 1986 (with December 1989 Addendum), published by the American Iron and Steel Institute, 1101 17th Street, NW, Suite 1300, Washington, DC, as if set out at length herein. The Specification for Design of Cold-Formed Steel Structural Members shall hereinafter be referred to as the AISI-ASD.

Where other codes, standards or specifications are referred to in this specification, they are to be considered as only an indication of an acceptable method or material that can be used with the approval of the building official.

SECTION 2218 — AMENDMENTS

The following amendments shall be made to the AISI ASD specification, as adopted in Section 2217:

1. Secs. A4.1 and A4.2. are deleted in their entirety without replacement.

2. Sec. A4.4. Revise as follows:

Where load combinations specified by Section 1612.3 include wind or earthquake loads, the resulting forces may be multiplied by 0.75 for strength determination. Such reduction shall not be allowed in combination with stress increases in accordance with Section 1612.3.1.

3. Sec. E6. Revise as follows:

The following notations apply to this section:

d = nominal screw diameter.

F_{u1} = tensile strength of member in contact with the screw head.

F_{u2} = tensile strength of member not in contact with the screw head.

P_{as} = allowable shear force per screw.

P_{at} = allowable tension force per screw.

P_{not} = pull-out force per screw.

P_{nov} = pull-over force per screw.

P_{ns} = nominal shear strength per screw.

P_{nt} = nominal tension strength per screw.

t_1 = thickness of member in contact with the screw head.

t_2 = thickness of member not in contact with the screw head.

Ω = factor of safety = 3.0.

All E6 requirements shall apply to self-tapping screws with 0.08 inch (2.03 mm) < d < 0.25 inch (6.35 mm). The screws shall be thread-forming or thread-cutting, with or without a self-drilling point. Alternatively, design values for a particular application shall be permitted to be based on tests according to Section F. For diaphragm applications, Section D5 shall be used.

Screws shall be installed and tightened in accordance with the manufacturer's recommendations.

The tension force on the net section of each member joined by a screw connection shall not exceed T_a from Section C2 or P_a from Section E3.2.

E6.1 Minimum Spacing. The distance between the centers of fasteners shall not be less than 3*d*.

E6.2 Minimum Edge and End Distance. The distance from the center of a fastener to the edge of any part shall not be less than 3*d*. If the connection is subjected to shear force in one direction only, the minimum edge distance shall be reduced to 1.5*d* in the direction perpendicular to the force.

E6.3 Shear.

E6.3.1 Connection shear. The shear force per screw shall not exceed P_{as} calculated as follows:

$$P_{as} = P_{ns}/\Omega$$

For $t_2/t_1 \leq 1.0$, P_{ns} = shall be taken as the smallest of

$$P_{ns} = 4.2\,(t_2^3\,d)^{1/2}\,F_{u2} \quad \text{(Eq. E6.3.1)}$$

$$P_{ns} = 2.7 t_1\,d\,F_{u1} \quad \text{(Eq. E6.3.2)}$$

$$P_{ns} = 2.7\,t_2\,d\,F_{u2} \quad \text{(Eq. E6.3.3)}$$

For $t_2/t_1 \geq 2.5$, P_{ns} shall be taken as the smaller of

$$P_{ns} = 2.7 t_1\,d\,F_{u1} \quad \text{(Eq. E6.3.4)}$$

$$P_{ns} = 2.7\,t_2\,d\,F_{u2} \quad \text{(Eq. E6.3.5)}$$

For $1.0 < t_2/t_1 < 2.5$, P_{ns} shall be determined by linear interpolation between the above two cases.

E6.3.2 Shear in screws. The shear capacity of the screw shall be determined by test according to Section F1(a). The shear capacity of the screw shall not be less than 1.25 P_{ns}.

E6.4 Tension. For screws that carry tensile loads, the head of the screw or washer, if a washer is provided, shall have a diameter d_w, not less than $^5/_{16}$ inch (7.95 mm). Washers shall be at least 0.050 inch (1.27 mm) thick.

The tension force per screw shall not exceed P_{at}, calculated as follows:

$$P_{at} = P_{nt}/\Omega \quad \text{(Eq. E6.4.l)}$$

P_{nt} = shall be taken as the lesser of P_{not} and P_{nov} as determined in Sections E4.4.l and E4.4.2.

E6.4.1 Pull-out. The pull-out force, P_{not}, shall be calculated as follows:

$$P_{not} = 0.85 t_c\,d\,F_{u2} \quad \text{(Eq. E6.4.1.)}$$

where t_c is the lesser of the depth of the penetration and the thickness, t_2.

E6.4.2 Pull-over. The pull-over force, P_{nov}, shall be calculated as follows:

$$P_{nov} = 1.5 t_1\,d_w\,F_{u1} \quad \text{(Eq. E6.4.2.l)}$$

where d_w is the larger of the screw head diameter or the washer diameter and shall be taken not larger than $^1/_2$ inch (12.7 mm).

E6.4.3 Tension in screws. The tensile capacity of the screw shall be determined by test according to Section F1(a). The tensile capacity of the screw shall not be less than 1.25 P_{nt}.

Division VIII—LATERAL RESISTANCE FOR STEEL STUD WALL SYSTEMS

SECTION 2219 — GENERAL

CHAP. 22, DIV. VIII

Steel stud wall systems in which shear panels are used to resist lateral loads produced by wind or earthquake shall comply with the requirements of this section. The nominal shear value used to establish the allowable shear value or design shear value shall not exceed the values set forth in Table 22-VIII-A or Table 22-VIII-B for wind loads or Table 22-VIII-C for seismic loads. The allowable shear value (ASD) or design shear value (LRFD) shall be determined using the ϕ or Ω factors as set forth in Section 2219.3.

All boundary members and connections thereto shall be proportioned to transmit the induced forces. Framing members shall be of a minimum size, shape and of a minimum specified yield stress as listed in Table 22-VIII-A, 22-VIII-B or 22-VIII-C. Fasteners between framing members and between the panels and the framing members shall be as specified in Table 22-VIII-A, 22-VIII-B or 22-VIII-C. Fasteners along the edges in shear panels shall be placed not less than $^{3}/_{8}$ inch (9.5 mm) in from panel edges. Screws shall be of sufficient length to ensure penetration into the steel stud by at least two full diameter threads.

Panel thickness shown in Tables 22-VIII-A and 22-VIII-B shall be considered as minimum.

No panels less than 12 inches (305 mm) wide shall be used. All panel edges shall be fully blocked. Where horizontal strap blocking is used, it shall be a minimum $1^{1}/_{2}$ inches (38 mm) wide and of the same material and thickness as the track and studs. Studs shall be doubled (back to back) at shear wall ends.

The height to length ratio of wall systems listed in Tables 22-VIII-A, 22-VIII-B and 22-VIII-C shall not exceed 2:1.

2219.1 Wood Structural Panel Sheathing. As an alternative to the provisions in Tables 22-VIII-A and 22-VIII-C, steel stud wall systems sheathed with wood structural panels may be used to resist horizontal forces from wind or seismic loads where allowable shear loads may be calculated by the principles of mechanics without limitation by using the wood structural panel shear values in the code and approved fastener values. Where $^{7}/_{16}$ inch (11 mm) OSB is specified, $^{15}/_{32}$-inch (12 mm) Structural 1 sheathing (plywood) may be substituted. Structural panels may be applied either parallel to or perpendicular to framing. No increase of the nominal loads shown in Tables 22-VIII-A and 22-VIII-C shall be permitted for duration of load nor shall an increase in nominal loads be permitted for installing sheathing on the opposite side unless indicated herein.

2219.2 Gypsum Board Panel Sheathing. Stud wall systems sheathed with gypsum board may be used to resist horizontal forces produced by wind loads when the nominal load used to establish the allowable shear value or design shear value does not exceed the nominal value set forth in Table 22-VIII-B.

The values listed in Table 22-VIII-B shall not be cumulative with the shear values of other materials applied to the same wall; values shown shall not be increased when applied to both sides of the same panel.

End joints of adjacent courses of gypsum board sheets shall not occur over the same stud. Gypsum board shall be applied perpendicular to studs in accordance with Table 22-VIII-B.

2219.3 Design. Where allowable stress design is used, the allowable shear value shall be determined by dividing the nominal shear value, shown in Tables 22-VIII-A and 22-VIII-B, by a factor of safety (Ω) which shall be taken as 3.0. The factor of safety (Ω) for the nominal loads shown in Table 22-VIII-C shall be taken as 2.5.

Where Load and Resistance Factor Design is used, the design shear value shall be determined by multiplying the nominal shear value, shown in Tables 22-VIII-A and 22-VIII-B, by a resistance factor (ϕ) which shall be taken as 0.45. The resistance factor (ϕ) for the nominal loads shown in Table 22-VIII-C shall be taken as 0.55.

SECTION 2220 — SPECIAL REQUIREMENTS IN SEISMIC ZONES 3 AND 4

2220.1 General. In Seismic Zones 3 and 4, in addition to the requirements of Section 2219, steel stud wall systems may be used to resist the specified seismic forces in buildings not over five stories in height. Such systems shall comply with the following:

1. The *l/r* of the brace may exceed 200 and is unlimited.

2. All boundary members, chords and collectors shall be designed and detailed to transmit the induced axial forces.

3. Connection of the diagonal bracing member, top chord splices, boundary members and collectors shall be designed to develop the full tensile strength of the member or Ω_o times the otherwise prescribed seismic forces.

4. Vertical and diagonal members of the braced bay shall be anchored so the bottom track is not required to resist uplift forces by bending of the track web.

5. Both flanges of studs in a bracing panel shall be braced to prevent lateral torsional buckling. Wire-tied bridging shall not be considered to provide such restraint.

6. Screws shall not be used to resist lateral forces by pullout resistance.

7. Provision shall be made for pretensioning or other methods of installation of tension-only bracing to guard against loose diagonal straps.

2220.2 Boundary Members and Anchorage. Boundary members and the uplift anchorage thereto shall have the strength to resist the forces determined by the load combinations in Section 2213.5.1.

2220.3 Wood Structural Panel Sheathing. Where wood structural panels provide lateral resistance, the design and construction of such walls shall be in accordance with the additional requirements of this section. Perimeter members at openings shall be provided and shall be detailed to distribute the shearing stresses. Wood sheathing shall not be used to splice these members.

Wood structural panels shall be manufactured using exterior glue.

Wall studs and track shall have a minimum uncoated base metal thickness of not less than 0.033 inch (0.84 mm) and shall not have an uncoated base metal thickness greater than 0.043 inch (1.10 mm).

TABLE 22-VIII-A—NOMINAL SHEAR VALUES FOR WIND FORCES IN POUNDS PER FOOT FOR SHEAR WALLS FRAMED WITH COLD-FORMED STEEL[1,2]

ASSEMBLY DESCRIPTION	FASTENER SPACING AT PANEL EDGES[3] (inches)				FRAMING SPACING (inches o.c.)
	× 25.4 for mm × 0.0146 for N/mm				
× 25.4 for mm	6	4	3	2	× 25.4 for mm
$^{15}/_{32}$-inch Structural 1 sheathing (4-ply) one side	1,065[4]	—	—	—	24
$^{7}/_{16}$-inch rated sheathing (OSB) one side	910[4]	1,410	1,735	1,910	24

[1]Nominal shear values shall be multiplied by the appropriate strength reduction factor, Φ, to determine design strength or divided by the appropriate safety factor, Ω, to determine allowable shear values as set forth in Section 2219.3.

[2]Unless otherwise shown, studs shall be a minimum $1^5/_8$ inches (41 mm) by $3^1/_2$ inches (89 mm) with a $^3/_8$-inch (9.5 mm) return lip. Track shall be a minimum $1^1/_4$ inches (32 mm) by $3^1/_2$ inches (89 mm). Both studs and track shall have a minimum uncoated base metal thickness of 0.033 inch (0.84 mm) and shall be ASTM A 446 Grade A [or ASTM A 653, SQ, Grade 33 (new designation)]. Framing screws shall be No. 8 by $^5/_8$-inch (16 mm) wafer head self-drilling. Plywood and OSB screws shall be approved and shall be a minimum No. 8 by 1-inch (25 mm) flat head with a minimum head diameter of 0.292 inch (7.4 mm). Stud spacing shown are maximums.

[3]Screws in the field of the panel shall be installed 12 inches o.c. (305 mm) unless otherwise shown.

[4]Where fully blocked gypsum board is applied to the opposite side of this assembly, per Table 22-VIII-B, these nominal values may be increased by 30 percent.

TABLE 22-VIII-B—NOMINAL SHEAR VALUES FOR WIND FORCES IN POUNDS PER FOOT FOR SHEAR WALLS FRAMED WITH COLD-FORMED STEEL STUDS AND FACED WITH GYPSUM WALLBOARD[1,2]

WALL CONSTRUCTION	ORIENTATION	SCREW SPACING (edge/field) (inches)	NOMINAL SHEAR VALUE (lbs/ft)
× 25.4 for mm		× 25.4 for mm	× 0.0146 for N/mm
$^1/_2$-inch gypsum board on both sides of wall with studs 24 inches o.c.	Gypsum board applied perpendicular to framing with strap blocking behind the horizontal joint and with solid blocking between the first two end studs.	7/7 4/4	585 850

[1]Nominal shear values shall be multiplied by the appropriate strength reduction factor, Φ, to determine design strength or divided by the appropriate safety factor, Ω, to determine allowable shear values as set forth in Section 2219.3.

[2]Unless otherwise shown, studs shall be a minimum $1^5/_8$ inches (41 mm) by $3^1/_2$ inches (89 mm) with a $^3/_8$-inch (9.5 mm) return lip. Track shall be a minimum $1^1/_4$ inches (32 mm) by $3^1/_2$ inches (89 mm). Both studs and track shall have a minimum uncoated base metal thickness of 0.033 inch (0.84 mm) and shall be ASTM A 446 Grade A [or ASTM A 653, SQ, Grade 33 (new designation)]. Framing screws shall be No. 8 by $^5/_8$-inch (16 mm) wafer head self-drilling. Drywall screws shall be a minimum No. 6 by 1 inch (25 mm).

TABLE 22-VIII-C—NOMINAL SHEAR VALUES FOR SEISMIC FORCES IN POUNDS PER FOOT FOR SHEAR WALLS FRAMED WITH COLD-FORMED STEEL STUDS[1,2]

ASSEMBLY DESCRIPTION	FASTENER SPACING AT PANEL EDGES[3] (inches)				FRAMING SPACING (inches o.c.)
	× 25.4 for mm × 0.0146 for N/mm				
× 25.4 for mm	6	4	3	2	× 25.4 for mm
$^{15}/_{32}$-inch Structural 1 sheathing (4-ply) one side	780	990	1,465	1,625	24
$^{7}/_{16}$-inch (OSB) one side	700	915	1,275	1,625	24

[1]Nominal shear values shall be multiplied by the appropriate strength reduction factor, Φ, to determine design strength or divided by the appropriate safety factor, Ω, to determine allowable shear values as set forth in Section 2219.3.

[2]Unless otherwise shown, studs shall be a minimum $1^5/_8$ inches (41 mm) by $3^1/_2$ inches (89 mm) with a $^3/_8$-inch (9.5 mm) return lip. Track shall be a minimum $1^1/_4$ inches (32 mm) by $3^1/_2$ inches (89 mm). Both studs and track shall have a minimum uncoated base metal thickness of 0.033 inch (0.084 mm) and shall not have a base metal thickness greater than 0.043 inch (1.10 mm) and shall be ASTM A 446 Grade A [or ASTM A 653, SQ, Grade 33 (new designation)]. Stud spacing shown are maximums. Framing screws shall be No. 8 by $^5/_8$-inch (16 mm) wafer head self-drilling. Plywood and OSB screws shall be approved and shall be a minimum No. 8 by 1-inch (25 mm) flat head with a minimum head diameter of 0.292 inch (7.4 mm).

[3]Screws in the field of the panel shall be installed 12 inches (305 mm) o.c. unless otherwise shown.

Division IX—OPEN WEB STEEL JOISTS

SECTION 2221 — ADOPTION

CHAP. 22, DIV. IX

In addition to the requirements in the building code, the design, manufacture and use of open web steel joists shall be in accordance with the *Standard Specification for Steel Joists, K-Series, LH-Series, DLH-Series and Joist Girders*, 1994, published by the Steel Joist Institute, 1205 48th Avenue, Suite A, Myrtle Beach, SC 29577, as if set out at length herein.

Where other codes, standards or specifications are referred to in this specification, they are to be considered as only an indication of an acceptable method or material that can be used with the approval of the building official.

Division X—DESIGN STANDARD FOR STEEL STORAGE RACKS

Based on the Specification for the Design, Testing and Utilization of Industrial Steel Storage Racks, 1990 Edition, by the Rack Manufacturers Institute

SECTION 2222 — GENERAL PROVISIONS

2222.1 Scope. This division shall apply to pallet racks, movable shelf racks and stacker-racks made of cold-formed or hot-rolled steel structural members. It shall not apply to other types of racks, such as cantilever racks, drive-in and drive-through racks and rack buildings.

The design of racks not covered by this standard shall be in accordance with the provisions of Section 1632 using the loads as defined in this division.

> **EXCEPTION:** The building official may waive the design requirements for storage racks less than or equal to 8 feet (2438 mm) in height.

2222.2 Definitions. For the purpose of this division, certain terms are defined as follows:

FRAMES are the rigid-connection frames composed of posts and pallet beams in pallet racks, and the upright (trussed) frames.

MOVABLE-SHELF RACKS are a type of rack where the shelves are removable and replaceable in multiple locations in the section opening.

PALLET is a portable platform on which goods are placed for storage or transportation.

PALLET GUIDE is a device to prevent a pallet from sliding off its support beam or rail.

PALLET RACK (also **Standard Pallet Rack**) is a rack which utilizes horizontal beams connected to prefabricated upright frames to provide independent, multiple-level storage (usually on either side of an aisle). The horizontal beams support pallets.

PALLET RACK BEAMS (also **Shelf Beams**) are horizontal structural members used to support pallets in a rack.

STACKER RACKS (also **Stacker Crane Racks**) are a rack arrangement, usually higher than other types of racks, where floor-running storage and retrieval machines are used to shuttle loads. These machines are generally rail mounted and often fully automated and computer controlled.

STACKER-RACK BEAMS are horizontal structural members used to support pallets in a stacker rack.

STEEL STORAGE RACK is a single or multilevel storage system in single or multi-bays consisting of vertical columns or posts and horizontal beams. Diagonal and horizontal trussed bracing is often used to resist horizontal loads. The beams generally support pallets, and the system may be one of a number of different types (Standard Pallet Rack, Stacker Rack, etc.); see definitions of each type.

UNIT LOAD is a standardized load, meaning, for example, pallet load if pallets are used. Also refers to other standardized loads such as barrels which may be stored without pallets.

2222.3 Materials. This standard contemplates the use of steel of structural quality as listed in Division I.

Steels not listed in the above provisions are not excluded, provided they conform to the chemical and mechanical requirements of one of the listed specifications or other published specifications which establish their properties and structural suitability; and provided they are subjected by either the producer or the purchaser to analyses, tests and other controls to the extent and in the manner prescribed by one of the two listed specifications, as applicable.

2222.4 Applicable Design Specifications. Except as either modified or supplemented herein, Division I, shall apply to the design of steel storage racks.

2222.5 Integrity of Rack Installations. Individual rack components and assemblies thereof shall comply with this standard.

All rack installations and racks manufactured in conformity with this standard shall display in one or more conspicuous locations a permanent plaque each not less than 50 square inches (32 258 mm^2] in area and showing the maximum permissible unit load in clear, legible print.

> **EXCEPTION:** The building official may waive plaque installation for racks not exceeding 12 feet (3658 mm) in height to top shelf, covering a floor area less than 300 square feet (27.87 m^2), with a unit load not exceeding 2,500 pounds (11 121 N), and without double stacking on top level.

Load application and rack configuration drawings shall be furnished with each rack installation. The drawings shall present the permissible configurations or limitations as to the maximum number of shelves or rails, the maximum distance between them, and the maximum distance from the floor to the bottom shelf or rail.

The bottom of all posts shall be furnished with bearing plates, according to Section 2227.2. Drive-in, drive-through and stacker racks shall be anchored to the floor by anchor bolts capable of resisting the horizontal shear forces caused by the horizontal and vertical loads on the rack.

The stability of movable-shelf racks shall not be dependent upon movable shelves. Those components which provide stability, such as permanently bolted or welded top shelves and the longitudinal and transverse diagonal bracing, shall be clearly identified on the rack configuration drawings. In specific movable-shelf rack installations where rack height requires it, a conspicuous warning is to be placed in the owner's utilization instruction manual of any restrictions on shelf placement or shelf removal. Such restrictions also are to be permanently posted in locations clearly visible to forklift operators.

Lower portions of posts exposed to damage by forklift trucks or other moving equipment shall have protective devices. If not so protected the rack structure may, at the option of the building official: (1) be designed to maintain its full design load capacity at allowable stresses with the exposed post capacity reduced by one-half, or (2) be designed to maintain its full design load capacity at 50 percent increased allowable stresses with the exposed post assumed to have no carrying capacity.

Where racks are braced against the building structure, the building structure shall be designed for the horizontal and vertical forces listed in Section 2226.1 imposed on the building structure.

Racks shall be installed with a maximum tolerance from the vertical of 1 inch in 10 feet (25.4 mm in 3048 mm) of height. Special conditions may require more restrictive tolerances.

Support of racks by foundations, concrete floor slabs or other means shall be in conformance with Chapter 18.

SECTION 2223 — DESIGN PROCEDURES AND DIMENSIONAL LIMITATIONS

2223.1 General. All computations for allowable loads, stresses and deflections shall be in accordance with conventional methods of structural design, and as specified in Section 2222.4, except where modified or supplemented herein. Where adequate methods of design calculations are not available, justification by a testing program acceptable to the building official may be used.

2223.2 Dimensional Limitations. The limitations on flat-width ratios and slenderness ratios in Division I and Division V shall apply except for the following conditions:

1. Slenderness limitations shall not be imposed on tension members which do not resist compression forces under any loading condition.

2. The unbraced length of compression or tension members shall be the length between connections to other structural members disposed in the direction of the pertinent radius of gyration, or from such a connection to the nearest attachment to an external fixed structure, such as a floor.

SECTION 2224 — ALLOWABLE STRESSES AND EFFECTIVE WIDTHS

2224.1 General. Allowable stresses and effective design widths shall be as specified in Division I and Division IV except as provided herein. Allowable stresses for working stress design may be increased one-third when considering wind or earthquake forces either acting alone or when combined with vertical loads.

2224.2 Perforated Compression Members. The effect of perforations on the carrying capacity of compression members shall be recognized by modification of the Q-factor. Q-values for perforated compression members shall be determined by stub column tests acceptable to the building official. These members shall be designed in an approved manner. The effects of perforations on the capacity of members may be considered by using the section properties based on the minimum net area.

2224.3 Torsional-flexural Buckling. Sections subject to torsional-flexural buckling shall be designed according to Division VII.

SECTION 2225 — PALLET AND STACKER-RACK BEAMS

2225.1 Allowable Loads. Where the shape of the cross section permits, allowable loads of pallet-carrying beams shall be determined in accordance with Division I or Division IV.

2225.2 Deflections. At working load the deflections, including possible deformations in the end connections, shall not exceed $^{1}/_{180}$ of the span measured with respect to the beam ends.

2225.3 Determination by Test. Where the configuration of the cross section precludes calculation of allowable loads and deflections, determination may be made with a testing program acceptable to the building official.

SECTION 2226 — FRAME DESIGN

2226.1 General. Frames shall be designed for the critical combinations of vertical loads in the most unfavorable positions, horizontal loads as specified in Section 2228.3, and the additional effects of horizontal sway caused by looseness, if any, of the top tie beam to post connections.

2226.2 Effective Lengths. Effective lengths based on valid engineering principles shall be used in the design of posts and upright frames.

SECTION 2227 — CONNECTIONS AND BEARING PLATES

2227.1 Connections. Adequate strength of connections to withstand calculated resultant forces and moments, and adequate rigidity where such is required, shall be demonstrated by calculation or by testing in an approved manner.

Beams shall have support connections capable of withstanding an upward force of 1,000 pounds (4448 N) per connection within allowable design values of this code.

For movable-shelf racks, the top shelf and other fixed shelves are to include support connections capable of withstanding an upward force of 1,000 pounds (4448 N) per connection within the allowable design values of this code.

The movable shelves are generally constructed of a set of front and rear longitudinal beams connected to each other rigidly by transverse members. The movable shelves are to be connected in such a way to prevent forward displacement when lifting out the front beam of the shelf.

2227.2 Bearing Plates. Provision shall be made to transfer post loads and moments into the floor. Said forces and moments shall be consistent in magnitude, sense and direction with the rack analysis. Allowable bearing stresses on the bottom of base plates shall be determined in accordance with Chapter 19.

SECTION 2228 — LOADS

2228.1 Gravity Loads. Racks shall be designed for dead loads, live loads and unit loads as posted on the rack installation under Section 2222.5.

2228.2 Vertical Impact. Unit load-carrying beams, supporting arms, if any, and end connections shall be designed for an additional vertical impact load of 25 percent of one unit load located to produce maximum moments and shears. Impact stresses shall not exceed stresses referenced in Section 2224, nor shall they cause detrimental permanent deformations in connections. When allowable loads are determined by tests, due allowance shall be made for the additional impact load. Impact loads may be omitted when checking beam deflections and designing upright frames, posts and other vertical components.

2228.3 Horizontal Loads.

2228.3.1 General. All racks shall be designed for the horizontal forces and allowable stresses specified in this standard. These forces shall not cause permanent distortions of connections when subject to test, or permanent residual sway deflections (of the entire rack when subject to full-scale rack tests) larger than 20 percent of the sway deflections measured under the simultaneous action of horizontal and vertical loads.

2228.3.2 Horizontal stability. Horizontal stability shall be determined by applying horizontal forces simultaneously at all beam-to-post connections equal to 1.5 percent of the maximum live load plus dead load at the connection. The forces shall be applied separately in each of the two principal directions of the rack and in conjunction with full dead and live loads.

2228.3.3 Stacker racks or racks wholly or partially supporting moving equipment. Racks shall be designed for maximum forces and their locations, transmitted from moving equipment to racks, and applicable longitudinal and transverse impact factors due to moving equipment.

Devices acting as bumpers to stop moving equipment shall be considered in the design.

Forces described in this section need not act concurrently with those described in Sections 2228.3.2 and 2228.5.1.

2228.4 Wind Loads. Outdoor racks exposed to wind shall be designed for the wind loads prescribed by Chapter 16 acting on the horizontal projection of rack plus contents. For stability, consideration shall be given to loading conditions that produce large wind forces combined with small stabilizing gravity forces, such as racks fully loaded, but with unit loads of much smaller weight than the maximum posted unit load.

Forces described in Sections 2228.3.2 and 2228.5.1 need not act concurrently with wind loads. Forces described in Section 2228.3.3 shall act concurrently with wind forces for design purposes.

2228.5 Earthquake Loads.

2228.5.1 General. Steel storage racks which are not connected to buildings or other structures shall be designed to resist seismic forces in conformance with this standard.

2228.5.2 Minimum earthquake forces. The total minimum lateral force at strength design levels shall be determined in accordance with Section 1630.2.1:

WHERE:

R = 4.4 for racks or portions thereof where lateral stability is dependent on diagonal or x-bracing. Connections for bracing members shall be capable of developing the required strength of the members.

R = 5.6 for racks where the lateral stability is wholly dependent on moment-resisting frame action.

W = weight of rack structure plus contents. Where a number of storage rack units are interconnected so there are a minimum of four columns in any direction on each column line designed to resist horizontal forces, W may be equal to the total dead load plus 50 percent of the rack-rated capacity. In Seismic Zones 3 and 4, wholesale and retail areas, the 50 percent may only be used when combined with C_v/RT taken equal to $0.70C_a$ in Formula (30-4) and with $2.5/R$ taken equal to 0.70 in Formula (30-5).

Total seismic force shall be assumed to act nonconcurrently in the direction of each of the main axes of the rack. For racks having more than two storage levels, the total lateral force, V, shall be distributed over the height of the rack in accordance with

$$F_i = \frac{VW_ih_i}{\sum_{i=1}^{n} W_ih_i}$$

in which F_i is the lateral force applied at Level i; W_i is the portion of the total weight; W, which is assigned to Level i; h_i is the height of Level i above the base of the rack; and n is the total number of storage levels. The lateral force, V, shall be distributed in proportion to the total weight, W.

Other R values may be considered based on submission of substantiating data.

2228.6 Storage Racks in Buildings. Storage racks located in buildings at levels above the ground level, rack buildings or racks that depend on attachments to buildings or other structures at other than the floor level for their lateral stability, shall be designed to resist earthquake forces that consider the responses of the building and storage rack to earthquake ground motions as specified in Chapter 16, Division III.

2228.7 Other Considerations.

2228.7.1 Overturning. In determining overturning moments, the total weight shall be assumed to act at a height equal to 1.15 times the distance from the floor to the actual center of gravity of all the horizontal forces.

Equal safety against an overturning moment shall be provided when only the top level of the rack is loaded, in which case it is to be assumed that the force acts through the center of gravity of the top load.

2228.7.2 Torsional forces. Torsional forces shall be considered based on the critical combination of loaded and unloaded storage spaces.

2228.7.3 Concurrent forces. Forces described in Sections 2228.3.2, 2228.3.3 and 2228.4 need not be assumed to act concurrently with earthquake loads.

SECTION 2229 — SPECIAL RACK DESIGN PROVISIONS

2229.1 Stability of Truss-braced Upright Frames. The maximum allowable compression stress in the posts of truss-braced upright frames shall be determined from Divisions I and IV.

2229.2 Overturning and Height-to-depth Ratio. Overturning shall be based on the critical combination of vertical and horizontal loads. Stabilizing forces provided by anchor bolts to the floor shall not be considered to resist overturning unless the anchors are specifically designed and installed to resist the uplift forces. Unless all columns are so anchored, the minimum ratio between righting moment and overturning moment shall be 1.5. Sections 2228.4 and 2228.7 shall be considered in the design.

The height-to-depth ratio of a storage rack shall not exceed 6 to 1 measuring to the top of the topmost load unless the rack is anchored or braced externally.

2229.3 Connections to Buildings. Connections of racks to buildings, if any, shall be designed and installed to prevent reactions or displacements of the buildings or racks from damaging one another. Section 2228.5 shall be considered.

Division XI—DESIGN STANDARD FOR STRUCTURAL APPLICATIONS OF STEEL CABLES FOR BUILDINGS

This standard is based on the American Society of Civil Engineers Standard 17-95, *Structural Applications of Steel Cables for Buildings* (ASCE 17-95) available from the American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400.

SECTION 2230 — ADOPTION

CHAP. 22, DIV. XI

The American Society of Civil Engineers standard adopted by this division provides requirements for the structural design, fabrication and the installation of steel cables for use as primary structural elements for the support of roofs and floors of buildings. Where other codes, standards or specifications are referred to in this division, they are to be considered as only an indication of an acceptable method of material that can be used with the approval of the building official.

UNIFORM BUILDING CODE STANDARD 22-1

MATERIAL SPECIFICATIONS FOR STRUCTURAL STEEL

Based on Standard Specifications A 27, A 36, A 48, A 53, A 148, A 242, A 252, A 283, A 307, A 325, A 366, A 446, A 449, A 490, A 500, A 501, A 514, A 529, A 563, A 569, A 570, A 572, A 588, A 606, A 607, A 611, A 618, A 666, A 690 and A 715 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 1808.6.1, 1808.7 and 2202, *Uniform Building Code,* and Section 402.2, *Uniform Sign Code*

SECTION 22.101 — SCOPE

This standard covers steel and iron shapes, plates, sheet, strip, connectors and bars for use in the construction of buildings and for general structural purposes.

SECTION 22.102 — MATERIAL REQUIREMENTS

The material shall conform to the requirements as to the tensile properties set forth in Table 22-1-A.

TABLE 22-1-A—TENSILE REQUIREMENTS

MATERIAL	GRADE	SPECIFICATION TITLE	SIZE AND PRODUCT LIMITATIONS	TENSILE STRENGTH (ksi)	YIELD POINT (ksi)	REFERENCED ELSEWHERE
			× 25.4 for mm	× 6.89 for MPa		
A27-81a	60-30 65-35 70-36 70-40	Mild- to medium-strength carbon steel castings		60 65 70 70	30 35 36 40	
A36-81a		Structural steel		58-80	36	UBC Chapter 22, Divisions VII and IX
A48-76	**Class No.** 20 A, B, C and S 25 ″ 30 ″ 35 ″ 40 ″ 45 ″ 50 ″ 55 ″ 60 ″	Gray iron castings		 20 25 30 35 40 45 50 55 60	 — — — — — — — — —	
A53-82	Type F A (Types E and S) B (Types E and S)	Steel pipe, black and hot-dipped, zinc-coated; welded and seamless	Furnace—butt welded Electric—resistance welded and seamless Electric—resistance welded and seamless	45 48 60	25 30 35	UMC Standard 11-1
A148-81	80-40 80-50 90-60 105-85 120-95 150-125 175-145	High-strength steel casting for structural purposes		80 80 90 105 120 150 175	40 50 60 85 95 125 145	
A242-81		High-strength Low-alloy Structural steel	$^3/_4$″ thick and under Over $^3/_4$″ to $1^1/_2$″, inclusive Over $1^1/_2$″ to 4″ thick	70 67 63	50 46 42	UBC Chapter 22, Divisions VII and IX
A252-82	1 2 3	Welded and seamless steel pipe piles		50 60 66	30 35 45	
A283-81	A B C D	Low and intermediate strength carbon steel plates shapes and bars		45-55 50-60 55-65 60-72	24 27 30 33	
A307-82a	A and B B	Bolts Bolts with cast-iron flanges		60 (min) 100 (max)	—	
A325-83c		High-strength bolts for structural steel joints	$^1/_2$″ to 1″ diameter, inclusive $1^1/_8$″ to $1^1/_2$″ diameter, inclusive	105 120	92 81	

(Continued)

TABLE 22-1-A—TENSILE REQUIREMENTS—(Continued)

MATERIAL	GRADE	SPECIFICATION TITLE	SIZE AND PRODUCT LIMITATIONS × 25.4 for mm	TENSILE STRENGTH (ksi) × 6.89 for MPa	YIELD POINT (ksi)	REFERENCED ELSEWHERE
A366-72 (79)		Carbon steel cold-rolled sheet, commercial quality		—	—	
A446-76 (81)	A B C D E F	Steel sheet zinc-coated (galvanized) by hot-dip process structural quality		45 52 55 65 82 70	33 37 40 50 80 50	UBC Chapter 22, Division VII
A449-83a		Quenched and tempered steel bolts and studs	$^1/_4$″ to 1″, inclusive Over 1″ to 1$^1/_2$″, inclusive Over 1$^1/_2$″ to 3″, inclusive	120 105 90	92 81 58	
A490-83a		Quenched and tempered alloy steel bolts for structural steel connections	$^1/_2$″ to 1$^1/_2$″, inclusive	150 (min) 170 (max)	130	
A500-82a	A B C A B C	Cold-formed welded and seamless carbon steel structural tubing in rounds and shapes	Rounds Shapes	45 58 62 45 58 62	33 42 46 39 46 50	
A501-83		Hot-formed welded and seamless carbon steel structural tubing		58	36	
A514-82a		High-yield strength quenched and tempered alloy steel plate	2$^1/_2$″ Over 2$^1/_2$″ to 6″, inclusive	110-130 100-130	100 90	
A529-82		Structural steel with 42,000 psi minimum yield point	$^1/_2$″ maximum thickness	60-85	42	UBC Chapter 22, Division VII
A563-88a	O A B C D DH	Carbon and alloy steel nuts				UBC Chapter 22, Division III
A569-72 (79)		Steel, carbon hot-rolled sheet and strip, commercial quality		—	—	
A570-79	30 33 36 40 45 50	Hot-rolled carbon steel sheets and strip, structural quality	Maximum thickness of 0.2299″	49 52 53 55 60 65	30 33 36 40 45 50	UBC Chapter 22, Divisions VII and IX
A572-82	42 50 60 65	High-strength low-alloy columbium-vanadium steel, structural quality	Shapes, plates, piling and bars	60 65 75 80	42 50 60 65	UBC Chapter 22, Divisions VII and IX
A588-82		High-strength low-alloy structural steel with a 50 ksi minimum yield point to 4 inches thick	Plate and bars to 4″, inclusive Over 4″ to 5″, inclusive Over 5″ to 8″, inclusive Structural shapes—all grades	70 67 63 70	50 46 42 50	UBC Chapter 22, Divisions VII and IX
A606-75		Steel sheet and strip hot-rolled and cold-rolled high-strength low-alloy improved atmospheric corrosion resistance	Hot-rolled cut lengths Hot-rolled coils, Annealed or normalized cut lengths and coils	70 65 65	50 45 45	UBC Chapter 22, Divisions VII and IX
A607-75 (81)	45 50 55 60 65 70	Steel sheet and strip hot-rolled and cold-rolled high-strength low-alloy columbium and/or vanadium	Cut lengths or coils	60 65 70 75 80 85	45 50 55 60 65 70	UBC Chapter 22, Divisions VII and IX
A611-82	A B C D E	Types I and II cold-rolled sheet carbon steel, structural		42 45 48 52 82	25 30 33 40 80	UBC Chapter 22, Divisions VII and IX

(Continued)

TABLE 22-1-A—TENSILE REQUIREMENTS—(Continued)

MATERIAL	GRADE	SPECIFICATION TITLE	SIZE AND PRODUCT LIMITATIONS	TENSILE STRENGTH (ksi)	YIELD POINT (ksi)	REFERENCED ELSEWHERE
			× 25.4 for mm	× 6.89 for MPa		
A618-81	Ia, Ib, II Ia, Ib, II III	Hot-formed welded and seamless high-strength low-alloy structural tubing	Walls $^3/_4''$ and under Walls over $^3/_4''$ to $1^1/_2''$, inclusive Walls over $^3/_4''$ to $1^1/_2''$, inclusive	70 67 65	50 46 50	UBC Chapter 22, Division VII
A666-82	A B C D	Austenitic stainless steel, sheet strip, plate and flat bar for structural applications		75 75-95 115-125 125-150	30 40-4 75 100-110	
A668-85a	A B C D E F G H J K L M N	Steel forgings, carbon and alloy for general industrial use		47 60 66 75 85-83 90-82 80 90 95-105 105-100 125-110 145-135 170-160	— 30 33 37 44-43 55-48 50 60-58 65-80 80-75 105-85 120-110 140-130	UBC Chapter 22, Division III
A690-81a		Sheet piling for marine environment		70	50	
A715-81	50 60 70 80	Steel sheet and strip hot-rolled high-strength low-alloy		60 70 80 90	50 60 70 80	UBC Chapter 22, Division VII
A792-85	33 37 40 50B 50A	Steel sheet, aluminum-zinc alloy coated by the hot-dip process	Coils and lengths	45 52 55 65 —	33 37 40 50 50	
A852-88a		Quenched and tempered low-alloy structural steel plate with 70 ksi minimum yield strength	Maximum 4″ thick	90-110	70	UBC Chapter 22, Division III

Chapter 23
WOOD

NOTE: This chapter has been revised in its entirety.

Division I—GENERAL DESIGN REQUIREMENTS

SECTION 2301 — GENERAL

2301.1 Scope. The quality and design of wood members and their fastenings shall conform to the provisions of this chapter.

2301.2 Design Methods. Design shall be based on one of the following methods.

2301.2.1 Allowable stress design. Design using allowable stress design methods shall resist the load combinations of Section 1612.3, in accordance with the applicable requirements of Section 2305.

2301.2.2 Conventional light-frame construction. The design and construction of conventional light-frame wood structures shall be in accordance with the applicable requirements of Section 2305.

SECTION 2302 — DEFINITIONS

2302.1 Definitions. The following terms used in this chapter shall have the meanings indicated in this section:

AFPA is the American Forest and Paper Association, 1111 19th Street, N.W., Suite 800, Washington, D.C. 20036 (formerly NFoPA, National Forest Products Association).

AHA is the American Hardboard Association, Inc., 1210 W. Northwest Highway, Palatine, Illinois 60067.

AITC is the American Institute of Timber Construction, 7012 S. Revere Parkway, Suite 140, Englewood, Colorado 80112.

ALSC is the American Lumber Standard Committee, Post Office Box 210, Germantown, Maryland 20875-0210.

APA is the American Plywood Association, 7011 South 19th Street, Tacoma, Washington 98411.

AWPA is the American Wood Preservers Association, Post Office Box 286, Woodstock, Maryland 21163-0286.

BLOCKED DIAPHRAGM is a diaphragm in which all sheathing edges not occurring on framing members are supported on and connected to blocking.

BRACED WALL LINE is a series of braced wall panels in a single story that meets the requirements of Section 2320.11.3.

BRACED WALL PANEL is a section of wall braced in accordance with Section 2320.11.3.

CONVENTIONAL LIGHT-FRAME CONSTRUCTION is a type of construction whose primary structural elements are formed by a system of repetitive wood-framing members. Refer to Section 2320 for conventional light-frame construction provisions.

DIAPHRAGM is a horizontal or nearly horizontal system acting to transmit lateral forces to the vertical-resisting elements. When the term “diaphragm” is used, it includes horizontal bracing systems.

FIBERBOARD is a fibrous-felted, homogeneous panel made from lignocellulosic fibers (usually wood or cane) and having a density of less than 31 pounds per cubic foot (497 kg/m^3) but more than 10 pounds per cubic foot (160 kg/m^3).

GLUED BUILT-UP MEMBERS are structural elements, the sections of which are composed of built-up lumber, wood structural panels or wood structural panels in combination with lumber, all parts bonded together with adhesives.

GRADE (Lumber) is the classification of lumber in regard to strength and utility in accordance with UBC Standard 23-1 and the grading rules of an approved lumber grading agency.

HARDBOARD is a fibrous-felted, homogeneous panel made from lignocellulosic fibers consolidated under heat and pressure in a hot press to a density not less than 31 pounds per cubic foot (497 kg/m^3).

NELMA is the Northeastern Lumber Manufacturers Association, 272 Tuttle Road, Post Office Box 87 A, Cumberland Center, Maine 04021.

NLGA is the National Lumber Grades Authority, 103-4000 Dominion Street, Burnaby B.C., Canada V5G 4G3.

NSLB is the Northern Softwood Lumber Bureau (serviced by NELMA), 272 Tuttle Road, Post Office Box 87 A, Cumberland Center, Maine 04021.

NOMINAL LOADING is a design load that stresses a member of fastening to the full allowable stress tabulated in this chapter. This loading may be applied for approximately 10 years, either continuously or cumulatively, and 90 percent of this load may be applied for the remainder of the life of the member or fastening.

NOMINAL SIZE (Lumber) is the commercial size designation of width and depth, in standard sawn lumber and glued-laminated lumber grades; somewhat larger than the standard net size of dressed lumber, in accordance with UBC Standard 23-1 for sawn lumber.

PARTICLEBOARD is a manufactured panel product consisting of particles of wood or combinations of wood particles and wood fibers bonded together with synthetic resins or other suitable bonding system by a bonding process in accordance with approved nationally recognized standards.

PLYWOOD is a panel of laminated veneers conforming to UBC Standard 23-2 or 23-3.

RIS is the Redwood Inspection Service, 405 Enfrente Drive, Suite 200, Novato, California 94949.

ROTATION is the torsional movement of a diaphragm about a vertical axis.

SPIB is the Southern Pine Inspection Bureau, 4709 Scenic Highway, Pensacola, Florida 32504.

STRUCTURAL GLUED-LAMINATED TIMBER is any member comprising an assembly of laminations of lumber in which the grain of all laminations is approximately parallel longitudinally, in which the laminations are bonded with adhesives.

SUBDIAPHRAGM is a portion of a larger wood diaphragm designed to anchor and transfer local forces to primary diaphragm struts and the main diaphragm.

TREATED WOOD is wood treated with an approved preservative under treating and quality control procedures.

WCLIB is the West Coast Lumber Inspection Bureau, 6980 S.W. Varnes Road, Post Office Box 23145, Portland, Oregon 97223.

WOOD OF NATURAL RESISTANCE TO DECAY OR TERMITES is the heartwood of the species set forth below. Corner sapwood is permitted on 5 percent of the pieces provided 90 percent or more of the width of each side on which it occurs is heartwood. Recognized species are:

Decay resistant: Redwood, Cedars, Black Locust

Termite resistant: Redwood, Eastern Red Cedar

WOOD STRUCTURAL PANEL is a structural panel product composed primarily of wood and meeting the requirements of UBC Standard 23-2 or 23-3. Wood structural panels include all-veneer plywood, composite panels containing a combination of veneer and wood-based material, and matformed panels such as oriented strand board and waferboard.

WWPA is the Western Wood Products Association, Yeon Building, 522 S. W. Fifth Avenue, Portland, Oregon 97204-2122.

SECTION 2303 — STANDARDS OF QUALITY

The standards listed below labeled a "UBC Standard" are also listed in Chapter 35, Part II, and are part of this code. The other standards listed below are recognized standards. (See Sections 3503 and 3504.)

1. **Grading rules.**
   - 1.1 UBC Standard 23-1, Classification, Definition, Methods of Grading and Development of Design Values for All Species of Lumber
   - 1.2 Standard Grading Rules for Canadian Lumber, United States Edition, NLGA
   - 1.3 Standard Grading Rules No. 17, WCLIB
   - 1.4 Standard Grading Rules, WWPA
   - 1.5 Grading Rules, NHPMA
   - 1.6 Grading Rules, SPIB
   - 1.7 Standard Specifications for Grades of California Redwood Lumber, RIS
   - 1.8 Standard Grading Rules, NELMA
2. **Structural glued-laminated timber.**
   - 2.1 ANSI/AITC Standard A190.1 and ASTM D 3737, Design and Manufacture of Structural Glued-laminated Timber
   - 2.2 Standard Specifications for Structural Glued-laminated Timber of Softwood Species, AITC 117; Manufacturing, AITC 117; Design and Standard Specifications for Hardwood Glued-laminated Timber, AITC 119.
   - 2.3 Inspection Manual AITC 200 of the American Institute of Timber Construction, Tests for Structural Glued-laminated Timber.
   - 2.4 AITC 500, Determination of Design Values for Structural Glued-laminated Timber in accordance with ASTM D 3737, American Institute of Timber Construction.
3. **Preservative treatment by pressure process and quality control.**
   - 3.1 Standard Specifications C1, C2, C3, C4, C9, C14, C15, C16, C22, C23, C24, C28 and M4, AWPA
4. **Product standards.**
   - 4.1 UBC Standard 23-2, Construction and Industrial Plywood
   - 4.2 UBC Standard 23-3, Performance Standard for Wood-Based Structural-Use Panels
   - 4.3 ANSI A208.1, Particleboard
   - 4.4 ASTM D 1037, Evaluating the Properties of Wood-based Fiber and Particle Panel Materials
   - 4.5 ASTM D 1333, Determining Formaldehyde Levels from Wood-based Products Under Defined Test Conditions Using a Large Chamber
   - 4.6 ANSI 05.1, Wood Poles—Specifications and Dimensions
   - 4.7 ASTM D 25, Round Timber Piles
   - 4.8 ANSI/AHA A194.1, Cellulosic Fiber Insulating Board (Fiberboard)
   - 4.9 ANSI/AHA 135.6, Hardboard Siding
5. **Design standards.**
   - 5.1 ASTM D 5055, Structural Capacities of Prefabricated Wood I-Joists
   - 5.2 ANSI/TPI 1 National Design Standard for Metal Plate Connected Wood Truss Construction
   - 5.3 ANSI/TPI 2 Standard for Testing Performance for Metal Plate Connected Wood Trusses
   - 5.4 ASCE 16, Load and Resistance Factor Design Standard for Engineered Wood Construction
6. **Fire retardancy.**
   - 6.1 UBC Standard 23-4, Fire-retardant-treated Wood Tests on Durability and Hygroscopic Properties
   - 6.2 UBC Standard 23-5, Fire-retardant-treated Wood
7. **Adhesives and glues.**
   - 7.1 ASTM D 3024, Dry Use Adhesive with Protein Base, Casein Type
   - 7.2 ASTM D 2559, Wet Use Adhesives
   - 7.3 APA Specification AFG-01, Adhesives for Field Gluing Plywood to Wood Framing
   - 7.4 ASTM D 1101 and AITC 200 in Testing of Glue Joints in Laminated Wood Product
8. **Design values.**
   - 8.1 ASTM D 1990, Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens
   - 8.2 ASTM D 245, Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber
   - 8.3 ASTM D 2555, Standard Test Methods for Establishing Clear Wood Strength Values

SECTION 2304 — MINIMUM QUALITY

2304.1 Quality and Identification. All lumber, wood structural panels, particleboard, structural glued-laminated timber, end-jointed lumber, fiberboard sheathing (when used structurally), hardboard siding (when used structurally), piles and poles regulated by this chapter shall conform to the applicable standards and grading rules specified in this code and shall be so identified by the grade mark or certificate of inspection issued by an approved agency.

All preservatively treated wood required to be treated under Section 2306 shall be identified by the quality mark of an inspection agency which has been accredited by an accreditation body which complies with the requirements of the American Lumber Standard Committee Treated Wood Program, or equivalent.

2304.2 Minimum Capacity or Grade. Minimum capacity of structural framing members may be established by performance tests. When tests are not made, capacity shall be based on allowable stresses and design criteria specified in this code.

Studs, joists, rafters, foundation plates or sills, planking 2 inches (51 mm) or more in depth, beams, stringers, posts, structural sheathing and similar load-bearing members shall be of at least the minimum grades set forth in the tables in this chapter.

Approved end-jointed lumber may be used interchangeably with solid-sawn members of the same species and grade. Such use shall include, but not be limited to, light-framing joists, planks and decking.

Wood structural panels shall be of the grades specified in UBC Standard 23-2 or 23-3.

2304.3 Timber Connectors and Fasteners. Safe loads and design practices for types of connectors and fasteners not mentioned or fully covered in Division III, Part III, may be determined in a manner approved by the building official.

The number and size of nails connecting wood members shall not be less than that set forth in Tables 23-II-B-1 and 23-II-B-2. Other connections shall be fastened to provide equivalent strength. End and edge distances and nail penetrations shall be in accordance with the applicable provisions of Division III, Part III.

Fasteners for pressure-preservative treated and fire-retardant treated wood shall be of hot-dipped zinc coated galvanized, stainless steel, silicon bronze or copper. Fasteners for wood foundations shall be as required in Chapter 18, Division II. Fasteners required to be corrosion resistant shall be either zinc-coated fasteners, aluminum alloy wire fasteners or stainless steel fasteners.

Connections depending on joist hangers or framing anchors, ties, and other mechanical fastenings not otherwise covered may be used where approved.

2304.4 Fabrication, Installation and Manufacture.

2304.4.1 General. Preparation, fabrication and installation of wood members and their fastenings shall conform to accepted engineering practices and to the requirements of this code. All members shall be framed, anchored, tied and braced to develop the strength and rigidity necessary for the purposes for which they are used.

2304.4.2 Timber connectors and fasteners. The installation of timber connectors and fasteners shall be in accordance with the provisions set forth in Division III, Part III.

2304.4.3 Structural glued-laminated timber. The manufacture and fabrication of structural glued-laminated timber shall be under the supervision of qualified personnel.

2304.4.4 Metal-plate-connected wood trusses. Metal-plate-connected wood trusses shall conform to the provisions of Division V. Each manufacturer of trusses using metal plate connectors shall retain an approved agency having no financial interest in the plant being inspected to make nonscheduled inspections of truss fabrication, delivery, and operations. The inspection shall cover all phases of truss operation, including lumber storage, handling, cutting, fixtures, presses or rollers, fabrication, bundling and banding, handling and delivery.

2304.5 Dried Fire-retardant-treated Wood. Approved fire-retardant-treated wood shall be dried, following treatment, to a maximum moisture content as follows: solid-sawn lumber 2 inches (51 mm) in thickness or less to 19 percent, and plywood to 15 percent.

2304.6 Size of Structural Members. Sizes of lumber and structural glued-laminated timber referred to in this code are nominal sizes. Computations to determine the required sizes of members shall be based on the net dimensions (actual sizes) and not the nominal sizes.

2304.7 Shrinkage. Consideration shall be given in design to the possible effect of cross-grain dimensional changes considered vertically which may occur in lumber fabricated in a green condition.

2304.8 Rejection. The building official may deny permission for the use of a wood member where permissible grade characteristics or defects are present in such a combination that they affect the serviceability of the member.

SECTION 2305 — DESIGN AND CONSTRUCTION REQUIREMENTS

2305.1 General. The following design requirements apply.

2305.2 All wood structures shall be designed and constructed in accordance with the requirements of Division I and Division II, Part I.

2305.3 Wind and earthquake load-resisting systems for all engineered wood structures shall be designed and constructed in accordance with the requirements of Division II, Part II.

2305.4 The design and construction of wood structures using allowable stress design methods shall be in accordance with Division III.

2305.5 The design and construction of conventional light-frame wood structures shall be in accordance with Division IV.

2305.6 The design and installation of timber connectors and fasteners shall be in accordance with Division III, Part III.

2305.7 Metal-plate-connected wood trusses shall conform to the provisions of Division V.

2305.8 Design of structural glued built-up members with plywood components shall be in accordance with Division VI.

2305.9 Design of joists and rafters shall be permitted to be in accordance with Division VII.

2305.10 Design of plank and beam flooring shall be permitted to be in accordance with Division VIII.

Division II—GENERAL REQUIREMENTS

Part I—REQUIREMENTS APPLICABLE TO ALL DESIGN METHODS

SECTION 2306 — DECAY AND TERMITE PROTECTION

2306.1 Preparation of Building Site. Site preparation shall be in accordance with Section 3302.

2306.2 Wood Support Embedded in Ground. Wood embedded in the ground or in direct contact with the earth and used for the support of permanent structures shall be treated wood unless continuously below the groundwater line or continuously submerged in fresh water. Round or rectangular posts, poles and sawn timber columns supporting permanent structures that are embedded in concrete or masonry in direct contact with earth or embedded in concrete or masonry exposed to the weather shall be treated wood. The wood shall be treated for ground contact.

2306.3 Under-floor Clearance. When wood joists or the bottom of wood structural floors without joists are located closer than 18 inches (457 mm) or wood girders are located closer than 12 inches (305 mm) to exposed ground in crawl spaces or unexcavated areas located within the periphery of the building foundation, the floor assembly, including posts, girders, joists and subfloor, shall be approved wood of natural resistance to decay as listed in Section 2306.4 or treated wood.

When the above under-floor clearances are required, the under-floor area shall be accessible. Accessible under-floor areas shall be provided with a minimum 18-inch-by-24-inch (457 mm by 610 mm) opening unobstructed by pipes, ducts and similar construction. All under-floor access openings shall be effectively screened or covered. Pipes, ducts and other construction shall not interfere with the accessibility to or within under-floor areas.

2306.4 Plates, Sills and Sleepers. All foundation plates or sills and sleepers on a concrete or masonry slab, which is in direct contact with earth, and sills that rest on concrete or masonry foundations, shall be treated wood or Foundation redwood, all marked or branded by an approved agency. Foundation cedar or No. 2 Foundation redwood marked or branded by an approved agency may be used for sills in territories subject to moderate hazard, where termite damage is not frequent and when specifically approved by the building official. In territories where hazard of termite damage is slight, any species of wood permitted by this code may be used for sills when specifically approved by the building official.

2306.5 Columns and Posts. Columns and posts located on concrete or masonry floors or decks exposed to the weather or to water splash or in basements and that support permanent structures shall be supported by concrete piers or metal pedestals projecting above floors unless approved wood of natural resistance to decay or treated wood is used. The pedestals shall project at least 6 inches (152 mm) above exposed earth and at least 1 inch (25 mm) above such floors.

Individual concrete or masonry piers shall project at least 8 inches (203 mm) above exposed ground unless the columns or posts that they support are of approved wood of natural resistance to decay or treated wood is used.

2306.6 Girders Entering Masonry or Concrete Walls. Ends of wood girders entering masonry or concrete walls shall be provided with a $^1/_2$-inch (12.7 mm) air space on tops, sides and ends unless approved wood of natural resistance to decay or treated wood is used.

2306.7 Under-floor Ventilation. Under-floor areas shall be ventilated by an approved mechanical means or by openings into the under-floor area walls. Such openings shall have a net area of not less than 1 square foot for each 150 square feet (0.067 m^2 for each 10 m^2) of under-floor area. Openings shall be located as close to corners as practical and shall provide cross ventilation. The required area of such openings shall be approximately equally distributed along the length of at least two opposite sides. They shall be covered with corrosion-resistant wire mesh with mesh openings of $^1/_4$ inch (6.4 mm) in dimension. Where moisture due to climate and groundwater conditions is not considered excessive, the building official may allow operable louvers and may allow the required net area of vent openings to be reduced to 10 percent of the above, provided the under-floor ground surface area is covered with an approved vapor retarder.

2306.8 Wood and Earth Separation. Protection of wood against deterioration as set forth in the previous sections for specified applications is required. In addition, wood used in construction of permanent structures and located nearer than 6 inches (152 mm) to earth shall be treated wood or wood of natural resistance to decay, as defined in Section 2302.1. Where located on concrete slabs placed on earth, wood shall be treated wood or wood of natural resistance to decay. Where not subject to water splash or to exterior moisture and located on concrete having a minimum thickness of 3 inches (76 mm) with an impervious membrane installed between concrete and earth, the wood may be untreated and of any species.

Where planter boxes are installed adjacent to wood frame walls, a 2-inch-wide (51 mm) air space shall be provided between the planter and the wall. Flashings shall be installed when the air space is less than 6 inches (152 mm) in width. Where flashing is used, provisions shall be made to permit circulation of air in the air space. The wood-frame wall shall be provided with an exterior wall covering conforming to the provisions of Section 2310.

2306.9 Wood Supporting Roofs and Floors. Wood structural members supporting moisture-permeable floors or roofs that are exposed to the weather, such as concrete or masonry slabs, shall be approved wood of natural resistance to decay or treated wood unless separated from such floors or roofs by an impervious moisture barrier.

2306.10 Moisture Content of Treated Wood. When wood pressure treated with a water-borne preservative is used in enclosed locations where drying in service cannot readily occur, such wood shall be at a moisture content of 19 percent or less before being covered with insulation, interior wall finish, floor covering or other material.

2306.11 Retaining Walls. Wood used in retaining or crib walls shall be treated wood.

2306.12 Weather Exposure. Those portions of glued-laminated timbers that form the structural supports of a building or other structure and are exposed to weather and not properly protected by a roof, eave overhangs of similar covering shall be pressure treated with an approved preservative or be manufactured from wood of natural resistance to decay.

All wood structural panels, when designed to be exposed in outdoor applications, shall be of exterior type, except as provided in Section 2306.2. In geographical areas where experience has demonstrated a specific need, approved wood of natural resistance to decay or treated wood shall be used for those portions of wood members which form the structural supports of buildings, balconies, porches or similar permanent building appurtenances when such members are exposed to the weather without adequate protection from a roof, eave, overhang or other covering to prevent moisture or water accumulation on the surface or at joints between members. Depending on local experience, such members may include horizontal members such as girders, joists and decking; or vertical members such as posts, poles and columns; or both horizontal and vertical members.

2306.13 Water Splash. Where wood-frame walls and partitions are covered on the interior with plaster, tile or similar materials and are subject to water splash, the framing shall be protected with approved waterproof paper conforming to Section 1402.1.

SECTION 2307 — WOOD SUPPORTING MASONRY OR CONCRETE

Wood members shall not be used to permanently support the dead load of any masonry or concrete.

EXCEPTIONS: 1. Masonry or concrete nonstructural floor or roof surfacing not more than 4 inches (102 mm) thick may be supported by wood members.

2. Any structure may rest upon wood piles constructed in accordance with the requirements of Chapter 18.

3. Veneer of brick, concrete or stone applied as specified in Section 1403.6.2 may be supported by approved treated wood foundations when the maximum height of veneer does not exceed 30 feet (9144 mm) above the foundations. Such veneer used as an interior wall finish may also be supported on wood floors that are designed to support the additional load and designed to limit the deflection and shrinkage to $^1/_{600}$ of the span of the supporting members.

4. Glass block masonry having an installed weight of 20 pounds per square foot (97.6 kg/m^2) or less and installed with the provisions of Section 2109.5. When glass block is supported on wood floors, the floors shall be designed to limit deflection and shrinkage to $^1/_{600}$ of the span of the supporting members and the allowable stresses for the framing members shall be reduced in accordance with Division III, Part I.

See Division II, Part II for wood members resisting horizontal forces contributed by masonry or concrete.

SECTION 2308 — WALL FRAMING

The framing of exterior and interior walls shall be in accordance with provisions specified in Division IV unless a specific design is furnished.

Wood stud walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the building official shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems, or other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternate, such systems shall be designed to accommodate the differential shrinkage or movements.

SECTION 2309 — FLOOR FRAMING

Wood-joisted floors shall be framed and constructed and anchored to supporting wood stud or masonry walls as specified in Chapter 16.

Fire block and draft stops shall be in accordance with Section 708.

SECTION 2310 — EXTERIOR WALL COVERINGS

2310.1 General. Exterior wood stud walls shall be covered on the outside with the materials and in the manner specified in this section or elsewhere in this code. Studs or sheathing shall be covered on the outside face with a weather-resistive barrier when required by Section 1402.1. Exterior wall coverings of the minimum thickness specified in this section are based on a maximum stud spacing of 16 inches (406 mm) unless otherwise specified.

2310.2 Siding. Solid wood siding shall have an average thickness of $^3/_8$ inch (9.5 mm) unless placed over sheathing permitted by this code.

Siding patterns known as rustic, drop siding or shiplap shall have an average thickness in place of not less than $^{19}/_{32}$ inch (15 mm) and shall have a minimum thickness of not less than $^3/_8$ inch (9.5 mm). Bevel siding shall have a minimum thickness measured at the butt section of not less than $^7/_{16}$ inch (11 mm) and a tip thickness of not less than $^3/_{16}$ inch (4.8 mm). Siding of lesser dimensions may be used, provided such wall covering is placed over sheathing which conforms to the provisions specified elsewhere in this code.

All weatherboarding or siding shall be securely nailed to each stud with not less than one nail, or to solid 1-inch (25 mm) nominal wood sheathing or $^{15}/_{32}$-inch (12 mm) wood structural panel sheathing or $^1/_2$-inch (13 mm) particleboard sheathing with not less than one line of nails spaced not more than 24 inches (610 mm) on center in each piece of the weatherboarding or siding.

Wood board sidings applied horizontally, diagonally or vertically shall be fastened to studs, nailing strips or blocking set at a maximum 24 inches (610 mm) on center. Fasteners shall be nails or screws with a penetration of not less than $1^1/_2$ inches (38 mm) into studs, studs and wood sheathing combined, or blocking. Distance between such fastenings shall not exceed 24 inches (610 mm) for horizontally or vertically applied sidings and 32 inches (813 mm) for diagonally applied sidings.

2310.3 Plywood. When plywood is used for covering the exterior of outside walls, it shall be of the exterior type not less than $^3/_8$ inch (9.5 mm) thick. Plywood panel siding shall be installed in accordance with Table 23-II-A-1. Unless applied over 1-inch (25 mm) wood sheathing or $^{15}/_{32}$-inch (12 mm) wood structural panel sheathing or $^1/_2$-inch (13 mm) particleboard sheathing, joints shall occur over framing members and shall be protected with a continuous wood batten, approved caulking, flashing, vertical or horizontal shiplaps; or joints shall be lapped horizontally or otherwise made waterproof.

2310.4 Shingles or Shakes. Wood shingles or shakes and asbestos cement shingles may be used for exterior wall covering, provided the frame of the structure is covered with building paper as specified in Section 1402.1. All shingles or shakes attached to sheathing other than wood sheathing shall be secured with approved corrosion-resistant fasteners or on furring strips attached to the studs. Wood shingles or shakes may be applied over fiberboard shingle backer and sheathing with annular grooved nails. The thickness of wood shingles or shakes between wood nailing boards shall not be less than $^3/_8$ inch (9.5 mm). Wood shingles or shakes and asbestos shingles or siding may be nailed directly to approved fiberboard nailbase sheathing not less than $^1/_2$-inch (13 mm) nominal thickness with annular grooved nails.

The weather exposure of wood shingle or shake siding used on exterior walls shall not exceed maximums set forth in Table 23-II-K.

2310.5 Particleboard. When particleboard is used for covering the exterior of outside walls, it shall be of the M-1, M-S and M-2 Exterior Glue grades. Particleboard panel siding shall be installed in accordance with Tables 23-II-A-2 and 23-II-B-1. Panels shall be gapped $^1/_8$ inch (3.2 mm) and nails shall be spaced not less than $^3/_8$ inch (9.5 mm) from edges and ends of sheathing. Unless applied over $^5/_8$-inch (16 mm) net wood sheathing or $^1/_2$-inch (13 mm) plywood sheathing or $^1/_2$-inch (13 mm) particleboard sheathing, joints shall occur over framing members and shall be covered with a continuous wood batt; or joints shall be lapped horizontally or otherwise made waterproof to the satisfaction of the building official. Particleboard shall be sealed and protected with exterior quality finishes.

2310.6 Hardboard. When hardboard siding is used for covering the outside of exterior walls, it shall conform to Table 23-II-C. Lap siding shall be installed horizontally and applied to sheathed or unsheathed walls. Corner bracing shall be installed in conformance with Division IV. A weather-resistive barrier shall be installed under the lap siding as required by Section 1402.1.

Square-edged nongrooved panels and shiplap grooved or nongrooved siding shall be applied vertically to sheathed or unsheathed walls. Siding that is grooved shall not be less than $^1/_4$ inch (6.4 mm) thick in the groove.

Nail size and spacing shall follow Table 23-II-C and shall penetrate framing $1^1/_2$ inches (38 mm). Lap siding shall overlap 1 inch (25 mm) minimum and be nailed through both courses and into framing members with nails located $^1/_2$ inch (13 mm) from bottom of the overlapped course. Square-edged nongrooved panels shall be nailed $^3/_8$ inch (9.5 mm) from the perimeter of the panel and intermediately into studs. Shiplap edge panel siding with $^3/_8$-inch (9.5 mm) shiplap shall be nailed $^3/_8$ inch (9.5 mm) from the edges on both sides of the shiplap. The $^3/_4$-inch (19 mm) shiplap shall be nailed $^3/_8$ inch (9.5 mm) from the edge and penetrate through both the overlap and underlap. Top and bottom edges of the panel shall be nailed $^3/_8$ inch (9.5 mm) from the edge. Shiplap and lap siding shall not be force fit. Square-edged panels shall maintain a $^1/_{16}$-inch (1.6 mm) gap at joints. All joints and edges of siding shall be over framing members, and shall be made resistant to weather penetration with battens, horizontal overlaps or shiplaps to the satisfaction of the building official. A $^1/_8$-inch (3.2 mm) gap shall be provided around all openings.

2310.7 Nailing. All fasteners used for the attachment of siding shall be of a corrosion-resistant type.

SECTION 2311 — INTERIOR PANELING

All softwood wood structural panels shall conform with the provisions of Chapter 8 and shall be installed in accordance with Table 23-II-B-1. Panels shall comply with UBC Standard 23-3.

SECTION 2312 — SHEATHING

2312.1 Structural Floor Sheathing. Structural floor sheathing shall be designed in accordance with the general provisions of this code and the special provisions in this section.

Sheathing used as subflooring shall be designed to support all loads specified in this code and shall be capable of supporting concentrated loads of not less than 300 pounds (1334 N) without failure. The concentrated load shall be applied by a loaded disc, 3 inches (76 mm) or smaller in diameter.

Flooring, including the finish floor, underlayment and subfloor, where used, shall meet the following requirements:

1. Deflection under uniform design load limited to $^1/_{360}$ of the span between supporting joists or beams.

2. Deflection of flooring relative to joists under a 1-inch-diameter (25 mm) concentrated load of 200 pounds (890 N) limited to 0.125 inch (3.2 mm) or less when loaded midway between supporting joists or beams not over 24 inches (610 mm) on center and $^1/_{360}$ of the span for spans over 24 inches (610 mm).

Floor sheathing conforming to the provisions of Table 23-II-D-1, 23-II-D-2, 23-II-E-1, 23-II-F-1 or 23-II-F-2 shall be deemed to meet the requirements of this section.

2312.2 Structural Roof Sheathing. Structural roof sheathing shall be designed in accordance with the general provisions of this code and the special provisions in this section. Structural roof sheathing shall be designed to support all loads specified in this code and shall be capable of supporting concentrated loads of not less than 300 pounds (1334 N) without failure. The concentrated load shall be applied by a loaded disc, 3 inches (76 mm) or smaller in diameter. Structural roof sheathing shall meet the following requirement:

1. Deflection under uniform design live and dead load limited to $^1/_{180}$ of the span between supporting rafters or beams and $^1/_{240}$ under live load only.

Roof sheathing conforming to the provisions of Tables 23-II-D-1 and 23-II-D-2 or 23-II-E-1 and 23-II-E-2 shall be deemed to meet the requirements of this section.

Wood structural panel roof sheathing shall be bonded by intermediate or exterior glue. Wood structural panel roof sheathing exposed on the underside shall be bonded with exterior glue.

SECTION 2313 — MECHANICALLY LAMINATED FLOORS AND DECKS

A laminated lumber floor or deck built up of wood members set on edge, when meeting the following requirements, may be designed as a solid floor or roof deck of the same thickness, and continuous spans may be designed on the basis of the full cross section using the simple span moment coefficient.

Nail length shall not be less than two and one-half times the net thickness of each lamination. When deck supports are 4 feet (1219 mm) on center or less, side nails shall be spaced not more than 30 inches (762 mm) on center and staggered one third of the spacing in adjacent laminations. When supports are spaced more than 4 feet (1219 mm) on center, side nails shall be spaced not more than 18 inches (457 mm) on center alternately near top and bottom edges, and also staggered one third of the spacing in adjacent laminations. Two side nails shall be used at each end of butt-jointed pieces.

Laminations shall be toenailed to supports with 20d or larger common nails. When the supports are 4 feet (1219 mm) on center or less, alternate laminations shall be toenailed to alternate supports; when supports are spaced more than 4 feet (1219 mm) on center, alternate laminations shall be toenailed to every support.

A single-span deck shall have all laminations full length.

A continuous deck of two spans shall not have more than every fourth lamination spliced within quarter points adjoining supports.

Joints shall be closely butted over supports or staggered across the deck but within the adjoining quarter spans.

No lamination shall be spliced more than twice in any span.

SECTION 2314 — POST-BEAM CONNECTIONS

Where post and beam or girder construction is used, the design shall be in accordance with the provisions of this code. Positive connection shall be provided to ensure against uplift and lateral displacement.

Part II—REQUIREMENTS APPLICABLE TO ENGINEERED DESIGN OF WIND AND EARTHQUAKE LOAD-RESISTING SYSTEMS

SECTION 2315 — WOOD SHEAR WALLS AND DIAPHRAGMS

2315.1 General. Particleboard vertical diaphragms and lumber and wood structural panel horizontal and vertical diaphragms may be used to resist horizontal forces in horizontal and vertical distributing or resisting elements, provided the deflection in the plane of the diaphragm, as determined by calculations, tests or analogies drawn therefrom, does not exceed the permissible deflection of attached distributing or resisting elements. See UBC Standard 23-2 for a method of calculating the deflection of a blocked wood structural panel diaphragm.

Permissible deflection shall be that deflection up to which the diaphragm and any attached distributing or resisting element will maintain its structural integrity under assumed load conditions, i.e., continue to support assumed loads without danger to occupants of the structure.

Connections and anchorages capable of resisting the design forces shall be provided between the diaphragms and the resisting elements. Openings in diaphragms that materially affect their strength shall be fully detailed on the plans and shall have their edges adequately reinforced to transfer all shearing stresses.

Size and shape of each horizontal diaphragm and shear wall shall be limited as set forth in Table 23-II-G. The height of a shear wall shall be defined as:

1. The maximum clear height from foundation to bottom of diaphragm framing above, or

2. The maximum clear height from top of diaphragm to bottom of diaphragm framing above.

The width of a shear wall shall be defined as the width of sheathing. See Figure 23-II-1, Section (a).

Where shear walls with openings are designed for force transfer around the openings, the limitations of Table 23-II-G shall apply to the overall shear wall including openings and to each wall pier at the side of an opening. The height of a wall pier shall be defined as the clear height of the pier at the side of an opening. The width of a wall pier shall be defined as the sheathed width of the pier at the side of an opening. Design for force transfer shall be based on a rational analysis. Detailing of boundary members around the opening shall be provided in accordance with Section 2315. See Figure 23-II-1, Section (b).

In buildings of wood-frame construction where rotation is provided for, the depth of the diaphragm normal to the open side shall not exceed 25 feet (7620 mm) or two thirds the diaphragm width, whichever is the smaller depth. Straight sheathing shall not be permitted to resist shears in diaphragms acting in rotation.

> **EXCEPTIONS:** 1. One-story, wood-framed structures with the depth normal to the open side not greater than 25 feet (7620 mm) may have a depth equal to the width.
>
> 2. Where calculations show that diaphragm deflections can be tolerated, the depth normal to the open end may be increased to a depth-to-width ratio not greater than $1^1/_2$:1 for diagonal sheathing or 2:1 for special diagonal sheathed or wood structural panel or particleboard diaphragms.

In masonry or concrete buildings, lumber and wood structural panel diaphragms shall not be considered as transmitting lateral forces by rotation.

Diaphragm sheathing nails or other approved sheathing connectors shall be driven so that their head or crown is flush with the surface of the sheathing.

2315.2 Wood Members Resisting Horizontal Forces Contributed by Masonry and Concrete. Wood members shall not be used to resist horizontal forces contributed by masonry or concrete construction in buildings over one story in height.

> **EXCEPTIONS:** 1. Wood floor and roof members may be used in horizontal trusses and diaphragms to resist horizontal forces imposed by wind, earthquake or earth pressure, provided such forces are not resisted by rotation of the truss or diaphragm. See Section 2315.1.
>
> 2. Vertical wood structural panel-sheathed shear walls may be used to provide resistance to wind or earthquake forces in two-story buildings of masonry or concrete construction, provided the following requirements are met:
>
> 2.1 Story-to-story wall heights shall not exceed 12 feet (3658 mm).
>
> 2.2 Horizontal diaphragms shall not be considered to transmit lateral forces by rotation or cantilever action.
>
> 2.3 Deflections of horizontal and vertical diaphragms shall not permit per-story deflections of supported masonry or concrete walls to exceed 0.005 times each story height.
>
> 2.4 Wood structural panel sheathing in horizontal diaphragms shall have all unsupported edges blocked. Wood structural panel sheathing for both stories of vertical diaphragms shall have all unsupported edges blocked and for the lower story walls shall have a minimum thickness of $^{15}/_{32}$ inch (12 mm).
>
> 2.5 There shall be no out-of-plane horizontal offsets between the first and second stories of wood structural panel shear walls.

2315.3 Wood Diaphragms.

2315.3.1 Conventional lumber diaphragm construction. Such lumber diaphragms shall be made up of 1-inch (25 mm) nominal sheathing boards laid at an angle of approximately 45 degrees to supports. Sheathing boards shall be directly nailed to each intermediate bearing member with not less than two 8d nails for 1-inch-by-6-inch (25 mm by 152 mm) nominal boards and three 8d nails for boards 8 inches (203 mm) or wider; and three 8d nails and four 8d nails shall be used for 6-inch and 8-inch (152 mm and 203 mm) boards, respectively, at the diaphragm boundaries. End joints in adjacent boards shall be separated by at least one joist or stud space, and there shall be at least two boards between joints on the same support. Boundary members at edges of diaphragms shall be designed to resist direct tensile or compressive chord stresses and adequately tied together at corners.

2315.3.2 Special lumber diaphragm construction. Special diagonally sheathed diaphragms shall conform to conventional lumber diaphragm construction and shall have all elements designed in conformance with the provisions of this code.

Each chord or portion thereof may be considered as a beam loaded with a uniform load per foot equal to 50 percent of the unit shear due to diaphragm action. The load shall be assumed as acting normal to the chord, in the plane of the diaphragm, and either toward or away from the diaphragm. The span of the chord, or portion thereof, shall be the distance between structural members of the diaphragm, such as the joists, studs and blocking, which serve to transfer the assumed load to the sheathing.

Special diagonally sheathed diaphragms shall include conventional diaphragms sheathed with two layers of diagonal sheathing at 90 degrees to each other and on the same face of the supporting members.

2315.3.3 Wood structural panel diaphragms. Horizontal and vertical diaphragms sheathed with wood structural panels may be used to resist horizontal forces not exceeding those set forth in Table 23-II-H for horizontal diaphragms and Table 23-II-I-1 for vertical diaphragms, or may be calculated by principles of mechanics without limitation by using values of nail strength and wood structural panel shear values as specified elsewhere in this code. Wood structural panels for horizontal diaphragms shall be as set forth in Tables 23-II-E-1 and 23-II-E-2 for corresponding joist spacing and loads. Wood structural panels in shear walls shall be at least $^5/_{16}$ inch (7.9 mm) thick for studs spaced 16 inches (406 mm) on center and $^3/_8$ inch (9.5 mm) thick where studs are spaced 24 inches (610 mm) on center.

Maximum spans for wood structural panel subfloor underlayment shall be as set forth in Table 23-II-F-1. Wood structural panels used for horizontal and vertical diaphragms shall conform to UBC Standard 23-2 or 23-3.

All boundary members shall be proportioned and spliced where necessary to transmit direct stresses. Framing members shall be at least 2-inch (51 mm) nominal in the dimension to which the wood structural panel is attached. In general, panel edges shall bear on the framing members and butt along their center lines. Nails shall be placed not less than $^3/_8$ inch (9.5 mm) in from the panel edge, shall be spaced not more than 6 inches (152 mm) on center along panel edge bearings, and shall be firmly driven into the framing members. No unblocked panels less than 12 inches (305 mm) wide shall be used.

Diaphragms with panel edges supported in accordance with Tables 23-II-E-1, 23-II-E-2 and 23-II-F-1 shall not be considered as blocked diaphragms unless blocking or other means of shear transfer is provided.

2315.4 Particleboard Diaphragms. Vertical diaphragms sheathed with particleboard may be used to resist horizontal forces not exceeding those set forth in Table 23-II-I-2.

All boundary members shall be proportioned and spliced where necessary to transmit direct stresses. Framing members shall be at least 2-inch (51 mm) nominal in the dimension to which the particleboard is attached. In general, panel edges shall bear on the framing members and butt along their center lines. Nails shall be placed not less than $^3/_8$ inch (9.5 mm) in from the panel edge, shall be spaced not more than 6 inches (152 mm) on center along panel edge bearings, and shall be firmly driven into the framing members. No unblocked panels less than 12 inches (305 mm) wide shall be used.

Diaphragms with panel edges supported in accordance with Table 23-II-F-2 shall not be considered as blocked diaphragms unless blocking or other means of shear transfer is provided.

2315.5 Wood Shear Walls and Diaphragms in Seismic Zones 3 and 4.

2315.5.1 Scope. Design and construction of wood shear walls and diaphragms in Seismic Zones 3 and 4 shall conform to the requirements of this section.

2315.5.2 Framing. Collector members shall be provided to transmit tension and compression forces. Perimeter members at openings shall be provided and shall be detailed to distribute the shearing stresses. Diaphragm sheathing shall not be used to splice these members.

Diaphragm chords and ties shall be placed in, or tangent to, the plane of the diaphragm framing unless it can be demonstrated that the moments, shears and deflections and deformations resulting from other arrangements can be tolerated.

2315.5.3 Wood structural panels. Wood structural panels shall be manufactured using exterior glue.

Wood structural panel diaphragms and shear walls shall be constructed with wood structural panel sheets not less than 4 feet by 8 feet (1219 mm by 2438 mm), except at boundaries and changes in framing where minimum sheet dimension shall be 24 inches (610 mm) unless all edges of the undersized sheets are supported by framing members or blocking.

Framing members or blocking shall be provided at the edges of all sheets in shear walls.

Wood structural panel sheathing may be used for splicing members, other than those noted in Section 2315.5.2, where the additional nailing required to develop the transfer of forces will not cause cross-grain bending or cross-grain tension in the nailed member.

2315.5.4 Heavy wood panels. Diagonally sheathed panels utilizing 2-inch (51 mm) nominal boards may be used to resist the same permissible shears as 1-inch (25 mm) nominal lumber, except that 16d nails shall be used instead of 8d nails.

Panels utilizing straight decking overlaid with wood structural panels may be used to resist shear forces using the same shear values as permitted for the wood structural panel alone. Wood structural panel joints parallel to the decking shall be located at least 1 inch (25 mm) offset from any parallel decking joint.

Heavy decking panels utilizing dowel pins, or vertically laminated panels connected by nailing units to each other, resist shear forces based on the permissible shear values of their connectors.

2315.5.5 Particleboard. Particleboard shall not be less than Type M "Exterior Glue."

Shear walls shall be sheathed with particleboard sheets not less than 4 feet by 8 feet (1219 mm by 2438 mm) except at boundaries and changes in framing. The required nail size and spacing in Table 23-II-B-1 apply to panel edges only. All panel edges shall be backed with 2-inch (51 mm) nominal or wider framing. Sheets are permitted to be installed either horizontally or vertically. For $^3/_8$-inch (9.5 mm) particleboard sheets installed with the long dimension parallel to the studs spaced 24 inches (610 mm) on center, nails shall be spaced at 6 inches (152 mm) on center along intermediate framing members. For all other conditions, nails of the same size shall be spaced at 12 inches (305 mm) on center along intermediate framing members.

2315.6 Fiberboard Sheathing Diaphragms. Wood stud walls sheathed with fiberboard sheathing may be used to resist horizontal forces not exceeding those set forth in Division III, Part IV. The fiberboard sheathing, 4 feet by 8 feet (1219 mm by 2438 mm), shall be applied vertically to wood studs not less than 2-inch (51 mm) nominal in thickness spaced 16 inches (406 mm) on center. Nailing shown in Table 23-II-J shall be provided at the perimeter of the sheathing board and at intermediate studs. Blocking not less than 2-inch (51 mm) nominal in thickness shall be provided at horizontal joints when wall height exceeds length of sheathing panel, and sheathing shall be fastened to the blocking with nails sized as shown in Table 23-II-J spaced 3 inches (76 mm) on centers each side of joint. Nails shall be spaced not less than $^3/_8$ inch (9.5 mm) from edges and ends of sheathing. Marginal studs of shear walls or shear-resisting elements shall be adequately anchored at top and bottom and designed to resist all forces. The maximum height-width ratio shall be $1^1/_2$:1.

TABLE 23-II-A-1—EXPOSED PLYWOOD PANEL SIDING

MINIMUM THICKNESS[1] (inch)	MINIMUM NUMBER OF PLIES	STUD SPACING (inches) PLYWOOD SIDING APPLIED DIRECTLY TO STUDS OR OVER SHEATHING
× 25.4 for mm		× 25.4 for mm
$^3/_8$	3	16[2]
$^1/_2$	4	24

[1]Thickness of grooved panels is measured at bottom of grooves.
[2]May be 24 inches (610 mm) if plywood siding applied with face grain perpendicular to studs or over one of the following: (1) 1-inch (25 mm) board sheathing, (2) $^7/_{16}$-inch (11 mm) wood structural panel sheathing or (3) $^3/_8$-inch (9.5 mm) wood structural panel sheathing with strength axis (which is the long direction of the panel unless otherwise marked) of sheathing perpendicular to studs.

TABLE 23-II-A-2—ALLOWABLE SPANS FOR EXPOSED PARTICLEBOARD PANEL SIDING

GRADE	STUD SPACING (inches)	MINIMUM THICKNESS (inches) × 25.4 for mm		
		Siding		Exterior Ceilings and Soffits
	× 25.4 for mm	Direct to Studs	Continuous Support	Direct to Supports
M-1 M-S M-2 “Exterior Glue”	16	$^5/_8$	$^3/_8$	$^3/_8$
	24	$^5/_8$	$^3/_8$	$^3/_8$

TABLE 23-II-B-1—NAILING SCHEDULE

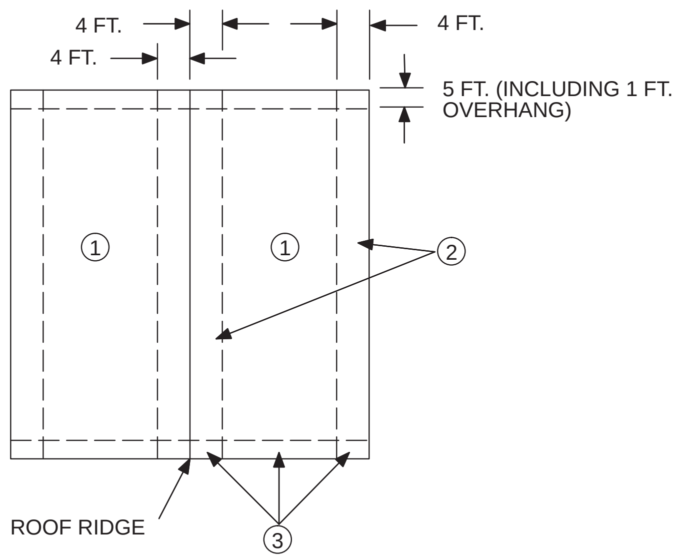
CONNECTION	NAILING[1]
1. Joist to sill or girder, toenail	3-8d
2. Bridging to joist, toenail each end	2-8d
3. 1" × 6" (25 mm × 152 mm) subfloor or less to each joist, face nail	2-8d
4. Wider than 1" × 6" (25 mm × 152 mm) subfloor to each joist, face nail	3-8d
5. 2" (51 mm) subfloor to joist or girder, blind and face nail	2-16d
6. Sole plate to joist or blocking, typical face nail Sole plate to joist or blocking, at braced wall panels	16d at 16" (406 mm) o.c. 3-16d per 16" (406 mm)
7. Top plate to stud, end nail	2-16d
8. Stud to sole plate	4-8d, toenail or 2-16d, end nail
9. Double studs, face nail	16d at 24" (610 mm) o.c.
10. Doubled top plates, typical face nail Double top plates, lap splice	16d at 16" (406 mm) o.c. 8-16d
11. Blocking between joists or rafters to top plate, toenail	3-8d
12. Rim joist to top plate, toenail	8d at 6" (152 mm) o.c.
13. Top plates, laps and intersections, face nail	2-16d
14. Continuous header, two pieces	16d at 16" (406 mm) o.c. along each edge
15. Ceiling joists to plate, toenail	3-8d
16. Continuous header to stud, toenail	4-8d
17. Ceiling joists, laps over partitions, face nail	3-16d
18. Ceiling joists to parallel rafters, face nail	3-16d
19. Rafter to plate, toenail	3-8d
20. 1" (25 mm) brace to each stud and plate, face nail	2-8d
21. 1" × 8" (25 mm × 203 mm) sheathing or less to each bearing, face nail	2-8d
22. Wider than 1" × 8" (25 mm × 203 mm) sheathing to each bearing, face nail	3-8d
23. Built-up corner studs	16d at 24" (610 mm) o.c.
24. Built-up girder and beams	20d at 32" (813 mm) o.c. at top and bottom and staggered 2-20d at ends and at each splice
25. 2" (51 mm) planks	2-16d at each bearing
26. Wood structural panels and particleboard:[2] Subfloor and wall sheathing (to framing): 1/2" (12.7 mm) and less 19/32"-3/4" (15 mm-19 mm) 7/8"-1" (22 mm-25 mm) 1 1/8"-1 1/4" (29 mm-32 mm) Combination subfloor-underlayment (to framing): 3/4" (19 mm) and less 7/8"-1" (22 mm-25 mm) 1 1/8"-1 1/4" (29 mm-32 mm)	 6d[3] 8d[4] or 6d[5] 8d[3] 10d[4] or 8d[5] 6d[5] 8d[5] 10d[4] or 8d[5]
27. Panel siding (to framing)[2]: 1/2" (12.7 mm) or less 5/8" (16 mm)	 6d[6] 8d[6]
28. Fiberboard sheathing:[7] 1/2" (12.7 mm) 25/32" (20 mm)	 No. 11 ga.[8] 6d[4] No. 16 ga.[9] No. 11 ga.[8] 8d[4] No. 16 ga.[9]
29. Interior paneling 1/4" (6.4 mm) 3/8" (9.5 mm)	 4d[10] 6d[11]

[1]Common or box nails may be used except where otherwise stated.
[2]Nails spaced at 6 inches (152 mm) on center at edges, 12 inches (305 mm) at intermediate supports except 6 inches (152 mm) at all supports where spans are 48 inches (1219 mm) or more. For nailing of wood structural panel and particleboard diaphragms and shear walls, refer to Sections 2315.3.3 and 2315.4. Nails for wall sheathing may be common, box or casing.
[3]Common or deformed shank.
[4]Common.
[5]Deformed shank.
[6]Corrosion-resistant siding or casing nails conforming to the requirements of Section 2304.3.
[7]Fasteners spaced 3 inches (76 mm) on center at exterior edges and 6 inches (152 mm) on center at intermediate supports.
[8]Corrosion-resistant roofing nails with 7/16-inch-diameter (11 mm) head and 1 1/2-inch (38 mm) length for 1/2-inch (12.7 mm) sheathing and 1 3/4-inch (44 mm) length for 25/32-inch (20 mm) sheathing conforming to the requirements of Section 2304.3.
[9]Corrosion-resistant staples with nominal 7/16-inch (11 mm) crown and 1 1/8-inch (29 mm) length for 1/2-inch (12.7 mm) sheathing and 1 1/2-inch (38 mm) length for 25/32-inch (20 mm) sheathing conforming to the requirements of Section 2304.3.
[10]Panel supports at 16 inches (406 mm) [20 inches (508 mm) if strength axis in the long direction of the panel, unless otherwise marked]. Casing or finish nails spaced 6 inches (152 mm) on panel edges, 12 inches (305 mm) at intermediate supports.
[11]Panel supports at 24 inches (610 mm). Casing or finish nails spaced 6 inches (152 mm) on panel edges, 12 inches (305 mm) at intermediate supports.

TABLE 23-II-B-2—WOOD STRUCTURAL PANEL ROOF SHEATHING NAILING SCHEDULE[1]

WIND REGION	NAILS	PANEL LOCATION	ROOF FASTENING ZONE[2]		
			1	2	3
			Fastening Schedule (inches on center)		
			× 25.4 for mm		
Greater than 90 mph (145 km/h)	8d common	Panel edges[3]	6	6	4[4]
		Panel field	6	6	6[4]
Greater than 80 mph (129 km/h) to 90 mph (145 km/h)	8d common	Panel edges[3]	6	6	4
		Panel field	12	6	6
80 mph (129 km/h) or less	8d common	Panel edges[3]	6	6	6
		Panel field	12	12	12

[1]Applies only to mean roof heights up to 35 feet (10 700 mm). For mean roof heights over 35 feet (10 700 mm), the nailing shall be designed.
[2]The roof fastening zones are shown below:



ROOF FASTENING ZONES

For **SI:** 1 foot = 304.8 mm.

[3]Edge spacing also applies over roof framing at gable-end walls.
[4]Use 8d ring-shank nails in this zone if mean roof height is greater than 25 feet (7600 mm).

TABLE 23-II-C—HARDBOARD SIDING

SIDING	MINIMAL NOMINAL THICKNESS (inch)	FRAMING (2" x 4") MAXIMUM SPACING	NAIL SIZE[1, 2]	NAIL SPACING General	NAIL SPACING Bracing Panels[3]
	× 25.4 for mm				
1. LAP SIDING					
Direct to studs	3/8	16" o.c.	8d	16" o.c.	Not applicable
Over sheathing	3/8	16" o.c.	10d	16" o.c.	Not applicable
2. SQUARE EDGE PANEL SIDING					
Direct to studs	3/8	24" o.c.	6d	6" o.c. edges; 12" o.c. at intermed. supports	4" o.c. edges; 8" o.c. intermed. supports
Over sheathing	3/8	24" o.c.	8d	6" o.c. edges; 12" o.c. at intermed. supports	4" o.c. edges; 8" o.c. intermed. supports
3. SHIPLAP EDGE PANEL SIDING					
Direct to studs	3/8	16" o.c.	6d	6" o.c. edges; 12" o.c. at intermed. supports	4" o.c. edges; 8" o.c. intermed. supports
Over sheathing	3/8	16" o.c.	8d	6" o.c. edges; 12" o.c. at intermed. supports	4" o.c. edges; 8" o.c. intermed. supports

[1]Nails shall be corrosion resistant in accordance with Division III, Part III.
[2]Minimum acceptable nail dimensions (inches).

	Panel Siding (inch)	Lap Siding (inch)
	× 25.4 for mm	
Shank diameter	0.092	0.099
Head diameter	0.225	0.240

[3]When used to comply with Division IV, Section 2320.11.3.

TABLE 23-II-D-1—ALLOWABLE SPANS FOR LUMBER FLOOR AND ROOF SHEATHING[1, 2]

SPAN (inches)	MINIMUM NET THICKNESS (inches) OF LUMBER PLACED — Perpendicular to Supports		Diagonally to Supports	
	× 25.4 for mm			
× 25.4 for mm	Surfaced Dry[3]	Surfaced Unseasoned	Surfaced Dry[3]	Surfaced Unseasoned
Floors				
1. 24	3/4	25/32	3/4	25/32
2. 16	5/8	11/16	5/8	11/16
Roofs				
3. 24	5/8	11/16	3/4	25/32

[1]Installation details shall conform to Sections 2320.9.1 and 2320.12.8 for floor and roof sheathing, respectively.
[2]Floor or roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2312.
[3]Maximum 19 percent moisture content.

TABLE 23-II-D-2—SHEATHING LUMBER SHALL MEET THE FOLLOWING MINIMUM GRADE REQUIREMENTS: BOARD GRADE

SOLID FLOOR OR ROOF SHEATHING	SPACED ROOF SHEATHING	GRADING RULES
1. Utility	Standard	NLGA, WCLIB, WWPA
2. 4 common or utility	3 common or standard	NLGA, WCLIB, WWPA, NHPMA or NELMA
3. No. 3	No. 2	SPIB
4. Merchantable	Construction common	RIS

TABLE 23-II-E-1—ALLOWABLE SPANS AND LOADS FOR WOOD STRUCTURAL PANEL SHEATHING AND SINGLE-FLOOR GRADES CONTINUOUS OVER TWO OR MORE SPANS WITH STRENGTH AXIS PERPENDICULAR TO SUPPORTS[1,2]

SHEATHING GRADES		ROOF[3]				FLOOR[4]
		Maximum Span (inches)		Load[5] (pounds per square foot)		
Panel Span Rating	Panel Thickness (inches)	× 25.4 for mm		× 0.0479 for kN/m²		Maximum Span (inches)
Roof/Floor Span	× 25.4 for mm	With Edge Support[6]	Without Edge Support	Total Load	Live Load	× 25.4 for mm
12/0	$^{5}/_{16}$	12	12	40	30	0
16/0	$^{5}/_{16}$, $^{3}/_{8}$	16	16	40	30	0
20/0	$^{5}/_{16}$, $^{3}/_{8}$	20	20	40	30	0
24/0	$^{3}/_{8}$, $^{7}/_{16}$, $^{1}/_{2}$	24	20[7]	40	30	0
24/16	$^{7}/_{16}$, $^{1}/_{2}$	24	24	50	40	16
32/16	$^{15}/_{32}$, $^{1}/_{2}$, $^{5}/_{8}$	32	28	40	30	16[8]
40/20	$^{19}/_{32}$, $^{5}/_{8}$, $^{3}/_{4}$, $^{7}/_{8}$	40	32	40	30	20[8,9]
48/24	$^{23}/_{32}$, $^{3}/_{4}$, $^{7}/_{8}$	48	36	45	35	24
54/32	$^{7}/_{8}$, 1	54	40	45	35	32
60/48	$^{7}/_{8}$, 1, $1^{1}/_{8}$	60	48	45	35	48
SINGLE-FLOOR GRADES		**ROOF[3]**				**FLOOR[4]**
		Maximum Span (inches)		Load[5] (pounds per square foot)		
Panel Span Rating (inches)	Panel Thickness (inches)	× 25.4 for mm		× 0.0479 for kN/m²		Maximum Span (inches)
× 25.4 for mm		With Edge Support[6]	Without Edge Support	Total Load	Live Load	× 25.4 for mm
16 oc	$^{1}/_{2}$, $^{19}/_{32}$, $^{5}/_{8}$	24	24	50	40	16[8]
20 oc	$^{19}/_{32}$, $^{5}/_{8}$, $^{3}/_{4}$	32	32	40	30	20[8,9]
24 oc	$^{23}/_{32}$, $^{3}/_{4}$	48	36	35	25	24
32 oc	$^{7}/_{8}$, 1	48	40	50	40	32
48 oc	$1^{3}/_{32}$, $1^{1}/_{8}$	60	48	50	50	48

[1]Applies to panels 24 inches (610 mm) or wider.
[2]Floor and roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2312.
[3]Uniform load deflection limitations $^{1}/_{180}$ of span under live load plus dead load, $^{1}/_{240}$ under live load only.
[4]Panel edges shall have approved tongue-and-groove joints or shall be supported with blocking unless $^{1}/_{4}$-inch (6.4 mm) minimum thickness underlayment or $1^{1}/_{2}$ inches (38 mm) of approved cellular or lightweight concrete is placed over the subfloor, or finish floor is $^{3}/_{4}$-inch (19 mm) wood strip. Allowable uniform load based on deflection of $^{1}/_{360}$ of span is 100 pounds per square foot (psf) (4.79 kN/m²) except the span rating of 48 inches on center is based on a total load of 65 psf (3.11 kN/m).
[5]Allowable load at maximum span.
[6]Tongue-and-groove edges, panel edge clips [one midway between each support, except two equally spaced between supports 48 inches (1219 mm) on center], lumber blocking, or other. Only lumber blocking shall satisfy blocked diaphgrams requirements.
[7]For $^{1}/_{2}$-inch (12.7 mm) panel, maximum span shall be 24 inches (610 mm).
[8]May be 24 inches (610 mm) on center where $^{3}/_{4}$-inch (19 mm) wood strip flooring is installed at right angles to joist.
[9]May be 24 inches (610 mm) on center for floors where $1^{1}/_{2}$ inches (38 mm) of cellular or lightweight concrete is applied over the panels.

TABLE 23-II-E-2—ALLOWABLE LOAD (PSF) FOR WOOD STRUCTURAL PANEL ROOF SHEATHING CONTINUOUS OVER TWO OR MORE SPANS AND STRENGTH AXIS PARALLEL TO SUPPORTS (Plywood structural panels are five-ply, five-layer unless otherwise noted.)[1,2]

PANEL GRADE	THICKNESS (inch)	MAXIMUM SPAN (inches)	LOAD AT MAXIMUM SPAN (psf)	
			× 0.0479 for kN/m²	
	× 25.4 for mm		Live	Total
Structural I	$^{7}/_{16}$	24	20	30
	$^{15}/_{32}$	24	35[3]	45[3]
	$^{1}/_{2}$	24	40[3]	50[3]
	$^{19}/_{32}$, $^{5}/_{8}$	24	70	80
	$^{23}/_{32}$, $^{3}/_{4}$	24	90	100
Other grades covered in UBC Standard 23-2 or 23-3	$^{7}/_{16}$	16	40	50
	$^{15}/_{32}$	24	20	25
	$^{1}/_{2}$	24	25	30
	$^{19}/_{32}$	24	40[3]	50[3]
	$^{5}/_{8}$	24	45[3]	55[3]
	$^{23}/_{32}$, $^{3}/_{4}$	24	60[3]	65[3]

[1]Roof sheathing conforming with this table shall be deemed to meet the design criteria of Section 2312.
[2]Uniform load deflection limitations: $^{1}/_{180}$ of span under live load plus dead load, $^{1}/_{240}$ under live load only. Edges shall be blocked with lumber or other approved type of edge supports.
[3]For composite and four-ply plywood structural panel, load shall be reduced by 15 pounds per square foot (0.72 kN/m²).

TABLE 23-II-F-1—ALLOWABLE SPAN FOR WOOD STRUCTURAL PANEL COMBINATION SUBFLOOR-UNDERLAYMENT (SINGLE FLOOR)[1,2] Panels Continuous over Two or More Spans and Strength Axis Perpendicular to Supports

IDENTIFICATION	MAXIMUM SPACING OF JOISTS (inches) × 25.4 for mm				
	16	20	24	32	48
	Thickness (inches) × 25.4 for mm				
Species Group[3]					
1	$^1/_2$	$^5/_8$	$^3/_4$	—	—
2, 3	$^5/_8$	$^3/_4$	$^7/_8$	—	—
4	$^3/_4$	$^7/_8$	1	—	—
Span rating[4]	16 o.c.	20 o.c.	24 o.c.	32 o.c.	48 o.c.

[1]Spans limited to value shown because of possible effects of concentrated loads. Allowable uniform loads based on deflection of $^1/_{360}$ of span is 100 pounds per square foot (psf) (4.79 kN/m^2), except allowable total uniform load for 1$^1/_8$-inch (29 mm) wood structural panels over joists spaced 48 inches (1219 mm) on center is 65 psf (3.11 kN/m^2). Panel edges shall have approved tongue-and-groove joints or shall be supported with blocking, unless $^1/_4$-inch (6.4 mm) minimum thickness underlayment or 1$^1/_2$ inches (38 mm) of approved cellular or lightweight concrete is placed over the subfloor, or finish floor is $^3/_4$-inch (19 mm) wood strip.

[2]Floor panels conforming with this table shall be deemed to meet the design criteria of Section 2312.

[3]Applicable to all grades of sanded exterior-type plywood. See UBC Standard 23-2 for plywood species groups.

[4]Applicable to underlayment grade and C-C (plugged) plywood, and single floor grade wood structural panels.

TABLE 23-II-F-2—ALLOWABLE SPANS FOR PARTICLEBOARD SUBFLOOR AND COMBINED SUBFLOOR-UNDERLAYMENT[1,2]

GRADE	THICKNESS (inches) × 25.4 for mm	MAXIMUM SPACING OF SUPPORTS (inches)[3] × 25.4 for mm	
		Subfloor	Combined Subfloor-Underlayment[4,5]
2-M-W	$^1/_2$	16	—
	$^5/_8$	20	16
	$^3/_4$	24	24
2-M-3	$^3/_4$	20	20

[1]All panels are continuous over two or more spans.
[2]Floor sheathing conforming with this table shall be deemed to meet the design criteria of Section 2312.
[3]Uniform deflection limitation: $^1/_{360}$ of the span under 100 pounds per square foot (4.79 kN/m^2) minimum load.
[4]Edges shall have tongue-and-groove joints or shall be supported with blocking. The tongue-and-groove panels are installed with the long dimension perpendicular to supports.
[5]A finish wearing surface is to be applied to the top of the panel.

TABLE 23-II-G—MAXIMUM DIAPHRAGM DIMENSION RATIOS

MATERIAL	HORIZONTAL DIAPHRAGMS Maximum Span-Width Ratios	SHEAR WALLS Maximum Height-Width Ratios
1. Diagonal sheathing, conventional	3:1	1:1[1]
2. Diagonal sheathing, special	4:1	2:1[2]
3. Wood structural panels and particleboard, nailed all edges	4:1	2:1[2, 3]
4. Wood structural panels and particleboard, blocking omitted at intermediate joints.	4:1	[4]

[1]In Seismic Zones 0, 1, 2 and 3, the maximum ratio may be 2:1.
[2]In Seismic Zones 0, 1, 2 and 3, the maximum ratio may be 3$^1/_2$:1.
[3]In Seismic Zone 4, the maximum ratio may be 3$^1/_2$:1 for walls not exceeding 10 feet (3048 mm) in height on one side of the door to a one-story Group U Occupancy.
[4]Not permitted.

TABLE 23-II-H—ALLOWABLE SHEAR IN POUNDS PER FOOT FOR HORIZONTAL WOOD STRUCTURAL PANEL DIAPHRAGMS WITH FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE[1]

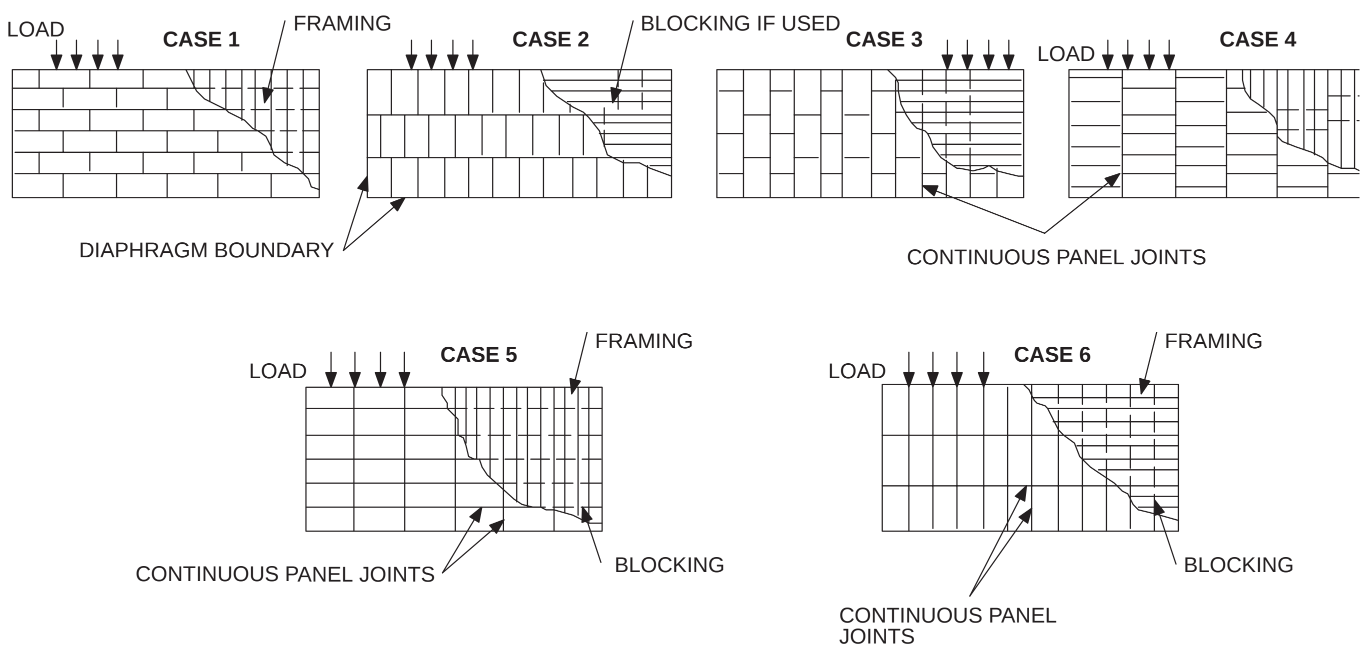
PANEL GRADE	COMMON NAIL SIZE	MINIMUM NAIL PENETRATION IN FRAMING (inches)	MINIMUM NOMINAL PANEL THICKNESS (inches)	MINIMUM NOMINAL WIDTH OF FRAMING MEMBER (inches)	BLOCKED DIAPHRAGMS				UNBLOCKED DIAPHRAGMS	
					Nail spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 and 4) and at all panel edges (Cases 5 and 6)				Nails spaced 6" (152 mm) max. at supported edges	
					× 25.4 for mm				Case 1 (No unblocked edges or continuous joints parallel to load)	All other configurations (Cases 2, 3, 4, 5 and 6)
					6	4	$2^1/_2$[2]	2[2]		
					Nail spacing (in.) at other panel edges					
					× 25.4 for mm					
					6	6	4	3		
		× 25.4 for mm			× 0.0146 for N/mm					
Structural 1	6d	$1^1/_4$	$^5/_{16}$	2 3	185 210	250 280	375 420	420 475	165 185	125 140
	8d	$1^1/_2$	$^3/_8$	2 3	270 300	360 400	530 600	600 675	240 265	180 200
	10d[3]	$1^5/_8$	$^{15}/_{32}$	2 3	320 360	425 480	640 720	730 820	285 320	215 240
C-D, C-C, Sheathing, and other grades covered in UBC Standard 23-2 or 23-3	6d	$1^1/_4$	$^5/_{16}$	2 3	170 190	225 250	335 380	380 430	150 170	110 125
			$^3/_8$	2 3	185 210	250 280	375 420	420 475	165 185	125 140
	8d	$1^1/_2$	$^3/_8$	2 3	240 270	320 360	480 540	545 610	215 240	160 180
			$^7/_{16}$	2 3	255 285	340 380	505 570	575 645	230 255	170 190
			$^{15}/_{32}$	2 3	270 300	360 400	530 600	600 675	240 265	180 200
	10d[3]	$1^5/_8$	$^{15}/_{32}$	2 3	290 325	385 430	575 650	655 735	255 290	190 215
			$^{19}/_{32}$	2 3	320 360	425 480	640 720	730 820	285 320	215 240

[1]These values are for short-time loads due to wind or earthquake and must be reduced 25 percent for normal loading. Space nails 12 inches (305 mm) on center along intermediate framing members.

Allowable shear values for nails in framing members of other species set forth in Division III, Part III, shall be calculated for all other grades by multiplying the shear capacities for nails in Structural I by the following factors: 0.82 for species with specific gravity greater than or equal to 0.42 but less than 0.49, and 0.65 for species with a specific gravity less than 0.42.

[2]Framing at adjoining panel edges shall be 3-inch (76 mm) nominal or wider and nails shall be staggered where nails are spaced 2 inches (51 mm) or $2^1/_2$ inches (64 mm) on center.

[3]Framing at adjoining panel edges shall be 3-inch (76 mm) nominal or wider and nails shall be staggered where 10d nails having penetration into framing of more than $1^5/_8$ inches (41 mm) are spaced 3 inches (76 mm) or less on center.



NOTE: Framing may be oriented in either direction for diaphragms, provided sheathing is properly designed for vertical loading.

TABLE 23-II-I-1—ALLOWABLE SHEAR FOR WIND OR SEISMIC FORCES IN POUNDS PER FOOT FOR WOOD STRUCTURAL PANEL SHEAR WALLS WITH FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE[1,2,3]

PANEL GRADE	MINIMUM NOMINAL PANEL THICKNESS (inches)	MINIMUM NAIL PENETRATION IN FRAMING (inches)	PANELS APPLIED DIRECTLY TO FRAMING: Nail Size (Common or Galvanized Box)[5]	Nail Spacing at Panel Edges (in.) 6	4	3	2	PANELS APPLIED OVER $^1/_2$-INCH (13 mm) OR $^5/_8$-INCH (16 mm) GYPSUM SHEATHING: Nail Size (Common or Galvanized Box)[5]	Nail Spacing at Panel Edges (in.) 6	4	3	2
	× 25.4 for mm			× 25.4 for mm / × 0.0146 for N/mm					× 25.4 for mm / × 0.0146 for N/mm			
Structural I	$^5/_{16}$	$1^1/_4$	6d	200	300	390	510	8d	200	300	390	510
	$^3/_8$	$1^1/_2$	8d	230[4]	360[4]	460[4]	610[4]	10d	280	430	550	730
	$^7/_{16}$			255[4]	395[4]	505[4]	670[4]					
	$^{15}/_{32}$			280	430	550	730					
	$^{15}/_{32}$	$1^5/_8$	10d	340	510	665	870	—	—	—	—	—
C-D, C-C Sheathing, plywood panel siding and other grades covered in UBC Standard 23-2 or 23-3	$^5/_{16}$	$1^1/_4$	6d	180	270	350	450	8d	180	270	350	450
	$^3/_8$			200	300	390	510		200	300	390	510
	$^3/_8$	$1^1/_2$	8d	220[4]	320[4]	410[4]	530[4]	10d	260	380	490	640
	$^7/_{16}$			240[4]	350[4]	450[4]	585[4]					
	$^{15}/_{32}$			260	380	490	640					
	$^{15}/_{32}$	$1^5/_8$	10d	310	460	600	770	—	—	—	—	—
	$^{19}/_{32}$			340	510	665	870					
			Nail Size (Galvanized Casing)					Nail Size (Galvanized Casing)				
Plywood panel siding in grades covered in UBC Standard 23-2	$^5/_{16}$	$1^1/_4$	6d	140	210	275	360	8d	140	210	275	360
	$^3/_8$	$1^1/_2$	8d	160	240	310	410	10d	160	240	310	410

[1]All panel edges backed with 2-inch (51 mm) nominal or wider framing. Panels installed either horizontally or vertically. Space nails at 6 inches (152 mm) on center along intermediate framing members for $^3/_8$-inch (9.5 mm) and $^7/_{16}$-inch (11 mm) panels installed on studs spaced 24 inches (610 mm) on center and 12 inches (305 mm) on center for other conditions and panel thicknesses. These values are for short-time loads due to wind or earthquake and must be reduced 25 percent for normal loading.

Allowable shear values for nails in framing members of other species set forth in Division III, Part III, shall be calculated for all other grades by multiplying the shear capacities for nails in Structural I by the following factors: 0.82 for species with specific gravity greater than or equal to 0.42 but less than 0.49, and 0.65 for species with a specific gravity less than 0.42.

[2]Where panels are applied on both faces of a wall and nail spacing is less than 6 inches (152 mm) on center on either side, panel joints shall be offset to fall on different framing members or framing shall be 3-inch (76 mm) nominal or thicker and nails on each side shall be staggered.

[3]In Seismic Zones 3 and 4, where allowable shear values exceed 350 pounds per foot (5.11 N/mm), foundation sill plates and all framing members receiving edge nailing from abutting panels shall not be less than a single 3-inch (76 mm) nominal member and foundation sill plates shall not be less than a single 3-inch (76 mm) nominal member. In shear walls where total wall design shear does not exceed 600 pounds per foot (8.76 N/mm), a single 2-inch (51 mm) nominal sill plate may be used, provided anchor bolts are designed for a load capacity of 50 percent or less of the allowable capacity and bolts have a minimum of 2-inch-by-2-inch-by-$^3/_{16}$-inch (51 mm by 51 mm by 5 mm) thick plate washers. Plywood joint and sill plate nailing shall be staggered in all cases.

[4]The values for $^3/_8$-inch (9.5 mm) and $^7/_{16}$-inch (11 mm) panels applied direct to framing may be increased to values shown for $^{15}/_{32}$-inch (12 mm) panels, provided studs are spaced a maximum of 16 inches (406 mm) on center or panels are applied with long dimension across studs.

[5]Galvanized nails shall be hot-dipped or tumbled.

TABLE 23-II-I-2—ALLOWABLE SHEAR IN POUNDS PER FOOT FOR PARTICLEBOARD SHEAR WALLS WITH FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE[1,2,3]

PANEL GRADE	MINIMUM NOMINAL PANEL THICKNESS (inches)	MINIMUM NAIL PENETRATION IN FRAMING (inches)	PANELS APPLIED DIRECT TO FRAMING: Nail size (Common or Galvanized Box)	Allowable Shear (pounds per foot)[1] Nail Spacing at Panel Edges (inches) 6	4	3	2
	× 25.4 for mm			× 25.4 for mm / × 0.0146 for N/mm			
M-S[4] and M-2[4]	$^3/_8$	$1^1/_2$	6d	120	180	230	300
	$^3/_8$	$1^1/_2$	8d	130	190	240	315
	$^1/_2$			140	210	270	350
	$^1/_2$	$1^5/_8$	10d[5]	185	275	360	460
	$^5/_8$			200	305	395	520

[1]All panel edges backed with 2-inch (51 mm) nominal or wider framing. Space nails at 6 inches (152 mm) on center along intermediate framing members for $^3/_8$-inch (9.5 mm) panel installed with the long dimension parallel to studs spaced 24 inches (610 mm) on center and 12 inches (305 mm) on center for other conditions and panel thicknesses. These values are for short-time loads due to wind or earthquake and must be reduced 25 percent for normal loading.

Allowable shear values for nails in framing members of other species set forth in Division III, Part III, shall be calculated for all grades by multiplying the values for common and galvanized box nails by the following factors: Group III, 0.82 and Group IV, 0.65.

[2]Where particleboard is applied on both faces of a wall and nail spacing is less than 6 inches (152 mm) on center on either side, panel joints shall be offset to fall on different framing members, or framing shall be 3-inch (76 mm) nominal or thicker and nails on each side shall be staggered.

[3]In Seismic Zones 3 and 4, where allowable shear values exceed 350 pounds per foot (5.11 N/mm), foundation sill plates and all framing members receiving edge nailing from abutting panels shall not be less than a single 3-inch (76 mm) nominal member and foundation sill plates shall not be less than a single 3-inch (76 mm) nominal member. In shear walls where total wall design shear does not exceed 600 pounds per foot (8.76 N/mm), a single 2-inch (51 mm) nominal sill plate may be used, provided anchor bolts are designed for a load capacity of 50 percent or less of the allowable capacity and bolts have a minimum of 2-inch-by-2-inch-by-$^3/_{16}$-inch (51 mm by 51 mm by 5 mm) thick plate washers. Plywood joint and sill plate nailing shall be staggered in all cases.

[4]Products shall be manufactured with exterior glue and shall be identified with the words “Exterior Glue” following the product grade designation.

[5]Framing at adjoining panel edges shall be 3-inch (76 mm) nominal or wider and nails shall be staggered where 10d nails having penetration into framing of more than $1^5/_8$ inches (41 mm) are spaced 3 inches (76 mm) or less on center.

TABLE 23-II-J—ALLOWABLE SHEARS FOR WIND OR SEISMIC LOADING ON VERTICAL DIAPHRAGMS OF FIBERBOARD SHEATHING BOARD CONSTRUCTION FOR TYPE V CONSTRUCTION ONLY[1]

SIZE AND APPLICATION	NAIL SIZE	SHEAR VALUE IN POUNDS PER FOOT (N/mm) 3-INCH (76 mm) NAIL SPACING AROUND PERIMETER AND 6-INCH (152 mm) AT INTERMEDIATE POINTS
		× 1.46 for N/mm
$^{1}/_{2}$" × 4' × 8' (13 × 1219 × 2438 mm)	No. 11 gage galvanized roofing nail 1$^{1}/_{2}$" (38 mm) long, $^{7}/_{16}$" (11 mm) head	125[2]
$^{25}/_{32}$" × 4' × 8' (20 × 1219 × 2438 mm)	No. 11 gage galvanized roofing nail 1$^{3}/_{4}$" (44 mm) long, $^{7}/_{16}$" (11 mm) head	175

[1]Fiberboard sheathing diaphragms shall not be used to brace concrete or masonry walls.
[2]The shear value may be 175 (778 N) for $^{1}/_{2}$-inch-by-4-foot-by-8-foot (12.7 by 1219 by 2438 mm) fiberboard nail-base sheathing.

TABLE 23-II-K—WOOD SHINGLE AND SHAKE SIDE WALL EXPOSURES

SHINGLE OR SHAKE	MAXIMUM WEATHER EXPOSURES (inches) × 25.4 for mm			
	Single-Coursing		Double-Coursing	
Length and Type	No. 1	No. 2	No. 1	No. 2
16-inch (405 mm) shingles	7$^{1}/_{2}$	7$^{1}/_{2}$	12	10
18-inch (455 mm) shingles	8$^{1}/_{2}$	8$^{1}/_{2}$	14	11
24-inch (610 mm) shingles	11$^{1}/_{2}$	11$^{1}/_{2}$	16	14
18-inch (455 mm) resawn shakes	8$^{1}/_{2}$	—	14	—
18-inch (455 mm) straight-split shakes	8$^{1}/_{2}$	—	16	—
24-inch (610 mm) resawn shakes	11$^{1}/_{2}$	—	20	—

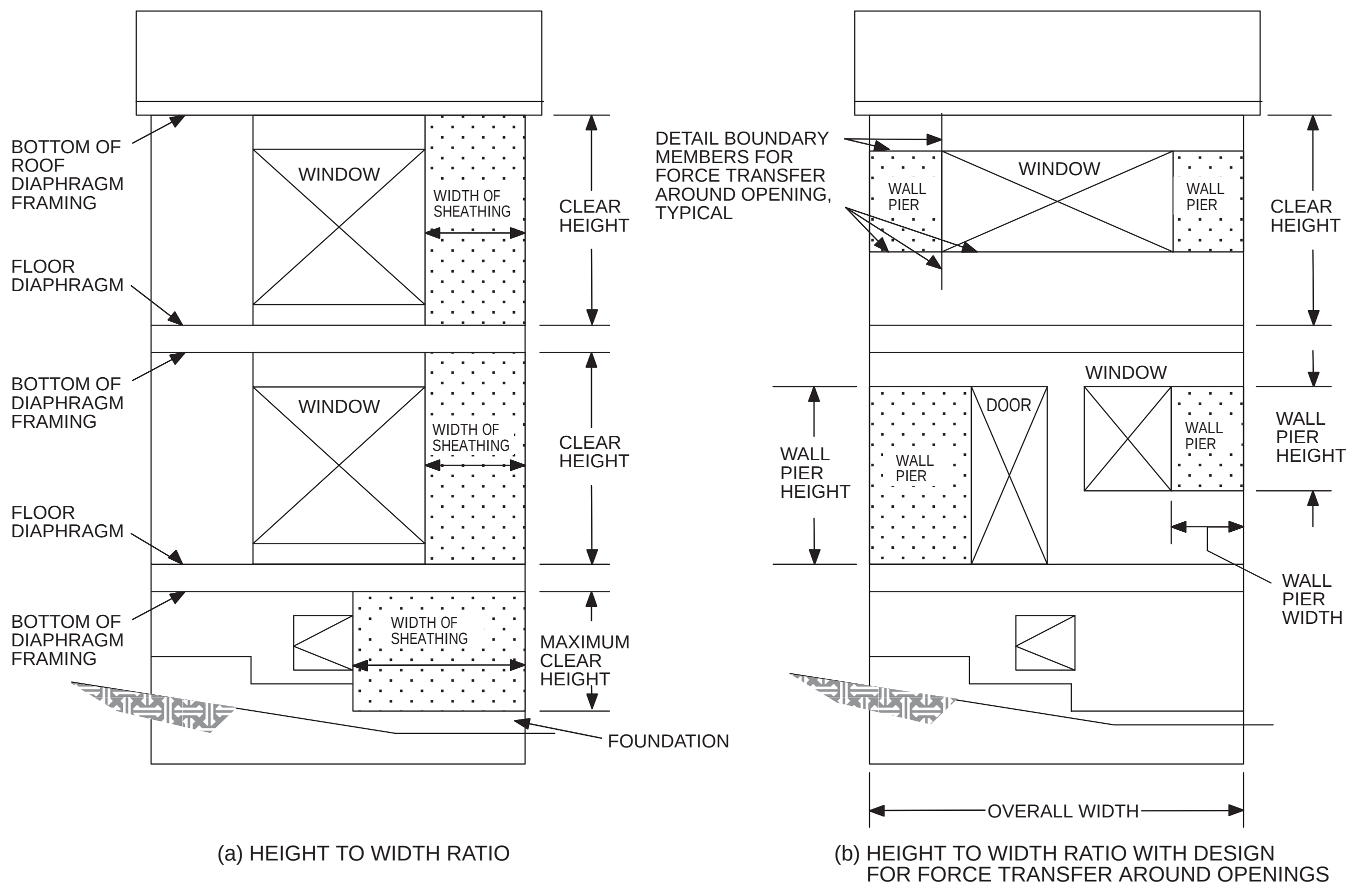


FIGURE 23-II-1—GENERAL DEFINITION OF SHEAR WALL HEIGHT TO WIDTH RATIO

Division III—DESIGN SPECIFICATIONS FOR ALLOWABLE STRESS DESIGN OF WOOD BUILDINGS

Part I—ALLOWABLE STRESS DESIGN OF WOOD

This standard, with certain exceptions, is the ANSI/NFoPA NDS-91 National Design Specification for Wood Construction of the American Forest and Paper Association, Revised 1991 Edition, and the Supplement to the 1991 Edition, National Design Specification, adopted by reference.

The National Design Specification for Wood Construction, Revised 1991 Edition, and supplement are available from the American Forest and Paper Association, 1111 19th Street, NW, Eighth Floor, Washington, DC, 20036.

SECTION 2316 — DESIGN SPECIFICATIONS

2316.1 Adoption and Scope. The National Design Specification for Wood Construction, Revised 1991 Edition (NDS), which is hereby adopted as a part of this code, shall apply to the design and construction of wood structures using visually graded lumber, mechanically graded lumber, structural glued laminated timber, and timber piles. National Design Specification Appendix Section F, Design for Creep and Critical Deflection Applications, Appendix Section G, Effective Column Length, and Appendix Section J, Solution of Hankinson Formula are specifically adopted and made a part of this standard. The Supplement to the 1991 Edition National Design Specification, Tables 2A, 4A, 4B, 4C, 4D, 4E, 5A, 5B and 5C are specifically adopted and made a part of this standard.

Other codes, standards or specifications referred to in this standard are to be considered as only an indication of an acceptable method or material that can be used with the approval of the building official, except where such other codes, standards or specifications are specifically adopted by this code as primary standards.

2316.2 Amendments.

1. Sec. 1.1. Delete and substitute the following:

The design of structures using visually graded lumber, mechanically graded lumber, structural glued laminated timber, timber piles, and design of their connections shall be in accordance with Chapter 23, Division III, Part 1.

2. Secs. 1.2 through 1.5. Delete.

3. Sec. 2.2. Delete first sentence and substitute the following:

Allowable stress design values for visually graded structural lumber, mechanically graded structural lumber and structural glued laminated timber shall be in accordance with NDS Supplement Tables 2A, 4A, 4B, 4C, 4D, 5A, 5B and 5C. Values for species and grades not tabulated shall be submitted to the building official for approval.

4. Sec. 2.3.2.1. In fourth sentence, delete "or Figure B1 (see Appendix B)."

5. Sec. 2.3.2.3. Delete and substitute the following:

2.3.2.3 When using Section 1612.3.1 basic load combinations, the Load Duration Factor, C_D, noted in Table 2.3.2 shall be permitted to be used. When using Section 1612.3.2 alternate load combinations, the one-third increase shall not be used concurrently with the Load Duration Factor, C_D.

6. Table 2.3.2. Delete and substitute as follows:

TABLE 2.3.2—LOAD DURATION FACTORS, C_D

DESIGN LOAD	LOAD DURATION	C_D
Dead Load	Permanent	0.9
Floor, Occupancy Live Load	Ten Years	1.0
Snow Load	Two Months	1.15
Roof Live Load	Seven Days	1.25
Earthquake Load[1]	—	1.33
Wind Load[2]	—	1.33
Impact	—	2.0

[1]1.60 may be used for nailed and bolted connections exhibiting Mode III or IV behavior, except that the increases for earthquake are not combined with the increase allowed in Section 1612.3. The 60-percent increase for nailed and bolted connections exhibiting Mode III or IV behavior for earthquake shall not be applicable to joist hangers, framing anchors, and other mechanical fastenings, including straps and hold-down anchors. The 60-percent increase shall not apply to the allowable shear values in Tables 23-II-H, 23-II-I-1, 23-II-I-2, 23-II-J or in Section 2315.3.

[2]1.60 may be used for members and nailed and bolted connections exhibiting Mode III or IV behavior, except that the increases for wind are not combined with the increase allowed in Section 1612.3. The 60-percent increase shall not apply to the allowable shear values in Tables 23-II-H, 23-II-I-1, 23-II-I-2, 23-II-J or in Section 2315.3.

7. Sec. 2.3.4. Add a second paragraph following Table 2.3.4:

The allowable unit stresses for fire-retardant-treated solid-sawn lumber and plywood, including fastener values, subject to prolonged elevated temperatures from manufacturing or equipment processes, but not exceeding 150°F (66°C), shall be developed from approved test methods that properly consider potential strength-reduction characteristics, including effects of heat and moisture.

8. Sec. 2.3.6. Add second, third and fourth paragraphs as follows:

The values for lumber and plywood impregnated with approved fire-retardant chemicals, including fastener values, shall be submitted to the building official for approval. Submittal to the building official shall include all substantiating data. Such values shall be developed from approved test methods and procedures that consider potential strength-reduction characteristics, including the effects of elevated temperatures and moisture. Other adjustments are applicable, except that the impact load-duration factor shall not apply.

Values for glued-laminated timber, including fastener design values, shall be recommended by the treater and submitted to the building official for approval. Submittal to the building official shall include all substantiating data.

In addition to the requirements specified in Section 207, fire-retardant lumber having structural applications shall be tested and identified by an approved inspection agency in accordance with UBC Standard 23-5.

9. Sec. 2.3.8. Add new second and third paragraphs following Table 2.3.8:

For lumber I beams and box beams, the form factor, C_f, shall be calculated as:

$$C_f = \left[1 + \left(\frac{d^2 + 143}{d^2 + 88} - 1\right) C_g\right]$$

For **SI:**

$$C_f = \left[1 + \left(\frac{\left(\frac{d}{25.4}\right)^2 + 143}{\left(\frac{d}{25.4}\right)^2 + 88} - 1\right) C_g\right]$$

WHERE:

C_f = form factor.

C_g = support factor = $p^2(6 - 8p + 3p^2)(1 - q) + q$.

d = depth of I or box beam.

p = ratio of depth of compression flange to full depth of beam.

q = ratio of thickness of web or webs to full width of beam.

10. Sec. 2.3.10. Add a paragraph at end of section as follows:

In joists supported on a ribbon or ledger board and spiked to the studding, the allowable stress in compression perpendicular to grain may be increased 50 percent.

11. Sec. 3.2.1. Add a second sentence as follows:

For continuous beams, the span shall be taken as the distance between centers of bearings on supports over which the beam is continuous.

12. Sec. 3.2.3.2. Add to end of paragraph as follows:

Cantilevered portions of beams less than 4 inches (102 mm) in nominal thickness shall not be notched unless the reduced section properties and lumber defects are considered in the design. For effects of notch on shear strength, see Section 3.4.4.

13. Sec. 3.3.2. Add a last paragraph as follows:

A beam of circular cross section may be assumed to have the same strength as a square beam having the same cross-sectional area. If a circular beam is tapered, it shall be considered a beam of variable cross section.

14. Sec. 3.4.4. Add a section as follows:

3.4.4.5 When girders, beams or joists are notched at points of support on the compression side, they shall meet design requirements for the net section in bending and in shear. The actual shear stress at such point shall be calculated as follows:

$$f_v = \frac{3V}{2b\left[d - \left(\frac{d-d'}{d'}\right)e\right]}$$

WHERE:

d = total depth of beam.

d' = actual depth of beam at notch.

e = distance notch extends inside the inner edge of support.

V = shear force.

Where e exceeds d', the actual shear stress for the notch on the compression side shall be calculated as follows:

$$f_v = \frac{3V}{2bd'}$$

15. Sec. 3.7.1.4. Delete and substitute as follows:

The slenderness ratio for solid columns, *le/d* shall not exceed 50.

16. Sec. 3.8.2. Delete and substitute as follows:

Where designs that induce tension stresses perpendicular to grain cannot be avoided, mechanical reinforcement sufficient to resist such forces shall be provided.

17. Sec. 4.2.5.5. Delete.

18. Sec. 4.4.1.1. Delete and substitute as follows:

Rectangular sawn lumber beams, rafters, joists or other bending members shall be supported laterally to prevent rotation or lateral displacement in accordance with Section 4.4.1.2, or shall be designed in accordance with the lateral stability provisions in Section 3.3.3.

19. Sec. 4.4.1.2. Delete first sentence.

20. Sec. 5.4.1. Delete second paragraph and substitute as follows:

For curved bending members having a varying cross section, the maximum actual radial stress induced, f_r, is given by:

$$f_r = K_r \frac{6M}{bd^2}$$

WHERE:

b = width of cross section, inches (mm).

d = depth of cross section at the apex in inches (mm).

K_r = radial stress factor determined from the following relationship:

$$K_r = A + B\left(\frac{d}{Rm}\right) + C\left(\frac{d}{Rm}\right)^2$$

M = bending moment at midspan in inch-pounds (N·mm).

WHERE:

Rm = radius of curvature at the center line of the member at midspan in inches (mm).

A, B and C = constants as follows:

β (1)	A (2)	B (3)	C (4)
(0.0)	(0.0)	(0.2500)	(0.0)
2.5°	0.0079	0.1747	0.1284
5.0°	0.0174	0.1251	0.1939
7.5°	0.0279	0.0937	0.2162
10.0°	0.0391	0.0754	0.2119
15.0°	0.0629	0.0619	0.1722
20.0°	0.0893	0.0608	0.1393
25.0°	0.1214	0.0605	0.1238
30.0°	0.1649	0.0603	0.1115

and β = angle between the upper edge of the member and the horizontal in degrees. Values of K_r for intermediate values of β may be interpolated linearly.

When the beam is loaded with a uniform load, K_r may be modified by multiplying by the reduction factor C_r as calculated by the following formula:

$$C_r = A + B\left(\frac{L}{L_t}\right) + C\left(\frac{d_c}{R_m}\right) + D\left(\frac{L}{L_t}\right)^2 + E\left(\frac{d_c}{R_m}\right)^2 + F\left(\frac{d_c}{R_m}\right)\left(\frac{L}{L_t}\right) + G\left(\frac{L}{L_t}\right)^3 + H\left(\frac{d_c}{R_m}\right)^3$$

WHERE:

C_r = reduction factor.

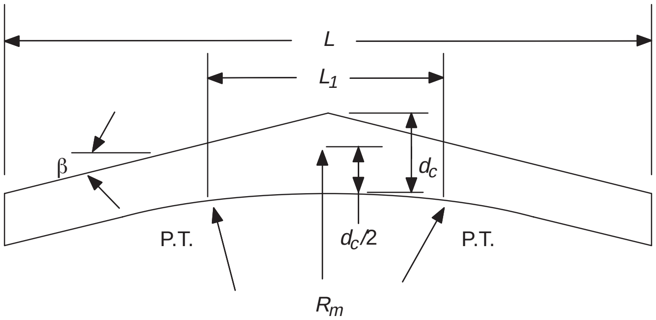
L = span of beam.

L_t = length of beam between tangent points.

A, B . . . H = constants for a given β as follows:

β	A	B	C	D	E	F	G	H
2.3°	-0.142	0.418	-2.358	-0.053	—	—	0.002	—
9.7°	0.143	0.376	-0.541	-0.060	—	—	0.003	—
14.9°	0.406	0.293	-0.927	-0.041	—	—	0.002	—
20.0°	0.423	0.364	-1.022	-0.067	—	0.146	—	—
25.2°	0.540	0.360	-1.061	-0.070	—	0.156	—	—
29.8°	0.502	0.372	—	-0.076	-3.712	0.138	0.004	4.336

and β = angle between the upper edge of the member and the horizontal in degrees. Values of C_r for intermediate values may be interpolated linearly.



PITCHED AND TAPERED CURVED BEAM

21. Sec. 5.4.1.2. Add a second paragraph:

These values are subject to modification for duration of load. If these values are exceeded, mechanical reinforcing sufficient to resist all radial tension shall be provided, but in no case shall the calculated radial tension stress exceed one third the allowable unit stress in horizontal shear. When mechanical reinforcing is used, the maximum moisture content of the laminations at the time of manufacture shall not exceed 12 percent for dry conditions of use.

22. Sec. 5.4.4. Add a section as follows:

5.4.4 Ponding. Roof-framing members shall be designed for the deflection and drainage or ponding requirements specified in Section 1506 and Chapter 16. In glued-laminated timbers, the minimum slope for roof drainage required by Section 1506 shall be in addition to a camber of one and one-half times the calculated dead load deflection. The calculation of the required slope shall not include any vertical displacement created by short taper cuts. In no case shall the deflection of glued-laminated timber roof members exceed $^{1}/_{2}$-inch (13 mm) for a 5 pound-per-square-foot (239 Pa) uniform load.

23. Sec. 5.4.5. Add a new section as follows:

5.4.5 Tapered Faces. Sawn tapered cuts shall not be permitted on the tension face of any beam. Pitched or curved beams shall be so fabricated that the laminations are parallel to the tension face. Straight, pitched or curved beams may have sawn tapered cuts on the compression face.

For other members subject to bending, the slope of tapered faces, measured from the tangent to the lamination of the section under consideration, shall not be steeper than 1 unit vertical in 24 units horizontal (4% slope) on the tension side.

EXCEPTIONS: 1. This requirement does not apply to arches.

2. Taper may be steeper at sections increased in size beyond design requirements for architectural projections.

24. Sec. 8.3. Add a section as follows:

8.3 Allowable shear values for bolts used to connect a wood member to concrete or masonry are permitted to be determined as one half the tabulated double shear value for a wood member twice the thickness of the member attached to the concrete or masonry.

25. Sec. 12.4.1. Delete and substitute as follows:

12.4.1 For wood-to-wood joints, the spacing center to center of nails in the direction of stress shall not be less than the required penetration. Edge or end distances in the direction of stress shall not be less than one-half of the required penetration. All spacing and edge and end distances shall be such as to avoid splitting of the wood.

26. Sec. 13.2.1. Delete and substitute as follows:

13.2.1 Test for design values. Tests to determine design values for metal plate connectors in lateral withdrawal, net section shear and net section tension shall be conducted in accordance with the test and evaluation procedures in ANSI/TPI 1-1995. Design values determined in accordance with these test procedures shall be multiplied by all applicable adjustment factors (see Table 7.3.1) to obtain allowable design values.

27. NDS Supplement Table 5A. Add combinations and design values as follows:

		DESIGN VALUES IN POUNDS PER SQUARE INCH (psi)													
		BENDING ABOUT X–X AXIS (Loaded Perpendicular to Wide Faces of Laminations)						BENDING ABOUT Y–Y AXIS (Loaded Parallel to Wide Faces of Laminations)					AXIALLY LOADED		
		Bending		Compression Perpendicualr to Grain											
COMBINATION SYMBOl[4]	SPECIES OUTER LAMINATIONS/ CORE LAMINATIONS[5]	Tension Zone Stressed in Tension F_{bxx}	Compression Zone Stressed in Tension[6] F_{bxx}	Tension Face[9,10] $F_{c\perp xx}$	Compression Face[9,10] $F_{c\perp xx}$	Shear Parallel to Grain[10] F_{vxx}	Modulus of Elasticity E_{xx}	Bending F_{byy}	Compression Perpendicular to Grain (Side Faces) $F_{c\perp yy}$	Shear Parallel to Grain F_{vyy}	Shear Parallel to Grain (For Members With Mulitple Piece Laminations Which are not Edge glued)[13] F_{vyy}	Modulus of Elasticity E_{yy}	Tension Parallel to Grain F_t	Compression Parallel to Grain F_c	Modulus of Elasticity E
VISUALLY GRADED SOUTHERN PINE															
26F–V1	SP/SP	2600	1300	650	650	200	1,800,000	1900	560	175	90	1,600,000	1150	1600	1,600,000
26F–V2	SP/SP	2600	1300	650	650	200	1,900,000	2200	650	175	90	1,800,000	1200	1650	1,800,000
26F–V3	SP/SP	2600	1300	650	650	200	1,900,000	2100	560	175	90	1,800,000	1150	1600	1,800,000
26F–V4[8]	SP/SP	2600	2600	650	650	200	1,900,000	2100	560	175	90	1,800,000	1150	1600	1,800,000
E–RATED SOUTHERN PINE															
28F–E1	SP/SP	2800	1400	650	650	200	2,000,000	1600	560	175	90	1,700,000	1300	1850	1,700,000
28F–E2[8]	SP/SP	2800	2800	650	650	200	2,000,000	1600	560	175	90	1,700,000	1300	1850	1,700,000
30F–E1[15]	SP/SP	3000	1500	650	650	200	2,000,000	1750	560	175	90	1,700,000	1250	1750	1,700,000
30F–E2[8,15]	SP/SP	3000	3000	650	650	200	2,000,000	1750	560	175	90	1,700,000	1250	1750	1,700,000

[15]These combinations are only for nominal widths 6 inches and less, in accordance with AITC 117–93.

Part II—PLYWOOD STRUCTURAL PANELS

SECTION 2317 — PLYWOOD STRUCTURAL PANELS

Values for plywood structural panels shall be in accordance with Table 23-III-A.

Part III—FASTENINGS

SECTION 2318 — TIMBER CONNECTORS AND FASTENERS

2318.1 General. Timber connectors and fasteners may be used to transmit forces between wood members and between wood and metal members. Allowable design values, Z and W, shall be determined in accordance with Division III, Part I or this section. Modifications to allowable design values, and installation of timber connectors and fasteners shall be in accordance with the provisions set forth in Division III, Part I.

2318.2 Bolts. Allowable lateral design values, $Z_{\|}$, $Z_{m\perp}$ and $Z_{s\perp}$, in pounds for bolts in shear in seasoned lumber of Douglas fir-larch and Southern pine shall be as set forth in Tables 23-III-B-1 and 23-III-B-2.

2318.3 Nails and Spikes.

2318.3.1 Allowable lateral loads. Allowable lateral design values, Z, for common wire and box nails driven perpendicular to the grain of the wood, when used to fasten wood members together, shall be as set forth in Tables 23-III-C-1 and 23-III-C-2.

A wire nail driven parallel to the grain of the wood shall not be subjected to more than two thirds of the lateral load allowed when driven perpendicular to the grain. Toenails shall not be subjected to more than five sixths of the lateral load allowed for nails driven perpendicular to the grain.

In Seismic Zones 3 and 4, toenails shall not be used to transfer lateral forces in excess of 150 pounds per foot (2188 N/m) from diaphragms to shear walls, drag struts (collectors) or other elements, or from shear walls to other elements.

EXCEPTION: Structures built in accordance with Section 2320.

2318.3.2 Allowable withdrawal loads. Allowable withdrawal design values, W, for wire nails driven perpendicular to the grain of the wood shall be as set forth in Table 23-III-D.

Nails driven parallel to the grain of the wood shall not be allowed for resisting withdrawal forces.

2318.3.3 Spacing and penetration. Common wire nails shall have penetration into the piece receiving the point as set forth in Tables 23-III-C-1 and 23-III-C-2. Nails or spikes for which the gages or lengths are not set forth in Tables 23-III-C-1 and 23-III-C-2 shall have a required penetration of not less than 11 diameters, and allowable loads may be interpolated. Allowable loads shall not be increased when the penetration of nails into the member holding the point is larger than required by this section.

2318.4 Joist Hangers and Framing Anchors. Connections depending on joist hangers or framing anchors, ties and other mechanical fastenings not otherwise covered may be used where approved.

2318.5 Miscellaneous Fasteners.

2318.5.1 Drift Bolts and Drift Pins.

2318.5.1.1 Withdrawal design values. Drift bolt and drift pin connections loaded in withdrawal shall be designed in accordance with good engineering practice.

2318.5.1.2 Lateral design values. Allowable lateral design values for drift bolts and drift pins driven in the side grain of wood shall not exceed 75 percent of the allowable lateral design values for common bolts of the same diameter and length in main member. Additional penetration of pin into members should be provided in lieu of the washer, head and nut on a common bolt.

2318.5.2 Spike Grids. Wood-to-wood connections involving spike grids for load transfer shall be designed in accordance with good engineering practice.

Part IV—ALLOWABLE STRESS DESIGN FOR WIND AND EARTHQUAKE LOADS

SECTION 2319 — WOOD SHEAR WALLS AND DIAPHRAGMS

2319.1 Conventional Lumber Diaphragms. Conventional lumber diaphragms of Douglas fir-larch or Southern pine, constructed in accordance with Section 2315.3.1, may be used to resist shear due to wind or seismic forces not exceeding 300 pounds per lineal foot (4.37 kN/m) of width. Where nails are used with sheathing and framing members with a specific gravity less than 0.49, the allowable unit shear strength of the diaphragm shall be multiplied by the following factors: 0.82 for species with specific gravity greater than or equal to 0.42 but less than 0.49, and 0.65 for species with a specific gravity less than 0.42.

2319.2 Special Lumber Diaphragms. Special diagonally sheathed diaphragms of Douglas fir-larch or Southern pine, constructed in accordance with Section 2315.3.2, may be used to resist shears due to wind or seismic loads, provided such shear do not stress the nails beyond their allowable safe lateral strength and do not exceed 600 pounds per lineal foot (8.75 kN/m) of width. Where nails are used with sheathing and framing members with a specific gravity less than 0.49, the allowable unit shear strength of the diaphragm shall be multiplied by the following factors: 0.82 for species with specific gravity greater than or equal to 0.42 but less than 0.49, and 0.65 for species with a specific gravity less than 0.42.

2319.3 Wood Structural Panel Diaphragms. Horizontal and vertical diaphragms sheathed with wood structural panels may be used to resist horizontal forces not exceeding those set forth in Table 23-II-H for horizontal diaphragms and Table 23-II-I-1 for vertical diaphragms.

Where the wood structural panel is applied to both faces of a shear wall in accordance with Table 23-II-I-1, allowable shear for the wall may be taken as twice the tabulated shear for one side, except that where the shear capacities are not equal, the allowable shear shall be either the shear for the side with the higher capacity or twice the shear for the side with the lower capacity, whichever is greater.

2319.4 Particleboard Diaphragms. Vertical diaphragms sheathed with particleboard may be used to resist horizontal forces not exceeding those set forth in Table 23-II-I-2.

2319.5 Fiberboard Sheathing Diaphragms. Wood stud walls sheathed with fiberboard sheathing may be used to resist horizontal forces not exceeding those set forth in Table 23-II-J.

TABLE 23-III-A—ALLOWABLE UNIT STRESSES FOR CONSTRUCTION AND INDUSTRIAL SOFTWOOD PLYWOOD
(In pounds per square inch—normal loading)
(To be used with section properties in Plywood-design Specifications—See UBC Standard 23-2)

STRESS	SPECIES[1] GROUP OF FACE PLY	EXTERIOR A-A, A-C, C-C Structural I A-C, C-C (Use Group I Stresses)		EXTERIOR A-B, B-B, B-C C-C (PLUGGED) Structural I C-D (Use Group 1 Stresses) Structural II C-D (Use Group 3 Stresses) C-D Sheathing (Exterior Glue) All Interior Grades with Exterior Glue		ALL OTHER GRADES OF INTERIOR INCLUDING C-D SHEATHING
		Wet[2]	Dry[3]	Wet[2]	Dry[3]	Dry[3]
		× 0.00689 for N/mm[2]				
1. Extreme fiber stress in bending (F_b) Tension in plane of plies (F_t) Face grain parallel or perpendicular to span (at 45° to face grain use $^1/_6\ F_t$)	1 2, 3 4	1,430 980 940	2,000 1,400 1,330	1,190 820 780	1,650 1,200 1,110	1,650 1,200 1,110
2. Compression in plane of plies (F_c) Parallel or perpendicular to face grain (at 45° to face grain use $^1/_3\ F_c$)	1 2 3 4	970 730 610 610	1,640 1,200 1,060 1,000	900 680 580 580	1,540 1,100 990 950	1,540 1,100 990 950
3. Shear in plane perpendicular to plies F_v[4] Parallel or perpendicular to face grain (at 45° to face grain use 2 F_v)	1 2, 3 4	155 120 110	190 140 130	155 120 110	190 140 130	160 120 115
4. Shear, rolling, in the plane of plies Parallel or perpendicular to face grain (at 45° to face grain use $1^1/_3\ F_s$)	Marine and Structural I Structural II All others[5]	 63 49 44	 75 56 53	 63 49 44	 75 56 53	 48
5. Bearing (on face) Perpendicular to plane of plies	1 2, 3 4	210 135 105	340 210 160	210 135 105	340 210 160	340 210 160
6. Modulus of elasticity In bending in plane of plies Face grain parallel or perpendicular to span	1 2 3 4	1,500,000 1,300,000 1,100,000 900,000	1,800,000 1,500,000 1,200,000 1,000,000	1,500,000 1,300,000 1,100,000 900,000	1,800,000 1,500,000 1,200,000 1,000,000	1,800,000 1,500,000 1,200,000 1,000,000

SPAN RATING

THICKNESS (inches)	C-C AND C-D							UNDERLAYMENT AND C-C PLUGGED			
								16" o.c.	20" o.c.	24" o.c.	48" o.c.
× 25.4 for mm	12/0	16/0	20/0	24/0	32/16	40/20	48/24	× 25.4 for mm			
5/16	4	3	1								
3/8			4[7]	1							
15/32[6], 1/2				4[7]	1			1			
19/32, 5/8					4[7]	1		4[7]	1		
23/32, 3/4						4[7]	1		4[7]	1	
7/8							3[8]			3[8]	
1 1/8											1

[1]See UBC Standard 23-2 for plywood species groups. For C-C, C-D underlayment, and C-C plugged, the combination of span rating and panel thickness determines the species group and, therefore, the stress permitted, as in the above table.

[2]Wet condition of use corresponds to a moisture content of 16 percent or more.

[3]Dry condition of use corresponds to a moisture content of less than 16 percent.

[4]See UBC Standard 23-2, Section 23.221, for provisions under which F_v stresses may be increased.

[5]Reduce stresses 25 percent for three-layer (four-ply) panels over $^5/_8$ inch (16 mm) thick.

[6]Thickness not applicable to underlayment and C-C plugged.

[7]Use Group 3 stresses for Structural II.

[8]Use Group 4 stresses for underlayment and C-C plugged 24 inches (610 mm) on center.

TABLE 23-III-B-1—BOLT DESIGN VALUES *(Z)* FOR SINGLE SHEAR (Two Member) CONNECTIONS[1,2,3]
(For sawn lumber with both members of identical species)

THICKNESS			G=0.55 SOUTHERN PINE			G=0.50 DOUGLAS FIR-LARCH			G=0.42 SPRUCE-PINE-FIR		
MAIN MEMBER *lm* (inches)	SIDE MEMBER *ls* (inches)	BOLT DIAMETER *D* (inches)	$Z_{\|\|}$ lbs.	Z_s lbs.	Z_m lbs.	$Z_{\|\|}$ lbs.	Z_s lbs.	Z_m lbs.	$Z_{\|\|}$ lbs.	Z_s lbs.	Z_m lbs.
× 25.4 for mm			× 4.45 for N								
1 1/2	1 1/2	1/2	530	330	330	480	300	300	410	240	240
		5/8	660	400	400	600	360	360	510	290	290
		3/4	800	460	460	720	420	420	610	340	340
		7/8	930	520	520	850	470	470	710	380	380
		1	1,060	580	580	970	530	530	810	430	430
3 1/2	1 1/2	1/2	660	400	470	610	370	430	540	320	370
		5/8	940	560	620	880	520	540	780	410	430
		3/4	1,270	660	690	1,200	590	610	1,080	450	480
		7/8	1,680	720	770	1,590	630	680	1,340	490	540
		1	2,010	770	830	1,830	680	740	1,530	530	590
5 1/2	1 1/2	5/8	940	560	640	880	520	590	780	410	520
		3/4	1,270	660	850	1,200	590	790	1,080	450	690
		7/8	1,680	720	1,090	1,590	630	980	1,440	490	760
		1	2,150	770	1,190	2,050	680	1,060	1,760	530	830
7 1/2	1 1/2	5/8	940	560	640	880	520	590	780	410	520
		3/4	1,270	660	850	1,200	590	790	1,080	450	690
		7/8	1,680	720	1,090	1,590	630	1,010	1,440	490	890
		1	2,150	770	1,350	2,050	680	1,270	1,760	530	1,110

[1]Tabulated lateral design values *(Z)* for bolted connections shall be multiplied by all applicable adjustment factors (see Division III, Part I).
[2]Tabulated lateral design values *(Z)* are for "full diameter" bolts with a bending yield strength (F_{yb}) of 45,000 psi (310 N/mm^2).
[3]For other species and configurations, see Division III, Part I.

TABLE 23-III-B-2—BOLT DESIGN VALUES *(Z)* FOR DOUBLE SHEAR (Three Member) CONNECTIONS[1,2,3]
(For sawn lumber with all members of identical species)

THICKNESS			G=0.55 SOUTHERN PINE			G=0.50 DOUGLAS FIR-LARCH			G=0.42 SPRUCE-PINE-FIR		
MAIN MEMBER *lm* (inches)	SIDE MEMBER *ls* (inches)	BOLT DIAMETER *D* (inches)	$Z_{\|\|}$ lbs.	Z_s lbs.	Z_m lbs.	$Z_{\|\|}$ lbs.	Z_s lbs.	Z_m lbs.	$Z_{\|\|}$ lbs.	Z_s lbs.	Z_m lbs.
× 25.4 for mm			× 4.45 for N								
1 1/2	1 1/2	1/2	1,150	800	550	1,050	730	470	880	640	370
		5/8	1,440	1,130	610	1,310	1,040	530	1,100	830	410
		3/4	1,730	1,330	660	1,580	1,170	590	1,320	900	450
		7/8	2,020	1,440	720	1,840	1,260	630	1,540	970	490
		1	2,310	1,530	770	2,100	1,350	680	1,760	1,050	530
3 1/2	1 1/2	1/2	1,320	800	940	1,230	730	860	1,080	640	740
		5/8	1,870	1,130	1,290	1,760	1,040	1,190	1,570	830	960
		3/4	2,550	1,330	1,550	2,400	1,170	1,370	2,160	900	1,050
		7/8	3,360	1,440	1,680	3,280	1,260	1,470	2,880	970	1,130
		1	4,310	1,530	1,790	4,090	1,350	1,580	3,530	1,050	1,230
5 1/2	1 1/2	5/8	1,870	1,130	1,290	1,760	1,040	1,190	1,570	830	1,040
		3/4	2,550	1,330	1,690	2,400	1,170	1,580	2,160	900	1,380
		7/8	3,360	1,440	2,170	3,180	1,260	2,030	2,880	970	1,780
		1	4,310	1,530	2,700	4,090	1,350	2,480	3,530	1,050	1,930
7 1/2	1 1/2	5/8	1,870	1,130	1,290	1,760	1,040	1,190	1,570	830	1,040
		3/4	2,550	1,330	1,690	2,400	1,170	1,580	2,160	900	1,380
		7/8	3,360	1,440	2,170	3,180	1,260	2,030	2,880	970	1,780
		1	4,310	1,530	2,700	4,090	1,350	2,530	3,530	1,050	2,240

[1]Tabulated lateral design values *(Z)* for bolted connections shall be multiplied by all applicable adjustment factors (see Divison III, Part I).
[2]Tabulated lateral design values *(Z)* are for "full diameter" bolts with a bending yield strength (F_{yb}) of 45,000 psi (310 N/mm^2).
[3]For other species and configurations, see Division III, Part I.

TABLE 23-III-C-1—BOX NAIL DESIGN VALUES *(Z)* FOR SINGLE SHEAR (Two Member) CONNECTIONS[1,2,3]
(With both members of identical species)

SIDE MEMBER THICKNESS t_s (inches)	NAIL LENGTH *L* (inches)	NAIL DIAMETER *D* (inches)	PENNY-WEIGHT	G=0.55 SOUTHERN PINE *Z* lbs.	G=0.50 DOUGLAS-FIR LARCH *Z* lbs.	G=0.42 SPRUCE-PINE-FIR *Z* lbs.
× 25.4 for mm				× 4.45 for N		
$^1/_2$	2	0.099	6d	55	48	38
	$2^1/_2$	0.113	8d	67	59	47
	3	0.128	10d	82	73	59
	$3^1/_4$	0.128	12d	82	73	59
	$3^1/_2$	0.135	16d	89	79	65
	4	0.148	20d	101	90	73
	$4^1/_2$	0.148	30d	101	90	73
	5	0.162	40d	117	105	87
$^3/_4$	2	0.099	6d	61	55	47
	$2^1/_2$	0.113	8d	79	72	57
	3	0.128	10d	101	87	68
	$3^1/_4$	0.128	12d	101	87	68
	$3^1/_2$	0.135	16d	108	94	74
	4	0.148	20d	121	105	83
	$4^1/_2$	0.148	30d	121	105	83
	5	0.162	40d	138	121	96
1	$2^1/_2$	0.113	8d	79	72	61
	3	0.128	10d	101	93	79
	$3^1/_4$	0.128	12d	101	93	79
	$3^1/_2$	0.135	16d	113	103	86
	4	0.148	20d	128	118	96
	$4^1/_2$	0.148	30d	128	118	96
	5	0.162	40d	154	141	109
$1^1/_2$	$3^1/_4$	0.128	12d	101	93	79
	$3^1/_2$	0.135	16d	113	103	88
	4	0.148	20d	128	118	100
	$4^1/_2$	0.148	30d	128	118	100
	5	0.162	40d	154	141	120

[1]Tabulated lateral design values *(Z)* for nailed connections shall be multiplied by all applicable adjustment factors (see Division III, Part I).

[2]Tabulated lateral design values *(Z)* are for box nails inserted in side grain with nail axis perpendicular to wood fibers and with the following nail bending yield strengths (F_{yb}):

F_{yb}=100,000 psi (690 N/mm^2) for 0.099- (2.5 mm), 0.113- (2.9 mm), 0.128- (3.3 mm) and 0.135-inch-diameter (3.4 mm) box nails.
F_{yb}=90,000 psi (621 N/mm^2) for 0.148- (3.8 mm) and 0.162-inch-diameter (4.1 mm) box nails.

[3]For other species and configurations, see Division III, Part I.

TABLE 23-III-C-2—COMMON WIRE NAIL DESIGN VALUES *(Z)* FOR SINGLE SHEAR (Two Member) CONNECTIONS[1,2,3] (with both members of identical species)

SIDE MEMBER THICKNESS t_s (inches)	NAIL LENGTH *L* (inches)	NAIL DIAMETER *D* (inches)	PENNY-WEIGHT	G=0.55 SOUTHERN PINE *Z* lbs.	G=0.50 DOUGLAS-FIR LARCH *Z* lbs	G=0.42 SPRUCE-PINE-FIR *Z* lbs.
× 25.4 for mm				× 4.45 for N		
1/2	2	0.113	6d	67	59	47
	2 1/2	0.131	8d	85	76	61
	3	0.148	10d	101	90	73
	3 1/4	0.148	12d	101	90	73
	3 1/2	0.162	16d	117	105	87
	4	0.192	20d	137	124	103
	4 1/2	0.207	30d	148	134	112
	5	0.225	40d	162	147	123
	5 1/2	0.244	50d	166	151	127
	6	0.263	60d	188	171	144
3/4	2 1/2	0.131	8d	104	90	70
	3	0.148	10d	121	105	83
	3 1/4	0.148	12d	121	105	83
	3 1/2	0.162	16d	138	121	96
	4	0.192	20d	157	138	111
	4 1/2	0.207	30d	166	147	119
	5	0.225	40d	178	158	129
	5 1/2	0.244	50d	182	162	132
	6	0.263	60d	203	181	149
1	3	0.148	10d	128	118	96
	3 1/4	0.148	12d	128	118	96
	3 1/2	0.162	16d	154	141	109
	4	0.192	20d	183	159	124
	4 1/2	0.207	30d	192	167	131
	5	0.225	40d	202	177	140
	5 1/2	0.244	50d	207	181	143
	6	0.263	60d	227	199	159
1 1/2	3 1/2	0.162	16d	154	141	120
	4	0.192	20d	185	170	144
	4 1/2	0.207	30d	203	186	158
	5	0.225	40d	224	205	172
	5 1/2	0.244	50d	230	211	175
	6	0.263	60d	262	240	191

[1]Tabulated lateral design values *(Z)* for nailed connections shall be multiplied by all applicable adjustment factors (see Division III, Part I).

[2]Tabulated lateral design values *(Z)* are for common wire nails inserted in side grain with nail axis perpendicular to wood fibers and with the following nail bending yield strengths (F_{yb}):

F_{yb}=100,000 psi (690 N/mm^2) for 0.113- (2.9 mm), 0.131- (3.3 mm) and 0.135-inch-diameter (3.4 mm) common wire nails.
F_{yb}=90,000 psi (621 N/mm^2) for 0.148- (3.8 mm) and 0.162-inch-diameter (4.1 mm) common wire nails.
F_{yb}=80,000 psi (552 N/mm^2) for 0.192- (4.9 mm), 0.207 (5.3 mm) and 0.225-inch-diameter (5.7 mm) common wire nails.
F_{yb}=70,000 psi (482 N/mm^2) for 0.244- (6.2 mm) and 0.263-inch-diameter (6.7 mm) common wire nails.

[3]For other species and configurations, see Division III, Part I.

TABLE 23-III-D—NAIL AND SPIKE WITHDRAWAL DESIGN VALUES *(W)*[1,2]

Tabulated Withdrawal Design Values *(W)* Are in Pounds per Inch of Penetration into Side Grain of Main Member

	SPECIFIC GRAVITY, *G*	COMMON WIRE NAILS, BOX NAILS AND COMMON WIRE SPIKES Diameter, *D*														
		0.099″	0.113″	0.128″	0.131″	0.135″	0.148″	0.162″	0.192″	0.207″	0.225″	0.244″	0.263″	0.283″	0.312″	0.375″
Southern Pine	0.55	31	35	40	41	42	46	50	59	64	70	76	81	88	97	116
Douglas-Fir Larch	0.50	24	28	31	32	33	36	40	47	50	55	60	64	69	76	91
Spruce-Pine-Fir	0.42	16	18	20	21	21	23	26	30	33	35	38	41	45	49	59

[1]Tabulated withdrawal design values *(W)* for nail or spike connections shall be multiplied by all applicable adjustment factors (see Division III, Part I).

[2]For other species and configurations, see Division III, Part I.

Division IV—CONVENTIONAL LIGHT-FRAME CONSTRUCTION

SECTION 2320 — CONVENTIONAL LIGHT-FRAME CONSTRUCTION DESIGN PROVISIONS

2320.1 General. The requirements in this section are intended for conventional light-frame construction. Other methods may be used provided a satisfactory design is submitted showing compliance with other provisions of this code.

Only the following occupancies may be constructed in accordance with this division:

1. One-, two- or three-story buildings housing Group R Occupancies.

2. One-story Occupancy Category 4 buildings, as defined in Table 16-K, when constructed on a slab-on-grade floor.

3. Group U Occupancies.

4. Top-story walls and roofs of Occupancy Category 4 buildings not exceeding two stories of wood framing.

5. Interior nonload-bearing partitions, ceilings and curtain walls in all occupancies.

When total loads exceed those specified in Tables 23-IV-J-1, 23-IV-J-3, and 23-IV-R-1, 23-IV-R-2, 23-IV-R-3, 23-IV-R-4, 23-IV-R-7, 23-IV-R-8, 23-IV-R-9, 23-IV-R-10, 23-IV-R-11 and 23-IV-R-12; 23-VII-R-1, 23-VII-R-3, 23-VII-R-7, 23-VII-R-9, 23-VIII-A, 23-VIII-B, 23-VIII-C, 23-VIII-D, an engineering design shall be provided for the gravity load system.

Other approved repetitive wood members may be used in lieu of solid-sawn lumber in conventional construction provided these members comply with the provisions of this code.

2320.2 Design of Portions. When a building of otherwise conventional construction contains nonconventional structural elements, those elements shall be designed in accordance with Section 1605.2.

2320.3 Additional Requirements for Conventional Construction in High-wind Areas. Appendix Chapter 23 provisions for conventional construction in high-wind areas shall apply when specifically adopted.

2320.4 Additional Requirements for Conventional Construction in Seismic Zones 0, 1, 2 and 3.

2320.4.1 Braced wall lines. Where the basic wind speed is not greater than 80 miles per hour (mph) (129 km/h), buildings shall be provided with exterior and interior braced wall lines. Spacing shall not exceed 34 feet (10 363 mm) on center in both the longitudinal and transverse directions in each story.

2320.4.2 Braced wall lines for high wind. Where the basic wind speed exceeds 80 mph (129 km/h), buildings shall be provided with exterior and interior braced wall lines. Spacing shall not exceed 25 feet (7620 mm) on center in both the longitudinal and transverse directions in each story.

> **EXCEPTION:** In one- and two-story Group R, Division 3 buildings, interior braced wall line spacing may be increased to not more than 34 feet (10 363 mm) on center in order to accommodate one single room per dwelling unit not exceeding 900 square feet (83.6 m^2). The building official may require additional walls to contain braced panels when this exception is used.

2320.4.3 Veneer. Anchored masonry and stone wall veneer shall not exceed 5 inches (127 mm) in thickness and shall conform to the requirements of Chapter 14.

2320.4.4 Lateral force-resisting system. Buildings in Seismic Zone 3 that are not provided with braced wall lines in accordance with Section 2320.4 or that are of unusual shape as described in Section 2320.5.4 shall have a lateral-force-resisting system designed to resist the forces specified in Chapter 16.

2320.5 Additional Requirements for Conventional Construction in Seismic Zone 4.

2320.5.1 Braced wall lines. Buildings shall be provided with exterior and interior braced wall lines. Spacing shall not exceed 25 feet (7620 mm) on center in both the longitudinal and transverse directions in each story.

> **EXCEPTION:** In one- and two-story Group R, Division 3 buildings, interior braced wall line spacing may be increased to not more than 34 feet (10 363 mm) on center in order to accommodate one single room per dwelling unit not exceeding 900 square feet (83.61 m^2). The building official may require additional walls to contain braced panels when this exception is used.

2320.5.2 Lateral-force-resisting system. When total loads supported on wood framing exceed those specified in Tables 23-IV-J-1, 23-IV-J-3, 23-IV-R-1, 23-IV-R-2, 23-IV-R-3, 23-IV-R-4, 23-IV-R-7, 23-IV-R-8, 23-IV-R-9 and 23-IV-R-10, 23-VII-R-1. 23-VII-R-3, 23-VII-R-7, 23-VII-R-9, 23-VIII-A, 23-VIII-B, 23-VIII-C and 23-VIII-D, an engineering design shall be provided for the lateral-force-resisting system.

2320.5.3 Veneer. Anchored masonry and stone wall veneer shall not exceed 5 inches (127 mm) in thickness, shall conform to the requirements of Chapter 14 and shall not extend above the first story.

2320.5.4 Unusually shaped buildings. When of unusual shape, buildings of light-frame construction shall have a lateral-force-resisting system designed to resist the forces specified in Chapter 16. Buildings shall be considered to be of unusual shape when the building official determines that the structure has framing irregularities, offsets, split levels or any configuration that creates discontinuities in the seismic load path and may include one or more of the following.

2320.5.4.1 When exterior braced wall panels, as required by Section 2320.11.3, are not in one plane vertically from the foundation to the uppermost story in which they are required.

> **EXCEPTION:** Floors with cantilevers or setbacks not exceeding four times the nominal depth of the floor joists may support braced wall panels provided:
>
> 1. Floor joists are 2 inches by 10 inches (51 mm by 254 mm) or larger and spaced at not more than 16 inches (406 mm) on center.
> 2. The ratio of the back span to the cantilever is at least 2 to 1.
> 3. Floor joists at ends of braced wall panels are doubled.
> 4. A continuous rim joist is connected to ends of all cantilevered joists. The rim joist may be spliced using a metal tie not less than 0.058 inch (1.47 mm) (16 galvanized gage) and $1^1/_2$ inches (38 mm) wide fastened with six 16d nails.
> 5. Gravity loads carried at the end of cantilevered joists are limited to uniform wall and roof load and the reactions from headers having a span of 8 feet (2438 mm) or less.

2320.5.4.2 When a section of floor or roof is not laterally supported by braced wall lines on all edges.

> **EXCEPTION:** Portions of roofs or floors which do not support braced wall panels above may extend up to 6 feet (1829 mm) beyond a braced wall line.

2320.5.4.3 When the end of a required braced wall panel extends more than 1 foot (305 mm) over an opening in the wall below. This provision is applicable to braced wall panels offset in plane and to braced wall panels offset out of plane as permitted by Section 2320.5.4.1, exception.

EXCEPTION: Braced wall panels may extend over an opening not more than 8 feet (2438 mm) in width when the header is a 4-inch by 12-inch (102 mm by 305 mm) or larger member.

2320.5.4.4 When an opening in a floor or roof exceeds the lesser of 12 feet (3657 mm) or 50 percent of the least floor or roof dimension.

2320.5.4.5 Construction where portions of a floor level are vertically offset such that the framing members on either side of the offset cannot be lapped or tied together in an approved manner as required by Section 2320.8.3.

EXCEPTION: Framing supported directly by foundations.

2320.5.4.6 When braced wall lines do not occur in two perpendicular directions.

2320.5.5 Lumber roof decks. Lumber roof decks shall have solid sheathing.

2320.5.6 Interior braced wall support. In one-story buildings, interior braced wall lines shall be supported on continuous foundations at intervals not exceeding 50 feet (15 240 mm). In buildings more than one story in height, all interior braced wall panels shall be supported on continuous foundations.

EXCEPTION: Two-story buildings may have interior braced wall lines supported on continuous foundations at intervals not exceeding 50 feet (15 240 mm) provided:

1. Cripple wall height does not exceed 4 feet (1219 mm).
2. First-floor braced wall panels are supported on doubled floor joists, continuous blocking or floor beams.
3. Distance between bracing lines does not exceed twice the building width parallel to the braced wall line.

2320.6 Foundation Plates or Sills. Foundations and footings shall be as specified in Chapter 18. Foundation plates or sills resting on concrete or masonry foundations shall be bolted as required by Section 1806.6.

2320.7 Girders. Girders for single-story construction or girders supporting loads from a single floor shall not be less than 4 inches by 6 inches (102 mm by 153 mm) for spans 6 feet (1829 mm) or less, provided that girders are spaced not more than 8 feet (2438 mm) on center. Other girders shall be designed to support the loads specified in this code. Girder end joints shall occur over supports. When a girder is spliced over a support, an adequate tie shall be provided. The end of beams or girders supported on masonry or concrete shall not have less than 3 inches (76 mm) of bearing.

2320.8 Floor Joists.

2320.8.1 General. Spans for joists shall be in accordance with Tables 23-IV-J-1 and 23-IV-J-2.

2320.8.2 Bearing. Except where supported on a 1-inch by 4-inch (25 mm by 102 mm) ribbon strip and nailed to the adjoining stud, the ends of each joist shall not have less than $1^1/_2$ inches (38 mm) of bearing on wood or metal, or less than 3 inches (76 mm) on masonry.

2320.8.3 Framing details. Joists shall be supported laterally at the ends and at each support by solid blocking except where the ends of joists are nailed to a header, band or rim joist or to an adjoining stud or by other approved means. Solid blocking shall not be less than 2 inches (51 mm) in thickness and the full depth of joist.

Notches on the ends of joists shall not exceed one fourth the joist depth. Holes bored in joists shall not be within 2 inches (51 mm) of the top or bottom of the joist, and the diameter of any such hole shall not exceed one third the depth of the joist. Notches in the top or bottom of joists shall not exceed one sixth the depth and shall not be located in the middle third of the span.

Joist framing from opposite sides of a beam, girder or partition shall be lapped at least 3 inches (76 mm) or the opposing joists shall be tied together in an approved manner.

Joists framing into the side of a wood girder shall be supported by framing anchors or on ledger strips not less than 2 inches by 2 inches (51 mm by 51 mm).

2320.8.4 Framing around openings. Trimmer and header joists shall be doubled, or of lumber of equivalent cross section, when the span of the header exceeds 4 feet (1219 mm). The ends of header joists more than 6 feet (1829 mm) long shall be supported by framing anchors or joist hangers unless bearing on a beam, partition or wall. Tail joists over 12 feet (3658 mm) long shall be supported at header by framing anchors or on ledger strips not less than 2 inches by 2 inches (51 mm by 51 mm).

2320.8.5 Supporting bearing partitions. Bearing partitions perpendicular to joists shall not be offset from supporting girders, walls or partitions more than the joist depth.

Joists under and parallel to bearing partitions shall be doubled.

2320.8.6 Blocking. Floor joists shall be blocked when required by the provisions of Division III, Part I or Section 2320.8.3.

2320.9 Subflooring.

2320.9.1 Lumber subfloor. Sheathing used as a structural subfloor shall conform to the limitations set forth in Tables 23-II-D-1 and 23-II-D-2.

Joints in subflooring shall occur over supports unless end-matched lumber is used, in which case each piece shall bear on at least two joists.

Subflooring may be omitted when joist spacing does not exceed 16 inches (406 mm) and 1-inch (25 mm) nominal tongue-and-groove wood strip flooring is applied perpendicular to the joists.

2320.9.2 Wood structural panels. Where used as structural subflooring, wood structural panels shall be as set forth in Tables 23-II-E-1 and 23-II-E-2. Wood structural panel combination subfloor underlayment shall have maximum spans as set forth in Table 23-II-F-1.

When wood structural panel floors are glued to joists with an adhesive in accordance with the adhesive manufacturer's directions, fasteners may be spaced a maximum of 12 inches (305 mm) on center at all supports.

2320.9.3 Plank flooring. Plank flooring shall be designed in accordance with the general provisions of this code.

In lieu of such design, 2-inch (51 mm) tongue-and-groove planking may be used in accordance with Table 23-IV-A. Joints in such planking may be randomly spaced, provided the system is applied to not less than three continuous spans, planks are center-matched and end-matched or splined, each plank bears on at least one support and joints are separated by at least 24 inches (610 mm) in adjacent pieces. One-inch (25 mm) nominal strip square-edged flooring, $^1/_2$-inch (12.7 mm) tongue-and-groove flooring or $^3/_8$-inch (9.5 mm) wood structural panel shall be applied over random-length decking used as a floor. The strip and tongue-and-groove flooring shall be applied at right angles to the span of the planks. The $^3/_8$-inch (9.5 mm) plywood shall be applied with the face grain at right angles to the span of the planks.

2320.9.4 Particleboard. Where used as structural subflooring or as combined subfloor underlayment, particleboard shall be as set forth in Table 23-II-F-2.

2320.10 Particleboard Underlayment. In accordance with approved recognized standards, particleboard floor underlayment shall conform to Type PBU. Underlayment shall not be less than $^1/_4$ inch (6.4 mm) in thickness and shall be identified by the grade mark of an approved inspection agency. Underlayment shall be installed in accordance with this code and as recommended by the manufacturer.

2320.11 Wall Framing.

2320.11.1 Size, height and spacing. The size, height and spacing of studs shall be in accordance with Table 23-IV-B except that Utility grade studs shall not be spaced more than 16 inches (406 mm) on center, or support more than a roof and ceiling, or exceed 8 feet (2438 mm) in height for exterior walls and load-bearing walls or 10 feet (3048 mm) for interior nonload-bearing walls.

2320.11.2 Framing details. Studs shall be placed with their wide dimension perpendicular to the wall. Not less than three studs shall be installed at each corner of an exterior wall.

> **EXCEPTION:** At corners, a third stud may be omitted through the use of wood spacers or backup cleats of $^3/_8$-inch-thick (9.5 mm) wood structural panel, $^3/_8$-inch (9.5 mm) Type M "Exterior Glue" particleboard, 1-inch-thick (25 mm) lumber or other approved devices that will serve as an adequate backing for the attachment of facing materials. Where fire-resistance ratings or shear values are involved, wood spacers, backup cleats or other devices shall not be used unless specifically approved for such use.

Bearing and exterior wall studs shall be capped with double top plates installed to provide overlapping at corners and at intersections with other partitions. End joints in double top plates shall be offset at least 48 inches (2438 mm).

> **EXCEPTION:** A single top plate may be used, provided the plate is adequately tied at joints, corners and intersecting walls by at least the equivalent of 3-inch by 6-inch (76 mm by 152 mm) by 0.036-inch-thick (0.9 mm) galvanized steel that is nailed to each wall or segment of wall by six 8d nails or equivalent, provided the rafters, joists or trusses are centered over the studs with a tolerance of no more than 1 inch (25 mm).

When bearing studs are spaced at 24-inch (610 mm) intervals and top plates are less than two 2-inch by 6-inch (51 mm by 152 mm) or two 3-inch by 4-inch (76 mm by 102 mm) members and when the floor joists, floor trusses or roof trusses which they support are spaced at more than 16-inch (406 mm) intervals, such joists or trusses shall bear within 5 inches (127 mm) of the studs beneath or a third plate shall be installed.

Interior nonbearing partitions may be capped with a single top plate installed to provide overlapping at corners and at intersections with other walls and partitions. The plate shall be continuously tied at joints by solid blocking at least 16 inches (406 mm) in length and equal in size to the plate or by $^1/_8$-inch by $1^1/_2$-inch (3.2 mm by 38 mm) metal ties with spliced sections fastened with two 16d nails on each side of the joint.

Studs shall have full bearing on a plate or sill not less than 2 inches (51 mm) in thickness having a width not less than that of the wall studs.

2320.11.3 Bracing. Braced wall lines shall consist of braced wall panels which meet the requirements for location, type and amount of bracing specified in Table 23-IV-C-1 and are in line or offset from each other by not more than 4 feet (1219 mm). Braced wall panels shall start at not more than 8 feet (2438 mm) from each end of a braced wall line. All braced wall panels shall be clearly indicated on the plans. Construction of braced wall panels shall be by one of the following methods:

1. Nominal 1-inch by 4-inch (25 mm by 102 mm) continuous diagonal braces let into top and bottom plates and intervening studs, placed at an angle not more than 60 degrees or less than 45 degrees from the horizontal, and attached to the framing in conformance with Table 23-II-B-1.

2. Wood boards of $^5/_8$-inch (16 mm) net minimum thickness applied diagonally on studs spaced not over 24 inches (610 mm) on center.

3. Wood structural panel sheathing with a thickness not less than $^5/_{16}$ inch (7.9 mm) for 16-inch (406 mm) stud spacing and not less than $^3/_8$ inch (9.5 mm) for 24-inch (610 mm) stud spacing in accordance with Tables 23-II-A-1 and 23-IV-D-1.

4. Fiberboard sheathing 4-foot by 8-foot (1219 mm by 2438 mm) panels not less than $^1/_2$ inch (13 mm) thick applied vertically on studs spaced not over 16 inches (406 mm) on center when installed in accordance with Section 2315.6 and Table 23-II-J.

5. Gypsum board [sheathing $^1/_2$ inch (13 mm) thick by 4 feet (1219 mm) wide, wallboard or veneer base] on studs spaced not over 24 inches (610 mm) on center and nailed at 7 inches (178 mm) on center with nails as required by Table 25-I.

6. Particleboard wall sheathing panels where installed in accordance with Table 23-IV-D-2.

7. Portland cement plaster on studs spaced 16 inches (406 mm) on center installed in accordance with Table 25-I.

8. Hardboard panel siding when installed in accordance with Section 2310.6 and Table 23-II-C.

Method 1 is not permitted in Seismic Zones 2B, 3 and 4. For cripple wall bracing, see Section 2320.11.5. For Methods 2, 3, 4, 6, 7 and 8, each braced panel must be at least 48 inches (1219 mm) in length, covering three stud spaces where studs are spaced 16 inches (406 mm) apart and covering two stud spaces where studs are spaced 24 inches (610 mm) apart.

For Method 5, each braced wall panel must be at least 96 inches (2438 mm) in length when applied to one face of a braced wall panel and 48 inches (1219 mm) when applied to both faces.

All vertical joints of panel sheathing shall occur over studs. Horizontal joints shall occur over blocking equal in size to the studding except where waived by the installation requirements for the specific sheathing materials.

Braced wall panel sole plates shall be nailed to the floor framing and top plates shall be connected to the framing above in accordance with Table 23-II-B-1. Sills shall be bolted to the foundation or slab in accordance with Section 1806.6. Where joists are perpendicular to braced wall lines above, blocking shall be provided under and in line with the braced wall panels.

2320.11.4 Alternate braced wall panels. Any braced wall panel required by Section 2320.11.3 may be replaced by an alternate braced wall panel constructed in accordance with the following:

1. In one-story buildings, each panel shall have a length of not less than 2 feet 8 inches (813 mm) and a height of not more than 10 feet (3048 mm). Each panel shall be sheathed on one face with $^3/_8$-inch-minimum-thickness (9.5 mm) plywood sheathing nailed with 8d common or galvanized box nails in accordance with Table 23-II-B-1 and blocked at all plywood edges. Two anchor bolts installed in accordance with Section 1806.6, shall be provided in each panel. Anchor bolts shall be placed at panel quarter points. Each panel end stud shall have a tie-down device fastened to the foundation, capable of providing an approved uplift capacity of not less than 1,800 pounds (816.5 kg). The tie-down device shall be installed in accordance with the manufacturer's recommendations. The panels shall be supported directly on a foundation or on floor framing supported directly on a foundation which is continuous across the entire length of the braced wall line. This founda-

tion shall be reinforced with not less than one No. 4 bar top and bottom.

2. In the first story of two-story buildings, each braced wall panel shall be in accordance with Section 2320.11.4, Item 1, except that the plywood sheathing shall be provided on both faces, three anchor bolts shall be placed at one-fifth points, and tie-down device uplift capacity shall not be less than 3,000 pounds (1360.8 kg).

2320.11.5 Cripple walls. Foundation cripple walls shall be framed of studs not less in size than the studding above with a minimum length of 14 inches (356 mm), or shall be framed of solid blocking. When exceeding 4 feet (1219 mm) in height, such walls shall be framed of studs having the size required for an additional story.

Cripple walls having a stud height exceeding 14 inches (356 mm) shall be braced in accordance with Table 23-IV-C-2. Solid blocking or wood structural panel sheathing may be used to brace cripple walls having a stud height of 14 inches (356 mm) or less. In Seismic Zone 4, Method 7 is not permitted for bracing any cripple wall studs.

Spacing of boundary nailing for required wall bracing shall not exceed 6 inches (152 mm) on center along the foundation plate and the top plate of the cripple wall. Nail size, nail spacing for field nailing and more restrictive boundary nailing requirements shall be as required elsewhere in the code for the specific bracing material used.

2320.11.6 Headers. Headers and lintels shall conform to the requirements set forth in this paragraph and together with their supporting systems shall be designed to support the loads specified in this code. All openings 4 feet (1219 mm) wide or less in bearing walls shall be provided with headers consisting of either two pieces of 2-inch (51 mm) framing lumber placed on edge and securely fastened together or 4-inch (102 mm) lumber of equivalent cross section. All openings more than 4 feet (1219 mm) wide shall be provided with headers or lintels. Each end of a lintel or header shall have a length of bearing of not less than $1^1/_2$ inches (38 mm) for the full width of the lintel.

2320.11.7 Pipes in walls. Stud partitions containing plumbing, heating, or other pipes shall be so framed and the joists underneath so spaced as to give proper clearance for the piping. Where a partition containing such piping runs parallel to the floor joists, the joists underneath such partitions shall be doubled and spaced to permit the passage of such pipes and shall be bridged. Where plumbing, heating or other pipes are placed in or partly in a partition, necessitating the cutting of the soles or plates, a metal tie not less than 0.058 inch (1.47 mm) (16 galvanized gage) and $1^1/_2$ inches (38 mm) wide shall be fastened to each plate across and to each side of the opening with not less than six 16d nails.

2320.11.8 Bridging. Unless covered by interior or exterior wall coverings or sheathing meeting the minimum requirements of this code, all stud partitions or walls with studs having a height-to-least-thickness ratio exceeding 50 shall have bridging not less than 2 inches (51 mm) in thickness and of the same width as the studs fitted snugly and nailed thereto to provide adequate lateral support.

2320.11.9 Cutting and notching. In exterior walls and bearing partitions, any wood stud may be cut or notched to a depth not exceeding 25 percent of its width. Cutting or notching of studs to a depth not greater than 40 percent of the width of the stud is permitted in nonbearing partitions supporting no loads other than the weight of the partition.

2320.11.10 Bored holes. A hole not greater in diameter than 40 percent of the stud width may be bored in any wood stud. Bored holes not greater than 60 percent of the width of the stud are permitted in nonbearing partitions or in any wall where each bored stud is doubled, provided not more than two such successive doubled studs are so bored.

In no case shall the edge of the bored hole be nearer than $^5/_8$ inch (16 mm) to the edge of the stud. Bored holes shall not be located at the same section of stud as a cut or notch.

2320.12 Roof and Ceiling Framing.

2320.12.1 General. The framing details required in this section apply to roofs having a minimum slope of 3 units vertical in 12 units horizontal (25% slope) or greater. When the roof slope is less than 3 units vertical in 12 units horizontal (25% slope), members supporting rafters and ceiling joists such as ridge board, hips and valleys shall be designed as beams.

2320.12.2 Spans. Allowable spans for ceiling joists shall be in accordance with Tables 23-IV-J-3 and 23-IV-J-4. Allowable spans for rafters shall be in accordance with Tables 23-IV-R-1 through 23-IV-R-12, where applicable.

2320.12.3 Framing. Rafters shall be framed directly opposite each other at the ridge. There shall be a ridge board at least 1-inch (25 mm) nominal thickness at all ridges and not less in depth than the cut end of the rafter. At all valleys and hips there shall be a single valley or hip rafter not less than 2-inch (51 mm) nominal thickness and not less in depth than the cut end of the rafter.

2320.12.4 Notches and holes. Notching at the ends of rafters or ceiling joists shall not exceed one fourth the depth. Notches in the top or bottom of the rafter or ceiling joist shall not exceed one sixth the depth and shall not be located in the middle one third of the span, except that a notch not exceeding one third of the depth is permitted in the top of the rafter or ceiling joist not further from the face of the support than the depth of the member.

Holes bored in rafters or ceiling joists shall not be within 2 inches (51 mm) of the top and bottom and their diameter shall not exceed one third the depth of the member.

2320.12.5 Framing around openings. Trimmer and header rafters shall be doubled, or of lumber of equivalent cross section, when the span of the header exceeds 4 feet (1219 mm). The ends of header rafters more than 6 feet (1829 mm) long shall be supported by framing anchors or rafter hangers unless bearing on a beam, partition or wall.

2320.12.6 Rafter ties. Rafters shall be nailed to adjacent ceiling joists to form a continuous tie between exterior walls when such joists are parallel to the rafters. Where not parallel, rafters shall be tied to 1-inch by 4-inch (25 mm by 102 mm) (nominal) minimum-size crossties. Rafter ties shall be spaced not more than 4 feet (1219 mm) on center.

2320.12.7 Purlins. Purlins to support roof loads may be installed to reduce the span of rafters within allowable limits and shall be supported by struts to bearing walls. The maximum span of 2-inch by 4-inch (51 mm by 102 mm) purlins shall be 4 feet (1219 mm). The maximum span of the 2-inch by 6-inch (51 mm by 152 mm) purlin shall be 6 feet (1829 mm) but in no case shall the purlin be smaller than the supported rafter. Struts shall not be smaller than 2-inch by 4-inch (51 mm by 102 mm) members. The unbraced length of struts shall not exceed 8 feet (2438 mm) and the minimum slope of the struts shall not be less than 45 degrees from the horizontal.

2320.12.8 Blocking. Roof rafters and ceiling joists shall be supported laterally to prevent rotation and lateral displacement when required by Division III, Part I, Section 4.4.1.2. Roof trusses shall be supported laterally at points of bearing by solid blocking to prevent rotation and lateral displacement.

2320.12.9 Roof sheathing. Roof sheathing shall be in accordance with Tables 23-II-E-1 and 23-II-E-2 for wood structural panels, and Tables 23-II-D-1 and 23-II-D-2 for lumber.

Joints in lumber sheathing shall occur over supports unless approved end-matched lumber is used, in which case each piece shall bear on at least two supports.

Wood structural panels used for roof sheathing shall be bonded by intermediate or exterior glue. Wood structural panel roof sheathing exposed on the underside shall be bonded with exterior glue.

2320.12.10 Roof planking. Planking shall be designed in accordance with the general provisions of this code.

In lieu of such design, 2-inch (51 mm) tongue-and-groove planking may be used in accordance with Table 23-IV-A. Joints in such planking may be randomly spaced, provided the system is applied to not less than three continuous spans, planks are center-matched and end-matched or splined, each plank bears on at least one support, and joints are separated by at least 24 inches (610 mm) in adjacent pieces.

2320.13 Exit Facilities. In Seismic Zones 3 and 4, exterior exit balconies, stairs and similar exit facilities shall be positively anchored to the primary structure at not over 8 feet (2438 mm) on center or shall be designed for lateral forces. Such attachment shall not be accomplished by use of toenails or nails subject to withdrawal.

TABLE 23-IV-A—ALLOWABLE SPANS FOR 2-INCH (51 mm) TONGUE-AND-GROOVE DECKING

SPAN[1] (feet)	LIVE LOAD	DEFLECTION LIMIT	*f* (psi)	*E* (psi)
× 304.8 for mm	× 0.0479 for kN/m²		× 0.00689 for N/mm²	
Roofs				
4	20	1/240 1/360	160	170,000 256,000
	30	1/240 1/360	210	256,000 384,000
	40	1/240 1/360	270	340,000 512,000
4.5	20	1/240 1/360	200	242,000 305,000
	30	1/240 1/360	270	363,000 405,000
	40	1/240 1/360	350	484,000 725,000
5.0	20	1/240 1/360	250	332,000 500,000
	30	1/240 1/360	330	495,000 742,000
	40	1/240 1/360	420	660,000 1,000,000
5.5	20	1/240 1/360	300	442,000 660,000
	30	1/240 1/360	400	662,000 998,000
	40	1/240 1/360	500	884,000 1,330,000
6.0	20	1/240 1/360	360	575,000 862,000
	30	1/240 1/360	480	862,000 1,295,000
	40	1/240 1/360	600	1,150,000 1,730,000
6.5	20	1/240 1/360	420	595,000 892,000
	30	1/240 1/360	560	892,000 1,340,000
	40	1/240 1/360	700	1,190,000 1,730,000
7.0	20	1/240 1/360	490	910,000 1,360,000
	30	1/240 1/360	650	1,370,000 2,000,000
	40	1/240 1/360	810	1,820,000 2,725,000
7.5	20	1/240 1/360	560	1,125,000 1,685,000
	30	1/240 1/360	750	1,685,000 2,530,000
	40	1/240 1/360	930	2,250,000 3,380,000
8.0	20	1/240 1/360	640	1,360,000 2,040,000
	30	1/240 1/360	850	2,040,000 3,060,000
Floors				
4 4.5 5.0	40	1/360	840 950 1060	1,000,000 1,300,000 1,600,000

[1]Spans are based on simple beam action with 10 pounds per square foot (0.48 kN/m^2) dead load and provisions for a 300-pound (1334 N) concentrated load on a 12-inch (305 mm) width of floor decking. Random lay-up permitted in accordance with the provisions of Section 2320.9.3 or 2320.12.9. Lumber thickness assumed at $1^1/_2$ inches (38 mm), net.

TABLE 23-IV-B—SIZE, HEIGHT AND SPACING OF WOOD STUDS

STUD SIZE (inches)	BEARING WALLS				NONBEARING WALLS	
	Laterally Unsupported Stud Height[1] (feet)	Supporting Roof and Ceiling Only	Supporting One Floor, Roof and Ceiling	Supporting Two Floors, Roof and Ceiling	Laterally Unsupported Stud Height[1] (feet)	Spacing (inches)
		Spacing (inches)				
× 25.4 for mm	× 304.8 for mm	× 25.4 for mm			× 304.8 for mm	× 25.4 for mm
1. 2 × 3[2]	—	—	—	—	10	16
2. 2 × 4	10	24	16	—	14	24
3. 3 × 4	10	24	24	16	14	24
4. 2 × 5	10	24	24	—	16	24
5. 2 × 6	10	24	24	16	20	24

[1]Listed heights are distances between points of lateral support placed perpendicular to the plane of the wall. Increases in unsupported height are permitted where justified by an analysis.
[2]Shall not be used in exterior walls.

TABLE 23-IV-C-1—BRACED WALL PANELS[1]

SEISMIC ZONE	CONDITION	CONSTRUCTION METHOD[2,3]								BRACED PANEL LOCATION AND LENGTH[4]
		1	2	3	4	5	6	7	8	
0, 1 and 2A	One story, top of two or three story	X	X	X	X	X	X	X	X	Each end and not more than 25 feet (7620 mm) on center
	First story of two story or second story of three story	X	X	X	X	X	X	X	X	
	First story of three story		X	X	X	X[5]	X	X	X	
2B, 3 and 4	One story, top of two story or three story		X	X	X	X	X	X[6]	X	Each end and not more than 25 feet (7620 mm) on center
	First story of two story or second of three story		X	X	X	X[5]	X	X[6]	X	Each end and not more than 25 feet (7620 mm) on center but not less than 25% of building length[7]
	First story of three story		X	X	X	X[5]	X	X[6]	X	Each end and not more than 25 feet (7620 mm) on center but not less than 40% of building length[7]

[1]This table specifies minimum requirements for braced panels which form interior or exterior braced wall lines.
[2]See Section 2320.11.3 for full description.
[3]See Section 2320.11.4 for alternate braced panel requirement.
[4]Building length is the dimension parallel to the braced wall length.
[5]Gypsum wallboard applied to supports at 16 inches (406 mm) on center.
[6]Not permitted for bracing cripple walls in Seismic Zone 4. See Section 2320.11.5.
[7]The required lengths shall be doubled for gypsum board applied to only one face of a braced wall panel.

TABLE 23-IV-C-2—CRIPPLE WALL BRACING

SEISMIC ZONE	CONDITION	AMOUNT OF CRIPPLE WALL BRACING[1,2]
		× 25.4 for mm
4	One story above cripple wall	$^3/_8''$ wood structural panel with 8d at $6''/12''$ nailing on 60 percent of wall length minimum
	Two story above cripple wall	$^3/_8''$ wood structural panel with 8d at $4''/12''$ nailing on 50 percent of wall length minimum or $^3/_8''$ wood structural panel with 8d at $6''/12''$ nailing on 75 percent of wall length minimum
3	One story above cripple wall	$^3/_8''$ wood structural panel with 8d at $6''/12''$ nailing on 40 percent of wall length minimum
0, 1 and 2	One story above cripple wall	$^3/_8''$ wood structural panel with 8d at $6''/12''$ nailing on 30 percent of wall length minimum
0, 1, 2 and 3	Two story above cripple wall	$^3/_8''$ wood structural panel with 8d at $4''/12''$ nailing on 40 percent of wall length minimum or $^3/_8''$ wood structural panel with 8d at $6''/12''$ nailing on 60 percent of wall length minimum

[1]Braced panel length shall be at least two times the height of the cripple wall, but not less than 48 inches (1219 mm).
[2]All panels along a wall shall be nearly equal in length and shall be nearly equally spaced along the length of the wall.

TABLE 23-IV-D-1—WOOD STRUCTURAL PANEL WALL SHEATHING[1]
(Not exposed to the weather, strength axis parallel or perpendicular to studs)

MINIMUM THICKNESS (inch)	PANEL SPAN RATING	STUD SPACING (inches)		
		× 25.4 for mm		
			Sheathing under Coverings Specified in Section 2310.4	
× 25.4 for mm		Siding Nailed to Studs	Sheathing Parallel to Studs	Sheathing Perpendicular to Studs
$^5/_{16}$	12/0, 16/0, 20/0 Wall—16 o.c.	16	—	16
$^3/_8$, $^{15}/_{32}$, $^1/_2$	16/0, 20/0, 24/0, 32/16 Wall—24 o.c.	24	16	24
$^7/_{16}$, $^{15}/_{32}$, $^1/_2$	24/0, 24/16, 32/16 Wall—24 o.c.	24	24[2]	24

[1]In reference to Section 2320.11.3, blocking of horizontal joints is not required.
[2]Plywood shall consist of four or more plies.

TABLE 23-IV-D-2—ALLOWABLE SPANS FOR PARTICLEBOARD WALL SHEATHING[1]
(Not exposed to the weather, long dimension of the panel parallel or perpendicular to studs)

GRADE	THICKNESS (Inch)	STUD SPACING (inches)	
		× 25.4 for mm	
		Siding Nailed to Studs	Sheathing under Coverings Specified in Section 2310.4 Parallel or Perpendicular to Studs
	× 25.4 for mm		
M-1 M-S M-2 "Exterior Glue"	$^3/_8$ $^1/_2$	16 16	16 16

[1]In reference to Section 2320.11.3, blocking of horizontal joints is not required.

TABLE 23-IV-J-1—FLOOR JOISTS WITH *L*/360 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 40 psf (1.92 kN/m^2) live load.
Limited to span in inches (mm) divided by 360.
Strength — Live load of 40 psf (1.92 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi × 0.00689 for N/mm^2																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 6	12.0	8-6	8-10	9-2	9-6	9-9	10-0	10-3	10-6	10-9	10-11	11-2	11-4	11-7	11-9	11-11	12-1	12-3
	16.0	7-9	8-0	8-4	8-7	8-10	9-1	9-4	9-6	9-9	9-11	10-2	10-4	10-6	10-8	10-10	11-0	11-2
	19.2	7-3	7-7	7-10	8-1	8-4	8-7	8-9	9-0	9-2	9-4	9-6	9-8	9-10	10-0	10-2	10-4	10-6
	24.0	6-9	7-0	7-3	7-6	7-9	7-11	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4	9-6	9-7	9-9
2 × 8	12.0	11-3	11-8	12-1	12-6	12-10	13-2	13-6	13-10	14-2	14-5	14-8	15-0	15-3	15-6	15-9	15-11	16-2
	16.0	10-2	10-7	11-0	11-4	11-8	12-0	12-3	12-7	12-10	13-1	13-4	13-7	13-10	14-1	14-3	14-6	14-8
	19.2	9-7	10-0	10-4	10-8	11-0	11-3	11-7	11-10	12-1	12-4	12-7	12-10	13-0	13-3	13-5	13-8	13-10
	24.0	8-11	9-3	9-7	9-11	10-2	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-3	12-6	12-8	12-10
2 × 10	12.0	14-4	14-11	15-5	15-11	16-5	16-10	17-3	17-8	18-0	18-5	18-9	19-1	19-5	19-9	20-1	20-4	20-8
	16.0	13-0	13-6	14-0	14-6	14-11	15-3	15-8	16-0	16-5	16-9	17-0	17-4	17-8	17-11	18-3	18-6	18-9
	19.2	12-3	12-9	13-2	13-7	14-0	14-5	14-9	15-1	15-5	15-9	16-0	16-4	16-7	16-11	17-2	17-5	17-8
	24.0	11-4	11-10	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-7	14-11	15-2	15-5	15-8	15-11	16-2	16-5
2 × 12	12.0	17-5	18-1	18-9	19-4	19-11	20-6	21-0	21-6	21-11	22-5	22-10	23-3	23-7	24-0	24-5	24-9	25-1
	16.0	15-10	16-5	17-0	17-7	18-1	18-7	19-1	19-6	19-11	20-4	20-9	21-1	21-6	21-10	22-2	22-6	22-10
	19.2	14-11	15-6	16-0	16-7	17-0	17-6	17-11	18-4	18-9	19-2	19-6	19-10	20-2	20-6	20-10	21-2	21-6
	24.0	13-10	14-4	14-11	15-4	15-10	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-4	19-8	19-11
F_b	12.0	718	777	833	888	941	993	1,043	1,092	1,140	1,187	1,233	1,278	1,323	1,367	1,410	1,452	1,494
	16.0	790	855	917	977	1,036	1,093	1,148	1,202	1,255	1,306	1,357	1,407	1,456	1,504	1,551	1,598	1,644
	19.2	840	909	975	1,039	1,101	1,161	1,220	1,277	1,333	1,388	1,442	1,495	1,547	1,598	1,649	1,698	1,747
	24.0	905	979	1,050	1,119	1,186	1,251	1,314	1,376	1,436	1,496	1,554	1,611	1,667	1,722	1,776	1,829	1,882

NOTE: The required bending design value, F_b, in pounds per square inch (× 0.00689 for N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-J-2—FLOOR JOISTS WITH *L*/360 DEFLECTION LIMITS
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 40 psf (1.92 kN/m^2) live load.
Limited to span in inches (mm) divided by 360.
Strength — Live load of 40 psf (1.92 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi × 0.00689 for N/mm^2																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 6	12.0	8-6	8-10	9-2	9-6	9-9	10-0	10-3	10-6	10-9	10-11	11-2	11-4	11-7	11-9	11-11	12-1	12-3
	16.0	7-9	8-0	8-4	8-7	8-10	9-1	9-4	9-6	9-9	9-11	10-2	10-4	10-6	10-8	10-10	11-0	11-2
	19.2	7-3	7-7	7-10	8-1	8-4	8-7	8-9	9-0	9-2	9-4	9-6	9-8	9-10	10-0	10-2	10-4	10-6
	24.0	6-9	7-0	7-3	7-6	7-9	7-11	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4	9-6	9-7	9-9
2 × 8	12.0	11-3	11-8	12-1	12-6	12-10	13-2	13-6	13-10	14-2	14-5	14-8	15-0	15-3	15-6	15-9	15-11	16-2
	16.0	10-2	10-7	11-0	11-4	11-8	12-0	12-3	12-7	12-10	13-1	13-4	13-7	13-10	14-1	14-3	14-6	14-8
	19.2	9-7	10-0	10-4	10-8	11-0	11-3	11-7	11-10	12-1	12-4	12-7	12-10	13-0	13-3	13-5	13-8	13-10
	24.0	8-11	9-3	9-7	9-11	10-2	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-3	12-6	12-8	12-10
2 × 10	12.0	14-4	14-11	15-5	15-11	16-5	16-10	17-3	17-8	18-0	18-5	18-9	19-1	19-5	19-9	20-1	20-4	20-8
	16.0	13-0	13-6	14-0	14-6	14-11	15-3	15-8	16-0	16-5	16-9	17-0	17-4	17-8	17-11	18-3	18-6	18-9
	19.2	12-3	12-9	13-2	13-7	14-0	14-5	14-9	15-1	15-5	15-9	16-0	16-4	16-7	16-11	17-2	17-5	17-8
	24.0	11-4	11-10	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-7	14-11	15-2	15-5	15-8	15-11	16-2	16-5
2 × 12	12.0	17-5	18-1	18-9	19-4	19-11	20-6	21-0	21-6	21-11	22-5	22-10	23-3	23-7	24-0	24-5	24-9	25-1
	16.0	15-10	16-5	17-0	17-7	18-1	18-7	19-1	19-6	19-11	20-4	20-9	21-1	21-6	21-10	22-2	22-6	22-10
	19.2	14-11	15-6	16-0	16-7	17-0	17-6	17-11	18-4	18-9	19-2	19-6	19-10	20-2	20-6	20-10	21-2	21-6
	24.0	13-10	14-4	14-11	15-4	15-10	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-4	19-8	19-11
F_b	12.0	862	932	1,000	1,066	1,129	1,191	1,251	1,310	1,368	1,424	1,480	1,534	1,587	1,640	1,692	1,742	1,793
	16.0	949	1,026	1,101	1,173	1,243	1,311	1,377	1,442	1,506	1,568	1,629	1,688	1,747	1,805	1,862	1,918	1,973
	19.2	1,008	1,090	1,170	1,246	1,321	1,393	1,464	1,533	1,600	1,666	1,731	1,794	1,857	1,918	1,978	2,038	2,097
	24.0	1,086	1,174	1,260	1,343	1,423	1,501	1,577	1,651	1,724	1,795	1,864	1,933	2,000	2,066	2,131	2,195	2,258

NOTE: The required bending design value, F_b, in pounds per square inch (× 0.00689 for N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-J-3—CEILING JOISTS WITH *L*/240 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 10 psf (0.48 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.
Strength — Live load of 10 psf (0.48 kN/mm^2) plus dead load of 5 psf (0.24 kN/m^2) determines the required fiber stress value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi × 0.00689 for N/mm^2																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 4	12.0	9-10	10-3	10-7	10-11	11-3	11-7	11-10	12-2	12-5	12-8	12-11	13-2	13-4	13-7	13-9	14-0	14-2
	16.0	8-11	9-4	9-8	9-11	10-3	10-6	10-9	11-0	11-3	11-6	11-9	11-11	12-2	12-4	12-6	12-9	12-11
	19.2	8-5	8-9	9-1	9-4	9-8	9-11	10-2	10-4	10-7	10-10	11-0	11-3	11-5	11-7	11-9	12-0	12-2
	24.0	7-10	8-1	8-5	8-8	8-11	9-2	9-5	9-8	9-10	10-0	10-3	10-5	10-7	10-9	10-11	11-1	11-3
2 × 6	12.0	15-6	16-1	16-8	17-2	17-8	18-2	18-8	19-1	19-6	19-11	20-3	20-8	21-0	21-4	21-8	22-0	22-4
	16.0	14-1	14-7	15-2	15-7	16-1	16-6	16-11	17-4	17-8	18-1	18-5	18-9	19-1	19-5	19-8	20-0	20-3
	19.2	13-3	13-9	14-3	14-8	15-2	15-7	15-11	16-4	16-8	17-0	17-4	17-8	17-11	18-3	18-6	18-10	19-1
	24.0	12-3	12-9	13-3	13-8	14-1	14-5	14-9	15-2	15-6	15-9	16-1	16-4	16-8	16-11	17-2	17-5	17-8
2 × 8	12.0	20-5	21-2	21-11	22-8	23-4	24-0	24-7	25-2	25-8								
	16.0	18-6	19-3	19-11	20-7	21-2	21-9	22-4	22-10	23-4	23-10	24-3	24-8	25-2	25-7	25-11		
	19.2	17-5	18-1	18-9	19-5	19-11	20-6	21-0	21-6	21-11	22-5	22-10	23-3	23-8	24-0	24-5	24-9	25-2
	24.0	16-2	16-10	17-5	18-0	18-6	19-0	19-6	19-11	20-5	20-10	21-2	21-7	21-11	22-4	22-8	23-0	23-4
2 × 10	12.0	26-0																
	16.0	23-8	24-7	25-5														
	19.2	22-3	23-1	23-11	24-9	25-5												
	24.0	20-8	21-6	22-3	22-11	23-8	24-3	24-10	25-5	26-0								
F_b	12.0	711	769	825	880	932	983	1,033	1,082	1,129	1,176	1,221	1,266	1,310	1,354	1,396	1,438	1,480
	16.0	783	847	909	968	1,026	1,082	1,137	1,191	1,243	1,294	1,344	1,394	1,442	1,490	1,537	1,583	1,629
	19.2	832	900	965	1,029	1,090	1,150	1,208	1,265	1,321	1,375	1,429	1,481	1,533	1,583	1,633	1,682	1,731
	24.0	896	969	1,040	1,108	1,174	1,239	1,302	1,363	1,423	1,481	1,539	1,595	1,651	1,706	1,759	1,812	1,864

NOTE: The required bending design value, F_b, in pounds per square inch (× 0.00689 for N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-J-4—CEILING JOISTS WITH *L*/240 DEFLECTION LIMITS
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi × 0.00689 for N/mm^2																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 4	12.0	7-10	8-1	8-5	8-8	8-11	9-2	9-5	9-8	9-10	10-0	10-3	10-5	10-7	10-9	10-11	11-1	11-3
	16.0	7-1	7-5	7-8	7-11	8-1	8-4	8-7	8-9	8-11	9-1	9-4	9-6	9-8	9-9	9-11	10-1	10-3
	19.2	6-8	6-11	7-2	7-5	7-8	7-10	8-1	8-3	8-5	8-7	8-9	8-11	9-1	9-3	9-4	9-6	9-8
	24.0	6-2	6-5	6-8	6-11	7-1	7-3	7-6	7-8	7-10	8-0	8-1	8-3	8-5	8-7	8-8	8-10	8-11
2 × 6	12.0	12-3	12-9	13-3	13-8	14-1	14-5	14-9	15-2	15-6	15-9	16-1	16-4	16-8	16-11	17-2	17-5	17-8
	16.0	11-2	11-7	12-0	12-5	12-9	13-1	13-5	13-9	14-1	14-4	14-7	14-11	15-2	15-5	15-7	15-10	16-1
	19.2	10-6	10-11	11-4	11-8	12-0	12-4	12-8	12-11	13-3	13-6	13-9	14-0	14-3	14-6	14-8	14-11	15-2
	24.0	9-9	10-2	10-6	10-10	11-2	11-5	11-9	12-0	12-3	12-6	12-9	13-0	13-3	13-5	13-8	13-10	14-1
2 × 8	12.0	16-2	16-10	17-5	18-0	18-6	19-0	19-6	19-11	20-5	20-10	21-2	21-7	21-11	22-4	22-8	23-0	23-4
	16.0	14-8	15-3	15-10	16-4	16-10	17-3	17-9	18-1	18-6	18-11	19-3	19-7	19-11	20-3	20-7	20-11	21-2
	19.2	13-10	14-5	14-11	15-5	15-10	16-3	16-8	17-1	17-5	17-9	18-1	18-5	18-9	19-1	19-5	19-8	19-11
	24.0	12-10	13-4	13-10	14-3	14-8	15-1	15-6	15-10	16-2	16-6	16-10	17-2	17-5	17-9	18-0	18-3	18-6
2 × 10	12.0	20-8	21-6	22-3	22-11	23-8	24-3	24-10	25-5	26-0								
	16.0	18-9	19-6	20-2	20-10	21-6	22-1	22-7	23-1	23-8	24-1	24-7	25-0	25-5	25-10			
	19.2	17-8	18-4	19-0	19-7	20-2	20-9	21-3	21-9	22-3	22-8	23-1	23-7	23-11	24-4	24-9	25-1	25-5
	24.0	16-5	17-0	17-8	18-3	18-9	19-3	19-9	20-2	20-8	21-1	21-6	21-10	22-3	22-7	22-11	23-4	23-8
F_b	12.0	896	969	1,040	1,108	1,174	1,239	1,302	1,363	1,423	1,481	1,539	1,595	1,651	1,706	1,759	1,812	1,864
	16.0	986	1,067	1,145	1,220	1,293	1,364	1,433	1,500	1,566	1,631	1,694	1,756	1,817	1,877	1,936	1,995	2,052
	19.2	1,048	1,134	1,216	1,296	1,374	1,449	1,522	1,594	1,664	1,733	1,800	1,866	1,931	1,995	2,058	2,120	2,181
	24.0	1,129	1,221	1,310	1,396	1,480	1,561	1,640	1,717	1,793	1,866	1,939	2,010	2,080	2,149	2,217	2,283	2,349

NOTE: The required bending design value, F_b, in pounds per square inch (× 0.00689 for N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-1—RAFTERS WITH L/240 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2										
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300
2 × 6	12.0	7-1	8-2	9-2	10-0	10-10	11-7	12-4	13-0	13-7	14-2	14-9
	16.0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10
	19.2	5-7	6-6	7-3	7-11	8-7	9-2	9-9	10-3	10-9	11-3	11-8
	24.0	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5
2 × 8	12.0	9-4	10-10	12-1	13-3	14-4	15-3	16-3	17-1	17-11	18-9	19-6
	16.0	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10
	19.2	7-5	8-7	9-7	10-6	11-4	12-1	12-10	13-6	14-2	14-10	15-5
	24.0	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9
2 × 10	12.0	11-11	13-9	15-5	16-11	18-3	19-6	20-8	21-10	22-10	23-11	24-10
	16.0	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6
	19.2	9-5	10-11	12-2	13-4	14-5	15-5	16-4	17-3	18-1	18-11	19-8
	24.0	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7
2 × 12	12.0	14-6	16-9	18-9	20-6	22-2	23-9	25-2				
	16.0	12-7	14-6	16-3	17-9	19-3	20-6	21-9	23-0	24-1	25-2	
	19.2	11-6	13-3	14-10	16-3	17-6	18-9	19-11	21-0	22-0	23-0	23-11
	24.0	10-3	11-10	13-3	14-6	15-8	16-9	17-9	18-9	19-8	20-6	21-5
E	12.0	0.15	0.24	0.33	0.44	0.55	0.67	0.80	0.94	1.09	1.24	1.40
	16.0	0.13	0.21	0.29	0.38	0.48	0.58	0.70	0.82	0.94	1.07	1.21
	19.2	0.12	0.19	0.26	0.35	0.44	0.53	0.64	0.75	0.86	0.98	1.10
	24.0	0.11	0.17	0.24	0.31	0.39	0.48	0.57	0.67	0.77	0.88	0.99

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2										
× 25.4 for mm		1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
2 × 6	12.0	15-4	15-11	16-5	16-11	17-5	17-10					
	16.0	13-3	13-9	14-2	14-8	15-1	15-6	15-11	16-3			
	19.2	12-2	12-7	13-0	13-4	13-9	14-2	14-6	14-10	15-2	15-7	
	24.0	10-10	11-3	11-7	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2
2 × 8	12.0	20-3	20-11	21-7	22-3	22-11	23-7					
	16.0	17-6	18-1	18-9	19-4	19-10	20-5	20-11	21-5			
	19.2	16-0	16-7	17-1	17-7	18-1	18-7	19-1	19-7	20-0	20-6	
	24.0	14-4	14-10	15-3	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9
2 × 10	12.0	25-10										
	16.0	22-4	23-1	23-11	24-7	25-4	26-0					
	19.2	20-5	21-1	21-10	22-6	23-1	23-9	24-5	25-0	25-7		
	24.0	18-3	18-11	19-6	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11
2 × 12	12.0											
	16.0											
	19.2	24-10	25-8									
	24.0	22-2	23-0	23-9	24-5	25-2	25-10					
E	12.0	1.56	1.73	1.91	2.09	2.28	2.47					
	16.0	1.35	1.50	1.65	1.81	1.97	2.14	2.31	2.48			
	19.2	1.23	1.37	1.51	1.65	1.80	1.95	2.11	2.27	2.43	2.60	
	24.0	1.10	1.22	1.35	1.48	1.61	1.75	1.89	2.03	2.18	2.33	2.48

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-2—RAFTERS WITH L/240 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2										
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300
2 × 6	12.0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10
	16.0	5-4	6-2	6-10	7-6	8-2	8-8	9-3	9-9	10-2	10-8	11-1
	19.2	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-11	9-4	9-9	10-1
	24.0	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1
2 × 8	12.0	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10
	16.0	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-0	14-7
	19.2	6-5	7-5	8-3	9-1	9-9	10-6	11-1	11-8	12-3	12-10	13-4
	24.0	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11
2 × 10	12.0	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6
	16.0	8-11	10-4	11-7	12-8	13-8	14-8	15-6	16-4	17-2	17-11	18-8
	19.2	8-2	9-5	10-7	11-7	12-6	13-4	14-2	14-11	15-8	16-4	17-0
	24.0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3
2 × 12	12.0	12-7	14-6	16-3	17-9	19-3	20-6	21-9	23-0	24-1	25-2	
	16.0	10-11	12-7	14-1	15-5	16-8	17-9	18-10	19-11	20-10	21-9	22-8
	19.2	9-11	11-6	12-10	14-1	15-2	16-3	17-3	18-2	19-0	19-11	20-8
	24.0	8-11	10-3	11-6	12-7	13-7	14-6	15-5	16-3	17-0	17-9	18-6
E	12.0	0.15	0.23	0.32	0.43	0.54	0.66	0.78	0.92	1.06	1.21	1.36
	16.0	0.13	0.20	0.28	0.37	0.47	0.57	0.68	0.80	0.92	1.05	1.18
	19.2	0.12	0.18	0.26	0.34	0.43	0.52	0.62	0.73	0.84	0.95	1.08
	24.0	0.11	0.16	0.23	0.30	0.38	0.46	0.55	0.65	0.75	0.85	0.96

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2										
× 25.4 for mm		1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
2 × 6	12.0	13-3	13-9	14-2	14-8	15-1	15-6	15-11				
	16.0	11-6	11-11	12-4	12-8	13-1	13-5	13-9	14-1	14-5		
	19.2	10-6	10-10	11-3	11-7	11-11	12-3	12-7	12-10	13-2	13-6	
	24.0	9-5	9-9	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4
2 × 8	12.0	17-6	18-1	18-9	19-4	19-10	20-5	20-11				
	16.0	15-2	15-8	16-3	16-9	17-2	17-8	18-1	18-7	19-0		
	19.2	13-10	14-4	14-10	15-3	15-8	16-2	16-7	16-11	17-4	17-9	
	24.0	12-5	12-10	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3
2 × 10	12.0	22-4	23-1	23-11	24-7	25-4	26-0					
	16.0	19-4	20-0	20-8	21-4	21-11	22-6	23-1	23-8	24-3		
	19.2	17-8	18-3	18-11	19-6	20-0	20-7	21-1	21-8	22-2	22-8	
	24.0	15-10	16-4	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8
2 × 12	12.0											
	16.0	23-6	24-4	25-2	25-11							
	19.2	21-6	22-3	23-0	23-8	24-4	25-0	25-8				
	24.0	19-3	19-11	20-6	21-2	21-9	22-5	23-0	23-6	24-1	24-8	25-2
E	12.0	1.52	1.69	1.86	2.04	2.22	2.41	2.60				
	16.0	1.32	1.46	1.61	1.76	1.92	2.08	2.25	2.42	2.60		
	19.2	1.20	1.33	1.47	1.61	1.75	1.90	2.05	2.21	2.37	2.53	
	24.0	1.08	1.19	1.31	1.44	1.57	1.70	1.84	1.98	2.12	2.27	2.41

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-3—RAFTERS WITH *L*/240 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi)												
		× 0.00689 for N/mm^2												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	6-7	7-7	8-6	9-4	10-0	10-9	11-5	12-0	12-7	13-2	13-8	14-2	14-8
	16.0	5-8	6-7	7-4	8-1	8-8	9-4	9-10	10-5	10-11	11-5	11-10	12-4	12-9
	19.2	5-2	6-0	6-9	7-4	7-11	8-6	9-0	9-6	9-11	10-5	10-10	11-3	11-7
	24.0	4-8	5-4	6-0	6-7	7-1	7-7	8-1	8-6	8-11	9-4	9-8	10-0	10-5
2 × 8	12.0	8-8	10-0	11-2	12-3	13-3	14-2	15-0	15-10	16-7	17-4	18-0	18-9	19-5
	16.0	7-6	8-8	9-8	10-7	11-6	12-3	13-0	13-8	14-4	15-0	15-7	16-3	16-9
	19.2	6-10	7-11	8-10	9-8	10-6	11-2	11-10	12-6	13-1	13-8	14-3	14-10	15-4
	24.0	6-2	7-1	7-11	8-8	9-4	10-0	10-7	11-2	11-9	12-3	12-9	13-3	13-8
2 × 10	12.0	11-1	12-9	14-3	15-8	16-11	18-1	19-2	20-2	21-2	22-1	23-0	23-11	24-9
	16.0	9-7	11-1	12-4	13-6	14-8	15-8	16-7	17-6	18-4	19-2	19-11	20-8	21-5
	19.2	8-9	10-1	11-3	12-4	13-4	14-3	15-2	15-11	16-9	17-6	18-2	18-11	19-7
	24.0	7-10	9-0	10-1	11-1	11-11	12-9	13-6	14-3	15-0	15-8	16-3	16-11	17-6
2 × 12	12.0	13-5	15-6	17-4	19-0	20-6	21-11	23-3	24-7	25-9				
	16.0	11-8	13-5	15-0	16-6	17-9	19-0	20-2	21-3	22-4	23-3	24-3	25-2	26-0
	19.2	10-8	12-3	13-9	15-0	16-3	17-4	18-5	19-5	20-4	21-3	22-2	23-0	23-9
	24.0	9-6	11-0	12-3	13-5	14-6	15-6	16-6	17-4	18-2	19-0	19-10	20-6	21-3
E	12.0	0.12	0.19	0.26	0.35	0.44	0.54	0.64	0.75	0.86	0.98	1.11	1.24	1.37
	16.0	0.11	0.16	0.23	0.30	0.38	0.46	0.55	0.65	0.75	0.85	0.96	1.07	1.19
	19.2	0.10	0.15	0.21	0.27	0.35	0.42	0.51	0.59	0.68	0.78	0.88	0.98	1.09
	24.0	0.09	0.13	0.19	0.25	0.31	0.38	0.45	0.53	0.61	0.70	0.78	0.88	0.97

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi)											
		× 0.00689 for N/mm^2											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	15-2	15-8	16-1	16-7	17-0	17-5	17-10					
	16.0	13-2	13-7	13-11	14-4	14-8	15-1	15-5	15-9	16-1	16-5		
	19.2	12-0	12-4	12-9	13-1	13-5	13-9	14-1	14-5	14-8	15-0	15-4	
	24.0	10-9	11-1	11-5	11-8	12-0	12-4	12-7	12-10	13-2	13-5	13-8	13-11
2 × 8	12.0	20-0	20-8	21-3	21-10	22-4	22-11	23-6					
	16.0	17-4	17-10	18-5	18-11	19-5	19-10	20-4	20-9	21-3	21-8		
	19.2	15-10	16-4	16-9	17-3	17-8	18-1	18-7	19-0	19-5	19-9	20-2	
	24.0	14-2	14-7	15-0	15-5	15-10	16-3	16-7	17-0	17-4	17-8	18-0	18-5
2 × 10	12.0	25-6											
	16.0	22-1	22-10	23-5	24-1	24-9	25-4	25-11					
	19.2	20-2	20-10	21-5	22-0	22-7	23-1	23-8	24-2	24-9	25-3	25-9	
	24.0	18-1	18-7	19-2	19-8	20-2	20-8	21-2	21-8	22-1	22-7	23-0	23-5
2 × 12	12.0												
	16.0												
	19.2	24-7	25-4	26-0									
	24.0	21-11	22-8	23-3	23-11	24-7	25-2	25-9					
E	12.0	1.51	1.66	1.81	1.96	2.12	2.28	2.44					
	16.0	1.31	1.44	1.56	1.70	1.83	1.97	2.11	2.26	2.41	2.56		
	19.2	1.20	1.31	1.43	1.55	1.67	1.80	1.93	2.06	2.20	2.34	2.48	
	24.0	1.07	1.17	1.28	1.39	1.50	1.61	1.73	1.85	1.97	2.09	2.22	2.35

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-4—RAFTERS WITH *L*/240 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	5-10	6-8	7-6	8-2	8-10	9-6	10-0	10-7	11-1	11-7	12-1	12-6	13-0
	16.0	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5	10-10	11-3
	19.2	4-7	5-4	5-11	6-6	7-0	7-6	7-11	8-4	8-9	9-2	9-6	9-11	10-3
	24.0	4-1	4-9	5-4	5-10	6-3	6-8	7-1	7-6	7-10	8-2	8-6	8-10	9-2
2 × 8	12.0	7-8	8-10	9-10	10-10	11-8	12-6	13-3	13-11	14-8	15-3	15-11	16-6	17-1
	16.0	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9	14-4	14-10
	19.2	6-0	7-0	7-10	8-7	9-3	9-10	10-6	11-0	11-7	12-1	12-7	13-1	13-6
	24.0	5-5	6-3	7-0	7-8	8-3	8-10	9-4	9-10	10-4	10-10	11-3	11-8	12-1
2 × 10	12.0	9-9	11-3	12-7	13-9	14-11	15-11	16-11	17-10	18-8	19-6	20-4	21-1	21-10
	16.0	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7	18-3	18-11
	19.2	7-8	8-11	9-11	10-11	11-9	12-7	13-4	14-1	14-9	15-5	16-1	16-8	17-3
	24.0	6-11	8-0	8-11	9-9	10-6	11-3	11-11	12-7	13-2	13-9	14-4	14-11	15-5
2 × 12	12.0	11-10	13-8	15-4	16-9	18-1	19-4	20-6	21-8	22-8	23-9	24-8	25-7	
	16.0	10-3	11-10	13-3	14-6	15-8	16-9	17-9	18-9	19-8	20-6	21-5	22-2	23-0
	19.2	9-4	10-10	12-1	13-3	14-4	15-4	16-3	17-1	17-11	18-9	19-6	20-3	21-0
	24.0	8-5	9-8	10-10	11-10	12-10	13-8	14-6	15-4	16-1	16-9	17-5	18-1	18-9
E	12.0	0.13	0.19	0.27	0.36	0.45	0.55	0.66	0.77	0.89	1.01	1.14	1.28	1.41
	16.0	0.11	0.17	0.24	0.31	0.39	0.48	0.57	0.67	0.77	0.88	0.99	1.10	1.22
	19.2	0.10	0.15	0.22	0.28	0.36	0.44	0.52	0.61	0.70	0.80	0.90	1.01	1.12
	24.0	0.09	0.14	0.19	0.25	0.32	0.39	0.46	0.54	0.63	0.72	0.81	0.90	1.00

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	13-5	13-10	14-2	14-7	15-0	15-4	15-8					
	16.0	11-7	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2			
	19.2	10-7	10-11	11-3	11-6	11-10	12-2	12-5	12-8	13-0	13-3	13-6	
	24.0	9-6	9-9	10-0	10-4	10-7	10-10	11-1	11-4	11-7	11-10	12-1	12-4
2 × 8	12.0	17-8	18-2	18-9	19-3	19-9	20-3	20-8					
	16.0	15-3	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9			
	19.2	13-11	14-5	14-10	15-2	15-7	16-0	16-4	16-9	17-1	17-5	17-9	
	24.0	12-6	12-10	13-3	13-7	13-11	14-4	14-8	15-0	15-3	15-7	15-11	16-3
2 × 10	12.0	22-6	23-3	23-11	24-6	25-2	25-10						
	16.0	19-6	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11			
	19.2	17-10	18-4	18-11	19-5	19-11	20-5	20-10	21-4	21-10	22-3	22-8	
	24.0	15-11	16-5	16-11	17-4	17-10	18-3	18-8	19-1	19-6	19-11	20-4	20-8
2 × 12	12.0												
	16.0	23-9	24-5	25-2	25-10								
	19.2	21-8	22-4	23-0	23-7	24-2	24-10	25-5	25-11				
	24.0	19-4	20-0	20-6	21-1	21-8	22-2	22-8	23-3	23-9	24-2	24-8	25-2
E	12.0	1.56	1.71	1.86	2.02	2.18	2.34	2.51					
	16.0	1.35	1.48	1.61	1.75	1.89	2.03	2.18	2.33	2.48			
	19.2	1.23	1.35	1.47	1.59	1.72	1.85	1.99	2.12	2.26	2.41	2.55	
	24.0	1.10	1.21	1.31	1.43	1.54	1.66	1.78	1.90	2.02	2.15	2.28	2.41

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-5—RAFTERS WITH *L*/240 DEFLECTION LIMITATION
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10	13-3	13-9
	16.0	5-4	6-2	6-10	7-6	8-2	8-8	9-3	9-9	10-2	10-8	11-1	11-6	11-11
	19.2	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-11	9-4	9-9	10-1	10-6	10-10
	24.0	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9
2 × 8	12.0	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10	17-6	18-1
	16.0	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-0	14-7	15-2	15-8
	19.2	6-5	7-5	8-3	9-1	9-9	10-6	11-1	11-8	12-3	12-10	13-4	13-10	14-4
	24.0	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10
2 × 10	12.0	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6	22-4	23-1
	16.0	8-11	10-4	11-7	12-8	13-8	14-8	15-6	16-4	17-2	17-11	18-8	19-4	20-0
	19.2	8-2	9-5	10-7	11-7	12-6	13-4	14-2	14-11	15-8	16-4	17-0	17-8	18-3
	24.0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4
2 × 12	12.0	12-7	14-6	16-3	17-9	19-3	20-6	21-9	23-0	24-1	25-2			
	16.0	10-11	12-7	14-1	15-5	16-8	17-9	18-10	19-11	20-10	21-9	22-8	23-6	24-4
	19.2	9-11	11-6	12-10	14-1	15-2	16-3	17-3	18-2	19-0	19-11	20-8	21-6	22-3
	24.0	8-11	10-3	11-6	12-7	13-7	14-6	15-5	16-3	17-0	17-9	18-6	19-3	19-11
E	12.0	0.10	0.15	0.22	0.28	0.36	0.44	0.52	0.61	0.71	0.80	0.91	1.01	1.13
	16.0	0.09	0.13	0.19	0.25	0.31	0.38	0.45	0.53	0.61	0.70	0.79	0.88	0.97
	19.2	0.08	0.12	0.17	0.23	0.28	0.35	0.41	0.48	0.56	0.64	0.72	0.80	0.89
	24.0	0.07	0.11	0.15	0.20	0.25	0.31	0.37	0.43	0.50	0.57	0.64	0.72	0.80

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	14-2	14-8	15-1	15-6	15-11	16-3	16-8	17-0	17-5	17-9	18-1	
	16.0	12-4	12-8	13-1	13-5	13-9	14-1	14-5	14-9	15-1	15-4	15-8	16-0
	19.2	11-3	11-7	11-11	12-3	12-7	12-10	13-2	13-6	13-9	14-0	14-4	14-7
	24.0	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1
2 × 8	12.0	18-9	19-4	19-10	20-5	20-11	21-5	21-11	22-5	22-11	23-5	23-10	
	16.0	16-3	16-9	17-2	17-8	18-1	18-7	19-0	19-5	19-10	20-3	20-8	21-1
	19.2	14-10	15-3	15-8	16-2	16-7	16-11	17-4	17-9	18-1	18-6	18-10	19-3
	24.0	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2
2 × 10	12.0	23-11	24-7	25-4	26-0								
	16.0	20-8	21-4	21-11	22-6	23-1	23-8	24-3	24-10	25-4	25-10		
	19.2	18-11	19-6	20-0	20-7	21-1	21-8	22-2	22-8	23-1	23-7	24-1	24-6
	24.0	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11
2 × 12	12.0												
	16.0	25-2	25-11										
	19.2	23-0	23-8	24-4	25-0	25-8							
	24.0	20-6	21-2	21-9	22-5	23-0	23-6	24-1	24-8	25-2	25-8		
E	12.0	1.24	1.36	1.48	1.60	1.73	1.86	2.00	2.14	2.28	2.42	2.57	
	16.0	1.07	1.18	1.28	1.39	1.50	1.61	1.73	1.85	1.97	2.10	2.22	2.35
	19.2	0.98	1.07	1.17	1.27	1.37	1.47	1.58	1.69	1.80	1.91	2.03	2.15
	24.0	0.88	0.96	1.05	1.13	1.22	1.32	1.41	1.51	1.61	1.71	1.82	1.92

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-6—RAFTERS WITH *L*/240 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	5-6	6-4	7-1	7-9	8-5	9-0	9-6	10-0	10-6	11-0	11-5	11-11	12-4
	16.0	4-9	5-6	6-2	6-9	7-3	7-9	8-3	8-8	9-1	9-6	9-11	10-3	10-8
	19.2	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9
	24.0	3-11	4-6	5-0	5-6	5-11	6-4	6-9	7-1	7-5	7-9	8-1	8-5	8-8
2 × 8	12.0	7-3	8-4	9-4	10-3	11-1	11-10	12-7	13-3	13-11	14-6	15-1	15-8	16-3
	16.0	6-3	7-3	8-1	8-11	9-7	10-3	10-10	11-6	12-0	12-7	13-1	13-7	14-0
	19.2	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10
	24.0	5-2	5-11	6-7	7-3	7-10	8-4	8-11	9-4	9-10	10-3	10-8	11-1	11-6
2 × 10	12.0	9-3	10-8	11-11	13-1	14-2	15-1	16-0	16-11	17-9	18-6	19-3	20-0	20-8
	16.0	8-0	9-3	10-4	11-4	12-3	13-1	13-10	14-8	15-4	16-0	16-8	17-4	17-11
	19.2	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4
	24.0	6-6	7-7	8-5	9-3	10-0	10-8	11-4	11-11	12-6	13-1	13-7	14-2	14-8
2 × 12	12.0	11-3	13-0	14-6	15-11	17-2	18-4	19-6	20-6	21-7	22-6	23-5	24-4	25-2
	16.0	9-9	11-3	12-7	13-9	14-11	15-11	16-10	17-9	18-8	19-6	20-3	21-1	21-9
	19.2	8-11	10-3	11-6	12-7	13-7	14-6	15-5	16-3	17-0	17-9	18-6	19-3	19-11
	24.0	7-11	9-2	10-3	11-3	12-2	13-0	13-9	14-6	15-3	15-11	16-7	17-2	17-9
E	12.0	0.11	0.17	0.23	0.31	0.38	0.47	0.56	0.66	0.76	0.86	0.97	1.09	1.21
	16.0	0.09	0.14	0.20	0.26	0.33	0.41	0.49	0.57	0.66	0.75	0.84	0.94	1.05
	19.2	0.09	0.13	0.18	0.24	0.30	0.37	0.44	0.52	0.60	0.68	0.77	0.86	0.95
	24.0	0.08	0.12	0.16	0.22	0.27	0.33	0.40	0.46	0.54	0.61	0.69	0.77	0.85

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	12-8	13-1	13-6	13-10	14-2	14-7	14-11	15-3	15-7	15-11		
	16.0	11-0	11-4	11-8	12-0	12-4	12-7	12-11	13-2	13-6	13-9	14-0	14-3
	19.2	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1
	24.0	9-0	9-3	9-6	9-9	10-0	10-3	10-6	10-9	11-0	11-3	11-5	11-8
2 × 8	12.0	16-9	17-3	17-9	18-3	18-9	19-2	19-8	20-1	20-6	20-11		
	16.0	14-6	14-11	15-5	15-10	16-3	16-7	17-0	17-5	17-9	18-1	18-6	18-10
	19.2	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2
	24.0	11-10	12-2	12-7	12-11	13-3	13-7	13-11	14-2	14-6	14-10	15-1	15-5
2 × 10	12.0	21-4	22-0	22-8	23-3	23-11	24-6	25-1	25-7				
	16.0	18-6	19-1	19-7	20-2	20-8	21-2	21-8	22-2	22-8	23-1	23-7	24-0
	19.2	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11
	24.0	15-1	15-7	16-0	16-6	16-11	17-4	17-9	18-1	18-6	18-11	19-3	19-7
2 × 12	12.0	26-0											
	16.0	22-6	23-2	23-10	24-6	25-2	25-9						
	19.2	20-6	21-2	21-9	22-5	23-0	23-6	24-1	24-8	25-2	25-8		
	24.0	18-4	18-11	19-6	20-0	20-6	21-1	21-7	22-0	22-6	23-0	23-5	23-10
E	12.0	1.33	1.46	1.59	1.72	1.86	2.00	2.14	2.29	2.44	2.60		
	16.0	1.15	1.26	1.37	1.49	1.61	1.73	1.86	1.99	2.12	2.25	2.39	2.53
	19.2	1.05	1.15	1.25	1.36	1.47	1.58	1.70	1.81	1.93	2.05	2.18	2.31
	24.0	0.94	1.03	1.12	1.22	1.31	1.41	1.52	1.62	1.73	1.84	1.95	2.06

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-7—RAFTERS WITH *L*/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi)														
		× 0.00689 for N/mm^2														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-8	4-6	5-3	5-10	6-5	6-11	7-5	7-10	8-3	8-8	9-0	9-5	9-9	10-1	10-5
	16.0	3-2	3-11	4-6	5-1	5-6	6-0	6-5	6-9	7-2	7-6	7-10	8-2	8-5	8-9	9-0
	19.2	2-11	3-7	4-1	4-7	5-1	5-5	5-10	6-2	6-6	6-10	7-2	7-5	7-9	8-0	8-3
	24.0	2-7	3-2	3-8	4-1	4-6	4-11	5-3	5-6	5-10	6-1	6-5	6-8	6-11	7-2	7-5
2 × 6	12.0	5-10	7-1	8-2	9-2	10-0	10-10	11-7	12-4	13-0	13-7	14-2	14-9	15-4	15-11	16-5
	16.0	5-0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10	13-3	13-9	14-2
	19.2	4-7	5-7	6-6	7-3	7-11	8-7	9-2	9-9	10-3	10-9	11-3	11-8	12-2	12-7	13-0
	24.0	4-1	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5	10-10	11-3	11-7
2 × 8	12.0	7-8	9-4	10-10	12-1	13-3	14-4	15-3	16-3	17-1	17-11	18-9	19-6	20-3	20-11	21-7
	16.0	6-7	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10	17-6	18-1	18-9
	19.2	6-0	7-5	8-7	9-7	10-6	11-4	12-1	12-10	13-6	14-2	14-10	15-5	16-0	16-7	17-1
	24.0	5-5	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9	14-4	14-10	15-3
2 × 10	12.0	9-9	11-11	13-9	15-5	16-11	18-3	19-6	20-8	21-10	22-10	23-11	24-10	25-10		
	16.0	8-5	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6	22-4	23-1	23-11
	19.2	7-8	9-5	10-11	12-2	13-4	14-5	15-5	16-4	17-3	18-1	18-11	19-8	20-5	21-1	21-10
	24.0	6-11	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7	18-3	18-11	19-6
E	12.0	0.06	0.12	0.18	0.25	0.33	0.41	0.51	0.60	0.71	0.82	0.93	1.05	1.17	1.30	1.43
	16.0	0.05	0.10	0.15	0.22	0.28	0.36	0.44	0.52	0.61	0.71	0.80	0.91	1.01	1.13	1.24
	19.2	0.05	0.09	0.14	0.20	0.26	0.33	0.40	0.48	0.56	0.64	0.73	0.83	0.93	1.03	1.13
	24.0	0.04	0.08	0.13	0.18	0.23	0.29	0.36	0.43	0.50	0.58	0.66	0.74	0.83	0.92	1.01

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi)													
		× 0.00689 for N/mm^2													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	10-9	11-1	11-4	11-8	11-11	12-3	12-6							
	16.0	9-4	9-7	9-10	10-1	10-4	10-7	10-10	11-1	11-4	11-6				
	19.2	8-6	8-9	9-0	9-3	9-5	9-8	9-11	10-1	10-4	10-6	10-9			
	24.0	7-7	7-10	8-0	8-3	8-5	8-8	8-10	9-0	9-3	9-5	9-7	9-9	9-11	10-1
2 × 6	12.0	16-11	17-5	17-10	18-4	18-9	19-3	19-8							
	16.0	14-8	15-1	15-6	15-11	16-3	16-8	17-0	17-5	17-9	18-1				
	19.2	13-4	13-9	14-2	14-6	14-10	15-2	15-7	15-11	16-2	16-6	16-10			
	24.0	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2	14-6	14-9	15-1	15-4	15-7	15-11
2 × 8	12.0	22-3	22-11	23-7	24-2	24-9	25-4	25-11							
	16.0	19-4	19-10	20-5	20-11	21-5	21-11	22-5	22-11	23-5	23-10				
	19.2	17-7	18-1	18-7	19-1	19-7	20-0	20-6	20-11	21-4	21-9	22-2			
	24.0	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9	19-1	19-6	19-10	20-3	20-7	20-11
2 × 10	12.0														
	16.0	24-7	25-4	26-0											
	19.2	22-6	23-1	23-9	24-5	25-0	25-7								
	24.0	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11	24-5	24-10	25-4	25-10		
E	12.0	1.57	1.71	1.85	2.00	2.15	2.31	2.47							
	16.0	1.36	1.48	1.60	1.73	1.86	2.00	2.14	2.28	2.42	2.57				
	19.2	1.24	1.35	1.46	1.58	1.70	1.82	1.95	2.08	2.21	2.34	2.48			
	24.0	1.11	1.21	1.31	1.41	1.52	1.63	1.74	1.86	1.98	2.10	2.22	2.34	2.47	2.60

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-8—RAFTERS WITH *L*/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-2	3-11	4-6	5-1	5-6	6-0	6-5	6-9	7-2	7-6	7-10	8-2	8-5	8-9	9-0
	16.0	2-9	3-5	3-11	4-4	4-10	5-2	5-6	5-10	6-2	6-6	6-9	7-1	7-4	7-7	7-10
	19.2	2-6	3-1	3-7	4-0	4-4	4-9	5-1	5-4	5-8	5-11	6-2	6-5	6-8	6-11	7-2
	24.0	2-3	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5
2 × 6	12.0	5-0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10	13-3	13-9	14-2
	16.0	4-4	5-4	6-2	6-10	7-6	8-2	8-8	9-3	9-9	10-2	10-8	11-1	11-6	11-11	12-4
	19.2	4-0	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-11	9-4	9-9	10-1	10-6	10-10	11-3
	24.0	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0
2 × 8	12.0	6-7	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10	17-6	18-1	18-9
	16.0	5-9	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-0	14-7	15-2	15-8	16-3
	19.2	5-3	6-5	7-5	8-3	9-1	9-9	10-6	11-1	11-8	12-3	12-10	13-4	13-10	14-4	14-10
	24.0	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
2 × 10	12.0	8-5	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6	22-4	23-1	23-11
	16.0	7-4	8-11	10-4	11-7	12-8	13-8	14-8	15-6	16-4	17-2	17-11	18-8	19-4	20-0	20-8
	19.2	6-8	8-2	9-5	10-7	11-7	12-6	13-4	14-2	14-11	15-8	16-4	17-0	17-8	18-3	18-11
	24.0	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11
E	12.0	0.06	0.11	0.17	0.24	0.32	0.40	0.49	0.59	0.69	0.79	0.91	1.02	1.14	1.27	1.39
	16.0	0.05	0.10	0.15	0.21	0.28	0.35	0.43	0.51	0.60	0.69	0.78	0.88	0.99	1.10	1.21
	19.2	0.05	0.09	0.14	0.19	0.25	0.32	0.39	0.47	0.54	0.63	0.72	0.81	0.90	1.00	1.10
	24.0	0.04	0.08	0.12	0.17	0.23	0.29	0.35	0.42	0.49	0.56	0.64	0.72	0.81	0.89	0.99

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2														
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	9-4	9-7	9-10	10-1	10-4	10-7	10-10	11-1						
	16.0	8-1	8-4	8-6	8-9	9-0	9-2	9-5	9-7	9-9	10-0				
	19.2	7-4	7-7	7-9	8-0	8-2	8-5	8-7	8-9	8-11	9-1	9-3	9-5		
	24.0	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5	8-7	8-9
2 × 6	12.0	14-8	15-1	15-6	15-11	16-3	16-8	17-0	17-5						
	16.0	12-8	13-1	13-5	13-9	14-1	14-5	14-9	15-1	15-4	15-8				
	19.2	11-7	11-11	12-3	12-7	12-10	13-2	13-6	13-9	14-0	14-4	14-7	14-10		
	24.0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3	13-6	13-9
2 × 8	12.0	19-4	19-10	20-5	20-11	21-5	21-11	22-5	22-11						
	16.0	16-9	17-2	17-8	18-1	18-7	19-0	19-5	19-10	20-3	20-8				
	19.2	15-3	15-8	16-2	16-7	16-11	17-4	17-9	18-1	18-6	18-10	19-3	19-7		
	24.0	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6	17-10	18-1
2 × 10	12.0	24-7	25-4	26-0											
	16.0	21-4	21-11	22-6	23-1	23-8	24-3	24-10	25-4	25-10					
	19.2	19-6	20-0	20-7	21-1	21-8	22-2	22-8	23-1	23-7	24-1	24-6	25-0		
	24.0	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4	22-9	23-1
E	12.0	1.53	1.66	1.80	1.95	2.10	2.25	2.40	2.56						
	16.0	1.32	1.44	1.56	1.69	1.82	1.95	2.08	2.22	2.36	2.50				
	19.2	1.21	1.32	1.43	1.54	1.66	1.78	1.90	2.03	2.15	2.28	2.42	2.55		
	24.0	1.08	1.18	1.28	1.38	1.48	1.59	1.70	1.81	1.93	2.04	2.16	2.28	2.41	2.53

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-9—RAFTERS WITH *L*/180 DEFLECTION LIMITATION
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-5	4-2	4-10	5-5	5-11	6-5	6-10	7-3	7-8	8-0	8-4	8-8	9-0	9-4	9-8
	16.0	2-11	3-7	4-2	4-8	5-1	5-6	5-11	6-3	6-7	6-11	7-3	7-6	7-10	8-1	8-4
	19.2	2-8	3-4	3-10	4-3	4-8	5-1	5-5	5-9	6-0	6-4	6-7	6-11	7-2	7-5	7-8
	24.0	2-5	2-11	3-5	3-10	4-2	4-6	4-10	5-1	5-5	5-8	5-11	6-2	6-5	6-7	6-10
2 × 6	12.0	5-4	6-7	7-7	8-6	9-4	10-0	10-9	11-5	12-0	12-7	13-2	13-8	14-2	14-8	15-2
	16.0	4-8	5-8	6-7	7-4	8-1	8-8	9-4	9-10	10-5	10-11	11-5	11-10	12-4	12-9	13-2
	19.2	4-3	5-2	6-0	6-9	7-4	7-11	8-6	9-0	9-6	9-11	10-5	10-10	11-3	11-7	12-0
	24.0	3-10	4-8	5-4	6-0	6-7	7-1	7-7	8-1	8-6	8-11	9-4	9-8	10-0	10-5	10-9
2 × 8	12.0	7-1	8-8	10-0	11-2	12-3	13-3	14-2	15-0	15-10	16-7	17-4	18-0	18-9	19-5	20-0
	16.0	6-2	7-6	8-8	9-8	10-7	11-6	12-3	13-0	13-8	14-4	15-0	15-7	16-3	16-9	17-4
	19.2	5-7	6-10	7-11	8-10	9-8	10-6	11-2	11-10	12-6	13-1	13-8	14-3	14-10	15-4	15-10
	24.0	5-0	6-2	7-1	7-11	8-8	9-4	10-0	10-7	11-2	11-9	12-3	12-9	13-3	13-8	14-2
2 × 10	12.0	9-0	11-1	12-9	14-3	15-8	16-11	18-1	19-2	20-2	21-2	22-1	23-0	23-11	24-9	25-6
	16.0	7-10	9-7	11-1	12-4	13-6	14-8	15-8	16-7	17-6	18-4	19-2	19-11	20-8	21-5	22-1
	19.2	7-2	8-9	10-1	11-3	12-4	13-4	14-3	15-2	15-11	16-9	17-6	18-2	18-11	19-7	20-2
	24.0	6-5	7-10	9-0	10-1	11-1	11-11	12-9	13-6	14-3	15-0	15-8	16-3	16-11	17-6	18-1
E	12.0	0.05	0.09	0.14	0.20	0.26	0.33	0.40	0.48	0.56	0.65	0.74	0.83	0.93	1.03	1.14
	16.0	0.04	0.08	0.12	0.17	0.23	0.28	0.35	0.41	0.49	0.56	0.64	0.72	0.80	0.89	0.98
	19.2	0.04	0.07	0.11	0.16	0.21	0.26	0.32	0.38	0.44	0.51	0.58	0.66	0.73	0.81	0.90
	24.0	0.04	0.07	0.10	0.14	0.18	0.23	0.28	0.34	0.40	0.46	0.52	0.59	0.66	0.73	0.80

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	9-11	10-3	10-6	10-10	11-1	11-4	11-7	11-10	12-1	12-4	12-7			
	16.0	8-7	8-10	9-1	9-4	9-7	9-10	10-0	10-3	10-5	10-8	10-10	11-1	11-3	11-5
	19.2	7-10	8-1	8-4	8-6	8-9	8-11	9-2	9-4	9-7	9-9	9-11	10-1	10-3	10-5
	24.0	7-0	7-3	7-5	7-8	7-10	8-0	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4
2 × 6	12.0	15-8	16-1	16-7	17-0	17-5	17-10	18-2	18-7	19-0	19-4	19-9			
	16.0	13-7	13-11	14-4	14-8	15-1	15-5	15-9	16-1	16-5	16-9	17-1	17-5	17-8	18-0
	19.2	12-4	12-9	13-1	13-5	13-9	14-1	14-5	14-8	15-0	15-4	15-7	15-11	16-2	16-5
	24.0	11-1	11-5	11-8	12-0	12-4	12-7	12-10	13-2	13-5	13-8	13-11	14-2	14-5	14-8
2 × 8	12.0	20-8	21-3	21-10	22-4	22-11	23-6	24-0	24-6	25-0	25-6	26-0			
	16.0	17-10	18-5	18-11	19-5	19-10	20-4	20-9	21-3	21-8	22-1	22-6	22-11	23-4	23-9
	19.2	16-4	16-9	17-3	17-8	18-1	18-7	19-0	19-5	19-9	20-2	20-7	20-11	21-4	21-8
	24.0	14-7	15-0	15-5	15-10	16-3	16-7	17-0	17-4	17-8	18-0	18-5	18-9	19-1	19-5
2 × 10	12.0														
	16.0	22-10	23-5	24-1	24-9	25-4	25-11								
	19.2	20-10	21-5	22-0	22-7	23-1	23-8	24-2	24-9	25-3	25-9				
	24.0	18-7	19-2	19-8	20-2	20-8	21-2	21-8	22-1	22-7	23-0	23-5	23-11	24-4	24-9
E	12.0	1.24	1.36	1.47	1.59	1.71	1.83	1.96	2.09	2.22	2.35	2.49			
	16.0	1.08	1.17	1.27	1.37	1.48	1.59	1.70	1.81	1.92	2.04	2.16	2.28	2.40	2.53
	19.2	0.98	1.07	1.16	1.25	1.35	1.45	1.55	1.65	1.75	1.86	1.97	2.08	2.19	2.31
	24.0	0.88	0.96	1.04	1.12	1.21	1.29	1.38	1.48	1.57	1.66	1.76	1.86	1.96	2.06

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-10—RAFTERS WITH *L*/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi)														
		× 0.00689 for N/mm^2														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-0	3-8	4-3	4-9	5-3	5-8	6-0	6-5	6-9	7-1	7-5	7-8	8-0	8-3	8-6
	16.0	2-7	3-2	3-8	4-1	4-6	4-11	5-3	5-6	5-10	6-1	6-5	6-8	6-11	7-2	7-5
	19.2	2-5	2-11	3-4	3-9	4-1	4-5	4-9	5-1	5-4	5-7	5-10	6-1	6-4	6-6	6-9
	24.0	2-2	2-7	3-0	3-4	3-8	4-0	4-3	4-6	4-9	5-0	5-3	5-5	5-8	5-10	6-0
2 × 6	12.0	4-9	5-10	6-8	7-6	8-2	8-10	9-6	10-0	10-7	11-1	11-7	12-1	12-6	13-0	13-5
	16.0	4-1	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5	10-10	11-3	11-7
	19.2	3-9	4-7	5-4	5-11	6-6	7-0	7-6	7-11	8-4	8-9	9-2	9-6	9-11	10-3	10-7
	24.0	3-4	4-1	4-9	5-4	5-10	6-3	6-8	7-1	7-6	7-10	8-2	8-6	8-10	9-2	9-6
2 × 8	12.0	6-3	7-8	8-10	9-10	10-10	11-8	12-6	13-3	13-11	14-8	15-3	15-11	16-6	17-1	17-8
	16.0	5-5	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9	14-4	14-10	15-3
	19.2	4-11	6-0	7-0	7-10	8-7	9-3	9-10	10-6	11-0	11-7	12-1	12-7	13-1	13-6	13-11
	24.0	4-5	5-5	6-3	7-0	7-8	8-3	8-10	9-4	9-10	10-4	10-10	11-3	11-8	12-1	12-6
2 × 10	12.0	8-0	9-9	11-3	12-7	13-9	14-11	15-11	16-11	17-10	18-8	19-6	20-4	21-1	21-10	22-6
	16.0	6-11	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7	18-3	18-11	19-6
	19.2	6-4	7-8	8-11	9-11	10-11	11-9	12-7	13-4	14-1	14-9	15-5	16-1	16-8	17-3	17-10
	24.0	5-8	6-11	8-0	8-11	9-9	10-6	11-3	11-11	12-7	13-2	13-9	14-4	14-11	15-5	15-11
E	12.0	0.05	0.09	0.15	0.20	0.27	0.34	0.41	0.49	0.58	0.67	0.76	0.86	0.96	1.06	1.17
	16.0	0.04	0.08	0.13	0.18	0.23	0.29	0.36	0.43	0.50	0.58	0.66	0.74	0.83	0.92	1.01
	19.2	0.04	0.08	0.12	0.16	0.21	0.27	0.33	0.39	0.46	0.53	0.60	0.68	0.76	0.84	0.92
	24.0	0.04	0.07	0.10	0.14	0.19	0.24	0.29	0.35	0.41	0.47	0.54	0.61	0.68	0.75	0.83

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi)													
		× 0.00689 for N/mm^2													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	8-9	9-0	9-3	9-6	9-9	10-0	10-3	10-5	10-8	10-10	11-1			
	16.0	7-7	7-10	8-0	8-3	8-5	8-8	8-10	9-0	9-3	9-5	9-7	9-9	9-11	10-1
	19.2	6-11	7-2	7-4	7-6	7-9	7-11	8-1	8-3	8-5	8-7	8-9	8-11	9-1	9-3
	24.0	6-3	6-5	6-7	6-9	6-11	7-1	7-3	7-5	7-6	7-8	7-10	8-0	8-1	8-3
2 × 6	12.0	13-10	14-2	14-7	15-0	15-4	15-8	16-1	16-5	16-9	17-1	17-5			
	16.0	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2	14-6	14-9	15-1	15-4	15-7	15-11
	19.2	10-11	11-3	11-6	11-10	12-2	12-5	12-8	13-0	13-3	13-6	13-9	14-0	14-3	14-6
	24.0	9-9	10-0	10-4	10-7	10-10	11-1	11-4	11-7	11-10	12-1	12-4	12-6	12-9	13-0
2 × 8	12.0	18-2	18-9	19-3	19-9	20-3	20-8	21-2	21-7	22-1	22-6	22-11			
	16.0	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9	19-1	19-6	19-10	20-3	20-7	20-11
	19.2	14-5	14-10	15-2	15-7	16-0	16-4	16-9	17-1	17-5	17-9	18-1	18-5	18-9	19-1
	24.0	12-10	13-3	13-7	13-11	14-4	14-8	15-0	15-3	15-7	15-11	16-3	16-6	16-10	17-1
2 × 10	12.0	23-3	23-11	24-6	25-2	25-10									
	16.0	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11	24-5	24-10	25-4	25-10		
	19.2	18-4	18-11	19-5	19-11	20-5	20-10	21-4	21-10	22-3	22-8	23-1	23-7	24-0	24-5
	24.0	16-5	16-11	17-4	17-10	18-3	18-8	19-1	19-6	19-11	20-4	20-8	21-1	21-5	21-10
E	12.0	1.28	1.39	1.51	1.63	1.76	1.88	2.01	2.15	2.28	2.42	2.56			
	16.0	1.11	1.21	1.31	1.41	1.52	1.63	1.74	1.86	1.98	2.10	2.22	2.34	2.47	2.60
	19.2	1.01	1.10	1.20	1.29	1.39	1.49	1.59	1.70	1.80	1.91	2.03	2.14	2.25	2.37
	24.0	0.90	0.99	1.07	1.15	1.24	1.33	1.42	1.52	1.61	1.71	1.81	1.91	2.02	2.12

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-11—RAFTERS WITH *L*/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 20 psf (0.96 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 20 psf (0.96 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	3-2	3-11	4-6	5-1	5-6	6-0	6-5	6-9	7-2	7-6	7-10	8-2	8-5	8-9	9-0
	16.0	2-9	3-5	3-11	4-4	4-10	5-2	5-6	5-10	6-2	6-6	6-9	7-1	7-4	7-7	7-10
	19.2	2-6	3-1	3-7	4-0	4-4	4-9	5-1	5-4	5-8	5-11	6-2	6-5	6-8	6-11	7-2
	24.0	2-3	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5
2 × 6	12.0	5-0	6-2	7-1	7-11	8-8	9-5	10-0	10-8	11-3	11-9	12-4	12-10	13-3	13-9	14-2
	16.0	4-4	5-4	6-2	6-10	7-6	8-2	8-8	9-3	9-9	10-2	10-8	11-1	11-6	11-11	12-4
	19.2	4-0	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-11	9-4	9-9	10-1	10-6	10-10	11-3
	24.0	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0
2 × 8	12.0	6-7	8-1	9-4	10-6	11-6	12-5	13-3	14-0	14-10	15-6	16-3	16-10	17-6	18-1	18-9
	16.0	5-9	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-0	14-7	15-2	15-8	16-3
	19.2	5-3	6-5	7-5	8-3	9-1	9-9	10-6	11-1	11-8	12-3	12-10	13-4	13-10	14-4	14-10
	24.0	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
2 × 10	12.0	8-5	10-4	11-11	13-4	14-8	15-10	16-11	17-11	18-11	19-10	20-8	21-6	22-4	23-1	23-11
	16.0	7-4	8-11	10-4	11-7	12-8	13-8	14-8	15-6	16-4	17-2	17-11	18-8	19-4	20-0	20-8
	19.2	6-8	8-2	9-5	10-7	11-7	12-6	13-4	14-2	14-11	15-8	16-4	17-0	17-8	18-3	18-11
	24.0	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11
E	12.0	0.04	0.08	0.12	0.16	0.21	0.27	0.33	0.39	0.46	0.53	0.60	0.68	0.76	0.84	0.93
	16.0	0.04	0.07	0.10	0.14	0.18	0.23	0.28	0.34	0.40	0.46	0.52	0.59	0.66	0.73	0.80
	19.2	0.03	0.06	0.09	0.13	0.17	0.21	0.26	0.31	0.36	0.42	0.48	0.54	0.60	0.67	0.73
	24.0	0.03	0.05	0.08	0.11	0.15	0.19	0.23	0.28	0.32	0.37	0.43	0.48	0.54	0.60	0.66

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) × 0.00689 for N/mm^2													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	9-4	9-7	9-10	10-1	10-4	10-7	10-10	11-1	11-4	11-6	11-9	11-11	12-2	12-4
	16.0	8-1	8-4	8-6	8-9	9-0	9-2	9-5	9-7	9-9	10-0	10-2	10-4	10-6	10-9
	19.2	7-4	7-7	7-9	8-0	8-2	8-5	8-7	8-9	8-11	9-1	9-3	9-5	9-7	9-9
	24.0	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5	8-7	8-9
2 × 6	12.0	14-8	15-1	15-6	15-11	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-5
	16.0	12-8	13-1	13-5	13-9	14-1	14-5	14-9	15-1	15-4	15-8	16-0	16-3	16-7	16-10
	19.2	11-7	11-11	12-3	12-7	12-10	13-2	13-6	13-9	14-0	14-4	14-7	14-10	15-1	15-4
	24.0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3	13-6	13-9
2 × 8	12.0	19-4	19-10	20-5	20-11	21-5	21-11	22-5	22-11	23-5	23-10	24-4	24-9	25-2	25-8
	16.0	16-9	17-2	17-8	18-1	18-7	19-0	19-5	19-10	20-3	20-8	21-1	21-5	21-10	22-2
	19.2	15-3	15-8	16-2	16-7	16-11	17-4	17-9	18-1	18-6	18-10	19-3	19-7	19-11	20-3
	24.0	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6	17-10	18-1
2 × 10	12.0	24-7	25-4	26-0											
	16.0	21-4	21-11	22-6	23-1	23-8	24-3	24-10	25-4	25-10					
	19.2	19-6	20-0	20-7	21-1	21-8	22-2	22-8	23-1	23-7	24-1	24-6	25-0	25-5	25-10
	24.0	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4	22-9	23-1
E	12.0	1.02	1.11	1.20	1.30	1.40	1.50	1.60	1.71	1.82	1.93	2.04	2.15	2.27	2.39
	16.0	0.88	0.96	1.04	1.13	1.21	1.30	1.39	1.48	1.57	1.67	1.76	1.86	1.96	2.07
	19.2	0.80	0.88	0.95	1.03	1.10	1.18	1.27	1.35	1.44	1.52	1.61	1.70	1.79	1.89
	24.0	0.72	0.78	0.85	0.92	0.99	1.06	1.13	1.21	1.28	1.36	1.44	1.52	1.60	1.69

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-R-12—RAFTERS WITH *L*/180 DEFLECTION LIMITATION

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 30 psf (1.44 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 30 psf (1.44 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi)														
		× 0.00689 for N/mm^2														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	2-10	3-6	4-0	4-6	4-11	5-4	5-9	6-1	6-5	6-8	7-0	7-3	7-7	7-10	8-1
	16.0	2-6	3-0	3-6	3-11	4-3	4-8	4-11	5-3	5-6	5-10	6-1	6-4	6-7	6-9	7-0
	19.2	2-3	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5
	24.0	2-0	2-6	2-10	3-2	3-6	3-9	4-0	4-3	4-6	4-9	4-11	5-2	5-4	5-6	5-9
2 × 6	12.0	4-6	5-6	6-4	7-1	7-9	8-5	9-0	9-6	10-0	10-6	11-0	11-5	11-11	12-4	12-8
	16.0	3-11	4-9	5-6	6-2	6-9	7-3	7-9	8-3	8-8	9-1	9-6	9-11	10-3	10-8	11-0
	19.2	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0
	24.0	3-2	3-11	4-6	5-0	5-6	5-11	6-4	6-9	7-1	7-5	7-9	8-1	8-5	8-8	9-0
2 × 8	12.0	5-11	7-3	8-4	9-4	10-3	11-1	11-10	12-7	13-3	13-11	14-6	15-1	15-8	16-3	16-9
	16.0	5-2	6-3	7-3	8-1	8-11	9-7	10-3	10-10	11-6	12-0	12-7	13-1	13-7	14-0	14-6
	19.2	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
	24.0	4-2	5-2	5-11	6-7	7-3	7-10	8-4	8-11	9-4	9-10	10-3	10-8	11-1	11-6	11-10
2 × 10	12.0	7-7	9-3	10-8	11-11	13-1	14-2	15-1	16-0	16-11	17-9	18-6	19-3	20-0	20-8	21-4
	16.0	6-6	8-0	9-3	10-4	11-4	12-3	13-1	13-10	14-8	15-4	16-0	16-8	17-4	17-11	18-6
	19.2	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11
	24.0	5-4	6-6	7-7	8-5	9-3	10-0	10-8	11-4	11-11	12-6	13-1	13-7	14-2	14-8	15-1
E	12.0	0.04	0.08	0.12	0.17	0.23	0.29	0.35	0.42	0.49	0.57	0.65	0.73	0.82	0.91	1.00
	16.0	0.04	0.07	0.11	0.15	0.20	0.25	0.31	0.36	0.43	0.49	0.56	0.63	0.71	0.78	0.86
	19.2	0.03	0.06	0.10	0.14	0.18	0.23	0.28	0.33	0.39	0.45	0.51	0.58	0.65	0.72	0.79
	24.0	0.03	0.06	0.09	0.12	0.16	0.20	0.25	0.30	0.35	0.40	0.46	0.52	0.58	0.64	0.71

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi)													
		× 0.00689 for N/mm^2													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	8-4	8-7	8-10	9-0	9-3	9-6	9-8	9-11	10-1	10-4	10-6	10-8	10-11	11-1
	16.0	7-3	7-5	7-8	7-10	8-0	8-2	8-5	8-7	8-9	8-11	9-1	9-3	9-5	9-7
	19.2	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5	8-7	8-9
	24.0	5-11	6-1	6-3	6-5	6-7	6-8	6-10	7-0	7-2	7-3	7-5	7-7	7-8	7-10
2 × 6	12.0	13-1	13-6	13-10	14-2	14-7	14-11	15-3	15-7	15-11	16-2	16-6	16-10	17-1	17-5
	16.0	11-4	11-8	12-0	12-4	12-7	12-11	13-2	13-6	13-9	14-0	14-3	14-7	14-10	15-1
	19.2	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3	13-6	13-9
	24.0	9-3	9-6	9-9	10-0	10-3	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-4
2 × 8	12.0	17-3	17-9	18-3	18-9	19-2	19-8	20-1	20-6	20-11	21-4	21-9	22-2	22-6	22-11
	16.0	14-11	15-5	15-10	16-3	16-7	17-0	17-5	17-9	18-1	18-6	18-10	19-2	19-6	19-10
	19.2	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6	17-10	18-1
	24.0	12-2	12-7	12-11	13-3	13-7	13-11	14-2	14-6	14-10	15-1	15-5	15-8	15-11	16-3
2 × 10	12.0	22-0	22-8	23-3	23-11	24-6	25-1	25-7							
	16.0	19-1	19-7	20-2	20-8	21-2	21-8	22-2	22-8	23-1	23-7	24-0	24-6	24-11	25-4
	19.2	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4	22-9	23-1
	24.0	15-7	16-0	16-6	16-11	17-4	17-9	18-1	18-6	18-11	19-3	19-7	20-0	20-4	20-8
E	12.0	1.09	1.19	1.29	1.39	1.50	1.61	1.72	1.83	1.95	2.07	2.19	2.31	2.43	2.56
	16.0	0.95	1.03	1.12	1.21	1.30	1.39	1.49	1.59	1.69	1.79	1.89	2.00	2.11	2.22
	19.2	0.86	0.94	1.02	1.10	1.19	1.27	1.36	1.45	1.54	1.63	1.73	1.83	1.92	2.03
	24.0	0.77	0.84	0.91	0.99	1.06	1.14	1.22	1.30	1.38	1.46	1.55	1.63	1.72	1.81

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch (psi) (× 0.00689 for N/mm^2) is shown at the bottom of this table, is limited to 2.6 million psi (17 914 N/mm^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER
For Use in Tables 23-IV-J-1 through 23-IV-R-12 and Chapter 23, Division VII only.

These "F_b" values are for use where repetitive members are spaced not more than 24 inches (610 mm). For wider spacing, the "F_b" values shall be reduced 13 percent.

Values for surfaced dry or surfaced green lumber apply at 19 percent maximum moisture content in use.

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm^2				
ASPEN						
Select Structural	2 × 4	1,510	1,735	1,885	1,100,000	NELMA NSLB WWPA
No. 1		1,080	1,240	1,350	1,100,000	
No. 2		1,035	1,190	1,295	1,000,000	
No. 3		605	695	755	900,000	
Stud		600	690	750	900,000	
Construction		805	925	1,005	900,000	
Standard		430	495	540	900,000	
Utility		200	230	250	800,000	
Select Structural	2 × 6	1,310	1,505	1,635	1,100,000	
No. 1		935	1,075	1,170	1,100,000	
No. 2		895	1,030	1,120	1,000,000	
No. 3		525	600	655	900,000	
Stud		545	630	685	900,000	
Select Structural	2 × 8	1,210	1,390	1,510	1,100,000	
No. 1		865	990	1,080	1,100,000	
No. 2		830	950	1,035	1,000,000	
No. 3		485	555	605	900,000	
Select Structural	2 × 10	1,105	1,275	1,385	1,100,000	
No. 1		790	910	990	1,100,000	
No. 2		760	875	950	1,000,000	
No. 3		445	510	555	900,000	
Select Structural	2 × 12	1,005	1,155	1,260	1,100,000	
No. 1		720	825	900	1,100,000	
No. 2		690	795	865	1,000,000	
No. 3		405	465	505	900,000	
BEECH-BIRCH-HICKORY						
Select Structural	2 × 4	2,500	2,875	3,125	1,700,000	NELMA
No. 1		1,810	2,085	2,265	1,600,000	
No. 2		1,725	1,985	2,155	1,500,000	
No. 3		990	1,140	1,240	1,300,000	
Stud		980	1,125	1,225	1,300,000	
Construction		1,325	1,520	1,655	1,400,000	
Standard		750	860	935	1,300,000	
Utility		345	395	430	1,200,000	
Select Structural	2 × 6	2,170	2,495	2,710	1,700,000	
No. 1		1,570	1,805	1,960	1,600,000	
No. 2		1,495	1,720	1,870	1,500,000	
No. 3		860	990	1,075	1,300,000	
Stud		890	1,025	1,115	1,300,000	
Select Structural	2 × 8	2,000	2,300	2,500	1,700,000	
No. 1		1,450	1,665	1,810	1,600,000	
No. 2		1,380	1,585	1,725	1,500,000	
No. 3		795	915	990	1,300,000	
Select Structural	2 × 10	1,835	2,110	2,295	1,700,000	
No. 1		1,330	1,525	1,660	1,600,000	
No. 2		1,265	1,455	1,580	1,500,000	
No. 3		725	835	910	1,300,000	
Select Structural	2 × 12	1,670	1,920	2,085	1,700,000	
No. 1		1,210	1,390	1,510	1,600,000	
No. 2		1,150	1,325	1,440	1,500,000	
No. 3		660	760	825	1,300,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi — Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm^2				
COTTONWOOD						
Select Structural	2 × 4	1,510	1,735	1,885	1,200,000	NSLB
No. 1		1,080	1,240	1,350	1,200,000	
No. 2		1,080	1,240	1,350	1,100,000	
No. 3		605	695	755	1,000,000	
Stud		600	690	750	1,000,000	
Construction		805	925	1,005	1,000,000	
Standard		460	530	575	900,000	
Utility		200	230	250	900,000	
Select Structural	2 × 6	1,310	1,505	1,635	1,200,000	
No. 1		935	1,075	1,170	1,200,000	
No. 2		935	1,075	1,170	1,100,000	
No. 3		525	600	655	1,000,000	
Stud		545	630	685	1,000,000	
Select Structural	2 × 8	1,210	1,390	1,510	1,200,000	
No. 1		865	990	1,080	1,200,000	
No. 2		865	990	1,080	1,100,000	
No. 3		485	555	605	1,000,000	
Select Structural	2 × 10	1,105	1,275	1,385	1,200,000	
No. 1		790	910	990	1,200,000	
No. 2		790	910	990	1,100,000	
No. 3		445	510	555	1,000,000	
Select Structural	2 × 12	1,005	1,155	1,260	1,200,000	
No. 1		720	825	900	1,200,000	
No. 2		720	825	900	1,100,000	
No. 3		405	465	505	1,000,000	
DOUGLAS FIR-LARCH						
Select Structural	2 × 4	2,500	2,875	3,125	1,900,000	WCLIB WWPA
No. 1 and better		1,985	2,280	2,480	1,800,000	
No. 1		1,725	1,985	2,155	1,700,000	
No. 2		1,510	1,735	1,885	1,600,000	
No. 3		865	990	1,080	1,400,000	
Stud		855	980	1,065	1,400,000	
Construction		1,150	1,325	1,440	1,500,000	
Standard		635	725	790	1,400,000	
Utility		315	365	395	1,300,000	
Select Structural	2 × 6	2,170	2,495	2,710	1,900,000	
No. 1 and better		1,720	1,975	2,150	1,800,000	
No. 1		1,495	1,720	1,870	1,700,000	
No. 2		1,310	1,505	1,635	1,600,000	
No. 3		750	860	935	1,400,000	
Stud		775	895	970	1,400,000	
Select Structural	2 × 8	2,000	2,300	2,500	1,900,000	
No. 1 and better		1,585	1,825	1,985	1,800,000	
No. 1		1,380	1,585	1,725	1,700,000	
No. 2		1,210	1,390	1,510	1,600,000	
No. 3		690	795	865	1,400,000	
Select Structural	2 × 10	1,835	2,110	2,295	1,900,000	
No. 1 and better		1,455	1,675	1,820	1,800,000	
No. 1		1,265	1,455	1,580	1,700,000	
No. 2		1,105	1,275	1,385	1,600,000	
No. 3		635	725	790	1,400,000	
Select Structural	2 × 12	1,670	1,920	2,085	1,900,000	
No. 1 and better		1,325	1,520	1,655	1,800,000	
No. 1		1,150	1,325	1,440	1,700,000	
No. 2		1,005	1,155	1,260	1,600,000	
No. 3		575	660	720	1,400,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm²				
DOUGLAS FIR-LARCH (North)						
Select Structural	2 × 4	2,245	2,580	2,805	1,900,000	NLGA
No. 1/No. 2		1,425	1,635	1,780	1,600,000	
No. 3		820	940	1,025	1,400,000	
Stud		820	945	1,030	1,400,000	
Construction		1,095	1,255	1,365	1,500,000	
Standard		605	695	755	1,400,000	
Utility		290	330	360	1,300,000	
Select Structural	2 × 6	1,945	2,235	2,430	1,900,000	
No. 1/No. 2		1,235	1,420	1,540	1,600,000	
No. 3		710	815	890	1,400,000	
Stud		750	860	935	1,400,000	
Select Structural	2 × 8	1,795	2,065	2,245	1,900,000	
No. 1/No. 2		1,140	1,310	1,425	1,600,000	
No. 3		655	755	820	1,400,000	
Select Structural	2 × 10	1,645	1,890	2,055	1,900,000	
No. 1/No. 2		1,045	1,200	1,305	1,600,000	
No. 3		600	690	750	1,400,000	
Select Structural	2 × 12	1,495	1,720	1,870	1,900,000	
No. 1/No. 2		950	1,090	1,185	1,600,000	
No. 3		545	630	685	1,400,000	
DOUGLAS FIR (South)						
Select Structural	2 × 4	2,245	2,580	2,805	1,400,000	WWPA
No. 1		1,555	1,785	1,940	1,300,000	
No. 2		1,425	1,635	1,780	1,200,000	
No. 3		820	940	1,025	1,100,000	
Stud		820	945	1,030	1,100,000	
Construction		1,065	1,225	1,330	1,200,000	
Standard		605	695	755	1,100,000	
Utility		290	330	360	1,000,000	
Select Structural	2 × 6	1,945	2,235	2,430	1,400,000	
No. 1		1,345	1,545	1,680	1,300,000	
No. 2		1,235	1,420	1,540	1,200,000	
No. 3		710	815	890	1,100,000	
Stud		750	860	935	1,100,000	
Select Structural	2 × 8	1,795	2,065	2,245	1,400,000	
No. 1		1,240	1,430	1,555	1,300,000	
No. 2		1,140	1,310	1,425	1,200,000	
No. 3		655	755	820	1,100,000	
Select Structural	2 × 10	1,645	1,890	2,055	1,400,000	
No. 1		1,140	1,310	1,425	1,300,000	
No. 2		1,045	1,200	1,305	1,200,000	
No. 3		600	690	750	1,100,000	
Select Structural	2 × 12	1,495	1,720	1,870	1,400,000	
No. 1		1,035	1,190	1,295	1,300,000	
No. 2		950	1,090	1,185	1,200,000	
No. 3		545	630	685	1,100,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
EASTERN HEMLOCK—TAMARACK						
Select Structural	2 × 4	2,155	2,480	2,695	1,200,000	NELMA NSLB
No. 1		1,335	1,535	1,670	1,100,000	
No. 2		990	1,140	1,240	1,100,000	
No. 3		605	695	755	900,000	
Stud		570	655	710	900,000	
Construction		775	895	970	1,000,000	
Standard		430	495	540	900,000	
Utility		200	230	250	800,000	
Select Structural	2 × 6	1,870	2,150	2,335	1,200,000	
No. 1		1,160	1,330	1,450	1,100,000	
No. 2		860	990	1,075	1,100,000	
No. 3		525	600	655	900,000	
Stud		520	595	645	900,000	
Select Structural	2 × 8	1,725	1,985	2,155	1,200,000	
No. 1		1,070	1,230	1,335	1,100,000	
No. 2		795	915	990	1,100,000	
No. 3		485	555	605	900,000	
Select Structural	2 × 10	1,580	1,820	1,975	1,200,000	
No. 1		980	1,125	1,225	1,100,000	
No. 2		725	835	910	1,100,000	
No. 3		445	510	555	900,000	
Select Structural	2 × 12	1,440	1,655	1,795	1,200,000	
No. 1		890	1,025	1,115	1,100,000	
No. 2		660	760	825	1,100,000	
No. 3		405	465	505	900,000	
EASTERN SOFTWOODS						
Select Structural	2 × 4	2,155	2,480	2,695	1,200,000	NELMA NSLB
No. 1		1,335	1,535	1,670	1,100,000	
No. 2		990	1,140	1,240	1,100,000	
No. 3		605	695	755	900,000	
Stud		570	655	710	900,000	
Construction		775	895	970	1,000,000	
Standard		430	495	540	900,000	
Utility		200	230	250	800,000	
Select Structural	2 × 6	1,870	2,150	2,335	1,200,000	
No. 1		1,160	1,330	1,450	1,100,000	
No. 2		860	990	1,075	1,100,000	
No. 3		525	600	655	900,000	
Stud		520	595	645	900,000	
Select Structural	2 × 8	1,725	1,985	2,155	1,200,000	
No. 1		1,070	1,230	1,335	1,100,000	
No. 2		795	915	990	1,100,000	
No. 3		485	555	605	900,000	
Select Structural	2 × 10	1,580	1,820	1,975	1,200,000	
No. 1		980	1,125	1,225	1,100,000	
No. 2		725	835	910	1,100,000	
No. 3		445	510	555	900,000	
Select Structural	2 × 12	1,440	1,655	1,795	1,200,000	
No. 1		890	1,025	1,115	1,100,000	
No. 2		660	760	825	1,100,000	
No. 3		405	465	505	900,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi × 0.00689 for N/mm² Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
EASTERN WHITE PINE						
Select Structural	2 × 4	2,155	2,480	2,695	1,200,000	NELMA NSLB
No. 1	2 × 4	1,335	1,535	1,670	1,100,000	NELMA NSLB
No. 2	2 × 4	990	1,140	1,240	1,100,000	NELMA NSLB
No. 3	2 × 4	605	695	755	900,000	NELMA NSLB
Stud	2 × 4	570	655	710	900,000	NELMA NSLB
Construction	2 × 4	775	895	970	1,000,000	NELMA NSLB
Standard	2 × 4	430	495	540	900,000	NELMA NSLB
Utility	2 × 4	200	230	250	800,000	NELMA NSLB
Select Structural	2 × 6	1,870	2,150	2,335	1,200,000	NELMA NSLB
No. 1	2 × 6	1,160	1,330	1,450	1,100,000	NELMA NSLB
No. 2	2 × 6	860	990	1,075	1,100,000	NELMA NSLB
No. 3	2 × 6	525	600	655	900,000	NELMA NSLB
Stud	2 × 6	520	595	645	900,000	NELMA NSLB
Select Structural	2 × 8	1,725	1,985	2,155	1,200,000	NELMA NSLB
No. 1	2 × 8	1,070	1,230	1,335	1,100,000	NELMA NSLB
No. 2	2 × 8	795	915	990	1,100,000	NELMA NSLB
No. 3	2 × 8	485	555	605	900,000	NELMA NSLB
Select Structural	2 × 10	1,580	1,820	1,975	1,200,000	NELMA NSLB
No. 1	2 × 10	980	1,125	1,225	1,100,000	NELMA NSLB
No. 2	2 × 10	725	835	910	1,100,000	NELMA NSLB
No. 3	2 × 10	445	510	555	900,000	NELMA NSLB
Select Structural	2 × 12	1,440	1,655	1,795	1,200,000	NELMA NSLB
No. 1	2 × 12	890	1,025	1,115	1,100,000	NELMA NSLB
No. 2	2 × 12	660	760	825	1,100,000	NELMA NSLB
No. 3	2 × 12	405	465	505	900,000	NELMA NSLB
HEM-FIR						
Select Structural	2 × 4	2,415	2,775	3,020	1,600,000	WCLIB WWPA
No. 1 and better	2 × 4	1,810	2,085	2,265	1,500,000	WCLIB WWPA
No. 1	2 × 4	1,640	1,885	2,050	1,500,000	WCLIB WWPA
No. 2	2 × 4	1,465	1,685	1,835	1,300,000	WCLIB WWPA
No. 3	2 × 4	865	990	1,080	1,200,000	WCLIB WWPA
Stud	2 × 4	855	980	1,065	1,200,000	WCLIB WWPA
Construction	2 × 4	1,120	1,290	1,400	1,300,000	WCLIB WWPA
Standard	2 × 4	635	725	790	1,200,000	WCLIB WWPA
Utility	2 × 4	290	330	360	1,100,000	WCLIB WWPA
Select Structural	2 × 6	2,095	2,405	2,615	1,600,000	WCLIB WWPA
No. 1 and better	2 × 6	1,570	1,805	1,960	1,500,000	WCLIB WWPA
No. 1	2 × 6	1,420	1,635	1,775	1,500,000	WCLIB WWPA
No. 2	2 × 6	1,270	1,460	1,590	1,300,000	WCLIB WWPA
No. 3	2 × 6	750	860	935	1,200,000	WCLIB WWPA
Stud	2 × 6	775	895	970	1,200,000	WCLIB WWPA
Select Structural	2 × 8	1,930	2,220	2,415	1,600,000	WCLIB WWPA
No. 1 and better	2 × 8	1,450	1,665	1,810	1,500,000	WCLIB WWPA
No. 1	2 × 8	1,310	1,510	1,640	1,500,000	WCLIB WWPA
No. 2	2 × 8	1,175	1,350	1,465	1,300,000	WCLIB WWPA
No. 3	2 × 8	690	795	865	1,200,000	WCLIB WWPA
Select Structural	2 × 10	1,770	2,035	2,215	1,600,000	WCLIB WWPA
No. 1 and better	2 × 10	1,330	1,525	1,660	1,500,000	WCLIB WWPA
No. 1	2 × 10	1,200	1,380	1,500	1,500,000	WCLIB WWPA
No. 2	2 × 10	1,075	1,235	1,345	1,300,000	WCLIB WWPA
No. 3	2 × 10	635	725	790	1,200,000	WCLIB WWPA
Select Structural	2 × 12	1,610	1,850	2,015	1,600,000	WCLIB WWPA
No. 1 and better	2 × 12	1,210	1,390	1,510	1,500,000	WCLIB WWPA
No. 1	2 × 12	1,095	1,255	1,365	1,500,000	WCLIB WWPA
No. 2	2 × 12	980	1,125	1,220	1,300,000	WCLIB WWPA
No. 3	2 × 12	575	660	720	1,200,000	WCLIB WWPA

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi — Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm^2				
HEM-FIR (North)						
Select Structural	2 × 4	2,245	2,580	2,805	1,700,000	NLGA
No. 1/No. 2	2 × 4	1,725	1,985	2,155	1,600,000	NLGA
No. 3	2 × 4	990	1,140	1,240	1,400,000	NLGA
Stud	2 × 4	980	1,125	1,225	1,400,000	NLGA
Construction	2 × 4	1,325	1,520	1,655	1,500,000	NLGA
Standard	2 × 4	720	825	900	1,400,000	NLGA
Utility	2 × 4	345	395	430	1,300,000	NLGA
Select Structural	2 × 6	1,945	2,235	2,430	1,700,000	NLGA
No. 1/No. 2	2 × 6	1,495	1,720	1,870	1,600,000	NLGA
No. 3	2 × 6	860	990	1,075	1,400,000	NLGA
Stud	2 × 6	890	1,025	1,115	1,400,000	NLGA
Select Structural	2 × 8	1,795	2,065	2,245	1,700,000	NLGA
No. 1/No. 2	2 × 8	1,380	1,585	1,725	1,600,000	NLGA
No. 3	2 × 8	795	915	990	1,400,000	NLGA
Select Structural	2 × 10	1,645	1,890	2,055	1,700,000	NLGA
No. 1/No. 2	2 × 10	1,265	1,455	1,580	1,600,000	NLGA
No. 3	2 × 10	725	835	910	1,400,000	NLGA
Select Structural	2 × 12	1,495	1,720	1,870	1,700,000	NLGA
No. 1/No. 2	2 × 12	1,150	1,325	1,440	1,600,000	NLGA
No. 3	2 × 12	660	760	825	1,400,000	NLGA
MIXED MAPLE						
Select Structural	2 × 4	1,725	1,985	2,155	1,300,000	NELMA
No. 1	2 × 4	1,250	1,440	1,565	1,200,000	NELMA
No. 2	2 × 4	1,210	1,390	1,510	1,100,000	NELMA
No. 3	2 × 4	690	795	865	1,000,000	NELMA
Stud	2 × 4	695	800	870	1,000,000	NELMA
Construction	2 × 4	920	1,060	1,150	1,100,000	NELMA
Standard	2 × 4	520	595	645	1,000,000	NELMA
Utility	2 × 4	260	300	325	900,000	NELMA
Select Structural	2 × 6	1,495	1,720	1,870	1,300,000	NELMA
No. 1	2 × 6	1,085	1,245	1,355	1,200,000	NELMA
No. 2	2 × 6	1,045	1,205	1,310	1,100,000	NELMA
No. 3	2 × 6	600	690	750	1,000,000	NELMA
Stud	2 × 6	635	725	790	1,000,000	NELMA
Select Structural	2 × 8	1,380	1,585	1,725	1,300,000	NELMA
No. 1	2 × 8	1,000	1,150	1,250	1,200,000	NELMA
No. 2	2 × 8	965	1,110	1,210	1,100,000	NELMA
No. 3	2 × 8	550	635	690	1,000,000	NELMA
Select Structural	2 × 10	1,265	1,455	1,580	1,300,000	NELMA
No. 1	2 × 10	915	1,055	1,145	1,200,000	NELMA
No. 2	2 × 10	885	1,020	1,105	1,100,000	NELMA
No. 3	2 × 10	505	580	635	1,000,000	NELMA
Select Structural	2 × 12	1,150	1,325	1,440	1,300,000	NELMA
No. 1	2 × 12	835	960	1,040	1,200,000	NELMA
No. 2	2 × 12	805	925	1,005	1,100,000	NELMA
No. 3	2 × 12	460	530	575	1,000,000	NELMA
MIXED OAK						
Select Structural	2 × 4	1,985	2,280	2,480	1,100,000	NELMA
No. 1	2 × 4	1,425	1,635	1,780	1,000,000	NELMA
No. 2	2 × 4	1,380	1,585	1,725	900,000	NELMA
No. 3	2 × 4	820	940	1,025	800,000	NELMA
Stud	2 × 4	790	910	990	800,000	NELMA
Construction	2 × 4	1,065	1,225	1,330	900,000	NELMA
Standard	2 × 4	605	695	755	800,000	NELMA
Utility	2 × 4	290	330	360	800,000	NELMA

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi — Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm^2				
MIXED OAK—(continued)						
Select Structural	2 × 6	1,720	1,975	2,150	1,100,000	NELMA
No. 1		1,235	1,420	1,540	1,000,000	
No. 2		1,195	1,375	1,495	900,000	
No. 3		710	815	890	800,000	
Stud		720	825	900	800,000	
Select Structural	2 × 8	1,585	1,825	1,985	1,100,000	
No. 1		1,140	1,310	1,425	1,000,000	
No. 2		1,105	1,270	1,380	900,000	
No. 3		655	755	820	800,000	
Select Structural	2 × 10	1,455	1,675	1,820	1,100,000	
No. 1		1,045	1,200	1,305	1,000,000	
No. 2		1,010	1,165	1,265	900,000	
No. 3		600	690	750	800,000	
Select Structural	2 × 12	1,325	1,520	1,655	1,100,000	
No. 1		950	1,090	1,185	1,000,000	
No. 2		920	1,060	1,150	900,000	
No. 3		545	630	685	800,000	
MIXED SOUTHERN PINE						
Select Structural	2 × 4	2,360	2,710	2,950	1,600,000	SPIB
No. 1		1,670	1,920	2,080	1,500,000	
No. 2		1,500	1,720	1,870	1,400,000	
No. 3		865	990	1,080	1,200,000	
Stud		890	1,020	1,110	1,200,000	
Construction		1,150	1,320	1,440	1,300,000	
Standard		635	725	790	1,200,000	
Utility		315	365	395	1,100,000	
Select Structural	2 × 6	2,130	2,450	2,660	1,600,000	
No. 1		1,490	1,720	1,870	1,500,000	
No. 2		1,320	1,520	1,650	1,400,000	
No. 3		775	895	970	1,200,000	
Stud		775	895	970	1,200,000	
Select Structural	2 × 8	2,010	2,310	2,520	1,600,000	
No. 1		1,380	1,590	1,720	1,500,000	
No. 2		1,210	1,390	1,510	1,400,000	
No. 3		720	825	900	1,200,000	
Select Structural	2 × 10	1,730	1,980	2,160	1,600,000	
No. 1		1,210	1,390	1,510	1,500,000	
No. 2		1,060	1,220	1,330	1,400,000	
No. 3		605	695	755	1,200,000	
Select Structural	2 × 12	1,610	1,850	2,010	1,600,000	
No. 1		1,120	1,290	1,400	1,500,000	
No. 2		1,010	1,160	1,260	1,400,000	
No. 3		575	660	720	1,200,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi: Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
NORTHERN RED OAK						
Select Structural	2 × 4	2,415	2,775	3,020	1,400,000	NELMA
No. 1	2 × 4	1,725	1,985	2,155	1,400,000	NELMA
No. 2	2 × 4	1,680	1,935	2,100	1,300,000	NELMA
No. 3	2 × 4	950	1,090	1,185	1,200,000	NELMA
Stud	2 × 4	950	1,090	1,185	1,200,000	NELMA
Construction	2 × 4	1,265	1,455	1,580	1,200,000	NELMA
Standard	2 × 4	720	825	900	1,100,000	NELMA
Utility	2 × 4	345	395	430	1,000,000	NELMA
Select Structural	2 × 6	2,095	2,405	2,615	1,400,000	NELMA
No. 1	2 × 6	1,495	1,720	1,870	1,400,000	NELMA
No. 2	2 × 6	1,460	1,675	1,820	1,300,000	NELMA
No. 3	2 × 6	820	945	1,030	1,200,000	NELMA
Stud	2 × 6	865	990	1,080	1,200,000	NELMA
Select Structural	2 × 8	1,930	2,220	2,415	1,400,000	NELMA
No. 1	2 × 8	1,380	1,585	1,725	1,400,000	NELMA
No. 2	2 × 8	1,345	1,545	1,680	1,300,000	NELMA
No. 3	2 × 8	760	875	950	1,200,000	NELMA
Select Structural	2 × 10	1,770	2,035	2,215	1,400,000	NELMA
No. 1	2 × 10	1,265	1,455	1,580	1,400,000	NELMA
No. 2	2 × 10	1,235	1,420	1,540	1,300,000	NELMA
No. 3	2 × 10	695	800	870	1,200,000	NELMA
Select Structural	2 × 12	1,610	1,850	2,015	1,400,000	NELMA
No. 1	2 × 12	1,150	1,325	1,440	1,400,000	NELMA
No. 2	2 × 12	1,120	1,290	1,400	1,300,000	NELMA
No. 3	2 × 12	635	725	790	1,200,000	NELMA
NORTHERN SPECIES						
Select Structural	2 × 4	1,640	1,885	2,050	1,100,000	NLGA
No. 1/No. 2	2 × 4	990	1,140	1,240	1,100,000	NLGA
No. 3	2 × 4	605	695	755	1,000,000	NLGA
Stud	2 × 4	570	655	710	1,000,000	NLGA
Construction	2 × 4	775	895	970	1,000,000	NLGA
Standard	2 × 4	430	495	540	900,000	NLGA
Utility	2 × 4	200	230	250	900,000	NLGA
Select Structural	2 × 6	1,420	1,635	1,775	1,100,000	NLGA
No. 1/No. 2	2 × 6	860	990	1,075	1,100,000	NLGA
No. 3	2 × 6	525	600	655	1,000,000	NLGA
Stud	2 × 6	520	595	645	1,000,000	NLGA
Select Structural	2 × 8	1,310	1,510	1,640	1,100,000	NLGA
No. 1/No. 2	2 × 8	795	915	990	1,100,000	NLGA
No. 3	2 × 8	485	555	605	1,000,000	NLGA
Select Structural	2 × 10	1,200	1,380	1,500	1,100,000	NLGA
No. 1/No. 2	2 × 10	725	835	910	1,100,000	NLGA
No. 3	2 × 10	445	510	555	1,000,000	NLGA
Select Structural	2 × 12	1,095	1,255	1,365	1,100,000	NLGA
No. 1/No. 2	2 × 12	660	760	825	1,100,000	NLGA
No. 3	2 × 12	405	465	505	1,000,000	NLGA

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi — Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm^2				
NORTHERN WHITE CEDAR						
Select Structural	2 × 4	1,335	1,535	1,670	800,000	NELMA
No. 1		990	1,140	1,240	700,000	
No. 2		950	1,090	1,185	700,000	
No. 3		560	645	700	600,000	
Stud		540	620	670	600,000	
Construction		720	825	900	700,000	
Standard		405	465	505	600,000	
Utility		200	230	250	600,000	
Select Structural	2 × 6	1,160	1,330	1,450	800,000	
No. 1		860	990	1,075	700,000	
No. 2		820	945	1,030	700,000	
No. 3		485	560	605	600,000	
Stud		490	560	610	600,000	
Select Structural	2 × 8	1,070	1,230	1,335	800,000	
No. 1		795	915	990	700,000	
No. 2		760	875	950	700,000	
No. 3		450	515	560	600,000	
Select Structural	2 × 10	980	1,125	1,225	800,000	
No. 1		725	835	910	700,000	
No. 2		695	800	870	700,000	
No. 3		410	475	515	600,000	
Select Structural	2 × 12	890	1,025	1,115	800,000	
No. 1		660	760	825	700,000	
No. 2		635	725	790	700,000	
No. 3		375	430	465	600,000	
RED MAPLE						
Select Structural	2 × 4	2,245	2,580	2,805	1,700,000	NELMA
No. 1		1,595	1,835	1,995	1,600,000	
No. 2		1,555	1,785	1,940	1,500,000	
No. 3		905	1,040	1,130	1,300,000	
Stud		885	1,020	1,105	1,300,000	
Construction		1,210	1,390	1,510	1,400,000	
Standard		660	760	825	1,300,000	
Utility		315	365	395	1,200,000	
Select Structural	2 × 6	1,945	2,235	2,430	1,700,000	
No. 1		1,385	1,590	1,730	1,600,000	
No. 2		1,345	1,545	1,680	1,500,000	
No. 3		785	905	980	1,300,000	
Stud		805	925	1,005	1,300,000	
Select Structural	2 × 8	1,795	2,065	2,245	1,700,000	
No. 1		1,275	1,470	1,595	1,600,000	
No. 2		1,240	1,430	1,555	1,500,000	
No. 3		725	835	905	1,300,000	
Select Structural	2 × 10	1,645	1,890	2,055	1,700,000	
No. 1		1,170	1,345	1,465	1,600,000	
No. 2		1,140	1,310	1,425	1,500,000	
No. 3		665	765	830	1,300,000	
Select Structural	2 × 12	1,495	1,720	1,870	1,700,000	
No. 1		1,065	1,225	1,330	1,600,000	
No. 2		1,035	1,190	1,295	1,500,000	
No. 3		605	695	755	1,300,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi — Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
RED OAK						
Select Structural	2 × 4	1,985	2,280	2,480	1,400,000	NELMA
No. 1	2 × 4	1,425	1,635	1,780	1,300,000	NELMA
No. 2	2 × 4	1,380	1,585	1,725	1,200,000	NELMA
No. 3	2 × 4	820	940	1,025	1,100,000	NELMA
Stud	2 × 4	790	910	990	1,100,006	NELMA
Construction	2 × 4	1,065	1,225	1,330	1,200,000	NELMA
Standard	2 × 4	605	695	755	1,100,000	NELMA
Utility	2 × 4	290	330	360	1,000,000	NELMA
Select Structural	2 × 6	1,720	1,975	2,150	1,400,000	NELMA
No. 1	2 × 6	1,235	1,420	1,540	1,300,000	NELMA
No. 2	2 × 6	1,195	1,375	1,495	1,200,000	NELMA
No. 3	2 × 6	710	815	890	1,100,000	NELMA
Stud	2 × 6	720	825	900	1,100,000	NELMA
Select Structural	2 × 8	1,585	1,825	1,985	1,400,000	NELMA
No. 1	2 × 8	1,140	1,310	1,425	1,300,000	NELMA
No. 2	2 × 8	1,105	1,270	1,380	1,200,000	NELMA
No. 3	2 × 8	655	755	820	1,100,000	NELMA
Select Structural	2 × 10	1,455	1,675	1,820	1,400,000	NELMA
No. 1	2 × 10	1,045	1,200	1,305	1,300,000	NELMA
No. 2	2 × 10	1,010	1,165	1,265	1,200,000	NELMA
No. 3	2 × 10	600	690	750	1,100,000	NELMA
Select Structural	2 × 12	1,325	1,520	1,655	1,400,000	NELMA
No. 1	2 × 12	950	1,090	1,185	1,300,000	NELMA
No. 2	2 × 12	920	1,060	1,150	1,200,000	NELMA
No. 3	2 × 12	545	630	685	1,100,000	NELMA
REDWOOD						
Clear Structural	2 × 4	3,020	3,470	3,775	1,400,000	RIS
Select Structural	2 × 4	2,330	2,680	2,910	1,400,000	RIS
Select Structural, open grain	2 × 4	1,900	2,180	2,370	1,100,000	RIS
No. 1	2 × 4	1,680	1,935	2,100	1,300,000	RIS
No. 1, open grain	2 × 4	1,335	1,535	1,670	1,100,000	RIS
No. 2	2 × 4	1,595	1,835	1,995	1,200,000	RIS
No. 2, open grain	2 × 4	1,250	1,440	1,565	1,000,000	RIS
No. 3	2 × 4	905	1,040	1,130	1,100,000	RIS
No. 3, open grain	2 × 4	735	845	915	900,000	RIS
Stud	2 × 4	725	835	910	900,000	RIS
Construction	2 × 4	950	1,090	1,185	900,000	RIS
Standard	2 × 4	520	595	645	900,000	RIS
Utility	2 × 4	260	300	325	800,000	RIS
Clear Structural	2 × 6	2,615	3,010	3,270	1,400,000	RIS
Select Structural	2 × 6	2,020	2,320	2,525	1,400,000	RIS
Select Structural, open grain	2 × 6	1,645	1,890	2,055	1,100,000	RIS
No. 1	2 × 6	1,460	1,675	1,820	1,300,000	RIS
No. 1, open grain	2 × 6	1,160	1,330	1,450	1,100,000	RIS
No. 2	2 × 6	1,385	1,590	1,730	1,200,000	RIS
No. 2, open grain	2 × 6	1,085	1,245	1,355	1,000,000	RIS
No. 3	2 × 6	785	905	980	1,100,000	RIS
No. 3, open grain	2 × 6	635	730	795	900,000	RIS
Stud	2 × 6	660	760	825	900,000	RIS

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm^2				
REDWOOD—(continued)						
Clear Structural	2 × 8	2,415	2,775	3,020	1,400,000	RIS
Select Structural		1,865	2,140	2,330	1,400,000	
Select Structural, open grain		1,520	1,745	1,900	1,100,000	
No. 1		1,345	1,545	1,680	1,300,000	
No. 1, open grain		1,070	1,230	1,335	1,100,000	
No. 2		1,275	1,470	1,595	1,200,000	
No. 2, open grain		1,000	1,150	1,250	1,000,000	
No. 3		725	835	905	1,100,000	
No. 3, open grain		585	675	735	900,000	
Clear Structural	2 × 10	2,215	2,545	2,765	1,400,000	
Select Structural		1,710	1,965	2,135	1,400,000	
Select Structural, open grain		1,390	1,600	1,740	1,100,000	
No. 1		1,235	1,420	1,540	1,300,000	
No. 1, open grain		980	1,125	1,225	1,100,000	
No. 2		1,170	1,345	1,465	1,200,000	
No. 2, open grain		915	1,055	1,145	1,000,000	
No. 3		665	765	830	1,100,000	
No. 3, open grain		540	620	670	900,000	
Clear Structural	2 × 12	2,015	2,315	2,515	1,400,000	
Select Structural		1,555	1,785	1,940	1,400,000	
Select Structural, open grain		1,265	1,455	1,580	1,100,000	
No. 1		1,120	1,290	1,400	1,300,000	
No. 1, open grain		890	1,025	1,115	1,100,000	
No. 2		1,065	1,225	1,330	1,200,000	
No. 2, open grain		835	960	1,040	1,000,000	
No. 3		605	695	755	1,100,000	
No. 3, open grain		490	560	610	900,000	
SOUTHERN PINE						
Dense Select Structural	2 × 4	3,510	4,030	4,380	1,900,000	SPIB
Select Structural		3,280	3,770	4,100	1,800,000	
Non-Dense Select Structural		3,050	3,500	3,810	1,700,000	
No. 1 Dense		2,300	2,650	2,880	1,800,000	
No. 1		2,130	2,450	2,660	1,700,000	
No. 1 Non-Dense		1,950	2,250	2,440	1,600,000	
No. 2 Dense		1,960	2,250	2,440	1,700,000	
No. 2		1,720	1,980	2,160	1,600,000	
No. 2 Non-Dense		1,550	1,790	1,940	1,400,000	
No. 3		980	1,120	1,220	1,400,000	
Stud		1,010	1,160	1,260	1,400,000	
Construction		1,270	1,450	1,580	1,500,000	
Standard		720	825	900	1,300,000	
Utility		345	395	430	1,300,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm²				
SOUTHERN PINE—(continued)						
Dense Select Structural	2 × 6	3,100	3,570	3,880	1,900,000	SPIB
Select Structural	2 × 6	2,930	3,370	3,670	1,800,000	SPIB
Non-Dense Select Structural	2 × 6	2,700	3,110	3,380	1,700,000	SPIB
No. 1 Dense	2 × 6	2,010	2,310	2,520	1,800,000	SPIB
No. 1	2 × 6	1,900	2,180	2,370	1,700,000	SPIB
No. 1 Non-Dense	2 × 6	1,720	1,980	2,160	1,600,000	SPIB
No. 2 Dense	2 × 6	1,670	1,920	2,080	1,700,000	SPIB
No. 2	2 × 6	1,440	1,650	1,800	1,600,000	SPIB
No. 2 Non-Dense	2 × 6	1,320	1,520	1,650	1,400,000	SPIB
No. 3	2 × 6	865	990	1,080	1,400,000	SPIB
Stud	2 × 6	890	1,020	1,110	1,400,000	SPIB
Dense Select Structural	2 × 8	2,820	3,240	3,520	1,900,000	SPIB
Select Structural	2 × 8	2,650	3,040	3,310	1,800,000	SPIB
Non-Dense Select Structural	2 × 8	2,420	2,780	3,020	1,700,000	SPIB
No. 1 Dense	2 × 8	1,900	2,180	2,370	1,800,000	SPIB
No. 1	2 × 8	1,730	1,980	2,160	1,700,000	SPIB
No. 1 Non-Dense	2 × 8	1,550	1,790	1,940	1,600,000	SPIB
No. 2 Dense	2 × 8	1,610	1,850	2,010	1,700,000	SPIB
No. 2	2 × 8	1,380	1,590	1,720	1,600,000	SPIB
No. 2 Non-Dense	2 × 8	1,260	1,450	1,580	1,400,000	SPIB
No. 3	2 × 8	805	925	1,010	1,400,000	SPIB
Dense Select Structural	2 × 10	2,470	2,840	3,090	1,900,000	SPIB
Select Structural	2 × 10	2,360	2,710	2,950	1,800,000	SPIB
Non-Dense Select Structural	2 × 10	2,130	2,450	2,660	1,700,000	SPIB
No. 1 Dense	2 × 10	1,670	1,920	2,080	1,800,000	SPIB
No. 1	2 × 10	1,500	1,720	1,870	1,700,000	SPIB
No. 1 Non-Dense	2 × 10	1,380	1,590	1,730	1,600,000	SPIB
No. 2 Dense	2 × 10	1,380	1,590	1,730	1,700,000	SPIB
No. 2	2 × 10	1,210	1,390	1,510	1,600,000	SPIB
No. 2 Non-Dense	2 × 10	1,090	1,260	1,370	1,400,000	SPIB
No. 3	2 × 10	690	795	865	1,400,000	SPIB
Dense Select Structural	2 × 12	2,360	2,710	2,950	1,900,000	SPIB
Select Structural	2 × 12	2,190	2,510	2,730	1,800,000	SPIB
Non-Dense Select Structural	2 × 12	2,010	2,310	2,520	1,700,000	SPIB
No. 1 Dense	2 × 12	1,550	1,790	1,940	1,800,000	SPIB
No. 1	2 × 12	1,440	1,650	1,800	1,700,000	SPIB
No. 1 Non-Dense	2 × 12	1,320	1,520	1,650	1,600,000	SPIB
No. 2 Dense	2 × 12	1,320	1,520	1,650	1,700,000	SPIB
No. 2	2 × 12	1,120	1,290	1,400	1,600,000	SPIB
No. 2 Non-Dense	2 × 12	1,040	1,190	1,290	1,400,000	SPIB
No. 3	2 × 12	660	760	825	1,400,000	SPIB

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches) × 25.4 for mm	DESIGN VALUE IN BENDING "F_b" psi Normal Duration	Snow Loading	7-day Loading	MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		× 0.00689 for N/mm²				
SPRUCE-PINE-FIR						
Select Structural	2 × 4	2,155	2,480	2,695	1,500,000	NLGA
No. 1/No. 2	2 × 4	1,510	1,735	1,885	1,400,000	NLGA
No. 3	2 × 4	865	990	1,080	1,200,000	NLGA
Stud	2 × 4	855	980	1,065	1,200,000	NLGA
Construction	2 × 4	1,120	1,290	1,400	1,300,000	NLGA
Standard	2 × 4	635	725	790	1,200,000	NLGA
Utility	2 × 4	290	330	360	1,100,000	NLGA
Select Structural	2 × 6	1,870	2,150	2,335	1,500,000	NLGA
No. 1/No. 2	2 × 6	1,310	1,505	1,635	1,400,000	NLGA
No. 3	2 × 6	750	860	935	1,200,000	NLGA
Stud	2 × 6	775	895	970	1,200,000	NLGA
Select Structural	2 × 8	1,725	1,985	2,155	1,500,000	NLGA
No. 1/No. 2	2 × 8	1,210	1,390	1,510	1,400,000	NLGA
No. 3	2 × 8	690	795	865	1,200,000	NLGA
Select Structural	2 × 10	1,580	1,820	1,975	1,500,000	NLGA
No. 1/No. 2	2 × 10	1,105	1,275	1,385	1,400,000	NLGA
No. 3	2 × 10	635	725	790	1,200,000	NLGA
Select Structural	2 × 12	1,440	1,655	1,795	1,500,000	NLGA
No. 1/No. 2	2 × 12	1,005	1,155	1,260	1,400,000	NLGA
No. 3	2 × 12	575	660	720	1,200,000	NLGA
SPRUCE-PINE-FIR (South)						
Select Structural	2 × 4	2,245	2,580	2,805	1,300,000	NELMA NSLB WCLIB WWPA
No. 1	2 × 4	1,465	1,685	1,835	1,200,000	NELMA NSLB WCLIB WWPA
No. 2	2 × 4	1,295	1,490	1,615	1,100,000	NELMA NSLB WCLIB WWPA
No. 3	2 × 4	735	845	915	1,000,000	NELMA NSLB WCLIB WWPA
Stud	2 × 4	725	835	910	1,000,000	NELMA NSLB WCLIB WWPA
Construction	2 × 4	980	1,125	1,220	1,000,000	NELMA NSLB WCLIB WWPA
Standard	2 × 4	545	630	685	900,000	NELMA NSLB WCLIB WWPA
Utility	2 × 4	260	300	325	900,000	NELMA NSLB WCLIB WWPA
Select Structural	2 × 6	1,945	2,235	2,430	1,300,000	NELMA NSLB WCLIB WWPA
No. 1	2 × 6	1,270	1,460	1,590	1,200,000	NELMA NSLB WCLIB WWPA
No. 2	2 × 6	1,120	1,290	1,400	1,100,000	NELMA NSLB WCLIB WWPA
No. 3	2 × 6	635	730	795	1,000,000	NELMA NSLB WCLIB WWPA
Stud	2 × 6	660	760	825	1,000,000	NELMA NSLB WCLIB WWPA
Select Structural	2 × 8	1,795	2,065	2,245	1,300,000	NELMA NSLB WCLIB WWPA
No. 1	2 × 8	1,175	1,350	1,465	1,200,000	NELMA NSLB WCLIB WWPA
No. 2	2 × 8	1,035	1,190	1,295	1,100,000	NELMA NSLB WCLIB WWPA
No. 3	2 × 8	585	675	735	1,000,000	NELMA NSLB WCLIB WWPA
Select Structural	2 × 10	1,645	1,890	2,055	1,300,000	NELMA NSLB WCLIB WWPA
No. 1	2 × 10	1,075	1,235	1,345	1,200,000	NELMA NSLB WCLIB WWPA
No. 2	2 × 10	950	1,090	1,185	1,100,000	NELMA NSLB WCLIB WWPA
No. 3	2 × 10	540	620	670	1,000,000	NELMA NSLB WCLIB WWPA
Select Structural	2 × 12	1,495	1,720	1,870	1,300,000	NELMA NSLB WCLIB WWPA
No. 1	2 × 12	980	1,125	1,220	1,200,000	NELMA NSLB WCLIB WWPA
No. 2	2 × 12	865	990	1,080	1,100,000	NELMA NSLB WCLIB WWPA
No. 3	2 × 12	490	560	610	1,000,000	NELMA NSLB WCLIB WWPA
WESTERN CEDARS						
Select Structural	2 × 4	1,725	1,985	2,155	1,100,000	WCLIB WWPA
No. 1	2 × 4	1,250	1,440	1,565	1,000,000	WCLIB WWPA
No. 2	2 × 4	1,210	1,390	1,510	1,000,000	WCLIB WWPA
No. 3	2 × 4	690	795	865	900,000	WCLIB WWPA
Stud	2 × 4	695	800	870	900,000	WCLIB WWPA
Construction	2 × 4	920	1,060	1,150	900,000	WCLIB WWPA
Standard	2 × 4	520	595	645	800,000	WCLIB WWPA
Utility	2 × 4	260	300	325	800,000	WCLIB WWPA

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOIST AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm^2				
WESTERN CEDARS—(continued)						
Select Structural	2 × 6	1,495	1,720	1,870	1,100,000	WCLIB WWPA
No. 1		1,085	1,245	1,355	1,000,000	
No. 2		1,045	1,205	1,310	1,000,000	
No. 3		600	690	750	900,000	
Stud		635	725	790	900,000	
Select Structural	2 × 8	1,380	1,585	1,725	1,100,000	
No. 1		1,000	1,150	1,250	1,000,000	
No. 2		965	1,110	1,210	1,000,000	
No. 3		550	635	690	900,000	
Select Structural	2 × 10	1,265	1,455	1,580	1,100,000	
No. 1		915	1,055	1,145	1,000,000	
No. 2		885	1,020	1,105	1,000,000	
No. 3		505	580	635	900,000	
Select Structural	2 × 12	1,150	1,325	1,440	1,100,000	
No. 1		835	960	1,040	1,000,000	
No. 2		805	925	1,005	1,000,000	
No. 3		460	530	575	900,000	
WESTERN WOODS						
Select Structural	2 × 4	1,510	1,735	1,885	1,200,000	WCLIB WWPA
No. 1		1,120	1,290	1,400	1,100,000	
No. 2		1,120	1,290	1,400	1,000,000	
No. 3		645	745	810	900,000	
Stud		635	725	790	900,000	
Construction		835	960	1,040	1,000,000	
Standard		460	530	575	900,000	
Utility		230	265	290	800,000	
Select Structural	2 × 6	1,310	1,505	1,635	1,200,000	
No. 1		970	1,120	1,215	1,100,000	
No. 2		970	1,120	1,215	1,000,000	
No. 3		560	645	700	900,000	
Stud		575	660	720	900,000	
Select Structural	2 × 8	1,210	1,390	1,510	1,200,000	
No. 1		895	1,030	1,120	1,100,000	
No. 2		895	1,030	1,120	1,000,000	
No. 3		520	595	645	900,000	
Select Structural	2 × 10	1,105	1,275	1,385	1,200,000	
No. 1		820	945	1,030	1,100,000	
No. 2		820	945	1,030	1,000,000	
No. 3		475	545	595	900,000	
Select Structural	2 × 12	1,005	1,155	1,260	1,200,000	
No. 1		750	860	935	1,100,000	
No. 2		750	860	935	1,000,000	
No. 3		430	495	540	900,000	
WHITE OAK						
Select Structural	2 × 4	2,070	2,380	2,590	1,100,000	NELMA
No. 1		1,510	1,735	1,885	1,000,000	
No. 2		1,465	1,685	1,835	900,000	
No. 3		820	940	1,025	800,000	
Stud		820	945	1,030	800,000	
Construction		1,095	1,255	1,365	900,000	
Standard		605	695	755	800,000	
Utility		290	330	360	800,000	

(Continued)

TABLE 23-IV-V-1—VALUES FOR JOISTS AND RAFTERS—VISUALLY GRADED LUMBER—(Continued)

SPECIES AND GRADE	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCY
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm²				
WHITE OAK—(continued)						
Select Structural	2 × 6	1,795	2,065	2,245	1,100,000	NELMA
No. 1		1,310	1,505	1,635	1,000,000	
No. 2		1,270	1,460	1,590	900,000	
No. 3		710	815	890	800,000	
Stud		750	860	935	800,000	
Select Structural	2 × 8	1,655	1,905	2,070	1,100,000	
No. 1		1,210	1,390	1,510	1,000,000	
No. 2		1,175	1,350	1,465	900,000	
No. 3		655	755	820	800,000	
Select Structural	2 × 10	1,520	1,745	1,900	1,100,000	
No. 1		1,105	1,275	1,385	1,000,000	
No. 2		1,075	1,235	1,345	900,000	
No. 3		600	690	750	800,000	
Select Structural	2 × 12	1,380	1,585	1,725	1,100,000	
No. 1		1,005	1,155	1,260	1,000,000	
No. 2		980	1,125	1,220	900,000	
No. 3		545	630	685	800,000	
YELLOW POPLAR						
Select Structural	2 × 4	1,725	1,985	2,155	1,500,000	NSLB
No. 1		1,250	1,440	1,565	1,400,000	
No. 2		1,210	1,390	1,510	1,300,000	
No. 3		690	795	865	1,200,000	
Stud		695	800	870	1,200,000	
Construction		920	1,060	1,150	1,300,000	
Standard		520	595	645	1,100,000	
Utility		230	265	290	1,100,000	
Select Structural	2 × 6	1,495	1,720	1,870	1,500,000	
No. 1		1,085	1,245	1,355	1,400,000	
No. 2		1,045	1,205	1,310	1,300,000	
No. 3		600	690	750	1,200,000	
Stud		635	725	790	1,200,000	
Select Structural	2 × 8	1,380	1,585	1,725	1,500,000	
No. 1		1,000	1,150	1,250	1,400,000	
No. 2		965	1,110	1,210	1,300,000	
No. 3		550	635	690	1,200,000	
Select Structural	2 × 10	1,265	1,455	1,580	1,500,000	
No. 1		915	1,055	1,145	1,400,000	
No. 2		885	1,020	1,105	1,300,000	
No. 3		505	580	635	1,200,000	
Select Structural	2 × 12	1,150	1,325	1,440	1,500,000	
No. 1		835	960	1,040	1,400,000	
No. 2		805	925	1,005	1,300,000	
No. 3		460	530	575	1,200,000	

TABLE 23-IV-V-2—VALUES FOR JOISTS AND RAFTERS—MECHANICALLY GRADED LUMBER
For use in Tables 23-V-J-1 through 23-V-R-12 and Division V only.

GRADE DESIGNATION	SIZE (inches)	DESIGN VALUE IN BENDING "F_b" psi			MODULUS OF ELASTICITY "E" psi	GRADING RULES AGENCIES
		Normal Duration	Snow Loading	7-day Loading		
	× 25.4 for mm	× 0.00689 for N/mm²				
MACHINE STRESS RATED (MSR) LUMBER						
900f-1.0E	2 × 4 and wider	1,040	1,190	1,290	1,000,000	WCLIB,WWPA
1200f-1.2E		1,380	1,590	1,730	1,200,000	NLGA,SPIB,WCLIB,WWPA
1350f-1.3E		1,550	1,790	1,940	1,300,000	SPIB,WCLIB,WWPA
1450f-1.3E		1,670	1,920	2,080	1,300,000	NLGA,WCLIB,WWPA
1500f-1.3E		1,730	1,980	2,160	1,300,000	SPIB
1500f-1.4E		1,730	1,980	2,160	1,400,000	NLGA,SPlB,WCLIB,WWPA
1650f-1.4E		1,900	2,180	2,370	1,400,000	SPIB
1650f-1.5E		1,900	2,180	2,370	1,500,000	NLGA,SPIB,WCLIB,WWPA
1800f-1.6E		2,070	2,380	2,590	1,600,000	NLGA,SPlB,WCLlB,WWPA
1950f-1.5E		2,240	2,580	2,800	1,500,000	SPlB
1950f-1.7E		2,240	2,580	2,800	1,700,000	NLGA,SPIB,WWPA
2100f-1.8E		2,420	2,780	3,020	1,800,000	NLGA,SPIB,WCLIB,WWPA
2250f-1.6E		2,590	2,980	3,230	1,600,000	SPIB
2250f-1.9E		2,590	2,980	3,230	1,900,000	NLGA,SPIB,WWPA
2400f-1.7E		2,760	3,170	3,450	1,700,000	SPIB
2400f-2.0E		2,760	3,170	3,450	2,000,000	NLGA,SPIB,WCLIB,WWPA
2550f-2.1E		2,930	3,370	3,670	2,100,000	NLGA,SPIB,WWPA
2700f-2.2E		3,110	3,570	3,880	2,200,000	NLGA,SPlB,WCLIB,WWPA
2850f-2.3E		3,280	3,770	4,100	2,300,000	SPlB,WWPA
3000f-2.4E		3,450	3,970	4,310	2,400,000	NLGA,SPlB
3150f-2.5E		3,620	4,170	4,530	2,500,000	SPlB
3300f-2.6E		3,800	4,360	4,740	2,600,000	SPlB
900f-1.2E	2 × 6 and wider	1,040	1,190	1,290	1,200,000	NLGA,WCLlB
1200f-1.5E		1,380	1,590	1,730	1,500,000	NLGA,WCLlB
1350f-1.8E		1,550	1,790	1,940	1,800,000	NLGA
1500f-1.8E		1,730	1,980	2,160	1,800,000	WCLIB
1800f-2.1E		2,070	2,380	2,590	2,100,000	NLGA,WCLIB
MACHINE EVALUATED LUMBER (MEL)						
M-10	2 × 4 and wider	1,610	1,850	2,010	1,200,000	SPlB
M-11		1,780	2,050	2,230	1,500,000	
M-12		1,840	2,120	2,300	1,600,000	
M-13		1,840	2,120	2,300	1,400,000	
M-14		2,070	2,380	2,590	1,700,000	
M-15		2,070	2,380	2,590	1,500,000	
M-16		2,070	2,380	2,590	1,500,000	
M-17		2,240	2,580	2,800	1,700,000	
M-18		2,300	2,650	2,880	1,800,000	
M-19		2,300	2,650	2,880	1,600,000	
M-20		2,300	2,650	2,880	1,900,000	
M-21		2,650	3,040	3,310	1,900,000	
M-22		2,700	3,110	3,380	1,700,000	
M-23		2,760	3,170	3,450	1,800,000	
M-24		3,110	3,570	3,880	1,900,000	
M-25		3,160	3,640	3,950	2,200,000	
M-26	2 × 4 and wider	3,220	3,700	4,030	2,000,000	SPlB
M-27		3,450	3,970	4,310	2,100,000	

The note to Table 23-IV-V-1 applies also to mechanically graded lumber.

Division V—DESIGN STANDARD FOR METAL PLATE CONNECTED WOOD TRUSS

Based on ANSI/TPI 1-1995, National Design Standard for Metal Plate Connected Wood Truss Construction, of the Truss Plate Institute

SECTION 2321 — METAL PLATE CONNECTED WOOD TRUSS DESIGN

2321.1 Design and Fabrication. The design and fabrication of metal plate connected wood trusses shall be in accordance with ANSI/TPI 1-1995.

2321.2 Performance. Full-scale load tests in accordance with ANSI/TPI 2 (see Section 2303.1, Item 5) may be required at the option of the building official to provide a means of demonstrating that minimum adequate performance is obtainable from specific metal connector plates, various lumber types and grades, a particular truss design and a particular fabrication procedure. ANSI/TPI 2 provides procedures for testing and evaluating wood trusses designed in accordance with ANSI/TPI 1.

2321.3 In-plant Inspection. Each truss manufacturer shall retain an approved agency having no financial interest in the plant being inspected to make nonscheduled inspections of truss fabrication and delivery operations. The inspections shall cover all phases of the truss operation, including lumber storage, handling, cutting, fixtures, presses or rollers, fabrication bundling and banding, handling, and delivery.

2321.4 Marking. Each truss shall be legibly branded, marked or otherwise have permanently affixed thereto the following information located within 2 feet (610 mm) of the center of the span on the face of the bottom chord:

1. Identity of the company manufacturing the truss.
2. The design load.
3. The spacing of trusses.

Division VI—DESIGN STANDARD FOR STRUCTURAL GLUED BUILT-UP MEMBERS—PLYWOOD COMPONENTS
Based on Design and Fabrication Specifications of the American Plywood Association

SECTION 2322 — PLYWOOD STRESSED SKIN PANELS

2322.1 Scope. This standard covers requirements for the design of plywood stressed skin panels as referred to in Section 2305.8.

2322.2 Definition. A panel with stressed covers, or a stressed skin panel, is one in which the covering acts integrally with the framing members to resist bending loads in proportion to its effective moment of inertia. It consists of several longitudinal framing members or ribs spaced by headers and covered on top alone or top and bottom with plywood panels.

2322.3 Design.

2322.3.1 Spacing of ribs. The clear distance between ribs shall not exceed twice the basic spacing set forth in Table 23-VI-A.

2322.3.2 Skin bending. The stressed skin shall be capable of resisting bending stresses due to loads normal to the skin with allowance for direction of the face grain.

2322.3.3 Determination of section properties. For determination of bending stresses, the section properties shall be calculated considering that only the ribs or plies of the ribs and the plies in the stressed skin with grain parallel to the span of the ribs are effective. If the clear distance between ribs is less than the basic spacing "*b*" as set forth in Table 23-VI-A, the effective width of the skin is equal to the full panel width. If the clear distance between ribs is greater than the basic spacing "*b*," the effective width of the skins equals the sum of the widths of the ribs in contact with the stressed skin plus a portion of the skin extending a distance equal to 0.5 "*b*" each side of each rib.

For determination of horizontal shear, rolling shear, deflection and splice stresses, the section properties shall be based on the gross section of all material having its grain parallel with the direction of the principal stress. The modulus of elasticity used to calculate deflection shall be based on the modulus of elasticity of the plywood stressed skins.

2322.3.4 Method of design. Stressed skin panels shall be designed in accordance with accepted engineering formulas, without exceeding the allowable stresses specified in Section 2322.4.

2322.3.5 Splices. The stressed skin panels and ribs shall be continuous in the longitudinal direction, except where adequately spliced and designed in accordance with Section 2322.4.

2322.4 Allowable Stresses.

2322.4.1 Panel stresses.

2322.4.1.1 Direct stress from bending. The allowable working stresses in the stressed skin flanges shall not exceed the values set forth in Table 23-III-A for tension or compression when multiplied by the factor "*F*":

b = the clear distance between ribs in inches (mm).

"b" = the basic spacing shown in Table 23-VI-A in inches (mm).

For b/"b" equal or less than 0.5, F equals 1.

For b/"b" greater than 0.5 and less than 1.0

$F = 0.67\ (2 - b/\text{“}b\text{”})$.

For b/"b" equal or greater than 1.0 and not greater than 2.0

$F = 0.67$.

2322.4.1.2 Rolling shear. The shear between interior ribs and plywood skin shall not exceed the values set forth in Table 23-III-A for rolling shear. The allowable working stresses shall be reduced 50 percent at exterior ribs. This reduction applies to exterior stringers whose clear distance to the panel edge is less than half the clear distance between stringers.

2322.4.1.3 Stress in plywood skin splices.

2322.4.1.3.1 Scarf-jointed splice in compression. The allowable stress in the skin at the splice shall not exceed the values specified in Section 2322.4.1.1. The slope of the scarf shall not be steeper than 1 unit vertical in 5 units horizontal (20% slope).

2322.4.1.3.2 Butt-jointed splice in compression. Where a splice plate is installed on one side of the joint, the allowable stress in the skin at the splice shall not exceed the values specified in Section 2322.4.1.1, provided said values are reduced in proportion to the ratio of the width of the splice plate to the width of the stressed skin. The splice plate shall be at least equal in thickness and grade to the skin being spliced. The splice plate shall be centered over the joint with the face grain parallel to the face grain of the skin. The minimum length of the splice plate, measured parallel to the span, shall not be less than the values set forth in Table 23-VI-B. Splice plates shall be preglued to the skins prior to assembly of the panel. No percentage reduction is taken for compressive stress.

2322.4.1.3.3 Scarf-jointed splice in tension. The allowable stress in the skin at the splice shall not exceed the values specified in Section 2322.4.1.1. The slope of scarf shall not be steeper than 1 unit vertical in 8 units horizontal (12.5% slope).

2322.4.1.3.4 Butt-jointed splice in tension. Where a splice plate is installed, the allowable stress in the skin at the splice shall not exceed the values set forth in Table 23-VI-C. The splice plate thickness, position, orientation to face grain, installation and length shall conform to Section 2322.4.1.3.2.

2322.4.2 Rib or longitudinal stresses.

2322.4.2.1 Bending. Bending stresses shall not exceed the values set forth in Chapter 23, Division III.

2322.4.2.2 Horizontal shear. Horizontal shear shall not exceed the values set forth in Chapter 23, Division III.

2322.4.2.3 Splices in ribs or longitudinal members. Accurately fitted and well-glued scarf or finger joints are permitted provided the maximum stress in bending does not exceed the percentages of the basic flexural stress shown in ANSI/AITC A190.1 and ASTM D 3737. In the finger joint, the portion of the joint occupied by the tips of the fingers at that cross section shall not be considered as effective. Finger joints and other nonstandard configurations of scarf joints may be prequalified in accordance with ANSI/AITC A190.1 and ASTM D 3737. The effective slope of the joint shall also be determined.

2322.5 Fabrication. The plywood stressed skins shall be fabricated in accordance with the procedures specified in Section 2326.

SECTION 2323 — PLYWOOD CURVED PANELS

2323.1 Scope. This division covers requirements for the design of plywood curved panels as referred to in Section 2305.8. Fabrication procedure shall be in accordance with the requirements of Section 2326.

2323.2 General Design. Curved panels may be designed as either curved flexural panels or arch panels. The curved flexural panels act as a simple beam, without developing horizontal thrust. Bearing details are designed accordingly, with provision for horizontal deflection. Tie rods are not required. Arch panels are stressed both in compression and in flexure. They exert horizontal thrust at the supports and therefore require tie rods or abutments.

2323.3 Definition.

2323.3.1 Core types. Curved plywood panels consist of full-length plywood faces top and bottom spaced by and joined with glue to a structural core capable of resisting the shearing forces. The core may consist of one or more layers of plywood, butt-jointed or full-length, glued over the full areas to the faces or spaced ribs constructed of single-piece or laminated plywood or lumber strips, spaced as required, either preglued or glued during panel assembly.

2323.4 Allowable Stresses.

2323.4.1 Plywood core. The allowable working stresses in plywood core type of construction in flexure, compression and tension shall not exceed the values set forth in Table 23-III-A and reduced for curvature by multiplication by the following curvature factor:

$$1 - 2000\left[\frac{t}{R}\right]^2$$

WHERE:

R = radius of curvature at center line of member, inches (mm).

t = thickness, out-to-out of plies parallel with the stress, inches (mm).

$\frac{t}{R}$ = shall not exceed $^1/_{125}$.

2323.4.2 Spaced ribs. The allowable working stresses in compression tension shall be established as specified in Section 2323.4.1. Additionally, the allowable stresses shall be further reduced as for stressed skin panels as specified in Section 2322.

2323.4.3 Radial stresses. The radial stresses induced by bending moment in a curved spaced rib or plywood core panel shall be computed by the formula:

$$S_R = \frac{3M}{2Rbh}$$

WHERE:

b = width of stringer, inches (mm).

h = overall height of panel, inches (mm).

M = bending moment, in inch-pounds (N·mm), on a width of panel equal to the rib spacing.

R = radius of curvature at center line of member, inches (mm).

S_R = actual stress in a radial direction, pounds per square inch (N/mm^2).

When M is in the direction tending to decrease curvature (increase the radius) the stress is in tension and S_R for plywood shall be limited to one half the values shown for rolling shear in the plane of the plies in Table 23-III-A. S_R for lumber ribs shall be limited to one third the values shown for horizontal shear in Chapter 23, Division III. When M is in the direction tending to increase curvature (decrease the radius) the stress is in compression and S_R for plywood shall be limited to the values shown for compression perpendicular to the grain in Table 23-III-A. S_R for lumber ribs shall be limited to the values shown for compression perpendicular to the grain in Chapter 23, Division III.

2323.5 Effective Cross Section.

2323.5.1 Direction of grain. All plywood and lumber having its grain parallel with the direction of stress shall be considered effective in resisting the stress, except for spaced-rib panels which should be as outlined in Section 2322.

2323.5.2 Scarfed plywood joints. The slope of scarfed joints shall not be steeper than one in eight in order to fully develop the strength of the plywood elements.

2323.5.3 Glued-plywood butt joints with splice plates. Butt joints with splice plates shall be designed in accordance with this standard. Splice plates shall be preglued to the skins prior to assembly of the panel.

2323.5.4 Butt joints without splice plates. The effective strength of solid plywood core panels and of laminated ribs in a spaced rib panel at a section containing a butt joint in any lamination shall be determined by ignoring the butted lamination and any other lamination containing a butt joint closer than 50 times the lamination thickness.

2323.5.5 Deflection. The deflection of curved panels containing butt joints in either the core or the faces may be based on the gross section of all material having its grain parallel with the direction of principal stress, provided all butt joints are staggered at least 10 times the lamination thickness.

2323.6 Design of Curved Flexural Panels. Curved flexural panels shall be designed as simple beams in accordance with the applicable parts of this standard, with provisions to permit horizontal displacement at supports. The extent of this displacement shall be determined in accordance with accepted engineering practice.

2323.7 Design of Arch Panels.

2323.7.1 General. Arch panels shall be designed in accordance with this standard as arches which are subjected to combined bending and direct stress. Determination of vertical and horizontal reactions and maximum axial loads, moments and shears shall be based on accepted engineering practice.

2323.7.2 Bending and direct stress. Combined bending and direct stress shall be calculated by the formula:

$$\frac{P}{Ac} + \frac{M}{Sf} = 1$$

$$c = \frac{0.3E}{(l/d)^2}$$

WHERE:

A = area in square inches (mm^2) of arch cross section per foot (mm) width of arch, of plies with their grain parallel to the direction of the stress.

c = allowable unit compressive stress in pounds per square inch (N/mm^2), as indicated by the above formula but not to exceed the values in Chapter 23, Division III.

d = thickness, out-to-out, of plies with their grain parallel to the direction of the stress in inches (mm).

E = modulus of elasticity of skins in pounds per square inch (N/mm^2).

f = allowable stress in extreme fiber, pounds per square inch (N/mm^2), tension or compression, modified by Sections 2322.4.1 and 2323.4.1 as applicable.

l = chord length in inches (mm) between points of zero moment.

M = moment, in inch-pounds per foot (N·mm/mm) width of arch.

P = direct force, pounds per foot (N/mm) width of arch.

S = section modulus, inches cubed per foot (mm^3/mm) width of arch, of plies with their grain parallel to the direction of the stress.

2323.7.3 Shear stresses. Shear stresses shall be calculated by the following formula:

$$S = \frac{VQ}{Ib}$$

WHERE:

b = width of rib, inches (mm). [b = 12 inches (305 mm) for solid plywood core panel.]

I = moment of inertia of arch panel, inches to the fourth power, per foot (mm^4/mm) width of arch panel, or per rib section.

Q = first moment about neutral axis of area of parallel grain material from panel face into plane at which shear stress is to be calculated, inches cubed per foot (mm^3/mm) width of arch panel, or per rib section.

S = shear stress, pounds per square inch (N/mm^2), either rolling shear in plywood, or horizontal shear in rib.

V = shear acting normal to the slope of the arch, pounds per foot (N/mm) of arch width, or per rib section.

2323.7.4 Connections. Connections of panels to supporting members shall be with nails, lag screws, bolts, or other means adequate to resist the maximum horizontal thrust and uplift, as well as any shear developed by assumed diaphragm action.

2323.7.5 Supports. The horizontal members supporting arch panels shall be adequate to resist vertical and horizontal loads between supports without deflection sufficient to alter the design basis of the arch panels. Horizontal thrust shall be resisted by properly designed tie rods, struts or abutments.

Where tie rods are used to resist thrust, such rods or other effective means of resisting thrust shall be placed in all bays.

Where abutments are used at the outer edges of exterior bays, struts or other means of resisting thrust, such as shear walls, shall be placed in all bays. Spacing shall be as required by the interior panel supporting members. Such struts are required to provide for unbalanced loads when all bays are not equally loaded.

2323.7.6 Buckling. Adequate design provisions shall be provided to ensure stability against buckling due to axial and/or shear forces.

SECTION 2324 — PLYWOOD BEAMS

2324.1 Scope. This standard covers requirements for design of plywood beams as referred to in Section 2305.8.

2324.2 Definition. Plywood beams are structural units consisting of one or more vertical plywood webs that are attached to lumber flanges. The lumber flanges carry the bending forces while the plywood webs transmit the shear. At intervals along the beam, stiffeners, inserted between the flanges and attached to the webs, serve to distribute concentrated loads and resist web buckling.

2324.3 Flanges.

2324.3.1 Design.

2324.3.1.1 Bending in symmetrical sections. The allowable resisting moment for a symmetrical section shall not exceed the values established by the following formula:

$$M = \frac{2t\,I}{h}$$

WHERE:

h = depth of the beam in inches (mm).

I = net moment of inertia in inches to the fourth power (mm^4) of all the continuous parallel grain material in the flange and web section. Location of the neutral axis shall be calculated without considering butt joints.

M = resisting moment in inch-pounds (N·mm).

t = allowable working stress in pounds per square inch (N/mm^2) in tension parallel to the grain of the flange lumber. Also see Sections 2324.3.1.3 and 2324.3.1.5.

2324.3.1.2 Bending in unsymmetrical sections. The allowable resisting moment for an unsymmetrical beam section shall not exceed the value established by the following formula:

$$M = \frac{f\,I}{Z}$$

WHERE:

f = allowable working stress in pounds per square inch (N/mm^2). Note that the allowable working stress for the tension flange and compression flange corresponds to allowable values for t and c, respectively. Also see Sections 2324.3.1.3 and 2324.3.1.5.

I = net moment of inertia in inches to the fourth power (mm^4) of all continuous parallel grain material in the flange and web section.

M = resisting moment in inch-pounds (N·mm).

Z = distance from the neutral axis to an outer flange fiber in inches (mm). Location of the neutral axis shall be calculated without considering butt joints.

2324.3.1.3 Lateral support of compression flange. The actual stress in the compression flange shall not exceed the allowable stress established by the following formula and in no case shall exceed the allowable unit stress for compression parallel to the grain:

$$\frac{P}{A} = \frac{0.3E}{\left(\frac{L}{d}\right)^2}$$

WHERE:

d = width of the upper flange in inches (mm).

E = modulus of elasticity in pounds per square inch (N/mm^2).

L = distance between lateral supports of the compression flange in inches (mm).

P/A = allowable compression stress parallel to the grain in pounds per square inch (N/mm^2).

Bracing elements and their connections providing restraint for the compression flange shall be capable of resisting a force F applied in a horizontal direction of not less than that established by the following formula:

$$F = 0.02\,A\,(c')\,\frac{L}{Lm}$$

WHERE:

A = area of the compression flange in square inches (mm^2).

c' = the allowable compressive stress or the actual stress in compression in pounds per square inch (N/mm^2) as governed by Section 2324.3.1

F = force applied in a horizontal direction in pounds (N).

Lm = maximum permissible bracing for the actual stress.

When the member is not symmetrical about the vertical neutral axis, due consideration shall be taken in the design for adequate lateral restraint.

2324.3.1.4 Lateral stability of deep narrow beam. The ratio I_x/I_y of the gross moment of inertia of all parallel grain material about the horizontal neutral axis to that about the vertical axis shall determine the type of bracing required as set forth in Table 23-VI-D.

2324.3.1.5 Flange splices. Scarf joints in tension and compression flanges may be assumed fully effective for the determination of moment of inertia. Scarf joints in adjacent laminations shall be spaced no closer than 16 times the lamination thickness, measured center to center, except that the spacing may be reduced to zero where the design indicates no bending stress.

Butt joints shall not be permitted in tension flanges except where the butted lamination is omitted in determination of the moment of inertia at that section. In addition, the moment of inertia shall be reduced at the above section where butted joints occur in adjacent laminations based upon the area reduction factors set forth in Table 23-VI-E.

The allowable stress in tension flanges having butt joints shall not exceed 80 percent of the allowable code values. Compression flanges having butt joints shall be designed as required for tension flanges except that a reduction in stress is not required.

The allowable stress in flanges having finger joints shall not exceed 2,200 pounds per square inch (0.015 16 N/mm^2). The portion of the joint occupied by the tips of the fingers at the cross section shall not be considered as effective.

Approved finger joints based on the performance tests set forth in ANSI/AITC A190.1 and ASTM D 3737, with the exception that the low test value be limited to twice the design stress, may be used in lieu of the preceding requirement.

2324.3.2 Fabrication. Flanges shall consist of one or more laminations of Douglas fir (Coast Region), West Coast hemlock or southern pine dry lumber not more than 2 inches (51 mm) thick that is stress-graded in accordance with WCLIB Standard Grading Rules No. 16 and SPIB Southern Pine Grading Rules. Finger joints may be used in lieu of scarf joints. All provisions of WCLIB Standard Grading Rules No. 16 are applicable except as further limited by Section 2324.3.1.5.

2324.4 Plywood Webs.

2324.4.1 Design.

2324.4.1.1 Horizontal shear. The allowable shear on the plywood web shall not exceed the value established by the following formula:

$$V = \frac{vI\,\Sigma\,t}{Q}$$

WHERE:

I = total moment of inertia in inches to the fourth power (mm^4) about the neutral axis of all parallel grain material regardless of any butt joints.

Q = statical moment about the neutral axis of all parallel grain material regardless of any butt joints lying above (or below) the neutral axis in inches to the third power (mm^3).

V = allowable total shear on the section in pounds (N).

v = allowable plywood shear stress through the panel thickness in pounds per square inch (N/mm^2). See Table 23-III-A and Section 2324.4.1.4.

Σt = total shear thickness of all webs at the section in inches (mm).

2324.4.1.2 Flange-web shear (rolling shear). For beams having one or two webs, the allowable flange-web shear on pressure-glued or nail-glued systems shall not exceed the value established by the following formula:

$$V = \left(\frac{nsdI}{Q_{fl}}\right)$$

WHERE:

d = depth of contact area between flange and plywood web in inches (mm).

I = total moment of inertia about the neutral axis of all parallel grain material, regardless of any butt joints in inches to the fourth power (mm^4).

n = number of contact surfaces between web and flange.

Q_{fl} = statical moment about the neutral axis of all parallel grain material, regardless of any butt joints, in the upper (or lower) flanges in inches to the third power (mm^3).

s = one half of the allowable plywood rolling shear stress in pounds per square inch (N/mm^2) as given in Table 23-III-A. Shear values shall not be assigned to the nails in the nail-glued systems.

V = allowable total shear on the section in pounds (N).

2324.4.1.3 Stiffeners for concentrated loads. Stiffeners shall be placed over reactions and where other heavy concentrated loads occur. They shall fit tightly against the flanges and their attachment to the webs shall be capable of transmitting the concentrated load or reaction. The width of the stiffeners shall be equal to the lumber flange width at the section. Their dimension parallel to the beam span shall not be less than *w*.

$$w = \frac{P}{c_{\perp}\, b}$$

WHERE:

b = flange width in inches (mm).

$c_{\perp}$ = allowable stress in compression perpendicular to grain in pounds per square inch (N/mm^2) for the flange lumber as set forth in Division III.

P = concentrated load or reaction in pounds (N).

2324.4.1.4 Intermediate stiffeners to prevent web buckling. Intermediate stiffeners shall be spaced not to exceed 48 inches (1219 mm) on center. The width of the stiffeners shall be equal to the lumber flange width at the section and shall be of not less than 2-inch (51 mm) nominal dimensioned lumber.

In regions of high shear, where shear stress is 100 percent of values set forth in Chapter 23, Division III, the spacing of the stiffeners specified above shall be reduced in accordance with Table 23-VI-F.

Where the webs are stressed to less than 100 percent of the shear strength, the stiffener spacing *b* shall be calculated by the following formula, except that where the shear stress is 90 percent or less of the shear strength of the webs, the intermediate stiffeners may be spaced at 48 inches (1219 mm) on center. In no case shall the spacing exceed 48 inches (1219 mm).

$$b' = b\left(1 + \frac{100 - p}{25}\right)$$

WHERE:

b = stiffener spacing in inches (mm) from Table 23-VI-F.

b' = actual stiffener spacing in inches (mm).

p = actual percentage of allowable plywood shear stress existing at the section.

2324.4.1.5 Tapered beams. Where the depth of the beam is tapered, the net vertical component of the direct forces in the flanges shall be added to or subtracted from the external shear to obtain the net shear acting at a section of web. This vertical component shall be calculated as follows:

$$P_v = \frac{M}{L_l}$$

WHERE:

L_l = distance from section to the intersection of the flange center lines in inches (mm).

M = bending moment acting on section in inch-pounds (N·mm).

P_v = vertical component of flange in pounds (N).

2324.4.1.6 Web splices. Scarfed and butt end joints in plywood webs shall be designed in accordance with Part I of this standard. Joints subject to more than one type of stress or to stress reversal shall be designed for the most severe case. The slope of scarf joints, 1 unit vertical in 8 units horizontal (12.5% slope) or flatter, and splice plate lengths in Table 23-VI-B of this standard are adequate to transmit 100 percent of the shear strength of the plywood webs being spliced, provided that the provisions of Section 2322.4.1.3.2 regarding splice plate thickness, grade and orientation, are adhered to.

All end joints in plywood webs shall be staggered at least 24 inches (610 mm) with intermediate stiffeners at each joint.

SECTION 2325 — PLYWOOD SANDWICH PANELS

2325.1 Scope. This standard covers requirements for the design of plywood sandwich panels as referred to in Section 2305.8.

2325.2 Definition. A structural sandwich panel is an assembly consisting of a lightweight core securely laminated between two relatively thin, strong facings. Axial compression forces are carried by compression in the facings, stabilized by the core material against buckling; bending moments are resisted by an internal couple composed of forces in the facings; shearing forces are resisted by the core.

2325.3 General Design.

2325.3.1 Material. For purposes of this standard, facings are assumed to be plywood meeting the requirements of UBC Standard 23-2. Cores may be a variety of material, including polystyrene foams, polyurethane foams and paper honeycombs.

2325.3.2 Bond between faces and core. Core may be glued to faces, or in the case of some foam materials, may adhere directly to the faces during expansion. In exterior wall panels, the bond shall be waterproof. The combination of core material and bond shall be such as not to creep excessively under the long-term loads and temperatures.

2325.3.3 Trial section. A trial section of an exterior wall sandwich panel shall be determined as described below. It shall then be investigated for all possible modes of failure.

2325.4 Faces and Cores.

2325.4.1 Plywood faces. The required parallel-grain plywood area shall be determined by the following formula:

$$A_1 + A_2 = \frac{P}{F_c}$$

WHERE:

A_1 = parallel-grain area of outside (top) skin in in.^{2}/ft. (mm^2/mm) of width.

A_2 = parallel-grain area of inside (bottom) skin in in.^{2}/ft. (mm^2/mm).

F_c = allowable compressive stress in parallel plies of plywood in pounds per square inch (N/mm^2).

P = axial load in pounds per foot (N/mm) of panel width.

2325.4.2 Core thickness. The minimum core thickness for structural purposes shall satisfy the following formula. In practice, core thickness is usually chosen on the basis of required insulating value.

$$S = \frac{M}{F_c} = \frac{A(h + c)^2}{4h}$$

WHERE:

A = parallel-grain area of skin in in.^{2}/ft. (mm^2/mm) of panel width, = $A_1 = A_2$.

c = core thickness in inches (mm).

h = total panel thickness in inches (mm).

L = panel span in feet (mm).

M = maximum bending moment applied to panel, in lb.-in. per foot (N·m/mm) of panel width (for simply supported end conditions, $M = 1.5wL^2$).

S = section modulus of panel in in.^{3}/ft. (mm^3/mm) of width.

w = normal loading in pounds per square foot (N/mm^2).

2325.5 Analysis.

2325.5.1 Neutral axis. The location of the neutral axis for the panel shall be calculated from the following formula:

$$\bar{y} = \frac{A_1\left(h - \frac{t_1}{2}\right) + A_2\left(\frac{t_2}{2}\right)}{A_1 + A_2}$$

WHERE:

t_1 = thickness of outside (top) skin in inches (mm).

t_2 = thickness of inside (bottom) skin in inches (mm).

$\bar{y}$ = distance from bottom (or inside) of panel to neutral axis in inches (mm).

2325.5.2 Moment of inertia and section modulus. Moment of inertia and section modulus shall be calculated from the following formulas:

$$I = \frac{A_1A_2(h + c)^2}{4\,(A_1 + A_2)}$$

$$S_1 = \frac{I}{h - \bar{y}},\ S_2 = \frac{I}{\bar{y}}$$

WHERE:

I = panel moment of inertia in inches^4 per foot (mm^4/mm) of width.

S_1 = section modulus calculated from the compression side of the panel, in inches^3 (mm^3).

S_2 = section modulus calculated from the tension side of the panel. in inches^3 (mm^3).

2325.5.3 Column buckling. Allowable axial load shall be no larger than the value calculated from the following formula:

$$P_{cr} = \frac{\pi^2EI}{(12L)^2\left[1 + \frac{\pi^2EI}{(12L)^2 \times 6(h + c)G_c}\right]}$$

For **SI:**

$$P_{cr} = \frac{\pi^2 EI}{L^2\left[1 + \frac{2\pi^2 EI}{L^2(h + c)G_c}\right]}$$

WHERE:

E = modulus of elasticity of plywood in pounds per square inch (N/mm^2). This value should include a 10 percent increase over published data to restore an allowance made when shear deflection is not computed separately.

G_c = modulus of rigidity of core in direction of span, in pounds per square inch (N/mm^2).

P_{cr} = theoretical column buckling load in pounds per foot (N/mm) of panel width.

2325.5.4 Skin buckling. Stress tending to cause buckling of skin shall be no larger than that given in the following formula:

$$C_{cr} = 0.5\sqrt[3]{EE_cG_c}$$

WHERE:

C_{cr} = theoretical skin buckling stress in pounds per square inch (N/mm^2).

E_c = modulus of elasticity of the core perpendicular to the skin, in pounds per square inch (N/mm^2).

2325.5.5 Deflection. The maximum deflection shall conform to Table 16-D. Deflection shall be calculated according to the following formulas.

Deflection due to transverse loading only is equal to:

$$\Delta = \Delta_b + \Delta_s = \frac{5wL^4 \times 1728}{384EI} + \frac{wL^2}{4(h + c)G_c}$$

For **SI:**

$$\Delta = \Delta_b + \Delta_s = \frac{5wL^4}{384EI} + \frac{wL^2}{4(h + c)G_c}$$

WHERE:

Δ = total deflection in inches (mm).

Δ_b = deflection due to loading.

Δ_s = deflection due to shear.

Total deflection including effects of axial load is approximately equal to:

$$\Delta_{max} = \frac{\Delta}{1 - P/P_{cr}}$$

WHERE:

Δ_{max} = maximum deflection in inches (mm).

2325.5.6 Bending stress. Bending stress shall be calculated using the following formula. This stress includes the bending due to the axial load through the initial transverse load deflection.

$$f_{b\ max} = \frac{1.5wL^2 + P\Delta_{max}}{S_1}$$

WHERE:

$f_{b\ max}$ = applied bending stress in the facings.

2325.5.7 Combined stress. Maximum combined stress will occur at midlength or midheight of the panel. It is the sum of the axial stress and the compressive bending stress in the concave side of the panel. It shall be calculated in accordance with the following formula:

$$f_{c\ max} = \frac{P}{A_1 + A_2} + f_{b\ max}$$

WHERE:

$f_{c\ max}$ = maximum combined stress in pounds per square inch (N/mm^2) (compression).

This stress shall be less than F_c and less than $^1/_3 C_{cr}$.

2325.5.8 Shear stress. Shear stress shall be computed by the formula:

$$f_v = \frac{wL}{(h + c)12} \leq F_v$$

For **SI:**

$$f_v = \frac{wL}{(h + c)} \leq F_v$$

WHERE:

f_v = applied shear stress in the core, in pounds per square inch (N/mm^2).

F_v = allowable shear stress in the core, in pounds per square inch (N/mm^2).

SECTION 2326 — FABRICATION OF PLYWOOD COMPONENTS

2326.1 Scope. This standard applies to the fabrication of glued plywood-lumber structural assemblies such as stressed skin panels, curved panels, beams, etc., that have been designed in accordance with accepted engineering principles, including Division VI, Sections 2322, 2323 and 2324, for stressed skin panels, curved panels and beams.

2326.2 Materials.

2326.2.1 Plywood.

2326.2.1.1 General. Plywood shall be as specified in the design and conform to UBC Standard 23-2. Each original panel shall bear the grade trademark of an approved independent inspection and testing agency.

2326.2.1.2 Type. When the equilibrium moisture content of the member in use exceeds 16 percent or if any edge or surface of the plywood is permanently exposed to the weather, the plywood affected shall be exterior type. Otherwise, it may be interior type with exterior glue.

2326.2.1.3 Moisture content. At time of gluing the plywood shall be conditioned to a moisture content of approximately that which it will attain in service, but shall be between 7 percent and 16 percent. Difference in average moisture content between panels glued to each other in any member shall not exceed 5 percent.

2326.2.1.4 Surface requirements. Surfaces of plywood to be glued shall be clean and free from oil, dust, paper tape and other material which would be detrimental to satisfactory gluing.

Medium density overlaid surfaces shall not be relied on for a structural glue bond.

2326.2.1.5 Dimensional tolerances. Scarfed panels of plywood shall be square, as measured on the diagonals, within $^1/_8$ inch (3.8 mm) for a 4-foot-wide (1219 mm) panel, and proportionately for other widths.

2326.2.2 Lumber.

2326.2.2.1 Grading. Lumber shall be uniformly manufactured and shall be of the grade required by the design. Lumber shall be graded and grade marked in accordance with applicable UBC standards for the species to be used, except as modified herein.

When lumber is resawn, it shall be regraded and grade marked on the basis of the new size.

2326.2.2.2 Knotholes. Knotholes to the same size as the sound and tight knots specified for the grade by applicable UBC standards may be permitted.

2326.2.2.3 Moisture content. At time of gluing, the lumber shall be conditioned to a moisture content of approximately that which it will attain in service, but shall be between 7 percent and 16 percent.

The range of moisture content of the various pieces assembled into a single panel or flange of a beam shall not exceed 5 percent.

2326.2.2.4 Surface requirements. Surfaces of lumber to be glued shall be clean and free from oil, dust and other foreign matter which would be detrimental to satisfactory gluing.

Each piece of lumber shall be machine finished, but not sanded, to a smooth surface with a maximum allowable variation of $^1/_{64}$ inch (0.40 mm) in the surface to be glued.

Warp, twist, cup or other characteristics which would prevent intimate contact of adjacent glued surfaces shall not be permitted.

2326.2.2.5 Flanges. Lumber for laminated flanges of beams and ribs for curved panels shall conform with the applicable requirements of ANSI/AITC Standard A190.1 and ASTM D 3737 regardless of the number of laminations.

2326.2.2.6 Transverse members. Lumber for headers, blocking and stiffeners shall be of minimum 2-inch (51 mm) nominal thickness and Standard Grade or higher Douglas fir or West Coast hemlock or equal.

2326.2.3 Glue.

2326.2.3.1 General. Mixing, spreading, storage life, pot life and working life, and assembly time and temperature shall be in accordance with the manufacturer's recommendations.

2326.2.3.2 Interior type. When the equilibrium moisture content of the member in use does not exceed 16 percent, glue may be casein type, containing a mold inhibitor, and conforming with ASTM D 3024.

2326.2.3.3 Exterior type. When the equilibrium moisture content of the member in use exceeds 16 percent, glue shall be of a phenol, resorcinol or melamine base and conform to ASTM D 3024 and D 2559 and APA AFG-01.

2326.3 Fabrication.

2326.3.1 General. Units may be assembled in a one-step process using either nail-gluing or mechanical pressure including pressure from clamps, presses, or other reasonably uniform measurable pressure, externally applied, to attach the plywood to the framing. If the unit is longer than available lengths of plywood, the skins and webs shall be spliced to full length, either with scarf joints, or butt joints with glued splice plates. Flange laminations of beams having glue lines parallel to the web may be glued at the same time as webs or preassembled. In either case, the laminating shall conform to the applicable requirements of ANSI/AITC Standard A1901.1 and ASTM D 3737.

If more than one unit is pressed at a time, care shall be taken to prevent distortion of any core material used in the assembly.

All cutouts for openings shall be reinforced as required in the design.

2326.3.2 Surfacing. The edges of framing members to which plywood skins or webs are to be glued shall be surfaced prior to assembly so that the members have a maximum variation in surface of $^1/_{64}$ inch (0.4 mm) and $^1/_{32}$ inch (0.8 mm) in depth for all framing members (allowing for actual thickness of any splice plates superimposed on blocking). This variation in depth shall apply to each framing member, as well as to the entire group of framing members within a unit.

Stiffeners for glued beams shall be surfaced prior to gluing so that their surfaces are flush with those of the flanges within $^1/_{32}$ inch (0.8 mm), allowing for any superimposed plywood splice plates.

For glued beams, flanges at all stiffener locations shall have a maximum deviation from square of $^1/_{16}$ inch (1.6 mm) in 6 inches (152 mm), measured perpendicular to an accurate square gage. Twist or bow which would prevent intimate contact of webs, or would cause the beam to deform, shall not be permitted.

Surfaces of high density overlaid plywood to be glued shall be roughened, as by a light sanding, before gluing.

2326.3.3 Glued joints. Plywood skins and webs shall be glued to all framing members over their full contact area, except that solid core curved panels may have the width and spacing of the contact area specified in the design.

All splice plates at butt joints in plywood skins and webs and all scarfed end joints shall be glued over their full contact area. Scarf joints shall be glued, under pressure, and those plywood surfaces in contact with the framing members shall be sanded smooth with tape removed prior to assembly.

2326.3.4 End joints in lumber.

2326.3.4.1 General. End joints in stringers, ribs and flange material, including shims, shall be as specified in the design for the grade and stress used.

2326.3.4.2 Scarf joints. Scarf joints in the lumber flanges shall be well scattered throughout. Unless otherwise specified, in adjoining laminations they shall be spaced not closer than 16 times the lamination thickness, measured from center to center. If shown on the approved plans, this spacing may be decreased to zero where the design indicates no bending stress. In flanges of three or less laminations, only one scarf joint shall be allowed at any one cross section; in flanges of four or more laminations, two scarf joints shall be allowed at the same cross section. Scarf slopes shall not be steeper than 1 unit vertical in 10 units horizontal (10% slope) unless otherwise permitted by the design.

2326.3.4.3 Butt joints. Stringer, rib and flange laminations shall not be butt jointed unless specified in the design. If permitted and not otherwise stipulated in the design, they shall be spaced at least 30 times the lamination thickness in adjoining (actually touching) laminations, and at least 10 times the lamination thickness in nonadjoining laminations.

2326.3.5 End joints in plywood.

2326.3.5.1 Scarf joints. When a skin or web is composed of panels less than full length, end joints shall be scarfed and glued, unless butt joints with plywood splice plates are permitted by the design. Slope of scarf joints shall not be steeper than 1 unit vertical in 8 units horizontal (12.5% slope).

2326.3.5.2 Butt joints in skins of panels. Butt joints shall be backed with plywood splice plates glued to one side of the skin. For ribbed panels, when glued during panel assembly the splice plate shall be backed with one or more pieces of lumber blocking, accurately machined in width so as to obtain adequate pressure. Lumber blocking by itself shall not be used for splicing skins unless shown on the approved plans.

Splice plates shall be centered over the butt joint, and shall have their grain parallel with that of the skin. Plates shall extend to within $^1/_4$ inch (6.4 mm) of the ribs; the latter shall not be notched to receive them, unless permitted by the design. Splice plates shall be at least equal in thickness to the skin, except that minimum thickness shall be $^1/_2$ inch (12.7 mm) if nail- or staple-glued. Minimum splice plate lengths shall be as shown in Table 23-VI-B.

Solid plywood core panels shall be scarf jointed to length if so specified by the design. If designated on the approved plans, joints in solid plywood core panels may be tightly butted, provided they will conform readily with the curvature of the surface. Spacing of butt joints shall not be less than 10 times the lamination thickness.

2326.3.5.3 Butt joints in webs of beams. Butt joints shall be staggered at least 24 inches (610 mm).

Splices at butt joints in webs shall be in accordance with the design. Unless otherwise noted in the design, at all web butt joints a plywood shear splice plate shall be centered over the joint and preglued prior to assembly. The plate shall extend to within $^1/_4$ inch (6.4 mm) of each flange on the inside of the beam, shall be at least equal in thickness to the web being spliced, of a length as specified on the approved plans, and shall have its grain parallel to that of the web. No splice plate shall consist of more than two pieces of plywood. Where the design provides for the stiffeners to act as the web splices, web butt joints shall be located over the center of the stiffener, within $^1/_{16}$ inch (1.6 mm), and webs shall be glued to the stiffener. The stiffener alone may be used as a splice plate when the web is 24 inches (610 mm) deep or less, and is no thicker than $^3/_8$ inch (9.5 mm), or carries no more shear than would be allowed on a $^3/_8$-inch (9.5 mm) panel.

2326.3.6 Stiffener location for beams. Stiffeners shall be placed as shown on the approved plans, but in any case they shall be spaced not to exceed 4 feet (1219 mm) on centers, and at reactions and other concentrated load joints.

Stiffeners shall be held in tight contact with the flanges by positive lateral pressure during fabrication.

2326.3.7 Assembly. Ribs, stringers, flanges and other framing members shall be assembled accurately and shall be square. Joints shall be made tight, and all framing members shall be of uniform thickness within $^1/_{32}$ inch (0.8 mm).

All gluing surfaces shall be flush within $^1/_{32}$ inch (0.8 mm).

Plywood may be lightly tacked to framing members so as to maintain alignment during pressing.

2326.3.8 Tongue-and-groove edge joint. Where a tongue-and-groove-type edge joint for stressed skin and curved panels is specified (and not otherwise detailed), the longitudinal framing member forming the tongue shall be of at least 2-inch (51 mm) nominal thickness, set out $^3/_4$ inch (19 mm) from the plywood edge plus or minus $^1/_{16}$ inch (1.6 mm). Edges of the tongue shall be eased so as to leave a flat shoulder at least $^3/_8$ inch (9.5 mm) wide. Any corresponding framing member forming the base of the groove shall be set back $^1/_4$ inch to 1 inch (6.4 mm to 25 mm) more than the amount by which the tongue protrudes. Abutting plywood edges may be chamfered. One face may be cut back $^1/_{16}$ inch (1.6 mm) to provide a tight fit for the opposite face.

2326.3.9 Nail- and pressure-gluing. Curved units shall be laminated over a form. Means shall be used that will provide close contact and substantially uniform pressure on panels and beams. Application of pressure or nailing may start at any point, but shall progress to an end or ends. Movement of the units shall not be permitted while the glue is setting.

Where clamping or other positive mechanical means are used, the pressure on the net framing area shall be sufficient to provide adequate contact and ensure good glue bond. Pressure shall be uniformly distributed by caul plates, beams or other effective means.

In place of mechanical pressure methods, nail-gluing may be used for bonding plywood to lumber and plywood to plywood, but shall not be used for bonding lumber to lumber. Regardless of the method used, the resulting glue line must meet the required standards. Nails shall be at least 4d for plywood up to $^3/_8$ inch (9.5 mm) thick, and 6d for $^1/_2$-inch to $^7/_8$-inch (12.7 mm to 22 mm) plywood, and 8d for 1-inch to $1^1/_8$-inch (25 mm to 29 mm) plywood. Nails shall be spaced not to exceed 3 inches (76 mm) along the ribs for plywood through $^3/_8$ inch (9.5 mm), or 4 inches (102 mm) for plywood $^1/_2$ inch (12.7 mm) and thicker, using one line for glue lines 2 inches (51 mm) wide or less, two lines for glue lines more than 2 inches (51 mm) wide and up to 4 inches (102 mm) wide, three lines for glue lines up to 10 inches (254 mm) wide and four lines for 12-inch-wide (305 mm) glue lines. (If shorter nail lengths are used in order to avoid penetrating the opposite face, spacing shall be decreased in proportion to actual penetration.)

Panels having solid plywood cores may be glued using staples or nails, following a schedule of demonstrated effectiveness, but in no case spaced farther apart than 6 inches (152 mm) both ways. Length of fasteners is limited by the available thickness of the laminations. Additional nailing, into temporary solid framing, may be required to provide close contact for adequate glue bonds.

In any case, it shall be the responsibility of the fabricator to produce a glue bond which meets or exceeds the requirements of this division.

2326.3.10 Insulation and ventilation. In hollow panels, insulating and vapor-barrier materials and ventilation provided as specified in the design shall be securely fastened in the assembly in such a way that they cannot interfere with the process of gluing the plywood skins to the framing members or with the ventilation pattern.

When specified, longitudinal sections shall be vented through blocking and headers on the cool side of the insulation. Provision shall be made to line up the ventholes in assembling panels, with a definite ventilation pattern leading to the outdoors. Framing members shall not be notched for ventilation, unless shown on the approved plans.

2326.4 Identification. Each member shall be identified by the appropriate trademark of the approved independent inspection and testing agency, legibly applied so as to be clearly visible. If the strength of one surface of a beam or panel is different from the other, the top surface shall be identified.

2326.5 Test Samples. When glue bond test samples are taken from a member and from trim, they shall be taken as cores approximately 2 inches (51 mm) in diameter, drilled perpendicular to the plane of the skins or webs, and no deeper than $^3/_4$ inch (19 mm) into any framing member. Samples at beam flanges shall be taken from the ends of the beams only. Centers of cores shall normally be located in the top corner of the beam at points within 2 inches (51 mm) from one edge and up to 6 inches (152 mm) from the other.

No samples shall be taken from the same skin or web closer together than 12 inches (305 mm), except as detailed in Exception 2. Samples shall be taken at a distance from the panel ends not greater than the panel depth.

EXCEPTIONS: 1. One sample may be taken from one of the outside longitudinal framing members, within the outer fourth points of the panel length, provided the framing member is notched no deeper than $^1/_2$ inch (12.7 mm) below its edge. The other outside longitudinal framing member may be sampled similarly, but at the opposite end of the panel.

2. Two samples per butt joint at any one cross section may be taken from skin or web splice plates. They shall be located midway between longitudinal framing members, and shall be aligned longitudinally, one on each side of the butt joint.

Samples through beam web splice plates shall be taken within the middle half of the span, at the center line of the beam depth.

Where the core of curved panels consists of solid plywood or a solid core material, only one core shall be taken at any one cross section. Cross sections shall be no closer than 12 inches (305 mm) along the arc. Not more than four cores shall be taken from a 4-foot-wide (1219 mm) panel, with a proportionate number limited to other widths. Ribs in such panels shall be sampled as required by this section, except that at ribs the core shall not extend more than $^{3}/_{4}$ inch (19 mm) into the rib.

Samples may be taken from other locations when approved by the building official.

2326.6 Testing of Glued Joints.

2326.6.1 General. This section shall govern all glued joints which have not been subjected to prior inspection and testing such as the glue line between plywood and lumber as contained in ASTM D 1101 and AITC 200. These joints shall be referred to as "secondary" glue lines. Glued joints subjected to prior testing such as those in plywood shall be referred to as "primary" glue lines. Before testing, specimens shall be allowed to cure.

All secondary glue line testing shall be performed by approved testing agencies. Test specimens containing localized defects permitted by the grade of the material involved shall be discarded.

2326.6.2 Lumber-plywood side grain combinations.

2326.6.2.1 Selection of test samples. Lumber-plywood side grain samples shall be taken from members selected at random. They shall consist of 2-inch-diameter (51 mm) core of adequate depth and location to yield sufficient material on both sides of the secondary glue line.

Members to be sampled shall be selected to include production variables such as different lots of material, glue batches, shifts and crews.

Trim may be acceptable in lieu of cores for sampling purposes if it is truly representative of the member.

2326.6.2.2 Dry shear strength testing. Lumber and plywood side grain specimens shall be tested in a block shear tool with the load applied through a self-aligning seat to ensure uniform lateral distribution of the load. Rate of load application shall be 0.2 inch (5.1 mm) per minute. Ultimate load shall be read to the nearest 5 pounds (22.2 N) and wood failure shall be determined to the nearest 5 percent.

2326.6.2.3 Durability testing.

2326.6.2.3.1 Interior. This test method shall be used in all cases where the durability requirement for the completed component is Interior.

Lumber and plywood side grain specimens shall be submerged in water at room temperature for a period of four hours and then dried at a temperature between 100°F and 105°F (37.8°C. and 40.6°C) for a period of 19 hours with sufficient air circulation in drying cabinet to lower moisture content of specimen to a maximum of 8 percent based on oven-dry weight. This test procedure shall be conducted through three cycles, unless all specimens have failed. All specimens shall be inspected after the first and third cycles and all failures recorded. Total continuous delamination 1 inch (25 mm) along the edge ofthe test specimen and $^{1}/_{4}$ inch (6.4 mm) deep shall be considered as failure.

2326.6.2.3.2 Exterior. This test method shall be used where the test specimen contains exterior-type adhesives throughout and where the durability requirement for the completed component is Exterior.

Lumber and plywood specimens shall be cycled by one of the following methods:

1. **Cold soak.** Test specimens shall be submerged in water at room temperature for 48 hours and then dried for eight hours at a temperature of 145°F (62.8°C) [± 5°F (2.8°C)], followed by two cycles of soaking for 16 hours and drying for eight hours under conditions described above. The specimens shall be soaked again for a period of 16 hours.

2. **Vacuum pressure.** Place the specimens in the pressure vessel and weight them down. Admit water at a temperature of 65°F to 80°F (18.3°C. to 26.7°C) in sufficient quantity so that the specimens are completely submerged. Separate the specimens by stickers, wire screens or other means in such a manner that all end grain surfaces are freely exposed to the water. Draw a vacuum of 20 inches to 25 inches (67.5 kPa to 84.4 kPa) of mercury (at sea level) and hold for 30 minutes. Release the vacuum and apply a pressure of 40 plus or minus 5 pounds per square inch (275.8 kPa ± 34.5 kPa) for two hours.

While still wet, the specimens shall be tested in accordance with the method specified above in Section 2326.6.2.2.

2326.6.2.4 Performance requirements.

2326.6.2.4.1 General. The minimum performance requirements for laboratory testing of all side grain glue joint specimens shall be as specified in this section. If two or more grain orientations are present in any one test run or combinations of test runs, an adjusted average shear stress performance requirement shall be computed by the weighted average method.

2326.6.2.4.2 Dry shear strength requirements. The specimens shall have an average dry strength shear stress as set forth in Table 23-VI-G.

2326.6.2.4.3 Interior durability requirement. Ninety-five percent of all specimens shall pass the first cycle and 85 percent shall pass three cycles.

2326.6.2.4.4 Exterior durability requirement. Eighty-five percent of more wood failure shall be required for the overall average. Ninety percent of all specimens tested shall show 60 percent or more wood failure, 80 percent of all specimens tested shall show 80 percent or more wood failure. Failure in any part of test specimen, except glue failure in the secondary glue bond tested, is wood failure.

2326.6.3 Lumber end joints.

2326.6.3.1 General. Plain scarf joints and finger joints shall be tested in accordance with the provisions of ASTM D 1101 and AITC 200.

2326.6.3.2 Selection of test samples. Test samples shall be obtained from full-size joints, or from scarf joints selected at random from routine production. The latter shall be taken from the center line of the lamination containing the scarf being sampled. No more than one sample shall be taken from any component cross section and scarf samples shall not be closer than 4 feet (1219 mm).

2326.6.3.3 Dry tension testing. Specimens shall be tested in accordance with AITC 200.

2326.6.3.4 Durability testing.

2326.6.3.4.1 Interior. Test specimens shall be submerged in water at room temperature for a period of four hours and then dried at a temperature between 100°F and 105°F (37.8°C. and 40.6°C) for a period of 19 hours with sufficient air circulation in drying cabinet to lower moisture content of specimen to a maximum of 8 percent based on oven-dry weight. This test procedure shall be conducted through three cycles, unless all specimens have failed.

The specimens then shall be tested dry in accordance with AITC 200.

2326.6.3.4.2 Exterior. Test specimens shall be cycled by one of the following methods:

1. **Cold soak.** Test specimens shall be submerged in water at room temperature for 48 hours and then dried for eight hours at a temperature of 145°F (62.8°C) [± 5°F (2.8°C)], followed by two cycles of soaking for 16 hours and drying for eight hours under conditions described above. The specimens shall be soaked again for a period of 16 hours.

2. **Vacuum pressure.** Place the specimens in the pressure vessel and weight them down. Admit water at a temperature of 65°F to 80°F (18.3°C. to 26.7°C) in sufficient quantity so that the specimens are completely submerged. Separate the specimens by stickers, wire screens, or other means in such a manner that all end grain surfaces are freely exposed to the water. Draw a vacuum of 20 inches to 25 inches (67.5 kPa to 84.4 kPa) of mercury (at sea level) and hold for 30 minutes. Release the vacuum and apply a pressure of 40 plus or minus 5 pounds per square inch (275.8 kPa ± 34.5 kPa) for two hours.

The specimens shall then be tested wet in accordance with AITC 200.

2326.6.3.5 Performance requirements.

2326.6.3.5.1 General. The minimum performance requirements for laboratory testing of all lumber end joint specimens shall be as specified in this section.

2326.6.3.5.2 Dry tension stress requirements. The test specimens shall have the tension stresses set forth in Table 23-VI-H. No test value shall be less than twice the normal allowable stress.

Dry tension wood failure requirements regardless of species shall average not less than 80 percent except tests averaging at least 10,000 pounds per square inch (69 N/mm^2) in tension shall not have less than 70 percent. The minimum requirement for 90 percent of the individual specimens shall not be less than 40 percent wood failure.

2326.6.3.5.3 Interior durability requirement. Average wood failure shall not be less than 70 percent.

2326.6.3.5.4 Exterior durability requirement. Average wood failure shall not be less than 85 percent and the minimum requirement for 90 percent of the individual specimens shall not be less than 50 percent.

2326.6.4 Plywood end joints.

2326.6.4.1 General. Plain plywood scarf joints shall be tested in accordance with the provisions of this section. Splice butt joints shall be tested as specified in Section 2326.6.2.

2326.6.4.2 Selection of test samples. Full width scarfs shall be selected at random from routine production. A minimum of 2 percent of the scarfs produced shall be sampled. At least 20 specimens suitable for testing shall be obtained from each 4 feet (1219 mm) of scarf. They shall be equally distributed across the width.

2326.6.4.3 Dry tension. Specimens shall be tested in a tension machine equipped with wedge-type grips. Dry tension specimens shall be loaded at a rate of 0.4 inch (10 mm) per minute. Ultimate load shall be read to the nearest 5 pounds (22.2 N) and wood failure on the joined surface estimated to the nearest 5 percent. Wood failure shall be estimated on the scarf surface of the plies parallel to the direction of the tension load.

2326.6.4.4 Durability.

2326.6.4.4.1 Interior. Interior durability test specimens shall be sub-merged in water at room temperature for a period of four hours and then dried at a temperature between 100°F and 105°F (37.8°C. and 40.6°C) for a period of 19 hours with sufficient air circulation in drying cabinet to lower moisture content of specimen to a maximum of 8 percent based on oven-dry weight. This test procedure shall be conducted through three cycles, unless all specimens have failed. Test specimens showing delamination on the face or end in excess of $^1/_{16}$ inch (1.6 mm) deep and $^1/_2$ inch (12.7 mm) long at the scarf glue line shall be considered as failing.

2326.6.4.4.2 Exterior. Exterior durability test specimens shall be cycled by one of the following methods:

1. **Cold soak.** Test specimens shall be submerged in water at room temperature for 48 hours and then dried for eight hours at a temperature of 145°F (62.8°C) [± 5°F (2.8°C)], followed by two cycles of soaking for 16 hours and drying for eight hours under conditions described above. The specimens shall be soaked again for a period of 16 hours.

2. **Vacuum pressure.** Place the specimens in the pressure vessel and weight them down. Admit water at a temperature of 65°F to 80°F (18.3°C. to 26.7°C) in sufficient quantity so that the specimens are completely submerged. Separate the specimens by stickers, wire screens, or other means in such a manner that all end grain surfaces are freely exposed to the water. Draw a vacuum of 20 inches to 25 inches of mercury (67.5 kPa to 84.4 kPa) (at sea level) and hold for 30 minutes. Release the vacuum and apply a pressure of 40 ± 5 pounds per square inch (275.8 kPa ± 34.5 kPa) for two hours.

While still wet, the specimens shall be tested in a tension machine equipped with wedge-type grips. Dry tension specimens shall be loaded at a rate of 0.4 inch (10 mm) per minute. Ultimate load shall be read to the nearest 5 pounds (22.2 N) and wood failure on the joined surface estimated to the nearest 5 percent.

2326.6.4.5 Performance requirements.

2326.6.4.5.1 General. The minimum performance requirements for laboratory testing of all lumber end joint specimens shall be as specified in this section.

2326.6.4.5.2 Dry tension stress. The average tension stress for Group 1 shall be 4,000 pounds per square inch (28 N/mm^2); for Groups 2 and 3, 2,800 pounds per square inch (19 N/mm^2); and 2,400 pounds per square inch (17 N/mm^2) for Group 4, all adjusted as required for inner ply species. Regardless of species, wood failure shall average not less than 80 percent and the minimum requirement for 90 percent of the individual test specimens shall not be less than 50 percent.

2326.6.4.5.3 Durability requirements.

1. **Interior.** Ninety-five percent of all test specimens shall pass one cycle and 85 percent shall pass three cycles.

2. **Exterior.** Average wood failure shall not be less than 85 percent.

SECTION 2327 — ALL-PLYWOOD BEAMS

2327.1 Scope. This part covers requirements for the design of all-plywood beams as referred to in Section 2305.8.

2327.2 Definition. All-plywood beams are staple-glued structural units consisting of one or more vertical layers of butt-jointed plywood for webs which resist both bending and shear forces. Plywood web splice plates located at web joints, and/or one or more vertical layers of butt-jointed plywood for flanges, may also be staple glued to the webs for added resistance to shear and bending forces, if necessary. Plywood web stiffeners are staple-glued to single-layer webs to distribute concentrated loads and resist web buckling at end supports and interior concentrated load points. (For design of plywood beams consisting of plywood webs attached to lumber flanges, see Section 2324 of this division.)

2327.3 Allowable Stresses. Allowable stresses for plywood used in all-plywood beams shall not exceed the values set forth in Table 23-III-A, except that allowable bending stress may be multiplied by 2 for five-ply, five-layer plywood, and by 1.7 for three-, four- or five-ply, three-layer plywood. Five-ply, five-layer plywood with butt-jointed center ply shall be considered as three-layer plywood for design purposes.

2327.4 Design.

2327.4.1 Bending. The allowable resisting moment for a beam section shall not exceed the value established by the following formula:

$$M = \frac{f\,I}{Z}$$

WHERE:

- f = allowable working stress in bending for plywood, in pounds per square inch (N/mm^2). Also, see Section 2327.3.
- I = the minimum net moment of inertia, in inches to the fourth power (mm^4), of all continuous parallel grain material at any beam section containing a web or flange butt joint. Location of the neutral axis shall be calculated without considering butt joints in the web of flanges (if used). Also, see Section 2327.6.2. A web splice plate (if used) shall be included in the net amount of inertia only if directly glued to the web layer containing the butt joint.
- M = resisting moment in inch-pounds (N·mm).
- Z = distance in inches (mm) from the neutral axis to the extreme fiber in bending.

2327.4.2 Horizontal shear. The allowable shear on the plywood web shall not exceed the value established by the following formula:

$$V = \frac{vI\,\Sigma t}{Q}$$

WHERE:

- I = total moment of inertia, in inches to the fourth power (mm^4), of all parallel grain material in the web and flanges regardless of butt joints. Stiffeners or web splice plates shall be disregarded.
- Q = statical moment about the neutral axis, in inches to the third power (mm^3), of all parallel grain material in the web and flanges, regardless of butt joints, lying above (or below) the neutral axis. Stiffeners or web splice plates shall be disregarded.
- V = allowable total shear on the section, in pounds (N). Loads may be disregarded that are located within a distance from the support equal to the beam depth.
- v = allowable plywood shear stress through the panel thickness, in pounds per square inch (N/mm^2).
- Σt = total shear thickness of continuous webs (and/or web splice plates and stiffeners, if applicable) at the neutral axis of the section, in inches (mm). Also, see Section 2327.6.2.

2327.4.3 Flange-web shear (rolling shear). For beams containing plywood flanges, the allowable flange-web shear on glued joints shall not exceed the value established by the following formula:

$$V = \frac{nsdI}{Q_{fl}}$$

WHERE:

- d = depth of contact area between flange and web, in inches (mm).
- I = total moment of inertia, in inches to the fourth power (mm^4), of all parallel grain material in the web and flanges regardless of butt joint. Stiffeners or web splice plates shall be disregarded.
- n = number of contact surfaces between web and flange.
- Q_{fl} = statical moment about the neutral axis, in inches to the third power (mm^3), of all parallel grain material in the upper (or lower) flanges, regardless of butt joints.
- s = one half of the allowable plywood rolling shear stress, in pounds per square inch (N/mm^2).
- V = allowable total shear on the section, in pounds (N). Loads may be disregarded that are located within a distance from the support equal to the beam depth.

2327.4.4 Lateral stability. The compression edges of the beam shall be positively restrained from lateral buckling, as by fastening to structural panel sheathing, framing spaced no further than 24 inches (610 mm) on center, and/or by ceiling material.

2327.4.5 Connections. Bolts, lag screws or other similar large-diameter connectors shall not be used in web or flange tension areas where bending stresses exceed the allowable values set forth in Table 23-III-A.

2327.5 Materials.

2327.5.1 Plywood. Plywood shall be as required in Section 2326.2.1. Plywood pieces cut $4^1/_2$ inches (114 mm) or less in width for flanges shall be visually inspected after cutting for size of knots. Pieces containing knots in face or back plies larger than two thirds of the flange width shall not be used in fabricating flanges for all-plywood beams.

2327.5.2 Glue. Glue shall be as specified in Section 2326.2.3.

2327.5.3 Staples. Staples shall be 16 gage by $^7/_{16}$-inch (1.6 mm by 11 mm) crown, made from galvanized steel wire. Staple length shall be $^1/_8$ inch (3.2 mm) less than the total thickness of materials joined.

2327.6 Fabrication.

2327.6.1 General. Plywood beams shall be fabricated with glue and staples. Plywood face grain for webs, flanges, web splice plates and stiffeners shall be oriented parallel to the span (i.e., horizontally).

2327.6.2 Web and flange end joints. End joints in plywood webs and flanges shall be located as specified in the design. Joints in any web or flange lamination shall be spaced at least 24 inches (610 mm) from the nearest joint in any other lamination. In single-web beams, joints in webs shall be located at least 24 inches (610 mm) from any end or interior support.

Butt joints at ends of plywood web or flange pieces shall be trimmed square and tightly butted [maximum gap $^1/_{32}$ inch (0.8 mm)].

2327.6.3 Adhesive application. Adhesive shall be spread uniformly over the full contact area of mating web and/or flange surfaces.

If web or flange laminations are glued under pressure, such pressure shall be applied by clamping or other mechanical means. Pressure shall be sufficient to provide adequate contact and ensure good glue bonds [100 to 150 psi (689 to 1034 kPa) is suggested, unless otherwise specified by the adhesive manufacturer]. Movement of the members shall be prevented until the adhesive develops sufficient handling strength as recommended by the adhesive manufacturer.

In any case, it shall be the responsibility of the fabricator to produce a glue bond which meets or exceeds applicable specifications.

2327.6.4 Staple installation. Staples shall be installed with their crowns parallel to the plywood face-grain direction. Staple spacing shall be as shown in Figure 23-VI-1.

Installation of staples may start at any point but shall progress to the end or ends of each piece. Pressure may be needed during stapling to flatten webs and flanges to ensure uniform contact between mating glued surfaces.

2327.6.5 Web splices. Splices at butt joints in webs shall be as specified in the design. Butt joints shall be spliced with a plywood plate centered over the joint. The splice plate shall be glued over its full contact area and stapled to the web in accordance with Figure 23-VI-1. The plate shall extend to at least $^1/_4$ inch (6.4 mm) of each flange (if applicable); shall be equal in thickness to the web; shall be of a length as specified in the design or in Table 23-VI-B; and shall have its face-grain direction parallel with that of the web. In multiple-layer webs, the splice plate shall be directly glued to the web containing the butt joint.

2327.6.6 Web stiffeners. Stiffeners for single-layer webs shall be located as shown in the design, but in any case they shall be placed at end supports and at interior concentrated-load points.

The stiffeners shall consist of a plywood plate glued over its full contact area and stapled to the web in accordance with Figure 23-VI-1. The plate shall extend to at least $^1/_4$ inch (6.4 mm) of each flange (if applicable); shall be at least equal in thickness to the web; shall be of a length as specified in the design, but in no case less than 10 inches (254 mm); and shall have its face-grain direction parallel with that of the web. The end or ends of the stiffener shall extend at least 6 inches (152 mm) beyond the edges of the support at the end and any interior supports.

Single-layer webs shall be reinforced at cutouts with a plywood web stiffener.

2327.7 Identification. Each member shall be identified as specified in Section 2326.4.

2327.8 Test Samples. Test samples shall be as specified in Section 2326.5.

2327.9 Testing of Glued Joints. Plywood splice butt joints shall be tested as specified in Section 2326.6.2.

TABLE 23-VI-A—BASIC SPACING

PLYWOOD THICKNESS (inches)	PLYWOOD FINISH	BASIC SPACING "*b*" (inches)	
× 25.4 for mm		× 25.4 for mm	
		Face Grain Parallel to Longitudinal Members	Face Grain Perpendicular to Longitudinal Members
1/4	Sanded	10.3	11.6
5/16	Rough	11.9	16.8
3/8	Rough (3-ply)	14.2	20.1
3/8	Sanded (3-ply)	16.4	16.4
3/8	Sanded (5-ply)	18.1	20.2
1/2	Rough and sanded (5-ply)	23.2	28.5
5/8	Rough and sanded (5-ply)	29.1	35.6
3/4	Rough and sanded (5-ply)	38.2	38.2
7/8	Sanded (7-ply)	41.6	48.1
1	Rough (7-ply)	45.5	58.9
1	Sanded (7-ply)	54.5	47.9

TABLE 23-VI-B—LENGTH OF SPLICE PLATES

THICKNESS OF SKIN (inches)	LENGTH OF SPLICE PLATE (inches)
× 25.4 for mm	
1/4	6
5/16	8
3/8 (sanded)	10
3/8 (unsanded)	12
1/2	14
5/8	16
3/4	16

TABLE 23-VI-C—ALLOWABLE PLYWOOD TENSION STRESS FOR BUTT JOINT SPLICE[1]

PLYWOOD THICKNESS (inches)	ALL STRUCT. I GRADES	GROUP 1	GROUP 2 AND GROUP 3	GROUP 4
× 25.4 for mm	× 0.00689 for N/mm^2			
1/4, 5/16, 3/8 sanded, 3/8 unsanded	1,200	960	800	720
1/2	1,200	800	760	720
5/8 and 3/4	960	640	600	560

[1]These values are based on stress acting parallel to the face grain and must be reduced in accordance with Table 23-III-A for stresses perpendicular or at 45 degrees to face grain. In addition, stresses are based on a ratio of width of splice plate to the width of the stressed skin of 80 percent. Where other ratios are used, the allowable stress shall be adjusted accordingly. For applicable species groups for unsanded panels, refer to Footnote 1 of Table 23-III-A.

TABLE 23-VI-D—BRACING FOR DEEP NARROW BEAM

$\frac{I_x}{I_y}$	TYPE OF BRACING REQUIRED
Not more than 5	None required
More than 5 to not more than 10	Ends held in position at bottom flanges at supports
More than 10 to not more than 20	Ends held in position at top and bottom flanges at supports
More than 20 to not more than 30	Top or bottom flange continuously supported in accordance with Section 2324.3.1.3
More than 30 to not more than 40	Beam restrained by bridging or other bracing at not more than 8 feet (2438 mm) on center
More than 40	Bridging at 8 feet (2438 mm) on center and compression flanges continuously supported in accordance with Section 2324.3.1.3

TABLE 23-VI-E—AREA REDUCTION FACTORS

BUTT JOINT SPACING T = LAMINATION THICKNESS	PERCENT OF GROSS AREA OF ADJACENT LAMINATION EFFECTIVE
$30T$ $20T$	90 80
$10T$	60
Less than $10T$	0

TABLE 23-VI-F—WEB STIFFENER SPACING

PLYWOOD WEB THICKNESS (inches)	CLEAR DISTANCE BETWEEN FLANGES (inches)					
	10	20	30	40	50	60 or More
× 25.4 for mm						
$^3/_8$	15	15	15	15	15	15
$^1/_2$	27	22	22	22	22	22
$^5/_8$	48	29	28	28	28	28
$^3/_4$	48	38	35	34	34	34
$^7/_8$	48	48	41	39	39	39
1	48	48	48	48	46	45
$1^3/_{16}$	48	48	48	48	48	48

TABLE 23-VI-G—DRY SHEAR STRENGTH STRESS REQUIREMENTS[1]

GRAIN ORIENTATION OF LUMBER OR PLYWOOD WITH RESPECT TO ADJACENT PLY OR LUMBER LAMINATION	AVERAGE SHEAR STRESS (pounds per square inch)
	× 0.00689 for N/mm^2
(Douglas Fir and Southern Pine)	
Parallel 45° Perpendicular	650 500 250
(Other Species)	
Parallel 45° Perpendicular	520 400 200

[1]The minimum shear test value shall not be less than twice the normal allowable rolling shear value.

TABLE 23-VI-H—DRY TENSION STRESS

AVERAGE TENSION STRESS (pounds per square inch)	MINIMUM TENSION STRESS FOR AT LEAST 80 PERCENT OF SPECIMENS (pounds per square inch)
× 0.00689 for N/mm^2	
[Douglas Fir (Coast type) and Southern Pine]	
7,000	6,000
(Other Species)	
6,000	5,000

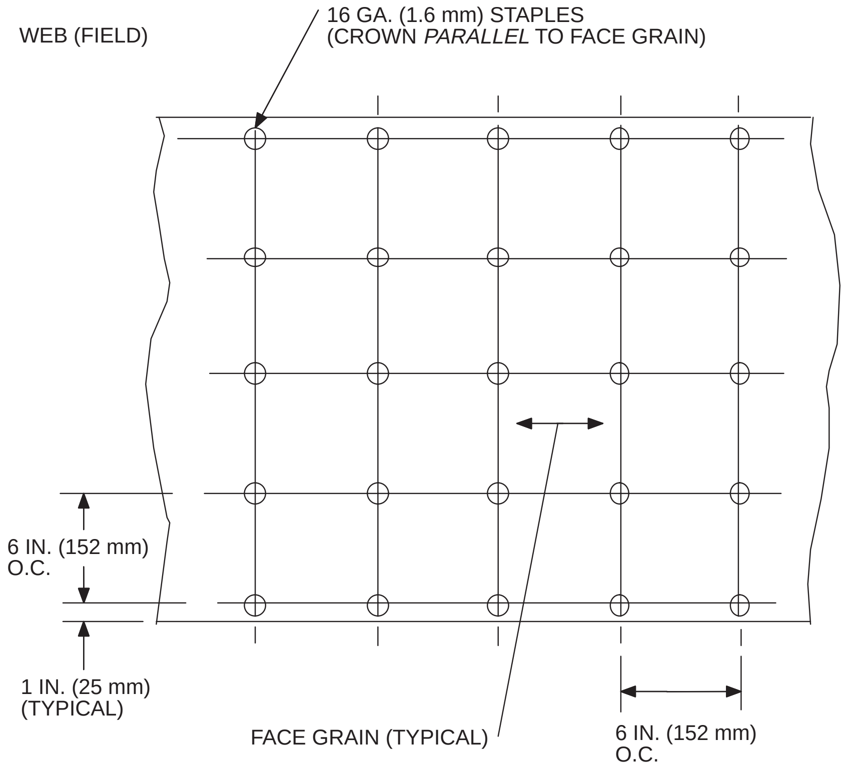
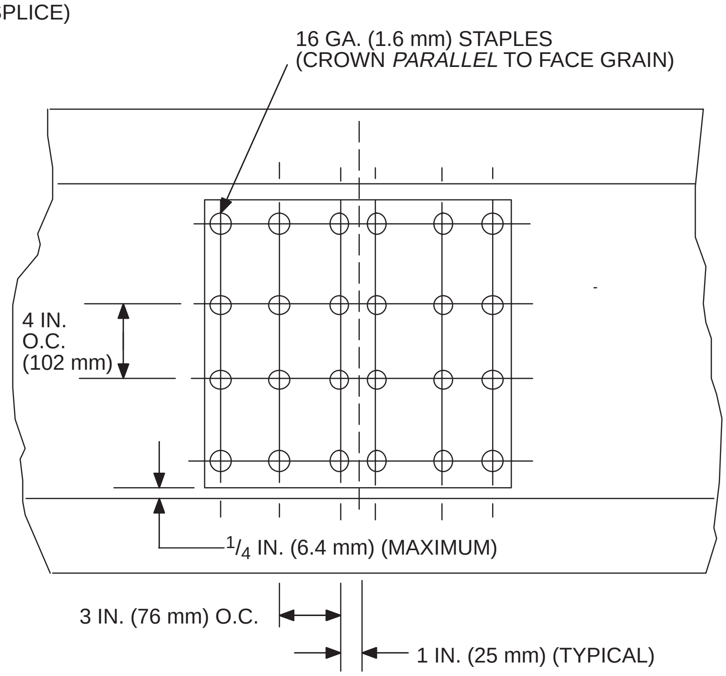


FIGURE 23-VI-1—STAPLE SPACING FOR PLYWOOD WEBS, FLANGES, SPLICE PLATES AND STIFFENERS

WEB (SPLICE)



WEB (JOINT)

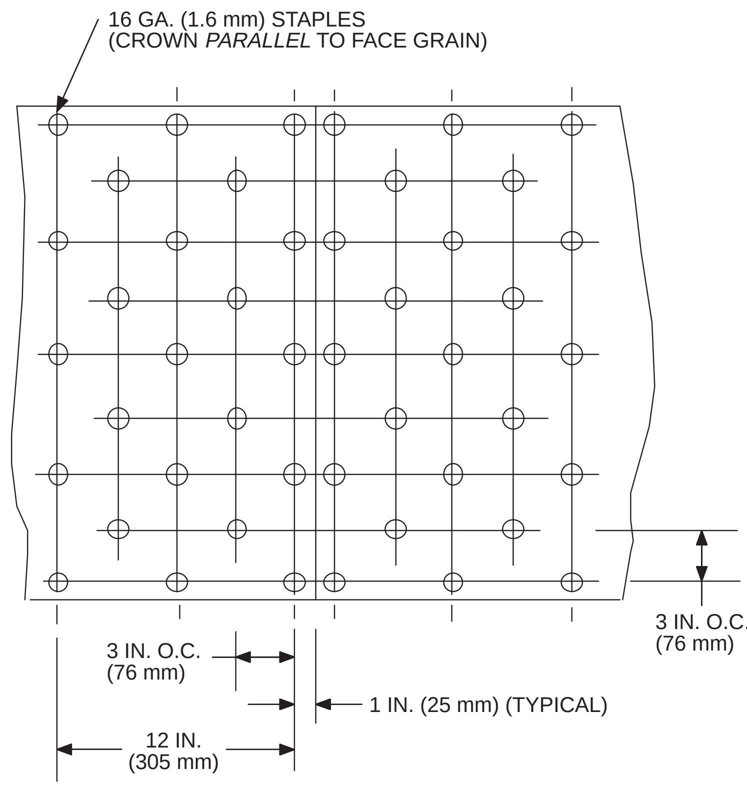
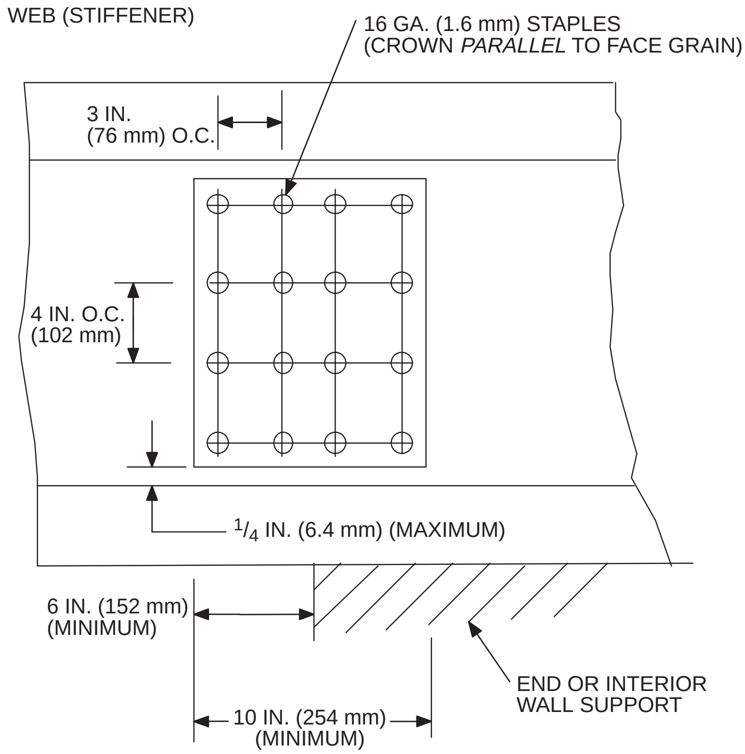


FIGURE 23-VI-1—STAPLE SPACING FOR PLYWOOD WEBS, FLANGES, SPLICE PLATES AND STIFFENERS—(Continued)



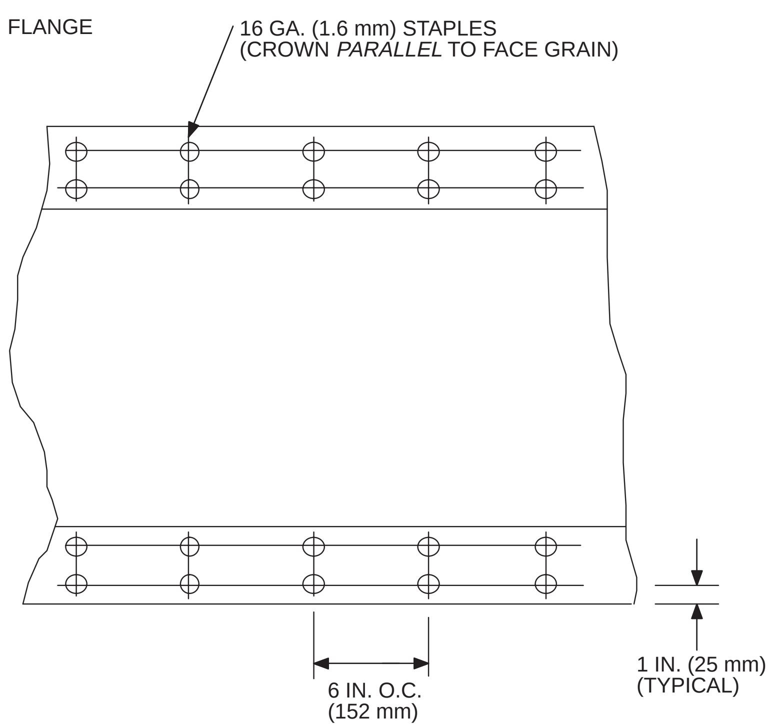


FIGURE 23-VI-1—STAPLE SPACING FOR PLYWOOD WEBS, FLANGES, SPLICE PLATES AND STIFFENERS—(Continued)

Division VII—DESIGN STANDARD FOR SPAN TABLES FOR JOISTS AND RAFTERS

SECTION 2328 — SPAN TABLES FOR JOISTS AND RAFTERS

2328.1 Scope. This standard covers the loading (DL and LL) and deflection criteria used to establish the allowable spans in Tables 23-IV-J-1 through 23-IV-R-12 and the tables of this division. The tables in this standard are intended for light-frame construction.

SECTION 2329 — DESIGN CRITERIA FOR JOISTS AND RAFTERS

The allowable spans of tables of this standard and Tables 23-IV-J-1 through 23-IV-R-12 are calculated on the basis of a series of modulus of elasticity (E), and fiber stress (F_b) values. The range of values in the tables provides allowable spans for all species and grades of nominal 2-inch lumber customarily used in construction. The allowable span is the clear distance between supports. For sloping rafters the span is measured along the horizontal projection.

SECTION 2330 — LUMBER STRESSES

The use of the span tables requires reference to the list of single or repetitive member bending stress values (F_b) and modulus of elasticity values (E) from Tables 23-IV-V-1 and 23-IV-V-2.

SECTION 2331 — MOISTURE CONTENT

Tabulated spans are calculated on the basis of the dry sizes and are also applicable to the corresponding green sizes. The spans in these tables are intended for use in covered structures or where moisture content in use does not exceed 19 percent.

SECTION 2332 — LUMBER SIZE

Tabulated spans apply to surfaced (S4S) lumber having dimensions which conform to UBC Standard 23-1.

SECTION 2333 — SPAN TABLES FOR JOISTS AND RAFTERS

The following tables are based on the design criteria set forth in each table and of this standard.

TABLE 23-VII-J-1—FLOOR JOISTS WITH *L*/360 DEFLECTION LIMITS
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 50 psf (2.4 kN/m^2) live load.
Limited to span in inches (mm) divided by 360.
Strength — Live load of 50 psf (2.4 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi (× 0.00689 for N/mm^2)																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 6	12.0	7-11	8-3	8-6	8-9	9-1	9-3	9-6	9-9	9-11	10-2	10-4	10-6	10-9	10-11	11-1	11-3	11-5
	16.0	7-2	7-6	7-9	8-0	8-3	8-5	8-8	8-10	9-1	9-3	9-5	9-7	9-9	9-11	10-1	10-2	10-4
	19.2	6-9	7-0	7-3	7-6	7-9	7-11	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4	9-6	9-7	9-9
	24.0	6-3	6-6	6-9	7-0	7-2	7-4	7-7	7-9	7-11	8-1	8-3	8-4	8-6	8-8	8-9	8-11	9-1
2 × 8	12.0	10-5	10-10	11-3	11-7	11-11	12-3	12-7	12-10	13-1	13-5	13-8	13-11	14-2	14-4	14-7	14-10	15-0
	16.0	9-6	9-10	10-2	10-6	10-10	11-1	11-5	11-8	11-11	12-2	12-5	12-7	12-10	13-1	13-3	13-5	13-8
	19.2	8-11	9-3	9-7	9-11	10-2	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-3	12-6	12-8	12-10
	24.0	8-3	8-7	8-11	9-2	9-6	9-9	10-0	10-2	10-5	10-8	10-10	11-0	11-3	11-5	11-7	11-9	11-11
2 × 10	12.0	13-3	13-10	14-4	14-9	15-2	15-7	16-0	16-5	16-9	17-1	17-5	17-9	18-0	18-4	18-7	18-11	19-2
	16.0	12-1	12-7	13-0	13-5	13-10	14-2	14-7	14-11	15-2	15-6	15-10	16-1	16-5	16-8	16-11	17-2	17-5
	19.2	11-4	11-10	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-7	14-11	15-2	15-5	15-8	15-11	16-2	16-5
	24.0	10-7	11-0	11-4	11-9	12-1	12-5	12-8	13-0	13-3	13-7	13-10	14-1	14-4	14-7	14-9	15-0	15-2
2 × 12	12.0	16-2	16-10	17-5	18-0	18-6	19-0	19-6	19-11	20-4	20-9	21-2	21-7	21-11	22-3	22-8	23-0	23-4
	16.0	14-8	15-3	15-10	16-4	16-10	17-3	17-8	18-1	18-6	18-10	19-3	19-7	19-11	20-3	20-7	20-10	21-2
	19.2	13-10	14-4	14-11	15-4	15-10	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-4	19-8	19-11
	24.0	12-10	13-4	13-10	14-3	14-8	15-1	15-5	15-10	16-2	16-6	16-10	17-1	17-5	17-8	18-0	18-3	18-6
F_b	12.0	743	803	862	918	973	1,026	1,078	1,129	1,179	1,228	1,275	1,322	1,368	1,413	1,458	1,502	1,545
	16.0	817	884	949	1,011	1,071	1,130	1,187	1,243	1,298	1,351	1,404	1,455	1,506	1,555	1,604	1,653	1,700
	19.2	869	940	1,008	1,074	1,138	1,201	1,261	1,321	1,379	1,436	1,491	1,546	1,600	1,653	1,705	1,756	1,807
	24.0	936	1,012	1,086	1,157	1,226	1,293	1,359	1,423	1,485	1,547	1,607	1,666	1,724	1,781	1,837	1,892	1,946

NOTE: The required bending design value, F_b, in pounds per square inch (N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less. Check sources of supply for availability of lumber in lengths greater than 20 feet (6096 mm).

TABLE 23-VII-J-2—FLOOR JOISTS WITH *L*/360 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 60 psf (2.87 kN/m^2) live load.
Limited to span in inches (mm) divided by 360.
Strength — Live load of 60 psf (2.87 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi (× 0.00689 for N/mm^2)																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 6	12.0	7-5	7-9	8-0	8-3	8-6	8-9	8-11	9-2	9-4	9-7	9-9	9-11	10-1	10-3	10-5	10-7	10-9
	16.0	6-9	7-0	7-3	7-6	7-9	7-11	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4	9-6	9-7	9-9
	19.2	6-4	6-7	6-10	7-1	7-3	7-6	7-8	7-10	8-0	8-2	8-4	8-6	8-8	8-9	8-11	9-0	9-2
	24.0	5-11	6-2	6-4	6-7	6-9	6-11	7-1	7-3	7-5	7-7	7-9	7-10	8-0	8-2	8-3	8-5	8-6
2 × 8	12.0	9-10	10-2	10-7	10-11	11-3	11-6	11-10	12-1	12-4	12-7	12-10	13-1	13-4	13-6	13-9	13-11	14-2
	16.0	8-11	9-3	9-7	9-11	10-2	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-3	12-6	12-8	12-10
	19.2	8-5	8-9	9-0	9-4	9-7	9-10	10-1	10-4	10-7	10-9	11-0	11-2	11-4	11-7	11-9	11-11	12-1
	24.0	7-9	8-1	8-5	8-8	8-11	9-2	9-4	9-7	9-10	10-0	10-2	10-5	10-7	10-9	10-11	11-1	11-3
2 × 10	12.0	12-6	13-0	13-6	13-11	14-4	14-8	15-1	15-5	15-9	16-1	16-5	16-8	17-0	17-3	17-6	17-9	18-0
	16.0	11-4	11-10	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-7	14-11	15-2	15-5	15-8	15-11	16-2	16-5
	19.2	10-8	11-1	11-6	11-11	12-3	12-7	12-11	13-2	13-6	13-9	14-0	14-3	14-6	14-9	15-0	15-2	15-5
	24.0	9-11	10-4	10-8	11-0	11-4	11-8	11-11	12-3	12-6	12-9	13-0	13-3	13-6	13-8	13-11	14-1	14-4
2 × 12	12.0	15-2	15-10	16-5	16-11	17-5	17-11	18-4	18-9	19-2	19-7	19-11	20-3	20-8	21-0	21-4	21-7	21-11
	16.0	13-10	14-4	14-11	15-4	15-10	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-4	19-8	19-11
	19.2	13-0	13-6	14-0	14-5	14-11	15-3	15-8	16-0	16-5	16-9	17-0	17-4	17-8	17-11	18-3	18-6	18-9
	24.0	12-1	12-7	13-0	13-5	13-10	14-2	14-7	14-11	15-2	15-6	15-10	16-1	16-5	16-8	16-11	17-2	17-5
F_b	12.0	767	830	890	949	1,005	1,061	1,114	1,167	1,218	1,268	1,317	1,366	1,413	1,460	1,506	1,551	1,596
	16.0	844	913	980	1,044	1,107	1,167	1,226	1,284	1,341	1,396	1,450	1,503	1,556	1,607	1,658	1,707	1,757
	19.2	897	971	1,041	1,110	1,176	1,240	1,303	1,365	1,425	1,483	1,541	1,597	1,653	1,708	1,761	1,814	1,867
	24.0	967	1,046	1,122	1,195	1,267	1,336	1,404	1,470	1,535	1,598	1,660	1,721	1,781	1,840	1,897	1,955	2,011

NOTE: The required bending design value, F_b, in pounds per square inch (N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less. Check sources of supply for availability of lumber in lengths greater than 20 feet (6096 mm).

TABLE 23-VII-J-3—FLOOR JOISTS WITH *L*/360 DEFLECTION LIMITS
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 50 psf (2.4 kN/m^2) live load.
Limited to span in inches (mm) divided by 360.
Strength — Live load of 50 psf (2.4 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi (× 0.00689 for N/mm^2)																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 6	12.0	7-11	8-3	8-6	8-9	9-1	9-3	9-6	9-9	9-11	10-2	10-4	10-6	10-9	10-11	11-1	11-3	11-5
	16.0	7-2	7-6	7-9	8-0	8-3	8-5	8-8	8-10	9-1	9-3	9-5	9-7	9-9	9-11	10-1	10-2	10-4
	19.2	6-9	7-0	7-3	7-6	7-9	7-11	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4	9-6	9-7	9-9
	24.0	6-3	6-6	6-9	7-0	7-2	7-4	7-7	7-9	7-11	8-1	8-3	8-4	8-6	8-8	8-9	8-11	9-1
2 × 8	12.0	10-5	10-10	11-3	11-7	11-11	12-3	12-7	12-10	13-1	13-5	13-8	13-11	14-2	14-4	14-7	14-10	15-0
	16.0	9-6	9-10	10-2	10-6	10-10	11-1	11-5	11-8	11-11	12-2	12-5	12-7	12-10	13-1	13-3	13-5	13-8
	19.2	8-11	9-3	9-7	9-11	10-2	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-3	12-6	12-8	12-10
	24.0	8-3	8-7	8-11	9-2	9-6	9-9	10-0	10-2	10-5	10-8	10-10	11-0	11-3	11-5	11-7	11-9	11-11
2 × 10	12.0	13-3	13-10	14-4	14-9	15-2	15-7	16-0	16-5	16-9	17-1	17-5	17-9	18-0	18-4	18-7	18-11	19-2
	16.0	12-1	12-7	13-0	13-5	13-10	14-2	14-7	14-11	15-2	15-6	15-10	16-1	16-5	16-8	16-11	17-2	17-5
	19.2	11-4	11-10	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-7	14-11	15-2	15-5	15-8	15-11	16-2	16-5
	24.0	10-7	11-0	11-4	11-9	12-1	12-5	12-8	13-0	13-3	13-7	13-10	14-1	14-4	14-7	14-9	15-0	15-2
2 × 12	12.0	16-2	16-10	17-5	18-0	18-6	19-0	19-6	19-11	20-4	20-9	21-2	21-7	21-11	22-3	22-8	23-0	23-4
	16.0	14-8	15-3	15-10	16-4	16-10	17-3	17-8	18-1	18-6	18-10	19-3	19-7	19-11	20-3	20-7	20-10	21-2
	19.2	13-10	14-4	14-11	15-4	15-10	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-4	19-8	19-11
	24.0	12-10	13-4	13-10	14-3	14-8	15-1	15-5	15-10	16-2	16-6	16-10	17-1	17-5	17-8	18-0	18-3	18-6
F_b	12.0	866	937	1,005	1,071	1,135	1,198	1,258	1,317	1,375	1,432	1,488	1,542	1,596	1,649	1,701	1,752	1,802
	16.0	954	1,032	1,107	1,179	1,250	1,318	1,385	1,450	1,514	1,576	1,637	1,698	1,757	1,815	1,872	1,928	1,984
	19.2	1,013	1,096	1,176	1,253	1,328	1,401	1,472	1,541	1,609	1,675	1,740	1,804	1,867	1,928	1,989	2,049	2,108
	24.0	1,092	1,181	1,267	1,350	1,430	1,509	1,585	1,660	1,733	1,804	1,874	1,943	2,011	2,077	2,143	2,207	2,271

NOTE: The required bending design value, F_b, in pounds per square inch (N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less. Check sources of supply for availability of lumber in lengths greater than 20 feet (6096 mm).

TABLE 23-VII-J-4—FLOOR JOISTS WITH *L*/360 DEFLECTION LIMITS
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Deflection — For 60 psf (2.87 kN/m^2) live load.
Limited to span in inches (mm) divided by 360.
Strength — Live load of 60 psf (2.87 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.

Joist Size (in)	Spacing (in)	Modulus of Elasticity, *E*, in 1,000,000 psi (× 0.00689 for N/mm^2)																
× 25.4 for mm		0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4
2 × 6	12.0	7-5	7-9	8-0	8-3	8-6	8-9	8-11	9-2	9-4	9-7	9-9	9-11	10-1	10-3	10-5	10-7	10-9
	16.0	6-9	7-0	7-3	7-6	7-9	7-11	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4	9-6	9-7	9-9
	19.2	6-4	6-7	6-10	7-1	7-3	7-6	7-8	7-10	8-0	8-2	8-4	8-6	8-8	8-9	8-11	9-0	9-2
	24.0	5-11	6-2	6-4	6-7	6-9	6-11	7-1	7-3	7-5	7-7	7-9	7-10	8-0	8-2	8-3	8-5	8-6
2 × 8	12.0	9-10	10-2	10-7	10-11	11-3	11-6	11-10	12-1	12-4	12-7	12-10	13-1	13-4	13-6	13-9	13-11	14-2
	16.0	8-11	9-3	9-7	9-11	10-2	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-3	12-6	12-8	12-10
	19.2	8-5	8-9	9-0	9-4	9-7	9-10	10-1	10-4	10-7	10-9	11-0	11-2	11-4	11-7	11-9	11-11	12-1
	24.0	7-9	8-1	8-5	8-8	8-11	9-2	9-4	9-7	9-10	10-0	10-2	10-5	10-7	10-9	10-11	11-1	11-3
2 × 10	12.0	12-6	13-0	13-6	13-11	14-4	14-8	15-1	15-5	15-9	16-1	16-5	16-8	17-0	17-3	17-6	17-9	18-0
	16.0	11-4	11-10	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-7	14-11	15-2	15-5	15-8	15-11	16-2	16-5
	19.2	10-8	11-1	11-6	11-11	12-3	12-7	12-11	13-2	13-6	13-9	14-0	14-3	14-6	14-9	15-0	15-2	15-5
	24.0	9-11	10-4	10-8	11-0	11-4	11-8	11-11	12-3	12-6	12-9	13-0	13-3	13-6	13-8	13-11	14-1	14-4
2 × 12	12.0	15-2	15-10	16-5	16-11	17-5	17-11	18-4	18-9	19-2	19-7	19-11	20-3	20-8	21-0	21-4	21-7	21-11
	16.0	13-10	14-4	14-11	15-4	15-10	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9	19-1	19-4	19-8	19-11
	19.2	13-0	13-6	14-0	14-5	14-11	15-3	15-8	16-0	16-5	16-9	17-0	17-4	17-8	17-11	18-3	18-6	18-9
	24.0	12-1	12-7	13-0	13-5	13-10	14-2	14-7	14-11	15-2	15-6	15-10	16-1	16-5	16-8	16-11	17-2	17-5
F_b	12.0	877	949	1,018	1,084	1,149	1,212	1,273	1,333	1,392	1,449	1,506	1,561	1,615	1,669	1,721	1,773	1,824
	16.0	965	1,044	1,120	1,193	1,265	1,334	1,402	1,468	1,532	1,595	1,657	1,718	1,778	1,837	1,894	1,951	2,008
	19.2	1,026	1,109	1,190	1,268	1,344	1,418	1,489	1,559	1,628	1,695	1,761	1,826	1,889	1,952	2,013	2,074	2,133
	24.0	1,105	1,195	1,282	1,366	1,448	1,527	1,604	1,680	1,754	1,826	1,897	1,967	2,035	2,102	2,169	2,234	2,298

NOTE: The required bending design value, F_b, in pounds per square inch (N/mm^2) is shown at the bottom of this table and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less. Check sources of supply for availability of lumber in lengths greater than 20 feet (6096 mm).

TABLE 23-VII-R-1—RAFTERS WITH *L*/240 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 40 psf (1.92 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.
Deflection — For 40 psf live (1.02 kN/m^2) load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for N/mm^2)										
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300
2 × 6	12.0	5-6	6-4	7-1	7-9	8-5	9-0	9-6	10-0	10-6	11-0	11-5
	16.0	4-9	5-6	6-2	6-9	7-3	7-9	8-3	8-8	9-1	9-6	9-11
	19.2	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1
	24.0	3-11	4-6	5-0	5-6	5-11	6-4	6-9	7-1	7-5	7-9	8-1
2 × 8	12.0	7-3	8-4	9-4	10-3	11-1	11-10	12-7	13-3	13-11	14-6	15-1
	16.0	6-3	7-3	8-1	8-11	9-7	10-3	10-10	11-6	12-0	12-7	13-1
	19.2	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11
	24.0	5-2	5-11	6-7	7-3	7-10	8-4	8-11	9-4	9-10	10-3	10-8
2 × 10	12.0	9-3	10-8	11-11	13-1	14-2	15-1	16-0	16-11	17-9	18-6	19-3
	16.0	8-0	9-3	10-4	11-4	12-3	13-1	13-10	14-8	15-4	16-0	16-8
	19.2	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3
	24.0	6-6	7-7	8-5	9-3	10-0	10-8	11-4	11-11	12-6	13-1	13-7
2 ×12	12.0	11-3	13-0	14-6	15-11	17-2	18-4	19-6	20-6	21-7	22-6	23-5
	16.0	9-9	11-3	12-7	13-9	14-11	15-11	16-10	17-9	18-8	19-6	20-3
	19.2	8-11	10-3	11-6	12-7	13-7	14-6	15-5	16-3	17-0	17-9	18-6
	24.0	7-11	9-2	10-3	11-3	12-2	13-0	13-9	14-6	15-3	15-11	16-7
E	12.0	0.14	0.22	0.31	0.41	0.51	0.63	0.75	0.88	1.01	1.15	1.30
	16.0	0.12	0.19	0.27	0.35	0.44	0.54	0.65	0.76	0.88	1.00	1.12
	19.2	0.11	0.18	0.24	0.32	0.41	0.50	0.59	0.69	0.80	0.91	1.03
	24.0	0.10	0.16	0.22	0.29	0.36	0.44	0.53	0.62	0.71	0.81	0.92

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for N/mm^2)										
× 25.4 for mm		1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
2 × 6	12.0	11-11	12-4	12-8	13-1	13-6	13-10	14-2				
	16.0	10-3	10-8	11-0	11-4	11-8	12-0	12-4	12-7	12-11		
	19.2	9-5	9-9	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4
	24.0	8-5	8-8	9-0	9-3	9-6	9-9	10-0	10-3	10-6	10-9	11-0
2 × 8	12.0	15-8	16-3	16-9	17-3	17-9	18-3	18-9				
	16.0	13-7	14-0	14-6	14-11	15-5	15-10	16-3	16-7	17-0		
	19.2	12-5	12-10	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3
	24.0	11-1	11-6	11-10	12-2	12-7	12-11	13-3	13-7	13-11	14-2	14-6
2 × 10	12.0	20-0	20-8	21-4	22-0	22-8	23-3	23-11				
	16.0	17-4	17-11	18-6	19-1	19-7	20-2	20-8	21-2	21-8		
	19.2	15-10	16-4	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8
	24.0	14-2	14-8	15-1	15-7	16-0	16-6	16-11	17-4	17-9	18-1	18-6
2 ×12	12.0	24-4	25-2	26-0								
	16.0	21-1	21-9	22-6	23-2	23-10	24-6	25-2	25-9			
	19.2	19-3	19-11	20-6	21-2	21-9	22-5	23-0	23-6	24-1	24-8	25-2
	24.0	17-2	17-9	18-4	18-11	19-6	20-0	20-6	21-1	21-7	22-0	22-6
E	12.0	1.45	1.61	1.77	1.94	2.12	2.30	2.48				
	16.0	1.26	1.39	1.54	1.68	1.83	1.99	2.15	2.31	2.48		
	19.2	1.15	1.27	1.40	1.54	1.67	1.81	1.96	2.11	2.26	2.42	2.58
	24.0	1.03	1.14	1.25	1.37	1.50	1.62	1.75	1.89	2.02	2.16	2.30

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92×10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-2—RAFTERS WITH *L*/240 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 50 psf (2.40 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.
Deflection — For 50 psf (2.4 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for N/mm^2)										
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300
2 × 6	12.0	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5
	16.0	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1
	19.2	4-0	4-7	5-1	5-7	6-1	6-6	6-10	7-3	7-7	7-11	8-3
	24.0	3-7	4-1	4-7	5-0	5-5	5-10	6-2	6-6	6-10	7-1	7-5
2 × 8	12.0	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9
	16.0	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11
	19.2	5-3	6-0	6-9	7-5	8-0	8-7	9-1	9-7	10-0	10-6	10-11
	24.0	4-8	5-5	6-0	6-7	7-2	7-8	8-1	8-7	9-0	9-4	9-9
2 × 10	12.0	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7
	16.0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3
	19.2	6-8	7-8	8-7	9-5	10-2	10-11	11-7	12-2	12-9	13-4	13-11
	24.0	6-0	6-11	7-8	8-5	9-1	9-9	10-4	10-11	11-5	11-11	12-5
2 × 12	12.0	10-3	11-10	13-3	14-6	15-8	16-9	17-9	18-9	19-8	20-6	21-5
	16.0	8-11	10-3	11-6	12-7	13-7	14-6	15-5	16-3	17-0	17-9	18-6
	19.2	8-1	9-4	10-6	11-6	12-5	13-3	14-1	14-10	15-7	16-3	16-11
	24.0	7-3	8-5	9-4	10-3	11-1	11-10	12-7	13-3	13-11	14-6	15-1
E	12.0	0.14	0.21	0.29	0.39	0.49	0.60	0.71	0.83	0.96	1.10	1.24
	16.0	0.12	0.18	0.26	0.34	0.42	0.52	0.62	0.72	0.83	0.95	1.07
	19.2	0.11	0.17	0.23	0.31	0.39	0.47	0.56	0.66	0.76	0.87	0.98
	24.0	0.10	0.15	0.21	0.27	0.35	0.42	0.50	0.59	0.68	0.77	0.87

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for N/mm^2)										
× 25.4 for mm		1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
2 × 6	12.0	10-10	11-3	11-7	11-11	12-4	12-8	13-0	13-3			
	16.0	9-5	9-9	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	
	19.2	8-7	8-11	9-2	9-5	9-9	10-0	10-3	10-6	10-9	11-0	11-3
	24.0	7-8	7-11	8-2	8-5	8-8	8-11	9-2	9-5	9-7	9-10	10-0
2 × 8	12.0	14-4	14-10	15-3	15-9	16-3	16-8	17-1	17-6			
	16.0	12-5	12-10	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	
	19.2	11-4	11-8	12-1	12-5	12-10	13-2	13-6	13-10	14-2	14-6	14-10
	24.0	10-1	10-6	10-10	11-2	11-6	11-9	12-1	12-5	12-8	12-11	13-3
2 × 10	12.0	18-3	18-11	19-6	20-1	20-8	21-3	21-10	22-4			
	16.0	15-10	16-4	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	
	19.2	14-5	14-11	15-5	15-11	16-4	16-10	17-3	17-8	18-1	18-6	18-11
	24.0	12-11	13-4	13-9	14-3	14-8	15-0	15-5	15-10	16-2	16-6	16-11
2 × 12	12.0	22-2	23-0	23-9	24-5	25-2	25-10					
	16.0	19-3	19-11	20-6	21-2	21-9	22-5	23-0	23-6	24-1	24-8	
	19.2	17-6	18-2	18-9	19-4	19-11	20-5	21-0	21-6	22-0	22-6	23-0
	24.0	15-8	16-3	16-9	17-3	17-9	18-3	18-9	19-3	19-8	20-1	20-6
E	12.0	1.38	1.53	1.69	1.85	2.01	2.18	2.36	2.54			
	16.0	1.20	1.33	1.46	1.60	1.74	1.89	2.04	2.20	2.35	2.52	
	19.2	1.09	1.21	1.33	1.46	1.59	1.73	1.86	2.00	2.15	2.30	2.45
	24.0	0.98	1.08	1.19	1.31	1.42	1.54	1.67	1.79	1.92	2.06	2.19

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92 × 10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-3—RAFTERS WITH *L*/240 DEFLECTION LIMITS
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 40 psf (1.92 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 40 psf (1.92 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) ($\times$ 0.00689 for kN/m^2)												
$\times$ 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	5-3	6-1	6-9	7-5	8-0	8-7	9-1	9-7	10-0	10-6	10-11	11-4	11-9
	16.0	4-6	5-3	5-10	6-5	6-11	7-5	7-10	8-3	8-8	9-1	9-5	9-10	10-2
	19.2	4-2	4-9	5-4	5-10	6-4	6-9	7-2	7-7	7-11	8-3	8-8	8-11	9-3
	24.0	3-8	4-3	4-9	5-3	5-8	6-1	6-5	6-9	7-1	7-5	7-9	8-0	8-3
2 × 8	12.0	6-11	8-0	8-11	9-9	10-7	11-3	12-0	12-7	13-3	13-10	14-5	14-11	15-5
	16.0	6-0	6-11	7-9	8-6	9-2	9-9	10-4	10-11	11-6	12-0	12-6	12-11	13-5
	19.2	5-6	6-4	7-1	7-9	8-4	8-11	9-6	10-0	10-6	10-11	11-5	11-10	12-3
	24.0	4-11	5-8	6-4	6-11	7-6	8-0	8-6	8-11	9-4	9-9	10-2	10-7	10-11
2 × 10	12.0	8-10	10-2	11-5	12-6	13-6	14-5	15-3	16-1	16-11	17-8	18-4	19-1	19-9
	16.0	7-8	8-10	9-10	10-10	11-8	12-6	13-3	13-11	14-8	15-3	15-11	16-6	17-1
	19.2	7-0	8-1	9-0	9-10	10-8	11-5	12-1	12-9	13-4	13-11	14-6	15-1	15-7
	24.0	6-3	7-2	8-1	8-10	9-6	10-2	10-10	11-5	11-11	12-6	13-0	13-6	13-11
2 × 12	12.0	10-9	12-5	13-10	15-2	16-5	17-6	18-7	19-7	20-6	21-5	22-4	23-2	24-0
	16.0	9-3	10-9	12-0	13-2	14-2	15-2	16-1	17-0	17-9	18-7	19-4	20-1	20-9
	19.2	8-6	9-10	10-11	12-0	12-11	13-10	14-8	15-6	16-3	17-0	17-8	18-4	19-0
	24.0	7-7	8-9	9-10	10-9	11-7	12-5	13-2	13-10	14-6	15-2	15-9	16-5	17-0
E	12.0	0.12	0.19	0.27	0.35	0.44	0.54	0.65	0.76	0.88	1.00	1.13	1.26	1.40
	16.0	0.11	0.17	0.23	0.31	0.39	0.47	0.56	0.66	0.76	0.86	0.98	1.09	1.21
	19.2	0.10	0.15	0.21	0.28	0.35	0.43	0.51	0.60	0.69	0.79	0.89	0.99	1.10
	24.0	0.09	0.14	0.19	0.25	0.31	0.38	0.46	0.54	0.62	0.71	0.80	0.89	0.99

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) ($\times$ 0.00689 for kN/m^2)											
$\times$ 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	12-1	12-6	12-10	13-2	13-6	13-10	14-2					
	16.0	10-6	10-10	11-1	11-5	11-9	12-0	12-4	12-7	12-10			
	19.2	9-7	9-10	10-2	10-5	10-8	11-0	11-3	11-6	11-9	12-0	12-2	
	24.0	8-7	8-10	9-1	9-4	9-7	9-10	10-0	10-3	10-6	10-8	10-11	11-1
2 × 8	12.0	16-0	16-5	16-11	17-5	17-10	18-3	18-9					
	16.0	13-10	14-3	14-8	15-1	15-5	15-10	16-3	16-7	16-11			
	19.2	12-7	13-0	13-5	13-9	14-1	14-6	14-10	15-2	15-5	15-9	16-1	
	24.0	11-3	11-8	12-0	12-4	12-7	12-11	13-3	13-6	13-10	14-1	14-5	14-8
2 × 10	12.0	20-4	21-0	21-7	22-2	22-9	23-4	23-11					
	16.0	17-8	18-2	18-9	19-3	19-9	20-2	20-8	21-2	21-7			
	19.2	16-1	16-7	17-1	17-7	18-0	18-5	18-11	19-4	19-9	20-2	20-6	
	24.0	14-5	14-10	15-3	15-8	16-1	16-6	16-11	17-3	17-8	18-0	18-4	18-9
2 × 12	12.0	24-9	25-6										
	16.0	21-5	22-1	22-9	23-5	24-0	24-7	25-2	25-9				
	19.2	19-7	20-2	20-9	21-4	21-11	22-5	23-0	23-6	24-0	24-6	25-0	
	24.0	17-6	18-1	18-7	19-1	19-7	20-1	20-6	21-0	21-5	21-11	22-4	22-9
E	12.0	1.54	1.68	1.83	1.99	2.15	2.31	2.48					
	16.0	1.33	1.46	1.59	1.72	1.86	2.00	2.15	2.29	2.45			
	19.2	1.22	1.33	1.45	1.57	1.70	1.83	1.96	2.09	2.23	2.37	2.52	
	24.0	1.09	1.19	1.30	1.41	1.52	1.63	1.75	1.87	2.00	2.12	2.25	2.38

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92×10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-4—RAFTERS WITH *L*/240 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 50 psf (2.40 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 50 psf (2.40 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for kN/m^2)												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	4-10	5-7	6-3	6-10	7-4	7-11	8-4	8-10	9-3	9-8	10-0	10-5	10-9
	16.0	4-2	4-10	5-5	5-11	6-5	6-10	7-3	7-8	8-0	8-4	8-8	9-0	9-4
	19.2	3-10	4-5	4-11	5-5	5-10	6-3	6-7	7-0	7-4	7-8	7-11	8-3	8-6
	24.0	3-5	3-11	4-5	4-10	5-3	5-7	5-11	6-3	6-6	6-10	7-1	7-4	7-8
2 × 8	12.0	6-4	7-4	8-3	9-0	9-9	10-5	11-0	11-7	12-2	12-9	13-3	13-9	14-3
	16.0	5-6	6-4	7-1	7-9	8-5	9-0	9-6	10-1	10-7	11-0	11-6	11-11	12-4
	19.2	5-0	5-10	6-6	7-1	7-8	8-3	8-8	9-2	9-8	10-1	10-6	10-10	11-3
	24.0	4-6	5-2	5-10	6-4	6-10	7-4	7-9	8-3	8-7	9-0	9-4	9-9	10-1
2 × 10	12.0	8-1	9-4	10-6	11-6	12-5	13-3	14-1	14-10	15-6	16-3	16-11	17-6	18-2
	16.0	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-1	14-8	15-2	15-9
	19.2	6-5	7-5	8-3	9-1	9-10	10-6	11-1	11-9	12-3	12-10	13-4	13-10	14-4
	24.0	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10
2 × 12	12.0	9-10	11-5	12-9	13-11	15-1	16-1	17-1	18-0	18-11	19-9	20-6	21-4	22-1
	16.0	8-7	9-10	11-0	12-1	13-1	13-11	14-10	15-7	16-4	17-1	17-9	18-6	19-1
	19.2	7-10	9-0	10-1	11-0	11-11	12-9	13-6	14-3	14-11	15-7	16-3	16-10	17-5
	24.0	7-0	8-1	9-0	9-10	10-8	11-5	12-1	12-9	13-4	13-11	14-6	15-1	15-7
E	12.0	0.12	0.19	0.26	0.34	0.43	0.53	0.63	0.74	0.85	0.97	1.10	1.22	1.36
	16.0	0.11	0.16	0.23	0.30	0.37	0.46	0.55	0.64	0.74	0.84	0.95	1.06	1.18
	19.2	0.10	0.15	0.21	0.27	0.34	0.42	0.50	0.58	0.67	0.77	0.87	0.97	1.07
	24.0	0.09	0.13	0.18	0.24	0.31	0.37	0.45	0.52	0.60	0.69	0.77	0.87	0.96

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for kN/m^2)											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	11-2	11-6	11-10	12-2	12-5	12-9	13-1	13-4				
	16.0	9-8	9-11	10-3	10-6	10-9	11-1	11-4	11-7	11-10	12-1		
	19.2	8-10	9-1	9-4	9-7	9-10	10-1	10-4	10-7	10-9	11-0	11-3	11-5
	24.0	7-11	8-1	8-4	8-7	8-10	9-0	9-3	9-5	9-8	9-10	10-0	10-3
2 × 8	12.0	14-8	15-2	15-7	16-0	16-5	16-10	17-3	17-7				
	16.0	12-9	13-1	13-6	13-10	14-3	14-7	14-11	15-3	15-7	15-11		
	19.2	11-7	12-0	12-4	12-8	13-0	13-4	13-7	13-11	14-3	14-6	14-10	15-1
	24.0	10-5	10-8	11-0	11-4	11-7	11-11	12-2	12-5	12-9	13-0	13-3	13-6
2 × 10	12.0	18-9	19-4	19-10	20-5	20-11	21-6	22-0	22-6				
	16.0	16-3	16-9	17-3	17-8	18-2	18-7	19-0	19-5	19-10	20-3		
	19.2	14-10	15-3	15-9	16-2	16-7	17-0	17-4	17-9	18-2	18-6	18-11	19-3
	24.0	13-3	13-8	14-1	14-5	14-10	15-2	15-6	15-11	16-3	16-7	16-11	17-3
2 × 12	12.0	22-9	23-6	24-2	24-10	25-6							
	16.0	19-9	20-4	20-11	21-6	22-1	22-7	23-2	23-8	24-2	24-8		
	19.2	18-0	18-7	19-1	19-8	20-2	20-8	21-1	21-7	22-1	22-6	23-0	23-5
	24.0	16-1	16-7	17-1	17-7	18-0	18-6	18-11	19-4	19-9	20-2	20-6	20-11
E	12.0	1.50	1.64	1.78	1.94	2.09	2.25	2.41	2.58				
	16.0	1.30	1.42	1.55	1.68	1.81	1.95	2.09	2.23	2.38	2.53		
	19.2	1.18	1.30	1.41	1.53	1.65	1.78	1.91	2.04	2.17	2.31	2.45	2.59
	24.0	1.06	1.16	1.26	1.37	1.48	1.59	1.71	1.82	1.94	2.07	2.19	2.32

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92 × 10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-5—RAFTERS WITH *L*/240 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 40 psf (1.92 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 40 psf (1.92 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for kN/m^2)												
× 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5	10-10	11-3
	16.0	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9
	19.2	4-0	4-7	5-1	5-7	6-1	6-6	6-10	7-3	7-7	7-11	8-3	8-7	8-11
	24.0	3-7	4-1	4-7	5-0	5-5	5-10	6-2	6-6	6-10	7-1	7-5	7-8	7-11
2 × 8	12.0	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9	14-4	14-10
	16.0	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10
	19.2	5-3	6-0	6-9	7-5	8-0	8-7	9-1	9-7	10-0	10-6	10-11	11-4	11-8
	24.0	4-8	5-5	6-0	6-7	7-2	7-8	8-1	8-7	9-0	9-4	9-9	10-1	10-6
2 × 10	12.0	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7	18-3	18-11
	16.0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4
	19.2	6-8	7-8	8-7	9-5	10-2	10-11	11-7	12-2	12-9	13-4	13-11	14-5	14-11
	24.0	6-0	6-11	7-8	8-5	9-1	9-9	10-4	10-11	11-5	11-11	12-5	12-11	13-4
2 × 12	12.0	10-3	11-10	13-3	14-6	15-8	16-9	17-9	18-9	19-8	20-6	21-5	22-2	23-0
	16.0	8-11	10-3	11-6	12-7	13-7	14-6	15-5	16-3	17-0	17-9	18-6	19-3	19-11
	19.2	8-1	9-4	10-6	11-6	12-5	13-3	14-1	14-10	15-7	16-3	16-11	17-6	18-2
	24.0	7-3	8-5	9-4	10-3	11-1	11-10	12-7	13-3	13-11	14-6	15-1	15-8	16-3
E	12.0	0.11	0.17	0.24	0.31	0.39	0.48	0.57	0.67	0.77	0.88	0.99	1.10	1.22
	16.0	0.09	0.15	0.20	0.27	0.34	0.41	0.49	0.58	0.67	0.76	0.86	0.96	1.06
	19.2	0.09	0.13	0.19	0.24	0.31	0.38	0.45	0.53	0.61	0.69	0.78	0.87	0.97
	24.0	0.08	0.12	0.17	0.22	0.28	0.34	0.40	0.47	0.54	0.62	0.70	0.78	0.87

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for kN/m^2)											
× 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	11-7	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2			
	16.0	10-0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1
	19.2	9-2	9-5	9-9	10-0	10-3	10-6	10-9	11-0	11-3	11-5	11-8	11-11
	24.0	8-2	8-5	8-8	8-11	9-2	9-5	9-7	9-10	10-0	10-3	10-5	10-8
2 × 8	12.0	15-3	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9			
	16.0	13-3	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2
	19.2	12-1	12-5	12-10	13-2	13-6	13-10	14-2	14-6	14-10	15-1	15-5	15-8
	24.0	10-10	11-2	11-6	11-9	12-1	12-5	12-8	12-11	13-3	13-6	13-9	14-0
2 × 10	12.0	19-6	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11			
	16.0	16-11	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11
	19.2	15-5	15-11	16-4	16-10	17-3	17-8	18-1	18-6	18-11	19-3	19-8	20-0
	24.0	13-9	14-3	14-8	15-0	15-5	15-10	16-2	16-6	16-11	17-3	17-7	17-11
2 × 12	12.0	23-9	24-5	25-2	25-10								
	16.0	20-6	21-2	21-9	22-5	23-0	23-6	24-1	24-8	25-2	25-8		
	19.2	18-9	19-4	19-11	20-5	21-0	21-6	22-0	22-6	23-0	23-5	23-11	24-4
	24.0	16-9	17-3	17-9	18-3	18-9	19-3	19-8	20-1	20-6	21-0	21-5	21-9
E	12.0	1.35	1.48	1.61	1.75	1.89	2.03	2.18	2.33	2.48			
	16.0	1.17	1.28	1.39	1.51	1.63	1.76	1.88	2.01	2.15	2.28	2.42	2.56
	19.2	1.07	1.17	1.27	1.38	1.49	1.60	1.72	1.84	1.96	2.08	2.21	2.34
	24.0	0.95	1.04	1.14	1.23	1.33	1.43	1.54	1.64	1.75	1.86	1.98	2.09

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92 × 10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-6—RAFTERS WITH *L*/240 DEFLECTION LIMITS
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 50 psf (2.40 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 50 psf (2.40 kN/m^2) live load.
Limited to span in inches (mm) divided by 240.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) ($\times$ 0.00689 for kN/m^2)												
$\times$ 25.4 for mm		300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
2 × 6	12.0	4-8	5-4	6-0	6-7	7-1	7-7	8-1	8-6	8-11	9-4	9-8	10-0	10-5
	16.0	4-0	4-8	5-2	5-8	6-2	6-7	7-0	7-4	7-8	8-1	8-5	8-8	9-0
	19.2	3-8	4-3	4-9	5-2	5-7	6-0	6-4	6-9	7-0	7-4	7-8	7-11	8-3
	24.0	3-3	3-10	4-3	4-8	5-0	5-4	5-8	6-0	6-4	6-7	6-10	7-1	7-4
2 × 8	12.0	6-2	7-1	7-11	8-8	9-4	10-0	10-7	11-2	11-9	12-3	12-9	13-3	13-8
	16.0	5-4	6-2	6-10	7-6	8-1	8-8	9-2	9-8	10-2	10-7	11-1	11-6	11-10
	19.2	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-10	9-3	9-8	10-1	10-6	10-10
	24.0	4-4	5-0	5-7	6-2	6-7	7-1	7-6	7-11	8-4	8-8	9-0	9-4	9-8
2 × 10	12.0	7-10	9-0	10-1	11-1	11-11	12-9	13-6	14-3	15-0	15-8	16-3	16-11	17-6
	16.0	6-9	7-10	8-9	9-7	10-4	11-1	11-9	12-4	13-0	13-6	14-1	14-8	15-2
	19.2	6-2	7-2	8-0	8-9	9-5	10-1	10-8	11-3	11-10	12-4	12-10	13-4	13-10
	24.0	5-6	6-5	7-2	7-10	8-5	9-0	9-7	10-1	10-7	11-1	11-6	11-11	12-4
2 × 12	12.0	9-6	11-0	12-3	13-5	14-6	15-6	16-6	17-4	18-2	19-0	19-10	20-6	21-3
	16.0	8-3	9-6	10-8	11-8	12-7	13-5	14-3	15-0	15-9	16-6	17-2	17-9	18-5
	19.2	7-6	8-8	9-8	10-8	11-6	12-3	13-0	13-9	14-5	15-0	15-8	16-3	16-10
	24.0	6-9	7-9	8-8	9-6	10-3	11-0	11-8	12-3	12-10	13-5	14-0	14-6	15-0
E	12.0	0.11	0.17	0.23	0.31	0.39	0.47	0.56	0.66	0.76	0.87	0.98	1.10	1.21
	16.0	0.09	0.14	0.20	0.27	0.34	0.41	0.49	0.57	0.66	0.75	0.85	0.95	1.05
	19.2	0.09	0.13	0.18	0.24	0.31	0.37	0.45	0.52	0.60	0.69	0.77	0.87	0.96
	24.0	0.08	0.12	0.17	0.22	0.27	0.33	0.40	0.47	0.54	0.61	0.69	0.77	0.86

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) ($\times$ 0.00689 for kN/m^2)											
$\times$ 25.4 for mm		1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700
2 × 6	12.0	10-9	11-1	11-5	11-8	12-0	12-4	12-7	12-10	13-2			
	16.0	9-4	9-7	9-10	10-2	10-5	10-8	10-11	11-2	11-5	11-7	11-10	12-1
	19.2	8-6	8-9	9-0	9-3	9-6	9-9	9-11	10-2	10-5	10-7	10-10	11-0
	24.0	7-7	7-10	8-1	8-3	8-6	8-8	8-11	9-1	9-4	9-6	9-8	9-10
2 × 8	12.0	14-2	14-7	15-0	15-5	15-10	16-3	16-7	17-0	17-4			
	16.0	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-8	15-0	15-4	15-7	15-11
	19.2	11-2	11-6	11-10	12-2	12-6	12-10	13-1	13-5	13-8	14-0	14-3	14-6
	24.0	10-0	10-4	10-7	10-11	11-2	11-6	11-9	12-0	12-3	12-6	12-9	13-0
2 × 10	12.0	18-1	18-7	19-2	19-8	20-2	20-8	21-2	21-8	22-1			
	16.0	15-8	16-1	16-7	17-0	17-6	17-11	18-4	18-9	19-2	19-7	19-11	20-4
	19.2	14-3	14-9	15-2	15-7	15-11	16-4	16-9	17-1	17-6	17-10	18-2	18-6
	24.0	12-9	13-2	13-6	13-11	14-3	14-8	15-0	15-4	15-8	15-11	16-3	16-7
2 × 12	12.0	21-11	22-8	23-3	23-11	24-7	25-2	25-9					
	16.0	19-0	19-7	20-2	20-9	21-3	21-9	22-4	22-10	23-3	23-9	24-3	24-8
	19.2	17-4	17-11	18-5	18-11	19-5	19-11	20-4	20-10	21-3	21-8	22-2	22-7
	24.0	15-6	16-0	16-6	16-11	17-4	17-9	18-2	18-7	19-0	19-5	19-10	20-2
E	12.0	1.34	1.47	1.60	1.73	1.87	2.01	2.16	2.31	2.46			
	16.0	1.16	1.27	1.38	1.50	1.62	1.74	1.87	2.00	2.13	2.26	2.40	2.54
	19.2	1.06	1.16	1.26	1.37	1.48	1.59	1.71	1.82	1.94	2.07	2.19	2.32
	24.0	0.95	1.04	1.13	1.22	1.32	1.42	1.53	1.63	1.74	1.85	1.96	2.07

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92×10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-7—RAFTERS WITH *L*/180 DEFLECTION LIMITS
The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 40 psf (1.92 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.
Deflection — For 40 psf (1.92 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for kN/m^2)														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	2-10	3-6	4-0	4-6	4-11	5-4	5-9	6-1	6-5	6-8	7-0	7-3	7-7	7-10	8-1
	16.0	2-6	3-0	3-6	3-11	4-3	4-8	4-11	5-3	5-6	5-10	6-1	6-4	6-7	6-9	7-0
	19.2	2-3	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5
	24.0	2-0	2-6	2-10	3-2	3-6	3-9	4-0	4-3	4-6	4-9	4-11	5-2	5-4	5-6	5-9
2 × 6	12.0	4-6	5-6	6-4	7-1	7-9	8-5	9-0	9-6	10-0	10-6	11-0	11-5	11-11	12-4	12-8
	16.0	3-11	4-9	5-6	6-2	6-9	7-3	7-9	8-3	8-8	9-1	9-6	9-11	10-3	10-8	11-0
	19.2	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0
	24.0	3-2	3-11	4-6	5-0	5-6	5-11	6-4	6-9	7-1	7-5	7-9	8-1	8-5	8-8	9-0
2 × 8	12.0	5-11	7-3	8-4	9-4	10-3	11-1	11-10	12-7	13-3	13-11	14-6	15-1	15-8	16-3	16-9
	16.0	5-2	6-3	7-3	8-1	8-11	9-7	10-3	10-10	11-6	12-0	12-7	13-1	13-7	14-0	14-6
	19.2	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
	24.0	4-2	5-2	5-11	6-7	7-3	7-10	8-4	8-11	9-4	9-10	10-3	10-8	11-1	11-6	11-10
2 × 10	12.0	7-7	9-3	10-8	11-11	13-1	14-2	15-1	16-0	16-11	17-9	18-6	19-3	20-0	20-8	21-4
	16.0	6-6	8-0	9-3	10-4	11-4	12-3	13-1	13-10	14-8	15-4	16-0	16-8	17-4	17-11	18-6
	19.2	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11
	24.0	5-4	6-6	7-7	8-5	9-3	10-0	10-8	11-4	11-11	12-6	13-1	13-7	14-2	14-8	15-1
E	12.0	0.06	0.11	0.17	0.23	0.31	0.38	0.47	0.56	0.66	0.76	0.86	0.97	1.09	1.21	1.33
	16.0	0.05	0.09	0.14	0.20	0.26	0.33	0.41	0.49	0.57	0.66	0.75	0.84	0.94	1.05	1.15
	19.2	0.05	0.09	0.13	0.18	0.24	0.30	0.37	0.44	0.52	0.60	0.68	0.77	0.86	0.95	1.05
	24.0	0.04	0.08	0.12	0.16	0.22	0.27	0.33	0.40	0.46	0.54	0.61	0.69	0.77	0.85	0.94

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 for kN/m^2)													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	8-4	8-7	8-10	9-0	9-3	9-6	9-8	9-11	10-1					
	16.0	7-3	7-5	7-8	7-10	8-0	8-2	8-5	8-7	8-9	8-11	9-1			
	19.2	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5	8-7	
	24.0	5-11	6-1	6-3	6-5	6-7	6-8	6-10	7-0	7-2	7-3	7-5	7-7	7-8	7-10
2 × 6	12.0	13-1	13-6	13-10	14-2	14-7	14-11	15-3	15-7	15-11					
	16.0	11-4	11-8	12-0	12-4	12-7	12-11	13-2	13-6	13-9	14-0	14-3			
	19.2	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3	13-6	
	24.0	9-3	9-6	9-9	10-0	10-3	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1	12-4
2 × 8	12.0	17-3	17-9	18-3	18-9	19-2	19-8	20-1	20-6	20-11					
	16.0	14-11	15-5	15-10	16-3	16-7	17-0	17-5	17-9	18-1	18-6	18-10			
	19.2	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6	17-10	
	24.0	12-2	12-7	12-11	13-3	13-7	13-11	14-2	14-6	14-10	15-1	15-5	15-8	15-11	16-3
2 × 10	12.0	22-0	22-8	23-3	23-11	24-6	25-1	25-7							
	16.0	19-1	19-7	20-2	20-8	21-2	21-8	22-2	22-8	23-1	23-7	24-0			
	19.2	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4	22-9	
	24.0	15-7	16-0	16-6	16-11	17-4	17-9	18-1	18-6	18-11	19-3	19-7	20-0	20-4	20-8
E	12.0	1.46	1.59	1.72	1.86	2.00	2.14	2.29	2.44	2.60					
	16.0	1.26	1.37	1.49	1.61	1.73	1.86	1.99	2.12	2.25	2.39	2.53			
	19.2	1.15	1.25	1.36	1.47	1.58	1.70	1.81	1.93	2.05	2.18	2.31	2.43	2.57	
	24.0	1.03	1.12	1.22	1.31	1.41	1.52	1.62	1.73	1.84	1.95	2.06	2.18	2.30	2.41

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92×10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-8—RAFTERS WITH *L*/180 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 50 psf (2.40 kN/m^2) plus dead load of 10 psf (0.48 kN/m^2) determines the required bending design value.
Deflection — For 50 psf (2.40 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) ($\times$ 0.00689 for kN/m^2)														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	2-7	3-2	3-8	4-1	4-6	4-11	5-3	5-6	5-10	6-1	6-5	6-8	6-11	7-2	7-5
	16.0	2-3	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5
	19.2	2-1	2-6	2-11	3-3	3-7	3-10	4-1	4-4	4-7	4-10	5-1	5-3	5-5	5-8	5-10
	24.0	1-10	2-3	2-7	2-11	3-2	3-5	3-8	3-11	4-1	4-4	4-6	4-8	4-11	5-1	5-3
2 × 6	12.0	4-1	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5	10-10	11-3	11-7
	16.0	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0
	19.2	3-3	4-0	4-7	5-1	5-7	6-1	6-6	6-10	7-3	7-7	7-11	8-3	8-7	8-11	9-2
	24.0	2-11	3-7	4-1	4-7	5-0	5-5	5-10	6-2	6-6	6-10	7-1	7-5	7-8	7-11	8-2
2 × 8	12.0	5-5	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9	14-4	14-10	15-3
	16.0	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
	19.2	4-3	5-3	6-0	6-9	7-5	8-0	8-7	9-1	9-7	10-0	10-6	10-11	11-4	11-8	12-1
	24.0	3-10	4-8	5-5	6-0	6-7	7-2	7-8	8-1	8-7	9-0	9-4	9-9	10-1	10-6	10-10
2 × 10	12.0	6-11	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7	18-3	18-11	19-6
	16.0	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11
	19.2	5-5	6-8	7-8	8-7	9-5	10-2	10-11	11-7	12-2	12-9	13-4	13-11	14-5	14-11	15-5
	24.0	4-11	6-0	6-11	7-8	8-5	9-1	9-9	10-4	10-11	11-5	11-11	12-5	12-11	13-4	13-9
E	12.0	0.06	0.10	0.16	0.22	0.29	0.37	0.45	0.53	0.63	0.72	0.82	0.93	1.04	1.15	1.26
	16.0	0.05	0.09	0.14	0.19	0.25	0.32	0.39	0.46	0.54	0.62	0.71	0.80	0.90	0.99	1.10
	19.2	0.04	0.08	0.13	0.17	0.23	0.29	0.35	0.42	0.49	0.57	0.65	0.73	0.82	0.91	1.00
	24.0	0.04	0.07	0.11	0.16	0.21	0.26	0.32	0.38	0.44	0.51	0.58	0.66	0.73	0.81	0.89

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) ($\times$ 0.00689 for kN/m^2)													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	7-7	7-10	8-0	8-3	8-5	8-8	8-10	9-0	9-3					
	16.0	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5		
	19.2	6-0	6-2	6-4	6-6	6-8	6-10	7-0	7-2	7-3	7-5	7-7	7-9	7-10	8-0
	24.0	5-5	5-6	5-8	5-10	6-0	6-1	6-3	6-5	6-6	6-8	6-9	6-11	7-0	7-2
2 × 6	12.0	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2	14-6					
	16.0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3		
	19.2	9-5	9-9	10-0	10-3	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-2	12-4	12-7
	24.0	8-5	8-8	8-11	9-2	9-5	9-7	9-10	10-0	10-3	10-5	10-8	10-10	11-0	11-3
2 × 8	12.0	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9	19-1					
	16.0	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6		
	19.2	12-5	12-10	13-2	13-6	13-10	14-2	14-6	14-10	15-1	15-5	15-8	16-0	16-3	16-7
	24.0	11-2	11-6	11-9	12-1	12-5	12-8	12-11	13-3	13-6	13-9	14-0	14-4	14-7	14-10
2 × 10	12.0	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11	24-5					
	16.0	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4		
	19.2	15-11	16-4	16-10	17-3	17-8	18-1	18-6	18-11	19-3	19-8	20-0	20-5	20-9	21-1
	24.0	14-3	14-8	15-0	15-5	15-10	16-2	16-6	16-11	17-3	17-7	17-11	18-3	18-7	18-11
E	12.0	1.39	1.51	1.64	1.77	1.90	2.04	2.18	2.32	2.47					
	16.0	1.20	1.31	1.42	1.53	1.65	1.77	1.89	2.01	2.14	2.27	2.40	2.54		
	19.2	1.10	1.19	1.29	1.40	1.50	1.61	1.72	1.84	1.95	2.07	2.19	2.32	2.44	2.57
	24.0	0.98	1.07	1.16	1.25	1.34	1.44	1.54	1.64	1.75	1.85	1.96	2.07	2.18	2.30

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92×10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-9—RAFTERS WITH *L*/180 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 40 psf (1.92 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 40 psf (1.92 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 kN/m^2)														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	2-9	3-4	3-10	4-4	4-9	5-1	5-5	5-9	6-1	6-5	6-8	6-11	7-3	7-6	7-8
	16.0	2-4	2-11	3-4	3-9	4-1	4-5	4-9	5-0	5-3	5-6	5-9	6-0	6-3	6-6	6-8
	19.2	2-2	2-8	3-1	3-5	3-9	4-0	4-4	4-7	4-10	5-1	5-3	5-6	5-8	5-11	6-1
	24.0	1-11	2-4	2-9	3-1	3-4	3-7	3-10	4-1	4-4	4-6	4-9	4-11	5-1	5-3	5-5
2 × 6	12.0	4-3	5-3	6-1	6-9	7-5	8-0	8-7	9-1	9-7	10-0	10-6	10-11	11-4	11-9	12-1
	16.0	3-8	4-6	5-3	5-10	6-5	6-11	7-5	7-10	8-3	8-8	9-1	9-5	9-10	10-2	10-6
	19.2	3-5	4-2	4-9	5-4	5-10	6-4	6-9	7-2	7-7	7-11	8-3	8-8	8-11	9-3	9-7
	24.0	3-0	3-8	4-3	4-9	5-3	5-8	6-1	6-5	6-9	7-1	7-5	7-9	8-0	8-3	8-7
2 × 8	12.0	5-8	6-11	8-0	8-11	9-9	10-7	11-3	12-0	12-7	13-3	13-10	14-5	14-11	15-5	16-0
	16.0	4-11	6-0	6-11	7-9	8-6	9-2	9-9	10-4	10-11	11-6	12-0	12-6	12-11	13-5	13-10
	19.2	4-6	5-6	6-4	7-1	7-9	8-4	8-11	9-6	10-0	10-6	10-11	11-5	11-10	12-3	12-7
	24.0	4-0	4-11	5-8	6-4	6-11	7-6	8-0	8-6	8-11	9-4	9-9	10-2	10-7	10-11	11-3
2 × 10	12.0	7-2	8-10	10-2	11-5	12-6	13-6	14-5	15-3	16-1	16-11	17-8	18-4	19-1	19-9	20-4
	16.0	6-3	7-8	8-10	9-10	10-10	11-8	12-6	13-3	13-11	14-8	15-3	15-11	16-6	17-1	17-8
	19.2	5-8	7-0	8-1	9-0	9-10	10-8	11-5	12-1	12-9	13-4	13-11	14-6	15-1	15-7	16-1
	24.0	5-1	6-3	7-2	8-1	8-10	9-6	10-2	10-10	11-5	11-11	12-6	13-0	13-6	13-11	14-5
E	12.0	0.05	0.09	0.14	0.20	0.26	0.33	0.41	0.49	0.57	0.66	0.75	0.84	0.94	1.05	1.15
	16.0	0.04	0.08	0.12	0.17	0.23	0.29	0.35	0.42	0.49	0.57	0.65	0.73	0.82	0.91	1.00
	19.2	0.04	0.07	0.11	0.16	0.21	0.26	0.32	0.38	0.45	0.52	0.59	0.67	0.75	0.83	0.91
	24.0	0.04	0.07	0.10	0.14	0.19	0.24	0.29	0.34	0.40	0.46	0.53	0.60	0.67	0.74	0.82

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 kN/m^2)													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	7-11	8-2	8-5	8-7	8-10	9-0	9-3	9-5	9-8	9-10	10-0			
	16.0	6-11	7-1	7-3	7-6	7-8	7-10	8-0	8-2	8-4	8-6	8-8	8-10	9-0	9-2
	19.2	6-3	6-6	6-8	6-10	7-0	7-2	7-4	7-6	7-7	7-9	7-11	8-1	8-2	8-4
	24.0	5-7	5-9	5-11	6-1	6-3	6-5	6-6	6-8	6-10	6-11	7-1	7-3	7-4	7-6
2 × 6	12.0	12-6	12-10	13-2	13-6	13-10	14-2	14-6	14-10	15-2	15-5	15-9			
	16.0	10-10	11-1	11-5	11-9	12-0	12-4	12-7	12-10	13-1	13-4	13-7	13-10	14-1	14-4
	19.2	9-10	10-2	10-5	10-8	11-0	11-3	11-6	11-9	12-0	12-2	12-5	12-8	12-11	13-1
	24.0	8-10	9-1	9-4	9-7	9-10	10-0	10-3	10-6	10-8	10-11	11-1	11-4	11-6	11-9
2 × 8	12.0	16-5	16-11	17-5	17-10	18-3	18-9	19-2	19-7	19-11	20-4	20-9			
	16.0	14-3	14-8	15-1	15-5	15-10	16-3	16-7	16-11	17-3	17-7	18-0	18-3	18-7	18-11
	19.2	13-0	13-5	13-9	14-1	14-6	14-10	15-2	15-5	15-9	16-1	16-5	16-8	17-0	17-3
	24.0	11-8	12-0	12-4	12-7	12-11	13-3	13-6	13-10	14-1	14-5	14-8	14-11	15-2	15-5
2 × 10	12.0	21-0	21-7	22-2	22-9	23-4	23-11	24-5	24-11	25-6	26-0				
	16.0	18-2	18-9	19-3	19-9	20-2	20-8	21-2	21-7	22-1	22-6	22-11	23-4	23-9	24-2
	19.2	16-7	17-1	17-7	18-0	18-5	18-11	19-4	19-9	20-2	20-6	20-11	21-4	21-8	22-1
	24.0	14-10	15-3	15-8	16-1	16-6	16-11	17-3	17-8	18-0	18-4	18-9	19-1	19-5	19-9
E	12.0	1.26	1.38	1.49	1.61	1.73	1.86	1.99	2.12	2.25	2.39	2.53			
	16.0	1.09	1.19	1.29	1.40	1.50	1.61	1.72	1.83	1.95	2.07	2.19	2.31	2.44	2.56
	19.2	1.00	1.09	1.18	1.27	1.37	1.47	1.57	1.67	1.78	1.89	2.00	2.11	2.22	2.34
	24.0	0.89	0.97	1.06	1.14	1.23	1.31	1.41	1.50	1.59	1.69	1.79	1.89	1.99	2.09

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92×10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-10—RAFTERS WITH *L*/180 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 50 psf (2.40 kN/m^2) plus dead load of 15 psf (0.72 kN/m^2) determines the required bending design value.
Deflection — For 50 psf (2.40 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 kN/m^2)														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	2-6	3-1	3-7	4-0	4-4	4-8	5-0	5-4	5-7	5-11	6-2	6-5	6-8	6-10	7-1
	16.0	2-2	2-8	3-1	3-5	3-9	4-1	4-4	4-7	4-10	5-1	5-4	5-6	5-9	5-11	6-2
	19.2	2-0	2-5	2-10	3-2	3-5	3-8	4-0	4-2	4-5	4-8	4-10	5-1	5-3	5-5	5-7
	24.0	1-9	2-2	2-6	2-10	3-1	3-4	3-7	3-9	4-0	4-2	4-4	4-6	4-8	4-10	5-0
2 × 6	12.0	3-11	4-10	5-7	6-3	6-10	7-4	7-11	8-4	8-10	9-3	9-8	10-0	10-5	10-9	11-2
	16.0	3-5	4-2	4-10	5-5	5-11	6-5	6-10	7-3	7-8	8-0	8-4	8-8	9-0	9-4	9-8
	19.2	3-1	3-10	4-5	4-11	5-5	5-10	6-3	6-7	7-0	7-4	7-8	7-11	8-3	8-6	8-10
	24.0	2-9	3-5	3-11	4-5	4-10	5-3	5-7	5-11	6-3	6-6	6-10	7-1	7-4	7-8	7-11
2 × 8	12.0	5-2	6-4	7-4	8-3	9-0	9-9	10-5	11-0	11-7	12-2	12-9	13-3	13-9	14-3	14-8
	16.0	4-6	5-6	6-4	7-1	7-9	8-5	9-0	9-6	10-1	10-7	11-0	11-6	11-11	12-4	12-9
	19.2	4-1	5-0	5-10	6-6	7-1	7-8	8-3	8-8	9-2	9-8	10-1	10-6	10-10	11-3	11-7
	24.0	3-8	4-6	5-2	5-10	6-4	6-10	7-4	7-9	8-3	8-7	9-0	9-4	9-9	10-1	10-5
2 × 10	12.0	6-7	8-1	9-4	10-6	11-6	12-5	13-3	14-1	14-10	15-6	16-3	16-11	17-6	18-2	18-9
	16.0	5-9	7-0	8-1	9-1	9-11	10-9	11-6	12-2	12-10	13-5	14-1	14-8	15-2	15-9	16-3
	19.2	5-3	6-5	7-5	8-3	9-1	9-10	10-6	11-1	11-9	12-3	12-10	13-4	13-10	14-4	14-10
	24.0	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
E	12.0	0.05	0.09	0.14	0.20	0.26	0.32	0.40	0.47	0.55	0.64	0.73	0.82	0.92	1.02	1.12
	16.0	0.04	0.08	0.12	0.17	0.22	0.28	0.34	0.41	0.48	0.55	0.63	0.71	0.80	0.88	0.97
	19.2	0.04	0.07	0.11	0.15	0.20	0.26	0.31	0.37	0.44	0.51	0.58	0.65	0.73	0.81	0.89
	24.0	0.04	0.06	0.10	0.14	0.18	0.23	0.28	0.33	0.39	0.45	0.52	0.58	0.65	0.72	0.79

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 kN/m^2)													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	7-4	7-6	7-9	7-11	8-1	8-4	8-6	8-8	8-10	9-0	9-3	9-5		
	16.0	6-4	6-6	6-8	6-10	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-1	8-3	8-5
	19.2	5-9	5-11	6-1	6-3	6-5	6-7	6-9	6-10	7-0	7-2	7-3	7-5	7-7	7-8
	24.0	5-2	5-4	5-6	5-7	5-9	5-11	6-0	6-2	6-3	6-5	6-6	6-8	6-9	6-10
2 × 6	12.0	11-6	11-10	12-2	12-5	12-9	13-1	13-4	13-8	13-11	14-2	14-6	14-9		
	16.0	9-11	10-3	10-6	10-9	11-1	11-4	11-7	11-10	12-1	12-4	12-6	12-9	13-0	13-3
	19.2	9-1	9-4	9-7	9-10	10-1	10-4	10-7	10-9	11-0	11-3	11-5	11-8	11-10	12-1
	24.0	8-1	8-4	8-7	8-10	9-0	9-3	9-5	9-8	9-10	10-0	10-3	10-5	10-7	10-9
2 × 8	12.0	15-2	15-7	16-0	16-5	16-10	17-3	17-7	18-0	18-4	18-9	19-1	19-5		
	16.0	13-1	13-6	13-10	14-3	14-7	14-11	15-3	15-7	15-11	16-3	16-6	16-10	17-1	17-5
	19.2	12-0	12-4	12-8	13-0	13-4	13-7	13-11	14-3	14-6	14-10	15-1	15-4	15-8	15-11
	24.0	10-8	11-0	11-4	11-7	11-11	12-2	12-5	12-9	13-0	13-3	13-6	13-9	14-0	14-3
2 × 10	12.0	19-4	19-10	20-5	20-11	21-6	22-0	22-6	22-11	23-5	23-11	24-4	24-9		
	16.0	16-9	17-3	17-8	18-2	18-7	19-0	19-5	19-10	20-3	20-8	21-1	21-6	21-10	22-3
	19.2	15-3	15-9	16-2	16-7	17-0	17-4	17-9	18-2	18-6	18-11	19-3	19-7	19-11	20-3
	24.0	13-8	14-1	14-5	14-10	15-2	15-6	15-11	16-3	16-7	16-11	17-3	17-6	17-10	18-2
E	12.0	1.23	1.34	1.45	1.57	1.69	1.81	1.93	2.06	2.19	2.32	2.46	2.60		
	16.0	1.06	1.16	1.26	1.36	1.46	1.57	1.67	1.78	1.90	2.01	2.13	2.25	2.37	2.49
	19.2	0.97	1.06	1.15	1.24	1.33	1.43	1.53	1.63	1.73	1.84	1.94	2.05	2.16	2.28
	24.0	0.87	0.95	1.03	1.11	1.19	1.28	1.37	1.46	1.55	1.64	1.74	1.84	1.94	2.04

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92×10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-11—RAFTERS WITH *L*/180 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 40 psf (1.92 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 40 psf (1.92 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 kN/m^2)														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	2-7	3-2	3-8	4-1	4-6	4-11	5-3	5-6	5-10	6-1	6-5	6-8	6-11	7-2	7-5
	16.0	2-3	2-9	3-2	3-7	3-11	4-3	4-6	4-10	5-1	5-4	5-6	5-9	6-0	6-2	6-5
	19.2	2-1	2-6	2-11	3-3	3-7	3-10	4-1	4-4	4-7	4-10	5-1	5-3	5-5	5-8	5-10
	24.0	1-10	2-3	2-7	2-11	3-2	3-5	3-8	3-11	4-1	4-4	4-6	4-8	4-11	5-1	5-3
2 × 6	12.0	4-1	5-0	5-10	6-6	7-1	7-8	8-2	8-8	9-2	9-7	10-0	10-5	10-10	11-3	11-7
	16.0	3-7	4-4	5-0	5-7	6-2	6-8	7-1	7-6	7-11	8-4	8-8	9-1	9-5	9-9	10-0
	19.2	3-3	4-0	4-7	5-1	5-7	6-1	6-6	6-10	7-3	7-7	7-11	8-3	8-7	8-11	9-2
	24.0	2-11	3-7	4-1	4-7	5-0	5-5	5-10	6-2	6-6	6-10	7-1	7-5	7-8	7-11	8-2
2 × 8	12.0	5-5	6-7	7-8	8-7	9-4	10-1	10-10	11-6	12-1	12-8	13-3	13-9	14-4	14-10	15-3
	16.0	4-8	5-9	6-7	7-5	8-1	8-9	9-4	9-11	10-6	11-0	11-6	11-11	12-5	12-10	13-3
	19.2	4-3	5-3	6-0	6-9	7-5	8-0	8-7	9-1	9-7	10-0	10-6	10-11	11-4	11-8	12-1
	24.0	3-10	4-8	5-5	6-0	6-7	7-2	7-8	8-1	8-7	9-0	9-4	9-9	10-1	10-6	10-10
2 × 10	12.0	6-11	8-5	9-9	10-11	11-11	12-11	13-9	14-8	15-5	16-2	16-11	17-7	18-3	18-11	19-6
	16.0	6-0	7-4	8-5	9-5	10-4	11-2	11-11	12-8	13-4	14-0	14-8	15-3	15-10	16-4	16-11
	19.2	5-5	6-8	7-8	8-7	9-5	10-2	10-11	11-7	12-2	12-9	13-4	13-11	14-5	14-11	15-5
	24.0	4-11	6-0	6-11	7-8	8-5	9-1	9-9	10-4	10-11	11-5	11-11	12-5	12-11	13-4	13-9
E	12.0	0.04	0.08	0.13	0.18	0.23	0.29	0.36	0.43	0.50	0.58	0.66	0.74	0.83	0.92	1.01
	16.0	0.04	0.07	0.11	0.15	0.20	0.25	0.31	0.37	0.43	0.50	0.57	0.64	0.72	0.80	0.88
	19.2	0.04	0.06	0.10	0.14	0.18	0.23	0.28	0.34	0.40	0.46	0.52	0.59	0.65	0.73	0.80
	24.0	0.03	0.06	0.09	0.13	0.16	0.21	0.25	0.30	0.35	0.41	0.46	0.52	0.59	0.65	0.72

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 kN/m^2)													
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	7-7	7-10	8-0	8-3	8-5	8-8	8-10	9-0	9-3	9-5	9-7	9-9	9-11	10-1
	16.0	6-7	6-9	7-0	7-2	7-4	7-6	7-8	7-10	8-0	8-2	8-4	8-5	8-7	8-9
	19.2	6-0	6-2	6-4	6-6	6-8	6-10	7-0	7-2	7-3	7-5	7-7	7-9	7-10	8-0
	24.0	5-5	5-6	5-8	5-10	6-0	6-1	6-3	6-5	6-6	6-8	6-9	6-11	7-0	7-2
2 × 6	12.0	11-11	12-4	12-8	13-0	13-3	13-7	13-11	14-2	14-6	14-9	15-1	15-4	15-7	15-11
	16.0	10-4	10-8	10-11	11-3	11-6	11-9	12-0	12-4	12-7	12-10	13-1	13-3	13-6	13-9
	19.2	9-5	9-9	10-0	10-3	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-2	12-4	12-7
	24.0	8-5	8-8	8-11	9-2	9-5	9-7	9-10	10-0	10-3	10-5	10-8	10-10	11-0	11-3
2 × 8	12.0	15-9	16-3	16-8	17-1	17-6	17-11	18-4	18-9	19-1	19-6	19-10	20-3	20-7	20-11
	16.0	13-8	14-0	14-5	14-10	15-2	15-6	15-10	16-3	16-7	16-10	17-2	17-6	17-10	18-1
	19.2	12-5	12-10	13-2	13-6	13-10	14-2	14-6	14-10	15-1	15-5	15-8	16-0	16-3	16-7
	24.0	11-2	11-6	11-9	12-1	12-5	12-8	12-11	13-3	13-6	13-9	14-0	14-4	14-7	14-10
2 × 10	12.0	20-1	20-8	21-3	21-10	22-4	22-10	23-5	23-11	24-5	24-10	25-4	25-10		
	16.0	17-5	17-11	18-5	18-11	19-4	19-10	20-3	20-8	21-1	21-6	21-11	22-4	22-9	23-1
	19.2	15-11	16-4	16-10	17-3	17-8	18-1	18-6	18-11	19-3	19-8	20-0	20-5	20-9	21-1
	24.0	14-3	14-8	15-0	15-5	15-10	16-2	16-6	16-11	17-3	17-7	17-11	18-3	18-7	18-11
E	12.0	1.11	1.21	1.31	1.41	1.52	1.63	1.74	1.86	1.98	2.10	2.22	2.34	2.47	2.60
	16.0	0.96	1.05	1.13	1.22	1.32	1.41	1.51	1.61	1.71	1.82	1.92	2.03	2.14	2.25
	19.2	0.88	0.95	1.04	1.12	1.20	1.29	1.38	1.47	1.56	1.66	1.75	1.85	1.95	2.05
	24.0	0.78	0.85	0.93	1.00	1.08	1.15	1.23	1.31	1.40	1.48	1.57	1.66	1.75	1.84

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92 × 10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

TABLE 23-VII-R-12—RAFTERS WITH *L*/180 DEFLECTION LIMITS

The allowable bending stress (F_b) and modulus of elasticity *(E)* used in this table shall be from Tables 23-IV-V-1 and 23-IV-V-2 only.

DESIGN CRITERIA:
Strength — Live load of 50 psf (2.40 kN/m^2) plus dead load of 20 psf (0.96 kN/m^2) determines the required bending design value.
Deflection — For 50 psf (2.40 kN/m^2) live load.
Limited to span in inches (mm) divided by 180.

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 kN/m^2)														
× 25.4 for mm		200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
2 × 4	12.0	2-5	2-11	3-5	3-10	4-2	4-6	4-10	5-1	5-5	5-8	5-11	6-2	6-5	6-7	6-10
	16.0	2-1	2-7	2-11	3-4	3-7	3-11	4-2	4-5	4-8	4-11	5-1	5-4	5-6	5-9	5-11
	19.2	1-11	2-4	2-8	3-0	3-4	3-7	3-10	4-1	4-3	4-6	4-8	4-10	5-1	5-3	5-5
	24.0	1-8	2-1	2-5	2-8	2-11	3-2	3-5	3-7	3-10	4-0	4-2	4-4	4-6	4-8	4-10
2 × 6	12.0	3-10	4-8	5-4	6-0	6-7	7-1	7-7	8-1	8-6	8-11	9-4	9-8	10-0	10-5	10-9
	16.0	3-3	4-0	4-8	5-2	5-8	6-2	6-7	7-0	7-4	7-8	8-1	8-5	8-8	9-0	9-4
	19.2	3-0	3-8	4-3	4-9	5-2	5-7	6-0	6-4	6-9	7-0	7-4	7-8	7-11	8-3	8-6
	24.0	2-8	3-3	3-10	4-3	4-8	5-0	5-4	5-8	6-0	6-4	6-7	6-10	7-1	7-4	7-7
2 × 8	12.0	5-0	6-2	7-1	7-11	8-8	9-4	10-0	10-7	11-2	11-9	12-3	12-9	13-3	13-8	14-2
	16.0	4-4	5-4	6-2	6-10	7-6	8-1	8-8	9-2	9-8	10-2	10-7	11-1	11-6	11-10	12-3
	19.2	3-11	4-10	5-7	6-3	6-10	7-5	7-11	8-5	8-10	9-3	9-8	10-1	10-6	10-10	11-2
	24.0	3-6	4-4	5-0	5-7	6-2	6-7	7-1	7-6	7-11	8-4	8-8	9-0	9-4	9-8	10-0
2 × 10	12.0	6-5	7-10	9-0	10-1	11-1	11-11	12-9	13-6	14-3	15-0	15-8	16-3	16-11	17-6	18-1
	16.0	5-6	6-9	7-10	8-9	9-7	10-4	11-1	11-9	12-4	13-0	13-6	14-1	14-8	15-2	15-8
	19.2	5-1	6-2	7-2	8-0	8-9	9-5	10-1	10-8	11-3	11-10	12-4	12-10	13-4	13-10	14-3
	24.0	4-6	5-6	6-5	7-2	7-10	8-5	9-0	9-7	10-1	10-7	11-1	11-6	11-11	12-4	12-9
E	12.0	0.04	0.08	0.13	0.18	0.23	0.29	0.35	0.42	0.50	0.57	0.65	0.74	0.82	0.91	1.00
	16.0	0.04	0.07	0.11	0.15	0.20	0.25	0.31	0.37	0.43	0.50	0.56	0.64	0.71	0.79	0.87
	19.2	0.04	0.06	0.10	0.14	0.18	0.23	0.28	0.33	0.39	0.45	0.52	0.58	0.65	0.72	0.79
	24.0	0.03	0.06	0.09	0.12	0.16	0.21	0.25	0.30	0.35	0.40	0.46	0.52	0.58	0.64	0.71

Rafter Size (in)	Spacing (in)	Bending Design Value, F_b (psi) (× 0.00689 kN/m^2)														
× 25.4 for mm		1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
2 × 4	12.0	7-0	7-3	7-5	7-8	7-10	8-0	8-2	8-4	8-6	8-8	8-10	9-0	9-2	9-4
	16.0	6-1	6-3	6-5	6-7	6-9	6-11	7-1	7-3	7-5	7-6	7-8	7-10	8-0	8-1
	19.2	5-7	5-9	5-11	6-0	6-2	6-4	6-6	6-7	6-9	6-11	7-0	7-2	7-3	7-5
	24.0	5-0	5-1	5-3	5-5	5-6	5-8	5-9	5-11	6-0	6-2	6-3	6-5	6-6	6-7
2 × 6	12.0	11-1	11-5	11-8	12-0	12-4	12-7	12-10	13-2	13-5	13-8	13-11	14-2	14-5	14-8
	16.0	9-7	9-10	10-2	10-5	10-8	10-11	11-2	11-5	11-7	11-10	12-1	12-4	12-6	12-9
	19.2	8-9	9-0	9-3	9-6	9-9	9-11	10-2	10-5	10-7	10-10	11-0	11-3	11-5	11-7
	24.0	7-10	8-1	8-3	8-6	8-8	8-11	9-1	9-4	9-6	9-8	9-10	10-0	10-3	10-5
2 × 8	12.0	14-7	15-0	15-5	15-10	16-3	16-7	17-0	17-4	17-8	18-0	18-5	18-9	19-1	19-5
	16.0	12-8	13-0	13-4	13-8	14-0	14-4	14-8	15-0	15-4	15-7	15-11	16-3	16-6	16-9
	19.2	11-6	11-10	12-2	12-6	12-10	13-1	13-5	13-8	14-0	14-3	14-6	14-10	15-1	15-4
	24.0	10-4	10-7	10-11	11-2	11-6	11-9	12-0	12-3	12-6	12-9	13-0	13-3	13-6	13-8
2 × 10	12.0	18-7	19-2	19-8	20-2	20-8	21-2	21-8	22-1	22-7	23-0	23-5	23-11	24-4	24-9
	16.0	16-1	16-7	17-0	17-6	17-11	18-4	18-9	19-2	19-7	19-11	20-4	20-8	21-1	21-5
	19.2	14-9	15-2	15-7	15-11	16-4	16-9	17-1	17-6	17-10	18-2	18-6	18-11	19-3	19-7
	24.0	13-2	13-6	13-11	14-3	14-8	15-0	15-4	15-8	15-11	16-3	16-7	16-11	17-2	17-6
E	12.0	1.10	1.20	1.30	1.40	1.51	1.62	1.73	1.84	1.96	2.08	2.20	2.32	2.45	2.58
	16.0	0.95	1.04	1.12	1.21	1.31	1.40	1.50	1.60	1.70	1.80	1.91	2.01	2.12	2.23
	19.2	0.87	0.95	1.03	1.11	1.19	1.28	1.37	1.46	1.55	1.64	1.74	1.84	1.94	2.04
	24.0	0.78	0.85	0.92	0.99	1.07	1.14	1.22	1.30	1.39	1.47	1.56	1.64	1.73	1.82

NOTE: The required modulus of elasticity, *E*, in 1,000,000 pounds per square inch is shown at the bottom of this table, is limited to 2.6 million psi (17.92×10^6 kN/m^2) and less, and is applicable to all lumber sizes shown. Spans are shown in feet-inches (1 foot = 304.8 mm, 1 inch = 25.4 mm) and are limited to 26 feet (7925 mm) and less.

Division VIII—DESIGN STANDARD FOR PLANK-AND-BEAM FRAMING
Based on Wood Construction Data No. 4 (1970) of the American Forest and Paper Association

SECTION 2334 — SCOPE

This division covers plank-and-beam construction under the provisions of this code and is subject to the regulations of this chapter. Tables in this division are for use where moderate uniform loads occur and are not applicable for concentrated loads such as partitions, bathtubs, refrigerators, etc. See also Table 23-IV-A.

SECTION 2335 — DEFINITION

The plank-and-beam structural floor or roof system consists of a plank subfloor or roof decking with supporting beams spaced a maximum of 8 feet (2438 mm) on center.

SECTION 2336 — DESIGN

The load strength and deflection requirements for 2-inch (51 mm) planks and beams are set forth in Tables 23-VIII-A, 23-VIII-B, 23-VIII-C and 23-VIII-D.

The allowable unit stress *f* appropriate for each grade and species of lumber is set forth in Chapter 23, Division III.

TABLE 23-VIII-A—2-INCH (51 mm) PLANK—REQUIRED MINIMUM *f* AND *E* LIVE LOAD: 20, 30 AND 40 POUNDS PER SQUARE FOOT (0.96, 1.44 and 1.92 kN/m^2) WITHOUT PLASTERED CEILING BELOW

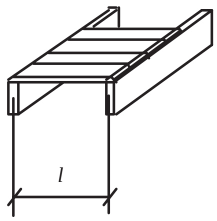
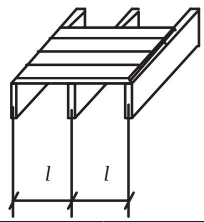
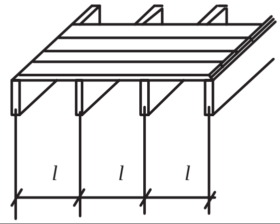
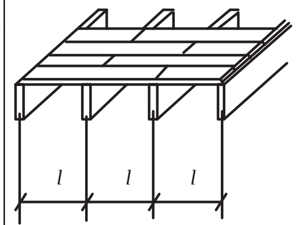
PLANK SPAN (feet)	LIVE LOAD (pounds per square foot)	DEFLECTION LIMITATION	TYPE A		TYPE B		TYPE C		TYPE D	
										
			f psi	*E* psi	*f* psi	*E* psi	*f* psi	*E* psi	*f* psi	*E* psi
× 304.8 for mm	× 0.0479 for kN/m^2		× 0.00689 for N/mm^2							
6	20	$l/240$	360	576,000	360	239,000	288	305,000	360	408,000
		$l/360$	360	864,000	360	359,000	288	457,000	360	611,000
	30	$l/240$	480	864,000	480	359,000	384	457,000	480	611,000
		$l/360$	480	1,296,000	480	538,000	384	685,000	480	917,000
	40	$l/240$	600	1,152,000	600	478,000	480	609,000	600	815,000
		$l/360$	600	1,728,000	600	717,000	480	914,000	600	1,223,000
7	20	$l/240$	490	915,000	490	380,000	392	484,000	490	647,000
		$l/360$	490	1,372,000	490	570,000	392	726,000	490	971,000
	30	$l/240$	653	1,372,000	653	570,000	522	726,000	653	971,000
		$l/360$	653	2,058,000	653	854,000	522	1,088,000	653	1,456,000
	40	$l/240$	817	1,829,000	817	759,000	653	968,000	817	1,294,000
		$l/360$	817	2,744,000	817	1,139,000	653	1,451,000	817	1,941,000
8	20	$l/240$	640	1,365,000	640	567,000	512	722,000	640	966,000
		$l/360$	640	2,048,000	640	850,000	512	1,083,000	640	1,449,000
	30	$l/240$	853	2,048,000	853	850,000	682	1,083,000	853	1,449,000
		$l/360$	853	3,072,000	853	1,275,000	682	1,625,000	853	2,174,000
	40	$l/240$	1,067	2,731,000	1067	1,134,000	853	1,444,000	1,067	1,932,000
		$l/360$	1,067	4,096,000	1067	1,700,000	853	2,166,000	1,067	2,898,000

TABLE 23-VIII-B—ROOF BEAMS—LIVE LOAD 20 POUNDS PER SQUARE FOOT (0.96 kN/m^2)—DEFLECTION LIMITATION *L*/240 (not for support of plaster)

SPAN OF BEAM (feet)	NOMINAL SIZE OF BEAM	MINIMUM *f* AND *E* IN PSI FOR BEAMS SPACED:					
		6′-0″ (1829 mm)		7′-0″ (2134 mm)		8′-0″ (2438 mm)	
		f	*E*	*f*	*E*	*f*	*E*
× 304.8 for mm	× 25.4 for mm	× 0.00689 for N/mm^2					
10	2–3 × 6	1,070	780,000	1,250	910,000	1,430	1,040,000
	1–3 × 8	1,235	680,000	1,440	794,000	1,645	906,000
	2–2 × 8	1,030	570,000	1,200	665,000	1,370	760,000
	1–4 × 8	880	485,000	1,030	566,000	1,175	646,000
	3–2 × 8	685	380,000	800	443,000	915	506,000
	2–3 × 8	615	340,000	720	397,000	820	453,000
	2–2 × 10	630	273,000	735	219,000	840	364,000
11	2–3 × 6	1,295	1,037,000	1,510	121,000	1,730	1,382,000
	1–3 × 8	1,490	905,000	1,740	1,056,000	1,990	1,206,000
	2–2 × 8	1,245	754,000	1,450	880,000	1,660	1,005,000
	1–4 × 8	1,065	647,000	1,245	755,000	1,420	862,000
	3–2 × 8	830	503,000	970	587,000	1,105	670,000
	2–3 × 8	745	453,000	870	529,000	995	604,000
	2–2 × 10	765	363,000	890	424,000	1,020	484,000
12	2–3 × 6	1,545	1,346,000	1,800	1,571,000	2,060	1,794,000
	1–3 × 8	1,775	1,175,000	2,070	1,371,000	2,370	1,566,000
	2–2 × 8	1,480	980,000	1,725	1,144,000	1,970	1,306,000
	1–4 × 8	1,270	840,000	1,480	980,000	1,690	1,120,000
	3–2 × 8	985	653,000	1,150	762,000	1,315	870,000
	2–3 × 8	890	588,000	1,035	686,000	1,185	784,000
	1–6 × 8	755	483,000	880	564,000	1,005	644,000
	2–2 × 10	910	472,000	1,060	551,000	1,210	629,000
	1–3 × 10	1,090	566,000	1,275	660,000	1,455	754,000
13	2–3 × 6	1,815	1,711,000	2,110	1,997,000	2,415	2,281,000
	1–3 × 8	2,085	1,494,000	2,430	1,743,000	2,780	1,991,000
	2–2 × 8	1,740	1,245,000	2,025	1,453,000	2,315	1,660,000
	1–4 × 8	1,490	1,067,000	1,735	1,245,000	1,985	1,422,000
	3–2 × 8	1,160	830,000	1,350	969,000	1,545	1,106,000
	2–3 × 8	1,045	747,000	1,215	872,000	1,390	996,000
	1–6 × 8	885	614,000	1,040	716,000	1,185	818,000
	2–2 × 10	1,070	600,000	1,245	700,000	1,420	800,000
	1–3 × 10	1,280	719,000	1,495	839,000	1,710	958,000
14	2–2 × 8	2,015	1,555,000	2,350	1,815,000	2,685	2,073,000
	3–2 × 8	1,340	1,037,000	1,570	1,210,000	1,790	1,382,000
	2–3 × 8	1,210	933,000	1,410	1,089,000	1,610	1,244,000
	1–6 × 8	1,025	766,000	1,200	894,000	1,370	1,021,000
	1–3 × 10	1,485	899,000	1,730	1,049,000	1,980	1,198,000
	2–2 × 10	1,235	749,000	1,445	874,000	1,650	998,000
	1–4 × 10	1,060	642,000	1,240	749,000	1,415	856,000
	3–2 × 10	825	499,000	965	582,000	1,100	665,000
	2–3 × 10	740	449,000	865	524,000	990	598,000
15	3–2 × 8	1,540	1,275,000	1,800	1,488,000	2,055	1,699,000
	2–3 × 8	1,390	1,148,000	1,620	1,340,000	1,850	1,530,000
	1–6 × 8	1,180	943,000	1,375	1,100,000	1,570	1,257,000
	1–3 × 10	1,705	1,105,000	1,990	1,289,000	2,270	1,473,000
	2–2 × 10	1,420	921,000	1,660	1,075,000	1,895	1,228,000
	1–4 × 10	1,220	789,000	1,420	921,000	1,625	1,052,000
	3–2 × 10	950	614,000	1,105	717,000	1,265	818,000
	2–3 × 10	850	553,000	995	645,000	1,135	737,000
	1–6 × 10	735	464,000	855	541,000	980	618,000
	4–2 × 10	710	461,000	830	538,000	945	614,000
	2–2 × 10	960	512,000	1,120	597,000	1,280	682,000

TABLE 23-VIII-C—ROOF BEAMS—LIVE LOAD 30 POUNDS PER SQUARE FOOT (1.44 kN/m²)— DEFLECTION LIMITATION *L*/240 (not for support of plaster)

SPAN OF BEAM (feet)	NOMINAL SIZE OF BEAM	MINIMUM *I* AND *E* IN PSI FOR BEAMS SPACED: 6′-0″ (1829 mm) *f*	6′-0″ (1829 mm) *E*	7′-0″ (2134 mm) *f*	7′-0″ (2134 mm) *E*	8′-0″ (2438 mm) *f*	8′-0″ (2438 mm) *E*
× 304.8 for mm	× 25.4 for mm	× 0.00689 for N/mm²					
10	2–3 × 6	1,430	1,170,000	1,670	1,365,000	1,905	1,560,000
	1–3 × 8	1,645	1,020,000	1,920	1,190,000	2,195	1,360,000
	1–4 × 8	1,175	727,000	1,370	848,000	1,565	969,000
	3–2 × 8	915	570,000	1,070	665,000	1,220	760,000
	2–3 × 8	820	510,000	955	595,000	1,095	680,000
	2–4 × 8	590	364,000	690	425,000	785	485,000
	2–2 × 10	840	409,000	980	477,000	1,120	545,000
11	2–3 × 6	1,725	1,555,000	2,015	1,815,000	2,300	2,073,000
	1–3 × 8	1,990	1,357,000	2,320	1,584,000	2,655	1,809,000
	1–4 × 8	1,420	970,000	1,660	1,132,000	1,895	1,293,000
	3–2 × 8	1,105	754,000	1,290	880,000	1,475	1,005,000
	2–3 × 8	995	679,000	1,160	792,000	1,325	905,000
	2–4 × 8	710	485,000	830	566,000	945	646,000
	2–2 × 10	1,020	544,000	1,190	635,000	1,360	725,000
12	1–4 × 8	1,690	1,260,000	1,970	1,470,000	2,255	1,679,000
	3–2 × 8	1,315	979,000	1,535	1,142,000	1,755	1,305,000
	2–3 × 8	1,185	882,000	1,385	1,029,000	1,580	1,176,000
	2–4 × 8	845	630,000	985	735,000	1,125	840,000
	1–6 × 8	1,005	724,000	1,175	845,000	1,340	965,000
	2–2 × 10	1,210	708,000	1,410	826,000	1,615	944,000
	3–2 × 10	810	472,000	945	551,000	1,080	629,000
	2–3 × 10	725	424,000	845	495,000	965	565,000
13	1–4 × 8	1,985	1,600,000	2,315	1,867,000	2,645	2,133,000
	3–2 × 8	1,545	1,245,000	1,805	1,453,000	2,060	1,659,000
	2–3 × 8	1,390	1,120,000	1,620	1,307,000	1,855	1,493,000
	2–4 × 8	990	801,000	1,155	935,000	1,320	1,068,000
	1–6 × 8	1,180	921,000	1,375	1,075,000	1,575	1,228,000
	2–2 × 10	1,425	900,000	1,665	1,050,000	1,900	1,200,000
	3–2 × 10	950	600,000	1,110	700,000	1,265	800,000
	2–3 × 10	855	540,000	1,000	630,000	1,140	720,000
	1–4 × 10	1,220	923,000	1,425	1,079,000	1,625	1,230,000
14	3–2 × 8	1,790	1,555,000	2,090	1,815,000	2,385	2,073,000
	2–3 × 8	1,610	1,400,000	1,880	1,634,000	2,145	1,866,000
	2–4 × 8	1,150	1,000,000	1,340	1,167,000	1,535	1,333,000
	1–6 × 8	1,370	1,149,000	1,600	1,341,000	1,825	1,532,000
	2–2 × 10	1,650	1,123,000	1,925	1,310,000	2,200	1,497,000
	3–2 × 10	1,100	748,000	1,285	873,000	1,465	997,000
	2–3 × 10	990	673,000	1,155	785,000	1,320	897,000
	1–4 × 10	1,415	963,000	1,650	1,124,000	1,885	1,283,000
	1–6 × 10	915	943,000	1,070	1,100,000	1,220	1,257,000
	2–4 × 10	705	481,000	825	561,000	940	641,000
15	2–4 × 8	1,320	1,230,000	1,540	1,435,000	1,760	1,640,000
	1–6 × 8	1,570	1,414,000	1,830	1,650,000	2,095	1,885,000
	2–2 × 10	1,895	1,381,000	2,210	1,612,000	2,525	1,841,000
	3–2 × 10	1,260	921,000	1,470	1,075,000	1,680	1,228,000
	2–3 × 10	1,135	829,000	1,325	967,000	1,515	1,105,000
	1–4 × 10	1,620	1,183,000	1,890	1,380,000	2,160	1,577,000
	1–6 × 10	980	696,000	1,145	812,000	1,305	928,000
	2–4 × 10	810	592,000	945	691,000	1,080	789,000
	4–2 × 10	945	691,000	1,105	806,000	1,260	921,000
	1–8 × 10	720	510,000	840	595,000	960	680,000
	2–2 × 12	1,280	768,000	1,495	896,000	1,705	1,024,000
	1–4 × 12	1,095	658,000	1,280	768,000	1,460	877,000

TABLE 23-VIII-D—ROOF AND FLOOR BEAMS—LIVE LOAD 40 POUNDS PER SQUARE FOOT (1.92 kN/m^2)—DEFLECTION LIMITATION *L*/360 (not for support of plaster)

SPAN OF BEAM (feet)	NOMINAL SIZE OF BEAM	MINIMUM *f* AND *E* IN PSI FOR BEAMS SPACED: 6′-0″ (1829 mm) *f*	6′-0″ (1829 mm) *E*	7′-0″ (2134 mm) *f*	7′-0″ (2134 mm) *E*	8′-0″ (2438 mm) *f*	8′-0″ (2438 mm) *E*
× 304.8 for mm	× 25.4 for mm	× 0.00689 for N/mm^2					
10	1–3 × 8	2,055	1,700,000	2,400	1,984,000	2,740	2,266,000
	2–2 × 8	1,710	1,417,000	1,995	1,654,000	2,280	1,889,000
	1–4 × 8	1,470	1,211,000	1,715	1,413,000	1,960	1,614,000
	1–6 × 8	875	697,000	1,020	813,000	1,165	929,000
	2–2 × 10	1,050	681,000	1,225	795,000	1,400	908,000
	1–3 × 10	1,260	819,000	1,470	956,000	1,680	1,092,000
	1–4 × 10	900	585,000	1,050	683,000	1,200	780,000
11	2–2 × 8	2,070	1,886,000	2,415	2,201,000	2,760	2,514,000
	1–4 × 8	1,775	1,616,000	2,070	1,886,000	2,365	2,154,000
	1–6 × 8	1,055	929,000	1,230	1,084,000	1,405	1,238,000
	2–2 × 10	1,275	906,000	1,490	1,057,000	1,700	1,208,000
	1–3 × 10	1,575	1,090,000	1,780	1,272,000	2,030	1,453,000
	1–4 × 10	1,090	779,000	1,270	909,000	1,455	1,038,000
	3–2 × 10	850	605,000	990	706,000	1,135	806,000
12	1–6 × 8	1,255	1,206,000	1,465	1,407,000	1,670	1,607,000
	3–2 × 8	1,645	1,631,000	1,920	1,903,000	2,190	2,174,000
	2–2 × 10	1,510	1,180,000	1,760	1,377,000	2,010	1,573,000
	1–3 × 10	1,820	1,415,000	2,125	1,651,000	2,425	1,886,000
	1–4 × 10	1,300	1,010,000	1,515	1,179,000	1,735	1,346,000
	3–2 × 10	1,010	786,000	1,180	917,000	1,345	1,048,000
	2–3 × 10	905	706,000	1,055	824,000	1,205	941,000
	1–6 × 10	785	594,000	915	693,000	1,045	792,000
	2–4 × 10	650	505,000	760	589,000	865	673,000
13	1–6 × 8	1,475	1,535,000	1,720	1,791,000	1,965	2,046,000
	2–3 × 8	1,735	1,866,000	2,025	2,178,000	2,315	2,487,000
	2–4 × 8	1,235	1,335,000	1,440	1,558,000	1,645	1,779,000
	3–2 × 10	1,185	1,000,000	1,380	1,167,000	1,580	1,333,000
	2–2 × 10	1,780	1,500,000	2,075	1,750,000	2,370	2,000,000
	1–3 × 10	2,130	1,799,000	2,485	2,099,000	2,840	2,398,000
	2–3 × 10	1,070	900,000	1,250	1,050,000	1,425	1,200,000
	1–4 × 10	1,525	1,537,000	1,780	1,794,000	2,035	2,049,000
	2–4 × 10	760	642,000	890	749,000	1,015	856,000
14	2–4 × 8	1,435	1,666,000	1,675	1,944,000	1,915	2,221,000
	3–2 × 10	1,375	1,246,000	1,605	1,454,000	1,830	1,661,000
	2–3 × 10	1,235	1,121,000	1,440	1,308,000	1,645	1,494,000
	1–4 × 10	1,770	1,605,000	2,065	1,873,000	2,360	2,139,000
	2–4 × 10	880	801,000	1,025	935,000	1,175	1,068,000
	3–3 × 10	825	749,000	960	874,000	1,100	998,000
	1–6 × 10	1,145	1,571,000	1,335	1,833,000	1,525	2,094,000
	1–8 × 10	780	691,000	910	806,000	1,040	921,000
	4–2 × 10	1,030	936,000	1,200	1,092,000	1,375	1,248,000
	2–2 × 12	1,395	1,040,000	1,630	1,214,000	1,860	1,386,000
15	3–2 × 10	1,575	1,535,000	1,840	1,791,000	2,100	2,046,000
	2–3 × 10	1,420	1,381,000	1,655	1,612,000	1,890	1,841,000
	2–4 × 10	1,010	986,000	1,175	1,151,000	1,345	1,314,000
	3–3 × 10	945	921,000	1,100	1,075,000	1,260	1,228,000
	1–6 × 10	1,225	1,160,000	1,430	1,354,000	1,635	1,546,000
	1–8 × 10	900	850,000	1,050	992,000	1,200	1,133,000
	4–2 × 10	1,180	1,151,000	1,375	1,343,000	1,575	1,534,000
	2–2 × 12	1,600	1,280,000	1,865	1,494,000	2,130	1,706,000
	3–2 × 12	1,065	854,000	1,240	997,000	1,420	1,138,000
	1–3 × 12	1,920	1,536,000	2,240	1,792,000	2,560	2,047,000
	4–2 × 12	800	640,000	935	747,000	1,065	853,000
	2–3 × 12	960	767,000	1,120	895,000	1,280	1,022,000

UNIFORM BUILDING CODE STANDARD 23-1

CLASSIFICATION, DEFINITION, METHODS OF GRADING AND DEVELOPMENT OF DESIGN VALUES FOR ALL SPECIES OF LUMBER

See Sections 2302.1 and 2303, *Uniform Building Code*

SECTION 23.101 — ADOPTION OF ASTM D 1990, ASTM D 245 AND ASTM D 2555, THE WOOD HANDBOOK NO. 72, PS20-94 AND THE NATIONAL GRADING RULE FOR DIMENSION LUMBER

Classification, definition, methods of grading and development of design values for all species of lumber shall be in accordance with ASTM D 1990-91, ASTM D 245-88 and ASTM D 2555-95 published by the American Society for Testing and Materials, Wood Handbook No. 72 published by the U.S. Department of Agriculture, Voluntary Product Standard PS20-94 published by the U.S. Department of Commerce and the National Grading Rule for Dimension Lumber promulgated by the National Grading Rule Committee, Post Office Box 210, Germantown, Maryland 20875-0210, and published in the American Lumber Standard Committee certified grading rules, as if set out at length herein.

The grade mark on lumber or end-jointed lumber shall include an approved, easily distinguished mark, or insignia of the grading agency which has been accredited by an accreditation body which complies with the requirements of U.S. Department of Commerce PS20-94, or equivalent.

UNIFORM BUILDING CODE STANDARD 23-2
CONSTRUCTION AND INDUSTRIAL PLYWOOD

Based on Product Standard PS 1-95 (for Construction and Industrial Plywood) of the United States Department of Commerce, and National Institute of Science and Technology Calculation of Diaphragm Action, an Engineering Standard of the International Conference of Building Officials

See Sections 1404.1, 2302.1, 2303 and 2304, and Tables 23-III-A, 23-II-H, 23-II-I-1 and 23-II-E-2, *Uniform Building Code*

SECTION 23.201 — SCOPE

23.201.1 General. This standard covers construction and industrial plywood for both Exterior and Interior types. This standard also covers construction and industrial hardwood plywood of red and white lauan (Philippine mahogany), tanoak, red alder and western poplar.

23.201.2 Wood Species. Plywood produced under this standard considers four species classifications: Groups 1, 2, 3 and 4. The species used for the face and back plies are at the option of the manufacturer. When face and back veneers are of the same species group, the panels shall be identified as being of that species group. The species covered in each group are set forth in Table 23-2-A. In addition, other softwood or hardwood species having an average specific gravity of 0.41 or more, based on green volume and oven dry weight, may be used for inner plies except as required for premium grades in Section 23.205.

SECTION 23.202 — DEFINITIONS

General definitions not included in the following section are to be interpreted as defined in UBC Standard 23-1.

BACK is the side of a panel that is of lower veneer quality on any panel whose outer plies are of different veneer grades.

BORER HOLES are voids made by wood-boring insects, such as grubs or worms.

BROKEN GRAIN is a (leafing, shelling, grain separation) separation on veneer surface between annual rings.

CENTERS are inner plies whose grain direction runs parallel to that of the outer plies. May be of parallel laminated plies.

CHECK is a lengthwise separation of wood fibers, usually extending across the rings of annual growth caused chiefly by strains produced in seasoning.

CLASS I, CLASS II are terms used to identify different species group combinations of B-B concrete form panels. The standard provides for two classes, Class I and Class II, as described in Section 23.205.3.

CORE is sometimes referred to as a crossband.

CROSSBAND GAP and CENTER GAP are open joints extending through or partially through a panel, which results when crossband or center veneers are not tightly butted.

CROSSBANDS are inner layers whose grain direction runs perpendicular to that of the outer plies. They may be of parallel laminated plies and are sometimes referred to as core.

DEFECTS, OPEN, are irregularities such as splits, open joints, knotholes, or loose knots, that interrupt the smooth continuity of the veneer.

DELAMINATION is a visible separation between plies that would normally receive glue at their interface and be firmly contacted in the pressing operation. Wood characteristics, such as checking, leafing, splitting and broken grain, are not to be construed as delamination. See corresponding definition for those terms.

1. For purposes of reinspection, areas coinciding with open knotholes, pitch pockets, splits and gaps and other voids or characteristics permitted in the panel grade are not considered in evaluating ply separation of Interior-type panels bonded with interior or intermediate glue.

2. In evaluating Interior panels bonded with exterior glue, delamination in any glueline shall not exceed 3 square inches (1935 mm^2) except where directly attributable to defects permitted in the grade as follows:

Delamination associated with:

2.1 Knots and knotholes—shall not exceed the size of the defect plus a surrounding band not wider than $^3/_4$ inch (19 mm).

2.2 All other forms of permissible defects—shall not exceed the size of the defect.

3. In evaluating Exterior-type panels for ply separation, the area coinciding with the grade characteristics noted in Item 1 are considered, and a panel is considered delaminated if visible ply separation at a single glueline in such area exceeds 3 square inches (1935 mm^2).

EDGE SPLITS are wedge-shaped openings in the inner plies caused by splitting of the veneer before pressing.

FACE is the better side of any panel whose outer plies are of different veneer grades; also either side of a panel where the grading rules draw no distinction between faces.

GROUP is the term used to classify species covered by this standard in an order that provides a basis for simplified marketing and efficient utilization. Species covered by the standard are classified as Groups 1, 2, 3 and 4. See Table 23-2-A for listing of species in individual groups.

HEARTWOOD is the nonactive core of a log generally distinguishable from the outer portion (sapwood) by its darker color.

INNER PLIES are other than exposed face and back plies in a panel construction.

JOINTED INNER PLIES are crossband and center veneer that have had edges machine-squared to permit tightest possible layup.

KNOT is a natural characteristic of wood that occurs where a branch base is embedded in the trunk of a tree. Generally the size of a knot is distinguishable by (1) a difference in color of limbwood and surrounding trunkwood; (2) abrupt change in growth ring width between knot and bordering trunkwood; and (3) diameter of circular or oval shape described by points where checks on the face of a knot that extend radially from its center to its side experience abrupt change in direction.

KNOTHOLES are voids produced by the dropping of knots from the wood in which they are originally embedded.

LAP is a condition where the veneers are so placed that one piece overlaps the other.

LAYER is a single veneer ply or two or more plies laminated with grain direction parallel. Two or more plies laminated with grain direction parallel is a parallel laminated layer.

NOMINAL THICKNESS is full "designated" thickness. For example, $^1/_{10}$-inch (2.5 mm) nominal veneer is 0.10 inch (2.5 mm) thick. Nominal $^1/_2$-inch-thick (13 mm) panel is 0.50 inch (13 mm) thick. Also, commercial size designations are subject to acceptable tolerances.

PATCHES are insertions of sound wood or synthetic material in veneers or panels for replacing defects. "Boat" patches are oval shaped with sides tapering in each direction to a point or to a small rounded end. "Router" patches have parallel sides and rounded ends. "Sled" patches are rectangular with feathered ends.

PITCH POCKET is a well-defined opening between rings of annual growth, usually containing, or which has contained, pitch, either solid or liquid.

PITCH STREAK is a localized accumulation of resin in coniferous woods which permeates the cells forming resin soaks, patches or streaks.

PLUGS are sound wood of various shapes, including, among others, circular and dogbone, for replacing defective portions of veneer used to fill openings and provide a smooth, level, durable surface. Plugs usually are held in veneer by friction until veneers are bonded into plywood.

PLY is a single veneer lamina in a glued plywood panel. (See also "layer.")

PLYWOOD is a flat panel, built up of sheets of veneer called plies, united under pressure by a bonding agent to create a panel with an adhesive bond between plies as strong as or stronger than the wood. Plywood is constructed of an odd number of layers with grain of adjacent layers perpendicular. Layers may consist of a single ply or two or more plies laminated with grain direction parallel. Outer layers and all odd-numbered layers generally have the grain direction oriented parallel to the long dimension of the panel. The odd number of layers with alternating grain direction equalizes strains, prevents splitting and minimizes dimensional change and warping of the panel.

Exterior type—Plywood of this type is produced with a C grade veneer or better throughout and is bonded with completely waterproof adhesives. It is a plywood that will retain its glue bond when repeatedly wetted and dried or otherwise subjected to the weather, and is therefore intended for permanent exterior exposure. Table 23-2-E lists the grades within this type. Adhesive performance requirements are provided in Section 23.207.

Interior type—Plywood of this type is moisture resistant. It is intended for all interior applications as well as applications where it may be temporarily exposed to the elements. Table 23-2-D lists the grades within this type. Adhesive performance requirements are provided in Section 23.207.

Intermediate glue (IMG) type—Plywood of this type is bonded with adhesives that possess high-level bacteria, mold and moisture resistance. It is plywood suitable for protected construction and industrial uses where delays in providing protection may be expected. Adhesive performance requirements are provided in Section 23.207. (The grades of IMG-type plywood generally available are given in Table 23-2-D.)

Overlaid plywood is Exterior-type plywood to which has been added a resin-treated fiber surfacing material on one or both sides. It is made in two standard categories, "High Density" and "Medium Density," and a "Special" category, all of which refer to the surfacing materials. The overlay surfaces are permanently fused to the base panel under heat and pressure. Although designed for all types of moisture exposure and service, all overlaid plywood is made only in the Exterior type. This refers to the base panel and to the overlay itself.

REPAIR is any patch, plug or shim.

SAPWOOD is the living wood of lighter color occurring in the outer portion of a log. Sapwood is sometimes referred to as "sap."

SHIM is a long narrow repair of wood or suitable synthetic not more than $^3/_{16}$ inch (4.8 mm) wide.

SHOP CUTTING PANELS are panels which have been rejected as not conforming to grade requirements of standard grades in this standard. Identification of these panels shall be with a separate mark that makes no reference to this standard and contains the notation, "Shop Cutting Panel—All Other Marks Void." Blistered panels are not considered as coming within the category covered by this stamp.

SPAN RATING is a set of numbers used in marking sheathing and combination subfloor underlayment (single floor) grades of plywood as described in Section 23.209.

SPLIT is lengthwise separation of wood fibers completely through the veneer caused chiefly by manufacturing process or handling.

STREAKS are synonymous with "pitch streaks."

STRUCTURAL I is a name used to identify panels that provide for greatest refinement of engineering properties which may be important in the use of plywood for structural components and other sophisticated engineered applications. Manufacturing requirements include special provisions for species, panel construction and veneer grade characteristics as described in Section 23.205.4.

TORN GRAIN. See "broken grain."

TOUCH-SANDING is a sizing operation consisting of a light surface sanding in a sander. Sander skips to any degree are admissible.

VENEER consists of thin sheets of wood of which plywood is made. Veneer is also referred to as plies in the glued panel.

WATERPROOF ADHESIVE is glue capable of bonding plywood in a manner to satisfy the exterior performance requirements given herein.

WHITE POCKET is a form of decay (*Fomes pini*) that attacks most conifers but has never been known to develop in wood in service. In plywood manufacture, routine drying of veneer effectively removes any possibility of decay surviving.

Heavy white pockets may contain a great number of pockets, in dense concentrations, running together and at times appearing continuous. Holes may extend through the veneer but wood between pockets appears firm. At any cross section extending across the width of the affected area, sufficient wood fiber shall be present to develop not less than 40 percent of the strength of clear veneer. Brown cubical and similar forms of decay which have caused the wood to crumble are prohibited.

Light white pockets are advanced beyond incipient or stain stage to the point where the pockets are present and plainly visible, mostly small and filled with white cellulose and generally distributed with no heavy concentrations. Pockets for the most part are separate and distinct with few to no holes through the veneer.

WOOD FAILURE (PERCENT) is the area of wood fiber remaining at the glueline following completion of the specified shear test. Determination is by means of visual examination and expressed as a percent of the 1-square-inch (645 mm^2) test area. (See Section 23.214 for test.)

SECTION 23.203 — REQUIREMENTS

23.203.1 Workmanship. Unless otherwise specified, sanded plywood shall be surfaced on two sides. Faces and backs of panels shall be full width and full length except that C grade and D grade backs may be narrow on one edge or short on one end only, but by not more than $^1/_8$ inch (3.2 mm) for half the panel length or width, respectively. Inner plies shall be full width and length except that one edge or end void not exceeding $^1/_8$ inch (3.2 mm) in depth or 8 inches (203 mm) in length per panel will be acceptable. Crossband veneers not exceeding $^1/_8$ inch (3.2 mm) in thickness may be lapped but by not more than $^3/_{16}$ inch (4.8 mm) when adjacent to faces, or $^1/_2$ inch (13 mm) when adjacent to backs, and provided such laps create no adjacent visible opening. Sanding defects resulting from crossband laps shall not be permitted in panel faces.

C or D grade veneers may be lapped by not more than $^1/_2$ inch (13 mm), provided such laps create no adjacent visible opening. All plies of CD panels only shall be full length and full width except that no more than half the length of one edge nor half the width of one end may contain short or narrow plies. This is contingent on such plies not being short or narrow by more than $^3/_{16}$ inch (4.8 mm), the aggregate area in the plane of the plies of such edge characteristics not exceeding 6 square inches (3871 mm^2) in the entire panel, and such edge characteristics not occurring in more than one ply at any panel cross section.

In grades other than CD, backs may be narrow on one edge or short on one end only, but by not more than $^1/_8$ inch (3.2 mm) for half the panel length or width, respectively; inner plies shall be full width and length, except that one edge or end void not exceeding $^1/_8$ inch (3.2 mm) in depth or 8 inches (203 mm) in length per panel will be acceptable.

Crossband gaps or center gaps, except as noted for plugged crossband and jointed crossband shall not exceed 1 inch (25 mm) in width for a depth of 8 inches (203 mm) (measured from panel edge) and the average of all gaps occurring in a panel shall not exceed $^1/_2$ inch (13 mm). Every effort shall be made to produce closely butted core joints.

Where plugged inner plies are specified, inner plies shall be of C-Plugged veneer and gaps between adjacent pieces of inner plies shall not exceed $^1/_2$ inch (13 mm). Where jointed inner plies are specified, gaps between pieces of inner plies shall not exceed $^3/_8$ inch (9.5 mm), and the average of all gaps occurring in a panel shall not exceed $^3/_{16}$ inch (4.8 mm).

Unless otherwise specified, plugged core (also referred to as solid core) shall be core and center construction of C-Plugged veneer, and gaps between adjacent pieces of core shall not exceed $^1/_2$ inch (13 mm). When jointed core is specified, gaps between pieces of core shall not exceed $^3/_8$ inch (9.5 mm), and the average of all gaps occurring in a panel shall not exceed $^3/_{16}$ inch (4.8 mm).

Plywood shall be clean, well manufactured, and free from blisters, laps and other defects, except as expressly permitted herein. Panels shall have no continuous holes or through openings from face to back.

End butt joints may be used only under the following conditions:

1. Decorative grades as provided in Section 23.205.2.

2. Butt joints having a total aggregate width not exceeding the width of the panel may occur in the center ply of five-ply, five-layer panels. The butt joints must be perpendicular to the grain of the panel face and back plies. The use of butt-jointed centers is allowed in Interior sanded grades in thicknesses up to and including $^1/_2$ inch (13 mm), and in C-D and C-D Plugged thicknesses up to and including $^3/_4$ inch (19 mm). End butt joints shall not be used in Structural I panels. Panels with butt joints in center plies shall be marked “butt-jointed center.”

Plywood panels shall be constructed in the grades and veneer combinations as set forth in Tables 23-2-D and 23-2-E. All terms used herein shall be interpreted as described in Section 23.202. Constructions for all panels shall conform to the minimum number of plies and layers as set forth in Table 23-2-C. The proportion of wood with grain perpendicular to panel face grain shall not be less than 33 percent or more than 70 percent of the total panel thickness. The combined thickness of inner layers in panels having four or more plies shall not be less than 45 percent of the total panel thickness. For application of the above requirements, the panel thickness shall be the actual finished panel thickness and veneer thickness shall be the dry veneer thickness before layup. The grain of all layers shall be at right angles to the grain of adjacent layers and to the ends or edges of the panels. The entire area of each contacting surface of the adjacent veneer plies including repairs shall be bonded with an adhesive in a manner to assure satisfactory compliance with the performance requirements for its type as set forth in the tests described in this standard. Where face or back plies consist of more than one piece of edge-joined veneer, gaps between adjacent pieces shall be graded as splits. Any adhesive or bonding system that causes degradation of the wood or latent failure of bond will not be permitted.

For the purpose of veneer repairing or edge joining, strings, ribbons or tapes up to $^3/_8$-inch (9.5 mm) maximum width can occur in a glueline and shall be considered as allowable localized defects in the evaluation of glueline test specimens. Wider strings, ribbons or tapes may be used for veneer repairing or joining if they are prequalified to show bonding equal to the required bonding for that panel. Glueline test specimens cut to include the strings, ribbons or tapes wider than $^3/_8$ inch (9.5 mm) shall not be discarded because of the presence of these materials.

Veneer strips may be joined by string stitching, provided the punch for making holes prior to stitching has a dimension across the grain of 0.095 inch (2.4 mm) or less and the holes are spaced $^1/_2$ inch (13 mm) center-to-center or greater. All veneer used for inner plies may be stitched. Stitched veneer used for outer plies is limited to panels with C or D grade faces or backs, except stitched C veneer may not be used for faces in decorative panels. Panels may have face or back plies stitched but not both.

Shims or strips of veneer shall not be used to repair panel edge voids. However, filling of permissible edge voids with approved synthetic fillers neatly applied will be admitted. Staples or pins of metal or synthetic material are prohibited. Face and back plies of exposed N, A and B veneer panels shall have the bark or tight surface out. Plies directly under surfaces of overlaid panels are not considered exposed veneers.

23.203.2 Tolerance. A tolerance of + 0.0 inch – $^1/_{16}$ inch (0.0625) (+ 0.0 mm – 1.6 mm) shall be allowed on the specified length and/or width. Sanded panels shall have a thickness tolerance of $^1/_{64}$ inch (0.0156) (0.4 mm) of the specified panel thickness of $^3/_4$ inch (19 mm) and less, and ± 3.0 percent of the specified thickness for panels thicker than $^3/_4$ inch (19 mm). Unsanded, touch-sanded, and overlaid panels shall fall within a plus or minus tolerance of $^1/_{32}$ inch (0.0312) (0.8 mm) of the specified panel thickness for all thicknesses through $^{13}/_{16}$ inch (21 mm), and such panels greater than $^{13}/_{16}$ inch (21 mm) shall have a thickness tolerance of 5 percent over or under the specified thickness. Panel thickness shall be based on a moisture content of 9 percent.

Panels shall be square within $^1/_{64}$ inch per lineal foot (1.3 mm per m) for panels of 4-foot by 4-foot (1219 mm by 1219 mm) size or larger. Panels less than 4 feet (1219 mm) in length or width shall be square within $^1/_{16}$ inch (1.6 mm) measured along the short dimension. All panels shall be sawn so that a straight line drawn from one comer to the adjacent corner shall fall within $^1/_{16}$ inch (1.6 mm) of panel edge.

23.203.3 Moisture Content. Moisture content of panels at time of shipment shall not exceed 18 percent of oven-dry weight as determined by the oven-dry test specified in Section 23.217.

SECTION 23.204 — VENEER

23.204.1 General. Except as noted, veneers shall be $^1/_{10}$ inch (2.5 mm) or thicker in panels $^3/_8$ inch (9.5 mm) rough (unsanded) thickness or over; $^1/_{12}$ inch (2.1 mm) or thicker in panels of lesser thickness. In no case shall veneers used in face or back layers be thicker than $^1/_4$ inch (6.4 mm), or veneers used in inner layers thicker than $^5/_{16}$ inch (7.9 mm).

One-twelfth-inch (2.1 mm) veneer may be used as crossbands in five-ply, five-layer, $^1/_2$-inch (13 mm) panels and in parallel laminated layers.

One-sixteenth-inch (1.6 mm) veneer may be used for any ply in five-ply Exterior-type panels less than $^1/_2$ inch (13 mm) in thickness, as the center only in other five-ply panels, and may be included in a parallel laminated layer.

Face and back veneers must be $^1/_8$-inch (3.2 mm) minimum thickness for $^{19}/_{32}$ inch and $^5/_8$ inch (15.1 mm and 15.9 mm), three-, four- and five-ply, three-layer panels of C-D, C-D Plugged, C-C, C-C Plugged and Underlayment grades.

For further limitations on panel layup, refer to Table 23-2-C panel constructions and workmanship.

The average veneer thickness shall conform to the limitations given in this standard within a tolerance of 5 percent of the specified nominal thickness measured dry before layup.

Parallel laminated outer layers may be used only in C-C, C-D, Structural I C-C and C-D grades. Such layers shall consist of veneers $^1/_{10}$ inch (2.5 mm) or thicker in any thickness combination not exceeding $^1/_4$-inch (6.4 mm) total layer thickness. The face and back plies or exposed plies of outer layers shall conform to the species group and grade requirements for faces and backs, respectively, of the panel grade. The unexposed plies of outer layers, or subface and subback plies, shall conform to the species group and grade requirements for inner plies of the panel grade as specified in Sections 23.204.3 and 23.204.4.

The maximum split or gap in subfaces and subbacks shall be $^1/_4$ inch (6.4 mm) under the faces of Structural I C-C and C-D panels, $^1/_2$ inch (13 mm) under the faces of C-C and C-D grades, and $^1/_2$ inch (13 mm) under D backs.

Parallel laminated inner layers in any grade shall consist of veneers $^1/_{16}$ inch (1.6 mm) or thicker in any thickness combination not exceeding $^7/_{16}$-inch (11 mm) total layer thickness. Individual plies in such layers shall conform to the species group and grade requirements for inner plies of the panel grade.

The veneers used in each ply of each panel and the completed panel shall conform with the applicable veneer grade and with the construction and workmanship requirements given herein. Additionally, the type and frequency of the characteristics shall be further limited as set forth for the grades listed in Table 23-2-B.

23.204.2 Number of Plies. For a given thickness, the number of plies used in the panel makeup shall not be less than as provided in Table 23-2-C.

23.204.3 Species for Faces and Backs. For purposes of this standard, veneer species are classified into the four groups given in Table 23-2-A. The species of face and back plies may be from any group; however, when a face or back is made of more than one piece, the entire ply shall be of the same species. Panels, other than unsanded and touch-sanded panels, with span ratings which are produced with face and back veneers of the same species group shall be classified as being of that species group. Touch-sanded panels without span ratings that are manufactured with face and back plies of different species groups shall be identified by the larger numbered species group (i.e., Group 4 is larger numbered than Group 1). Sanded panels $^3/_8$ inch (9.5 mm) or less in thickness and decorative panels of any thickness that are manufactured with face and back plies of different species groups shall be identified by the face species group number. Sanded panels greater than $^3/_8$ inch (9.5 mm) that are manufactured with face and back plies of different species groups shall be identified by the larger numbered species group, except that sanded panels with C or D grade backs may be identified by the face species group number if backs are no more than one species group larger in number than the face and are $^1/_8$ inch (3.2 mm) or thicker before sanding. The species classification group (except for unsanded and touch-sanded panels with span ratings) shall be set forth in the grade mark on each panel. See Section 23.209 for identification requirements for unsanded and touch-sanded panels with span ratings. Where intermixing between species groups occurs in the faces and backs of unsanded or touch-sanded panels with span ratings, provisions of Table 23-2-G shall be followed. (Douglas fir for the purpose . . . and loblolly *[Pinus taeda]* pines.) Because black, white and Engelmann spruce cannot be separated in veneer form by gross structure or minute anatomy, these species shall be classed as Engelmann spruce unless procedures are established for identification prior to peeling.

23.204.4 Species for Inner Plies. Inner plies may be of any species or of any softwood species or any hardwood species having a published average specific gravity value of 0.41 or more, based on green volume and oven-dry weight, except as required for premium panels in Section 23.205.

23.204.5 Scarfed Veneers. Scarfed veneer may be used for any face, back or inner ply except as provided in Section 23.211. Scarfed joints shall not have a slope steeper than 1 in 8, but may be specified at less than 1 in 8. Veneer in the scarf area shall not contain defects which reduce its effective cross section by more than 20 percent. Veneer scarfed joints shall be glued with a waterproof adhesive.

23.204.6 Classification. All veneers used in the construction of the plywood panels shall conform to one of the following grade requirements of which N grade is the highest classification:

23.204.6.1 Grade N veneer. Grade N veneer (intended for natural finish) shall be smoothly cut 100 percent heartwood or 100 percent sapwood, free from knots, knotholes, pitch pockets, open splits, other open defects, and stain; limited to not more than two pieces in a 48-inch (1219 mm) width; not more than three pieces in wider panels; and well matched for color and grain.

Suitable synthetic fillers may be used to fill small cracks or checks not more than $^1/_{32}$ inch (0.8 mm) wide; small splits or openings up to $^1/_{16}$ inch (1.6 mm) wide if not exceeding 2 inches (51 mm) in length; and small chipped areas or openings not more than $^1/_8$ inch (3.2 mm) wide by $^1/_4$ inch (6.4 mm) long. Pitch streaks averaging not more than $^3/_8$ inch (9.5 mm) in width and blending with color of wood are permitted.

Repairs shall be neatly made and parallel to grain and are limited to a total of six in number in any 4-foot by 8-foot (1219 mm by 2438 mm) face, with proportional limits for other sizes. They shall also be well matched for color and grain.

Patches are limited to three "router" patches not exceeding 1 inch (25 mm) in width and $3^1/_2$ inches (89 mm) in length.

No overlapping is permitted.

Wood shims not exceeding $^3/_{16}$ inch (4.8 mm) in width and 12 inches (305 mm) in length that occur only at the ends of the panel are permitted.

23.204.6.2 Grade A veneer. Grade A veneer (suitable for painting) shall be firm, smoothly cut and free from knots, pitch pockets, open splits and other open defects. It shall be well joined when of more than one piece.

Suitable synthetic fillers may be used to fill, in Exterior-type panels, small cracks or checks not more than $^1/_{32}$ inch (0.8 mm) wide; small splits or openings up to $^1/_{16}$ inch (1.6 mm) wide, if not exceeding 2 inches (51 mm) in length; and small chipped areas or openings not more than $^1/_8$ inch (3.2 mm) wide by $^1/_4$ inch (6.4 mm) long. In Interior-type panels: small cracks or checks not more than $^3/_{16}$ inch (4.8 mm) wide; openings or depressions up to $^1/_2$ inch (13 mm) wide by 2 inches (51 mm) long or equivalent area.

Pitch streaks averaging not more than $^3/_8$ inch (9.5 mm) in width, blending with color of wood, are permitted.

Sapwood and discolorations are also permitted.

Repairs shall be wood or of synthetic patching material neatly made and parallel to grain, limited to a total of 18 in number, excluding shims, in any 4-foot by 8-foot (1219 mm by 2438 mm) face and shall have proportional limits on other sizes.

Patches are limited to the boat, router and sled types. Radius of ends of boat patches shall not exceed $^1/_8$ inch (3.2 mm). Patches shall not exceed $2^1/_4$ inches (57 mm) in width singly. Multiple patches consisting of not more than two patches, neither of which may exceed 7 inches (178 mm) in length if either is wider than 1 inch (25 mm) are permitted, except that there may be one multiple repair consisting of three die-cut veneer patches. Synthetic repairs shall not exceed $2^1/_4$ inches (57 mm) in width. Shims are permitted except over or around patches or as multiple repairs.

23.204.6.3 Grade B veneer. Grade B veneer shall be solid and free from open defects and broken grain except as noted. Slightly rough grain and minor sanding and patching defects, including sander skips not exceeding 5 percent of panel area are permitted.

Suitable synthetic filler may be used to fill, in Exterior-type panels, small splits or openings up to $^1/_{16}$ inch (1.6 mm) wide if not exceeding 2 inches (51 mm) in length and small chipped areas or openings not more than $^1/_8$ inch (3.2 mm) wide by $^1/_4$ inch (6.4 mm) long. In Interior-type panels: small cracks or checks not more than $^3/_{16}$ inch (4.8 mm) wide; openings or depressions up to $^1/_2$ inch (13 mm) wide by 2 inches (51 mm) long or equivalent area.

Knots up to 1 inch (25 mm) measured across the grain if both sound and tight, pitch streaks averaging not more than 1 inch (25 mm) in width, and discolorations are permitted.

Splits not wider than $^1/_{32}$ inch (0.8 mm) and vertical holes not exceeding $^1/_{16}$ inch (1.6 mm) in diameter if not exceeding an average of one per square foot in number are permitted. Horizontal or surface tunnels limited to $^1/_{16}$ inch (1.6 mm) across, 1 inch (25 mm) in length, and 12 in number in a 4-foot by 8-foot (1219 mm by 2438 mm) panel or proportionately in panels of other dimensions are also permitted.

Repairs shall be neatly made of wood or synthetic patching material. Repairs permitted are patches ("boat," "router" and "sled") not exceeding 3 inches (76 mm) in width individually where occurring in multiple repairs, or 4 inches (102 mm) in width where occurring singly. Synthetic veneer repairs shall not exceed 4 inches (102 mm) in width. Synthetic panel repairs shall not exceed $2^1/_4$ inches (57 mm) in width. Shims are permitted. Synthetic shims shall completely fill kerfs or voids; shall present a smooth level surface; and shall not crack, shrink or lose their bond under Exterior-type plywood test exposures described in Sections 23.215.2 and 23.215.3. Performance of synthetic shims under normal conditions of service shall be comparable to that of wood shims.

Synthetic plugs not exceeding dimensions specified previously which present solid, level, hard surfaces and whose performances under normal conditions of service are comparable to that of wood plugs are permitted.

23.204.6.4 Grade C veneer. Grade C veneer permits sanding defects that will not impair the strength or serviceability of the panel, knots if tight and not more than $1^1/_2$ inches (38 mm) across the grain, and knotholes up to 1 inch (25 mm) measured across the grain. An occasional knothole more than 1 inch (25 mm) but not more than $1^1/_2$ inches (38 mm) measured across the grain, occurring in any section 12 inches (305 mm) along the grain in which the aggregate width of all knots and knotholes occurring wholly within the section does not exceed 6 inches (152 mm) in a 48-inch (1219 mm) width, and proportionately for other widths is also permitted.

Splits tapering to a point and limited to $^1/_2$ inch (13 mm) by one-half panel length, $^3/_8$ inch (9.5 mm) by any panel length are permitted, provided separation at one end does not exceed $^1/_{16}$ inch (1.6 mm) where split runs full panel length, or $^1/_4$ inch (6.4 mm) maximum width where located within 1 inch (25 mm) of parallel panel edge.

Voids due to missing wood on panel faces and backs not otherwise specified above shall not exceed the maximum width of knotholes permitted in the grade and the length of such voids shall not exceed 6 inches (152 mm).

Repairs shall be wood or synthetic material, neatly made. Wood veneer repairs shall be die cut, and wood panel repairs shall be router or sled type. Wood repairs shall not exceed 3 inches (76 mm) in width individually where occurring in multiple repairs, or 4 inches (102 mm) in width where occurring singly; plugs (circular or "dog bone") not exceeding 3 inches (76 mm) in width individually where occurring in multiple repairs or 4 inches (102 mm) in width where occurring singly; and shims including synthetic as provided for in B grade.

Synthetic veneer repairs shall not exceed 4 inches (102 mm) in width.

Synthetic panel repairs shall not exceed $2^1/_4$ inches (57 mm) in width.

Shims are permitted.

C-Plugged veneer (veneer used for faces of underlayment, C-D Plugged and C-C Plugged grades, and inner plies of overlaid panels and other products if specified) may contain knotholes, worm and borer holes, and other open defects not larger than $^1/_4$ inch by $^1/_2$ inch (6.4 mm by 13 mm), sound and tight knots up to $1^1/_2$ inches (38 mm) measured across the grain, splits up to $^1/_8$ inch (3.2 mm) wide, broken grain, pitch pockets, if solid and tight, plugs, patches and shims. Synthetic repairs in veneer shall not exceed 4 inches (102 mm) in width. Synthetic panel repairs shall not exceed $2^1/_4$ inches (57 mm) in width. Where grades having C-Plugged face veneer are specified as fully sanded, sanding defects shall be the same as admitted under B grade. Sander skips to any degree shall be admissible in C-Plugged veneer.

23.204.6.5 Grade D veneer. Grade D veneer permits any number of plugs, patches, shims, worm or borer holes, sanding defects and other characteristics, provided they do not seriously impair the strength or serviceability of the panels. See also Section 23.203.

Tight knots are permitted in inner plies; and in D grade backs where limited to $2^1/_2$ inches (64 mm) measured across the grain.

In D grade backs, an occasional tight knot larger than $2^1/_2$ inches (64 mm) but not larger than 3 inches (76 mm) measured across the grain, occurring in any section 12 inches (305 mm) along the grain in which the aggregate width of all knots and knotholes occurring wholly within the section does not exceed 10 inches (254 mm) in a 48-inch (1219 mm) width and proportionately for other widths is also permitted.

Knotholes up to $2^1/_2$ inches (64 mm) across the grain, an occasional knothole larger than $2^1/_2$ inches (64 mm) but not larger than 3-inch (76 mm) dimension occurring in any section 12 inches (305 mm) along the grain in which the aggregate width of all knots and knotholes occurring wholly within the section does not exceed 10 inches (254 mm) in a 48-inch (1219 mm) width, and proportionately for other widths; in sanded panels, knotholes not exceeding $2^1/_2$ inches (64 mm) across the grain in veneer thicker than $^1/_8$ inch (3.2 mm); and knotholes not exceeding $3^1/_2$ inches (89 mm) across the grain are permitted in veneers at least two plies removed from the face and back plies of C-D and C-D Plugged grades having five or more plies.

Splits measured at a point 8 inches (203 mm) from their end shall not exceed 1 inch (25 mm) in width, tapering to not more than $^1/_{16}$ inch (1.6 mm) where split runs full panel length; how-ever, the maximum width within 8 inches (203 mm) of the end of the split shall not exceed the maximum width of knotholes permitted within the grade.

Splits on panel faces and backs shall not exceed $^1/_4$ inch (6.4 mm) where located within 1 inch (25 mm) of parallel panel edge.

Voids due to missing wood on panel backs not otherwise specified above shall not exceed the maximum width of knotholes permitted in the grade and the length of such voids shall not exceed 6 inches (152 mm).

Any area 24 inches (610 mm) wide across the grain and 12 inches (305 mm) long, in which light or heavy white pocket occurs, shall not contain more than three of the following characteristics, in any combination: 6-inch (152 mm) width of heavy white pocket; 12-inch (305 mm) width of light white pocket. One knot or knothole, $1^1/_2$ inches to $2^1/_2$ inches (38 mm to 64 mm), or two knots or knotholes, 1 inch to $1^1/_2$ inches (25 mm to 38 mm); knots or knotholes less than 1 inch (25 mm) shall not be considered. Size of any knot or knothole shall be measured in greatest dimension. Any repair in white pocket area shall be treated for grading purposes as a knothole.

23.204.6.6 Synthetic repairs. Synthetic fillers shall be limited to the repair of minor defects as specified in this standard. Synthetic fillers shall be of an approved type.

23.204.6.7 Synthetic shims, patches and plugs. These repairs shall completely fill kerfs or voids; shall present a smooth, level surface; and shall not crack, shrink, or lose their bond. Performance of synthetic shims, patches and plugs under normal conditions of service shall be comparable to that of wood repairs. The equivalency shall be established by testing and evaluation in accordance with approved procedures.

SECTION 23.205 — PREMIUM GRADES

23.205.1 Marine Plywood. Marine grade shall be of Exterior-type meeting applicable requirements of this standard, and of one of the following grades: A-A, A-B, B-B, High Density Overlay, or Medium Density Overlay, all as modified below for "Marine" plywood.

Only Douglas fir 1 and western larch veneer shall be used.

"A" faces shall be limited to a total of nine single repairs in a 4-foot by 8-foot (1219 mm by 2438 mm) sheet, or to a proportionate number in any other size as manufactured. "B" faces or backs where specified, and all inner plies, shall conform to "B" quality veneer requirements and shall be full length and width.

All patches shall be glued with an adhesive meeting Exterior-type performance requirements of this standard and, in addition, shall be set in the panel using a technique involving both heat and pressure.

When the inner ply veneers consist of two or more pieces of veneer, the edges shall be straight and square without lapping.

Neither edge of a panel shall have any crossband gap or edge-split in excess of $^1/_8$ inch (3.2 mm) wide. Crossband gaps and edge-splits per 8 feet (2438 mm) of crossband ply shall not exceed four in number. End splits and gaps on either end of a panel shall not exceed $^1/_8$ inch (3.2 mm) in aggregate width. Filling of crossband gaps and edge-splits with crossband gaps and edge-split materials that serve to conceal the gaps or splits is prohibited.

23.205.2 Decorative Panels. Specialty panels with decorative face veneer treatments in the form of striations, grooving, embossing, brushing, etc., which, except for the special face treatment, meet all of the requirements of this standard, including veneer qualities, glue bond performance and workmanship, shall be considered as conforming to the standard.

An occasional butt joint up to 6 inches (152 mm) in width shall be permitted for decorative effect in veneer on one panel face only. Where butt joints occur, the aggregate width of all knots and knotholes and two thirds the aggregate width of all repairs, including butt joints, shall not exceed 6 inches (152 mm) in any area 12 inches (305 mm) along the grain by 48 inches (1219 mm) wide or proportionately for other widths.

23.205.3 Exterior B-B (Concrete Form) Panels. A panel especially made for general concrete form use. Face veneers shall not be less than B grade and shall always be from the same species group. Inner plies shall not be less than C grade. (See Table 23-2-E for veneer grade limitations of High Density overlaid concrete form panels.) This grade of plywood is produced in two classes and panels of each class shall be identified accordingly. Panels shall be sanded two sides, edge-sealed and, unless otherwise specified, mill-oiled. Species shall be limited as follows and are applicable also to High Density overlaid exterior concrete form panels.

Class I—Faces of any Group 1 species, crossband of any Group 1 or 2 species, and centers of any Group 1, 2, 3 or 4 species.

Class II—Faces of any Group 1 or 2 species, and crossband and centers of any Group 1, 2, 3 or 4 species, or faces of Group 3 species of $^1/_8$-inch (3.2 mm) minimum thickness before sanding, crossband of any Group 1, 2 or 3 species, and centers of any Group 1, 2, 3 or 4 species.

23.205.4 Structural Grade Panels. Panels especially designed for engineered applications such as structural components where design properties including tension, compression, shear, cross-panel flexural properties and nail bearing may be of significant importance. In addition to the special species, grade and glue bond requirements set forth in Table 23-2-F, all other provisions of this standard for the specific types and grades form a part of the specifications for Structural grade panels.

23.205.5 Special Exterior. A premium panel of Exterior type that may be produced of any specified species covered by this standard. It shall otherwise meet all of the requirements for Marine Exterior and be produced in one of the following grades: A-A, A-B, B-B, High Density Overlay, or Medium Density Overlay.

23.205.6 Underlayment, C-C Plugged. Face veneer shall be $^1/_{10}$ inch (2.5 mm) or thicker before sanding. The veneer immediately adjacent to the face ply of C-C Plugged and Underlayment shall be C grade or better with no knotholes over 1 inch (25 mm) across the grain, except that (1) veneer immediately adjacent to the face ply of Underlayment may be D grade with open defects up to $2^1/_2$ inches (64 mm) across the grain or (2) veneer immediately adjacent to the face ply of C-C Plugged may be C grade with open defects up to $1^1/_2$ inches (38 mm) across the grain, provided the face veneer is Group 1 or Group 2 species of $^1/_6$-inch (4.2 mm) minimum thickness before sanding. Also see requirements set forth in Table 23-2-B.

SECTION 23.206 — OVERLAYS

23.206.1 General. The standard grades of overlaid plywood are listed in Table 23-2-E.

23.206.2 High Density. The surfacing on the finished product shall be hard, smooth and of such character that further finishing by paint or varnish is not necessary. It shall consist of a cellulose-fiber sheet or sheets, containing not less than 45 percent resin solids based on a volatile-free weight of fiber and resin. The resin shall be a thermosetting phenol or melamine type. The total resin-impregnated materials for each face shall not be less than 0.012 inch (0.3 mm) thick before pressing and shall weigh not less than 60 pounds per 1,000 square feet (0.29 kg/m^2), including both resin and fiber. The resin impregnation shall be sufficient to make a continuous bond without voids or blisters between the surfacing material and the plywood. The overlay face is usually produced in natural translucent color, but certain other colors may be used by manufacturers for identification.

Other resin-cellulose fiber overlay systems having a weight of not less than 60 pounds per 1,000 square feet (0.29 kg/m^2) of single surface exclusive of glueline, and which possess performance capabilities of the above phenol system, may be identified as High Density Overlay. Determination of equivalent performance shall be based on approved tests.

23.206.3 Medium Density. The resin-treated facing on the finished product shall present a smooth, uniform surface intended for high-quality paint finishes. It shall consist of a cellulose-fiber sheet containing not less than 17 percent resin solids for a beater loaded sheet, or 22 percent for an impregnated sheet, both based on the volatile-free weight of resin and fiber exclusive of glueline. The resin shall be a thermosetting phenol or melamine type. The resin-treated material shall not weigh less than 58 pounds per 1,000 square feet (0.28 kg/m^2) of single face including both resin and fiber but exclusive of glueline. After application, the material shall not measure less than 0.012 inch (0.3 mm) thick. Some evidence of the underlying grain may appear. The overlay face is produced in a natural color and certain other colors.

Other resin-cellulose fiber overlay systems having a weight of 58 pounds per 1,000 square feet (0.28 kg/m^2) of single surface exclusive of glueline, and which possess performance capabilities of the above phenol system, may be identified as Medium Density Overlay. Determination of equivalent performance shall be based on approved test methods.

23.206.4 Special Overlays. Surfacing materials having special characteristics which do not fit the exact description of High Density or Medium Density types as outlined previously. These must meet the test requirements for overlaid plywood and have a durable surface material. Panels shall be identified as "Special Overlay."

SECTION 23.207 — ADHESIVE BOND REQUIREMENTS

23.207.1 General. Lots represented by test panels shall be considered as meeting the requirements of this standard if all of the following minimum requirements are met.

23.207.2 Interior-type Bonded with Interior Glue (Underlayment, C-D Plugged and C-D). A panel shall be considered as meeting the requirements of the standard if three or more of the five test specimens pass. The material represented by the sampling shall be considered as meeting the requirements of this standard if 90 percent or more of the panels pass the test described in Section 23.213.

23.207.3 Interior-type Bonded with Exterior Glue (Structural C-D). When tested in accordance with Section 23.213, the average wood failure of all test specimens, regardless of the number of panels tested, shall not be less than 80 percent.

When more than one panel is tested:

1. At least 90 percent of the panels represented by the test pieces shall have 60 percent wood failure or better.

2. At least 95 percent of the panels represented by the test pieces shall have 30 percent wood failure or better.

These requirements are applicable separately and independently to the results obtained from the vacuum-pressure test and the boiling test. Specimens cut through localized defects permitted in the grade shall be discarded. Test specimens showing delamination in excess of $^1/_8$ inch (3.2 mm) deep and 1 inch (25 mm) long shall be rated as 0 percent wood failure.

23.207.4 All Other Grades of Interior-type Plywood. A panel shall be classed as failing if more than two of the five test specimens fail. The material represented by the sampling shall be considered as meeting the requirements of this standard if 85 percent or more of the panels pass, when tested in accordance with Section 23.213.

23.207.5 Mold Resistance. Underlayment, C-D Plugged, and Standard shall be made with an adhesive possessing a mold resistance equivalent to that created by adding, to plain protein glue, 5 pounds (2.27 kg) of pentachlorophenol or its sodium salt per 100 pounds (45.36 kg) of dry glue base.

IMG-type plywood shall be made with an adhesive possessing a high degree of resistance to attack by bacteria and mold organisms. Adhesives, in order to qualify for use in the manufacture of IMG-type panels, must meet the "bacteria test" requirements published by the American Plywood Association. This procedure is specifically designed for adhesive qualification and is not applicable to inspection and testing, as covered in Section 23.212.

23.207.6 Resistance to Elevated Temperature. Underlayment, C-D Plugged shall be made with an adhesive possessing resistance to temperatures up to 160°F (71°C) at least equal to that of plain protein glue. Urea resin glue shall not be used in these grades unless evidence is submitted indicating performance equivalent to plain protein glues.

23.207.7 Interior-type Bonded with Intermediate Glue (IMG-type). When tested in accordance with Section 23.214, IMG-type plywood shall be considered as meeting the requirements of the standard if all of the following minimum conditions are met:

1. The average wood failure of all test specimens, regardless of the number of panels tested, shall not be less than 45 percent.

2. When more than one panel is tested, at least 90 percent of the panels represented by the test pieces shall have 30 percent wood failure or better.

Specimens cut through localized defects permitted in the grade shall be discarded. Test specimens showing delamination in excess of $^1/_8$ inch (3.2 mm) deep and 1 inch (25 mm) long shall be rated as 0 percent wood failure.

23.207.8 Exterior Type. When tested in accordance with Section 23.215, Exterior-type plywood shall be considered as meeting the requirements of this standard if all of the following minimum conditions are met:

1. The average wood failure of all test specimens, regardless of the number of panels tested, shall not be less than 85 percent.

2. When more than one panel is tested:

   2.1 At least 75 percent of the panels represented by the test pieces shall have 80 percent wood failure or better.

   2.2 At least 90 percent of the panels represented by the test pieces shall have 60 percent wood failure or better.

   2.3 At least 95 percent of the panels represented by the test pieces shall have 30 percent wood failure or better.

These requirements are applicable separately and independently to the results obtained from the vacuum-pressure test and the boiling test. Specimens cut through localized defects permitted in the grade shall be discarded. Test specimens showing delamination in excess of $^1/_8$ inch (3.2 mm) deep and 1 inch (25 mm) long shall be rated as 0 percent wood failure.

Plywood shall be tested for heat durability as described in Section 23.215. Any delamination due to combustion shall be considered as failure, except when occurring at a localized defect permitted in the grade. When testing overlaid plywood. blisters or bubbles in the surface caused by combustion shall not be considered delamination.

The bond between veneers of overlaid plywood as well as the bond between the overlay and the base panel shall meet the wood failure requirements described above for exterior. In evaluating specimens for separation of resin-treated face from the plywood, fiber failure shall be considered the same as wood failure.

SECTION 23.208 — GRADE MARKING

All plywood shall be grade marked in accordance with Section 2303 of this code. No reference shall be made to this standard in the certification or trademarking or grade marking of panels not conforming to all provisions of the standard. Each panel shall be identified with the mark of a qualified inspection and testing agency that shall designate the species group classification or span rating, glue bond type (Interior or Exterior), grade name or the grade of face and back veneers, and a symbol signifying conformance with the standard.

Panels not fully satisfying Exterior veneer requirements shall be identified as "Interior." However, the additional notation "Exterior Glue" or "Intermediate" (IMG) may be used where applicable to supplement the designation of Interior grades bonded with Exterior glue or Intermediate glue. Any further reference to adhesive bond, including those which imply premium performance or special warranty by the manufacturer, as well as manufacturer's proprietary designations, shall be separated from the grade marks or trademarks of the testing agency by not less than 6 inches (152 mm).

SECTION 23.209 — SPAN RATING FOR UNSANDED AND TOUCH-SANDED PANELS

Grade marking or trademarking of C-C, C-D, Structural C-C and Structural C-D, and of C-C Plugged and Underlayment to be used as combination subfloor underlayment (single floor) shall include a span rating for the thickness shown in Table 23-2-G. The numbers are presented as a fraction in the marking of sheathing grades of plywood, and as a single number for C-C Plugged and Underlayment. They describe the recommended maximum spans in inches (mm) under normal use conditions and correspond with commonly accepted criteria. For sheathing, the left-hand number refers to spacing of roof framing, and the right-hand number relates to spacing of the floor framing. The single number for Underlayment and C-C Plugged refers to spacing of the floor framing in single floor applications. The span rating number is related to species and thickness of the panel face and back veneers and panel thickness. It is established by either one of the following procedures:

1. By specification as detailed in Table 23-2-G.

2. By performance testing to satisfy the strength, stiffness and durability criteria as detailed in Section 23.210. Such performance testing is to be performed by a qualified testing agency.

Panels manufactured as C-C, C-D, Structural C-C and Structural C-D shall not be sanded, touch-sanded, surface textured or thickness sized by any mechanical means. However, sanded or touch-sanded panels which do not meet the grades for which they were intended may be reclassified and marked as C-C or C-D, provided the panels meet all applicable requirements for C-C or C-D and the finished face and back veneers after sanding each have a minimum net thickness equal to 90 percent of the applicable thickness in Table 23-2-G.

SECTION 23.210 — PERFORMANCE TESTING QUALIFICATION REQUIREMENTS

23.210.1 General. Acceptance of performance-tested plywood under this standard is based upon testing of panel strength, stiffness and durability. Panels selected for testing shall be of near-minimum grade and near-minimum thickness. All provisions of veneer grade and panel workmanship are applicable.

23.210.2 Performance Testing. Panels qualified for performance testing shall satisfy the criteria called for in this section when tested as required in Sections 23.210.3 and 23.210.4.

23.210.3 Structural Performance.

23.210.3.1 Concentrated loads. A minimum of 10 tests (specimens taken from at least five panels) shall be conducted for both concentrated static and impact loads according to Section 23.216. The tests shall be conducted for each exposure condition specified in Table 23-2-L or 23-2-N (wet, dry and/or wet/redry).

23.210.3.1.1 Deflection. At least 90 percent of tests shall deflect no more than the specified maximum.

23.210.3.1.2 Retest. If no more than two tests in a lot of 10 fail to meet the deflection requirements, another lot of 10 may be tested for that requirement. If no more than one test fails in this second round of testing, the requirements shall be considered satisfied.

23.210.3.1.3 Ultimate load. For each lot, 100 percent of tests shall support the specified minimum ultimate load.

23.210.3.1.4 Retest. If no more than one test in a lot of ten fails to meet the minimum ultimate load requirement, another lot of 10 may be tested for that requirement. If all pass the retest, the requirements shall be considered satisfied.

23.210.3.2 Uniform loads. A minimum of 10 tests (specimens taken from at least five panels) shall be conducted for uniform load capacity according to Section 23.217. The tests shall be conducted for each exposure condition specified in Table 23-2-M or 23-2-O.

23.210.3.2.1 Deflection. The average deflection shall not be greater than that specified.

23.210.3.2.2 Retest. If the average deflection is greater than specified, but does not exceed the requirement by 20 percent, another lot of 10 may be tested for that requirement. If the average of the first and second lot taken together does not exceed that specified, the requirement shall be considered satisfied.

23.210.3.2.3 Ultimate load. For each lot, 100 percent of tests shall support the specified minimum ultimate load.

23.210.3.2.4 Retest. If no more than one test in a lot of 10 fails to meet the ultimate load requirement, another lot of 10 may be tested for that requirement. If all specimens pass this retest, the requirements shall be completely satisfied.

23.210.4 Bond Durability. Panels shall be classed as Exposure 1 or Exterior.

23.210.4.1 Exposure Panels rated as Exposure 1 shall be so identified and shall satisfy the bond requirements for Interior panels bonded with exterior glue as specified in Section 23.207.3.

23.210.4.2 Exterior. Panels rated as Exterior shall be so identified and shall satisfy the bond requirements as specified in Section 23.207.8.

23.210.5 Product Evaluation. Upon satisfactory completion of the appropriate requirements of Sections 23.210.3 and 23.210.4, a manufacturing specification will be written based on product evaluation under this section. This specification is to be used for quality assurance purposes by the manufacturer and the manufacturer's qualified testing agency. Product evaluation will be made on the same lot supplied by the manufacturer for qualification testing. Control values established during product evaluation will be the basis for quality evaluation of future production. The mill specification shall contain the following information.

23.210.5.1 Panel construction. Panels shall be defined as to veneer species and construction.

23.210.5.2 Mechanical properties. Twenty tests (specimens taken from at least 10 panels) shall be evaluated for bending stiffness both along and across the major panel axis according to the procedures of Section 23.218. The control value for each panel direction will be the sample mean and the minimum will be the lower value of a 90 percent confidence interval established on the mean.

Ten tests (specimens taken from at least 10 different panels) shall be tested for maximum bending moment both along and across the major panel axis according to the procedures of Section 23.218. The control value for each panel direction will be the minimum observed value, or the sample mean less 1.8 times the sample standard deviation, whichever is the higher value.

23.210.6 Reexamination.

23.210.6.1 Quarterly reexamination. A product qualified by performance testing shall be subjected to quarterly reexamination by the manufacturer's qualified testing agency. Panels shall be tested according to the procedures of Section 23.210.5.2.

23.210.6.2 Resampling. Failure to meet established control values shall result in an immediate intensive resampling of current production which will be tested for the failing property. This resampling shall consist of 20 panels.

23.210.6.3 Requalification. When results of the resampling fail to meet the applicable test requirements, a requalification for structural properties under Section 23.210.3 shall be required.

SECTION 23.211 — SCARF- AND FINGER-JOINTED PANELS

23.211.1 General. Neither panels with N faces nor the faces of such panels, unless longer than 10 feet (3048 mm), shall be scarfed or finger jointed except when specifically so ordered. Panels of other grades may be scarfed or finger jointed. Panels longer than 12 feet (3658 mm) are necessarily scarfed. Scarf joints shall not have a slope greater than 1 to 8, but may be specified as less than 1 to 8. Joints shall be glued with a waterproof adhesive and meet the test requirements specified in this section as applicable. In addition, the adhesive shall not show creep or flow characteristics greater than unjointed wood when subject to load under any conditions of temperature and moisture.

23.211.2 Strength Requirements (Interior, IMG and Exterior) Scarfed and Finger-jointed Panels. Panels shall be tested in accordance with Section 23.216.1. If the average ultimate stress of the three test specimens of any one panel is less than 4,000 psi (27.58 N/mm^2) for panels of Group 1 species, or less than 2,800 psi (19.3 N/mm^2) for panels of Group 2 or Group 3 species, or 2,400 psi (16.55 N/mm^2) for panels of Group 4 species, then that panel fails. The jointed panels represented by the sampling are acceptable if not more than one of the panels fails.

23.211.3 Scarf- and Finger-joint Durability for Interior and IMG Panels. Panels shall be tested as outlined in Section 23.216.2. Test specimens showing continuous delamination in excess of $^1/_{16}$ inch (1.6 mm) deep and $^1/_2$ inch (13 mm) long at the joint glueline shall be considered as failing. More than one failing specimen in a panel shall constitute failure of that panel. The jointed panels represented by the sampling are acceptable if not more than one of the panels fails.

23.211.4 Scarf-joint Durability for Exterior and Interior Panel Bonded with Exterior and Intermediate Glue. Panels shall be tested in accordance with Section 23.219.3. The material represented by the sampling shall be evaluated in accordance with Sections 23.207.2 and 23.207.3.

23.211.5 Finger-joint Durability for Exterior-type Panels and Interior-type Panels Bonded with Exterior or Intermediate Glue. Panels shall be tested in accordance with Section 23.216. The joints shall meet the following minimum conditions:

23.211.5.1 The average wood failure rating of all specimens from each panel when tested in accordance with Section 23.216 shall not be less than 85 percent.

23.211.5.2 No single specimen from a panel (average of face and back gluelines) shall rate less than 60 percent wood failure.

23.211.5.3 No single face or back glueline in any specimen shall rate less than 30 percent wood failure.

SECTION 23.212 — INSPECTION AND TESTING

23.212.1 General. The tests specified in this section shall be used to determine the glue bond quality of plywood produced under this standard.

23.212.2 Inspections. All plywood designated as complying with this standard shall be subject to inspection prior to coating or finishing, except that concrete form material may have a priming coat of oil or other clear preparation before inspection. The above requirement does not apply to Interior-type plywood bonded with exterior glue or to Exterior-type plywood when tested for glue bond quality.

23.212.3 Plywood Panel Grade, Size and Thickness Reinspections. If reinspection establishes that an item is more than 5 percent below grade or out of dimensional tolerance according to the grade description, that item fails to pass the reinspection. The below-grade panels shall not be accepted. If reinspection establishes that a disputed item is 5 percent or less below grade or out of dimensional tolerance, it passes the reinspection. In addition to the above 5 percent grade and dimensional tolerance, a 5 percent tolerance shall apply separately to the inner-ply gap limitations, including the limitations applicable to the plugged crossband and jointed crossband, as specified in Section 23.203.

23.212.4 Plywood Glue Bond Quality Reinspections. Reinspection of the unused panels shall be carried out following the procedures specified in Sections 23.212, 23.213, 23.214 and 23.215. If the reinspection tests establish that the glue bond quality does not meet the requirements of Section 23.207, as applicable, the panels fail to pass the reinspection. If the glue bond quality requirements are met, panels pass the reinspection. Any delaminated Exterior-type or overlaid panels are not acceptable.

23.212.5 Sampling for Panel Grade, Size and Thickness Reinspections. Grade, size and thickness may include all panels of an item in dispute. However, when approved, a reduced basis for sampling consisting of at least 20 percent or 300 panels, whichever is smaller, shall be inspected for conformance to grade. For reduced sampling, the quantity of panels selected from each disputed item shall be prorated according to the number of panels. Panels found to be below grade or out of tolerance for size and thickness shall have improper grademarks obliterated and shall be remarked for appropriate classification with a special inspection mark registered by the qualified agency conducting the reinspection and applied by this agency's authorized representative.

23.212.6 Sampling for Glue Bond Reinspections. For test purposes, 20 panels, or 5 percent of the panels, whichever is less, shall be selected at random from the item which is in dispute. The number of panels required shall be calculated by applying the "percent panels" to the lot size and converting part panels to whole panels by using a rounding procedure where 0.01 to 0.49 parts are considered to be the smaller whole number, while 0.50 to 0.99 parts are considered to be the larger whole number. These panels shall be selected from locations distributed as widely as practicable throughout the material being sampled. When an item, lot, or shipment involves panels with different adhesive bond requirements as provided for in Section 23.207, testing and evaluation shall apply separately to each category.

Sampling shall include no less than 20 panels of Interior-type Underlayment, C-D Plugged, and C-D. Sampling of Interior-type (including the different adhesive qualities) or Exterior-type shall be prorated on the basis of ratio of their volume to total volume (i.e., for shipments containing 50 percent Exterior, 10 Exterior panels shall be selected), but in no case shall less than 10 panels of each type or adhesive quality be selected. Shipments of Interior-type plywood bonded with exterior glue shall be sampled in the same manner as Exterior plywood.

23.212.7 Specimen Preparation. One piece shall be cut from each Interior panel selected and from that piece five test specimens shall be cut. Each specimen shall be 2 inches wide by 5 inches (51 mm wide by 127 mm) along the grain. From each Exterior panel selected, one piece shall be cut from the panel and from that piece 10 test specimens shall be cut as described in Section 23.215.1. Of the 10 specimens cut from each test piece, five shall be for vacuum pressure test, and five shall be for the boil test. From each overlaid panel selected, 10 specimens shall be cut as described for Exterior plywood. These shall be for testing the bond between veneers. A second set of 10 specimens shall be cut to test the bond between the overlay and the base panel as described in Section 23.215.1.

From five of the Exterior test panels and five of the overlaid test panels, $5^1/_2$-inch by 8-inch (140 mm by 203 mm) specimens shall be cut and tested as described in Section 23.215.4.

SECTION 23.213 — TEST FOR INTERIOR-TYPE PLYWOOD

The test specimens prepared as described in Section 23.219.3 shall be placed in a pressure vessel and completely submerged in 110°F (43.3°C) water. A vacuum of 15 inches of mercury (50.7 kPa) shall be drawn, maintained for 30 minutes and released. Specimens shall then be allowed to soak in the same water at atmospheric pressure for four and one half hours with no additional heating. They shall be removed and dried for 15 hours at 150°F (65.6°C) in an oven with fan-forced air circulation of 45 to 50 air changes per minute. Specimens shall then be examined for delamination and evaluated in accordance with requirements given in the following paragraph.

Total continuous visible delamination of $^1/_4$ inch (6.4 mm) or more in depth and 2 inches (51 mm) in length along the edges of a 2-inch by 5-inch (51 mm by 127 mm) test specimen shall be considered as failure. Where required, this shall be determined by probing with a suitable feeler gage not greater than 0.013 inch (0.3 mm) in thickness. When delamination occurs by reason of a localized defect permitted in the grade, other than white pocket, that test specimen shall be discarded.

SECTION 23.214 — TESTS FOR IMG-TYPE PLYWOOD

23.214.1 Preparation of Test Specimens. Test specimens, taken as described in Section 23.219.3, shall be cut $3^1/_4$ inches (83 mm) long and 1 inch (25 mm) wide, and kerfed one third of the length of the specimen from each end, as illustrated in Figure 23-2-1, so that a 1-inch (25 mm) square test area in the center results. Specimens shall be oriented so that the grain direction of the ply under test runs at a 90-degree angle to the length of the specimen. Kerfing shall extend two thirds of the way through the ply under test, and shall not penetrate the next glueline.

If the number of plies exceeds three, the cuts shall be made so as to test any two of the joints, but the additional plies need not be stripped except as demanded by the limitations of the width of the retaining jaws on the testing device. When desired, special jaws may be constructed to accommodate the thicker plywood. If the number of plies exceeds three, the choice of joints to be tested shall be left to the discretion of the approved inspection and testing agency, but at least one half of the tests shall include the innermost joints.

23.214.2 Vacuum Soak Test. The test specimens shall be placed in a pressure vessel and submerged in water 120°F (48.9°C). A vacuum of 15 inches of mercury (50.7 kPa) shall be drawn and maintained for 30 minutes. Following release of vacuum, specimens shall continue soaking for 15 hours at atmospheric pressure. The temperature of the water shall not drop below 75°F (23.9°C) at any time during the 15-hour soaking period. Specimens shall then be removed from the vessel and tested while wet by tension loading to failure in a shear testing machine operated at a maximum head travel of 16 inches per minute (406 mm per minute). Jaws of the machine shall securely grip the specimen so there is no slippage. The percentage of wood failure of the specimens shall be determined with specimens in a dry condition and evaluated as described in Section 23.207.7.

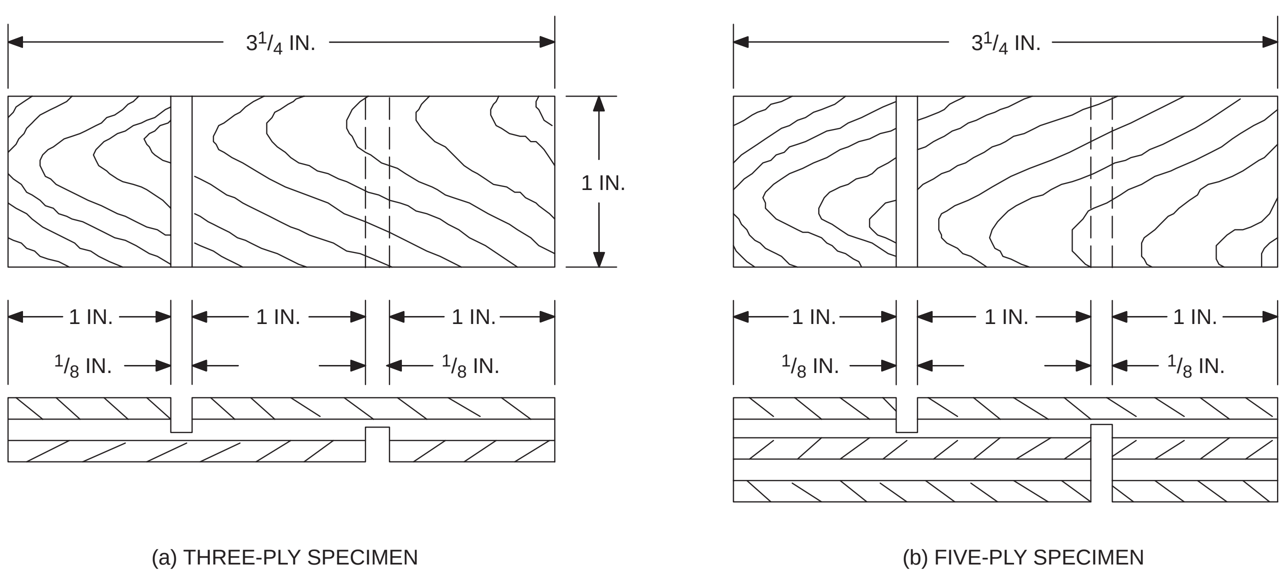
SECTION 23.215 — TESTS FOR EXTERIOR- AND INTERIOR-TYPE BONDED EXTERIOR GLUE (INCLUDES STRUCTURAL C-D AND C-D WITH EXTERIOR GLUE)

23.215.1 Preparation of Test Specimens. Test specimens, taken as described in Section 23.212.4 shall be cut $3^1/_4$ inches (83 mm) long and 1 inch (25 mm) wide, and kerfed one third of the length of the specimen from each end, as illustrated in Figure 23-2-1, so that a 1-inch (25 mm) square test area in the center results. Specimens shall be oriented so that the grain direction of the ply under test runs at a 90-degree angle to the length of the specimen. Kerfing shall extend two thirds of the way through the ply under test, and shall not penetrate the next glueline. Overlaid plywood specimens, taken as described in Section 23.212.3 for testing of bond between veneers, shall be cut as described above for Exterior specimens. Overlaid specimens for testing the bond between the overlay and the base panel, shall be cut 1 inch (25 mm) wide and long enough for handling (3 inches [76 mm] is a convenient length) and kerfed just through the overlay 1 inch (25 mm) from the end, on each overlay face.

If the number of plies exceeds three, the cuts shall be made so as to test any two of the joints, but the additional plies need not be stripped except as demanded by the limitations of the width of the retaining jaws on the testing device. When desired, special jaws may be constructed to accommodate the thicker plywood. If the number of plies exceeds three, the choice of joints to be tested shall be left to the discretion of the approved inspection and testing agency, but at least one half of the tests shall include the innermost joints.

23.215.2 Vacuum-pressure Test. The test specimen shall be placed in a pressure vessel and submerged in cold tap water. A vacuum of 25 inches of mercury (84.4. kPa) shall be drawn and maintained for 30 minutes, followed immediately with application of 65-70 psi (448-483 kPa) of pressure for 30 minutes duration. Specimens shall then be removed from the vessel and tested while wet by tension loading to failure in a shear testing machine operated at a maximum head travel of 16 inches per minute (406 mm per minute). Jaws of the machine shall securely grip the specimens so there is no slippage. The percentage of wood failure of the specimens shall be determined with specimens in a dry condition and evaluated as described in Section 23.207.8.

The bond between veneers in overlaid plywood shall be tested in an identical manner and evaluated as described in Section 23.207.8. Specimens for testing the bond between the overlay and the base panel shall be subjected to the same test cycle described above. The bond between the overlay and the base panel shall be tested by inserting a sharp, thin blade of adequate stiffness into the corner of the 1-inch (25 mm) test area at the overlay-veneer interface, taking care not to cut into the overlay, and attempting to peel off the overlay. It may be necessary to reinsert the blade several times in order to remove the overlay from the 1-square-inch (645 mm^2) area. The percentage of wood and/or fiber failure shall then be estimated with specimens in a dry condition and evaluated as described in Section 23.207.8. The value for each specimen shall be the average of the test areas on each face.



For **SI:** 1 inch = 25.4 mm.

NOTE: Orient grain direction across specimens to test inner two joints.

FIGURE 23-2-1—SHEAR TEST SPECIMENS

23.215.3 Boiling Test. Test specimens shall be boiled in water for four hours and then dried for 20 hours at a temperature of 145°F ± 5°F (62.8°C ± 2.8°C) with sufficient air circulation to lower moisture content of the specimens to a maximum of 8 percent, based on oven-dry weight. The specimens shall be boiled again for a period of four hours, cooled in water, and tested while wet by tension loading for failure in a shear testing machine operated at a maximum head travel of 16 inches per minute (406 mm per minute). Jaws of the machine shall securely grip the specimens so there is no slippage. The percentage of wood failure of the specimens shall be determined with specimens in a dry condition and evaluated as described in Section 23.207.8. The bond between veneers in overlaid plywood shall be tested and evaluated in an identical manner. Specimens to test the bond between the overlay and the base panels shall be subjected to the same test cycle described above. The bond between the overlay and the base panel shall be tested by inserting a sharp, thin blade of adequate stiffness into the corner of the 1-inch (25 mm) test area at the overlay-veneer interface, taking care not to cut into the overlay, and attempting to peel off the overlay. It may be necessary to reinsert the blade several times in order to remove the overlay from the 1-square-inch (645 mm^2) area. The percentage of wood and/or fiber failure shall then be estimated with specimens in a dry condition and evaluated as described in Section 23.207.8. The value for each specimen shall be the average of the test areas on each face.

23.215.4 Heat Durability Test. Specimens cut as described in Section 23.212.3 shall be placed on a stand as illustrated in Figure 23-2-1. It shall then be subjected to a 1,472°F to 1,652°F (800°C to 900°C) flame from a Bunsen-type burner for a period of 10 minutes or, in the case of a thin specimen, until a brown char area appears on the backside. The burner shall be equipped with a wing top to envelop the entire width of the specimen in flame. The top of the burner shall be 1 inch (25 mm) from the specimen face and the flame $1^1/_2$ inches (38 mm) high. The flame shall impinge on the face of the specimen 2 inches (51 mm) from the bottom end. After the test, the sample shall be removed from the stand and the gluelines examined for delamination by separating the charred plies with a sharp, chisel-like instrument. Specimens shall be evaluated in accordance with Section 23.207.8.

SECTION 23.216 — TESTS FOR PERFORMANCE UNDER CONCENTRATED STATIC AND IMPACT LOADS

23.216.1 Preparation of Test Specimens. Samples shall be selected representative of the plywood product being evaluated. Length, *L*, of panels shall conform to the maximum center-to-center support spacing, *S*, anticipated in service, continuous over the minimum number of spans recommended for its use. See Figures 23-2-7 and 23-2-8. Width, *W*, of individual pieces shall be 24 inches (610 mm) or greater for span ratings up to 24 inches (610 mm) on center and 48 inches (1219 mm) for greater span ratings.

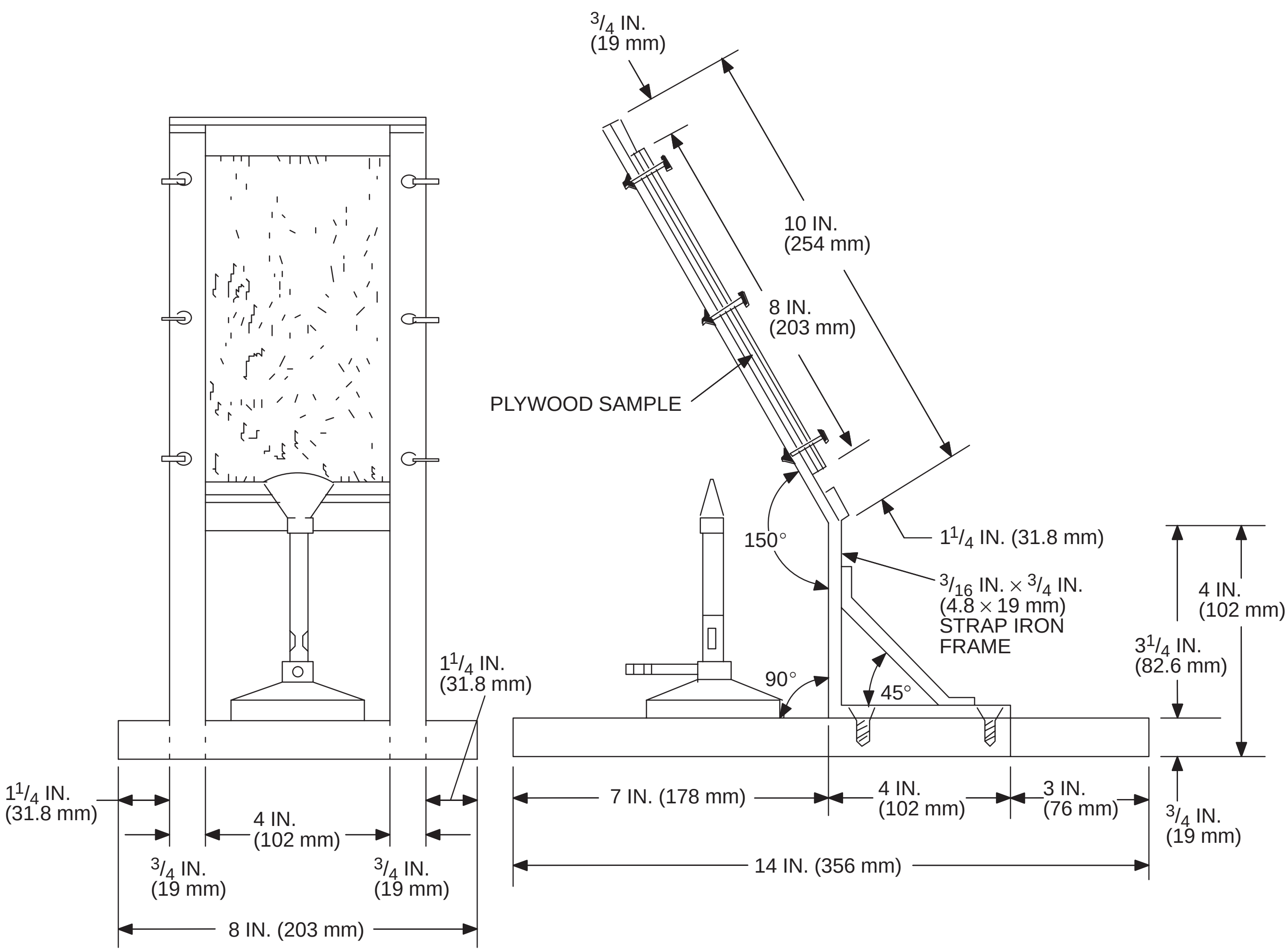


FIGURE 23-2-2—APPARATUS FOR HEAT DURABILITY TEST

23.216.2 Test Procedure.

23.216.2.1 Concentrated static. Specimens shall be loaded at locations shown in Figure 23-2-7 using a 3-inch-diameter (76 mm) loading disc, except a 1-inch-diameter (25 mm) loading disc shall be used to determine strength of single-layer floor panels in the dry or redried condition.

Stiffness shall be determined by measuring deflection in 50-pound (222 N) increments to 200 pounds (890 N). Strength shall be determined by loading to failure.

23.216.2.2 Concentrated impact. Specimens shall be loaded at locations shown in Figure 23-2-8 using an impact device 9 to $10^1/_2$ inches (229 to 267 mm) in diameter and weighing 30 pounds (13.6 kg), except that for span ratings greater than 24 inches (610 mm) on center, the impact device shall weigh 60 pounds (27.2 kg).

Strength shall be determined by impacting the specimen from the specified height at increments of 6 inches (152 mm). Deflection under a 200-pound (890 N) concentrated load, using a 3-inch-diameter (76 mm) disc, shall be measured before the test and after each impact. After the specified impact load has been reached, the concentrated load shall be applied to failure.

SECTION 23.217 — TEST FOR PERFORMANCE UNDER UNIFORM LOADS

23.217.1 Apparatus. A vacuum chamber is used consisting of a sealed box with the panel to be tested forming the top. See Figure 23-2-9. A 6-mil (0.15 mm) polyethylene sheet or equivalent is securely taped at the perimeter to seal the top surface. A vacuum pump reduces air pressure under the specimen such that load is measured.

23.217.2 Preparation of Test Specimens. Samples shall be selected representative of the plywood product being evaluated. The specimen length perpendicular to framing shall be equal to twice the maximum center-to-center support spacing, *S*, anticipated in service. See Figure 23-2-10. The specimen width is at least $23^1/_2$ inches (597 mm).

23.217.3 Test Procedure. The specimen is mounted in the vacuum box following anticipated joist spacing and recommended nail size and spacing and sealed. The panel is loaded to the specified level. Deflections are measured at locations shown in Figure 23-2-10 sufficient to develop the straight-line portion of the load-deflection curve, but in no case shall the number of data points be less than six.

SECTION 23.218 — TEST FOR PANEL BENDING

23.218.1 Apparatus. A testing machine shall be used capable of applying pure moments to opposite ends of the test panel through loading frames and measurement of moment and deformation.

23.218.2 Preparation of Test Specimens. Samples shall be selected representative of the plywood product being evaluated. Specimens shall measure 4 feet by 4 feet (1219 mm by 1219 mm).

23.218.3 Test Procedure. Separate specimens are subjected to pure moment along and across the major axis. Deformation or curvature is measured in a manner adequate to calculate bending stiffness. Test is carried on to failure to evaluate maximum moment.

SECTION 23.219 — SCARF- AND FINGER-JOINT TESTS

23.219.1 Strength. Three test specimens shall be cut at random along each joint from panels selected as directed in Section 23.219.3. Type, grade and species of the panels shall be recorded. The specimens shall be cut so as to include the joint and shall be prepared as illustrated in Figure 23-2-3.

Insofar as possible, the joint test area shall contain no localized natural defects permitted within the grade. At the joint, the maximum thickness and width of plies parallel with the load shall be recorded. Each specimen shall then be placed in the tension grips of a testing machine and loaded continuously at a rate of cross-head travel of 0.030 to 0.040 inch per minute (0.76 to 1.02 mm per minute) until failure, and the ultimate load recorded. The ultimate stress in pounds per square inch shall be computed using the ultimate load and area of those plies whose grain is parallel with direction of load. Moisture content of specimens at the time of testing shall not exceed 16 percent.

23.219.2 Scarf-joint Durability of Interior-type Panels Bonded with Interior Glue. Ten test specimens shall be cut at random along each scarf joint from panels selected as directed in Section 23.219.3, and shall be prepared following the general procedure in the same subsection, but shall be cut so that the scarf joint occurring on one surface of the panel runs across the middle of five specimens and the joint occurring on the opposite surface runs across the middle of the other five specimens. The specimens shall be subjected to the same test procedure as outlined in Section 23.212.

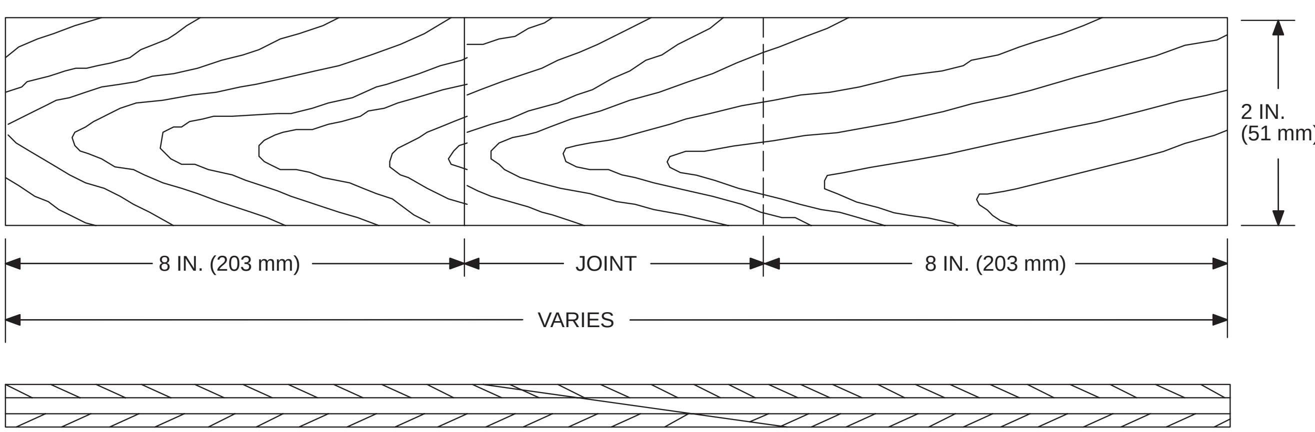


FIGURE 23-2-3—TENSION SPECIMEN FOR SCARF-JOINTED PANELS

23.219.3 Scarf-joint Durability of Exterior-type Panels and Interior-type Panels Bonded with Exterior or Intermediate Glue. Ten test specimens shall be cut at random along each joint from panels selected as directed in Section 23.219.3. The specimens shall be prepared following the general procedure described in Section 23.221.1, but, in addition, shall be cut so that the joints run through the test specimens as shown in Figure 23-2-4. For Exterior-type panels and Interior-type bonded with exterior glue, five specimens shall be subjected to the vacuum-pressure test described in Section 23.215.2, and five to the boiling test of Section 23.215.3. The panels shall be evaluated as described in Section 23.207.

For Interior-type panels bonded with intermediate glue (IMG), the 10 specimens shall be subjected to the vacuum soak test outlined in Section 23.214.2. The panels shall be evaluated as described in Section 23.207.

23.219.4 Finger-joint Durability of Interior-type Panels Bonded with Interior Glue. Five specimens shall be cut at random along the finger joint from each panel selected and shall be prepared following the general procedure in Section 23.211 so that the middle of the joint coincides with the middle of the five specimens. The specimens shall be subjected to the same test procedure as outlined in Section 23.219.

23.219.5 Finger-joint Durability of Exterior-type Panels and Interior-type Panels Bonded with Exterior or Intermediate-type Glue. Ten specimens shall be cut at random along the finger joint from each panel selected according to Section 23.211. These specimens shall be cut so as to include the joint and shall be prepared as illustrated in Figure 23-2-5.

For Exterior-type panels and Interior-type panels bonded with exterior glue, five of the specimens shall be subjected to the vacuum pressure test of Section 23.215.2 and five to the boiling test of Section 23.215.1.

For Interior-type panels bonded with intermediate glue, the 10 specimens shall be subjected to the vacuum soak test of Section 23.214.

Upon completion of the vacuum pressure and boil tests, or vacuum soak tests, as applicable, a wedge or chisel (see Figure 23-2-6) shall be inserted in locations shown in Figure 23-2-5 in such a manner as to pry apart the scarfed portions of the joint without directly contacting the glued area. Test specimens shall be dried and percent wood failure in the test area estimated and applied separately for both the boil and vacuum pressure treatments. The panels shall be evaluated as described in Section 23.207.

SECTION 23.220 — TEST FOR DETERMINATION OF MOISTURE CONTENT (OVEN-DRYING METHOD)

The moisture content of the plywood shall be determined as follows: a small test specimen shall be cut from each sample panel; the test specimen shall measure not less than 9 square inches (5806 mm^2) in area and shall weigh not less than 20 grams (approximately $^3/_4$ ounce). All loose splinters shall be removed from the specimen. The specimen shall be immediately weighed on a scale that is accurate to 0.5 percent, and the weight shall be recorded as original weight. The specimen shall then be dried in an oven at 212°F to 221°F (100°C to 105°C) until constant weight is attained. After drying, the specimen shall be reweighed immediately, and this weight shall be recorded as the oven-dry weight. The moisture content shall be calculated as follows:

$$\frac{\text{Original weight} - \text{Oven-dry weight}}{\text{Oven-dry weight}} \times 100 = \text{Moisture content (percent)}$$

SECTION 23.221 — PLYWOOD SECTION PROPERTIES

23.221.1 General. Section properties set forth in Tables 23-2-H and 23-2-I shall be used with all species and grades of plywood in this standard. The section properties shall be used in determining compliance with allowable stresses set forth in Table 23-III-A of this code. The properties have been adjusted to reflect “effective” section properties in each of two directions, assuming a homogenous material. As a result of these adjusted values, moment of inertia “*I*” shall be used only in stiffness calculations, with section modulus “*S*” used in bending stress calculations.

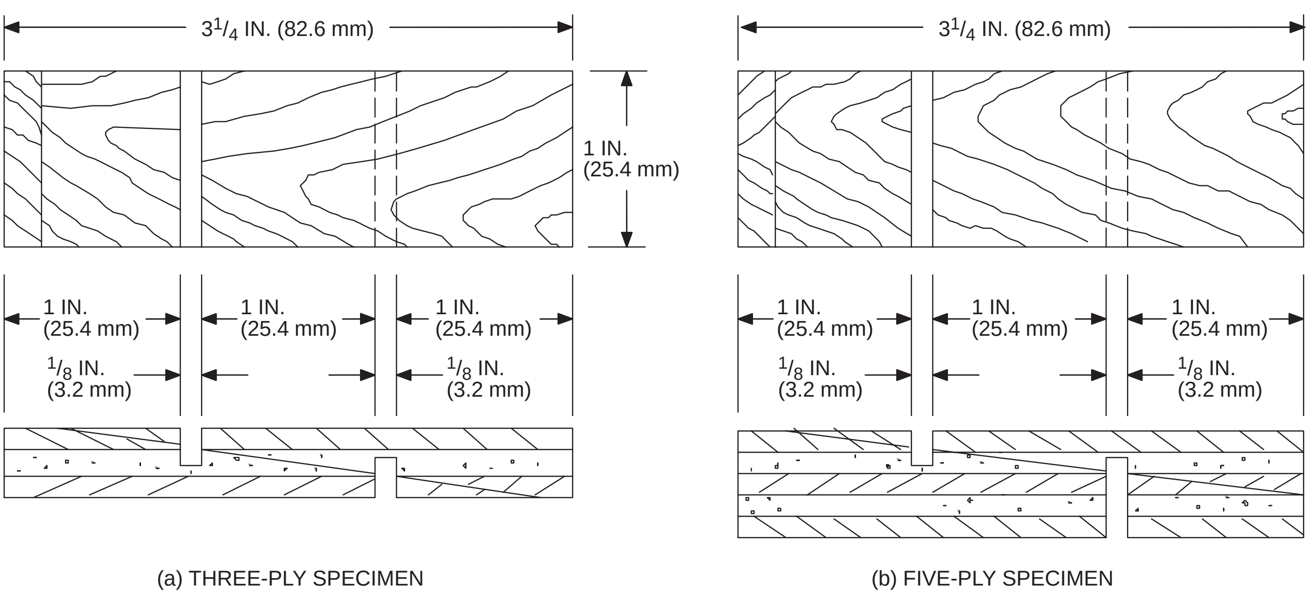


FIGURE 23-2-4—SCARF-JOINT SPECIMENS FOR VACUUM SOAK, VACUUM PRESSURE AND BOILING TESTS

23.221.2 Veneer Lay-up. Section properties listed are adjusted to allow for variations in panel veneer constructions. Properties parallel to the face grain of the plywood are based on a panel construction giving minimum values in that direction. Properties perpendicular to the face grain are based on a different panel construction, giving minimum values in that direction. Properties for the two directions, however, cannot be added to achieve properties of the full panel.

SECTION 23.222 — CALCULATION OF DIAPHRAGM DEFLECTION

Calculations for diaphragm deflection shall account for the usual bending and shear components as well as any other factors, such as nail deformation, which will contribute to the deflection.

The deflection (Δ) of a blocked plywood diaphragm uniformly nailed throughout may be calculated by use of the following formula. If not uniformly nailed, the constant 0.188 (0.614) in the third term must be modified accordingly.

$$\Delta = \frac{5vL^3}{8EAb} + \frac{vL}{4Gt} + 0.188\,Le_n + \frac{\Sigma(\Delta_c X)}{2b}$$

For **SI:**
$$\Delta = \frac{52vL^3}{EAb} + \frac{vL}{4Gt} + 0.614\,Le_n + \frac{\Sigma(\Delta_c X)}{2b}$$

WHERE:

A = area of chord cross section, in square inches (mm^2).
b = diaphragm width, in feet (m).
E = elastic modulus of chords, in pounds per square inch (N/mm^2).
e_n = nail deformation, in inches (mm) (see Table 23-2-K).
G = modulus of rigidity of plywood, in pounds per square inch (N/mm^2) (see Table 23-2-J).
L = diaphragm length, in feet (m).
t = effective thickness of plywood for shear, in inches (mm) (see Tables 23-2-H and 23-2-I).
v = maximum shear due to design loads in the direction under consideration, in pounds per lineal foot (N/m).
Δ = the calculated deflection, in inches (mm).
$\Sigma(\Delta_c X)$ = sum of individual chord-splice slip values on both sides of the diaphragm, each multiplied by its distance to the nearest support.

SECTION 23.223 — CALCULATION OF SHEAR WALL DEFLECTION

The deflection (Δ) of a blocked shear wall uniformly nailed throughout may be calculated by use of the following formula:

$$\Delta = \frac{8vh^3}{EAb} + \frac{vh}{Gt} + 0.75he_n + \frac{h}{b}\,d_a$$

For **SI:**
$$\Delta = \frac{2000\,vh^3}{3EAb} + \frac{vh}{Gt} + 2.46\,he_n + \frac{h}{b}\,d_a$$

WHERE:

A = area of boundary element cross section in square inches (mm^2) (vertical member at shear wall boundary).
b = wall width, in feet (m).
d_a = deflection due to anchorage details (rotation and slip at tie-down bolts).
E = elastic modulus of boundary element (vertical member at shear wall boundary), in pounds per square inch (N/mm^2).
e_n = nail deformation, in inches (mm) (see Table 23-2-K).
G = modulus of rigidity of plywood, in pounds per square inch (N/mm^2) (see Table 23-2-J).
h = wall height, in feet (m).
t = effective thickness of plywood for shear, in inches (mm) (see Tables 23-2-H and 23-2-I).
v = maximum shear due to design loads at the top of the wall, in pounds per lineal foot (N/m).
Δ = the calculated deflection, in inches (mm).

SECTION 23.224 — ALLOWABLE STRESSES FOR SHEAR THROUGH THE THICKNESS

Shear-through-the-thickness stresses in Table 23-III-A of this code are based on the most common structural applications, as where plywood is mechanically fastened to framing. If the plywood is rigidly glued to full-length, continuous (unjointed) framing around all panel edges, increase allowable shear-through-the-thickness stresses by 33 percent. If the continuous framing is glued to only two edges parallel to the face grain, increase stresses by 19 percent. When continuous framing is only at edges perpendicular to the face grain, no increase in stresses shall be taken.

In lieu of the increase in shear-through-the-thickness stresses given above for continuous glued framing, a 33 percent increase may be taken when panels are regraded to limit core gap width and placement. Contiguous core gaps in adjacent plies within a layer shall be measured as a single gap from the outermost edge of one to the opposite edge of the other. Noncontiguous core gaps in any parallel ply of the panel shall be offset by at least 1 inch (25 mm), measured from innermost edges of the gaps. Gap width limitations are as follows:

1. For all three-layer panels (including three-ply and four-ply), core gaps shall not be wider than $^1/_4$ inch (6.4 mm).

2. For panels with five or more layers, core gaps shall be limited to 1 inch (25 mm) in $^1/_2$-inch-thick (13 mm) panels and to $^1/_2$ inch (13 mm) in thicker panels.

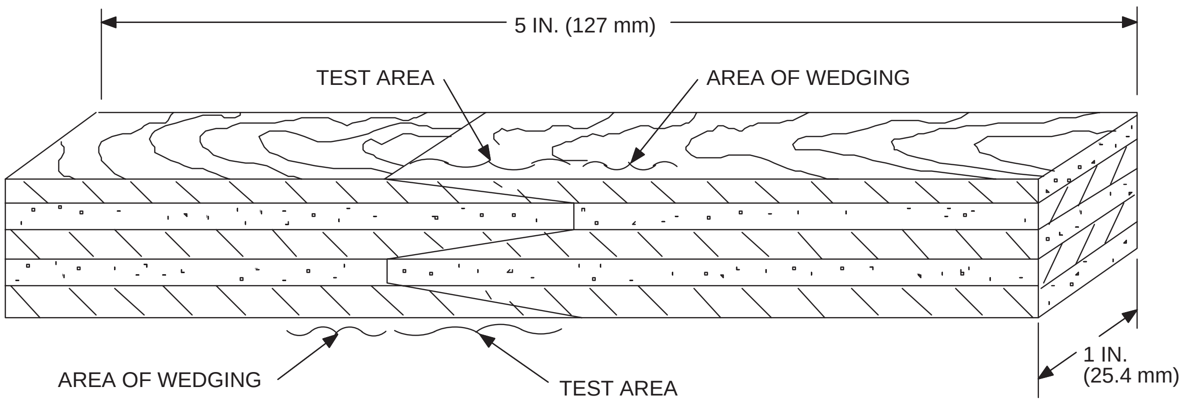


FIGURE 23-2-5—CLEAVAGE TEST, TYPICAL TEST SPECIMEN

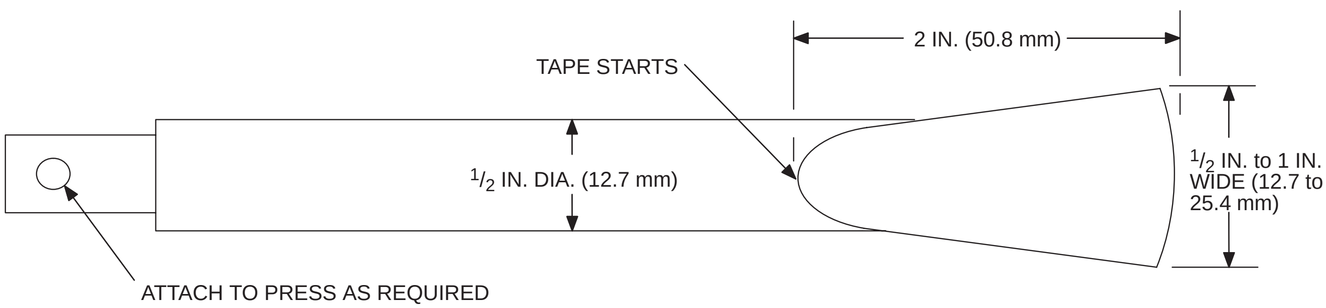
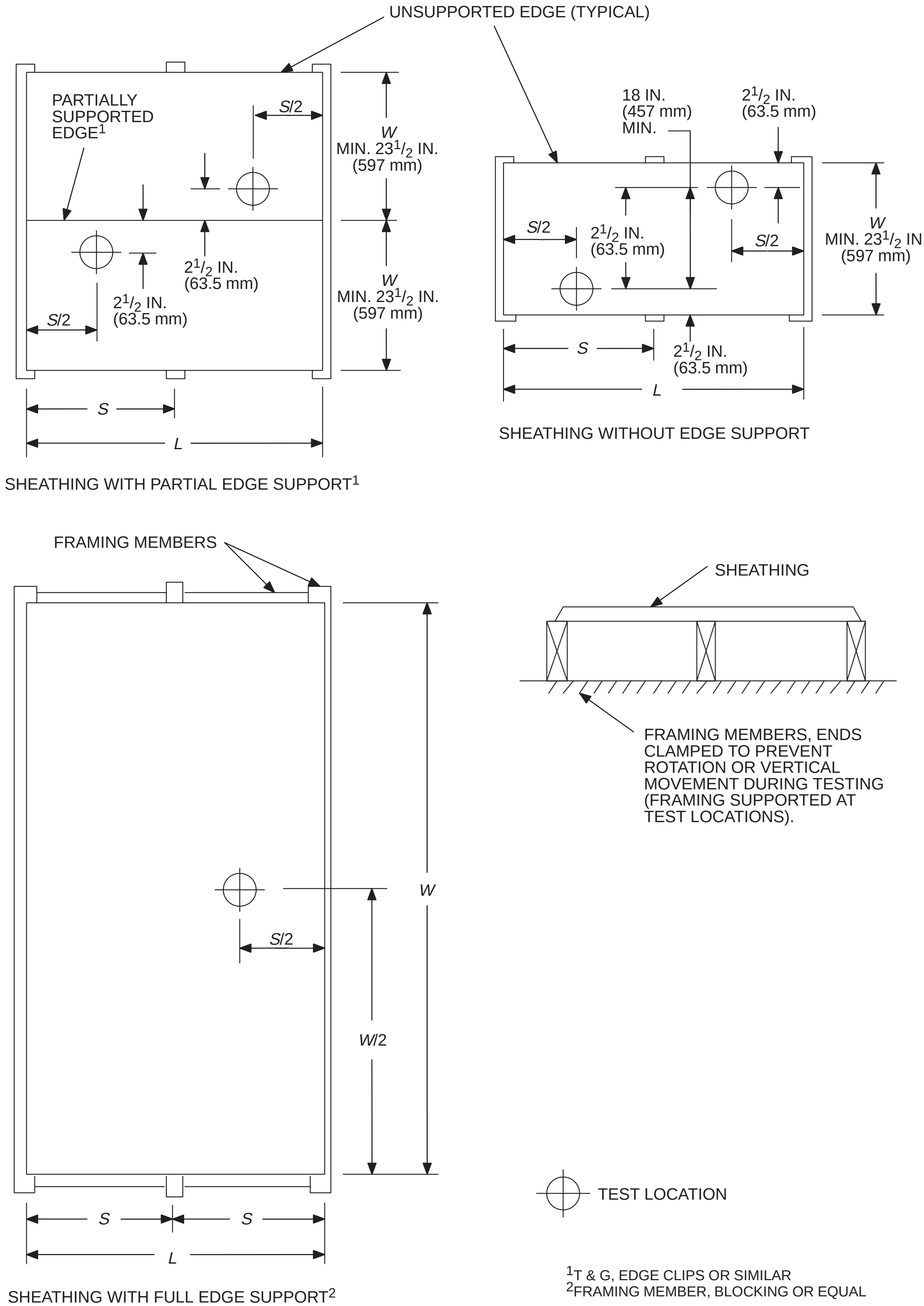
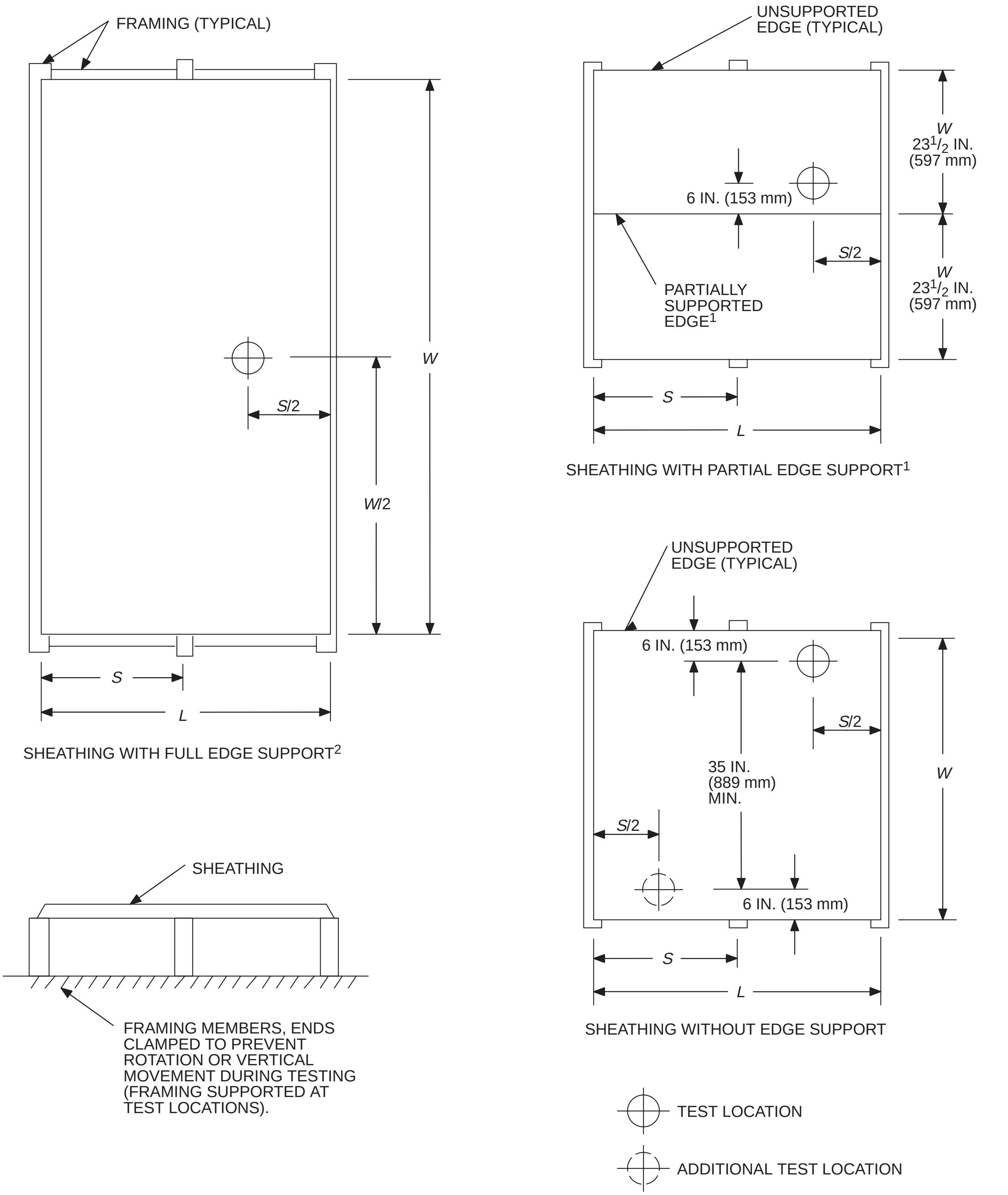


FIGURE 23-2-6—WEDGE OR CHISEL FOR CLEAVAGE TEST



[1]T & G, EDGE CLIPS OR SIMILAR
[2]FRAMING MEMBER, BLOCKING OR EQUAL

FIGURE 23-2-7—CONCENTRATED STATIC LOAD TEST SPECIMENS



[1]T & G, edge clips or similar.
[2]Framing member, blocking or equal.

FIGURE 23-2-8—IMPACT LOAD TEST SPECIMENS

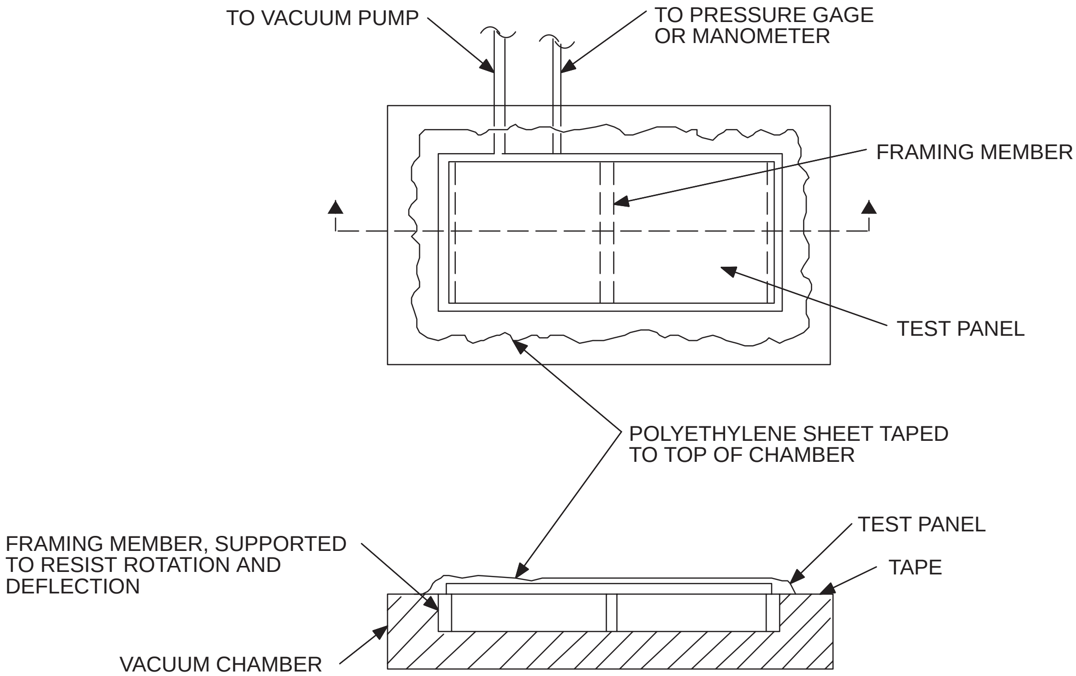
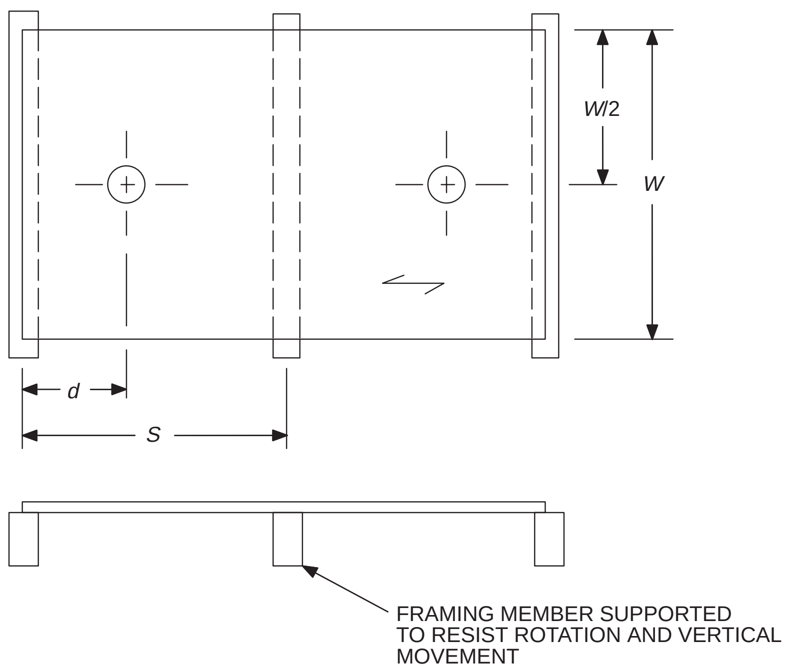


FIGURE 23-2-9—VACUUM CHAMBER TEST EQUIPMENT



S = Center-to-center support spacing.
d = 0.4215(S) for two span.
W = Panel width, minimum = 23.5 inches (597 mm).
⊕ = Location of deflection measurement.

FIGURE 23-2-10—UNIFORM LOAD TEST SPECIMENS

TABLE 23-2-A—CLASSIFICATION OF SPECIES

GROUP 1	GROUP 2	GROUP 3	GROUP 4

Aptiong[1, 2]
Beech, American
Birch
  Sweet
  Yellow
Douglas fir 1[3]
Kapur[1]
Keruing[1, 2]
Larch, western
Maple, sugar
Pine
  Caribbean
  Ocote
Pine, southern
  Loblolly
  Longleaf
  Shortleaf
  Slash
Tanoak
	Cedar, Port Oxford
	Cypress
	Douglas fir 2[3]
	Fir
	  Balsam
	  California red
	  Grand
	  Noble
	  Pacific silver
	  White
	Hemlock, western
	Lauan
	  Almon
	  Bagtikan
	  Mayapis
	  Red lauan
	  Tangile
	  White lauan
	Maple, black
	Mengkulang[1]
	Meranti, red[1, 4]
	Mersawa[1]
	Pine
	  Pond
	  Red
	  Virginia
	  Western White
	Spruce
	  Black
	  Red
	  Sitka
	Sweetgum
	Tamarack
	Yellow-poplar
		Alder, red
		Birch, paper
		Cedar, Alaska
		Fir, subalpine
		Hemlock, eastern
		Maple, bigleaf
		Pine
		  Jack
		  Lodgepole
		  Ponderosa
		  Spruce
		Redwood
		Spruce
		  Engelmann
		  White
			Aspen
			  Bigtooth
			  Quaking
			Cativo
			Cedar
			  Incense
			  Western red
			Cottonwood
			  Eastern
			  Black (western poplar)
			Pine
			  Eastern white
			  Sugar

[1]Each of these names represents a trade group of woods consisting of a number of closely related species.

[2]Species from the genus Dipterocarpus are marked collectively: Aptiong if originating in the Philippines; Keruing if originating in Malaysia or Indonesia.

[3]Douglas fir from trees grown in the states of Washington, Oregon, California, Idaho, Montana, Wyoming, and the Canadian provinces of Alberta and British Columbia shall be classed as Douglas fir No. 1. Douglas fir from trees grown in the states of Nevada, Utah, Colorado, Arizona and New Mexico shall be classed as Douglas fir No. 2.

[4]Red meranti shall be limited to species having a specific gravity of 0.41 or more based on green volume and oven-dry weight.

TABLE 23-2-B—CHARACTERISTICS PROHIBITED OR RESTRICTED IN CERTAIN PANEL GRADES

PANEL GRADE DESIGNATION	DESCRIPTION AND NUMBER OF CHARACTERISTICS PER PANEL
N-N, N-A	No crossband laps adjacent to faces and backs
N-B	No crossband laps adjacent to N faces No more than 2 crossband laps adjacent to B grade side Laps are limited to $^3/_{16}$ inch (4.8 mm)
N-D	No crossband laps adjacent to faces No more than a total of 2 of any combination of the following: — Knothole in D veneer over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Split in D veneer over $^1/_2$ inch (13 mm) [not over 1 inch (25 mm)] — Crossband lap adjacent to backs
Underlayment and C-C Plugged	No knotholes in veneer adjacent to face over 1 inch (25 mm) across the grain where C grade is required per Tables 23-2-D and 23-2-E No knotholes in veneer adjacent to face over $2^1/_2$ inches (64 mm) where D grade is permitted or $1^1/_2$ inches (38 mm) where C grade is permitted per Section 23.205.6 No laps adjacent to face
Structural I C-D	No splits in faces over $^1/_4$ inch (6.4 mm) No splits in backs over $^1/_2$ inch (13 mm) No more than a total of 2 of any combination of the following: — Knothole in C veneer over 1 inch (25 mm) but not over $1^1/_2$ inches (38 mm) — Knot in D backs over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Knothole in D veneer over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Crossband lap adjacent to faces per Section 23.205.4 — Crossband lap adjacent to backs per Section 23.205.4
Structural I C-D Plugged	No splits in backs over $^1/_2$ inch (13 mm) No more than a total of 2 of any combination of the following: — Knot in D backs over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Knothole in D veneer over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Crossband lap adjacent to faces per Section 23.205.4 — Crossband lap adjacent to backs per Section 23.205.4
Structural I Underlayment	No knotholes in core veneer next to face over 1 inch (25 mm) No crossband laps adjacent to faces No splits in backs over $^1/_2$ inch (13 mm) No more than a total of 2 of any combination of the following: — Knot in D backs over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Knothole in D veneer over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Crossband lap adjacent to backs per Section 23.205.4

TABLE 23-2-C—PANEL CONSTRUCTIONS

PANEL GRADES	FINISHED PANEL NOMINAL THICKNESS RANGE (inch) × 25.4 for mm	MINIMUM NUMBER OF PLIES	MINIMUM NUMBER OF LAYERS
Exterior Marine Special Exterior (See Section 23.205.4) B-B concrete form High Density Overlay High Density concrete form overlay	Through $^3/_8$ Over $^3/_8$, through $^3/_4$ Over $^3/_4$	3 5 7	3 5 7
Interior N-N, N-A, N-B, N-D, A-A, A-B, A-D, B-B, B-D Structural I (C-D, C-D Plugged and Underlayment) Exterior A-A, A-B, A-C, B-B, B-C Structural I C-C and C-C Plugged (See Section 23.205.4) Medium Density and Special Overlays	Through $^3/_8$ Over $^3/_8$, through $^1/_2$ Over $^1/_2$, through $^7/_8$ Over $^7/_8$	3 4 5 6	3 3 5 5
Interior (including grades with Exterior glue) Underlayment Exterior C-C Plugged	Through $^1/_2$ Over $^1/_2$, through $^3/_4$ Over $^3/_4$	3 4 5	3 3 5
Interior (including grades with Exterior glue) C-D C-D Plugged Exterior C-C	Through $^5/_8$ Over $^5/_8$, through $^3/_4$ Over $^3/_4$	3 4 5	3 3 5

TABLE 23-2-D—INTERIOR-TYPE GRADES

PANEL GRADES DESIGNATIONS	MINIMUM VENEER QUALITY			SURFACE
	Face	Back	Inner Plies	
N-N	N	N	C	Sanded 2 sides
N-A	N	A	C	Sanded 2 sides
N-B	N	B	C	Sanded 2 sides
N-D	N	D	D	Sanded 2 sides
A-A	A	A	D	Sanded 2 sides
A-B	A	B	D	Sanded 2 sides
A-D	A	D	D	Sanded 2 sides
B-B	B	B	D	Sanded 2 sides
B-D	B	D	D	Sanded 2 sides
Underlayment[1]	C Plugged	D	C and D	Touch-sanded
C-D Plugged	C Plugged	D	D	Touch-sanded
Structural I C-D	See Section 23.205.4			Unsanded[2]
Structural I C-D Plugged, Underlayment	See Section 23.205.4			Touch-sanded
C-D	C	D	D	Unsanded[2]
C-D with Exterior glue (See Section 23.215)	C	D	D	Unsanded[2]

[1]See Section 23.205.6 for special limitations.

[2]Except for decorative grades, panels shall not be sanded, touch-sanded, surface textured or thickness sized by any mechanical means.

TABLE 23-2-E—EXTERIOR-TYPE GRADES[1]

PANEL GRADES DESIGNATIONS	MINIMUM VENEER QUALITY			SURFACE
	Face	Back	Inner Plies	
Marine, A-A, A-B, B-B, HDO, MDO		Section 23.205.1		See regular grades
Special Exterior, A-A,				See regular grades
A-B, B-B, HDO, MDO		Section 23.205.5		Sanded 2 sides
A-A				Sanded 2 sides
A-B	A	A	C	Sanded 2 sides
A-C	A	B	C	
B-B (concrete form)	A	C	C	Sanded 2 sides
B-B		Section 23.205.3		Sanded 2 sides
B-C	B	B	C	Touch-sanded
C-C Plugged[2]	B	C	C	Unsanded[3]
C-C	C Plugged	C	C	
A-A High Density	C	C	C	
Overlay				
B-B High Density	A	A	C Plugged	
Overlay				
B-B High Density	B	B	C Plugged[4]	
Concrete Form Overlay				
(See Section 23.205.3)				
B-B Medium Density	B	B	C Plugged	
Overlay				
Special Overlays	B	B	C	
	C	C	C	

[1]Available also in Structural I classification as provided in Section 23.205.4.
[2]See Section 23.205.6 for special limitations.
[3]Except for decorative grades, panels shall not be sanded, touch-sanded, surface textured or thickness sized by any mechanical means.
[4]C centers may be used in panels of five or more plies.

TABLE 23-2-F—PREMIUM GRADES

GRADE	GLUE BOND	SPECIES
Structural I C-D[1.1] C-D Plugged[1] Underlayment[1]	Shall meet the requirements of Section 23.215	Face, back and all inner plies limited to Group 1 species
Structural I All Exterior grades (see Table 23-2-E)	Exterior	Face, back and all inner plies limited to Group 1 species

[1]Special limitations applying to Structural (C-D, C-D Plugged, Underlayment) grade panels are:

1.1 In D grade veneers white pocket in any area larger than the size of the largest knot hole, pitchpocket or split specifically permitted in D grade shall not be permitted in any ply.

1.2 Sound tight knots in D grade shall not exceed $2^1/_2$ inches (64 mm) measured across the grain, except as provided in Table 23-2-B.

1.3 Plugs, including multiple repairs, shall not exceed 4 inches (102 mm) in width.

1.4 Panel construction shall be as specified in Section 23.203.1.

TABLE 23-2-G—SPAN RATINGS FOR SHEATHING AND SINGLE-FLOOR PANELS
(For special ply-layer and species requirements applicable to STRUCTURAL panels, see Section 23.205.4 and Tables 23-2-C and 23-2-F. For crossband and total inner-ply thickness proportion requirements, see Section 23.203.1.)

SPAN RATING[1]	NOMINAL PANEL THICKNESS (inch)[2] × 25.4 for mm	MINIMUM NUMBER OF PLIES-LAYERS	MINIMUM FACE AND BACK VENEER THICKNESS BEFORE PRESSING, FOR SPECIES GROUP[3] (inches) × 25.4 for mm				INNER-PLY SPECIES GROUP
			1	2	3	4	
SHEATHING PANELS (C-D, C-C)							
12/0	5/16	3-3	1/12	1/12	1/12	1/12	1, 2, 3 or 4
16/0	5/16	3-3	1/12	1/12	1/12	[4]	1, 2, 3 or 4
	11/32	3-3	1/12	1/12	1/12	1/12	1, 2, 3 or 4
20/0	5/16	3-3	1/12	[4]	[4]	[4]	1, 2, 3 or 4
	11/32	3-3	1/12	1/12	1/10	[4]	1, 2, 3 or 4
	3/8	3-3	1/10	1/10	1/10	1/10	1, 2, 3 or 4
24/0	3/8	3-3	1/10	[4]	[4]	[4]	1, 2, 3 or 4
	13/32	3-3	1/10	1/10	[4]	[4]	1, 2, 3 or 4
	1/2	3-3	1/10	1/10	1/10	1/10	1, 2, 3 or 4
32/16	1/2	3-3	1/10	1/6	[4]	[4]	1, 2, 3 or 4
	17/32	3-3	1/10	1/10	1/6	[4]	1, 2, 3 or 4
	5/8	3-3	[5]	[5]	[5]	[5]	1, 2, 3 or 4
40/20	5/8	3-3	[5]	1/6	[4]	[4]	1, 2, 3 or 4
	21/32	3-3	1/10	1/8	1/6	[4]	1, 2, 3 or 4
	3/4	4-3	1/10	1/10	1/10	1/8	1, 2, 3 or 4
	25/32	4-3	1/10	1/10	1/10	1/10	1, 2, 3 or 4
48/24	3/4	4-3	1/10	1/6	[4]	[4]	1, 2, 3 or 4
	25/32	4-3	1/10	1/8	1/6	[4]	1, 2, 3 or 4
	7/8	5-5	1/10	1/10	1/10	[4]	1, 2, 3 or 4
	29/32	5-5	1/10	1/10	1/10	1/8	1, 2, 3 or 4
SINGLE-FLOOR PANELS (UNDERLAYMENT, C-C PLUGGED)							
16 o.c.	1/2	3-3	1/10	[4]	[4]	[4]	1, 2, 3 or 4
	19/32	4-3	[5]	[5]	[5]	1/6	1, 2, 3 or 4
	5/8	4-3	[5]	[5]	[5]	[5]	1, 2, 3 or 4
20 o.c.	19/32	4-3	[5]	1/6	[4]	[4]	1, 2, 3 or 4
	5/8	4-3	[5]	1/8	1/6	[4]	1, 2, 3 or 4
	23/32	4-3	1/10	1/10	1/10	1/8	1, 2, 3 or 4
	3/4	4-3	1/10	1/10	1/10	1/10	1, 2, 3 or 4
24 o.c.	23/32	4-3	1/10	1/6	3/16	[4]	1, 2, 3 or 4
	3/4	4-3	1/10	1/8	1/6	[4]	1, 2, 3 or 4
	7/8	5-5	1/10	1/10	1/10	1/8	1, 2, 3 or 4
48 o.c.	1 1/8	7-5	1/8	1/6	[4]	[4]	1 or 2
	1 1/8	7-5	1/7	1/6	[4]	[4]	1, 2 or 3
	1 1/8	7-7	1/10	1/6	3/16	[4]	1
	1 1/8	7-7	1/8	1/6	3/16	[4]	1, 2 or 3

[1]See Section 23.209 for description.

[2]Panels for which there is no span rating shall be identified by largest species group number of the face and back, or by the span rating of the next thinner comparable panel. Sheathing panels manufactured 1/32-inch (0.8 mm) over standard thickness may be identified as the standard thickness.

[3]Intermixing between species groups and/or thicknesses in the faces and backs of panel is permitted. Use the lowest applicable span rating to identify the panel.

[4]Not permitted.

[5]One-eighth-inch minimum for 3-, 4- and 5-ply three-layer panels per Section 23.204.1. May be 1/10 inch (2.5 mm) minimum for five-ply, five-layer panels.

TABLE 23-2-H—FACE PLIES OF DIFFERENT SPECIES GROUP THAN INNER PLIES
(Includes all standard grades except those noted in Table 23-2-I)

NOMINAL THICKNESS (inches)	APPROXIMATE WEIGHT (psf)	EFFECTIVE THICKNESS FOR SHEAR (inches)	STRESS APPLIED PARALLEL TO FACE GRAIN				STRESS APPLIED PERPENDICULAR TO FACE GRAIN			
			A Area (in.^{2}/ft.)	*I* Moment of Inertia (in.^{4}/ft.)	*KS* Eff. Section Modulus (in.^{3}/ft.)	*Ib/Q* Rolling Shear Constant (in.^{2}/ft.)	*A* Area (in.^{2}/ft.)	*I* Moment of Inertia (in.^{4}/ft.)	*KS* Eff. Section Modulus (in.^{3}/ft.)	*Ib/Q* Rolling Shear Constant (in.^{2}/ft.)
$\times$ 25.4 for mm	$\times$ 4.882 for kg/m^2	$\times$ 25.4 for mm	2.117 for mm^2/mm	1365.6 for mm^4/mm	53.76 for mm^3/mm	2.117 for mm^2/mm	2.117 for mm^2/mm	1365.6 for mm^4/mm	53.76 for mm^3/mm	2.117 for mm^2/mm
Unsanded Panels										
$^{5}/_{16}$-U	1.0	0.268	1.491	0.022	0.112	2.569	0.660	0.001	0.023	4.497
$^{3}/_{8}$-U	1.1	0.278	1.866	0.037	0.154	3.110	0.799	0.002	0.031	5.444
$^{15}/_{32}$ and $^{1}/_{2}$-U	1.5	0.298	2.292	0.074	0.247	3.921	1.007	0.004	0.051	2.450
$^{19}/_{32}$ and $^{5}/_{8}$-U	1.8	0.319	2.330	0.146	0.355	5.273	1.354	0.010	0.091	3.126
$^{23}/_{32}$ and $^{3}/_{4}$-U	2.2	0.445	3.247	0.227	0.496	6.544	1.563	0.033	0.208	3.613
$^{7}/_{8}$-U	2.6	0.607	3.509	0.340	0.678	7.175	1.950	0.112	0.397	5.097
1-U	3.0	0.842	3.916	0.493	0.859	9.244	3.611	0.210	0.660	7.115
1$^{1}/_{8}$-U	3.3	0.859	4.725	0.676	1.047	9.960	3.079	0.288	0.768	8.821
Sanded Panels										
$^{1}/_{4}$-S	0.8	0.267	0.996	0.008	0.059	2.010	0.348	0.001	0.009	2.019
$^{11}/_{32}$-S	1.0	0.284	0.996	0.019	0.093	2.765	0.417	0.001	0.016	2.589
$^{3}/_{8}$-S	1.1	0.288	1.307	0.027	0.125	3.088	0.626	0.002	0.023	3.510
$^{15}/_{32}$-S	1.4	0.421	1.947	0.066	0.214	4.113	1.251	0.006	0.067	2.832
$^{1}/_{2}$-S	1.5	0.425	1.947	0.077	0.236	4.466	1.409	0.009	0.087	3.099
$^{19}/_{32}$-S	1.7	0.546	2.423	0.115	0.315	5.471	1.389	0.021	0.137	2.861
$^{5}/_{8}$-S	1.8	0.550	2.475	0.129	0.339	5.824	1.528	0.027	0.164	3.119
$^{23}/_{32}$-S	2.1	0.563	2.822	0.179	0.389	6.717	1.737	0.050	0.231	3.818
$^{3}/_{4}$-S	2.2	0.568	2.884	0.197	0.412	7.121	2.084	0.063	0.285	4.079
$^{7}/_{8}$-S	2.6	0.586	2.942	0.278	0.515	8.182	2.841	0.122	0.470	5.078
1-S	3.0	0.817	3.721	0.423	0.664	8.882	3.163	0.185	0.591	7.031
1$^{1}/_{8}$-S	3.3	0.836	3.854	0.548	0.820	9.883	3.180	0.271	0.744	8.428
Touch-sanded Panels										
$^{1}/_{2}$-T	1.5	0.342	2.698	0.083	0.271	4.252	1.159	0.006	0.061	2.746
$^{19}/_{32}$ and $^{5}/_{8}$-T	1.8	0.408	2.354	0.122	0.291	5.350	1.555	0.017	0.138	3.220
$^{23}/_{32}$ and $^{3}/_{4}$-T	2.2	0.439	2.715	0.196	0.398	6.589	2.014	0.032	0.219	3.635
1$^{1}/_{8}$-T	3.3	0.839	4.548	0.633	0.977	11.258	4.067	0.272	0.743	8.535

TABLE 23-2-I—STRUCTURAL I AND MARINE WITH ALL PLIES FROM SAME SPECIES GROUP

NOMINAL THICKNESS (inches)	APPROXIMATE WEIGHT (psf)	EFFECTIVE THICKNESS FOR SHEAR (inches)	STRESS APPLIED PARALLEL TO FACE GRAIN				STRESS APPLIED PERPENDICULAR TO FACE GRAIN			
			A Area (in.^{2}/ft.)	*I* Moment of Inertia (in.^{4}/ft.)	*KS* Eff. Section Modulus (in.^{3}/ft.)	*Ib/Q* Rolling Shear Constant (in.^{2}/ft.)	*A* Area (in.^{2}/ft.)	*I* Moment of Inertia (in.^{4}/ft.)	*KS* Eff. Section Modulus (in.^{3}/ft.)	*Ib/Q* Rolling Shear Constant (in.^{2}/ft.)
× 25.4 for mm	× 4.882 for kg/m^2	× 25.4 for mm	2.117 for mm^2/mm	1365.6 for mm^4/mm	53.76 for mm^3/mm	2.117 for mm^2/mm	2.117 for mm^2/mm	1365.6 for mm^4/mm	53.76 for mm^3/mm	2.117 for mm^2/mm
Unsanded Panels										
${}^{5}/_{16}$-U	1.0	0.356	1.619	0.022	0.126	2.567	1.188	0.002	0.029	6.037
${}^{3}/_{8}$-U	1.1	0.371	2.226	0.041	0.195	3.107	1.438	0.003	0.043	7.307
${}^{15}/_{32}$ and ${}^{1}/_{2}$-U	1.5	0.535	2.719	0.074	0.279	4.206	2.175	0.014	0.127	2.408
${}^{19}/_{32}$ and ${}^{5}/_{8}$-U	1.8	0.707	3.464	0.154	0.437	5.685	2.742	0.045	0.240	3.072
${}^{23}/_{32}$ and ${}^{3}/_{4}$-U	2.2	0.739	4.219	0.241	0.572	6.148	2.813	0.064	0.299	3.540
${}^{7}/_{8}$-U	2.6	0.776	4.388	0.346	0.690	6.948	3.510	0.192	0.584	5.086
1-U	3.0	1.088	5.200	0.529	0.922	8.512	6.500	0.366	0.970	7.052
$1{}^{1}/_{8}$-U	3.3	1.118	6.654	0.751	1.164	9.061	5.542	0.503	1.131	8.755
Sanded Panels										
${}^{1}/_{4}$-S	0.8	0.342	1.280	0.012	0.083	2.009	0.626	0.001	0.013	2.723
${}^{11}/_{32}$-S	1.0	0.365	1.280	0.026	0.133	2.764	0.751	0.001	0.023	3.397
${}^{3}/_{8}$-S	1.1	0.373	1.680	0.038	0.177	3.086	1.126	0.002	0.033	4.927
${}^{15}/_{32}$-S	1.4	0.537	1.947	0.067	0.247	4.107	2.251	0.009	0.093	2.807
${}^{1}/_{2}$-S	1.5	0.545	1.947	0.078	0.271	4.457	2.536	0.014	0.123	3.076
${}^{19}/_{32}$-S	1.7	0.709	3.018	0.116	0.338	5.566	2.501	0.034	0.199	2.811
${}^{5}/_{8}$-S	1.8	0.717	3.112	0.131	0.361	5.934	2.751	0.045	0.238	3.073
${}^{23}/_{32}$-S	2.1	0.741	3.735	0.183	0.439	6.707	3.126	0.085	0.338	3.780
${}^{3}/_{4}$-S	2.2	0.748	3.848	0.202	0.464	7.146	3.751	0.108	0.418	4.047
${}^{7}/_{8}$-S	2.6	0.778	3.952	0.288	0.569	7.539	5.114	0.212	0.692	5.046
1-S	3.0	1.091	5.215	0.479	0.827	7.978	5.693	0.321	0.870	6.981
$1{}^{1}/_{8}$-S	3.3	1.121	5.593	0.623	0.955	8.841	5.724	0.474	1.098	8.377
Touch-sanded Panels										
${}^{1}/_{2}$-T	1.5	0.543	2.698	0.084	0.282	4.511	2.486	0.020	0.162	2.720
${}^{19}/_{32}$ and ${}^{5}/_{8}$-T	1.8	0.707	3.127	0.124	0.349	5.500	2.799	0.050	0.259	3.183
${}^{23}/_{32}$ and ${}^{3}/_{4}$-T	2.2	0.739	4.059	0.201	0.469	6.592	3.625	0.078	0.350	3.596

TABLE 23-2-J—VALUES OF *G* FOR USE WITH EFFECTIVE THICKNESS FOR SHEAR (TABLES 23-2-H AND 23-2-I) IN CALCULATING DEFLECTION OF PLYWOOD DIAPHRAGMS

PLYWOOD GRADES OR SPECIES GROUP NOS.	*G*—(MODULUS OF RIGIDITY—psi)[1]
	× 0.00689 for N/mm^2
Group 1	90,000
Group 2	75,000
Group 3	60,000
Group 4	50,000
Structural I	90,000
Exterior C-C and C-D with Exterior glue	
The combination of Identification Index designation and panel thickness determines the minimum species group and, therefore, the modulus of rigidity to be used: ${}^{5}/_{16}$ (7.9 mm)—20/0; ${}^{3}/_{8}$ (9.5 mm)—24/0; ${}^{15}/_{32}$, ${}^{1}/_{2}$ (12, 13 mm)—32/16; ${}^{19}/_{32}$, ${}^{5}/_{8}$ (16 mm)—42/20; ${}^{23}/_{32}$, ${}^{3}/_{4}$ (18, 19 mm)—48/24	90,000
All other combinations of C-C and C-D with Exterior glue	50,000

[1]Values of *"G"* shown apply to plywood bonded with Exterior glue. For plywood bonded with Interior glue, multiply by 0.91.

TABLE 23-2-K—“e_n” VALUES (INCHES) FOR USE IN CALCULATING DIAPHRAGM DEFLECTION DUE TO NAIL SLIP (STRUCTURAL I)[1]

LOAD PER NAIL (pounds)	NAIL DESIGNATION		
	6d	8d	10d
× 4.448 for N	× 25.4 for mm		
60	0.012	0.008	0.006
80	0.020	0.012	0.010
100	0.030	0.018	0.013
120	0.045	0.023	0.018
140	0.068	0.031	0.023
160	0.102	0.041	0.029
180	—	0.056	0.037
200	—	0.074	0.047
220	—	0.096	0.060
240	—	—	0.077

[1]Increase “e_n” values 20 percent for plywood grades other than Structural I.
Values apply to common wire nails.
Load per nail = maximum shear per foot divided by the number of nails per foot at interior panel edges.
Decrease values 50 percent for seasoned lumber.

TABLE 23-2-L—CONCENTRATED STATIC AND IMPACT TEST PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.216—SHEATHING

END USE—SPAN RATING	TEST EXPOSURE CONDITIONS[1]	PERFORMANCE REQUIREMENTS		
		Minimum Ultimate Load (lb.)		Maximum Deflection (in.) under 200-Lb. (890 N) Load[3]
		× 4.448 for N		
		Static	Following Impact[2]	× 25.4 for mm
Roof—16	Dry	400	300	7/16 (0.438)
	Wet	400	300	[4]
Roof—20	Dry	400	300	15/32 (0.469)
	Wet	400	300	[4]
Roof—24	Dry	400	300	1/2 (0.500)
	Wet	400	300	[4]
Roof—32	Dry	400	300	1/2 (0.500)
	Wet	400	300	[4]
Roof—40	Dry	400	300	1/2 (0.500)
	Wet	400	300	[4]
Roof—48	Dry	400	300	1/2 (0.500)
	Wet	400	300	[4]
Subfloor—16	Dry	400	400	3/16 (0.188)
	Wet/redry	400	400	3/16 (0.188)
Subfloor—20	Dry	400	400	7/32 (0.219)
	Wet/redry	400	400	7/32 (0.219)
Subfloor—24	Dry	400	400	1/4 (0.250)
	Wet/redry	400	400	1/4 (0.250)

[1]Wet/redry is exposure to three days continuous wetting followed by testing dry. Wet conditioning is exposure to three days continuous wetting and tested wet.
[2]Impact shall be 75 foot-pounds (102 N·m) for span ratings up to 24 on center (610 mm), 90 foot-pounds (122 N·m) for 32 on center (813 mm), 120 foot-pounds (163 N·m) for 40 on center (1016 mm), and 150 foot-pounds (203 N·m) for 48 on center (1219 mm).
[3]Criteria apply under static concentrated load according to Section 23.216. They do not apply following impact.
[4]Not applicable.

TABLE 23-2-M—UNIFORM LOAD PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.217—SHEATHING

END USE—SPAN RATING	TEST EXPOSURE CONDITIONS[1]	PERFORMANCE REQUIREMENTS	
		Average Deflection (in.) under Load (psf)	Minimum Ultimate Uniform Load (psf)
		× 25.4 for mm × 0.0000479 for N/mm²	× 0.0000479 for N/mm²
Roof—16	Dry	0.067 at 35 psf	150
Roof—20	Dry	0.080 at 35 psf	150
Roof—24	Dry	0.100 at 35 psf	150
Roof—32	Dry	0.133 at 35 psf	150
Roof—40	Dry	0.167 at 35 psf	150
Roof—48	Dry	0.200 at 35 psf	150
Subfloor—16	Dry	0.044 at 100 psf	330
	Wet/Redry	0.044 at 100 psf	330
Subfloor—20	Dry	0.053 at 100 psf	330
	Wet/Redry	0.053 at 100 psf	330
Subfloor—24	Dry	0.067 at 100 psf	330
	Wet/Redry	0.067 at 100 psf	330

[1]Wet/redry is exposure to three days continuous wetting followed by testing dry.

TABLE 23-2-N—CONCENTRATED STATIC AND IMPACT TEST PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.216—SINGLE FLOOR

SPAN RATING	TEST EXPOSURE CONDITIONS[1]	PERFORMANCE REQUIREMENTS: Minimum Ultimate Load (lb.) × 4.45 for N — Static	Following 75 Ft.·Lb. (102 N•m) Impact	Maximum Deflection (in.) (mm) Under 200-Lb. (890 N) Load[2] × 25.4 for mm
16	Dry	550	400	$^5/_{64}$ (0.078)
	Wet/redry	550	400	$^5/_{64}$ (0.078)
20	Dry	550	400	$^6/_{64}$ (0.094)
	Wet/redry	550	400	$^6/_{64}$ (0.094)
24	Dry	550	400	$^7/_{64}$ (0.108)
	Wet/redry	550	400	$^7/_{64}$ (0.108)

[1]Wet/redry is exposure to three days continuous wetting followed by testing dry.

[2]Criteria apply under static concentrated load and following a 75 foot-pounds (102 N·m) impact according to Section 23.216.

TABLE 23-2-O—UNIFORM LOAD PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.217—SINGLE FLOOR

SPAN RATING	TEST EXPOSURE CONDITIONS[1]	PERFORMANCE REQUIREMENTS: Average Deflection (in.) (mm) under Load (psf) (N/mm^2) × 25.4 for mm × 0.00689 for N/mm^2	Minimum Ultimate Uniform Load (psf) × 0.00689 for N/mm^2
16	Dry or wet/redry	0.044 at 100 psf	330
20	Dry or wet/redry	0.053 at 100 psf	330
24	Dry or wet/redry	0.067 at 100 psf	330

[1]Wet/redry is exposure to three days continuous wetting followed by testing dry.

UNIFORM BUILDING CODE STANDARD 23-3

PERFORMANCE STANDARD FOR WOOD-BASED STRUCTURAL-USE PANELS

See Sections 2302.1, 2303, 2304.2 and 2502, and Tables 23-II-H, 23-II-I-1 and 23-II-E-2, *Uniform Building Code*

SECTION 23.301 — ADOPTION OF USVPS CODE

Wood-based structural-use panels shall be in accordance with United States Voluntary Product Standard PS 2-92, "Performance Standard for Wood-Based Structural-Use Panels," published by the Department of Commerce, the American Plywood Association, copyright 1992, Post Office Box 11700, Tacoma, Washington 98411 and TECO, 2401 Daniels Street, Madison, Wisconsin 53704, as if set out at length herein.

UNIFORM BUILDING CODE STANDARD 23-4

FIRE-RETARDANT-TREATED WOOD TESTS ON DURABILITY AND HYGROSCOPIC PROPERTIES

Based on American Society for Testing and Materials Standard Test Methods ASTM D 2898-81 and D 3201-79. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428, and American Wood Preservers Association Standards C 20-83 and C 27-83

See Sections 201, 207 and 2303, *Uniform Building Code*

SECTION 23.401 — SCOPE

These methods cover the (1) durability of a fire-retardant treatment of wood and wood-base products under exposure to accelerated weathering, (2) measurement of the hygroscopic properties of fire-retardant-treated wood, and (3) identification classifications for material having qualified under these tests. The fire-retardant treatment for lumber and plywood is by pressure impregnation.

SECTION 23.402 — ACCELERATED WEATHERING

23.402.1 Scope. This section describes the conditioning method for a test specimen prior to subjecting that specimen to an appropriate fire test. The condition simulates effects of leaching, drying and temperature such as might reasonably be anticipated on a wood element exposed to the weather over a long term.

23.402.2 Apparatus. The test apparatus shall be capable of subjecting the specimen uniformly to the test conditions described in Section 23.402.4.

No special means of protecting the specimen back and edges are required, but water shall not impinge directly on those surfaces which are not exposed either to the weather in the assembled form, or to fire in the subsequent test. Water spray nozzles shall be provided and arranged so as to distribute water evenly over the exposed specimen surface.

Heating shall be thermostatically controlled. Forced-air movement shall be uniform across the specimen surface, with provisions made for adequate air changes to assure thorough drying.

23.402.3 Test Specimen. The test specimen shall include all those essential parts of the corresponding fire test specimen that may be subjected to weather exposure in normal use.

Specimens may be mounted in sections which can be reassembled subsequently without trimming into the appropriate fire test specimen.

The specimen surface shall have a slope of 4 in 12.

23.402.4 Exposure Cycle. Subject the specimens to an exposure cycle consisting of twelve one-week cycles. Each cycle is to consist of 96 hours of water exposure and 72 hours of drying.

Apply water in a moderately fine spray uniformly over the exposed specimen surfaces by spray nozzles that deliver an average of 0.7 inch of water (174 Pa) per hour [0.0073 gallons per minute per square foot (0.000307 m^3/minute/m^2) of specimen surface] at a temperature between 35°F and 60°F (1.7°C to 15.6°C). Do not recirculate the water.

Dry at a thermostatically controlled temperature of 135°F to 140°F (57.2°C to 60.0°C) in a room or cell. The controlling temperature shall be the air temperature measured 1 inch (25.4 mm) above the specimen surface. Accompany drying with the air movement directed across the face of the specimens at a rate of at least 25 feet (7620 mm) per minute.

At the end of each cycle, change the position of each specimen within the apparatus so that each specimen or segment occupies approximately an equal number of cycles in each location used.

23.402.5 Conditioning. Upon completion of the prescribed exposure, the specimen shall be conditioned to a moisture content specified by the applicable fire test standard.

SECTION 23.403 — HYGROSCOPIC PROPERTIES OF FIRE-RETARDANT WOOD

23.403.1 Scope. This section prescribes the method for determining the moisture content of fire-retardant-treated wood samples after exposure to a standard high relative humidity condition of 92 ± 2 percent at 27°C ± 2°C.

23.403.2 Apparatus. Conditioning room or chamber with air circulation and controlling instruments capable of being maintained at 27°C ± 2°C and a relative humidity of 92 ± 2 percent. Other suitable means of maintaining these conditions are also acceptable.

Oven, air-circulated and vented, capable of maintaining a temperature of 103°C ± 2°C.

A weighing scale or balance that will weigh a specimen within an accuracy of ± 0.2 percent.

23.403.3 Test Specimens. Specimens shall be selected that represent the lot. Unless otherwise specified, specimens shall be full cross sections, no less than 25.4 millimeters along the grain, but longer as needed to provide a minimum volume of 33 cubic centimeters.

The specimens shall be penetrated by the chemical to be representative for the treated product.

The specimens shall be in moisture equilibrium with a laboratory ambient condition of 30 to 65 percent relative humidity or shall be exposed for at least seven days at such a condition prior to high-humidity exposure.

Untreated specimens, when available, of the same species or wood-base product and of the same size, shall be exposed to the preconditioning, high-humidity exposure, and drying along with the treated specimens.

23.403.4 Procedure. Weigh each specimen to an accuracy of ± 0.2 percent.

Expose all specimens under constant humidity conditions of 92 ± 2 percent at 27°C ± 2°C for seven days. Specimens shall be suitably suspended so that all surfaces are exposed.

Weigh each specimen immediately to an accuracy of ± 0.2 percent one at a time as they are removed from the conditioning chamber. Observe and record the general appearance of the specimens.

Dry each specimen in an oven at 103°C ± 2°C until approximately constant weight is attained, and reweigh. Constant weight can be assumed when two consecutive readings taken two hours apart agree within 0.2 percent. Avoid drying for periods longer than necessary to achieve constant weight, since thermal decomposition of chemical or wood might occur reflecting a higher than actual moisture content.

23.403.5 Calculations. Calculate the "apparent" moisture content of each sample prior to high-humidity exposure as follows:

$$\text{Moisture content: percent} = [(A - B)/B] \times 100$$

WHERE:

A = weight prior to high-humidity exposure.

B = oven-dry weight.

Calculate the "apparent" moisture content of each sample after high-humidity exposure as follows:

$$\text{Moisture content: percent} = [(C - B)/B] \times 100$$

WHERE:

B = oven-dry weight.

C = weight after high-humidity exposure.

The change in the "apparent" moisture content of the specimens shall be calculated as the difference between the average moisture content for the treated and untreated specimens as calculated in this section.

23.403.6 Report. The report shall include the following:

Complete identification of the fire-retardant product as to species of wood, wood product, and treatment.

Description of sampling procedure and number and dimensions of test specimens.

General description of humidity chamber and controls used for the test.

The average moisture content of the untreated specimens shall be reported.

The average "apparent" moisture content for the treated specimens, both before and after high-humidity exposure, including the basis of the computation; treated specimen (wood and chemical) or wood-only basis, shall be reported. The change in the average moisture content after high-humidity exposure compared to the moisture content of untreated specimens shall also be reported.

Report any change in the appearance of the specimen during exposure, including surface wetness, chemical exudation, or crystals on surface.

SECTION 23.404 — CLASSIFICATION

23.404.1 Scope. This part establishes the classification of fire-retardant-treated wood.

23.404.2 Classifications.

23.404.2.1 Interior Type A. Material that has been fire tested in accordance with Section 207 of the code to qualify as fire-retardant-treated wood and has an equilibrium moisture content of not over 28 percent when tested at 92 ± 2 percent relative humidity when conditioned as specified in Section 23.403.

23.404.2.2 Interior Type B. Material that has been fire tested in accordance with Section 207 of the code to qualify as fire-retardant-treated wood, but does not qualify as Interior Type A when conditioned as specified in Section 23.403.

23.404.2.3 Exterior type. Material that has been subjected to the weathering test of Section 23.402 and then fire tested in accordance with Section 207 of the Building Code to qualify as fire-retardant-treated wood.

UNIFORM BUILDING CODE STANDARD 23-5
FIRE-RETARDANT-TREATED WOOD
Design Values for Fire-retardant-treated Lumber
See Sections 207 and 2303, *Uniform Building Code*

SECTION 23.501 — SCOPE

This standard establishes the test protocol, acceptance criteria, and quality control procedure for assuring that fire-retardant treatments qualify for the design values assigned and that appropriate treating and redrying methods are used. Only lumber pressure impregnated with fire-retardant chemicals that is identified by the quality mark of an approved inspection agency shall be eligible for the design values specified in the Building Code.

Part I—Test Protocol

SECTION 23.502 — TYPE OF MATERIAL

The effects of fire-retardant treatment shall be determined on the basis of tests on matched samples of clear, straight-grain material. This is consistent with procedures presently used to establish design values and modifications for condition of use for visually graded sawn lumber.

SECTION 23.503 — NUMBER OF SPECIES

The effects of fire-retardant treatment may vary depending upon species. Because evaluation of such treatment for all species and properties is considered prohibitive, testing of three species representative of a range of wood density and treating characteristics is recommended. A specific treatment may be evaluated for only one of these species, but testing of three species representative of a range of wood density and treated characteristics is recommended.

Qualification may be obtained for any one species by evaluation of that species.

SECTION 23.504 — IDENTIFICATION

Each fire-retardant treatment shall be identified by the commercial name assigned by the developer of the treatment and each specimen shall be marked to identify the drying temperatures and relative humidity schedules used.

SECTION 23.505 — STRENGTH TESTING

Material to be subjected to strength testing shall be treated to the penetration and retention level required for that treatment and species to meet the definition of fire-retardant-treated wood given in Section 207.

To allow for variability in treatment especially for species classified as moderate to difficult to treat, it may be necessary to treat up to twice the number of samples required for test. Equal numbers of samples of low and high treatability may be excluded from strength testing to ensure that material of average treatability is evaluated.

Following treatment, strength test material shall be dried at a maximum temperature of 160°F (71.1°C) with relative humidity schedules and air velocities that will simulate commercial conditions. A record of the operating conditions of the kiln shall be kept for the entire run and shall include humidity conditions and temperature in the hottest part of the kiln.

SECTION 23.506 — SAMPLING AND TREATMENT

23.506.1 Species. For each fire-retardant treatment to be evaluated for general qualification, strength test material shall be selected from each of the following species:

Southern pine (*Pinus taeda or echinata*)

Coast Douglas fir

White spruce (*Picea glauca*)

The southern pine material shall be all sapwood. Where a treatment is to be evaluated only for a particular species, strength test material shall be selected from each such species.

23.506.2 Number of Samples, Size and Quality. For each species to be evaluated, 25 essentially clear, straight-grained 2 by 4s (51 by 102), 8 feet (2438 mm) or longer shall be selected from the production of one or more mills. All pieces shall be identified as being Surfaced Dry and shall have an average specific gravity within ± 10 percent of the average specific gravity (green volume basis) of the species.

23.506.3 Sample Identification. From each 2-inch-by-4-inch (51 mm by 102 mm) member selected for sampling, two end-matched 4-foot (1219 mm) blanks shall be cut for strength testing. One blank shall be designated for treatment and the other as control. All blanks shall be coded as to member number and treatment or control.

23.506.4 Pressure Treatment of Samples. All blanks to be fire-retardant treated shall be processed in accordance with the specific procedures established for the treatment being evaluated. Blanks shall be pressure treated and dried to a maximum moisture content of 19 percent in 2-inch by 4-inch (51 mm by 102 mm) by 4-foot (1219 mm) size. The same treatment and drying times, stickering practices, and other procedures to be employed in commercial charges shall be used.

23.506.5 Conditioning of Blanks. After redrying to a maximum moisture content of 19 percent, treated blanks and untreated controls shall be conditioned at 68°F ± 6°F (20°C ± 3.3°C) and 65 percent ± 1 percent relative humidity until approximate equilibrium weight is attained.

SECTION 23.507 — STRENGTH TESTS

23.507.1 Type and Number of Specimens. One- and one-half-inch-by-1$^{1}/_{2}$-inch-by-23-inch (38 mm by 38 mm by 584 mm) static bending specimen, two 1-inch-by-$^{1}/_{4}$-inch-by-16-inch (25 mm by 6.4 mm by 406 mm) tension specimens, one 1$^{1}/_{2}$-inch-by-1$^{1}/_{2}$-inch-by-6-inch (38 mm by 38 mm by 152 mm) compression specimen, one 1$^{1}/_{2}$-inch-by-1$^{1}/_{2}$-inch-by-2$^{1}/_{2}$-inch (38 mm by 38 mm by 64 mm) shear specimen, and 1$^{1}/_{2}$-inch-by-1$^{1}/_{2}$-inch-by-2-inch (38 mm by 38 mm by 51 mm) specific gravity specimen shall be cut from each treated and untreated blank. Bending and compression specimens from both treated and control blanks shall be cut such that three sides of the specimen represent the original surfaces or edge of the 2-inch-by-4-inch (51 mm by 102 mm) member. Two sides of the shear and specific gravity specimens shall represent original surfaces. One of the 1-inch-wide (25 mm) faces of one of the tension specimens shall represent one original surface of the blank and one of the wide surfaces of the other specimen shall represent the opposite original blank surface.

One method of selecting specimens to obtain the required placement of original surfaces is shown in Figure 23-5-3. Any orientation of growth rings relative to the edge of the specimens shall be acceptable.

Tension specimens shall be further machined to the size and shape shown in Figure 23-5-2. Shear specimens shall be notched as shown in Figure 23-5-1.

23.507.2 Slope of Grain. The slope of grain in all bending specimens and in the critical section of tension specimens shall be 1 in 20 or less. Compression and shear specimens shall have a slope of grain of 1 in 16 or less.

23.507.3 Identification and Conditioning. The blank identification of each treated and control specimen shall be retained. After final machining, test specimens shall be reconditioned to constant weight before test.

SECTION 23.508 — TESTING PROCEDURE

23.508.1 General. Testing procedures of an approved nationally recognized test standard shall be used. Load deformation curves shall be taken for static bending tests only. Maximum load shall be observed in all tests.

23.508.2 Order of Testing. The treated specimen and the matching untreated control from each blank shall be tested consecutively.

23.508.3 Measurement. The dimensions of the critical cross-sectional area, or in the case of the shear specimen the area of the shear plane of each specimen, shall be measured to an accuracy of at least 0.01 inch (0.254 mm).

23.508.4 Static Bending. Bending specimens shall be center loaded at span of 21 inches (533 mm). A machine cross-head speed of 0.075 inch per minute (1.9 mm per minute) shall be used. Bending specimens shall be positioned in the testing machine such that two opposite original surfaces represent the compression and tension faces of the beam.

23.508.5 Moisture Samples. All moisture samples selected from each specimen after test shall be oven dried at 103°C ± 2°C until approximately constant weight of the untreated control is reached.

23.508.6 Specific Gravity. Dimensions of the specific gravity samples shall be measured after final conditioning to determine volume at 65 percent relative humidity. Samples shall be dried at 103°C ± 2°C until approximate constant weight of the untreated control is reached.

SECTION 23.509 — REPORT

The treatment and redrying procedures shall be described in accordance with Section 23.505.

The species evaluated and testing procedures followed shall be fully described.

Individual values of treated and control specimens shall be reported for specific gravity, moisture content, modulus of elasticity, modulus of rupture, maximum tensile stress, maximum compression stress, and maximum shear stress. Average values, standard deviations, average ratios of treated to control values, and median ratios of treated to control values shall be reported for each strength and stiffness property and each species.

Part II—Acceptance Criteria

SECTION 23.510 — MINIMUM PROPERTY RATIO

A fire-retardant treatment evaluated for a particular species under this standard shall qualify for the design value adjustments in Section 2304.3 of the Building Code if the median ratio of treated to untreated strength or stiffness for each of the following properties equals or exceeds the specified adjustment factor for that property:

Extreme fiber in bending

Modulus of elasticity

Maximum stress in tension parallel to grain

Maximum stress in compression parallel to grain

Maximum stress in horizontal shear

Qualification of the adjustment factor for compression perpendicular to grain shall be based on the median factor for maximum stress in compression parallel to grain. Qualification of the adjustment factor for fastener loads shall be based on the lower of the median ratio for maximum stress in compression parallel to grain and the median ratio for maximum stress in horizontal shear.

SECTION 23.511 — RESAMPLING

Where marginal results occur for one property, a second 25-piece sample may be taken for that property and the combined results of the first and second samples be used to determine qualification.

SECTION 23.512 — GENERAL QUALIFICATION

A treatment meeting the requirements of Section 23.510 for each of the three species identified in Section 23.506 of this standard shall be considered qualifying for the design value adjustments in Section 2304.3 of the Building Code for all species.

Part III—Identification

SECTION 23.513 — PRODUCT ELIGIBILITY

Only lumber pressure impregnated with fire-retardant chemicals that is identified by the quality mark of an approved inspection agency shall be eligible for the design value adjustments given in Section 2304.3 of the Building Code. Such agency shall maintain continuing supervision, testing and inspection over the quality of the treated product as necessary to (1) ensure compliance with the fire performance requirements for fire-retardant-treated wood in Section 207 and (2) ensure eligibility for strength classification under the provisions of this standard.

SECTION 23.514 — QUALIFICATION COMPLIANCE

The approved agency shall review and analyze the test data developed in accordance with Part I of this standard and shall attest to the following:

1. Competency of the personnel and the adequacy of the facilities of the testing laboratory.

2. Conformance of reported sampling and testing procedures to Part I of this standard.

3. Compliance of test results with acceptance criteria in Part II of this standard.

SECTION 23.515 — QUALITY MARK

The quality symbol shall indicate that the treated lumber bearing the mark has been treated and redried in conformance with the procedures established by the manufacturer of the treatment which were used in the evaluation and qualification of that treatment under Parts I and II of this standard.

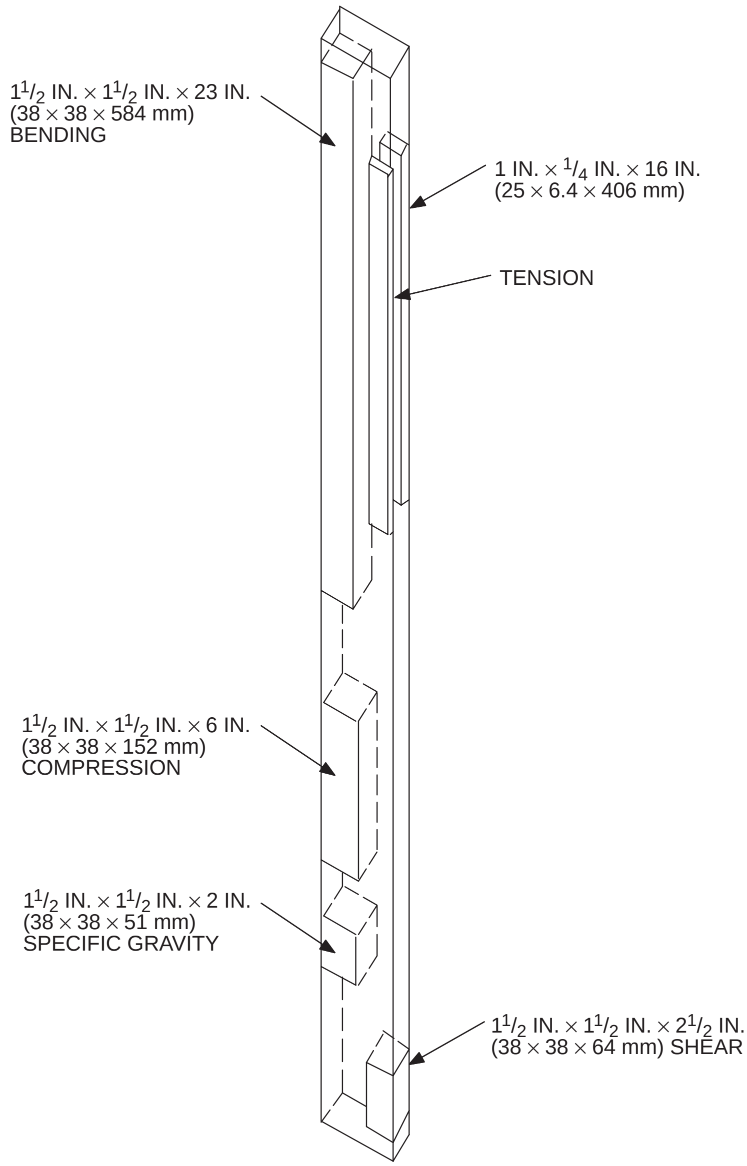


FIGURE 23-5-1—MATCHING DIAGRAM

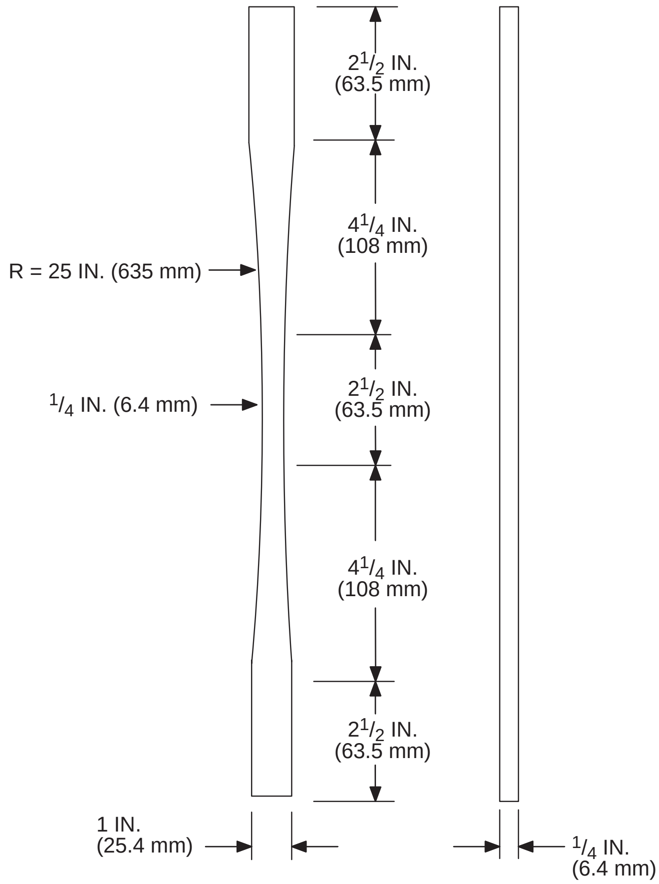


FIGURE 23-5-2—TENSION SPECIMEN

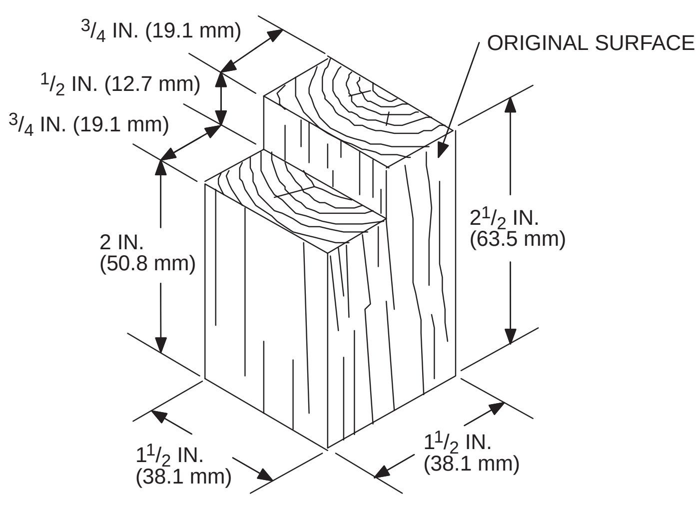


FIGURE 23-5-3—SHEAR SPECIMEN

Appendix

Appendix Chapters 3 through 15 are printed in Volume 1 of the *Uniform Building Code*

Appendix Chapter 16
STRUCTURAL FORCES

Division I—SNOW LOAD DESIGN

SECTION 1637 — GENERAL

1637.1 Scope. Buildings, structures and portions thereof shall be designed and constructed to sustain all loads required by Chapter 16, combined in accordance with Section 1612.2 for load and resistance factor design or Section 1612.3 for allowable stress design.

1637.2 Definitions. For the purpose of this appendix, certain terms are defined as follows:

HEATED GREENHOUSE is a production greenhouse provided with heating facilities capable of maintaining an interior temperature of no less than 50°F (10°C) at any point 3 feet (914 mm) above the floor, and provided with roof-ceiling assembly with a thermal resistance (R) less than 2.0.

PRODUCTION GREENHOUSE is a greenhouse used exclusively for the growing of flowers or plants on a production basis or for research, with no public access.

SECTION 1638 — NOTATIONS

a = roof slope expressed in degrees.

B = width of projection measured parallel to ridge, feet (m). Minimum assumed width shall be 1 foot (305 mm).

C_e = snow exposure factor (see Table A-16-A).

C_s = slope-reduction factor.

C_v = valley design coefficient (see Figure A-16-11).

D = density of snow, pounds per cubic foot (pcf) (N/m^3) (refer to Formula 44-2).

F_s = ice splitter horizontal load, pounds (N).

F_v = ice splitter snow weight, pounds (N).

h_b = height of balanced snow load on lower roof or deck, feet (m).

h_d = maximum height of drift surcharge, feet (m) (refer to Formula 44-1).

h_g = depth of ground snow (as determined by the building official), feet (m).

h_r = difference in height between the upper and lower roof or deck, feet (m).

I = importance factor (see Table A-16-B).

L = horizontal distance between projection and ridge, feet (m).

P_f = minimum roof snow load, pounds per square foot (psf) (N/m^2).

P_g = basic ground snow load, psf (N/m^2).

P_m = maximum intensity of the load at the height change, psf (N/m^2).

S = horizontal separation between adjacent structures, feet (m) (see Figure A-16-5).

W_b = horizontal dimension in feet of upper roof normal to the line of change in roof level, but not less than 50 feet (15.2 m), or greater than 500 feet (152.4 m).

W_d = width of drift, base of triangular drift load, feet (m).

X = vertical component of roof slope (rise), feet (m).

Y = horizontal component of roof slope (run), feet (m).

SECTION 1639 — GROUND SNOW LOADS

The ground snow load, P_g, to be used in the determination of design snow loads for buildings and other structures shall be as shown in Figures A-16-1, A-16-2 and A-16-3. For the hatched areas in Figure A-16-1, the basic ground snow loads shall be determined by the building official. The ground snow load, P_g, may be adjusted by the building official when a registered engineer or architect submits data substantiating the adjustments.

SECTION 1640 — ROOF SNOW LOADS

The value of roof (or other member) snow load, P_f, shall be determined by the following formula:

$$P_f = C_e \, I \, P_g \qquad (40\text{-}1\text{-}1)$$

where C_e is given in Table A-16-A and I is given in Table A-16-B.

EXCEPTION: The value of roof snow load, P_f, for heated greenhouses shall be determined by the following formula:

$$P_f = 0.83 \, C_e \, IP_g \qquad (40\text{-}1\text{-}2)$$

The roof snow load shall be assumed to act vertically upon the area projected upon a horizontal plane. Portions of curved roofs or inclined walls having a slope exceeding 70 degrees shall be considered free from snow load. The point at which the slope exceeds 70 degrees shall be considered the eave for such roofs. For curved roofs, the roof slope factor, C_s, shall be determined from the appropriate slope reduction formula by basing the slope on the vertical angle from the eave to the crown.

Where roof snow loads are in excess of 20 psf (958 N/m^2) and a is greater than 30 degrees, Formula (40-1-1) or (40-1-2) may be multiplied by C_s given by the formula:

$$C_s = 1 - \frac{a - 30}{40} \qquad (40\text{-}2\text{-}1)$$

for unobstructed slippery surfaces, and

$$C_s = 1 - \frac{a - 45}{25} \qquad (40\text{-}2\text{-}2)$$

for all other surfaces where a is greater than 45 degrees.

EXCEPTION: For heated greenhouses C_s is given in the formulas:

$$C_s = 1 - \frac{(a - 15)}{55} \text{ for unobstructed slippery surfaces} \qquad (40\text{-}2\text{-}3)$$

$$C_s = 1 - \frac{(a - 30)}{40} \text{ for other surfaces} \qquad (40\text{-}2\text{-}4)$$

Where the ground snow load P_g is greater than 100 psf (4788 N/m^2) and a is greater than 20 degrees,

$$C_s = 1 - \left(\frac{P_f - 20}{P_f}\right)\left(\frac{a - 20}{40}\right) \qquad (40\text{-}2\text{-}5)$$

For **SI:**
$$C_s = 1 - \left(\frac{P_f - 958}{P_f}\right)\left(\frac{a - 20}{40}\right)$$

The following conditions must be met before using Formulas (40-2-1), (40-2-2), (40-2-3), (40-2-4) and (40-2-5):

1. The height of all eaves exceeds h_g, and

2. There are no obstructions adjacent to the structure for a distance h_g measured from the eave normal to the ridge line.

Where the eave height is less than h_g but greater than $h_g/2$, and condition 2 above is met, the roof snow load reduction represented by the last term in Formulas (40-2-1), (40-2-2) and (40-2-3) shall be divided by 2.

3. If P_g is 20 psf (958 N/m^2) or less, design roof snow load must not be less than P_g. If P_g exceeds 20 psf (958 N/m^2), design roof snow load must not be less than 20 psf (958 N/m^2).

4. Reduced roof loads where P_g exceeds 70 psf (3352 N/m^2) shall not be less than those obtained through use of Formula (40-1-1) for P_g equal to 70 psf (3352 N/m^2).

SECTION 1641 — UNBALANCED SNOW LOADS, GABLE ROOFS

1641.1 General. In addition to the balanced load condition, unbalanced loading shall be considered for gable roofs in accordance with this section.

1641.2 Single-gable Roofs. Single-gable roofs with slopes greater than $^1/_2$ unit vertical in 12 units horizontal (4.2% slope) and less than 3 units vertical in 12 units horizontal (25% slope) shall be designed to sustain a uniformly distributed load of 0.5 P_f acting on one slope and 1.0 P_f on the opposite slope. Roofs with slopes greater than 3 units vertical in 12 units horizontal (25% slope) shall be designed to sustain a uniformly distributed load equal to 1.25 P_f applied to one slope only.

1641.3 Multiple-gable Roofs.

1641.3.1 With parallel ridge lines. For multiple-gable roofs with parallel ridge lines having slopes exceeding 2 units vertical in 12 units horizontal (16.7% slope), the roof snow load shall be increased from one half the applicable uniform roof load at the ridge (0.5P_f) to three times the uniform load at the valley (3.0 P_f).

1641.3.2 With nonparallel ridge lines. Structural members at roof valleys for multiple-gable roofs having intersecting ridge lines in areas where P_g is greater than 70 psf (3352 N/m^2) and where the slope is 3 units vertical in 12 units horizontal (16.7% slope) or greater shall be designed for P_f times C_v and the distribution of loads is as shown in Figures A-16-12 and A-16-13 where C_v shall be determined from Figure A-16-11.

SECTION 1642 — UNBALANCED SNOW LOAD FOR CURVED ROOFS

Portions of curved roofs having a slope exceeding 70 degrees shall be considered free of snow load. The equivalent slope of a curved roof for calculating C_s is equal to the slope of a line from the point at which the slope exceeds 70 degrees to the crown. If the equivalent slope is less than 10 degrees or greater than 60 degrees, unbalanced snow loads need not be considered.

In all cases the windward side shall be considered free of snow. The unbalanced load varies linearly from 0.5C_s P_f to 2C_s P_f/C_e where the slope is 30 degrees and decreasing to

$$\frac{2C_s P_f}{C_e}\left(1 - \frac{a - 30}{40}\right) \text{ at the eave.}$$

If the ground or another roof abuts an arched roof structure with a slope exceeding 30 degrees at or within 3 feet (914 mm) of its eave, the snow load shall not be decreased between the 30-degree point and the eave, but shall remain constant at 2C_s P_f/C_e.

SECTION 1643 — SPECIAL EAVE REQUIREMENTS

Eave overhanging roof structures shall be designed to sustain a uniformly distributed load of 2.0 P_f, or as determined by the building official, to account for ice dams and snow accumulation as shown in Figure A-16-10. Heat strips or other exposed heat methods may not be used in lieu of this design criterion. For shingle or shake roofs, hot or cold underlayment roofing is required on all roofs from the building edge for a distance of 5 feet (1524 mm) or to the ridge, whichever is less. All building exits under down-slope eaves shall be protected from sliding snow and ice.

SECTION 1644 — DRIFT LOADS ON LOWER ROOFS, DECKS AND ROOF PROJECTIONS

1644.1 General. Multilevel roofs, lower roofs and decks of adjacent structures and roofs adjacent to projections shall be designed in accordance with this section.

1644.2 Drift Loads for Lower Roofs. The geometry of the surcharge load produced by snow drifting shall be taken as the triangular load distributions shown in Figures A-16-4, A-16-5, A-16-6, A-16-7 and A-16-8. The height of the drift shall be calculated according to the formula:

$$h_d = 0.43 \sqrt[3]{W_b} \sqrt[4]{P_g + 10} - 1.5 \qquad (44\text{-}1)$$

For **SI:** 1 foot = 304.8 mm.

The value of h_d can be taken from Figure A-16-9 for $W_b \leq 600$ feet (182 880 mm).

WHERE:

$$D = 0.13P_g + 14.0 \leq 35 \text{ pcf} \qquad (44\text{-}2)$$

For **SI:** $D = 0.43\ P_g + 2198 \leq 5495$.

The width of the drift, W_d, in feet (mm), shall be taken as the smaller of 4h_d or 4 $(h_r - h_b)$. If W_d exceeds the width of the lower roof, the drift shall be truncated at the far edge of the roof, not reduced to zero at this location. Drift loads need be considered only when:

$$(h_r - h_b)/h_b > 0.2 \qquad (44\text{-}3)$$

WHERE:

$$h_b = P_f/D$$

and where P_f is evaluated on the basis of the lower roof.

The maximum intensity, P_m, of the snow load at the high point of the drift in pounds per square foot (N/m^2) is given by:

$$P_m = D\,(h_d + h_b) \le D\,h_r \tag{44-4}$$

1644.3 Roof of an Adjacent Lower Structure. Drifts may occur on lower roofs of structures sited within 20 feet (6096 mm) of a higher structure as depicted in Figure A-16-5. The height of the surcharge on the lower structure shall be taken as h_d multiplied by $(20 - S)/20$ [For **SI:** $(6.1 - S)/6.1$]to account for the horizontal separation between structures, S, in feet (mm).

1644.4 Sliding Snow. Lower roofs that are located below roofs having a slope greater than 2 units vertical in 12 units horizontal (16.7% slope) shall be designed for an increase in drift height of $0.4h_d$, except that the total drift surcharge ($1.4\ h_d$) shall not exceed the height of the roof above the uniform snow depth ($h_r - h_b$). Sliding snow need not be considered if the lower roof is separated a distance, S, greater than h_r or 20 feet (6096 mm) as shown in Figures A-16-5 and A-16-6.

1644.5 Roof Projections. Mechanical equipment, penthouses, parapets and other projections above the roof can produce drifting as depicted in Figure A-16-7. Such drift loads shall be calculated on all sides of projections having horizontal dimensions exceeding 15 feet (4572 mm). Drifts created at the perimeter of the roof by projections shall be computed using half the drift height from Formula (44-1) (i.e., $0.5\ h_d$) with W_b taken equal to the length of the roof associated with the projections. The value of W_b shall be taken as the maximum distance from the projection to the edges of the roof, or 50 feet (15 240 mm), whichever is less.

1644.6 Intersecting Drifts. When one snow drift intersects another at an angle as depicted in Figure A-16-8, the maximum unit pressure of the drift shall be taken as the greater of the two individual drifts, but not the sum of the two. The total load on the area of intersection is increased, however, simply because of the assumed geometry of the intersecting drifts.

SECTION 1645 — RAIN ON SNOW

In geographic areas where intense rains may add to the roof snow load, the building official may require the use of an additional rain on snow surcharge of 5 psf (239 N/m^2). This surcharge may be disregarded where roof slopes exceed $^1/_2$ unit vertical in 12 units horizontal (4.2% slope) or where the basic ground snow load, P_g, exceeds 50 psf (2394 N/m^2). See Section 1611.7 for ponding.

SECTION 1646 — DEFLECTIONS

For roof slopes less than $^1/_2$ unit vertical in 12 units horizontal (4.2% slope), the deflection of any structural member shall not exceed L/180 evaluated on the basis of roof snow loads plus K times dead load, where K is defined in Table 16-E.

SECTION 1647 — IMPACT LOADS

Whenever P_g exceeds 70 psf (3352 N/m^2), structures which could be subjected to impact loads (snow unloading from a higher roof) shall be designed for impact loading.

SECTION 1648 — VERTICAL OBSTRUCTIONS

Whenever P_g exceeds 70 psf (3352 N/m^2), roof projections which could be subjected to sliding ice or snow shall be protected with ice splitters or crickets, or shall be designed for these forces. These conditions apply whenever the roof slope is 3 units vertical in 12 units horizontal (25% slope) or greater [except those projections within 36 inches (914 mm) of the ridge]. All ice splitters shall be constructed the full width of the projection base (see Figure A-16-14).

Ice splitters shall be designed for a horizontal force F_s and the resultant moment produced from F_s being applied at midheight of the splitter given by:

$$F_s = \frac{F_v\,X}{\sqrt{X^2 + Y^2}} \tag{48-1}$$

WHERE:

$$F_v = L\,(0.5L + B)\,P_f$$

The projection width, B, shall not exceed 6 feet (1829 mm) where the roof slope is greater than 2 units vertical in 12 units horizontal (16.7% slope) unless approved by the building official. Chimneys and similar projections at or near the eave of a roof shall have footings and roof/wall ties designed to resist the force of the sliding snow. Cross-grain bending of wood ledgers and edge nailing of plywood shall not be considered to resist such forces. Snow melting equipment shall not be considered to reduce the required design loads.

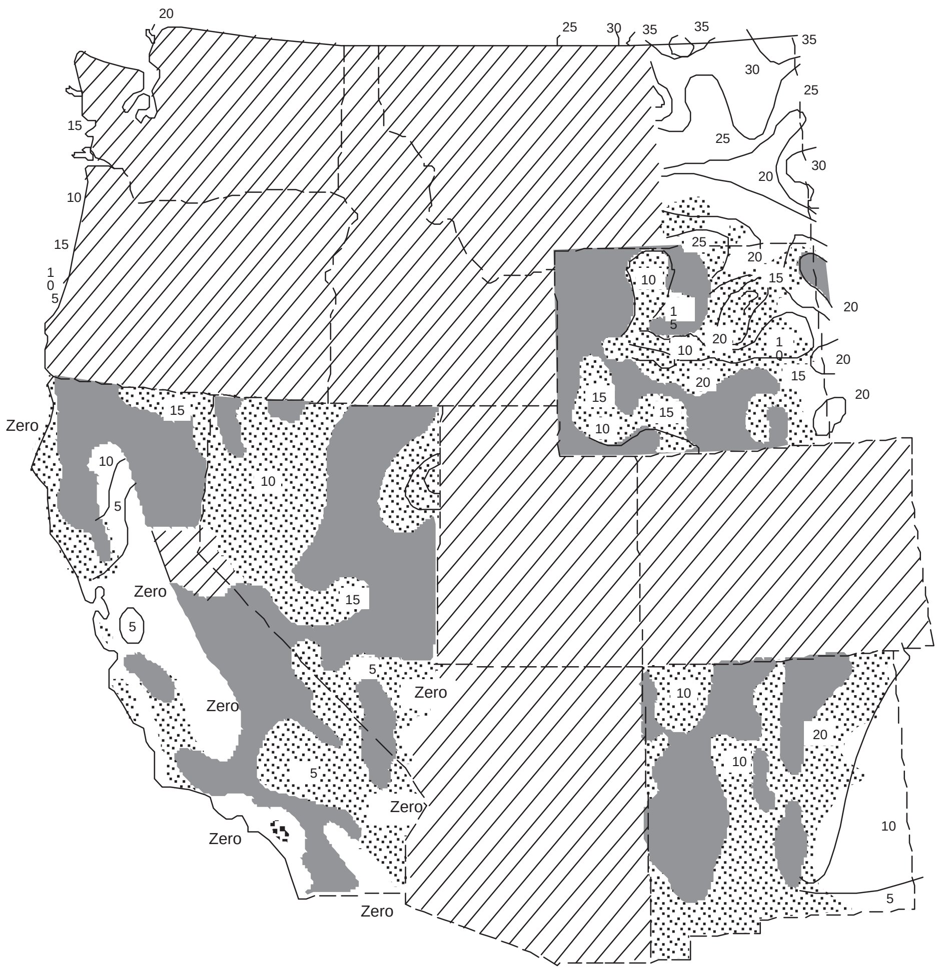
TABLE A-16-A—SNOW EXPOSURE COEFFICIENT (C_e)[1,2]

1. Roofs located in generally open terrain extending one-half mile (804.7 m) or more from the structure.	0.6
2. Structures located in densely forested or sheltered areas.	0.9
3. All other structures.	0.7

[1]The building official may determine this coefficient for specific structures with special local conditions. For Alaska, Arizona and Hawaii, the coefficient shall be determined by the building official.
[2]For roofs at or near grade with slopes less than 3 units vertical in 12 units horizontal (25% slope) or decks at or near grade, C_e equals 1.0.

TABLE A-16-B—VALUES FOR OCCUPANCY IMPORTANCE FACTOR *I*

TYPE OF OCCUPANCY	*I* Snow
1. Essential facilities.	1.15
2. Any building where the primary occupancy is for assembly use for more than 300 persons (in one room).	1.15
3. Agricultural buildings, production greenhouses and other miscellaneous structures.	0.9
4. All others.	1.0



In these areas, extreme local variations in snow loads preclude mapping at this scale; ground snow load, P_g, shall be established by the building official.

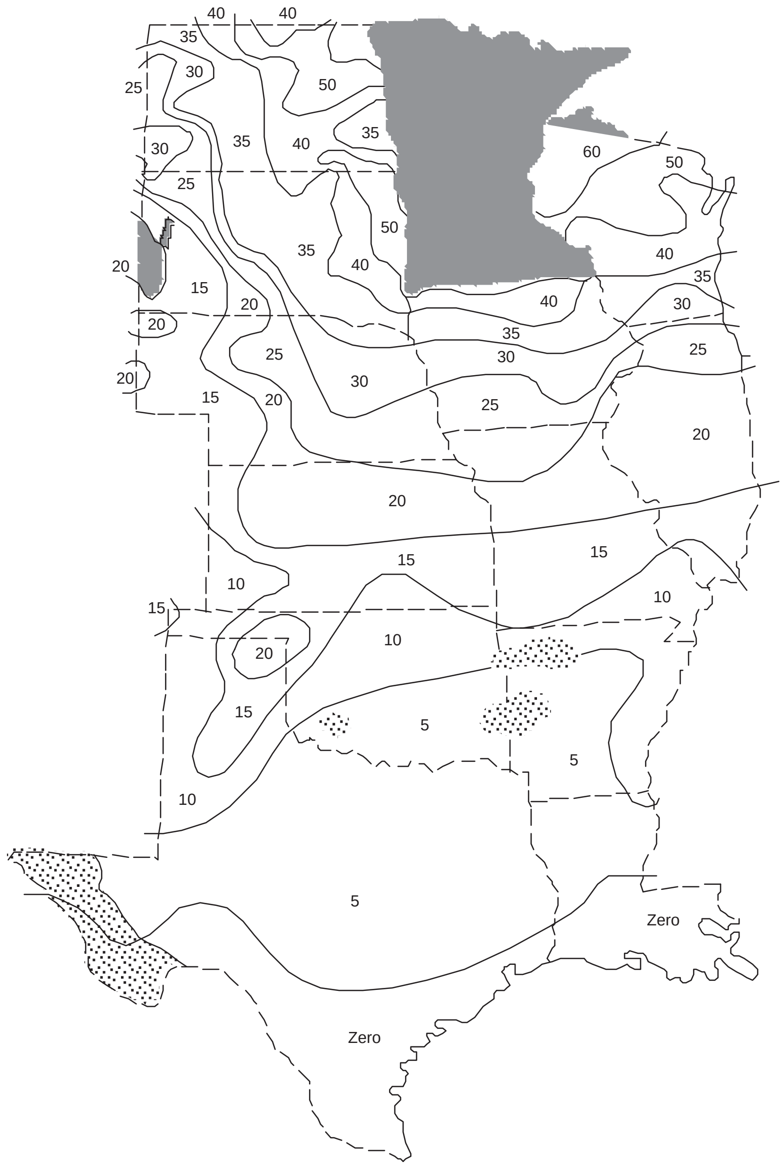
The zoned value is not appropriate for certain geographic settings, such as high country; in these areas, ground snow load, P_g, shall be established by the building official.

In these areas, ground snow load, P_g, shall be established by the building official.

Those areas shown as 0 psf, 5 psf and 10psf (0 N/m^2, 239 N/m^2 and 479 N/m^2) are for information only.

For **SI:** 1 psf = 47.8 N/m^2.

FIGURE A-16-1—GROUND SNOW LOAD, P_g, FOR 50-YEAR MEAN RECURRENCE INTERVAL FOR THE WESTERN UNITED STATES



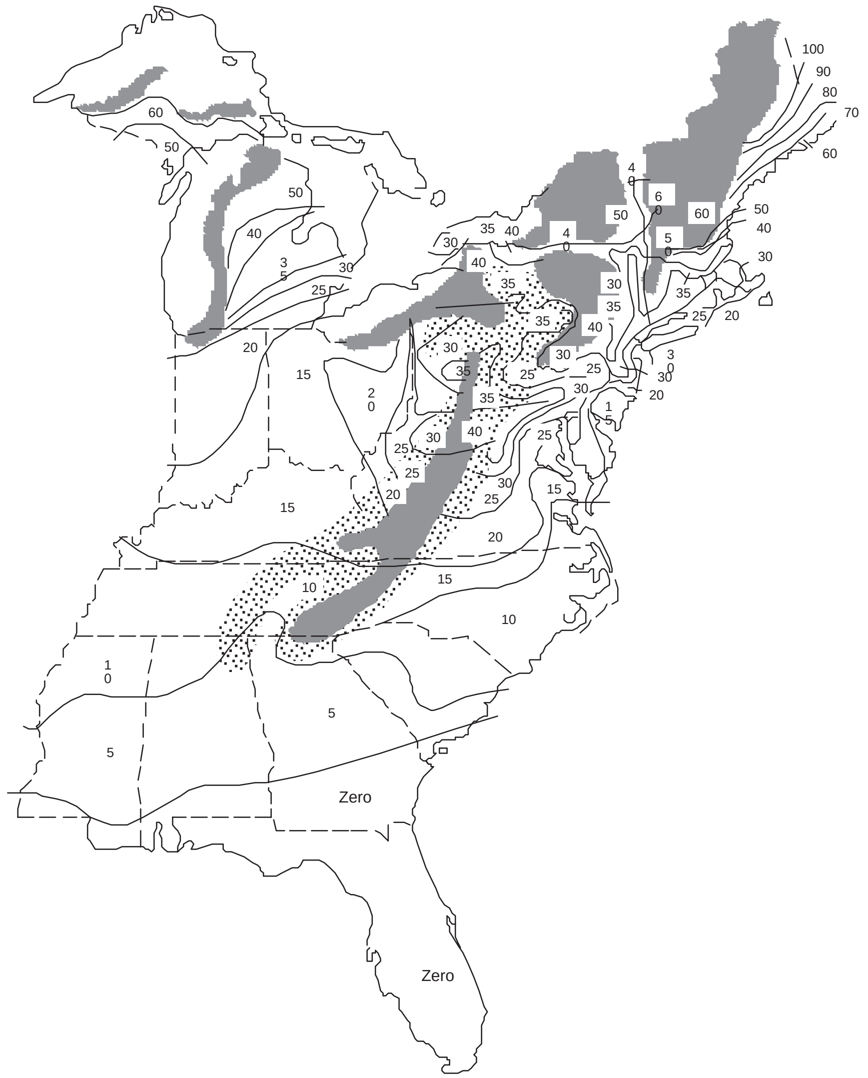
Those areas shown as 0 psf, 5 psf and 10psf (0 N/m^2, 239 N/m^2 and 479 N/m^2) are for information only.

In these areas, extreme local variations in snow loads preclude mapping at this scale; ground snow load, P_g, shall be established by the building official.

The zoned value is not appropriate for certain geographic settings, such as high country; in these areas, ground snow load, P_g, shall be established by the building official.

For **SI:** 1 psf = 47.8 N/m^2.

FIGURE A-16-2—GROUND SNOW LOAD, P_g, FOR 50-YEAR MEAN RECURRENCE INTERVAL FOR THE CENTRAL UNITED STATES



Those areas shown as 0 psf, 5 psf and 10psf (0 N/m^2, 239 N/m^2 and 479 N/m^2) are for information only.

In these areas, extreme local variations in snow loads preclude mapping at this scale; ground snow load, P_g, shall be established by the building official.

The zoned value is not appropriate for certain geographic settings, such as high country; in these areas, ground snow load, P_g, shall be established by the building official.

For **SI:** 1 psf = 47.8 N/m^2.

FIGURE A-16-3—GROUND SNOW LOAD, P_g, FOR 50-YEAR MEAN RECURRENCE INTERVAL FOR THE EASTERN UNITED STATES

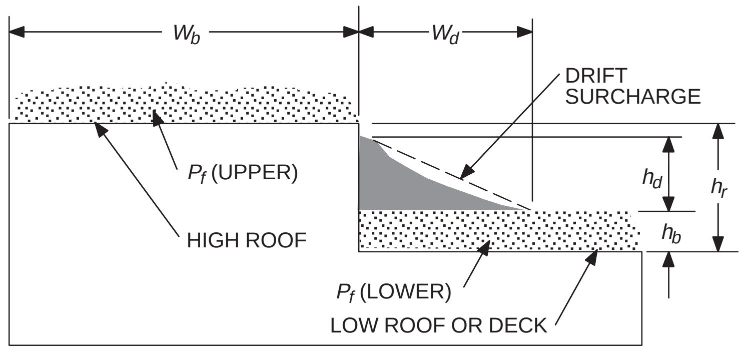
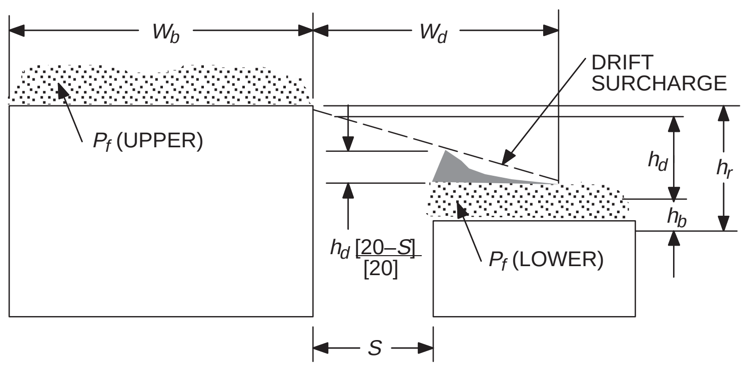


FIGURE A-16-4—DRIFTING SNOW ON LOW ROOFS AND DECKS



68 **SI:** $S_M\left[\frac{534 - S}{534}\right]3$

FIGURE A-16-5—DRIFTING SNOW ONTO ADJACENT LOW STRUCTURES

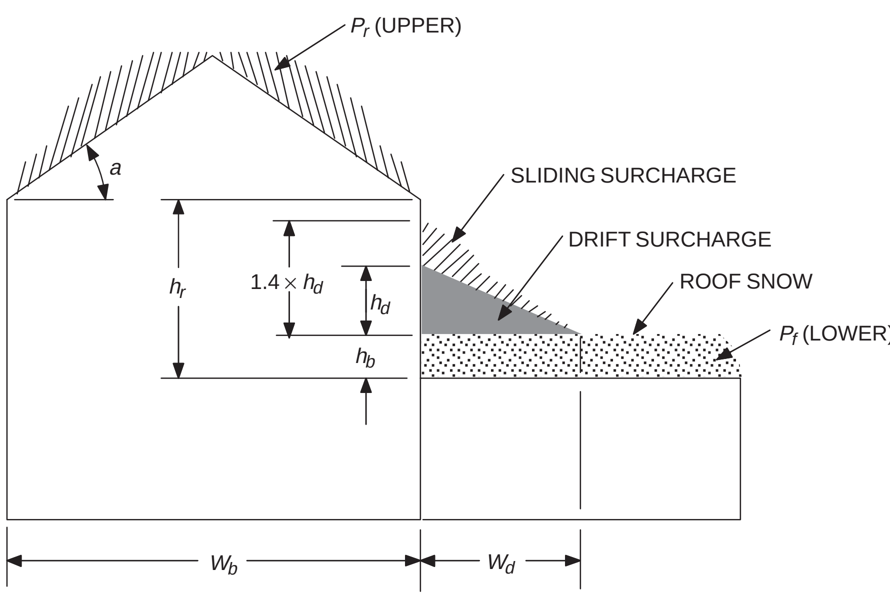


FIGURE A-16-6—ADDITIONAL SURCHARGE DUE TO SLIDING SNOW

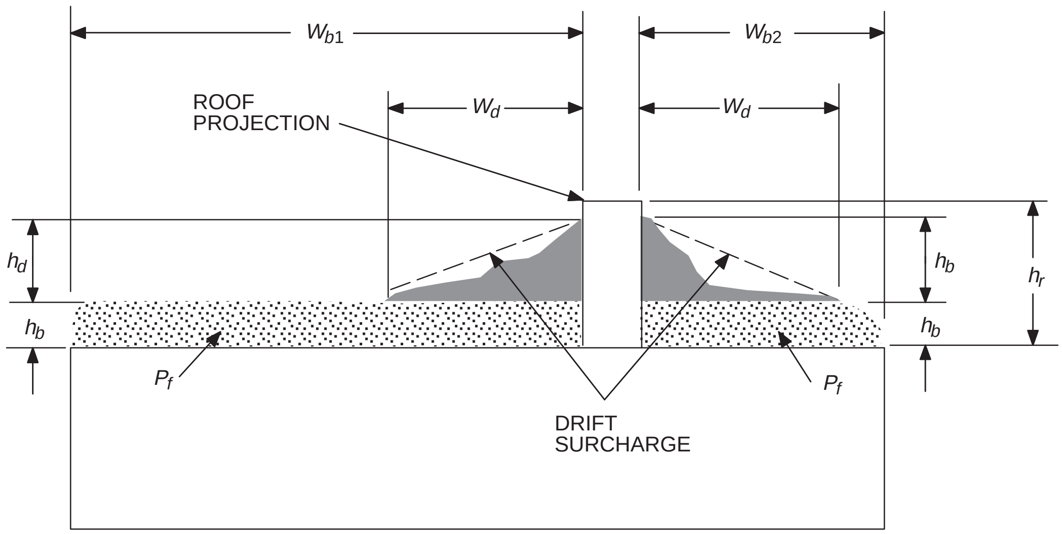


FIGURE A-16-7—SNOW DRIFTING AT ROOF PROJECTIONS

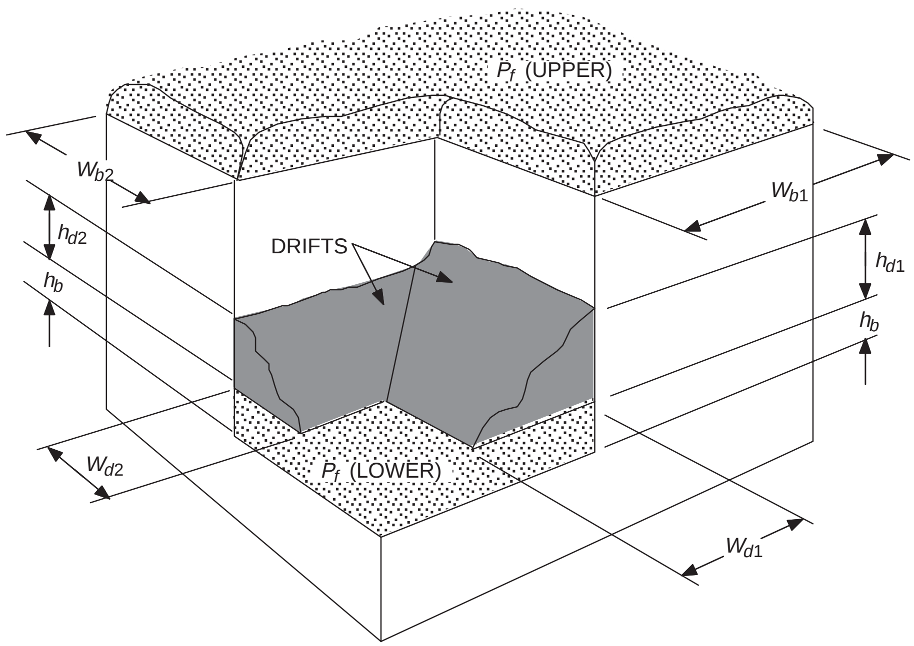


FIGURE A-16-8—INTERSECTING SNOW DRIFTS

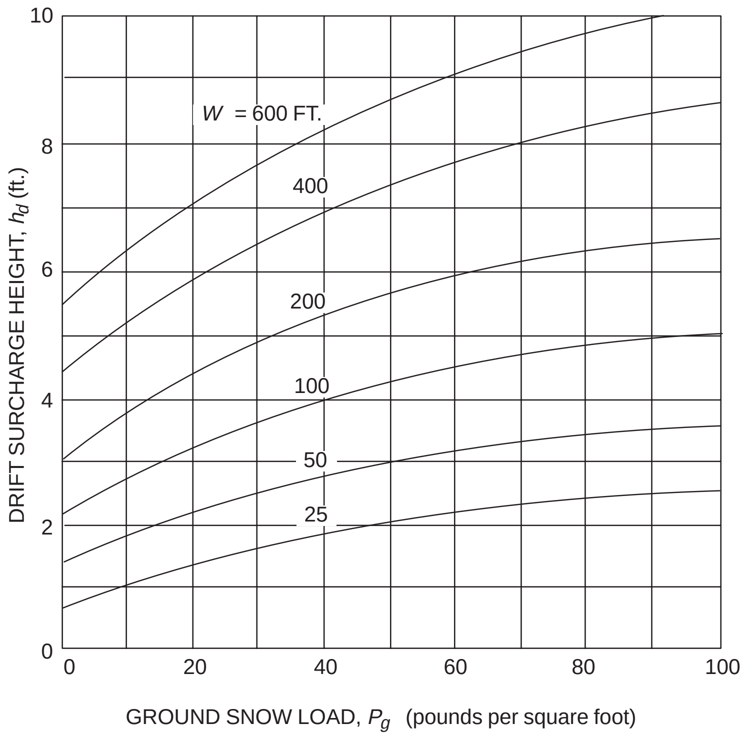
NOTE:

$$h_{d1} = 0.43 \sqrt[3]{W_{b1}} \sqrt[4]{P_g + 10} - 1.5$$

$$h_{d2} = 0.43 \sqrt[3]{W_{b2}} \sqrt[4]{P_g + 10} - 1.5$$

For **SI:** 1 foot = 304.8 mm.

P_f is evaluated on the basis of upper roof.



For **SI:** 1 foot = 304.8 mm, 1 psf = 47.8 N/m^2.

FIGURE A-16-9—DETERMINATION OF h_d

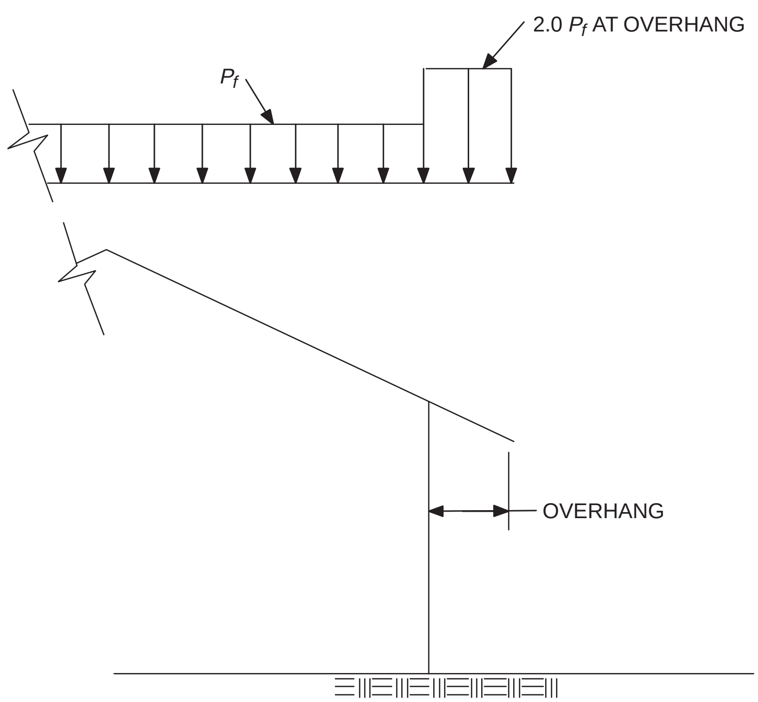
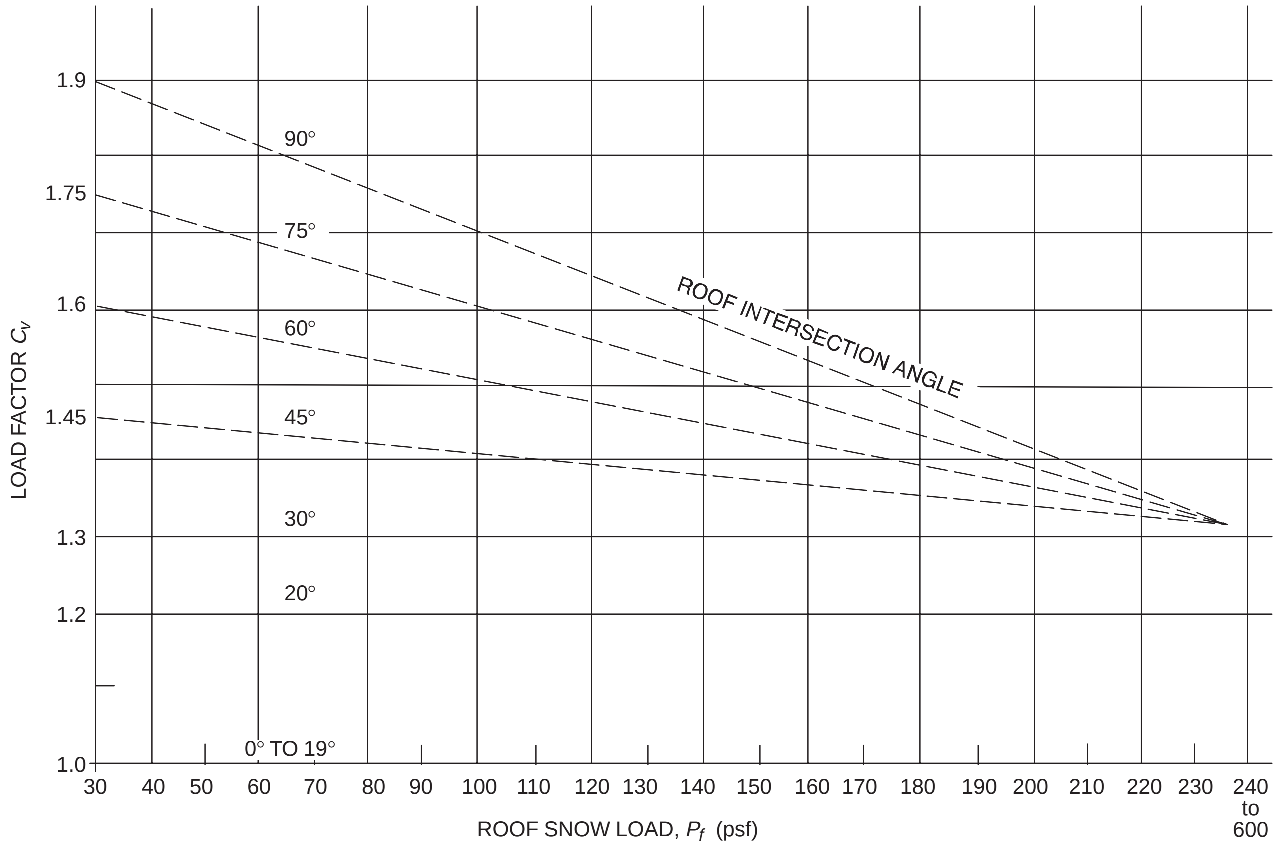
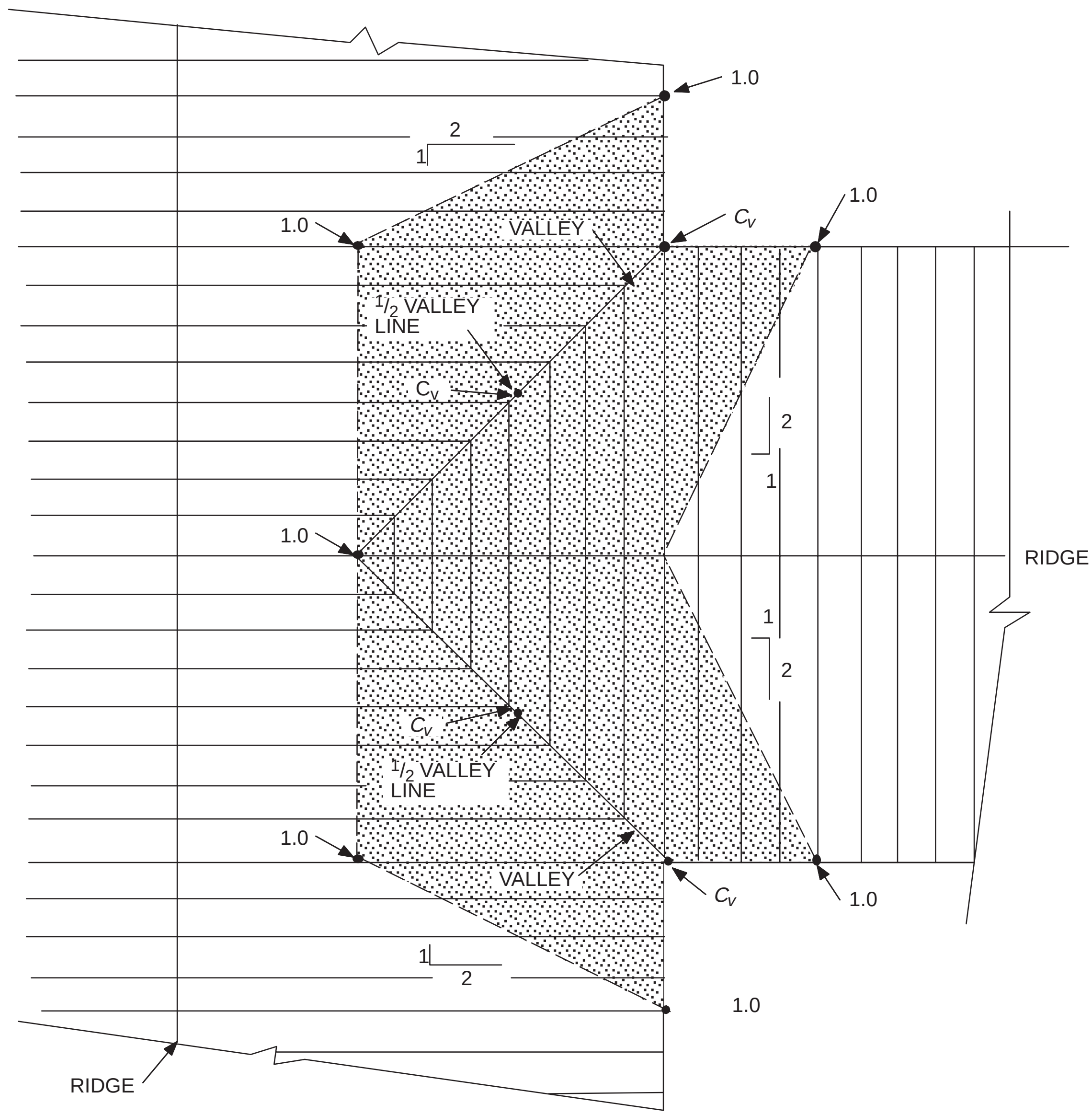


FIGURE A-16-10—OVERHANG LOADS



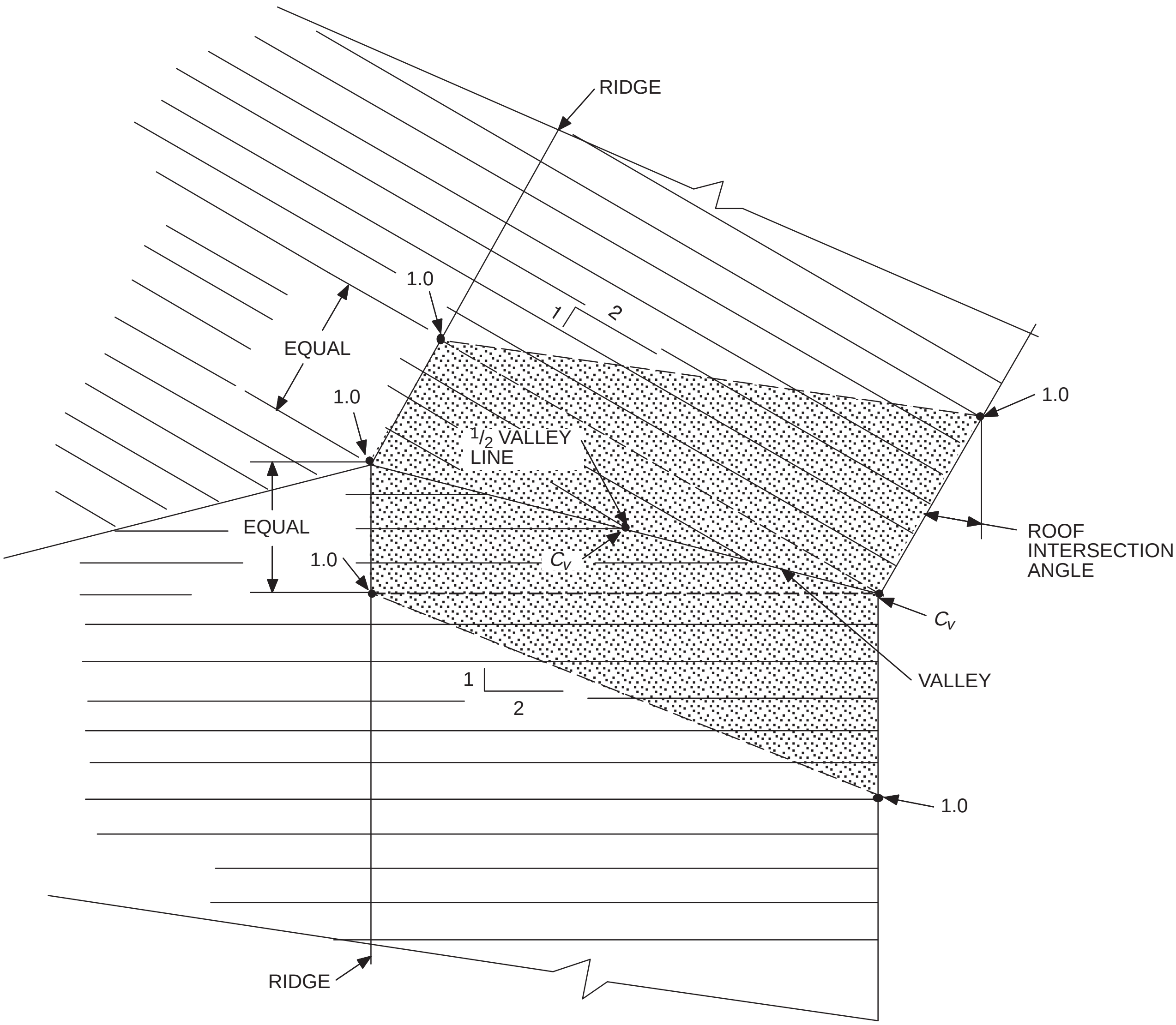
For **SI:** 1 psf = 47.8 N/m^2.

FIGURE A-16-11—VALLEY COEFFICIENT, C_V



DENOTES INCREASED LOAD AREA:
1. Load is constant on lines connecting points noted 1.0.
2. Load is constant on lines connecting points noted C_V.
3. Load varies linearly between 1.0 and C_V.

FIGURE A-16-12—VALLEY DESIGN COEFFICIENTS, C_V



DENOTES INCREASED LOAD AREA:
1. Load is constant on lines connecting points noted 1.0.
2. Load is constant on lines connecting points noted C_V.
3. Load varies linearly between 1.0 and C_V.

FIGURE A-16-13—VALLEY DESIGN COEFFICIENTS, C_V

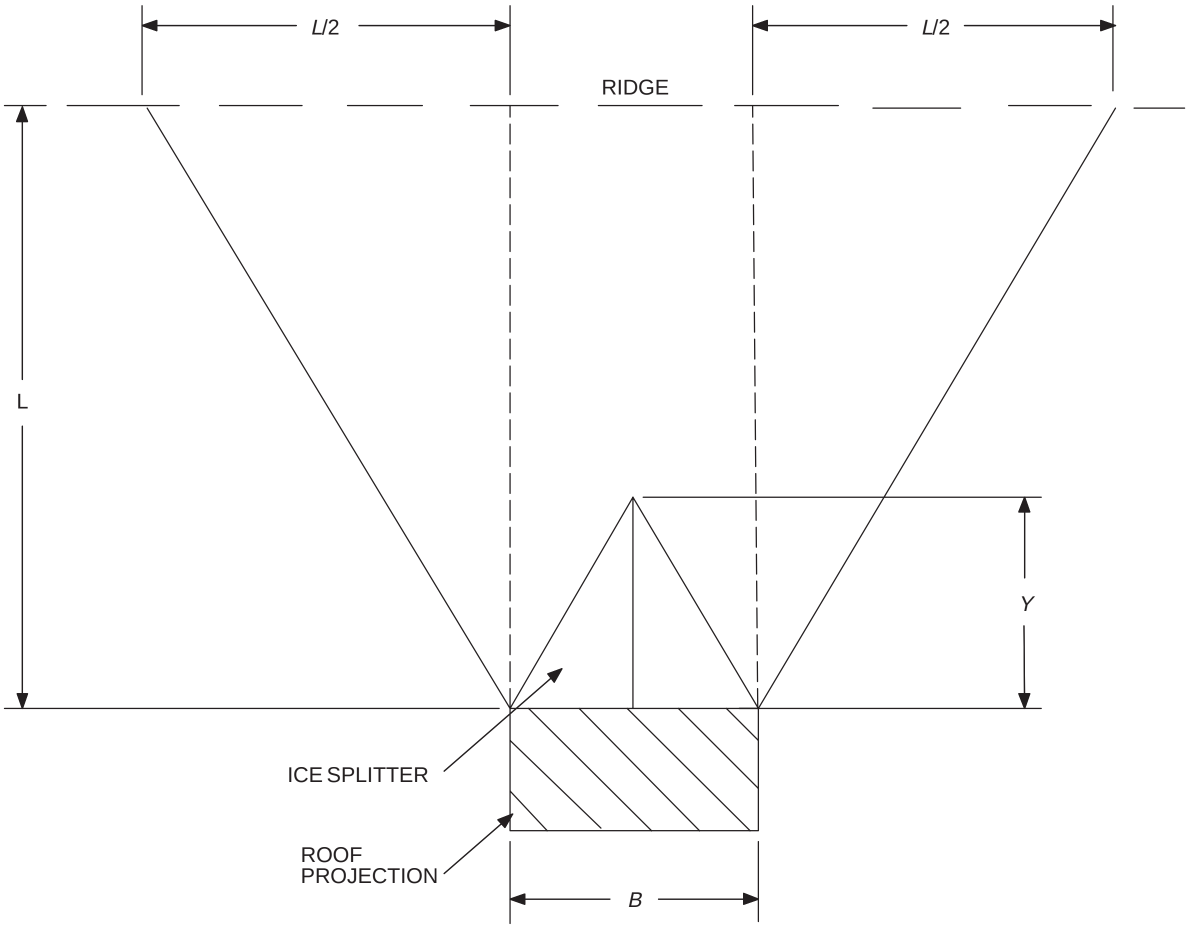


FIGURE A-16-14—ICE SPLITTER—PLAN VIEW

Division II—EARTHQUAKE RECORDING INSTRUMENTATION

SECTION 1649 — GENERAL

In Seismic Zones 3 and 4 every building over six stories in height with an aggregate floor area of 60,000 square feet (5574 m^2) or more, and every building over 10 stories in height regardless of floor area, shall be provided with not less than three approved recording accelerographs.

The accelerographs shall be interconnected for common start and common timing.

SECTION 1650 — LOCATION

The instruments shall be located in the basement, midportion, and near the top of the building. Each instrument shall be located so that access is maintained at all times and is unobstructed by room contents. A sign stating MAINTAIN CLEAR ACCESS TO THIS INSTRUMENT shall be posted in a conspicuous location.

SECTION 1651 — MAINTENANCE

Maintenance and service of the instruments shall be provided by the owner of the building, subject to the approval of the building official. Data produced by the instruments shall be made available to the building official on request.

SECTION 1652 — INSTRUMENTATION OF EXISTING BUILDINGS

All owners of existing structures selected by the jurisdiction authorities shall provide accessible space for the installation of appropriate earthquake-recording instruments. Location of said instruments shall be determined by the jurisdiction authorities. The jurisdiction authorities shall make arrangements to provide, maintain and service the instruments. Data shall be the property of the jurisdiction, but copies of individual records shall be made available to the public on request and the payment of an appropriate fee.

Division III—SEISMIC ZONE TABULATION

NOTE: This division has been revised in its entirety.

SECTION 1653 — FOR AREAS OUTSIDE THE UNITED STATES

Location	Seismic Zone
AFRICA	
Algeria	
Alger	3
Oran	3
Angola	
Luanda	0
Benin	
Cotonou	0
Botswana	
Gaborone	0
Burundi	
Bujumbura	3
Cameroon	
Douala	0
Yaounde	0
Cape Verde	
Praia	0
Central African Republic	
Bangui	0
Chad	
Ndjamena	0
Congo	
Brazzaville	0
Djibouti	3
Egypt	
Alexandria	2A
Cairo	2A
Port Said	2A
Equatorial Guinea	
Malabo	0
Ethiopia	
Addis Ababa	3
Asmara	3
Gabon	
Libreville	0
Gambia	
Banjul	0
Ghana	
Accra	3
Guinea	
Bissau	1
Conakry	0
Ivory Coast	
Abidjan	0
Kenya	
Nairobi	2A
Lesotho	
Maseru	2A
Liberia	
Monrovia	1
Libya	
Tripoli	2A
Wheelus AFB	2A
Malagasy Republic	
Tananarive	0
Malawi	
Blantyre	3
Lilongwe	3
Zomba	3
Mali	
Bamako	0
Mauritania	
Nouakchott	0
Mauritius	
Port Louis	0
Morocco	
Casablanca	2A
Port Lyautcy	1
Rabat	2A
Tangier	3
Mozambique	
Maputo	2A
Niger	
Niamey	0
Nigeria	
Ibadan	0
Kaduna	0
Lagos	0
Republic of Rwanda	
Kigali	3
Senegal	
Dakar	0
Seychelles	
Victoria	0
Sierra Leone	
Freetown	0
Somalia	
Mogadishu	0
South Africa	
Cape Town	3
Durban	2A
Johannesburg	2A
Natal	1
Pretoria	2A
Swaziland	
Mbabane	2A
Tanzania	
Dar es Salaam	2A
Zanzibar	2A
Togo	
Lome	1
Tunisia	
Tunis	3
Uganda	
Kampala	2A
Upper Volta	
Ougadougou	0
Zaire	
Bukavu	3
Kinshasa	0
Lubumbashi	2A
Zambia	
Lukasa	2A
Zimbabwe	
Harare (Salisbury)	3
ASIA	
Afghanistan	
Kabul	4

Location	Seismic Zone
Bahrain	
Manama	0
Bangladesh	
Dacca	3
Brunei	
Bandar Seri Begawan	1
Burma	
Mandalay	3
Rangoon	3
China	
Beijing	4
Chengdu	3
Guangzhou	2A
Nanjing	2A
Qingdao	3
Shanghai	2A
Shengyang	4
Taiwan	
All	4
Tihwa	4
Wuhan	2A
Xianggang	2A
Cyprus	
Nicosia	3
India	
Bombay	3
Calcutta	2A
Madras	1
New Delhi	3
Indonesia	
Bandung	4
Jakarta	4
Medan	3
Surabaya	4
Iran	
Isfahan	3
Shiraz	3
Tabriz	4
Tehran	4
Iraq	
Baghdad	3
Basra	1
Israel	
Haifa	3
Jerusalem	3
Tel Aviv	3
Japan	
Fukuoka	3
Itazuke AFB	3
Misawa AFB	3
Naha, Okinawa	4
Osaka/Kobe	4
Sapporo	3
Tokyo	4
Wakkami	3
Yokohama	4
Yokota	4
Jordan	
Amman	3
Korea	
Kimhae	1
Kwangju	1
Pusan	1
Seoul	0
Kuwait	
Kuwait	1

Location	Seismic Zone
Laos	
Vientiane	1
Lebanon	
Beirut	3
Malaysia	
Kuala Lumpur	1
Nepal	
Kathmandu	4
Oman	
Muscat	2A
Pakistan	
Islamabad	4
Karachi	4
Lahore	2A
Peshawar	4
Qatar	
Doha	0
Saudi Arabia	
Al Batin	1
Dharan	1
Jiddah	2A
Khamis Mushayf	1
Riyadh	0
Singapore	
All	1
South Yemen	
Aden City	3
Sri Lanka	
Colombo	0
Syria	
Aleppo	3
Damascus	3
Thailand	
Bangkok	1
Chiang Mai	2A
Songkhla	0
Udorn	1
Turkey	
Adana	2A
Ankara	2A
Ismir	4
Istanbul	4
Karamursel	3
United Arab Emirates	
Abu Dhabi	0
Dubai	0
Viet Nam	
Ho Chi Minh (Saigon)	0
Yemen Aran Republic	
Sanaa	3
ATLANTIC OCEAN AREA	
Azores	
All	2A
Bermuda	
All	1
CARIBBEAN SEA	
Bahama Islands	
All	1
Cuba	
All	2A
Dominican Republic	
Santo Domingo	3
French West Indies	
Martinique	3
Grenada	
Saint Georges	3

Location	Seismic Zone
Haiti	
Port au Prince	3
Jamaica	
Kingston	3
Leeward Islands	
All	3
Trinidad & Tobago	
All	3
CENTRAL AMERICA	
Belize	
Belmopan	2A
Canal Zone	
All	2A
Costa Rica	
San Jose	3
El Salvador	
San Salvador	4
Guatemala	
Guatemala	4
Honduras	
Tegucigalpa	3
Mexico	
Ciudad Juarez	2A
Guadalajara	3
Hermosillo	3
Matamoros	0
Mazatlan	2A
Merida	0
Mexico City	3
Monterrey	0
Nuevo Laredo	0
Tijuana	3
Nicaragua	
Managua	4
Panama	
Colon	3
Galeta	2B
Panama	3
EUROPE	
Albania	
Tirana	3
Austria	
Salzburg	2A
Vienna	2A
Belgium	
Antwerp	1
Brussels	2A
Bosnia-Herzegovina	
Belgrade	2A
Bulgaria	
Sofia	3
Croatia	
Zagreb	3
Czechoslovakia	
Bratislava	2A
Prague	1
Denmark	
Copenhagen	1
Finland	
Helsinki	1
France	
Bordeaux	2A
Lyon	1
Marseille	3
Nice	3

Location	Seismic Zone
Paris	0
Strasbourg	2A
Germany, Federal Republic	
Berlin	0
Bonn	2A
Bremen	0
Dusseldorf	1
Frankfurt	2A
Hamburg	0
Munich	1
Stuttgart	2A
Vaihigen	2A
Greece	
Athens	3
Kavalla	4
Makri	4
Rhodes	3
Sauda Bay	4
Thessaloniki	4
Hungary	
Budapest	2A
Iceland	
Keflavick	3
Reykjavik	4
Ireland	
Dublin	0
Italy	
Aviano AFB	3
Brindisi	0
Florence	3
Genoa	3
Milan	2A
Naples	3
Palermo	3
Rome	2A
Sicily	3
Trieste	3
Turin	2A
Luxembourg	
Luxembourg	1
Malta	
Valleta	2A
Netherlands	
All	0
Norway	
Oslo	2A
Poland	
Krakow	2A
Poznan	1
Warszawa	1
Portugal	
Lisbon	4
Opporto	3
Romania	
Bucharest	3
Russia	
Moscow	0
St. Petersburg	0
Spain	
Barcelona	2A
Bilbao	2A
Madrid	0
Rota	2A
Seville	2A
Sweden	
Goteborg	2A
Stockholm	1

Location	Seismic Zone
Switzerland	
Bern	2A
Geneva	1
Zurich	2A
Ukraine	
Kiev	0
United Kingdom	
Belfast	0
Edinburgh	1
Edzell	1
Glasgow/Renfrew	1
Hamilton	1
Liverpool	1
London	2A
Londonderry	1
Thurso	1
NORTH AMERICA	
Greenland	
All	1
Canada	
Argentia NAS	2A
Calgary, Alb	1
Churchill, Man	0
Cold Lake, Alb	1
Edmonton, Alb	1
E. Harmon AFB	2A
Fort Williams, Ont	0
Frobisher N.W. Ter.	0
Goose Airport	1
Halifax	1
Montreal, Quebec	3
Ottawa, Ont	2A
St. John's Nfd	3
Toronto, Ont	1
Vancouver	3
Winnepeg, Man	1
SOUTH AMERICA	
Argentina	
Buenos Aires	0
Bolivia	
La Paz	3
Santa Cruz	1
Brazil	
Belem	0
Belo Horizonte	0
Brasilia	0
Manaus	0
Porto Allegre	0
Recife	0
Rio de Janeiro	0
Salvador	0
Sao Paulo	1
Chile	
Santiago	4
Valparaiso	4
Colombia	
Bogota	3
Ecuador	
Guayaquil	3
Quito	4
Paraguay	
Asuncion	0

Location	Seismic Zone
Peru	
Lima	4
Piura	4
Uruguay	
Montevideo	0
Venezuela	
Caracas	4
Maracaibo	2A
PACIFIC OCEAN AREA	
Australia	
Brisbane	1
Canberra	1
Melbourne	1
Perth	1
Sydney	1
Caroline Islands	
Koror, Palau Is.	2A
Ponape	0
Fiji	
Suva	3
Johnson Island	
All	1
Mariana Islands	
Guam	3
Saipan	3
Tinian	3
Marshall Islands	
All	1
New Zealand	
Auckland	3
Wellington	4
Papau New Guinea	
Port Moresby	3
Phillipine Islands	
Baguio	3
Cebu	4
Manila	4
Samoa	
All	3
Wake Island	
All	0

The above compilation is a partial listing of seismic zones for cities and countries outside of the United States. It has been provided in this code primarily as a source of information, and may not, in all cases, reflect local ordinances or current scientific information.

When an authority having jurisdiction requires seismic design forces that are higher than would be indicated by the above zones, the local requirements shall govern. When an authority having jurisdiction requires seismic design forces that are lower than would be indicated by the above zones, and these forces have been developed with consideration of regional tectonics and up-to-date geologic and seismologic information, the local requirements may be used.

When no local seismic design requirements exist, properly determined information on site-specific ground motions may be used to justify a lower seismic zone. Such site-specific ground motions shall have been developed with proper consideration of regional tectonics and local geologic and seismologic information, and shall have no more than a 10 percent chance of being exceeded in a 50-year period.

Division IV—EARTHQUAKE REGULATIONS FOR SEISMIC-ISOLATED STRUCTURES

SECTION 1654 — GENERAL

Every seismic-isolated structure and every portion thereof shall be designed and constructed in accordance with the requirements of this division and the applicable requirements of Chapter 16, Part IV.

The lateral-force-resisting system and the isolation system shall be designed to resist the deformations and stresses produced by the effects of seismic ground motions as provided in this division.

Where wind forces prescribed by Chapter 16, Part III, produce greater deformations or stresses, such loads shall be used for design in lieu of the deformations and stresses resulting from earthquake forces.

SECTION 1655 — DEFINITIONS

The definitions of Section 1627 and the following apply to the provisions of this division:

DESIGN DISPLACEMENT is the design-basis earthquake lateral displacement, excluding additional displacement due to actual and accidental torsion, required for design of the isolation system.

DESIGN-BASIS EARTHQUAKE is defined in Section 1631.2.

EFFECTIVE DAMPING is the value of equivalent viscous damping corresponding to energy dissipated during cyclic response of the isolation system.

EFFECTIVE STIFFNESS is the value of the lateral force in the isolation system, or an element thereof, divided by the corresponding lateral displacement.

ISOLATION INTERFACE is the boundary between the upper portion of the structure, which is isolated, and the lower portion of the structure, which moves rigidly with the ground.

ISOLATION SYSTEM is the collection of structural elements that includes all individual isolator units, all structural elements that transfer force between elements of the isolation system, and all connections to other structural elements. The isolation system also includes the wind-restraint system if such a system is used to meet the design requirements of this section.

ISOLATOR UNIT is a horizontally flexible and vertically stiff structural element of the isolation system that permits large lateral deformations under design seismic load. An isolator unit may be used either as part of or in addition to the weight-supporting system of the building.

MAXIMUM CAPABLE EARTHQUAKE is the maximum level of earthquake ground shaking that may ever be expected at the building site within the known geological framework. In Seismic Zones 3 and 4, this intensity may be taken as the level of earthquake ground motion that has a 10 percent probability of being exceeded in a 100-year time period.

MAXIMUM DISPLACEMENT is the maximum capable earthquake lateral displacement, excluding additional displacement due to actual and accidental torsion, required for design of the isolation system.

TOTAL DESIGN DISPLACEMENT is the design-basis earthquake lateral displacement, including additional displacement due to actual and accidental torsion, required for design of the isolation system, or an element thereof.

TOTAL MAXIMUM DISPLACEMENT is the maximum capable earthquake lateral displacement, including additional displacement due to actual and accidental torsion, required for verification of the stability of the isolation system, or elements thereof, design of building separations, and vertical load testing of isolator unit prototypes.

WIND-RESTRAINT SYSTEM is the collection of structural elements that provide restraint of the seismic-isolated structure for wind loads. The wind-restraint system may be either an integral part of isolator units or may be a separate device.

SECTION 1656 — SYMBOLS AND NOTATIONS

The symbols and notations of Section 1628 and the following provisions apply to the provisions of this division:

B_D = numerical coefficient related to the effective damping of the isolation system at the design displacement, β_D, as set forth in Table A-16-C.

B_M = numerical coefficient related to the effective damping of the isolation system at the maximum displacement, β_M, as set forth in Table A-16-C.

b = the shortest plan dimension of the structure, in feet (mm), measured perpendicular to d.

C_{AD} = the seismic coefficient, C_a, as set forth in Table 16-Q.

C_{AM} = the seismic coefficient, C_a, as set forth in Table A-16-F for shaking intensity, $M_M ZN_a$.

C_{VD} = seismic coefficient, C_v, as set forth in Table 16-R.

C_{VM} = seismic coefficient, C_v, as set forth in Table A-16-G for shaking intensity, $M_M ZN_v$.

D_D = design displacement, in inches (mm), at the center of rigidity of the isolation system in the direction under consideration, as prescribed by Formula (58-1).

D_D' = design displacement, in inches (mm), at the center of rigidity of the isolation system in the direction under consideration, as prescribed by Formula (59-1).

D_M = maximum displacement, in inches (mm), at the center of rigidity of the isolation system in the direction under consideration, as prescribed by Formula (58-3).

D_M' = maximum displacement, in inches (mm), at the center of rigidity of the isolation system in the direction under consideration, as prescribed by Formula (59-2).

D_{TD} = total design displacement, in inches (mm), of an element of the isolation system including both translational displacement at the center of rigidity, D_D, and the component of torsional displacement in the direction under consideration, as specified in Section 1658.3.5.

D_{TM} = total maximum displacement, in inches (mm), of an element of the isolation system, including both translational displacement at the center of rigidity, D_M, and the component of torsional displacement in the direction under consideration, as specified by Section 1658.3.3.

d = the longest plan dimension of the structure, in feet (mm).

E_{LOOP} = energy dissipated in kip-inches (kN-mm), in an isolator unit during a full cycle of reversible load over a test displacement range from Δ^+ to Δ^-, as measured by the area enclosed by the loop of the force-deflection curve.

ΣE_D = total energy dissipated, in kip-inches (kN-mm), of all units of the isolation system during a full cycle of response at the design displacement, D_D.

ΣE_M = total energy dissipated, in kip-inches (kN-mm), of all units of the isolation system during a full cycle of response at the maximum displacement, D_M.

e = the actual eccentricity, in feet (mm), measured in plan between the center of mass of the structure above the isolation interface and the center of rigidity of the isolation system, plus accidental eccentricity, in feet (mm), taken as 5 percent of the maximum building dimension perpendicular to the direction of force under consideration.

$F-$ = negative force, in kips (kN), in an isolator unit during a single cycle of prototype testing at a displacement amplitude of $\Delta-$.

$F+$ = positive force, in kips (kN), in an isolator unit during a single cycle of prototype testing at a displacement amplitude of $\Delta+$.

$\Sigma|F_D{}^+|_{max}$ = sum, for all isolator units, of the absolute values of the individual isolator unit's maximum positive force in kips (kN) at positive displacement D_D. For a given isolator unit, the maximum positive force at positive displacement, D_D, is determined by comparing each of the maximum positive forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_D, and selecting the maximum positive value at positive displacement, D_D.

$\Sigma|F_D{}^+|_{min}$ = sum, for all isolator units, of the absolute values of the individual isolator unit's minimum positive force in kips (kN) at positive displacement D_D. For a given isolator unit, the minimum positive force at positive displacement, D_D, is determined by comparing each of the minimum positive forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_D, and selecting the minimum positive value at positive displacement, D_D.

$\Sigma|F_D{}^-|_{max}$ = sum, for all isolator units, of the absolute values of the individual isolator unit's maximum negative force in kips (kN) at negative displacement D_D. For a given isolator unit, the maximum negative force at negative displacement, D_D, is determined by comparing each of the maximum negative forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_D, and selecting the maximum negative value at negative displacement, D_D.

$\Sigma|F_D{}^-|_{min}$ = sum, for all isolator units, of the absolute values of the individual isolator unit's minimum negative force in kips (kN) at negative displacement D_D. For a given isolator unit, the minimum negative force at negative displacement, D_D, is determined by comparing each of the minimum negative forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_D, and selecting the minimum negative value at negative displacement, D_D.

$\Sigma|F_M{}^+|_{max}$ = sum, for all isolator units, of the absolute values of the individual isolator unit's maximum positive force in kips (kN) at positive displacement D_M. For a given isolator unit, the maximum positive force at positive displacement, D_M, is determined by comparing each of the maximum positive forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_M, and selecting the maximum positive value at positive displacement, D_M.

$\Sigma|F_M{}^+|_{min}$ = sum, for all isolator units, of the absolute values of the individual isolator unit's minimum positive force in kips (kN) at positive displacement, D_M. For a given isolator unit, the minimum positive force at positive displacement, D_M, is determined by comparing each of the minimum positive forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_M and selecting the minimum positive value at positive displacement, D_M.

$\Sigma|F_M{}^-|_{max}$ = sum, for all isolator units, of the absolute values of the individual isolator unit's maximum negative force in kips (kN) at negative displacement D_M. For a given isolator unit, the maximum negative force at negative displacement, D_M, is determined by comparing each of the maximum negative forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_M and selecting the maximum negative value at negative displacement, D_M.

$\Sigma|F_M{}^-|_{min}$ = sum, for all isolator units, of the absolute values of the individual isolator unit's minimum negative force in kips (kN) at negative displacement D_M. For a given isolator unit, the minimum negative force at negative displacement, D_M, is determined by comparing each of the minimum negative forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_M and selecting the minimum negative value at negative displacement, D_M.

g = gravity constant (386.4 in/sec.^{2}, or 9,810 mm/sec.^{2}, for **SI**).

k_{eff} = effective stiffness of an isolator unit, in kips/inch as prescribed by Formula (65-1).

k_{Dmax} = maximum effective stiffness, in kips/inch (kN/mm), of the isolation system at the design displacement in the horizontal direction under consideration.

k_{Mmax} = maximum effective stiffness, in kips/inch (kN/mm), of the isolation system at the maximum displacement in the horizontal direction under consideration.

k_{Dmin} = minimum effective stiffness, in kips/inch (kN/mm), of the isolation system at the design displacement in the horizontal direction under consideration.

k_{Mmin} = minimum effective stiffness, in kips/inch (kN/mm), of the isolation system at the maximum displacement in the horizontal direction under consideration.

M_M = numerical coefficient related to maximum capable earthquake response as set forth in Table A-16-D.

N_a = near-source factor used in the determination of C_{AD} and C_{AM} related to both the proximity of the building or structure to known faults with magnitudes and slip rates as set forth in Tables 16-S and 16-U.

N_v = near-source factor used in the determination of C_{VD} and C_{VM} related to both the proximity of the building or structure to known faults with magnitudes and slip rates as set forth in Tables 16-T and 16-U.

R_I = numerical coefficient related to the type of lateral-force-resisting system above the isolation system as set forth in Table A-16-E for seismic-isolated structures.

T_D = effective period, in seconds, of seismic-isolated structure at the design displacement in the direction under consideration, as prescribed by Formula (58-2).

T_M = effective period, in seconds, of seismic-isolated structure at the maximum displacement in the direction under consideration, as prescribed by Formula (58-4).

V_b = the total lateral seismic design force or shear on elements of the isolation system or elements below the isolation system as prescribed by Formula (58-5).

V_s = the total lateral seismic design force or shear on elements above the isolation system as prescribed by Formula (58-8) and the limits specified in Section 1658.

W = the total seismic dead load defined in Section 1630.1. For design of the isolation system, W is the total seismic dead load weight of the structure above the isolation interface.

y = the distance, in feet (mm), between the center of rigidity of the isolation system rigidity and the element of interest, measured perpendicular to the direction of seismic loading under consideration.

β_{eff} = effective damping of the isolation system and isolator unit, as prescribed by Formula (65-2).

β_D = effective damping of the isolation system at the design displacement, as prescribed by Formula (65-3).

β_M = effective damping of the isolation system at the maximum displacement, as prescribed by Formula (65-4).

$\Delta+$ = maximum positive displacement of an isolator unit during each cycle of prototype testing.

$\Delta-$ = maximum negative displacement of an isolator unit during each cycle of prototype testing.

SECTION 1657 — CRITERIA SELECTION

1657.1 Basis for Design. The procedures and limitations for the design of seismic-isolated structures shall be determined considering zoning, site characteristics, vertical acceleration, cracked section properties of concrete and masonry members, occupancy, configuration, structural system and height in accordance with Section 1629, except as noted below.

1657.2 Stability of the Isolation System. The stability of the vertical load-carrying elements of the isolation system shall be verified by analysis and test, as required, for lateral seismic displacement equal to the total maximum displacement.

1657.3 Occupancy Categories. The importance factor, I, for a seismic-isolated building shall be taken as 1.0 regardless of occupancy category.

1657.4 Configuration Requirements. Each structure shall be designated as being regular or irregular on the basis of the structural configuration above the isolation system, in accordance with Section 1629.5.

1657.5 Selection of Lateral Response Procedure.

1657.5.1 General. Any seismic-isolated structure may be, and certain seismic-isolated structures defined below shall be, designed using the dynamic lateral response procedure of Section 1659.

1657.5.2 Static analysis. The static lateral response procedure of Section 1658 may be used for design of a seismic-isolated structure, provided:

1. The structure is located at least 10 kilometers (km) from all active faults.

2. The structure is located on Soil Profile Type S_A, S_B, S_C or S_D.

3. The structure above the isolation interface is equal to or less than four stories, or 65 feet (19.8 m), in height.

4. The effective period of the isolated structure, T_M, is equal to or less than 3.0 seconds.

5. The effective period of the isolated structure, T_D, is greater than three times the elastic, fixed-base period of the structure above the isolation system, as determined by Formula (30-8) of Section 1630.

6. The structure above the isolation system is of regular configuration.

7. The isolation system is defined by all of the following attributes:

7.1 The effective stiffness of the isolation system at the design displacement is greater than one third of the effective stiffness at 20 percent of the design displacement.

7.2 The isolation system is capable of producing a restoring force, as specified in Section 1661.2.4.

7.3 The isolation system has force-deflection properties which are independent of the rate of loading.

7.4 The isolation system has force-deflection properties which are independent of vertical load and bilateral load.

7.5 The isolation system does not limit maximum capable earthquake displacement to less than C_{VM}/C_{VD} times the total design displacement.

1657.5.3 Dynamic analysis. The dynamic lateral response procedure of Section 1659 shall be used for design of seismic-isolated structures as specified below:

1. **Response spectrum analysis.** Response spectrum analysis may be used for design of a seismic-isolated structure, provided:

1.1 The structure is located on Soil Profile Type S_A, S_B, S_C or S_D.

1.2 The isolation system is defined by all of the attributes specified in Section 1657.5.2, Item 7.

2. **Time-history analysis.** Time-history analysis may be used for design of any seismic-isolated structure and shall be used for design of all seismic-isolated structures not meeting the criteria of Section 1657.5.3, Item 1.

3. **Site-specific design spectra.** Site-specific ground motion spectra of the design-basis earthquake and the maximum capable earthquake, developed in accordance with Section 1631.2, shall be used for design and analysis of all seismic-isolated structures as specified below:

1. The structure is located on Soil Profile Type S_E or S_F.

2. The structure is located within 10 km of an active fault.

SECTION 1658 — STATIC LATERAL RESPONSE PROCEDURE

1658.1 General. Except as provided in Section 1659, every seismic-isolated structure, or portion thereof, shall be designed and constructed to resist minimum earthquake displacements and forces as specified by this section and the applicable requirements of Section 1630.

1658.2 Deformation Characteristics of the Isolation System. Minimum lateral earthquake design displacements and forces on seismic-isolated structures shall be based on the deformation characteristics of the isolation system.

The deformation characteristics of the isolation system shall explicitly include the effects of the wind-restraint system if such a system is used to meet the design requirements of this document.

The deformation characteristics of the isolation system shall be based on properly substantiated tests performed in accordance with Section 1665.

1658.3 Minimum Lateral Displacements.

1658.3.1 Design displacement. The isolation system shall be designed and constructed to withstand minimum lateral earthquake displacements which act in the direction of each of the main horizontal axes of the structure in accordance with the formula:

$$D_D = \frac{\left(\frac{g}{4\pi^2}\right) C_{VD} T_D}{B_D} \qquad (58\text{-}1)$$

1658.3.2 Effective period at the design displacement. The effective period of the isolated structure at the design displacement, T_D, shall be determined using the deformational characteristics of the isolation system in accordance with the formula:

$$T_D = 2\pi \sqrt{\frac{W}{k_{Dmin} g}} \qquad (58\text{-}2)$$

1658.3.3 Maximum displacement. The maximum displacement of the isolation system, D_M, in the most critical direction of horizontal response shall be calculated in accordance with the formula:

$$D_M = \frac{\left(\frac{g}{4\pi^2}\right) C_{VM} T_M}{B_M} \qquad (58\text{-}3)$$

1658.3.4 Effective period at the maximum displacement. The effective period of the isolated structure at the maximum displacement, T_M, shall be determined using the deformational characteristics of the isolation system in accordance with the formula:

$$T_M = 2\pi \sqrt{\frac{W}{k_{Mmin} g}} \qquad (58\text{-}4)$$

1658.3.5 Total displacement. The total design displacement, D_{TD}, and the total maximum displacement, D_{TM}, of elements of the isolation system shall include additional displacement due to actual and accidental torsion calculated considering the spatial distribution of the lateral stiffness of the isolation system and the most disadvantageous location of mass eccentricity.

The total design displacement, D_{TD}, and the of total maximum displacement D_{TM}, of elements of an isolation system with uniform spatial distribution of lateral stiffness shall not be taken as less than that prescribed by the formulas:

$$D_{TD} = D_D \left[1 + y \frac{12e}{b^2 + d^2} \right] \qquad (58\text{-}5)$$

$$D_{TM} = D_M \left[1 + y \frac{12e}{b^2 + d^2} \right] \qquad (58\text{-}6)$$

The total design displacement, D_{TD}, and the total maximum displacement, D_{TM}, may be taken as less than the value prescribed by Formulas (58-5) and (58-6), but not less than 1.1 times D_D and 1.1 times D_M, respectively, provided the isolation system is shown by calculation to be configured to resist torsion accordingly.

1658.4 Minimum Lateral Forces.

1658.4.1 Isolation system and structural elements at or below the isolation system. The isolation system, the foundation, and all structural elements below the isolation system shall be designed and constructed to withstand a minimum lateral seismic force, V_b, using all of the appropriate provisions for a nonisolated structure where:

$$V_b = k_{Dmax} D_D \qquad (58\text{-}7)$$

1658.4.2 Structural elements above the isolation system. The structure above the isolation system shall be designed and constructed to withstand a minimum shear force, V_s, using all of the appropriate provisions for a nonisolated structure where:

$$V_s = \frac{k_{Dmax} D_D}{R_I} \qquad (58\text{-}8)$$

The R_I factor shall be based on the type of lateral-force-resisting system used for the structure above the isolation system.

1658.4.3 Limits on V_s. The value of V_s shall not be taken as less than the following:

1. The lateral seismic force required by Chapter 16, Division III, for a fixed-base structure of the same weight, W, and a period equal to the isolated period, T_D.

2. The base shear corresponding to the design wind load.

3. The lateral seismic force required to fully activate the isolation system factored by 1.5 (e.g., one and one-half times the yield level of a softening system, the ultimate capacity of a sacrificial wind-restraint system or the static friction level of a sliding system).

1658.5 Vertical Distribution of Force. The total force shall be distributed over the height of the structure above the isolation interface in accordance with the formula:

$$F_x = \frac{V_s w_x h_x}{\sum_{i=1}^{n} w_i h_i} \qquad (58\text{-}9)$$

At each level designated as x, the force F_x shall be applied over the area of the building in accordance with the mass distribution at the level. Stresses in each structural element shall be calculated as the effect of force, F_x, applied at the appropriate levels above the base.

1658.6 Drift Limits. The maximum interstory drift ratio of the structure above the isolation system shall not exceed $0.010/R_I$.

SECTION 1659 — DYNAMIC LATERAL-RESPONSE PROCEDURE

1659.1 General. As required by Section 1657, every seismic-isolated structure, or portion thereof, shall be designed and constructed to resist earthquake displacements and forces as specified in this section and the applicable requirements of Section 1631.

1659.2 Isolation System and Structural Elements below the Isolation System. The total design displacement of the isolation system shall not be taken as less than 90 percent of D_{TD} as specified by Section 1658.3.3.

The total maximum displacement of the isolation system shall not be taken as less than 80 percent of D_{TM} as prescribed by Formula (58-6).

The design lateral shear force on the isolation system and structural elements below the isolation system shall not be taken as less than 90 percent of V_b as prescribed by Formula (58-7).

The limits of the first and second paragraphs shall be evaluated using values of D_{TD} and D_{TM} determined in accordance with Section 1658.3, except that $D_D{}'$ may be used in lieu of D_D and $D_M{}'$ may be used in lieu of D_M, where $D_D{}'$ and $D_M{}'$ are prescribed by the formulas:

$$D_{D'} = \frac{D_D}{\sqrt{1 + \left(\frac{T}{T_D}\right)^2}} \tag{59-1}$$

$$D_{M'} = \frac{D_M}{\sqrt{1 + \left(\frac{T}{T_M}\right)^2}} \tag{59-2}$$

and T is the elastic, fixed-base period of the structure above the isolation system, as determined only by Formula (30-4) of Section 1630.

1659.3 Structural Elements above the Isolation System. The design lateral shear force on the structure above the isolation system, if regular in configuration, shall not be taken as less than 80 percent of V_S as prescribed by Formula (58-8) or less than the limits specified by Section 1658.4.3.

> **EXCEPTION:** The design lateral shear force on the structure above the isolation system, if regular in configuration, may be taken as less than 80 percent, but not less than 60 percent, of V_S provided time-history analysis is used for design of the structure.

The design lateral shear force on the structure above the isolation system, if irregular in configuration, shall not be taken as less than V_S as prescribed by Formula (58-8) or less than the limits specified by Section 1658.4.3.

> **EXCEPTION:** The design lateral shear force on the structure above the isolation system, if irregular in configuration, may be taken as less than 100 percent, but not less than 80 percent, of V_S, provided time-history analysis is used for design of the structure.

1659.4 Ground Motion.

1659.4.1 Design spectra. Properly substantiated, site-specific spectra are required for design of all structures with an isolated period, T_M, greater than 3.0 seconds, or located on Soil Profile Type S_E or S_F or located within 10 km of an active fault or located in Seismic Zone 1, 2A or 2B. Structures that do not require site-specific spectra and for which site-specific spectra have not been calculated shall be designed using spectra based on Figure 16-3 of Chapter 16, Division III.

A design spectrum shall be constructed for the design-basis earthquake. This design spectrum shall not be taken as less than the response spectrum given in Figure 16-3 of Chapter 16, Division III, where the values of C_a shall be taken as equal to C_{AD} and C_v shall be taken as equal to C_{VD}.

> **EXCEPTION:** If a site-specific spectrum is calculated for the design-basis earthquake, then the design spectrum may be taken as less than 100 percent, but not less than 80 percent of the response spectrum given in Figure 16-3 of Chapter 16, Division III, where the values of C_a shall be taken as equal to C_{AD} and C_v shall be taken as equal to C_{VD}.

A design spectrum shall be constructed for the maximum capable earthquake. This spectrum shall not be taken as less than the spectrum given in Figure 16-3 of Chapter 16, Division III where the values of C_a shall be taken as equal to C_{AM} and C_v shall be taken as equal to C_{VM}. This spectrum shall be used to determine the total maximum displacement and overturning forces for design and testing of the isolation system.

> **EXCEPTION:** If a site-specific spectrum is calculated for the maximum capable earthquake, then the design spectrum may be taken as less than 100 percent, but not less than 80 percent of the response spectrum given in Figure 16-3 of Chapter 16, Division III, where the values of C_a shall be taken as equal to C_{AM} and C_v shall be taken as equal to C_{VM}.

1659.4.2 Time histories. Pairs of appropriate horizontal ground-motion time-history components shall be selected and scaled from not less than three recorded events. Appropriate time histories shall have magnitudes, fault distances and source mechanisms that are consistent with those that control the design-basis earthquake (or maximum capable earthquake). Where three appropriate recorded ground motion time history pairs are not available, appropriate simulated ground motion time history pairs may be used to make up the total number required. For each pair of horizontal ground-motion components, the square root sum of the squares (SRSS) of the 5 percent-damped spectrum of the scaled horizontal components shall be constructed. The motions shall be scaled such that the average value of the SRSS spectra does not fall below 1.3 times the 5 percent-damped spectrum of the design-basis earthquake (or maximum capable earthquake) by more than 10 percent for periods from $0.5T_D$ seconds to $1.25T_M$ seconds.

1659.5 Mathematical Model.

1659.5.1 General. The mathematical models of the isolated structure, including the isolation system, the lateral-force-resisting system and other structural elements, shall conform to Section 1631.3 and to the requirements of Sections 1659.5.2 and 1659.5.3 below.

1659.5.2 Isolation system. The isolation system shall be modeled using deformational characteristics developed and verified by test in accordance with the requirements of Section 1658.2.

The isolation system shall be modeled with sufficient detail to:

1. Account for the spatial distribution of isolator units,

2. Calculate translation, in both horizontal directions, and torsion of the structure above the isolation interface, considering the most disadvantageous location of mass eccentricity,

3. Assess overturning/uplift forces on individual isolator units; and

4. Account for the effects of vertical load, bilateral load and/or the rate of loading if the force deflection properties of the isolation system are dependent on one or more of these attributes.

1659.5.3 Isolated structure.

1659.5.3.1 Displacement. The maximum displacement of each floor and the total design displacement and total maximum displacement across the isolation system shall be calculated using a model of the isolated structure that incorporates the force-deflection characteristics of nonlinear elements of the isolation system and the lateral-force-resisting system.

Lateral-force-resisting systems with nonlinear elements include, but are not limited to, irregular structural systems designed for a lateral force less than V_S as prescribed by Formula (58-8) and the limits specified by Section 1658.4.3, and regular structural systems designed for a lateral force less than 80 percent of V_S.

1659.5.3.2 Forces and displacements in key elements. Design forces and displacements in key elements of the lateral-force-resisting system may be calculated using a linear elastic model of the isolated structure, provided:

1. Pseudo-elastic properties assumed for nonlinear isolation system components are based on the maximum effective stiffness of the isolation system.

2. All key elements of the lateral-force-resisting system are linear.

1659.6 Description of Analysis Procedures.

1659.6.1 General. A response spectrum analysis or a time-history analysis, or both, shall be performed in accordance with Sections 1631.4 and 1631.5 and the requirements of this section.

1659.6.2 Input earthquake. The design-basis earthquake shall be used to calculate the total design displacement of the isolation system and the lateral forces and displacements of the isolated structure. The maximum capable earthquake shall be used to calculate the total maximum displacement of the isolation system.

1659.6.3 Response spectrum analysis. Response spectrum analysis shall be performed using a modal damping value for the fundamental mode in the direction of interest not greater than the effective damping of the isolation system or 30 percent of critical, whichever is less. Modal damping values for higher modes shall be selected consistent with those appropriate for response spectrum analysis of the structure above the isolation system on a fixed base.

Response spectrum analysis used to determine the total design displacement and the total maximum displacement shall include simultaneous excitation of the model by 100 percent of the most critical direction of ground motion and 30 percent of the ground motion on the orthogonal axis. The maximum displacement of the isolation system shall be calculated as the vectorial sum of the two orthogonal displacements.

1659.6.4 Time-history analysis. Time-history analysis shall be performed with at least three appropriate pairs of horizontal time-history components, as defined in Section 1659.4.2.

Each pair of time histories shall be applied simultaneously to the model, considering the most disadvantageous location of mass eccentricity. The maximum displacement of the isolation system shall be calculated from the vectorial sum of the two orthogonal displacements at each time step.

The parameter of interest shall be calculated for each time-history analysis. If three time-history analyses are performed, then the maximum response of the parameter of interest shall be used for design. If seven or more time-history analyses are performed, then the average value of the response parameter of interest may be used for design.

1659.7 Design Lateral Force.

1659.7.1 Isolation system and structural elements at or below the isolation system. The isolation system, foundation and all structural elements below the isolation system shall be designed using all of the appropriate provisions for a nonisolated structure and the forces obtained from the dynamic analysis.

1659.7.2 Structural elements above the isolation system. Structural elements above the isolation system shall be designed using the appropriate provisions for a nonisolated structure and the forces obtained from the dynamic analysis divided by a factor of R_I. The R_I factor shall be based on the type of lateral-force-resisting system used for the structure above the isolation system.

1659.7.3 Scaling of results. When the factored lateral shear force on structural elements, determined using either response spectrum or time-history analysis, is less than minimum level prescribed by Sections 1659.1 and 1659.2, then all response parameters, including member forces and moments shall be adjusted upward proportionally.

1659.8 Drift Limits. Maximum interstory drift corresponding to the design lateral force, including displacement due to vertical deformation of the isolation system, shall not exceed the following limits:

1. The maximum interstory drift ratio of the structure above the isolation system, calculated by response spectrum analysis, shall not exceed $0.015/R_I$.

2. The maximum interstory drift ratio of the structure above the isolation system, calculated by time-history analysis considering the force-deflection characteristics of nonlinear elements of the lateral-force-resisting system, shall not exceed $0.020/R_I$.

The secondary effects of the maximum capable earthquake lateral displacement, Δ, of the structure above the isolation system combined with gravity forces shall be investigated if the interstory drift ratio exceeds $0.010/R_I$.

SECTION 1660 — LATERAL LOAD ON ELEMENTS OF STRUCTURES AND NONSTRUCTURAL COMPONENTS SUPPORTED BY STRUCTURES

1660.1 General. Parts or portions of an isolated structure, permanent nonstructural components and the attachments to them, and the attachments for permanent equipment supported by a structure shall be designed to resist seismic forces and displacements as prescribed by this section and the applicable requirements of Section 1632.

1660.2 Forces and Displacements.

1660.2.1 Components at or above the isolation interface. Elements of seismic-isolated structures and nonstructural components, or portions thereof, which are at or above the isolation interface, shall be designed to resist a total lateral seismic force equal to the maximum dynamic response of the element or component under consideration.

> **EXCEPTION:** Elements of seismic-isolated structures and nonstructural components, or portions thereof, may be designed to resist total lateral seismic force as prescribed by Formula (32-1) or (32-2) of Section 1632.

1660.2.2 Components that cross the isolation interface. Elements of seismic-isolated structures and nonstructural components, or portions thereof, that cross the isolation interface shall be designed to withstand the total maximum displacement.

1660.2.3 Components below the isolation interface. Elements of seismic-isolated structures and nonstructural components, or portions thereof, which are below the isolation interface shall be designed and constructed in accordance with the requirements of Section 1632.

SECTION 1661 — DETAILED SYSTEMS REQUIREMENTS

1661.1 General. The isolation system and the structural system shall comply with the requirements of Section 1633 and the material requirements of Chapters 19 through 23. In addition, the isolation system shall comply with the detailed system requirements of this section and the structural system shall comply with the detailed system requirements of this section and the applicable portions of Section 1633.

1661.2 Isolation System.

1661.2.1 Environmental conditions. In addition to the requirements for vertical and lateral loads induced by wind and earthquake, the isolation system shall be designed with consideration given to other environmental conditions including aging effects, creep, fatigue, operating temperature and exposure to moisture or damaging substances.

1661.2.2 Wind forces. Isolated structures shall resist design wind loads at all levels above the isolation interface in accordance with the general wind design provisions. At the isolation interface, a wind restraint system shall be provided to limit lateral displacement in the isolation system to a value equal to that required between floors of the structure above the isolation interface.

1661.2.3 Fire resistance. Fire resistance for the isolation system shall meet that required for the building columns, walls or other structural elements in which it is installed.

Isolator systems required to have a fire-resistive rating shall be protected with approved materials or construction assemblies designed to provide the same degree of fire resistance as the structural element in which it is installed when tested in accordance with UBC Standard 7-1. See Section 703.2.

Such isolation system protection applied to isolator units shall be capable of retarding the transfer of heat to the isolator unit in such a manner that the required gravity load-carrying capacity of the isolator unit will not be impaired after exposure to the standard time-temperature curve fire test prescribed in UBC Standard 7-1 for a duration not less than that required for the fire-resistive rating of the structural element in which it is installed.

Such isolation system protection applied to isolator units shall be suitably designed and securely installed so as not to dislodge, loosen, sustain damage, or otherwise impair its ability to accommodate the seismic movements for which the isolator unit is designed and to maintain its integrity for the purpose of providing the required fire-resistive protection.

1661.2.4 Lateral restoring force. The isolation system shall be configured to produce a restoring force such that the lateral force at the total design displacement is at least $0.025W$ greater than the lateral force at 50 percent of the total design displacement.

> **EXCEPTION:** The isolation system need not be configured to produce a restoring force, as required above, provided the isolation system is capable of remaining stable under full vertical load and accommodating a total maximum displacement equal to the greater of either 3.0 times the total design displacement 36 C_{VM}, inches (For **SI:** 914.4 C_{VM}, mm).

1661.2.5 Displacement restraint. The isolation system may be configured to include a displacement restraint that limits lateral displacement due to the maximum capable earthquake to less than C_{VM}/C_{VD} times the total design displacement, provided that the seismic-isolated structure is designed in accordance with the following criteria when more stringent than the requirements of Section 1629.

1. Maximum capable earthquake response is calculated in accordance with the dynamic analysis requirements of Sections 1631 and 1659, explicitly considering the nonlinear characteristics of the isolation system and the structure above the isolation system.

2. The ultimate capacity of the isolation system and structural elements below the isolation system shall exceed the strength and displacement demands of the maximum capable earthquake.

3. The structure above the isolation system is checked for stability and ductility demand of the maximum capable earthquake.

4. The displacement restraint does not become effective at a displacement less than 0.75 times the total design displacement unless it is demonstrated by analysis that earlier engagement does not result in unsatisfactory performance.

1661.2.6 Vertical load stability. Each element of the isolation system shall be designed to be stable under the maximum vertical load, $1.2D + 1.0L + |E|_{max}$ and the minimum vertical load, $0.80\text{-}|E_{min}|$, at a horizontal displacement equal to the total maximum displacement. The vertical earthquake load on an individual isolation unit due to overturning, $|E|_{max}$ and $|E|_{min}$, shall be based on peak response due to the maximum capable earthquake.

1661.2.7 Overturning. The factor of safety against global structural overturning at the isolation interface shall not be less than 1.0 for required load combinations. All gravity and seismic loading conditions shall be investigated. Seismic forces for overturning calculations shall be based on the maximum capable earthquake and W shall be used for the vertical restoring force.

Local uplift of individual elements is permitted provided the resulting deflections do not cause overstress or instability of the isolator units or other building elements.

1661.2.8 Inspection and replacement.

1. Access for inspection and replacement of all components of the isolation system shall be provided.

2. The architect or engineer of record or a person designated by the architect or engineer of record shall complete a final series of inspections or observations of building separation areas and of components that cross the isolation interface prior to the issuance of the certificate of occupancy for the seismic-isolated building. Such inspections and observations shall indicate that as-built conditions allow for free and unhindered displacement of the structure to maximum design levels and that all components that cross the isolation interface as installed, are able to accommodate the stipulated displacements.

3. Seismic-isolated buildings shall have a periodic monitoring, inspection and maintenance program for the isolation system established by the architect or engineer responsible for the design of the system. The objective of such a program shall be to ensure that all elements of the isolation system are able to perform to minimum design levels at all times.

4. Remodeling, repair or retrofitting at the isolation system interface, including that of components that cross the isolation interface, shall be performed under the direction of an architect or engineer licensed in the appropriate disciplines and experienced in the design and construction of seismic-isolated structures.

5. Horizontal displacement recording devices shall be installed at the isolation interface in seismic-isolated buildings.

1661.2.9 Quality control. A quality control testing program for isolator units shall be established by the engineer responsible for the structural design.

1661.3 Structural System.

1661.3.1 Horizontal distribution of force. A horizontal diaphragm or other structural elements shall provide continuity above the isolation interface and shall have adequate strength and ductility to transmit forces (due to nonuniform ground motion) from one part of the building to another.

1661.3.2 Building separations. Minimum separations between the isolated building and surrounding retaining walls or other fixed obstructions shall not be less than the total maximum displacement.

SECTION 1662 — NONBUILDING STRUCTURES

Nonbuilding structures shall be designed in accordance with the requirements of Section 1634 using design displacements and forces calculated in accordance with Section 1658 or 1659.

SECTION 1663 — FOUNDATIONS

Foundations shall be designed and constructed in accordance with the requirements of Chapter 18 using design forces calculated in accordance with Section 1658 or 1659.

SECTION 1664 — DESIGN AND CONSTRUCTION REVIEW

1664.1 General. A design review of the isolation system and related test programs shall be performed by an independent engineering team including persons licensed in the appropriate disciplines, experienced in seismic analysis methods and the theory and application of seismic isolation.

1664.2 Isolation System. Isolation system design review shall include, but not be limited to, the following:

1. Review of site-specific seismic criteria, including the development of site-specific spectra and ground motion time histories, and all other design criteria developed specifically for the project.

2. Review of the preliminary design, including the determination of the total design displacement of the isolation system design displacement and lateral force design level.

3. Overview and observation of prototype testing (Section 1665).

4. Review of the final design of the entire structural system and all supporting analyses.

5. Review of the isolation system quality control testing program (Section 1661.2.9).

The engineer of record shall submit with the plans and calculations a statement by all members of the independent engineering team stating that the above has been completed.

SECTION 1665 — REQUIRED TESTS OF ISOLATION SYSTEM

1665.1 General. The deformation characteristics and damping values of the isolation system used in the design and analysis of seismic-isolated structures shall be based on the following tests of a selected sample of the components prior to construction.

The isolation system components to be tested shall include the wind restraint system if such systems are used in the design.

The tests specified in this section are for establishing and validating the design properties of the isolation system, and shall not be considered as satisfying the manufacturing quality control tests of Section 1661.2.9.

1665.2 Prototype Tests.

1665.2.1 General. Prototype tests shall be performed separately on two full-size specimens or sets of specimens, as appropriate, of each type and size of isolator unit of the isolation system. The test specimens shall include the wind restraint system, as well as individual isolator units, if such systems are used in the design. Specimens tested shall not be used for construction.

1665.2.2 Record. For each cycle of tests the force-deflection behavior of the test specimen shall be recorded.

1665.2.3 Sequence and cycles. The following sequence of tests shall be performed for the prescribed number of cycles at a vertical load equal to the average $D + 0.5L$ on all isolator units of a common type and size:

1. Twenty fully reversed cycles of loading at a lateral force corresponding to the wind design force.

2. Three fully reversed cycles of loading at each of the following increments of displacement: 0.2 D_D, 0.5 D_D and 1.0 D_D, 1.0 D_M.

3. Three fully reversed cycles at the total maximum displacement, $1.0D_{TM}$.

4. $(15C_{VD}/C_{VA}B_D)$, but not less than 10, fully reversed cycles of loading at 1.0 times the total design displacement, $1.0D_{TD}$.

If an isolator unit is also a vertical load-carrying element, then Item 2 of the sequence of cyclic tests specified above shall be performed for two additional vertical load cases:

$$(1)\ 1.2D + 0.5L + |E|$$

$$(2)\ 0.8D - |E|$$

where D and L are defined in Chapter 16, Division III. The vertical test load on an individual isolator unit shall include the load increment due to earthquake overturning, $|E|$, and shall be equal to or greater than the peak earthquake vertical force response corresponding to the test displacement being evaluated. In these tests, the combined vertical load shall be taken as the typical or average downward force on all isolator units of a common type and size.

1665.2.4 Units dependent on loading rates. If the force-deflection properties of the isolator units are dependent on the rate of loading, then each set of tests specified in Section 1665.2.3 shall be performed dynamically at a frequency equal to the inverse of the effective period, T_D, of the isolated structure.

If reduced-scale prototype specimens are used to quantify rate-dependent properties of isolators, the reduced-scale prototype specimens shall be of the same type and material and be manufactured with the same processes and quality as full-scale prototypes, and shall be tested at a frequency that represents full-scale prototype loading rates.

The force-deflection properties of an isolator unit shall be considered to be dependent on the rate of loading if there is greater than a plus or minus 10 percent difference in the effective stiffness at the design displacement when tested at a frequency equal to the inverse of the effective period, T_D, of the isolated structure and when tested at any frequency in the range of 0.1 to 2.0 times the inverse of the effective period, T_D, of the isolated structure.

1665.2.5 Units dependent on bilateral load. If the force-deflection properties of the isolator units are dependent on bilateral load, then the tests specified in Sections 1665.2.3 and 1665.2.4 shall be augmented to include bilateral load at increments of the total design displacement 0.25 and 1.0, 0.50 and 1.0, 0.75 and 1.0, and 1.0 and 1.0.

> **EXCEPTION:** If reduced-scale prototype specimens are used to quantify bilateral-load-dependent properties, then such scaled specimens shall be of the same type and material, and manufactured with the same processes and quality as full-scale prototypes.

The force-deflection properties of an isolator unit shall be considered to be dependent on bilateral load, if the bilateral and unilateral force-deflection properties have greater than a plus or minus 10 percent difference in effective stiffness at the design displacement.

1665.2.6 Maximum and minimum vertical load. Isolator units that carry vertical load shall be statically tested for the maximum and minimum vertical load, at the total maximum displacement. In these tests, the combined vertical loads of $1.2D + 1.0L + |E|_{max}$ shall be taken as the maximum vertical force, and the combined vertical load of $0.8D - |E|_{min}$ shall be taken as the minimum vertical force, on any one isolator unit of a common type and size. The vertical load on an individual isolator unit shall include the load increment due to earthquake overturning, $|E|_{max}$ and $|E|_{min}$, and shall be based on peak response due to the maximum capable earthquake.

1665.2.7 Sacrificial wind-restraint systems. If a sacrificial wind-restraint system is to be utilized, then the ultimate capacity shall be established by test.

1665.2.8 Testing similar units. The prototype tests are not required if an isolator unit is of similar dimensional characteristics and of the same type and material as the prototype isolator unit that has been previously tested using the specified sequence of tests.

1665.3 Determination of Force-deflection Characteristics. The force-deflection characteristics of the isolation system shall be based on the cyclic load tests of isolator prototypes specified in Section 1665.2.3.

As required, the effective stiffness of an isolator unit, k_{eff}, shall be calculated for each cycle of loading by the formula:

$$k_{eff} = \frac{F^+ - F^-}{\Delta^+ - \Delta^-} \qquad (65\text{-}1)$$

where $F+$ and $F-$ are the positive and negative forces at Δ^+ and Δ^-, respectively.

As required, the effective damping (β_{eff}) of an isolator unit shall be calculated for each cycle of loading by the formula:

$$\beta_{eff} = \frac{2}{\pi}\left[\frac{E_{Loop}}{k_{eff}(|\Delta^+| + |\Delta^-|)^2}\right] \qquad (65\text{-}2)$$

where the energy dissipated per cycle of loading, E_{Loop}, and the effective stiffness, k_{eff}, shall be based on test displacements of Δ^+ and Δ^-.

1665.4 System Adequacy. The performance of the test specimens shall be assessed as adequate if the following conditions are satisfied:

1. The force-deflection plots of all tests specified in Section 1665.2 have a positive incremental force-carrying capacity.

2. For each increment of test displacement specified in Section 1665.2.3, Item 2, and for each vertical load case specified in Section 1665.2.3:

   2.1 There is no greater than a plus or minus 10 percent difference between the effective stiffness at each of the three cycles of test and the average value of effective stiffness for each test specimen.

   2.2 There is no greater than a 10 percent difference in the average value of effective stiffness of the two test specimens of a common type and size of the isolator unit over the required three cycles of test.

3. For each specimen there is no greater than a plus or minus 20 percent change in the initial effective stiffness of each test specimen over the $(15C_{VD}/C_{VA}B_D)$, but not less than 10, cycles of the test specified in Section 1665.2.3, Item 4.

4. For each specimen there is no greater than a 20 percent decrease in the initial effective damping over for the $(15C_{VD}/C_{VA}B_D)$, but not less than 10, cycles of the test specified in Section 1665.2.3, Item 4.

5. All specimens of vertical load-carrying elements of the isolation system remain stable at the total maximum displacement for static load as prescribed in Section 1665.2.6.

1665.5 Design Properties of the Isolation System.

1665.5.1 Maximum and minimum effective stiffness. At the design displacement, the maximum and minimum effective stiffnesses of the isolation system, k_{Dmax} and k_{Dmin}, shall be based on the cyclic tests of Section 1665.2.3 and calculated by the formulas:

$$k_{Dmax} = \frac{\sum |F_D^+|_{max} + \sum |F_D^-|_{max}}{2D_D} \qquad (65\text{-}3)$$

$$k_{Dmin} = \frac{\sum |F_D^+|_{min} + \sum |F_D^-|_{min}}{2D_D} \qquad (65\text{-}4)$$

At the maximum displacement, the maximum and minimum effective stiffness of the isolation system, k_{Mmax} and k_{Mmin}, shall be based on the cyclic tests of Section 1665.2.3 and calculated by the formulas:

$$k_{Mmax} = \frac{\sum |F_M^+|_{max} + \sum |F_M^-|_{max}}{2D_M} \qquad (65\text{-}5)$$

$$k_{Mmin} = \frac{\sum |F_M^+|_{min} + \sum |F_M^-|_{min}}{2D_M} \qquad (65\text{-}6)$$

For isolator units that are found by the tests of Sections 1665.2.3, 1665.2.4 and 1665.2.5 to have force-deflection characteristics which vary with vertical load, rate of loading or bilateral load, respectively, the values of k_{Dmax} and k_{Mmax} shall be increased and the values of k_{Dmin} and k_{Mmin} shall be decreased, as necessary, to bound the effects of measured variation in effective stiffness.

1665.5.2 Effective damping. At the design displacement, the effective damping of the isolation system, β_D, shall be based on the cyclic tests of Section 1665.2.3 and calculated by the formula:

$$\beta_D = \frac{1}{2\pi}\left[\frac{\sum E_D}{k_{Dmax}D_D^2}\right] \qquad (65\text{-}7)$$

In Formula (65-7), the total energy dissipated in the isolation system per cycle of design displacement response, ΣE_D, shall be taken as the sum of the energy dissipated per cycle in all isolator units measured at test displacements, Δ^+ and Δ^-, that are equal in magnitude to the design displacement, D_D.

At the maximum displacement, the effective damping of the isolation system, β_M, shall be based on the cyclic tests of Section 1665.2.3 and calculated by the formula:

$$\beta_M = \frac{1}{2\pi}\left[\frac{\sum E_M}{k_{Mmax}D_M^2}\right] \qquad (65\text{-}8)$$

In Formula (65-8), the total energy dissipated in the isolation system per cycle of response, E_M, shall be taken as the sum of the energy dissipated per cycle in all isolator units measured at test displacements, Δ^+ and Δ^-, that are equal in magnitude to the maximum displacement, D_M.

TABLE A-16-C—DAMPING COEFFICIENTS, B_D AND B_M

EFFECTIVE DAMPING, β_D or β_M (percentage of critical)[1,2]	B_D or B_M FACTOR
≤ 2	0.8
5	1.0
10	1.2
20	1.5
30	1.7
40	1.9
≥ 50	2.0

[1]The damping coefficient shall be based on the effective damping of the isolation system determined in accordance with the requirements of Section 1665.5.

[2]The damping coefficient shall be based on linear interpolation for effective damping values other than those given.

TABLE A-16-D—MAXIMUM CAPABLE EARTHQUAKE RESPONSE COEFFICIENT, M_M

DESIGN BASIS EARTHQUAKE SHAKING INTENSITY, ZN_v	MAXIMUM CAPABLE EARTHQUAKE RESPONSE COEFFICIENT, M_M
0.075	2.67
0.15	2.0
0.20	1.75
0.30	1.50
0.40	1.25
≥ 0.50	1.20

TABLE A-16-E—STRUCTURAL SYSTEMS ABOVE THE ISOLATION INTERFACE[1]

BASIC STRUCTURAL SYSTEM[2]	LATERAL-FORCE-RESISTING SYSTEM DESCRIPTION	R_I	HEIGHT LIMIT FOR SEISMIC ZONES 3 AND 4 × 304.8 for mm
1. Bearing wall system	1. Light-framed walls with shear panels		
	a. Wood structural panel walls for structures three stories or less	2.0	65
	b. All other light-framed walls	2.0	65
	2. Shear walls		
	a. Concrete	2.0	160
	b. Masonry	2.0	160
	3. Light steel-framed bearing walls with tension-only bracing	1.6	65
	4. Braced frames where bracing carries gravity load		
	a. Steel	1.6	160
	b. Concrete[3]	1.6	—
	c. Heavy timber	1.6	65
2. Building frame system	1. Steel eccentrically braced frame (EBF)	2.0	240
	2. Light-framed walls with shear panels		
	a. Wood structural panel walls for structures three stories or less	2.0	65
	b. All other light-framed walls	2.0	65
	3. Shear walls		
	a. Concrete	2.0	240
	b. Masonry	2.0	160
	4. Ordinary braced frames		
	a. Steel	1.6	160
	b. Concrete[3]	1.6	—
	c. Heavy timber	1.6	65
	5. Special concentrically braced frames		
	a. Steel	2.0	240

(Continued)

TABLE A-16-E—STRUCTURAL SYSTEMS ABOVE THE ISOLATION INTERFACE[1]—(Continued)

BASIC STRUCTURAL SYSTEM[2]	LATERAL-FORCE-RESISTING SYSTEM DESCRIPTION	R_I	HEIGHT LIMIT FOR SEISMIC ZONES 3 AND 4 (× 304.8 for mm)
3. Moment-resisting frame system	1. Special moment-resisting frame (SMRF)		
	a. Steel	2.0	N.L.
	b. Concrete	2.0	N.L.
	2. Masonry moment-resisting wall frame (MMRWF)	2.0	160
	3. Concrete intermediate moment-resisting frame (IMRF)[4]	2.0	—
	4. Ordinary moment-resisting frame (OMRF)		
	a. Steel[5]	2.0	160
	b. Concrete[6]	2.0	—
	5. Special truss moment frames of steel (STMF)	2.0	240
4. Dual systems	1. Shear walls		
	a. Concrete with SMRF	2.0	N.L.
	b. Concrete with steel OMRF	2.0	160
	c. Concrete with IMRF[4]	2.0	160
	d. Masonry with SMRF	2.0	160
	e. Masonry with steel OMRF	2.0	160
	f. Masonry with concrete IMRF[3]	2.0	—
	g. Masonry with masonry MMRWF	2.0	160
	2. Steel EBF		
	a. With steel SMRF	2.0	N.L.
	b. With steel OMRF	2.0	160
	3. Ordinary braced frames		
	a. Steel with steel SMRF	2.0	N.L.
	b. Steel with steel OMRF	2.0	160
	c. Concrete with concrete SMRF[3]	2.0	—
	d. Concrete with concrete IMRF[3]	2.0	—
	4. Specially concentrically braced frames		
	a. Steel with steel SMRF	2.0	N.L.
	b. Steel with steel OMRF	2.0	160
5. Cantilevered column building systems	1. Cantilevered column elements	1.4	35[7]
6. Shear wall-frame interaction systems	1. Concrete[6]	2.0	—
7. Undefined systems	See Sections 1629.6.7 and 1629.9.2		—

N.L.—no limit.

[1]See Section 1630.4 for combination of structural systems.
[2]Basic structural systems are defined in Section 1629.6.
[3]Prohibited in Seismic Zones 3 and 4.
[4]Prohibited in Seismic Zones 3 and 4, except as permitted in Section 1633.2.
[5]Ordinary moment-resisting frames in Seismic Zone 1 meeting the requirements of Section 2213.6 may use an R_I value of 2.0.
[6]Prohibited in Seismic Zones 2A, 2B, 3 and 4. See Section 1633.2.7.
[7]Total height of the building including cantilevered columns.

TABLE A-16-F—SEISMIC COEFFICIENT, C_{AM}[1]

SOIL PROFILE TYPE	MAXIMUM CAPABLE EARTHQUAKE SHAKING INTENSITY $M_M ZN_a$				
	$M_M ZN_a = 0.075$	$M_M ZN_a = 0.15$	$M_M ZN_a = 0.2$	$M_M ZN_a = 0.3$	$M_M ZN_a \geq 0.4$
S_A	0.06	0.12	0.16	0.24	$0.8M_M ZN_a$
S_B	0.08	0.15	0.20	0.30	$1.0M_M ZN_a$
S_C	0.09	0.18	0.24	0.33	$1.0M_M ZN_a$
S_D	0.12	0.22	0.28	0.36	$1.1M_M ZN_a$
S_E	0.19	0.30	0.34	0.36	$0.9M_M ZN_a$
S_F	See Footnote 2				

[1]Linear interpolation may be used to determine the value of C_{AM} for values of $M_M ZN_a$ for other than those shown in the table.
[2]Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for soil.

TABLE A-16-G—SEISMIC COEFFICIENT, C_{VM}[1]

SOIL PROFILE TYPE	MAXIMUM CAPABLE EARTHQUAKE SHAKING INTENSITY $M_M ZN_v$				
	$M_M ZN_v$ = 0.075	$M_M ZN_v$ = 0.15	$M_M ZN_v$ = 0.20	$M_M ZN_v$ = 0.30	$M_M ZN_v \geq$ 0.40
S_A	0.06	0.12	0.16	0.24	$0.8 M_M ZN_v$
S_B	0.08	0.15	0.20	0.30	$1.0 M_M ZN_v$
S_C	0.13	0.25	0.32	0.45	$1.4 M_M ZN_v$
S_D	0.18	0.32	0.40	0.54	$1.6 M_M ZN_v$
S_E	0.26	0.50	0.64	0.84	$2.4 M_M ZN_v$
S_F	See Footnote 2				

[1]Linear Interpolation may be used to determine the value of C_{VM} for values of $M_M ZN_v$ for other than those shown in the table.

[2]Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for soil.

Appendix Chapter 18
WATERPROOFING AND DAMPPROOFING FOUNDATIONS

SECTION 1820 — SCOPE

Walls, or portions thereof, retaining earth and enclosing interior spaces and floors below grade shall be waterproofed or dampproofed according to this appendix chapter.

EXCEPTION: Walls enclosing crawl spaces.

SECTION 1821 — GROUNDWATER TABLE INVESTIGATION

A subsurface soils investigation shall be made in accordance with Section 1804.3, Item 3, to determine the possibility of the groundwater table rising above the proposed elevation of the floor or floors below grade. The building official may require that this determination be made by an engineer or architect licensed by the state to practice as such.

EXCEPTIONS: 1. When foundation waterproofing is provided.

2. When dampproofing is provided and the building official finds that there is satisfactory data from adjacent areas to demonstrate that groundwater has not been a problem.

SECTION 1822 — DAMPPROOFING REQUIRED

Where the groundwater investigation required by Section 1821 indicates that a hydrostatic pressure caused by the water table will not occur, floors and walls shall be dampproofed and a subsoil drainage system shall be installed in accordance with this appendix chapter.

EXCEPTION: Wood foundation systems shall be constructed in accordance with Chapter 18, Division II.

SECTION 1823 — FLOOR DAMPPROOFING

1823.1 General. Dampproofing materials shall be installed between the floor and base materials required by Section 1825.2.

EXCEPTION: Where a separate floor is provided above a concrete slab, the dampproofing may be installed on top of the slab.

1823.2 Dampproofing Materials. Dampproofing installed beneath the slab shall consist of not less than 6-mil (0.152 mm) polyethylene, or other approved methods or materials. When permitted to be installed on top of the slab, dampproofing shall consist of not less than 4-mil (0.1 mm) polyethylene, mopped-on bitumen or other approved methods or materials. Joints in membranes shall be lapped and sealed in an approved manner.

SECTION 1824 — WALL DAMPPROOFING

1824.1 General. Dampproofing materials shall be installed on the exterior surface of walls, and shall extend from a point 6 inches (152 mm) above grade, down to the top of the spread portion of the footing.

1824.2 Surface Preparation. Prior to application of dampproofing materials on concrete walls, fins or sharp projections that may pierce the membrane shall be removed and all holes and recesses resulting from the removal of form ties shall be sealed with a dry-pack mortar, bituminous material, or other approved methods or materials.

1824.3 Dampproofing Materials. Wall dampproofing shall consist of a bituminous material, acrylic modified cement base coating, any of the materials permitted for waterproofing in Section 1828.4, or other approved methods or materials. When such materials are not approved for direct application to unit masonry, the wall shall be parged on the exterior surface below grade with not less than $^{3}/_{8}$ inch (9.5 mm) of portland cement mortar.

SECTION 1825 — OTHER DAMPPROOFING REQUIREMENTS

1825.1 Subsoil Drainage System. When dampproofing is required, a base material shall be installed under the floor and a drain shall be installed around the foundation perimeter in accordance with this subsection.

EXCEPTION: When the finished ground level is below the floor level for more than 25 percent of the perimeter of the building, the base material required by Section 1825.2 need not be provided and the foundation drain required by Section 1825.3 need be provided only around that portion of the building where the ground level is above the floor level.

1825.2 Base Material. Floors shall be placed over base material not less than 4 inches (102 mm) in thickness consisting of gravel or crushed stone containing not more than 10 percent material that passes a No. 4 sieve (4.75 mm).

1825.3 Foundation Drain. The drain shall consist of gravel, crushed stone or drain tile.

Gravel or crushed stone drains shall contain not more than 10 percent material that passes a No. 4 sieve (4.75 mm). The drain shall extend a minimum of 12 inches (305 mm) beyond the outside edge of the footing. The depth shall be such that the bottom of the drain is not higher than the bottom of the base material under the floor, and the top of the drain is not less than 6 inches (152 mm) above the spread portion of the footing. The top of the drain shall be covered with an approved filter membrane material.

When drain tile or perforated pipe is used, the invert of the pipe or tile shall be not higher than the floor elevation. The top of joints or the top of perforations shall be protected with an approved filter membrane material. The pipe or tile shall be placed on not less than 2 inches (51 mm) of gravel or crushed stone complying with this section and covered with not less than 6 inches (152 mm) of the same material.

1825.4 Drainage Disposal. The floor base and foundation perimeter drain shall discharge by gravity or mechanical means into an approved drainage system.

EXCEPTION: Where a site is located in well-drained gravel or sand-gravel mixture soils, a dedicated drainage system need not be provided.

SECTION 1826 — WATERPROOFING REQUIRED

Where the groundwater investigation required by Section 1821 indicates that a hydrostatic pressure caused by the water table does exist, walls and floors shall be waterproofed in accordance with this appendix chapter.

EXCEPTIONS: 1. When the groundwater table can be lowered and maintained at an elevation not less than 6 inches (152 mm) below the bottom of the lowest floor, dampproofing provisions in accordance with Section 1822 may be used in lieu of waterproofing.

The design of the system to lower the groundwater table shall be based on accepted principles of engineering which shall consider, but not necessarily be limited to, the permeability of the soil, the rate at which water enters the drainage system, the rated capacity of pumps, the head against which pumps are to pump, and the rated capacity of the disposal area of the system.

2. Wood foundation systems constructed in accordance with Chapter 18, Division II, are to be provided with additional moisture-control measures as specified in Section 1812.

SECTION 1827 — FLOOR WATERPROOFING

1827.1 General. Floors required to be waterproofed shall be of concrete designed to withstand anticipated hydrostatic pressure.

1827.2 Waterproofing Materials. Waterproofing of floors shall be accomplished by placing under the slab a membrane of rubberized asphalt, polymer-modified asphalt, butyl rubber, neoprene, or not less than 6-mil (0.15 mm) polyvinyl chloride or polyethylene, or other approved materials capable of bridging nonstructural cracks. Joints in the membrane shall be lapped not less than 6 inches (152 mm) and sealed in an approved manner.

SECTION 1828 — WALL WATERPROOFING

1828.1 General. Walls required to be waterproofed shall be of concrete or masonry designed to withstand the anticipated hydrostatic pressure and other lateral loads.

1828.2 Wall Preparation. Prior to the application of waterproofing materials on concrete or masonry walls, the wall surfaces shall be prepared in accordance with Section 1824.2.

1828.3 Where Required. Waterproofing shall be applied from a point 12 inches (305 mm) above the maximum elevation of the groundwater table down to the top of the spread portion of the footing. The remainder of the wall located below grade shall be dampproofed with materials in accordance with Section 1824.3.

1828.4 Waterproofing Materials. Waterproofing shall consist of rubberized asphalt, polymer-modified asphalt, butyl rubber, or other approved materials capable of bridging nonstructural cracks. Joints in the membrane shall be lapped and sealed in an approved manner.

1828.5 Joints. Joints in walls and floors, and between the wall and floor, and penetrations of the wall and floor shall be made watertight using approved methods and materials.

SECTION 1829 — OTHER DAMPPROOFING AND WATERPROOFING REQUIREMENTS

1829.1 Placement of Backfill. The excavation outside the foundation shall be backfilled with soil which is free of organic material, construction debris and large rocks. The backfill shall be placed in lifts and compacted in a manner which does not damage the waterproofing or dampproofing material or structurally damage the wall.

1829.2 Site Grading. The ground immediately adjacent to the foundation shall be sloped away from the building at not less than 1 unit vertical in 12 units horizontal (8.3% slope) for a minimum distance of 6 feet (1829 mm) measured perpendicular to the face of the wall or an approved alternate method of diverting water away from the foundation shall be used. Consideration shall be given to possible additional settlement of the backfill when establishing final ground level adjacent to the foundation.

1829.3 Erosion Protection. Where water impacts the ground from the edge of the roof, downspout, scupper, valley, or other rainwater collection or diversion device, provisions shall be used to prevent soil erosion and direct the water away from the foundation.

Appendix Chapter 19
PROTECTION OF RESIDENTIAL CONCRETE EXPOSED TO FREEZING AND THAWING

SECTION 1928 — GENERAL

1928.1 Purpose. The purpose of this appendix is to provide minimum standards for the protection of residential concrete exposed to freezing and thawing conditions.

1928.2 Scope. The provisions of this appendix apply to concrete used in buildings of Groups R and U Occupancies that are three stories or less in height.

1928.3 Special Provisions. Normal-weight aggregate concrete used in buildings of Groups R and U Occupancies three stories or less in height which are subject to de-icer chemicals or freezing and thawing conditions as determined from Figure A-19-1 shall comply with the requirements of Table A-19-A.

TABLE A-19-A—MINIMUM SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE[1]

TYPE OR LOCATION OF CONCRETE CONSTRUCTION	MINIMUM SPECIFIED COMPRESSIVE STRENGTH[2] (f'_c) × 6.89 for kPa — Weathering Potential[3]		
	Negligible	Moderate	Severe
Basement walls and foundations not exposed to the weather	2,500	2,500	2,500[4]
Basement slabs and interior slabs on grade, except garage floor slabs	2,500	2,500	2,500[4]
Basement walls, foundation walls, exterior walls and other vertical concrete work exposed to the weather	2,500	3,000[5]	3,000[5]
Porches, carport slabs and steps exposed to the weather, and garage floor slabs	2,500	3,000[5]	3,500[5]

[1]Increases in compressive strength above those used in the design shall not cause implementation of the special inspection provisions of Section 1701.5, Item 1.

[2]At 28 days, pounds per square inch (kPa).

[3]See Figure A-19-1 for weathering potential.

[4]Concrete in these locations which may be subject to freezing and thawing during construction shall be air-entrained concrete in accordance with Footnote 5.

[5]Concrete shall be air entrained. Total air content (percentage by volume of concrete) shall not be less than 5 percent or more than 7 percent.

FIGURE A-19-1—WEATHERING REGIONS FOR RESIDENTIAL CONCRETE

NOTES:

[1]The three exposures are:

A. Severe—Outdoor exposure in a cold climate where concrete may be exposed to the use of de-icing salts or where there may be a continuous presence of moisture during frequent cycles of freezing and thawing. Examples are pavements, driveways, walks, curbs, steps, porches and slabs in unheated garages. Destructive action from de-icing salts may occur either from direct application or from being carried onto an unsalted area from a salted area, such as on the undercarriage of a car traveling on a salted street but parked on an unsalted driveway or garage slab.

B. Moderate—Outdoor exposure in a climate where concrete will not be exposed to the application of de-icing salts but will occasionally be exposed to freezing and thawing.

C. Mild—Any exposure where freezing and thawing in the presence of moisture is rare or totally absent.

[2]Data needed to determine the weathering index for any locality may be found or estimated from the tables of Local Climatological Data, published by the Weather Bureau, U.S. Department of Commerce.

[3]The weathering regions map provides the location of severe, moderate and mild winter weathering areas as they occur in the United States (Alaska and Hawaii are classified as severe and mild, respectively). The map cannot be precise. This is especially true in mountainous areas where conditions change dramatically within very short distances. It is intended to classify as severe any area in which weathering conditions may cause de-icing salt to be used, either by individuals or for street or highway maintenance. These conditions are significant snowfall combined with extended periods during which there is little or no natural thawing. If there is any doubt about which of two regions is applicable, the more severe exposure should be selected.

[4]The Weathering Index:

Severe—As a guideline, the number of days during which the temperature does not rise above 32°F (0°C) is multiplied by the inches of snowfall. An index of 150 or more is classified as severe. Cold, humid climates may be more severe than cold, dry climates for a given index.

Moderate, Mild—Multiply the inches of precipitation times the number of days the temperature registers below 32°F (0°C) Use the occurrence between the first day in the fall and the last day in the spring that the temperature registers below 32°F (0°C) An index above 200 is moderate. An index below 200 is mild.

Appendix Chapter 21
PRESCRIPTIVE MASONRY CONSTRUCTION IN HIGH-WIND AREAS

SECTION 2112 — GENERAL

2112.1 Purpose. The provisions of this chapter are intended to promote public safety and welfare by reducing the risk of wind-induced damages to masonry construction.

2112.2 Scope. The requirements of this chapter shall apply to masonry construction in buildings when all of the following conditions are met:

1. The building is located in an area with a basic wind speed from 80 through 110 miles per hour (mph) (129 km/h through 177 km/h).

2. The building is located in Seismic Zone 0, 1 or 2.

3. The building does not exceed two stories.

4. Floor and roof joists shall be wood or steel or of precast hollowcore concrete planks with a maximum span of 32 feet (9754 mm) between bearing walls. Masonry walls shall be provided for the support of steel joists or concrete planks.

5. The building is of regular shape.

2112.3 General. The requirements of Chapter 21 are applicable except as specifically modified by this chapter. Other methods may be used provided a satisfactory design is submitted showing compliance with the provisions of Chapter 16, Part II, and other applicable provisions of this code.

Wood floor, roof and interior walls shall be constructed as specified in Appendix Chapter 23 and as further regulated in this section.

In areas where the wind speed exceeds 110 mph (177 km/h), masonry buildings shall be designed in accordance with Chapter 16, Part II, and other applicable provisions of this code.

Buildings of unusual shape or size, or split-level construction, shall be designed in accordance with Chapter 16, Part II, and other applicable provisions of this code.

In addition to the other provisions of this chapter, foundations for buildings in areas subject to wave action or tidal surge shall be designed in accordance with approved national standards.

All metal connectors and fasteners used in exposed locations or in areas otherwise subject to corrosion shall be of corrosion-resistant or noncorrosive material. When the terms “corrosion resistant” or “noncorrosive” are used in this chapter, they shall mean having a corrosion resistance equal to or greater than a hot-dipped galvanized coating of 1.5 ounces of zinc per square foot (3.95 g/m^2) of surface area. When an element is required to be corrosion resistant or noncorrosive, all of its parts, such as screws, nails, wire, dowels, bolts, nuts, washers, shims, anchors, ties and attachments, shall be corrosion resistant.

2112.4 Materials.

2112.4.1 General. All masonry materials shall comply with Section 2102.2 as applicable for standards of quality.

2112.4.2 Hollow-unit masonry.

1. Exterior concrete block shall be a minimum of Grade N-II with a compressive strength of not less than 1,900 pounds per square inch (psi) (13 091 kPa) on the net area.

2. Interior concrete block shall be a minimum of Grade S-II with a compressive strength of not less than 700 psi (4823 kPa) on the gross area.

3. Exterior clay or shale hollow brick shall have a compressive strength of not less than 2,500 psi (17 225 kPa) on the net area. Such hollow brick shall be at least Grade MW except that where subject to severe freezing it shall be Grade SW.

4. Interior clay or shale hollow brick shall be Grade MW with a compressive strength of 2,000 psi (13 780 kPa) on the net area.

2112.4.3 Solid masonry.

1. Exterior clay or shale bricks shall have a compressive strength of not less than 2,500 psi (17 225 kPa) on the net area.

2. Exterior clay or shale bricks shall be Grade MW, except that where subject to severe freezing they shall be Grade SW.

3. Interior clay or shale bricks shall have a compressive strength of not less than 2,000 psi (13 780 kPa).

2112.4.4 Grout. Grout shall achieve a compressive strength of not less than 2,000 psi (13 780 kPa).

2112.4.5 Mortar. Mortar for exterior walls and for interior shear walls shall be Type M or Type S.

2112.5 Construction Requirements. Grouted cavity wall and block wall construction shall comply with Section 2104.

Unburned clay masonry and stone masonry shall not be used.

2112.6 Foundations. Footings shall have a thickness of not less than 8 inches (203 mm) and shall comply with Tables A-21-A-1 and A-21-A-2 for width. See Figure A-21-1 for other applicable details.

Footings shall extend 18 inches (457 mm) below the undisturbed ground surface or the frost depth, whichever is deeper.

Foundation stem walls shall be as wide as the wall they support. They shall be reinforced with reinforcing bar sizes and spacing to match the reinforcement of the walls they support.

Basement and other below-grade walls shall comply with Table A-21-B.

2112.7 Drainage. Basement walls and other walls or portions thereof retaining more than 3 feet (914 mm) of earth and enclosing interior spaces or floors below grade shall have a minimum 4-inch-diameter (102 mm) footing drain as illustrated in Table A-21-B and Figure A-21-3.

The finish elevations around the building shall be graded to provide a slope away from the building of not less than $^1/_4$ unit vertical in 12 units horizontal (2% slope).

2112.8 Wall Construction.

2112.8.1 Minimum thickness. Reinforced exterior bearing walls shall have a minimum 8-inch (203 mm) nominal thickness. Interior masonry nonbearing walls shall have a minimum 6-inch (152 mm) nominal thickness. Unreinforced grouted brick walls shall have a minimum 10-inch (254 mm) thickness. Unreinforced hollow-unit and solid masonry shall have a minimum 8-inch (203 mm) nominal thickness.

> **EXCEPTION:** In buildings not more than two stories or 26 feet (7924.8 mm) in height, masonry walls may be of 8-inch (203 mm) nominal thickness. Solid masonry walls in one-story buildings may be of 6-inch (152 mm) nominal thickness when not over 9 feet (2743 mm)

in height, provided that when gable construction is used an additional 6 feet (1829 mm) are permitted to the peak of the gable.

2112.8.2 Lateral support and height. All walls shall be laterally supported at the top and bottom. The maximum unsupported height of bearing walls or other masonry walls shall be 12 feet (3658 mm). Gable-end walls may be 15 feet (4572 mm) at their peak.

Wood-framed gable-end walls on buildings shall comply with Table A-21-I and Figure A-21-17 or A-21-18.

2112.8.3 Walls in Seismic Zone 2 and use of stack bond. In Seismic Zone 2, walls shall comply with Figure A-21-2 as a minimum. Walls with stack bond shall be designed.

2112.8.4 Lintels. The span of lintels over openings shall not exceed 12 feet (3658 mm), and lintels shall be reinforced. The reinforcement bars shall extend not less than 2 feet (610 mm) beyond the edge of opening and into lintel supports.

Lintel reinforcement shall be within fully grouted cells in accordance with Table A-21-E.

2112.8.5 Reinforcement. Walls shall be reinforced as shown in Tables A-21-C-1 through A-21-C-5 and Figure A-21-2.

2112.8.6 Anchorage of walls to floors and roofs. Anchors between walls and floors or roofs shall be embedded in grouted cells or cavities and shall conform to Section 2112.9.

2112.9 Floor and Roof Systems. The anchorage of wood roof systems which are supported by masonry walls shall comply with Appendix Sections 2337.5.1 and 2337.5.8, Table A-21-D and Figure A-21-7.

Wood roof and floor systems which are supported by ledgers at the inside face of masonry walls shall comply with Table A-21-D, Part I.

The ends of joist girders shall extend a distance of not less than 6 inches (152 mm) over masonry or concrete supports and be attached to a steel bearing plate. This plate is to be located not more than $^1/_2$ inch (12.7 mm) from the face of the wall and is to be not less than 9 inches (229 mm) wide perpendicular to the length of the joist girder. Ends of joist girders resting on steel bearing plates on masonry or structural concrete shall be attached thereto with a minimum of two $^1/_4$-inch (6.4 mm) fillet welds 2 inches (51 mm) long, or with two $^3/_4$-inch (19 mm) bolts.

Ends of joist girders resting on steel supports shall be connected thereto with a minimum of two $^1/_4$-inch (6.4 mm) fillet welds 2 inches (51 mm) long, or with two $^3/_4$-inch (19 mm) bolts. In steel frames, joist girders at column lines shall be field bolted to the columns to provide lateral stability during construction.

Steel joist roof and floor systems shall be anchored in accordance with Table A-21-H.

Wall ties spaced as shown in Table A-21-D, Part II, shall connect to framing or blocking at roofs and walls. Wall ties shall enter grouted cells or cavities and shall be $1^1/_8$-inch (29 mm) minimum width by 0.036 inch (0.91 mm) (No. 20 galvanized sheet gage) sheet steel.

Roof and floor hollow-core precast plank systems shall be anchored in accordance with Table A-21-G.

Roof uplift anchorage shall enter a grouted bond beam reinforced with horizontal bars as shown in Tables A-21-C-1 through A-21-C-5 and Figure A-21-7.

2112.10 Lateral Force Resistance.

2112.10.1 Complete load path and uplift resistance. Strapping, approved framing anchors, and mechanical fasteners, bond beams, and vertical reinforcement shall be installed to provide a continuous tie from the roof to the foundation system. (See Figure A-21-8.) In addition, roof and floor systems, masonry shear walls, or masonry or wood cross walls shall provide lateral stability.

2112.10.2 Floor and roof diaphragms. Floor and roof diaphragms shall be connected to masonry walls as shown in Table A-21-F, Part II.

Gabled and sloped roof members not supported at the ridge shall be tied by ceiling joists or equivalent lateral ties located as close to where the roof member bears on the wall as is practically possible, at not more than 48 inches (1219 mm) on center. Collar ties shall not be used for these lateral ties. (See Figure A-21-17 and Table A-21-I.)

2112.10.3 Walls. Masonry walls shall be provided around all sides of floor and roof systems in accordance with Figure A-21-9 and Table A-21-F.

The cumulative length of exterior masonry walls along each side of the floor or roof systems shall be at least 20 percent of the parallel dimension. Required elements shall be without openings and shall not be less than 48 inches (1219 mm) in width.

Interior cross walls (nonbearing) at right angles to bearing walls shall be provided when the length of the building perpendicular to the span of the floor or roof framing exceeds twice the distance between shear walls or 32 feet (9754 mm), whichever is greater. Cross walls, when required, shall conform to Section 2112.10.4.

2112.10.4 Interior cross walls. When required by Table A-21-F, Part I, masonry walls shall be at least 6 feet (1829 mm) long and reinforced with 9 gage wire joint reinforcement spaced not more than 16 inches (406 mm) on center. Cross walls shall comply with Footnote 3 of Table A-21-F, Part I.

Interior wood stud walls may be used to resist the wind load from one-story masonry buildings in areas where the basic wind speed is 100 mph (161 km/h), Exposure C or less, and 110 mph (177 km/h), Exposure B. When wood stud walls are so used, they shall:

1. Be perpendicular to exterior masonry walls at 15 feet (4572 mm) or less on center.

2. Be at least 8 feet (2438 mm) long without openings and be sheathed on at least one side with $^{15}/_{32}$-inch (12 mm) wood structural panel nailed with 8d common or galvanized box nails at 6 inches (152 mm) on center edge and field nailing. All unsupported edges of wood structural panels shall be blocked.

3. Be connected to wood blocking or wood joists below with two 16d nails at 16 inches (406 mm) on center through their sill plates. They shall be connected to footings with $^1/_2$-inch-diameter (12.7 mm) bolts at 3 feet 6 inches (1067 mm) on center.

4. Connect to wood roof systems as outlined in Table A-21-F, Part II, as a cross wall. Wood structural panel roof sheathing shall have all unsupported edges blocked.

TABLE A-21-A-1—EXTERIOR FOUNDATION REQUIREMENTS FOR MASONRY BUILDINGS WITH 6- AND 8-INCH-THICK WALLS
(Wood or Steel Framing)
(Width of Footings in Inches)[1,2,3]
See Figure A-21-1 for typical details.

WALL HEIGHT (feet)	SPAN TO BEARING WALLS (feet)	ONE-STORY BUILDINGS Roof Live Load[4] × 0.0479 for kN/m²			TWO-STORY BUILDINGS Roof Live Load[4] (psf) × 0.0479 for kN/m²					
					20		30		40	
					Plus Floor Live Load[5] (psf) × 0.0479 for kN/m²					
		20 psf (inches)	30 psf (inches)	40 psf (inches)	50	100	50	100	50	100
		Minimum Width of Footing (inches)								
× 304.8 for mm		× 25.4 for mm								
8	8	12			12	12	12	12	12	12
	16				12	14	12	14	12	14
	24				14	18	14	18	16	18
	32				16	20	18	20	18	20
10	8	12			12	12	12	12	12	12
	16				14	16	14	16	14	16
	24				16	20	16	18	16	20
	32				20	24	20	22	20	24
12	8	12	12	12	12	14	12	14	12	14
	16	12	12	12	16	18	16	16	14	16
	24	12	12	14	18	20	18	20	18	20
	32	12	14	16	20	22	22	22	22	24

[1]For buildings with under-floor space or basements, footing thickness is to be a minimum of 12 inches (305 mm). It shall be reinforced with No. 4 bars at 24 inches (610 mm) on center when its width is required to be 18 inches (457 mm) or larger and it supports more than the roof and one floor.
[2]Soil to be at least Class 4 as shown in Table 18-I-A.
[3]Footings are a minimum of 10 inches (254 mm) thick for a one-story building and 12 inches (305 mm) thick for a two-story building. Bottom of footing to be 18 inches (457 mm) below grade or the frost depth, whichever is deeper. Footing to be reinforced with No. 4 bars at 24 inches (610 mm) on center when supporting more than the roof and one floor.
[4]From Table 21-C or local snow load tables. For areas without snow loads use 20 pounds per square foot (0.96 kN/m²).
[5]From Table 21-A. For intermediate floor loads go to next higher value.

TABLE A-21-A-2—INTERIOR FOUNDATION REQUIREMENTS FOR MASONRY BUILDINGS WITH 6- AND 8-INCH-THICK WALLS (Wood or Steel Framing) (Width of Footings in Inches)[1,2,3,4] See Figure A-21-1 for typical details.

WALL HEIGHT (feet)	SPAN TO BEARING WALLS (feet)	ONE-STORY BUILDINGS Roof Live Load[5] × 0.0479 for kN/m²			TWO-STORY BUILDINGS Roof Live Load[5] (psf) × 0.0479 for kN/m²					
					20		30		40	
					Plus Floor Live Load[6] (psf) × 0.0479 for kN/m²					
		20 psf (inches)	30 psf (inches)	40 psf (inches)	50	100	50	100	50	100
		Minimum Width of Footing (inches)								
× 304.8 for mm		× 25.4 for mm								
8	8	12	12	12	12	14	12	14	12	14
	16	12	12	12	16	20	18	20	18	22
	24	12	12	14	20	26	22	28	22	28
	32	14	14	16	24	28	26	32	28	34
10	8	12	12	12	14	16	14	16	14	16
	16	12	12	12	20	24	20	22	20	22
	24	12	14	14	22	28	22	28	22	28
	32	14	14	16	26	34	26	32	28	34
12	8	12	12	12	14	16	16	18	16	18
	16	12	14	16	20	24	20	22	20	22
	24	14	14	16	24	28	22	28	24	28
	32	16	16	18	28	30	28	32	28	34

[1]For buildings with under-floor space or basements, footing thickness is to be a minimum of 12 inches (305 mm). It shall be reinforced with No. 4 bars at 24 inches (610 mm) on center when its width is required to be 18 inches (457 mm) or larger and it supports more than the roof and one floor.

[2]Soil to be at least Class 4 as shown in Table 18-I-A.

[3]Footings are 10 inches (254 mm) thick for up to 24 inches (610 mm) wide and 12 inches (305 mm) thick for up to 34 inches (864 mm) wide. Footings shall be reinforced with No. 4 bars at 24 inches (610 mm) on center when supporting more than the roof and one floor.

[4]These interior footings support roof-ceiling or floors or both for a distance on each side equal to the span length shown. A tributary width equal to the span length may be used.

[5]From Table 16-C or local snow load tables. For areas without snow loads use 20 pounds per square foot (0.96 kN/m²).

[6]From Table 16-A. For intermediate floor loads go to next higher value.

TABLE A-21-B—VERTICAL REINFORCEMENT AND TOP RESTRAINT FOR VARIOUS HEIGHTS OF BASEMENT AND OTHER BELOW-GRADE WALLS

DESIGN ASSUMPTIONS

A. Materials:
1. **Concrete Masonry Units**—Grade hollow load-bearing units conforming to Section 2112.4.2 for strength of units should not be less than that required for applicable f'_m.
2. **Mortar**—Type M, 2,500 psi (17 240 kPa) strength.
3. **Corefill**—Fine or coarse grout (UBC Standard 21-19) with an ultimate strength (28 days) of at least 2,500 psi. (17 240 kPa)
4. **Reinforcement**—Deformed billet-steel bars.
5. 1,500 psf (71.8 kPa) soil bearing required.[1]

B. Allowable stresses in accordance with Section 2106 and Table 21-M.

Soil Equiv.-fluid wt. = 30 pcf[1] (4.71 kN/m^3) — Vertical Reinforcement with Axial Compressive Load (P) Equal to or Less than 5,000 lb./lin. ft. (72.92 kN/m)

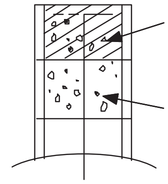
Wall Depth below Grade h (feet) × 304.8 for mm	Floor Connection[2,3] Wood Floor: Bolt and Spacing	Angle Clip Spacing	f'_m = 1,500 psi (10 335 kPa) Spacing of Reinforcement (inches)[4] × 25.4 for mm: No. 3	No. 4	No. 5
8-Inch Walls × 25.4 for mm					
4	$^1/_2$″ at 60″	48″ o.c.	24	40	56
5	$^1/_2$″ at 40″	32″ o.c.	16	24	40
6	$^5/_8$″ at 32″	20″ o.c.	—	16	24

10-Inch Walls × 25.4 for mm			Spacing of Reinforcement (inches) × 25.4 for mm: No. 4	No. 5	No. 6	No. 7
6	$^5/_8$″ at 32″	20″ o.c.	40	56	64	72
7	$^5/_8$″ at 24″	16″ o.c.	24	40	48	56
9	$^3/_4$″ at 20″	2 at 24″ o.c.	16	24	32	40

12-Inch Walls × 25.4 for mm			Spacing of Reinforcement (inches) × 25.4 for mm: No. 4	No. 5	No. 6	No. 7
7	$^5/_8$″ at 24″	16″ o.c.	40	56	80	80
8	$^3/_4$″ at 20″	2 at 24″ o.c.	32	48	56	64
9	$^7/_8$″ at 18″	2 at 18″ o.c.	24	40	48	48
10	1″ at 16″	2 at 16″ o.c.	16	32	40	40

[1]Soil type is at least Class 4 as shown in Table 18-I-A.
[2]There shall be no backfill placed until after the wall is anchored to the floor and seven days have passed after grouting.
[3]For Figure A-21-4 only.
[4]See Figure A-21-5 for placement of reinforcement.

TABLE A-21-C-1—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 6-INCH-THICK (153 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5]
(Wood or Steel Roof and Floor Framing)



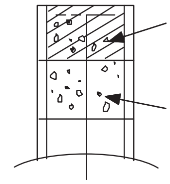
Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m^2 to 1.9 kN/m^2); Floor Live Load = 50 psf (2.4 kN/m^2); enclosed building[6]

EXPOSURE	STORIES	UNSUPPORTED HEIGHT (feet) × 304.8 for mm	80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet) × 304.8 for mm															
			8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
			Size of Rebar and Spacing (inches) × 25.4 for mm															
B	One-story building	8	NR*								No. 4 80	No. 4 80	No. 4 80	No. 4 80	No. 4 64	No. 4 64	No. 4 72	No. 4 88
		10	No. 4 80	No. 4 88	No. 4 96	No. 4 96	No. 4 64	No. 4 64	No. 4 72	No. 4 80	No. 4 48	No. 4 48	No. 4 48	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 48
		12	No. 4 48	No. 4 48	No. 4 56	No. 4 64	No. 4 40	No. 4 40	No. 4 48	No. 4 48	No. 5 48	No. 5 48	No. 5 56	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40
	Two-story building		Design required or use 8-inch or larger units for two-story condition.															
C	One-story building	8	No. 4 72	No. 4 72	No. 4 72	No. 4 96	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 48	No. 4 48	No. 4 32	No. 4 32	No. 4 32	No. 4 40
		10	No. 4 40	No. 4 40	No. 4 40	No. 4 48	No. 4 32	No. 4 32	No. 4 32	No. 4 32	No. 5 40	No. 5 40	No. 5 40	No. 5 48	No. 5 32	No. 5 32	No. 5 32	No. 5 40
		12	No. 5 40	No. 5 48	No. 5 48	No. 5 48	No. 5 32	No. 5 32	No. 5 32	No. 5 40	Use 8-inch or larger units							
	Two-story building		Design required or use 8-inch or larger units for two-story condition.															
D	One-story building	8	No. 4 56	No. 4 56	No. 4 64	No. 4 80	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 4 32	No. 4 40	No. 4 40	No. 4 40	No. 4 32	No. 4 32	No. 4 32	No. 4 32
		10	No. 4 32	No. 4 32	No. 4 32	No. 4 40	No. 5 40	No. 5 40	No. 5 48	No. 5 48	No. 5 48	No. 5 32	No. 5 32	No. 5 40				
		12	No. 5 32	No. 5 40	No. 5 40	No. 5 40	Use 8-inch or larger units											
	Two-story building		Design required or use 8-inch or larger units for two-story condition.															

*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.
[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60. The vertical bars are centered in the middle of the wall.
[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.
[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.
[5]Hook vertical bars over bond beam bars as shown. Extend bars into footing using lap splices where necessary.
[6]Design required for open buildings of 6-inch-thick (153 mm) masonry.
To use this table, check criteria by the following method:
6.1 Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.
6.2 Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.
6.3 Choose proper floor load from Table 16-A. [For loads less than 50 pounds per square foot (psf) (2.4 kN/m^2), use 50 psf (2.4 kN/m^2), and for loads between 50 psf (2.4 kN/m^2) and 100 psf (4.8 kN/m^2), use 100 psf (4.8 kN/m^2).]
6.4 Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.
6.5 Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.
6.6 Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)
6.7 For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-C-2—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 8-INCH-THICK (203 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5] (Wood or Steel Roof and Floor Framing)



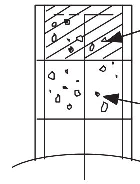
Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m^2 to 1.9 kN/m^2); Floor Live Load = 50 psf (2.4 kN/m^2); enclosed building

EXPO-SURE	STORIES	UNSUP-PORTED HEIGHT (feet) × 304.8 for mm	80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet)															
			× 304.8 for mm															
			8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
			Size of Rebar and Spacing (inches)															
			× 25.4 for mm															
B	One-story building or top story of two-story building	8	NR*												No. 3 56	No. 3 56	No. 3 64	No. 3 64
		10					No. 4 80	No. 4 80	No. 4 88	No. 4 88	No. 4 64	No. 4 64	No. 4 64	No. 4 72	No. 4 48	No. 4 48	No. 4 56	No. 4 56
		12	No. 4 64	No. 4 72	No. 4 72	No. 4 72	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 5 64	No. 5 64	No. 5 56	No. 5 56	No. 5 56	No. 5 56
	First story of a two-story building	8	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 96	No. 3 88	No. 3 80	No. 3 72	No. 3 72	No. 3 72	No. 3 64	No. 3 64
		10	No. 3 88	No. 3 80	No. 3 72	No. 3 64	No. 3 64	No. 3 64	No. 3 56	No. 3 56	No. 4 72	No. 4 72	No. 4 64	No. 4 64	No. 4 64	No. 4 56	No. 4 56	No. 4 56
		12	No. 4 80	No. 4 72	No. 4 64	No. 4 64	No. 4 64	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 5 64	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48
C	One-story building or top story of two-story building	8	NR*				No. 3 48	No. 3 48	No. 3 48	No. 3 56	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 48	No. 4 56	No. 4 56	No. 4 56
		10	No. 4 56	No. 4 56	No. 4 64	No. 4 64	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		12	No. 5 56	No. 5 64	No. 5 64	No. 5 64	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 6 56	No. 6 56	No. 6 56	No. 6 56	No. 6 40	No. 6 40	No. 6 40	No. 6 48
	First story of a two-story building	8	No. 3 80	No. 3 80	No. 3 56	No. 3 72	No. 3 56	No. 3 56	No. 3 56	No. 3 56	No. 4 72	No. 4 72	No. 4 72	No. 4 64	No. 4 56	No. 4 56	No. 4 56	No. 4 56
		10	No. 4 72	No. 4 64	No. 4 64	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 5 64	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		12	No. 5 64	No. 5 64	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 6 56	No. 6 56	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40
D	One-story building or top story of two-story building	8	No. 3 48	No. 3 48	No. 3 56	No. 3 56	No. 4 64	No. 4 72	No. 4 72	No. 4 80	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 48	No. 4 48	No. 4 48
		10	No. 4 48	No. 4 48	No 4 48	No. 4 56	No. 5 56	No. 5 64	No. 5 64	No. 5 64	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40
		12	No. 5 48	No. 5 48	No. 5 56	No. 5 56	No. 6 56	No. 6 56	No. 6 56	No. 6 56	No. 6 48	No. 6 48	No .6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40
	First story of a two-story building	8	No. 3 64	No. 3 64	No. 3 64	No. 3 56	No. 4 80	No. 4 80	No. 4 72	No. 4 72	No. 4 64	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 4 48
		10	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 5 64	No. 5 64	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 32
		12	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 6 56	No. 6 56	No. 6 56	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32

*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.
[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60.
[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.
[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.
[5]Hook vertical bars over bond beam as shown. Extend bars into footing using lap splices where necessary. Where second-story bar spacing does not match those on the first story, hook bars around floor bond beam also.
To use this table, check criteria by the following method:
5.1 Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.
5.2 Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.
5.3 Choose proper floor load from Table 16-A. [For loads less that 50 psf (2.4 kN/m^2), use 50 psf (2.4 kN/m^2), and for loads between 50 psf (2.4 kN/m^2) and 100 psf (4.8 kN/m^2), use 100 psf (4.8 kN/m^2).]
5.4 Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.
5.5 Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.
5.6 Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)
5.7 For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-C-3—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 8-INCH-THICK (203 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5]
(Wood or Steel Roof and Floor Framing)



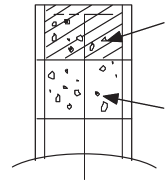
Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m^2 to 1.9 kN/m^2);
Floor Live Load = 100 psf (4.8 kN/m^2); enclosed building

EXPOSURE	STORIES	UNSUPPORTED HEIGHT (feet) × 304.8 for mm	80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet)															
			× 304.8 for mm															
			8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
			Size of Rebar and Spacing (inches)															
			× 25.4 for mm															
B	One-story building or top story of two-story building	8	NR*	NR*	NR*	NR*	NR*	NR*	NR*	NR*	NR*	NR*	NR*	NR*	No. 3 56	No. 3 56	No. 3 64	No. 3 64
		10	NR*	NR*	NR*	NR*	No. 4 64	No. 4 64	No. 4 64	No. 4 72	No. 4 64	No. 4 64	No. 4 64	No. 4 72	No. 4 48	No. 4 48	No. 4 56	No. 4 56
		12	No. 4 64	No. 4 72	No. 4 72	No. 4 72	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 56	No. 5 56	No. 5 56	No. 5 56
	First story of a two-story building	8	No. 3 96	No. 3 96	No. 3 80	No. 3 64	No. 3 96	No. 3 88	No. 3 72	No. 3 56	No. 3 80	No. 3 64	No. 3 56	No. 3 48	No. 3 64	No. 3 56	No. 3 48	No. 4 64
		10	No. 3 72	No. 3 64	No. 3 56	No. 3 48	No. 3 56	No. 3 48	No. 4 64	No. 4 56	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 5 56
		12	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 4 40	No. 4 48	No. 4 40	No. 5 48	No. 5 48	No. 5 56	No. 5 48	No. 5 48	No. 5 40
C	One-story building or top story of two-story building	8	NR*	NR*	NR*	NR*	No. 3 48	No. 3 48	No. 3 48	No. 3 56	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 48	No. 4 56	No. 4 56	No. 4 56
		10	No. 4 56	No. 4 56	No. 4 64	No. 4 64	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		12	No. 4 40	No. 5 64	No. 5 64	No. 5 64	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 6 56	No. 6 56	No. 6 56	No. 6 40	No. 6 40	No. 6 40	No. 5 32
	First story of a two-story building	8	No. 3 72	No. 3 64	No. 3 56	No. 3 48	No. 3 56	No. 3 48	No. 4 64	No. 4 56	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 5 56
		10	No. 4 64	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40
		12	No. 4 40	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 6 48	No. 5 40	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 32
D	One-story building or top story of two-story building	8	No. 3 48	No. 3 48	No. 3 56	No. 3 56	No. 3 64	No. 4 72	No. 4 72	No. 4 80	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 48	No. 4 48	No. 4 48
		10	No. 4 48	No. 4 48	No 4 48	No. 4 56	No. 5 56	No. 5 64	No. 5 64	No. 5 64	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40
		12	No. 5 48	No. 5 48	No. 5 56	No. 5 56	No. 5 40	No. 5 40	No. 6 56	No. 6 56	No. 6 48	No. 6 48	No .6 48	No. 5 32	No. 6 40	No. 6 40	No. 6 40	No. 6 40
	First story of a two-story building	8	No. 3 56	No. 3 56	No. 3 48	No. 4 64	No. 3 48	No. 4 64	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 5 64	No. 4 48	No. 5 64	No. 5 56	No. 5 56
		10	No. 4 56	No. 4 48	No. 4 48	No. 5 56	No. 5 64	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48
		12	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 40	No. 6 48	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32	No. 6 32	No. 6 24

*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.
[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60.
[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.
[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.
[5]Hook vertical bars over bond beam as shown. Extend bars into footing using lap splices where necessary. Where second-story bar spacing does not match those on the first story, hook bars around floor bond beam also.
To use this table, check criteria by the following method:
- [5.1]Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.
- [5.2]Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.
- [5.3]Choose proper floor load from Table 16-A. [For loads less than 50 psf (2.4 kN/m^2), use 50 psf (2.4 kN/m^2), and for loads between 50 psf (2.4 kN/m^2) and 100 psf (4.8 kN/m^2), use 100 psf (4.8 kN/m^2).]
- [5.4]Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.
- [5.5]Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.
- [5.6]Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)
- [5.7]For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-C-4—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 8-INCH-THICK (203 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5]
(Wood or Steel Roof and Floor Framing)



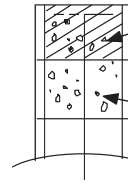
Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m^2 to 1.9 kN/m^2); Floor Live Load = 50 psf (2.4 kN/m^2); partially enclosed building

EXPOSURE	STORIES	UNSUPPORTED HEIGHT (feet) × 304.8 for mm	80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet) × 304.8 for mm															
			8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
			Size of Rebar and Spacing (inches) × 25.4 for mm															
B	One-story building or top story of two-story building	8	No. 4 96	No. 4 96	No. 3 80	No. 3 88	No. 3 56	No. 3 56	No. 3 64	No. 3 64	No. 3 40	No. 3 48	No. 3 48	No. 3 48	No. 4 64	No. 4 64	No. 4 64	No. 4 72
		10	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 48	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 56	No. 5 56	No. 5 56
		12	No. 4 40	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 48
	First story of a two-story building	8	No. 3 96	No. 3 96	No. 3 88	No. 3 80	No. 3 72	No. 3 72	No. 3 64	No. 3 64	No. 3 48	No. 3 48	No. 3 48	No. 3 48	No. 4 64	No. 4 64	No. 4 64	No. 4 64
		10	No. 3 48	No. 3 48	No. 3 48	No. 3 48	No. 4 64	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 4 40	No.4 40	No. 5 56	No. 5 56	No. 5 48
		12	No. 4 48	No. 4 48	No. 4 48	No. 4 40	No. 4 40	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 48
C	One-story building or top story of two-story building	8	No. 3 40	No. 3 40	No. 3 40	No. 3 40	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56
		10	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 32	No. 5 32	No. 5 40	No. 5 40	No. 6 40	No. 6 40	No. 6 40	No. 6 40
		12	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 40	No. 6 48	No. 6 48	No. 6 48	No. 6 32	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
	First story of a two-story building	8	No. 3 48	No. 3 48	No. 3 48	No. 3 48	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 48	No. 4 48	No. 4 40	No. 4 40	No. 5 56	No. 5 56	No. 5 56	No. 5 48
		10	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40
		12	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
D	One-story building or top story of two-story building	8	No. 4 56	No. 4 56	No. 4 56	No. 4 64	No. 4 40	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		10	No. 5 48	No. 5 48	No. 5 48	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 56	No. 6 48	No. 6 48	No. 6 48	No. 6 32	No. 6 32	No. 6 40	No. 6 40
		12	No. 6 48	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 24	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
	First story of a two-story building	8	No. 4 64	No. 4 64	No. 4 64	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 4 48	No. 4 40	No. 4 40	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 40
		10	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32
		12	No. 6 48	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	Use 10-inch or larger units									

*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.
[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60.
[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.
[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.
[5]Hook vertical bars over bond beam as shown. Extend bars into footing using lap splices where necessary.
To use this table, check criteria by the following method:
5.1 Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.
5.2 Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.
5.3 Choose proper floor load from Table 16-A. [For loads less than 50 psf (2.4 kN/m^2), use 50 psf (2.4 kN/m^2), and for loads between 50 psf (2.4 kN/m^2) and 100 psf (4.8 kN/m^2) , use 100 psf (4.8 kN/m^2).]
5.4 Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.
5.5 Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.
5.6 Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)
5.7 For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-C-5—VERTICAL REINFORCING STEEL REQUIREMENTS FOR 8-INCH-THICK (203 mm) MASONRY WALLS[1] IN AREAS WHERE BASIC WIND SPEEDS ARE 80 MILES PER HOUR (129 km/h) OR GREATER[2,3,4,5]
(Wood or Steel Roof and Floor Framing)



Criteria: Roof Live Load = 20 psf to 40 psf (0.96 kN/m^2 to 1.9 kN/m^2); Floor Live Load = 100 psf (4.8 kN/m^2); partially enclosed building

EXPOSURE	STORIES	UNSUPPORTED HEIGHT (feet) × 304.8 for mm	80 MPH				90 MPH				100 MPH				110 MPH			
			× 1.61 for km/h															
			Span between Bearing Walls (feet) × 304.8 for mm															
			8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
			Size of Rebar and Spacing (inches) × 25.4 for mm															
B	One-story building or top story of two-story building	8	No. 3 72	No. 4 96	No. 3 80	No. 3 88	No. 3 56	No. 3 56	No. 3 64	No. 3 64	No. 4 80	No. 4 80	No. 4 80	No. 4 88	No. 4 64	No. 4 64	No. 4 64	No. 4 72
		10	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 48	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 56	No. 5 56	No. 5 56
		12	No. 4 40	No. 4 48	No. 4 48	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 48
	First story of a two-story building	8	No. 3 88	No. 3 96	No. 3 56	No. 4 72	No. 3 64	No. 3 56	No. 3 64	No. 4 64	No. 4 80	No. 4 72	No. 4 64	No. 4 56	No. 4 64	No. 4 56	No. 4 48	No. 4 48
		10	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 4 40	No. 4 48	No. 4 40	No. 5 56	No. 5 48	No. 5 56	No. 5 48	No. 5 48	No. 5 40
		12	No. 4 48	No. 4 40	No. 4 40	No. 5 48	No. 5 56	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40
C	One-story building or top story of two-story building	8	No. 4 64	No. 4 64	No. 4 72	No. 4 72	No. 4 56	No. 4 56	No. 4 56	No. 4 56	No. 4 40	No. 4 40	No. 4 40	No. 4 48	No. 5 56	No. 5 56	No. 5 56	No. 5 56
		10	No. 5 56	No. 5 56	No. 4 40	No. 4 40	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 32	No. 6 56	No. 6 56	No. 5 40	No. 6 40	No. 6 40	No. 6 40	No. 6 40
		12	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 40	No. 6 48	No. 6 48	No. 6 48	No. 6 32	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
	First story of a two-story building	8	No. 4 72	No. 4 64	No. 4 56	No. 4 48	No. 4 56	No. 4 48	No. 4 48	No. 4 40	No. 4 40	No. 4 40	No. 4 40	No. 5 48	No. 5 56	No. 5 48	No. 5 48	No. 5 40
		10	No. 5 64	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 32
		12	No. 5 40	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units				
D	One-story building or top story of two-story building	8	No. 4 56	No. 4 56	No. 4 56	No. 4 64	No. 4 40	No. 5 72	No. 5 72	No. 5 72	No. 5 56	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48
		10	No. 5 48	No. 5 48	No. 5 48	No. 5 56	No. 5 40	No. 5 40	No. 5 40	No. 5 40	No. 6 56	No. 6 48	No. 6 48	No. 6 48	No. 6 32	No. 6 32	No. 6 40	No. 6 40
		12	No. 6 48	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 24	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units			
	First story of a two-story building	8	No. 4 64	No. 4 56	No. 4 48	No. 4 48	No. 4 48	No. 5 64	No. 5 56	No. 5 56	No. 5 56	No. 5 48	No. 5 48	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40
		10	No. 5 56	No. 5 48	No. 5 48	No. 5 40	No. 5 40	No. 5 40	No. 6 48	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32
		12	No. 6 48	No. 6 48	No. 6 40	No. 6 40	No. 6 40	No. 6 32	No. 6 32	No. 6 32	Use 10-inch or larger units							

*NR — No vertical reinforcement required. However, see Table A-21-F for shear wall reinforcement.

[1]These values are for walls with running bond. For stack bond see Section 2112.8.3.
[2]The figure on top of the listed data is the bar size; the figure below it is the maximum spacing in inches (mm). Reinforcing bar strength shall be A 615 Grade 60.
[3]Roof load is assumed to be concentrically loaded on the wall. For roofs which hang on ledgers, a design is required.
[4]Minimum horizontal reinforcement shall be one No. 4 at the ledger and foundation. Also, see Table A-21-E for lintels and Table A-21-F for shear wall reinforcing where applicable.
[5]Hook vertical bars over bond beam as shown. Extend bars into footing using lap splices where necessary.
To use this table, check criteria by the following method:
- 5.1 Choose proper roof live load from Table 16-C or snow load criteria for the locality in which the building is located.
- 5.2 Check if building is enclosed or partially enclosed by the procedure in Chapter 16, Part III.
- 5.3 Choose proper floor load from Table 16-A. [For loads less than 50 psf (2.4 kN/m^2), use 50 psf (2.4 kN/m^2), and for loads between 50 psf (2.4 kN/m^2) and 100 psf (4.8 kN/m^2), use 100 psf (4.8 kN/m^2).]
- 5.4 Find proper wind speed and exposure for the site—see Figure 16-1, Chapter 16, Sections 1619 and 1620.
- 5.5 Within the proper vertical column, choose appropriate span-to-bearing wall and appropriate height and story.
- 5.6 Read proper size and spacing of reinforcement for the thickness of the wall mentioned in the title of the table. (Equivalent area of steel, taking spacing into account, may be substituted.)
- 5.7 For buildings in Seismic Zone 2 (see Figure 16-2 in Chapter 16), use minimum reinforcement in Figure A-21-2 if it is more restrictive than the table values.

TABLE A-21-D—ANCHORAGE OF WOOD MEMBERS TO EXTERIOR WALLS FOR VERTICAL AND UPLIFT FORCES

[In areas where basic wind speeds are 80 miles per hour (129 km/h) or greater]

See Figure A-21-7 for details

Part I—Anchor bolt size and spacing [in inches (mm)][1,2,3] on wood ledgers carrying vertical loads from roofs and floors[4,5] Douglas fir-larch, California redwood (close grain) and southern pine[6,7]

TYPE OF LOADING	LIVE LOAD[8,9] psf	2-INCH (51 mm) × LEDGER				3-INCH (76 mm) × LEDGER				4-INCH (102 mm) × LEDGER			
		Span between Bearing Walls (feet)											
		× 304.8 for mm											
		8	16	24	32	8	16	24	32	8	16	24	32
	× 0.0479 for kN/m^2)	× 25.4 for mm											
Roof	20	$^1/_2$ 32	(2)$^1/_2$ 16	$^5/_8$ 16	$^7/_8$ 16	$^1/_2$ 32	$^1/_2$ 16	(2)$^1/_2$ 32	$^7/_8$ 16	— —	$^5/_8$ 32	$^7/_8$ 32	(2)$^5/_8$ 32
	30	(2)$^1/_2$ 32	$^1/_2$ 16	$^3/_4$ 16	$^7/_8$ 16	$^1/_2$ 16	(2)$^7/_8$ 32	$^7/_8$ 16	$^7/_8$ 16	— —	(2)$^1/_2$ 32	$^5/_8$ 16	$^3/_4$ 16
	40	$^1/_2$ 16	$^5/_8$ 16	$^3/_4$ 8	— —	$^5/_8$ 16	(2)$^5/_8$ 32	$^7/_8$ 16	1 16	$^5/_8$ 32	$^5/_8$ 16	$^3/_4$ 16	$^7/_8$ 16
Floor[10]	50	$^1/_2$ 16	1 12	— —	— —	$^5/_8$ 24	$^3/_4$ 32	$^3/_4$ 12	1$^1/_4$ 12	$^5/_8$ 24	$^7/_8$ 24	$^7/_8$ 16	$^7/_8$ 12
	100	1 16	(2)$^3/_4$ 12	— —	— —	$^5/_8$ 16	1 12	(2)$^3/_4$ 12	(2)1 12	$^7/_8$ 16	$^3/_4$ 12	1 12	(2)$^3/_4$ 12

[1]Closer spacing may be used.
[2]Use two bolts, one above the other, at splices and locate them away from the splice end by 3$^1/_2$ inches (89 mm) for $^1/_2$-inch (13 mm) diameter, 4$^1/_2$ inches (114.3 mm) for $^5/_8$-inch (15.9 mm) diameter, 5$^1/_4$ inches (133 mm) for $^3/_4$-inch (19 mm) diameter, 6$^1/_4$ inches (158 mm) for $^7/_8$-inch (22.2 mm) diameter and 7 inches (178 mm) for 1-inch (25.4 mm) diameter.
[3]See Table A-21-F for lateral force requirements (when applicable).
[4]Tabulated values are based on short-term loading due to roof loads (25 percent) or snow loads (15 percent), whichever controls. No increase is allowed for floor loads.
[5]See details in Figure A-21-7 for location relative to other construction. Note that roofs are concentrically loaded.
[6]See Chapter 23, Division III, Part I, for other species. Adjust spacing in direct proportion to the perpendicular-to-grain values for the applicable ledger and bolt sizes shown using the procedure described in Chapter 23, Division III, Part I. No increase is allowed for special inspection.
[7]Values on top are bolt sizes and underneath are spacing. Multiple bolts are shown in parenthesis: example (2) = two.
[8]See Table 16-C or Appendix Chapter 16, Division I, for values.
[9]Joist spacing is limited to 30 inches (762 mm) on center maximum.
[10]Where two bolts are required they shall be staggered at half the spacing shown or be placed one above the other.

Part II—Uplift anchors[1] for wood roof members [number of common nails in a 0.036 inch (0.91 mm) (No. 20 galvanized sheet gage) by 1$^1/_8$-inch (28.6 mm) tie strap embedded 5 inches (127 mm) into a masonry bond beam[2]]

ENCLOSURE[3]	EXPOSURE[4]	80 MPH				90 MPH				100 MPH				110 MPH			
		× 1.61 for km/h															
		Span between Bearing Walls (feet)[5]															
		× 304.8 for mm															
		8	16	24	32	8	16	24	32	8	16	24	32	8	16	24	32
Enclosed	B	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	2-8d	2-8d
	C	NR	NR	NR	NR	NR	2-8d	3-8d	4-8d	2-8d	4-8d	5-10d	5-10d	2-10d	4-10d	3-10d 24″	4-10d 24″
	D	NR	2-8d	3-8d	4-8d	2-8d	4-8d	4-10d	5-10d	3-8d	5-8d	5-10d	4-10d 24″	3-10d	5-10d	4-10d 24″	5-10d 24″
Open	B	NR	NR	NR	NR	NR	NR	2-8d	2-8d	NR	2-8d	4-8d	5-10d	2-8d	4-8d	5-8d	6-10d
	C	2-8d	4-8d	5-8d	5-10d	3-8d	5-8d	3-10d 24″	4-10d 24″	3-10d	5-10d	5-10d 24″	5-10d 16″	5-8d	4-10d 24″	5-10d 16″	6-10d 16″
	D	2-8d	5-8d	5-10d	5-10d 24″	4-8d	5-10d	4-10d 24″	5-10d 24″	5-8d	4-10d 24″	6-10d 24″	6-10d 16″	4-8d	5-10d 24″	6-10d 16″	6-10d 12″

NR — No requirements; use Table 23-II-B-1 minimum.

[1]Tie straps are at 48 inches (1219 mm) on center unless otherwise stated. See Figure A-21-7 for illustration of tie straps.
[2]Bond beam to be at least 48 inches (1219 mm) deep nominal and shall be reinforced as shown in Table A-21-E for lintels, or Tables A-21-C-1 through A-21-C-5 for walls in general where they are more restrictive.
[3]See Chapter 21, Part II, for definitions.
[4]See Section 1616 for definitions.
[5]For flat roofs connected to interior walls, the span shall be one half the larger distance on either side of the wall.

TABLE A-21-E—LINTEL REINFORCEMENT OVER EXTERIOR OPENINGS[1,2]—WOOD AND STEEL FRAMING[3]
[Lintels larger than 12 feet 0 inch (3658 mm) shall be designed.][4]
8-INCH (203 mm) MASONRY UNITS[5]

Part I—Roof Loads[5]

ANY WALL HEIGHT (feet)	SPAN TO BEARING WALLS (feet)[9]	SECOND STORY OF A TWO-STORY OR ONE-STORY BUILDINGS ROOF LIVE LOAD[6,7,8]					
		20-30 psf			40 psf		
		× 0.0479 for kN/m²					
		Width of Opening[9] (feet)					
		× 304.8 for mm					
		4	8	12	4	8	12
		Lintel depth (inches) number and size of rebar					
× 304.8 for mm		× 25.4 for mm					
Any (up to 12′)	8	8 1 No. 3	8 1 No. 3	16 1 No. 4 (B)	8 1 No. 3	8 1 No. 4	16 1 No. 4 (B)
	16	8 1 No. 3	8 1 No. 3	16 1 No. 4 (B)	8 1 No. 3	8 2 No. 4 (A)	16 2 No. 5 (B)
	24	8 1 No. 3	8 1 No. 4	16 1 No. 4 (B)	8 1 No. 3	16 1 No. 4 (B)	24 2 No. 5 (B)
	32	8 1 No. 3	16 1 No. 4 (B)	16 1 No. 5 (B)	8 1 No. 3	16 1 No. 5 (B)	24 2 No. 5 (C)

Part II—Floor and Roof Loads[5]

WALL HEIGHT	SPAN TO BEARING[9,11] WALLS (feet)	FIRST STORY OF TWO-STORY BUILDINGS FLOOR LIVE LOAD[10]					
		50 psf			100 psf		
		× 0.0479 for kN/m²					
		Width of Opening[9] (feet)					
		× 304.8 for mm					
		4	8	12	4	8	12
		Lintel depth (inches) number and size of rebar					
× 304.8 for mm		× 25.4 for mm					
Any (up to 12′)	8	8 1 No. 3	8 1 No. 4	16 1 No. 4 (B)	8 1 No. 3	8 2 No. 4 (A)	16 2 No. 5 (B)
	16	8 1 No. 3	8 2 No. 4 (A)	16 2 No. 5 (B)	8 1 No. 3	16 1 No. 4 (B)	24 2 No. 4 (C)
	24	8 1 No. 3	16 1 No. 4 (B)	24 2 No. 5 (B)	8 1 No. 3 (A)	16 1 No. 5 (B)	24 3 No. 5 (C)
	32	8 1 No. 3	16 1 No. 5 (B)	24 2 No. 5 (C)	8 1 No. 4 (B)	24 2 No. 5 (C)	Design Required

[1]The values shown are number and size of A 615, 60 grade steel reinforcement bars: Example—2 No. 4 is two $^1/_2$-inch-diameter (13 mm) deformed reinforcing bars. See also Figure A-21-8 for continuous load path.
[2]Stirrup spacing requirements: A = No. 3 at 8 inches (203 mm) on center, B = No. 3 at 4 inches (102 mm) on center, C = No. 4 at 8 inches (203 mm) on center. None are required unless specifically mentioned in the table.
[3]Design required for lintels supporting precast planks.
[4]Lintels are 8-inch (203 mm) nominal depth where supporting roof loads only and 16-inch (406 mm) nominal depth where supporting floor and roofs unless otherwise stated. All lintels are solidly grouted.
[5]Wall weight is included.
[6]The stirrup size and spacing, where required, as indicated in parenthesis below the reinforcing bar requirements.
[7]All exposure categories are included for wind uplift on the lintel. See Footnote 4 of Tables A-21-C-1 through A-21-C-5 as a minimum bond beam. Table A-21-F may also control.
[8]Two No. 5 vertical bars minimum are required on each side of the lintel for 100 and 110 miles per hour (161 and 177 km/h), Exposure D. Bar to extend 25 inches (635 mm) beyond opening or hook over top bars.
[9]For spans between the figures shown, go to next higher span width.
[10]From Table 21-A. For other floor loads go to next higher value. Where required floor load exceeds 100 pounds per square foot (4.8 kN/m²), a design is required.
[11]When interior walls support floors from each side, these values may be used if the spans on each side are less than 16 feet 0 inch (4877 mm) each. Enter the table with the total of both span widths.

TABLE A-21-F—MASONRY SHEAR WALL[1,2,3] AND DIAPHRAGM REQUIREMENTS IN HIGH-WIND AREAS[4]

Part I—Minimum wall length and horizontal bar reinforcement required for exterior shear walls and cross walls[5] (all wall heights). [Design criteria: 20 psf to 40 psf (0.96 kN/m^2 to 1.9 kN/m^2) roof load; 50 psf or 100 psf (2.4 kN/m^2 or 4.8 kN/m^2) floor load; open or enclosed buildings.]

8-INCH (203 mm) WALLS[6]				
Wind Speed	Exposure	Distance between Shear Resisting Walls[7] "*L*" or "*b*" (feet)	One-story Building or Second Story of a Two-story Building	First Story of a Two-story Building
× 1.61 for km/h		× 304.8 for mm	inch × 25.4 for mm foot × 304.8 mm	
80 mph	B	32	NSR	9′-4″
		48	NSR	5′-4″ DBL (D)
		64	10′-0″	7′-6″ DBL (C)
	C	32	NSR	5′-4″ DBL (C)
		48	11′-0″	8′-8″ DBL (C)
		64	13′-4″	15′-0″ (D)
	D	32	8′-8″	7′-0″ (C)
		48	9′-4″ (C)	10′-8″ (D)
		64	10′-0″ (D)	13′-8″ (D)
90 mph	B	32	NSR	7′-8″ DBL (C)
		48	NSR	8′-0″ (D)
		64	12′-8″	12′-0″ (D)
	C	32	NSR	14′-8″
		48	13′-8″	10′-0″ (D)
		64	10′-8″ (C)	15′-6″ DBL (B)
	D	32	7′-8″ (C)	11′-8″ (D)
		48	12′-0″ (C)	12′-8″ DBL (B)
		64	11′-8″ (D)	18′-4″ DBL (C)
100 mph	B	32	NSR	5′-4″ DBL (C)
		48	10′-0″	10′-0″ (D)
		64	15′-4″	64′-8″ DBL (C)

(Continued)

TABLE A-21-F—MASONRY SHEAR WALL[1,2,3] AND DIAPHRAGM REQUIREMENTS IN HIGH-WIND AREAS[4]—(Part I Continued)

8-INCH (203 mm) WALLS[6]				
Wind Speed	Exposure	Distance between Shear Resisting Walls[7] "*L*" or "*b*" (feet)	One-story Building or Second Story of a Two-story Building	First Story of a Two-story Building
× 1.61 for km/h		× 304.8 for mm	inch × 25.4 for mm foot × 304.8 mm	
100 mph (cont.)	C	32	5′-4″ (D)	11′-8″ (D)
		48	12′-8″ (C)	12′-8″ DBL (C)
		64	12′-4″ (D)	19′-8″ DBL (C)
	D	32	5′-4″ DBL (B)	9′-4″ DBL (C)
		48	9′-4″ (D)	14′-8″ DBL (C)
		64	17′-4″ (D)	21′-0″ DBL (C)
110 mph	B	32	NSR	6′-0″ DBL (C)
		48	12′-0″	10′-0″ DBL (C)
		64	12′-8″ (C)	14′-0″ (D)
	C	32	5′-4″ DBL (B)	9′-8″ (D)
		48	12′-0″ (C)	15′-4″ (D)
		64	16′-8″ (C)	18′-8″ DBL (C)
	D	32	8′-8″ (C)	11′-4″ (D)
		48	12′-4″ (C)	18′-0″ (D)
		64	18′-8″ (C)	20′-8″ DBL (C)

*NSR—No special horizontal reinforcement required for shear resistance if 5 feet 4 inches (1626 mm) long minimum.

[1]Cumulative shear wall length is to be at least as long as is shown in this table. However, see Figure A-21-9. The top figure is the minimum length. When required, the figure below it in parenthesis is the spacing of steel reinforcing wire installed as shown in Figure A-21-10, below. (A) = two 0.148 inch (3.76 mm) (No. 9 B.W. gage) at 16 inches (406 mm) on center, (B) = two $^3/_{16}$ inch (4.76 mm) at 16 inches (406 mm) on center, (C) = two 0.148 inches (3.76 mm) (No. 9 B.W. gage) at 8 inches (203 mm) on center, (D) = two $^3/_{16}$ inch (4.76 mm) at 8 inches (203 mm) on center. The symbol DBL means double these amounts. Equivalent areas of reinforcing bars spaced not over 4 feet 0 inch (1219 mm) on center may be used.
[2]All bearing and shear walls are to be in-plane with vertical reinforcement, when required, extending from one floor to the other as dictated in Tables A-21-C-1 through A-21-C-5.
[3]Minimum bond beam shall be 100 miles per hour (mph) (161 km/h), Exposure B; 90 mph (145 km/h), Exposure B, and 80 mph (129 km/h), Exposures B and C, one No. 4; 100 mph (161 km/h), Exposure C; 80 and 90 mph (129 and 145 km/h); Exposures C and D, two No. 4; all others two No. 5.
[4]Table is adjusted to include provisions for Seismic Zones 0, 1 and 2.
[5]Cross walls are to be at least twice as long as shown in the table for shear walls. The tributary width (*L*/2) shall be the distance used in the third column above to find minimum reinforcement and length.
[6]For walls which width is equal to or less than half its height, add an extra No. 5 vertical bar at each end.
[7]Use 32-foot (9753 mm) requirements for distances less than 32 feet (9754 mm). Also use it for bearing walls used as shear walls.

(Continued)

TABLE A-21-F—MASONRY SHEAR WALL[1,2,3] AND DIAPHRAGM REQUIREMENTS IN HIGH-WIND AREAS[4]—(Continued)

Part II—Wood floor and roof diaphragms and connections[8,9]
[All wall heights 8 feet to 12 feet (2438 mm to 3657 mm).]

FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE					
Wind Speed × 1.61 for km/h	Exposure	Distance between Shear Walls[10] "*L*" or "*b*" (feet) × 304.8 for mm	Minimum Wood Structural Panel/Particleboard Size[9] and Nailing[11,12]		
			Thickness (inches) × 25.4 for mm	Common Nail Size (penny)	Nail Spacing (inches) × 25.4 for mm
80 mph	B	16	5/16	6	6 o.c.
		32	3/8	6	6 o.c.
		48	3/8	8	6 o.c.
		64	3/8	8	6 o.c.
	C	16	3/8	8	6 o.c.
		32	1/2 or 15/32	8	6 o.c.
		48	1/2 or 15/32	10	6 o.c.
		64	5/8 or 19/32	10	6 o.c.
	D	16	1/2 or 15/32	8	6 o.c.
		32	5/8 or 19/32	10	6 o.c.
		48	1/2 or 15/32 blocked	8	4/6 o.c.
		64	1/2 or 15/32 blocked	8	4/6 o.c.
90 mph	B	16	5/16	6	6 o.c.
		32	3/8	8	6 o.c.
		48	3/8	8	6 o.c.
		64	3/8	8	6 o.c.
	C	16	1/2 or 15/32	10	6 o.c.
		32	3/8 blocked	8	4/6 o.c.
		48	3/8 blocked	8	4/6 o.c.
		64	5/8 or 19/32 blocked	10	6 o.c.
	D	16	5/8 or 19/32	10	6 o.c.
		32	1/2 or 15/32 blocked	10	4/6 o.c.
		48	1/2 or 15/32 blocked	10	4/6 o.c.
		64	Design required or provide extra cross walls		
100 mph	B	16	3/8	8	6 o.c.
		32	1/2 or 15/32	8	6 o.c.
		48	1/2 or 15/32	8	6 o.c.
		64	5/8 or 19/32	10	6 o.c.

(Continued)

TABLE A-21-F—MASONRY SHEAR WALL[1,2,3] AND DIAPHRAGM REQUIREMENTS IN HIGH-WIND AREAS[4]—(Part II Continued)

FRAMING OF DOUGLAS FIR-LARCH OR SOUTHERN PINE					
Wind Speed	Exposure	Distance between Shear Walls[10] "*L*" or "*b*" (feet)	Minimum Wood Structural Panel/Particleboard Size[9] and Nailing[11,12]		
			Thickness (inches)	Common Nail Size (penny)	Nail Spacing (inches)
× 1.61 for km/h		× 304.8 for mm	× 25.4 for mm		× 25.4 for mm
100 mph (cont.)	C	16	$^3/_8$ blocked	8	4/6 o.c.
		32	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		48	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		64	Design required or provide extra cross walls		
	D	16	$^1/_2$ or $^{15}/_{32}$ blocked	10	4/6 o.c.
		32	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		48	Design required or provide extra cross walls		
		64	Design required or provide extra cross walls		
110 mph	B	16	$^1/_2$ or $^{15}/_{32}$	8	6 o.c.
		32	$^1/_2$ or $^{15}/_{32}$	10	6 o.c.
		48	$^5/_8$ or $^{19}/_{32}$	10	6 o.c.
		64	$^1/_2$ or $^{15}/_{32}$ blocked	8	4/6 o.c.
	C	16	$^1/_2$ or $^{15}/_{32}$ blocked	8	4/6 o.c.
		32	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		48	Design required or provide extra cross walls		
		64	Design required or provide extra cross walls		
	D	16	$^5/_8$ or $^{19}/_{32}$ blocked	10	4/6 o.c.
		32	Design required or provide extra cross walls		
		48	Design required or provide extra cross walls		
		64	Design required or provide extra cross walls		

[8]These requirements represent the maximum values for a diaphragm which is within a maximum 32-foot-by-64-foot (9.75 m by 19.5 m) module surrounded by shear walls, cross walls or bearing walls. (See Figure A-21-9.)
[9]See Tables 23-II-E-1 and 23-II-E-2 for minimum sizes depending on span between joists.
[10]See Figure A-21-9 for "*L*" and "*b*."
[11]The wood structural panel/particleboard (all grades) thickness is given first. The nailing size and boundary/supported edge spacing is shown next. Blocking of unsupported edges is stated where required. Twelve-inch (305 mm) spacing required in the field of the roof/floor. Boundary nailing is required over interior walls [see Figure A-21-12 (b)].
[12]Use Case 1 for unblocked diaphragms and any case for blocked diaphragms.

TABLE A-21-G—MINIMUM WALL CONNECTION REQUIREMENTS IN HIGH-WIND AREAS
Precast Hollow-core Plank Floors and Roofs

Spacing of No. 4 bent reinforcing bar in block or brick walls connected to precast concrete planks[1,2]

WIND SPEED AND EXPOSURE	EXTERIOR WALLS	INTERIOR WALLS
	× 25.4 for mm	
90 mph (145 km/h) Exposure C and less 100 mph (161 km/h) Exposure B	32″ o.c.	16″ o.c.
90 mph (145 km/h) Exposure D 100 mph (161 km/h) Exposure C 110 mph (177 km/h) Exposure B	24″ o.c.	12″ o.c.
100 mph (161 km/h) Exposure D 110 mph (177 km/h) Exposures C and D	16″ o.c.	12″ o.c.

[1]This table assumes maximum wall height of 12 feet (3.7 m) and a width-to-length ratio of diaphragm between shear walls of 3:1 or less.
[2]The precast planks shall be designed as shall the walls and footings supporting them.

TABLE A-21-H—MINIMUM HOLD-DOWN REQUIREMENTS IN HIGH-WIND AREAS
Steel Floors and Roofs

WIND SPEED AND EXPOSURE	MAXIMUM SPACING OF ROOF JOISTS WITH CONNECTION SHOWN[1,2,3]
	× 25.4 for mm
100 mph (161 km/h) Exposure B 90 mph (145 km/h) Exposures B and C 80 mph (129 km/h) Exposures B, C and D	48″
110 mph (177 km/h) Exposure B 100 mph (161 km/h) Exposure C	30″
110 mph (177 km/h) Exposures C and D 100 mph (161 km/h) Exposure D	Design required

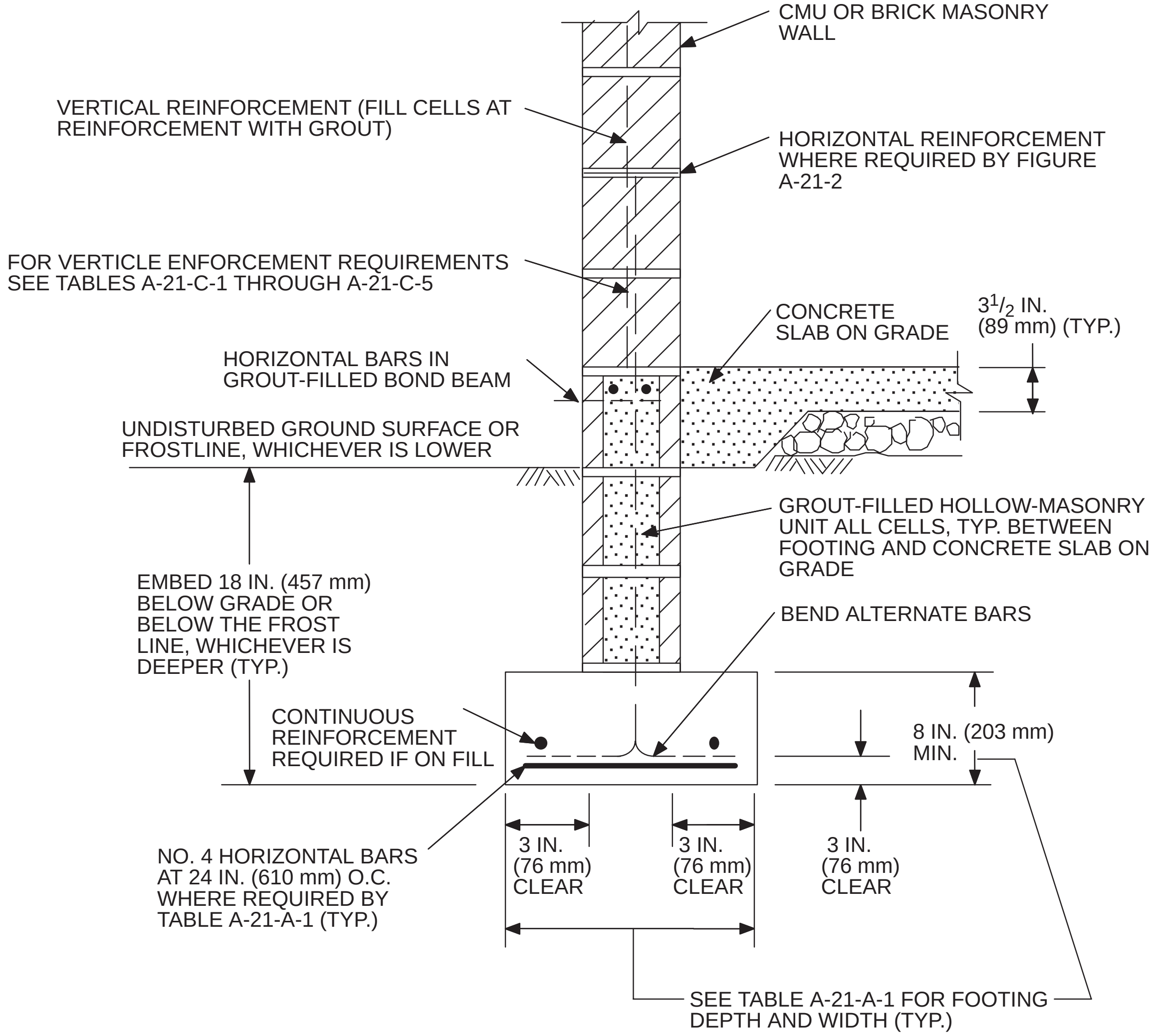
[1]Maximum span is 32 feet (9.75 m) to bearing walls.
[2]Joists and decking to be designed.
[3]Bottom chord of joists to be braced for reversal of stresses caused by wind uplift.

TABLE A-21-I—DIAGONAL BRACING REQUIREMENTS FOR GABLE-END WALL[1,2] ROOF PITCH 3:12 to 5:12

EXPOSURE	BASIC WIND SPEED (mph)							
	× 1.61 for km/h							
	80		90		100		110	
	3:12 (25%)	4:12 (33%) and 5:12 (42%)	3:12 (25%)	4:12 (33%) and 5:12 (42%)	3:12 (25%)	4:12 (33%) and 5:12 (42%)	3:12 (25%)	4:12 (33%) and 5:12 (42%)
	× 25.4 for mm							
B	I at 48″ o.c.	III at 48″ o.c.	I at 48″ o.c.	III at 48″ o.c.	I at 24″ o.c.	III at 24″ o.c.	I at 24″ o.c.	III at 24″ o.c.
C	I at 24″ o.c.	III at 48″ o.c.	I at 24″ o.c.	III at 24″ o.c.	II at 24″ o.c.	IV at 24″ o.c.	II at 24″ o.c.	IV at 24″ o.c.
D	I at 24″ o.c.	III at 48″ o.c.	II at 24″ o.c.	IV at 24″ o.c.	II at 24″ o.c.	IV at 24″ o.c.	Two-II at 24″ o.c.	Two-III at 24″ o.c.

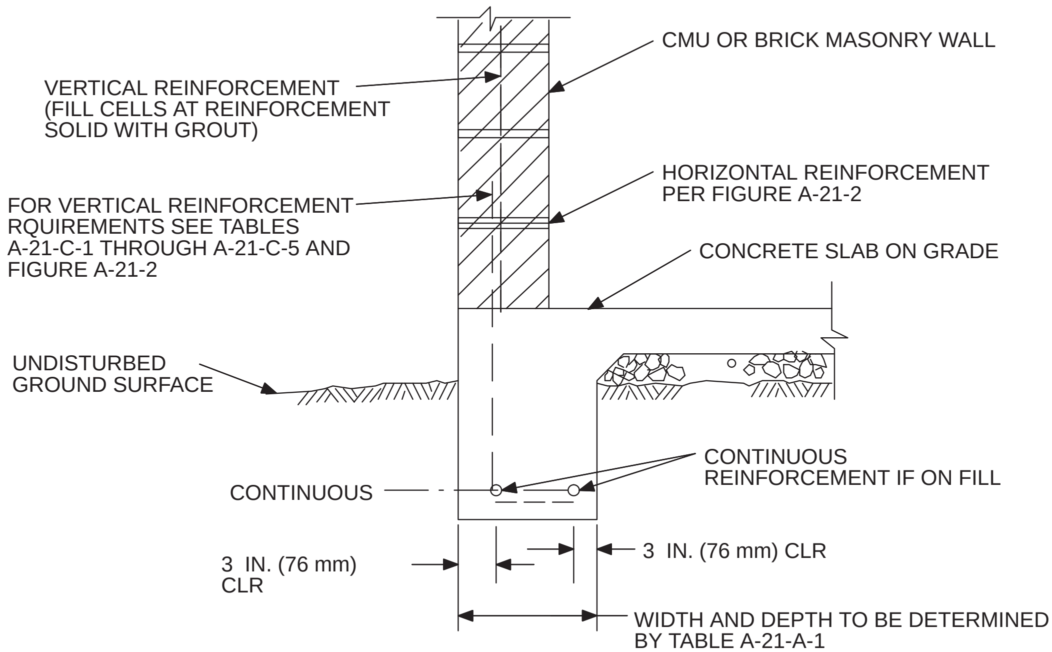
[1] I = 2-inch-by-4-inch brace, one clip angle (51 mm × 102 mm).
II = 2-inch-by-4-inch brace, two clip angles (one each side) (51 mm × 102 mm).
III = 3-inch-by-4-inch brace, one clip angle (76 mm × 102 mm).
IV = 3-inch-by-4-inch brace, two clip angles (one each side) (76 mm × 102 mm).
The spacing requirements of the brace are shown below the symbol.
[2]See Figures A-21-17 and A-21-18 for details and size of clip angles.

NOTE: Horizontal and vertical reinforcement to be determined by Tables A-21-C-1 through A-21-C-5 and A-21-F.



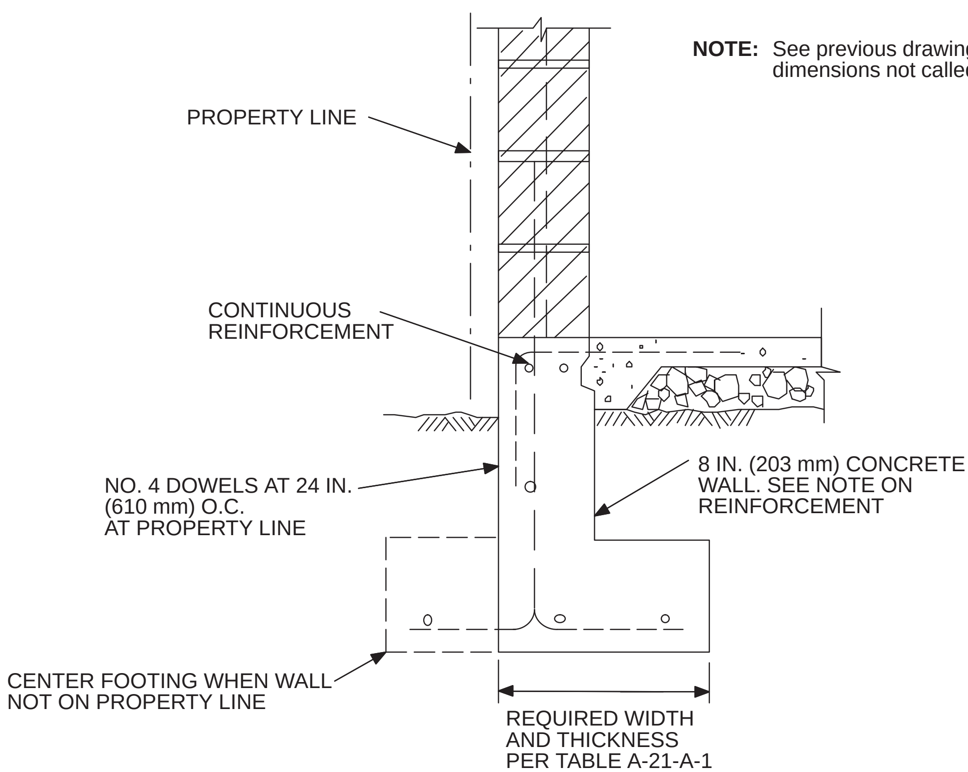
HOLLOW-MASONRY UNIT EXTERIOR FOUNDATION WALL

FIGURE A-21-1—VARIOUS DETAILS OF FOOTINGS
(See Tables A-21-A-1 and A-21-A-2 for widths.)



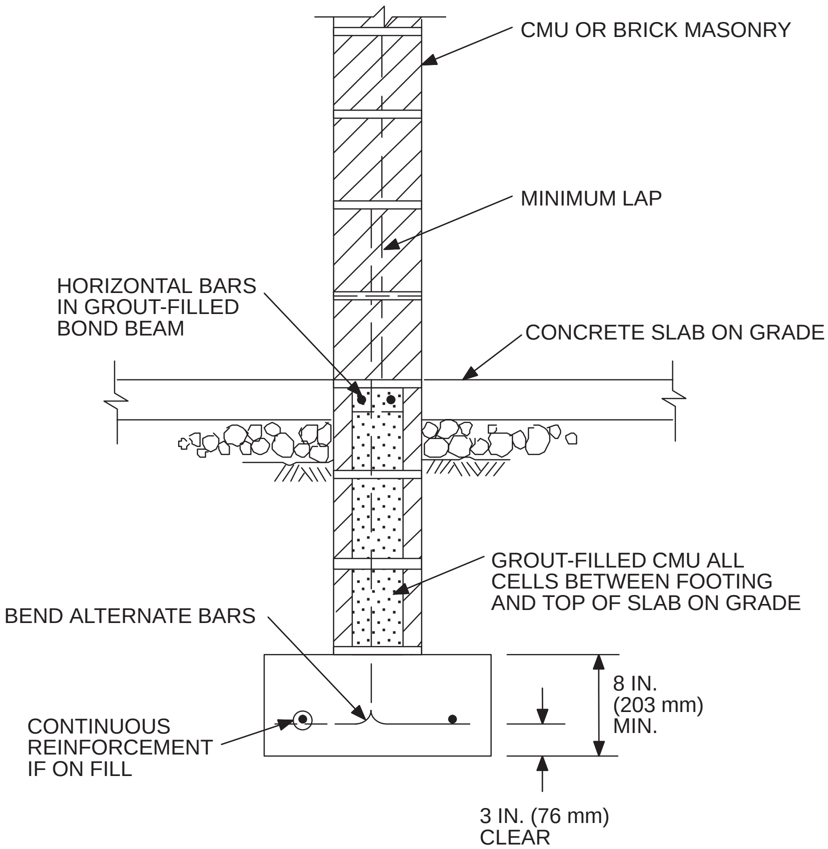
GRADE BEAM OR CONTINUOUS CONCRETE SLAB—TURN DOWN

NOTE: See previous drawing for details and dimensions not called out.

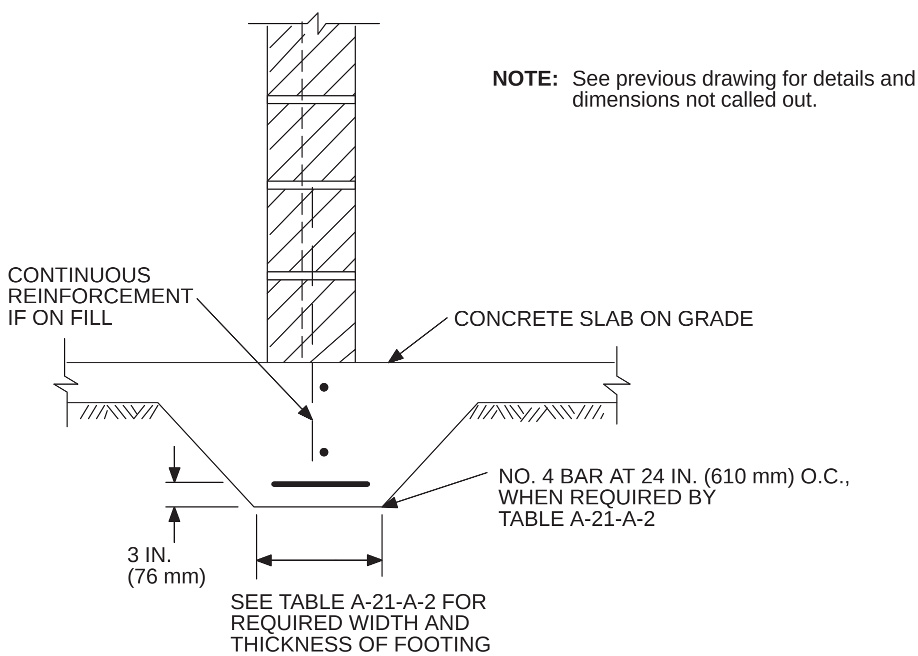


HOLLOW-MASONRY UNIT CONCRETE EXTERIOR FOUNDATION WALL

FIGURE A-21-1—VARIOUS DETAILS OF FOOTINGS—(Continued)
(See Tables A-21-A-1 and A-21-A-2 for widths.)



HOLLOW–MASONRY UNIT INTERIOR FOUNDATION WALL



CONCRETE INTERIOR NONBEARING WALL FOOTING

FIGURE A-21-1—VARIOUS DETAILS OF FOOTINGS—(Continued)
(See Tables A-21-A-1 and A-21-A-2 for widths.)

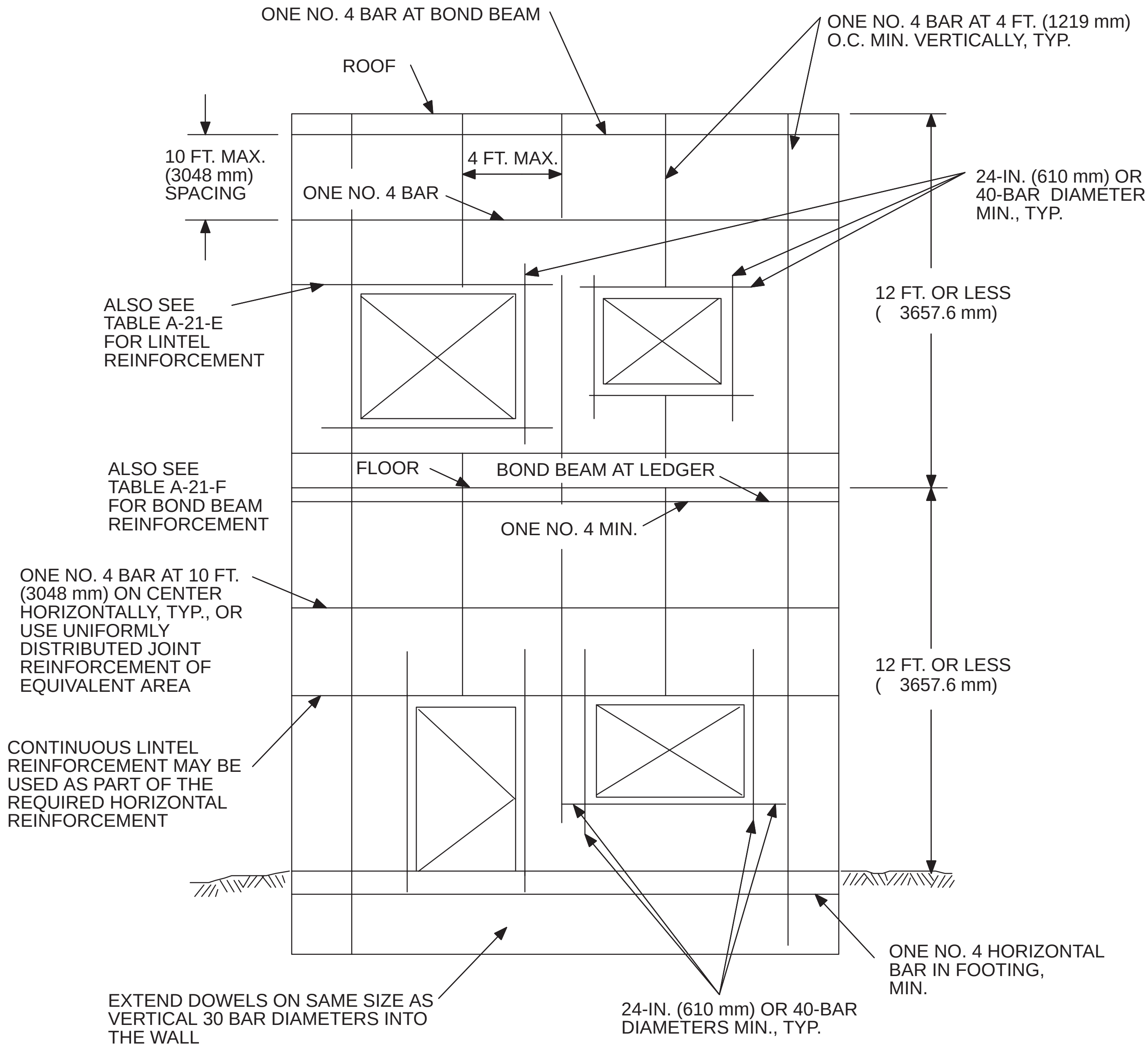


FIGURE A-21-2—MINIMUM MASONRY WALL REQUIREMENTS IN SEISMIC ZONE 2

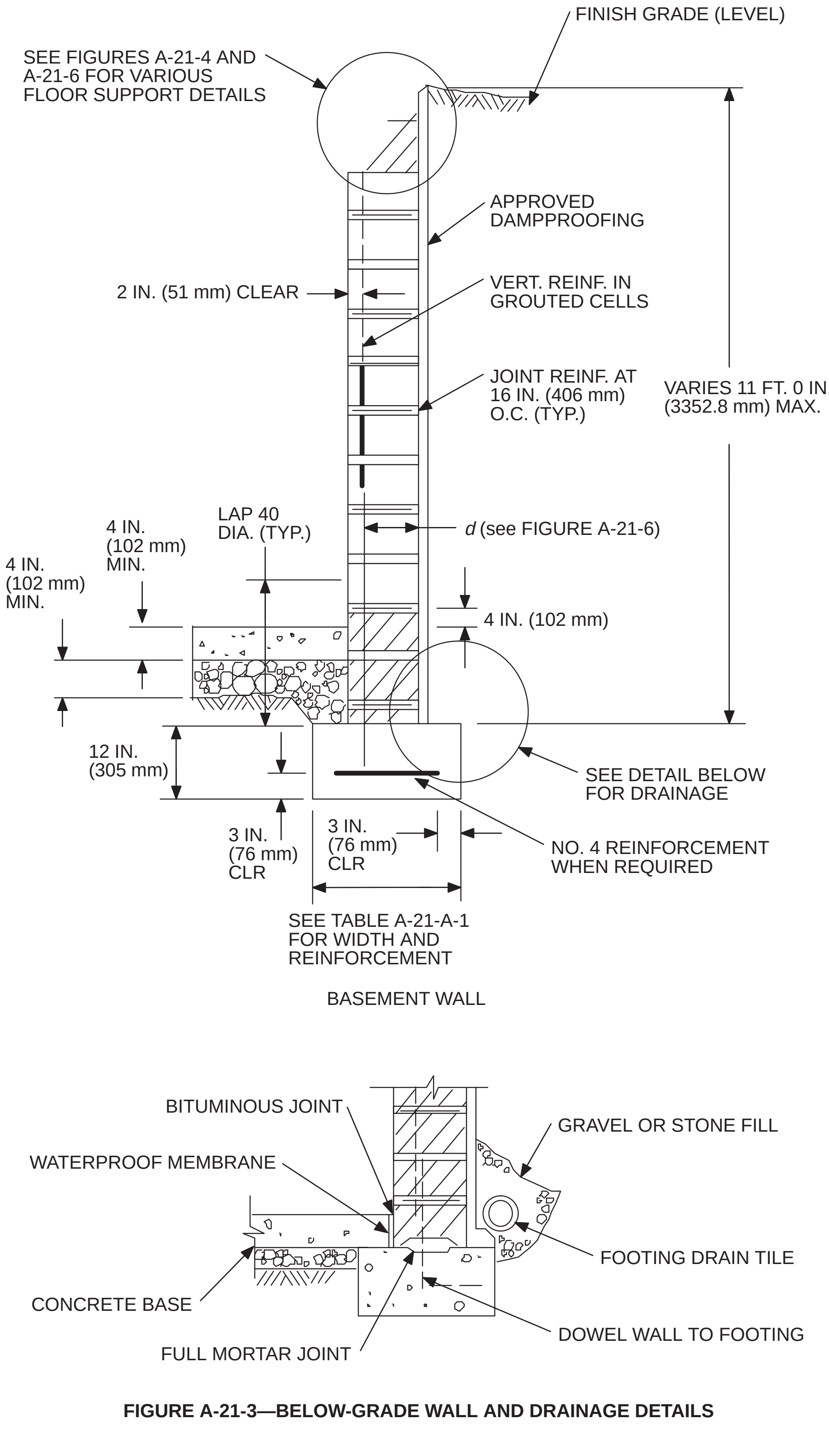


FIGURE A-21-3—BELOW-GRADE WALL AND DRAINAGE DETAILS

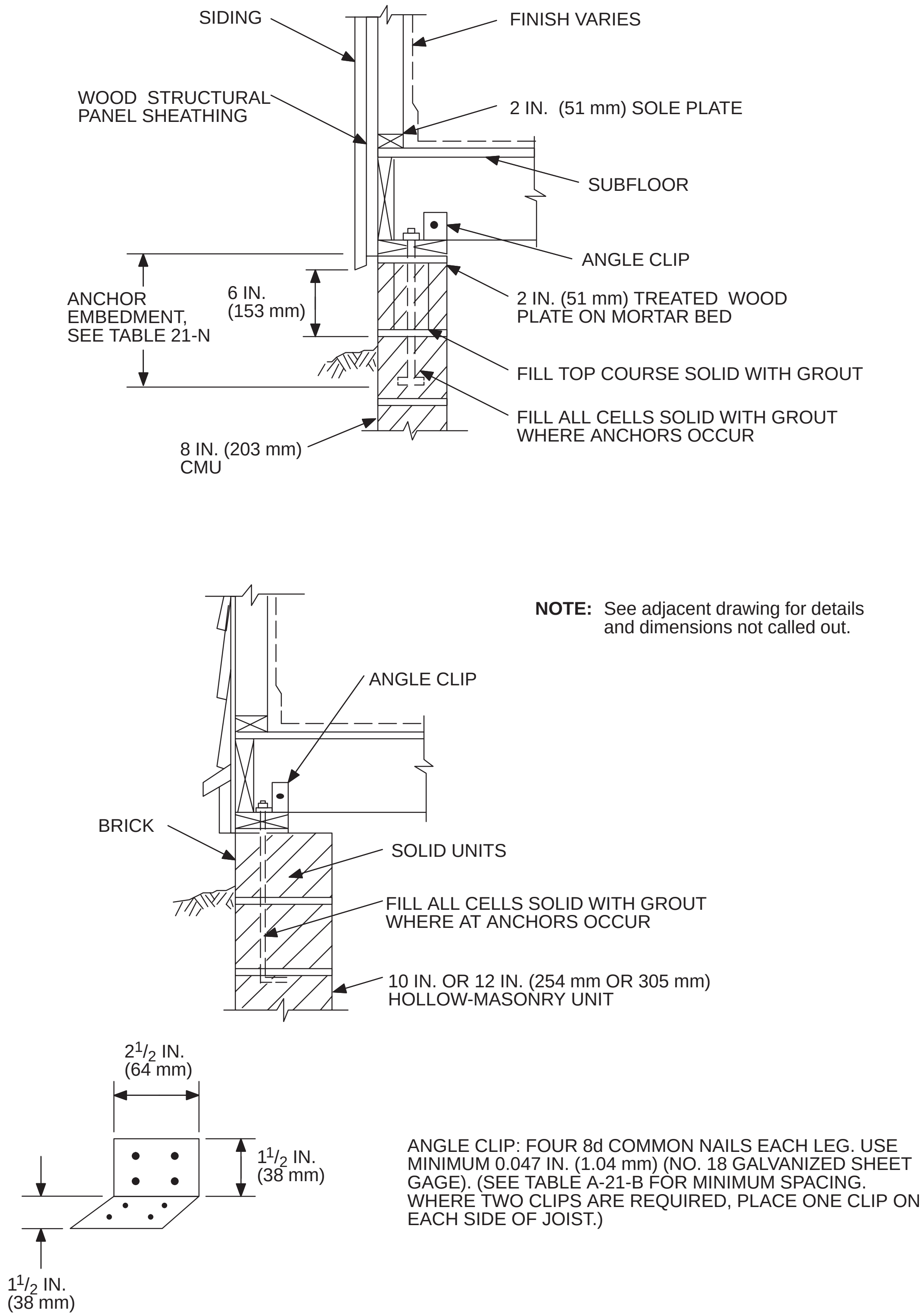
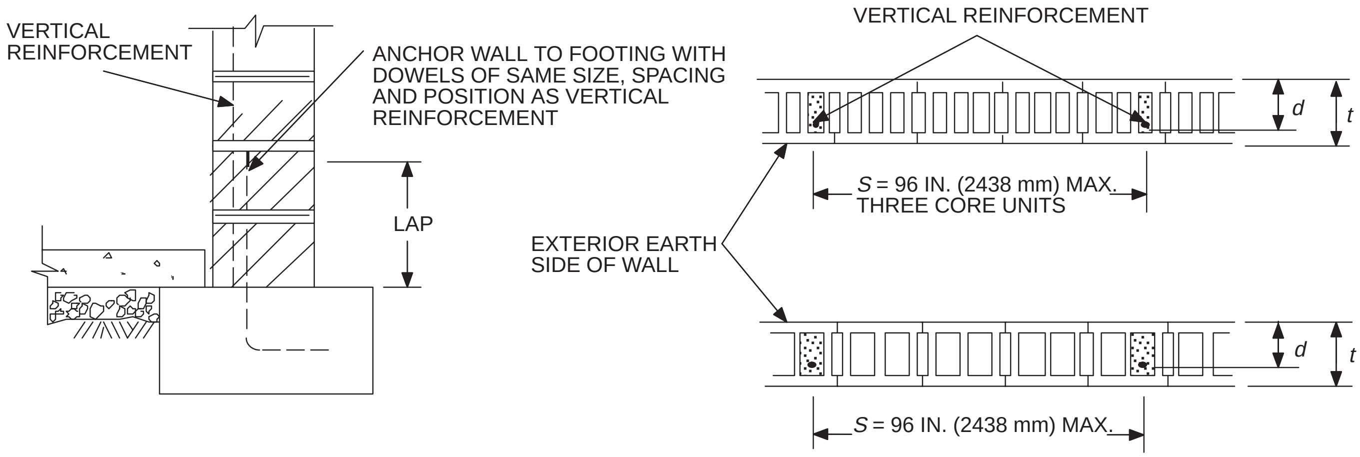


FIGURE A-21-4—HOLLOW-MASONRY UNIT FOUNDATION WALL—WOOD FLOOR



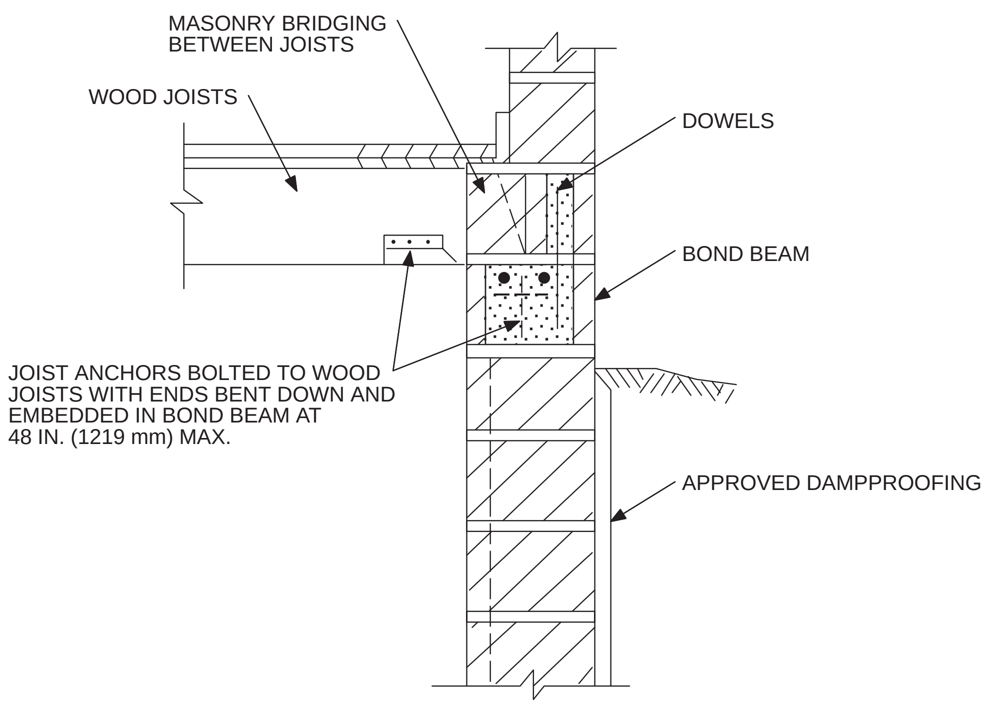
ALTERNATE ANCHORAGE DETAIL

TWO CORE UNITS

TYPICAL HORIZONTAL SECTION

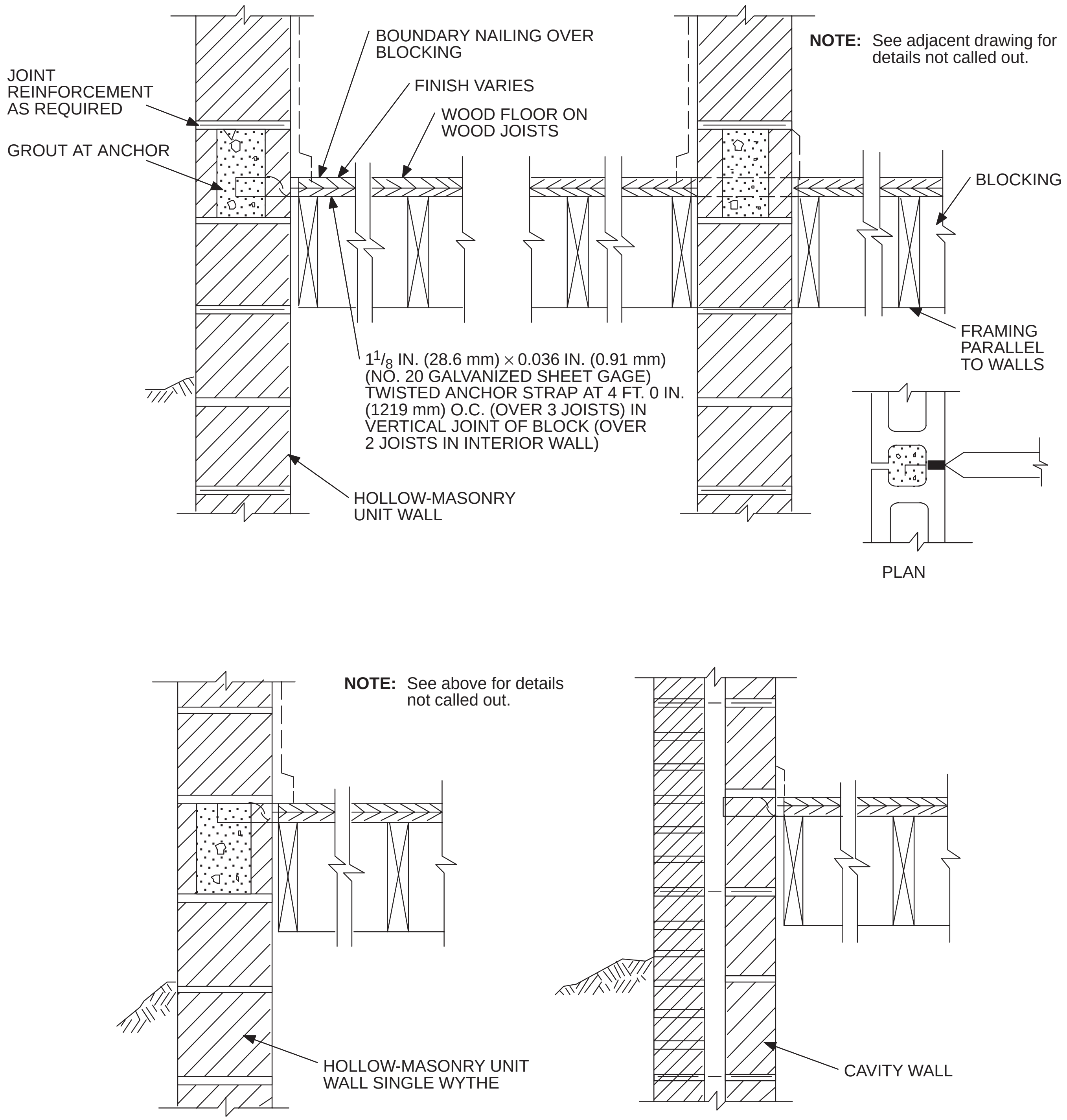
8 IN. (203 mm) WALLS: $t = 7^5/_8$ IN. (194 mm) $d = 5$ IN. (127 mm)
10 IN. (254 mm) WALLS: $t = 9^5/_8$ IN. (245 mm) $d = 7$ IN. (153 mm)
12 IN. (305 mm) WALLS: $t = 11^5/_8$ IN. (295 mm) $d = 8^3/_4$ IN. (225 mm)

FIGURE A-21-5—PLACEMENT OF REINFORCEMENT



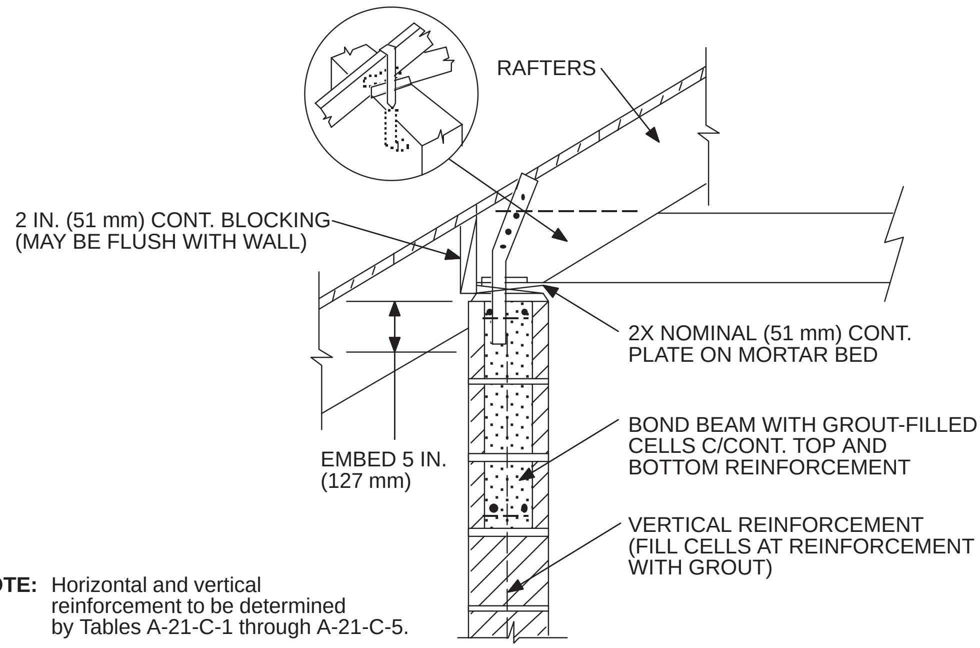
(A) HOLLOW–MASONRY UNIT WALL—WOOD FLOOR

FIGURE A-21-6—VARIOUS CONNECTIONS OF FLOORS TO BASEMENT WALLS



(B) WOOD FLOOR, JOISTS PARALLEL TO WALL

FIGURE A-21-6—VARIOUS CONNECTIONS OF FLOORS TO BASEMENT WALLS—(Continued)



NOTE: Horizontal and vertical reinforcement to be determined by Tables A-21-C-1 through A-21-C-5.

ROOF WITH OVERHANG

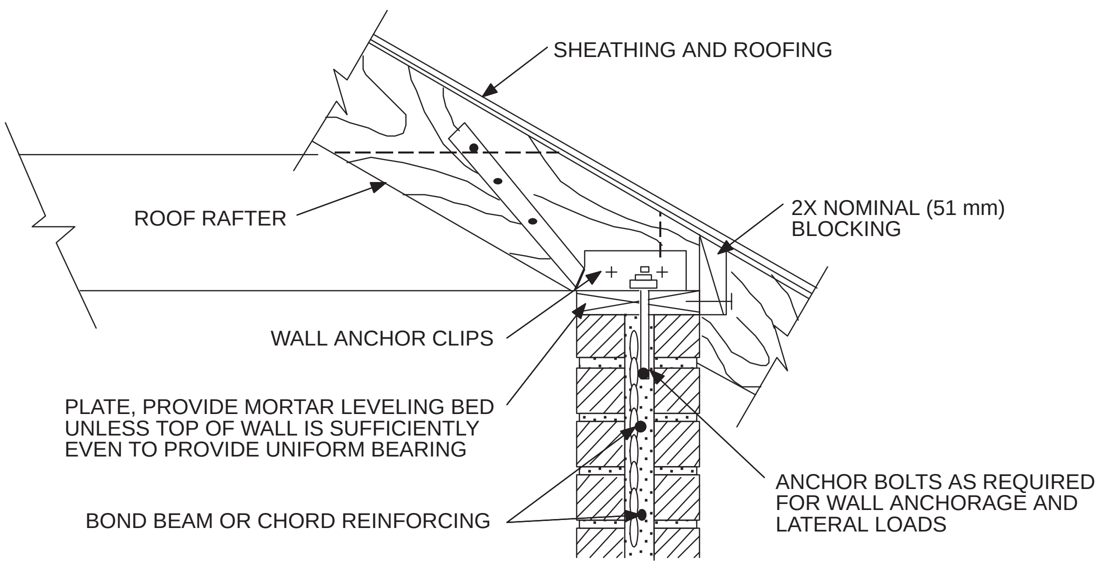
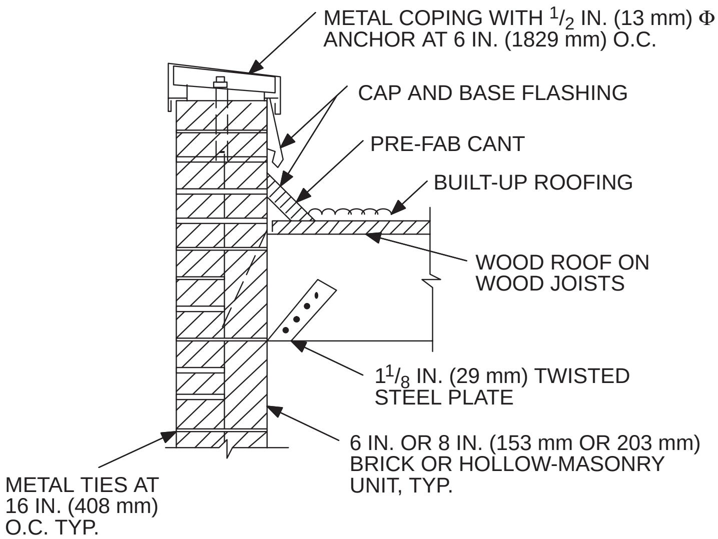
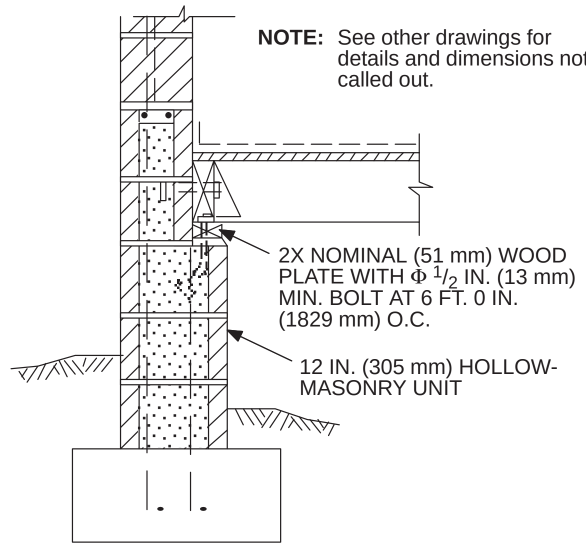


FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)

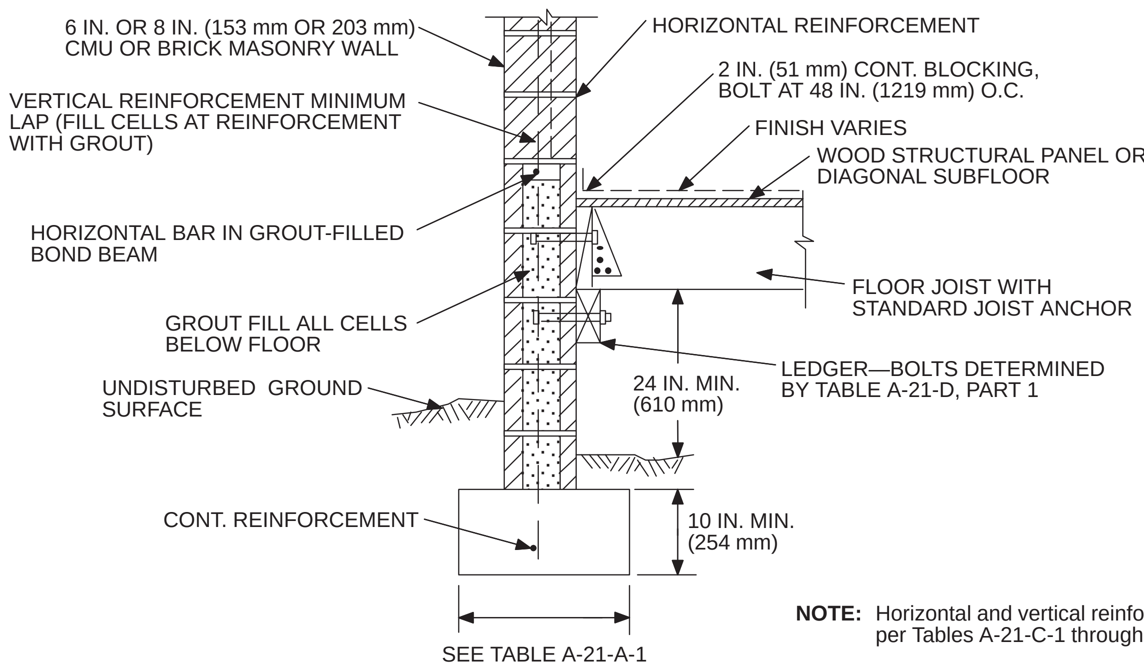


WOOD JOIST ROOF COMPOSITE WALL



NOTE: See other drawings for details and dimensions not called out.

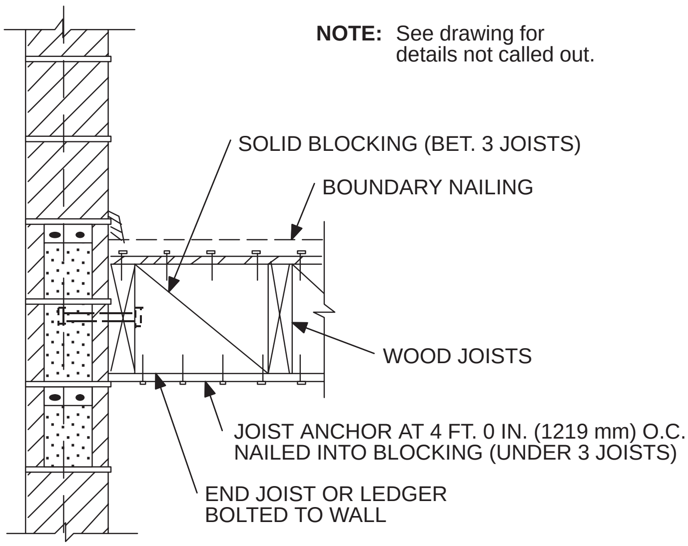
HOLLOW-MASONRY UNIT FOUNDATION WALL—JOIST PERPENDICULAR



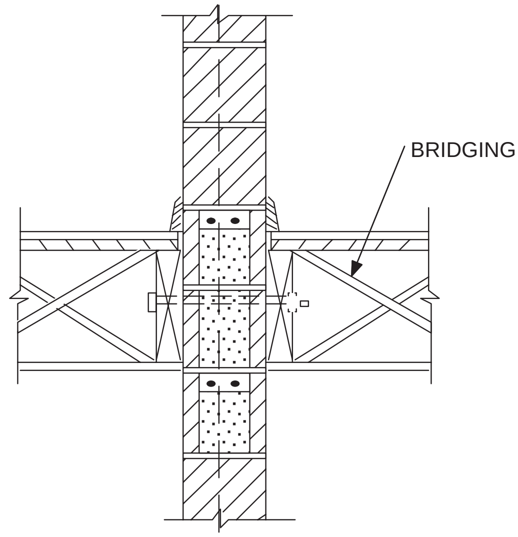
NOTE: Horizontal and vertical reinforcement per Tables A-21-C-1 through A-21-C-5.

HOLLOW-MASONRY UNIT FOUNDATION WALL—JOIST PERPENDICULAR—(Continued)

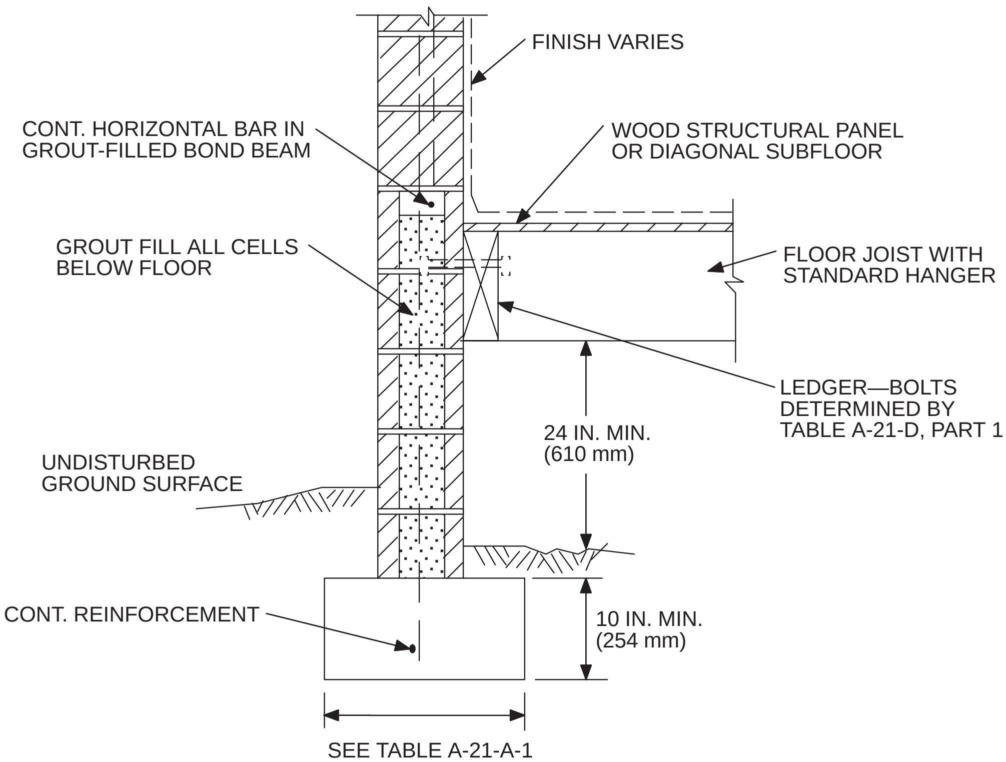
FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)—(Continued)



EXTERIOR WALL—JOIST PARALLEL

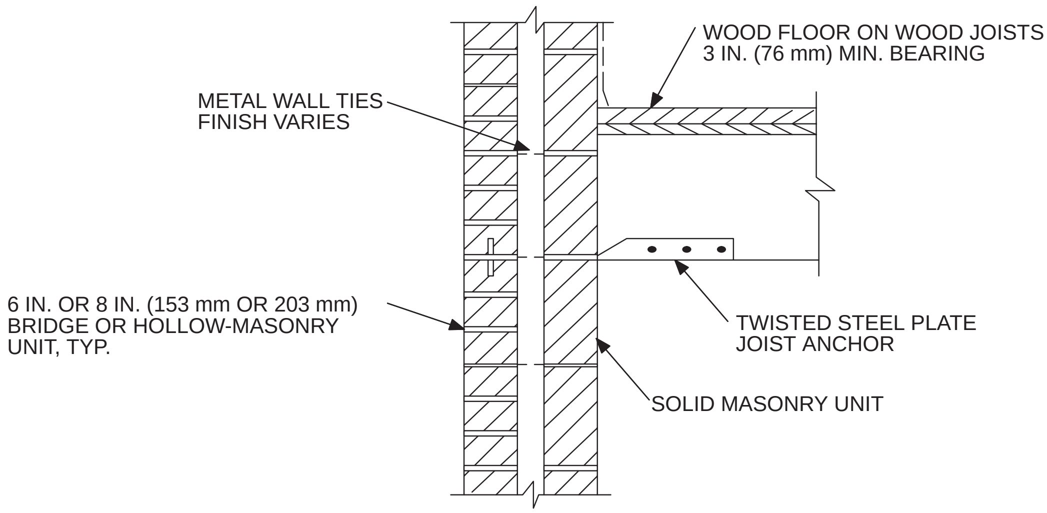


INTERIOR WALL—JOIST PARALLEL

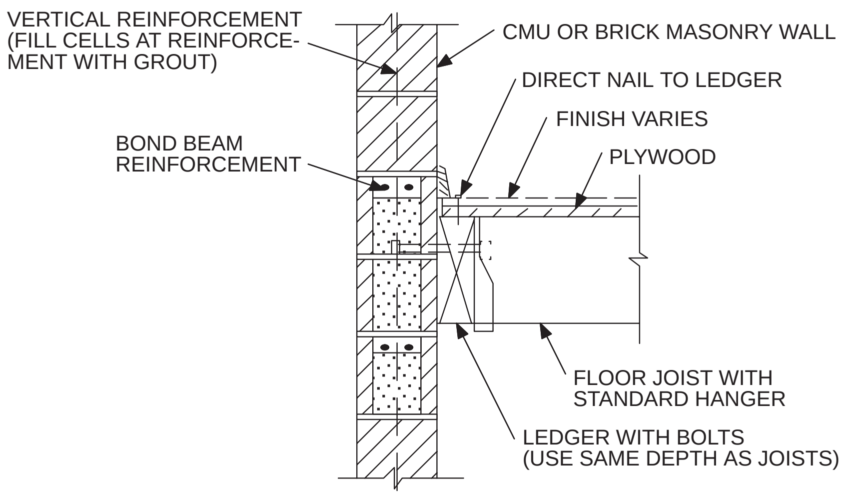


HOLLOW-MASONRY UNIT FOUNDATION WALL—JOIST PERPENDICULAR

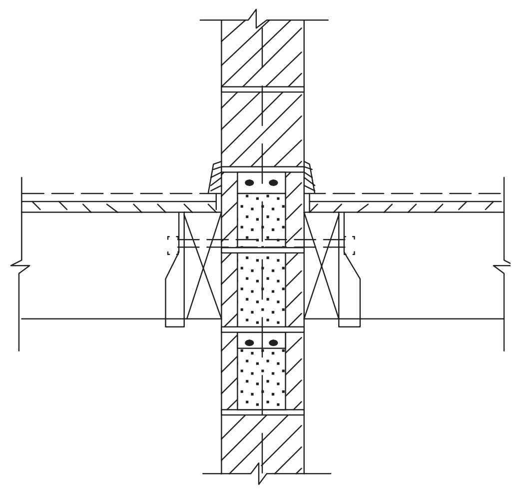
FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)—(Continued)



WOOD FLOOR

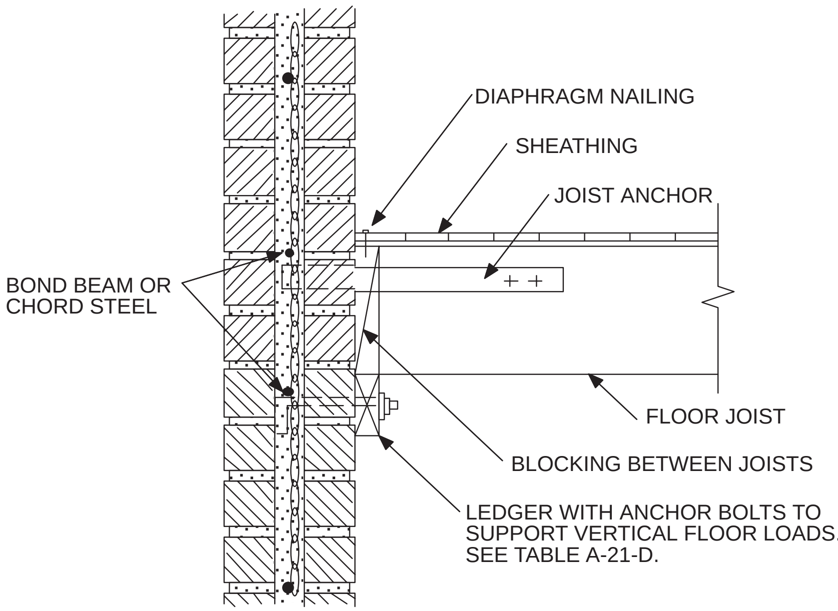


EXTERIOR WALL—
JOIST PERPENDICULAR



INTERIOR WALL—
JOIST PERPENDICULAR

FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)—(Continued)



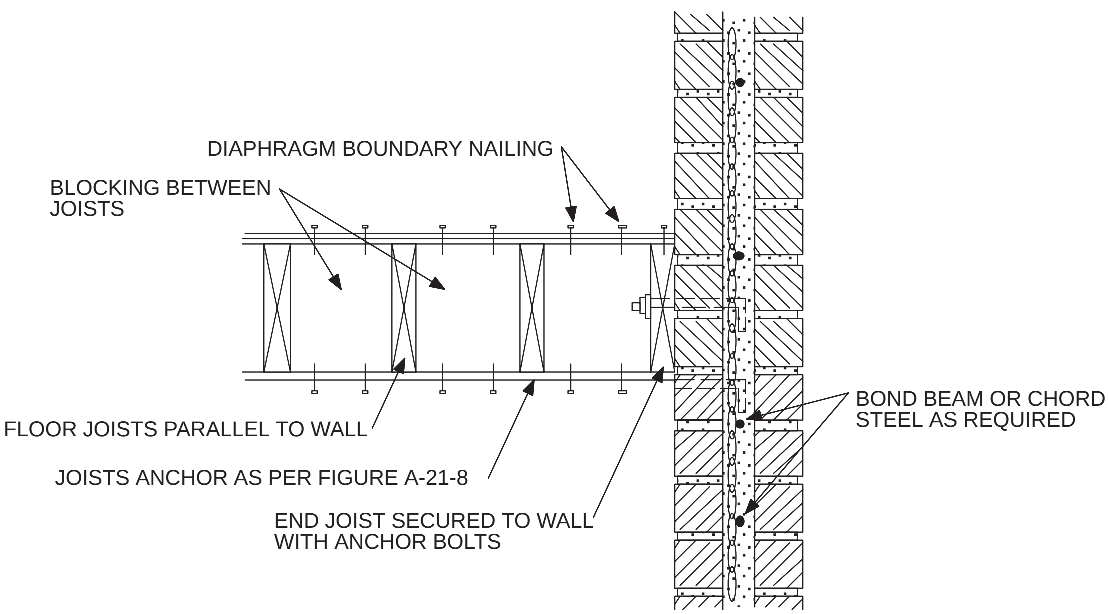


FIGURE A-21-7—VARIOUS DETAILS ASSOCIATED WITH TABLE A-21-D (Uplift Resistance)—(Continued)

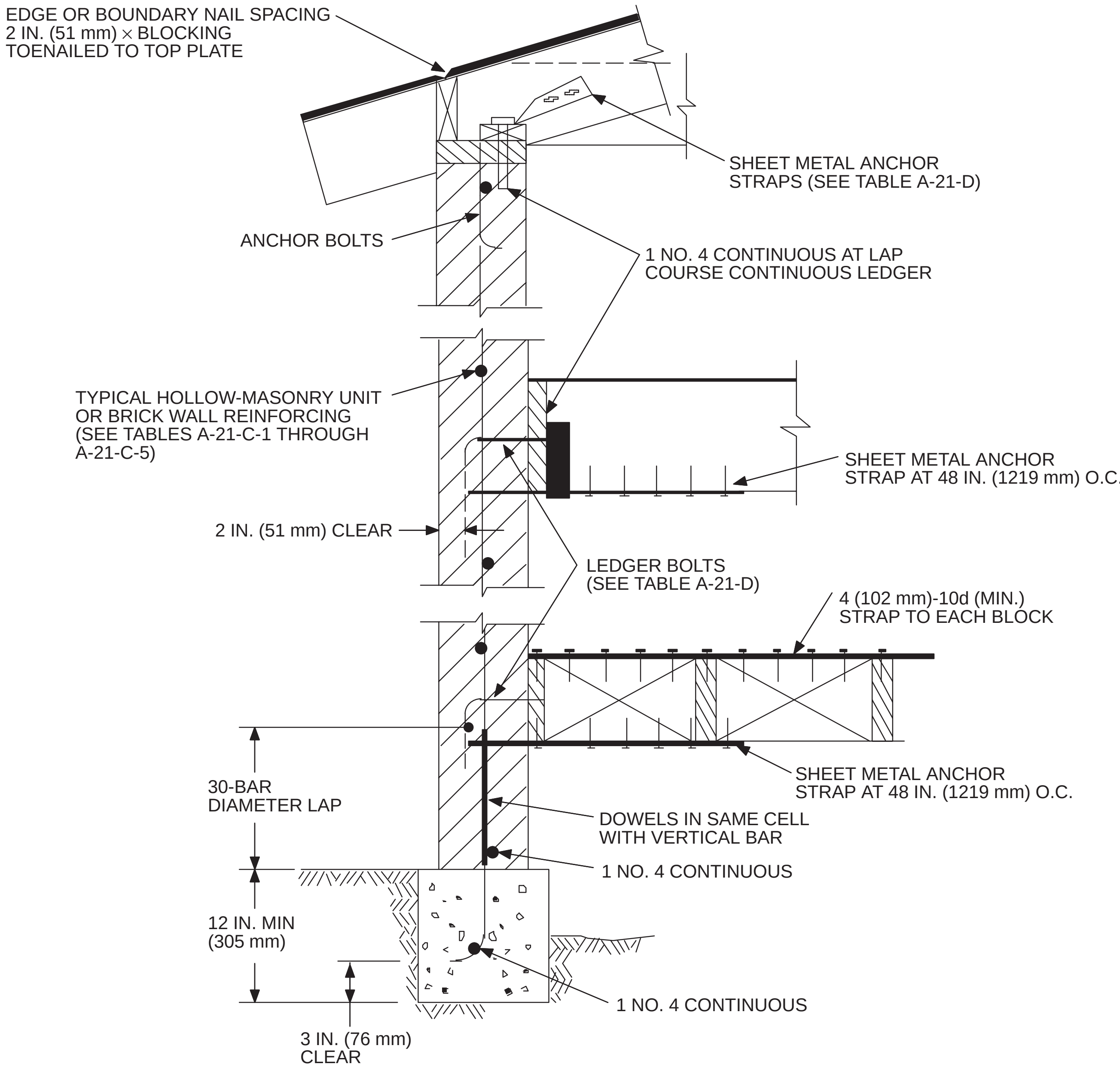
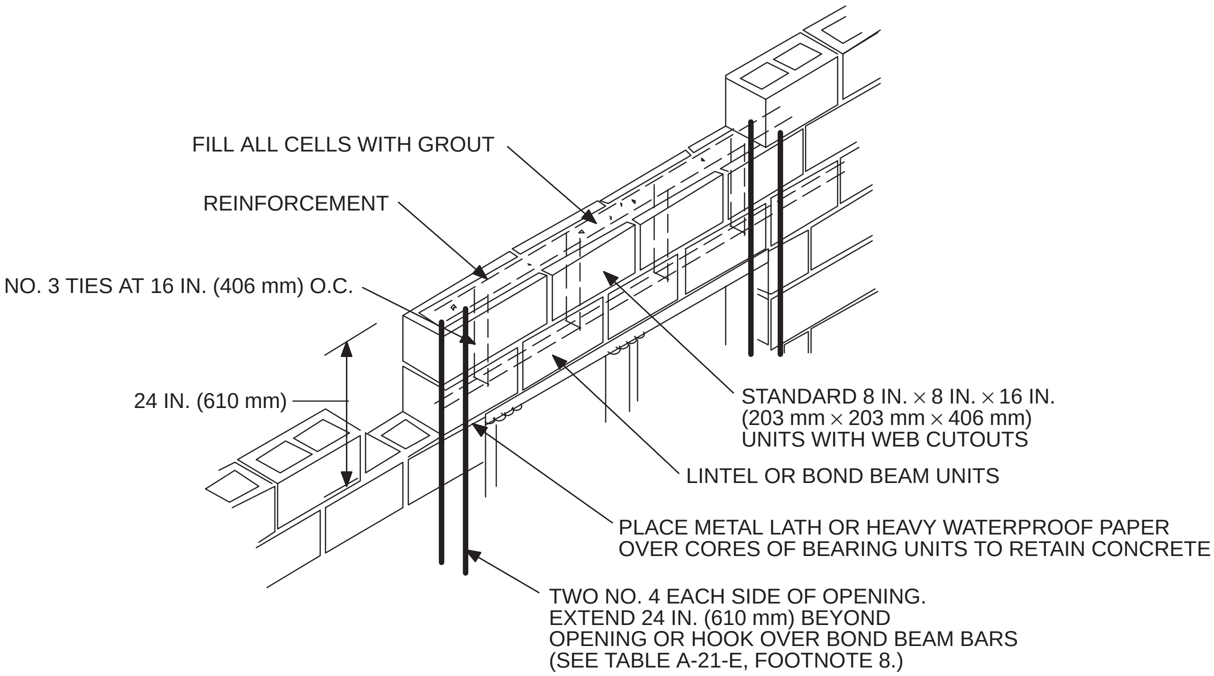
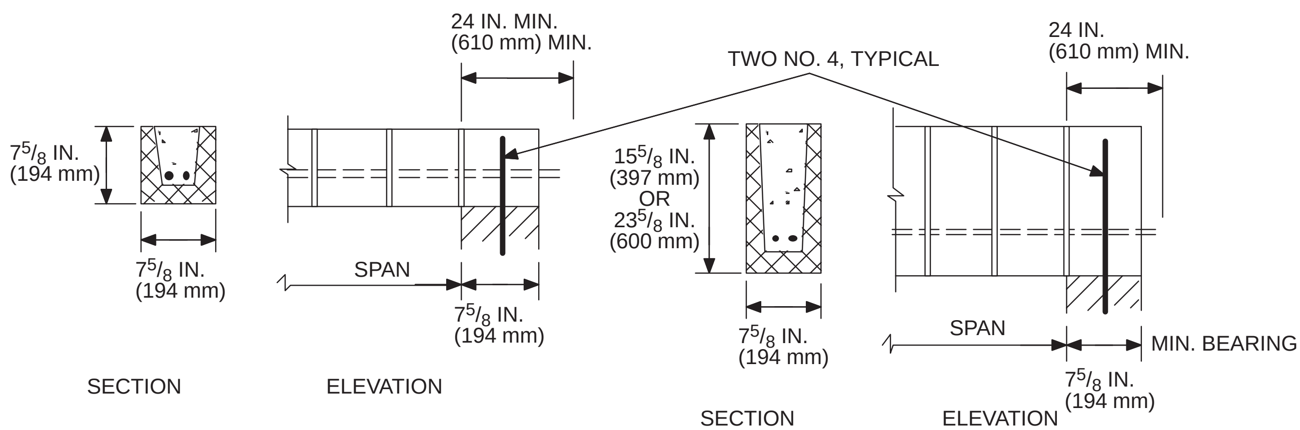


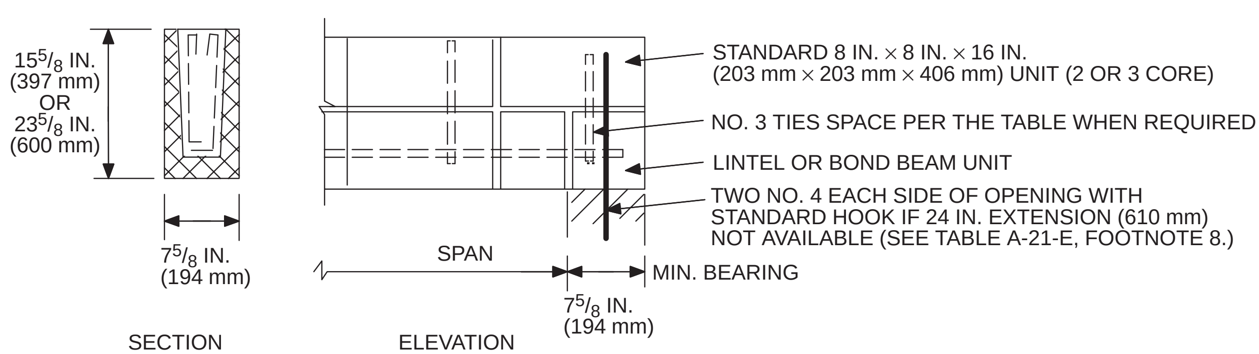
FIGURE A-21-8—CONTINUOUS LOAD PATH



REINFORCING DETAILS



WITHOUT STIRRUPS



WITH STIRRUPS

FIGURE A-21-8—CONTINUOUS LOAD PATH—(Continued)

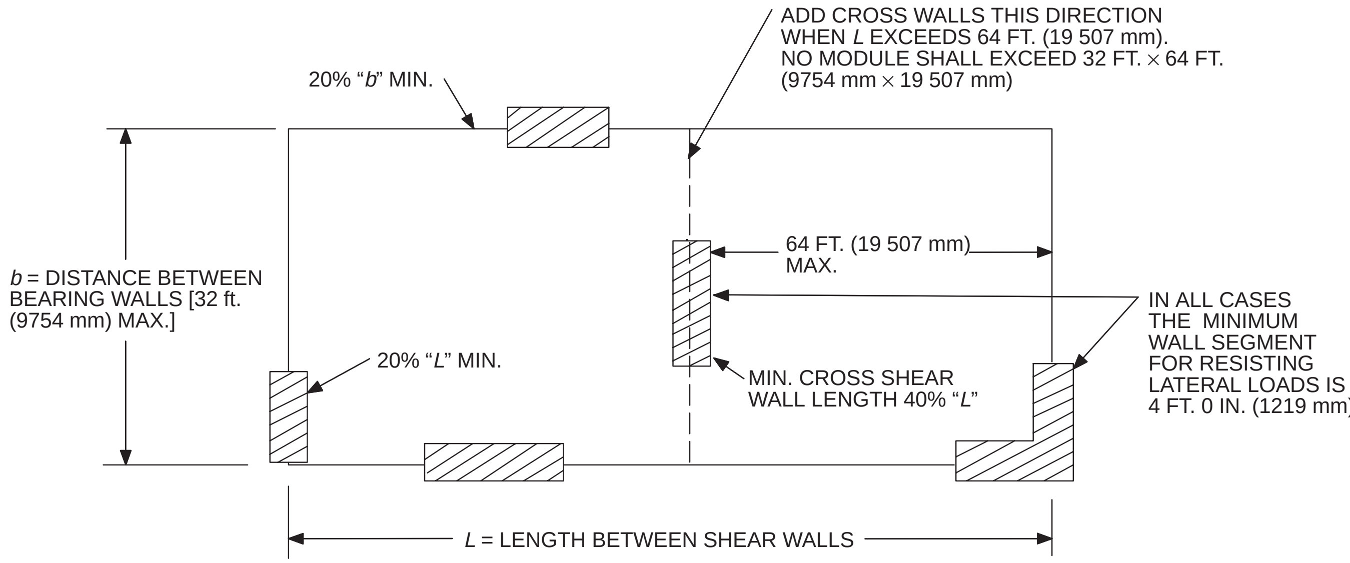


FIGURE A-21-9—SPACING AND LENGTHS OF SHEAR WALLS

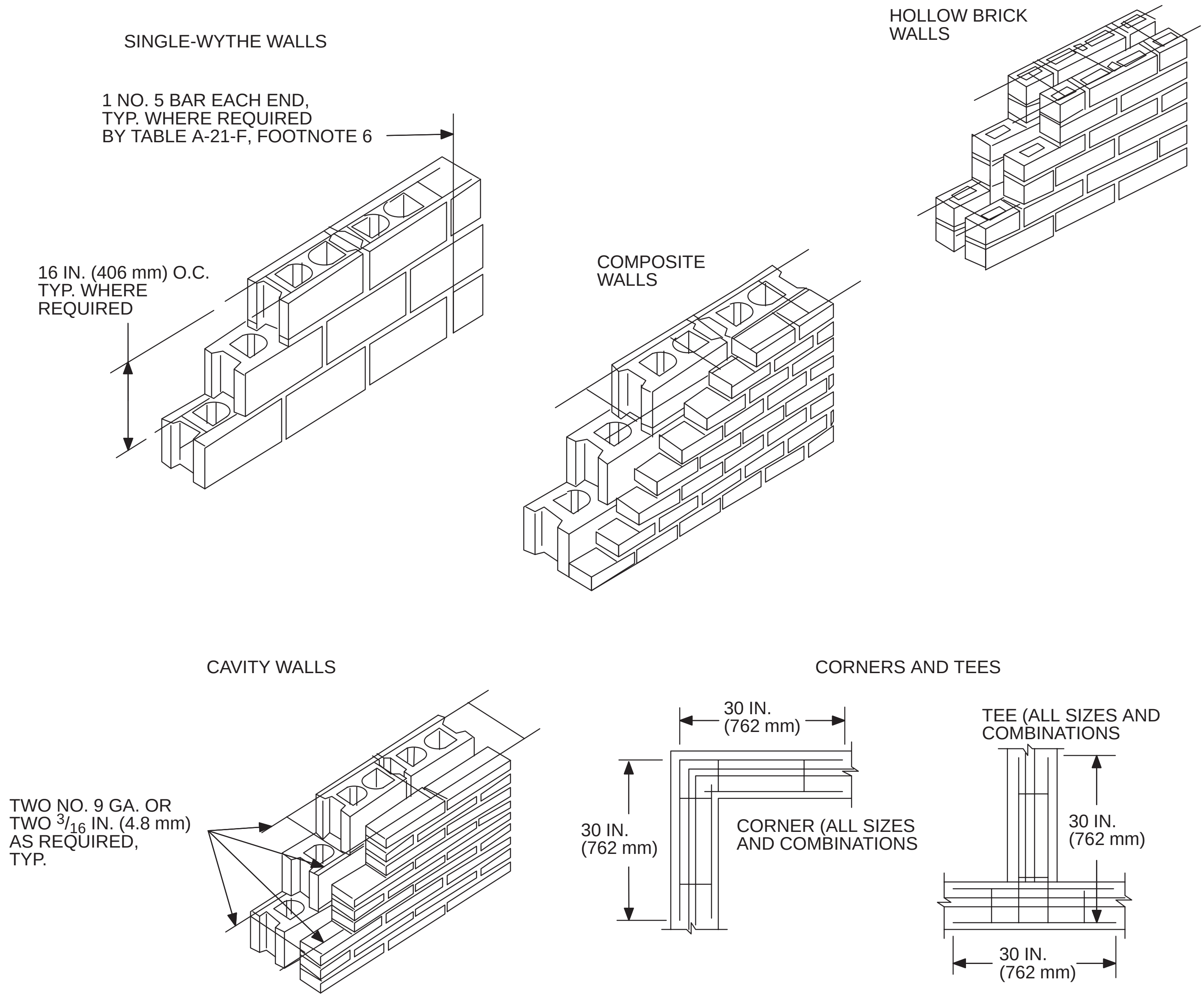
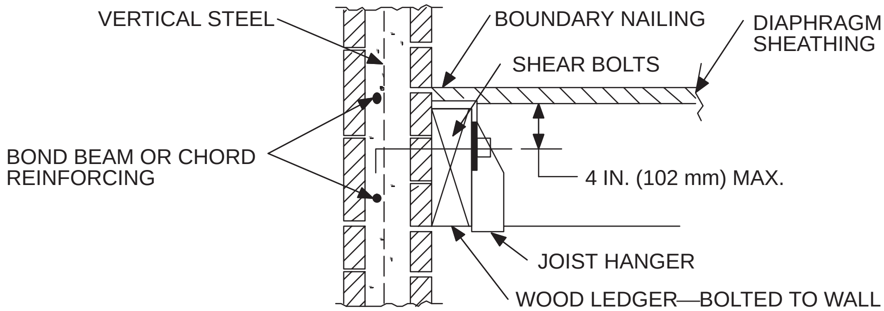
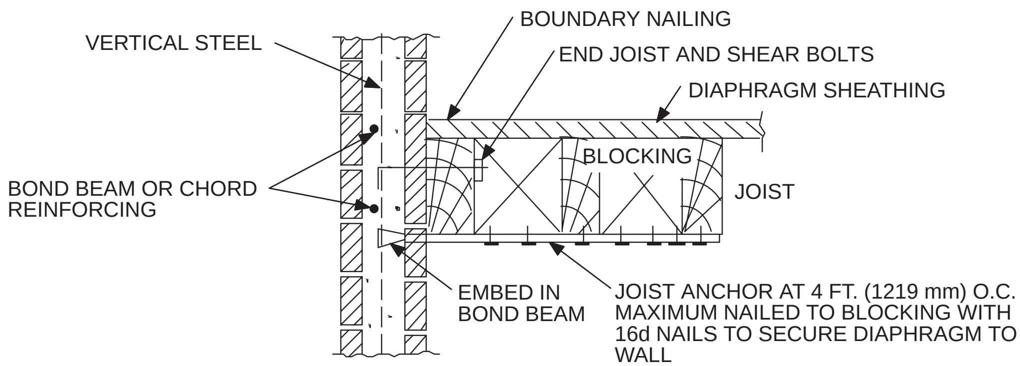


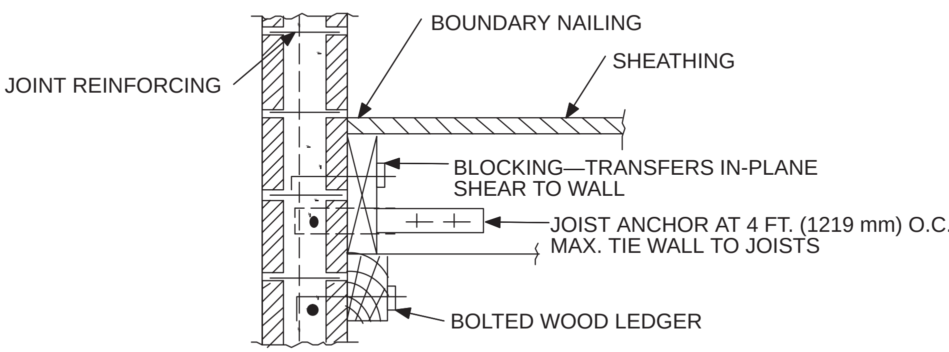
FIGURE A-21-10—SPACING OF STEEL REINFORCING WIRE



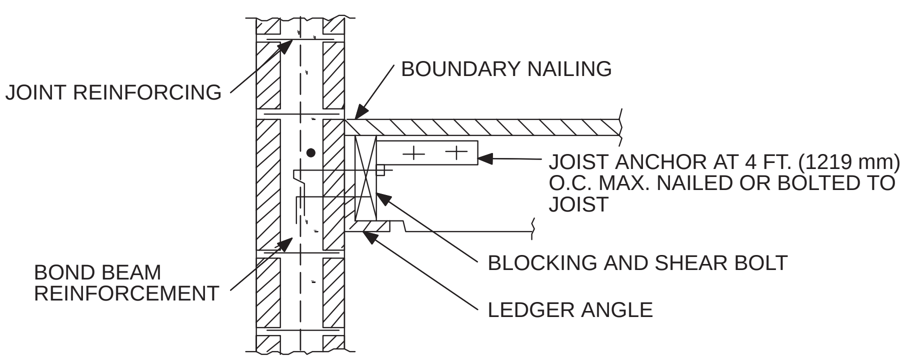
(a) FLOOR JOISTS PERPENDICULAR TO WALL JOIST HANGER SUPPORTS



(b) FLOOR JOISTS PARALLEL TO WALL

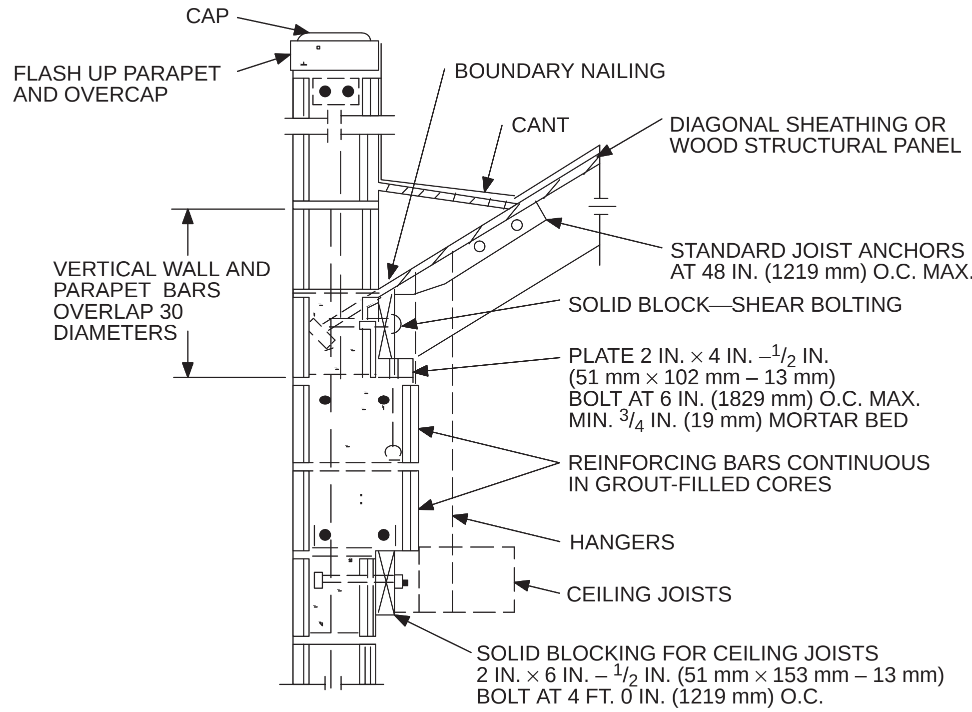


(c) WOOD LEDGER FLOOR JOIST SUPPORT

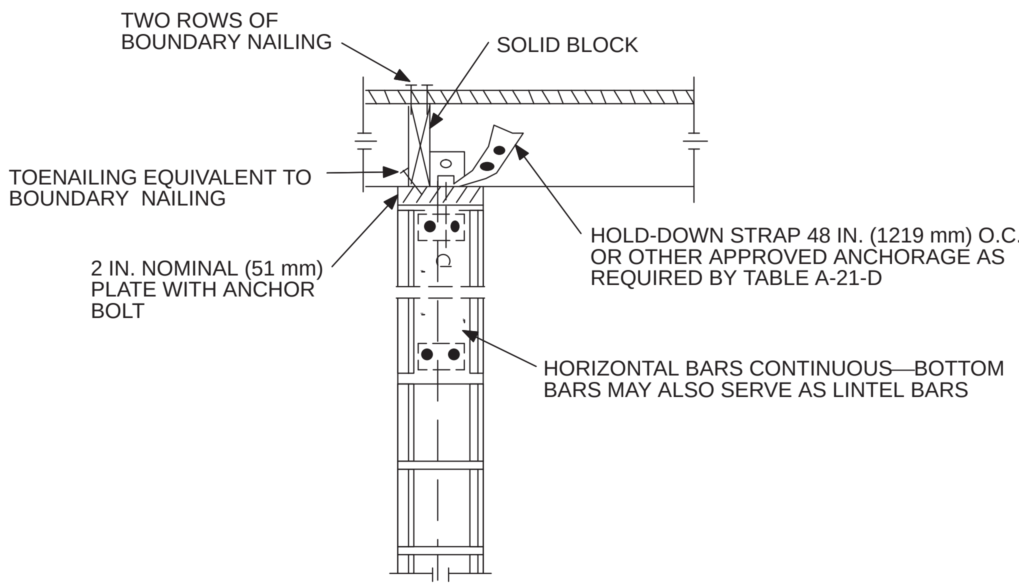


(d) STEEL LEDGER FLOOR JOIST SUPPORT

FIGURE A-21-11—FLOOR-TO-WALL CONNECTION DETAILS

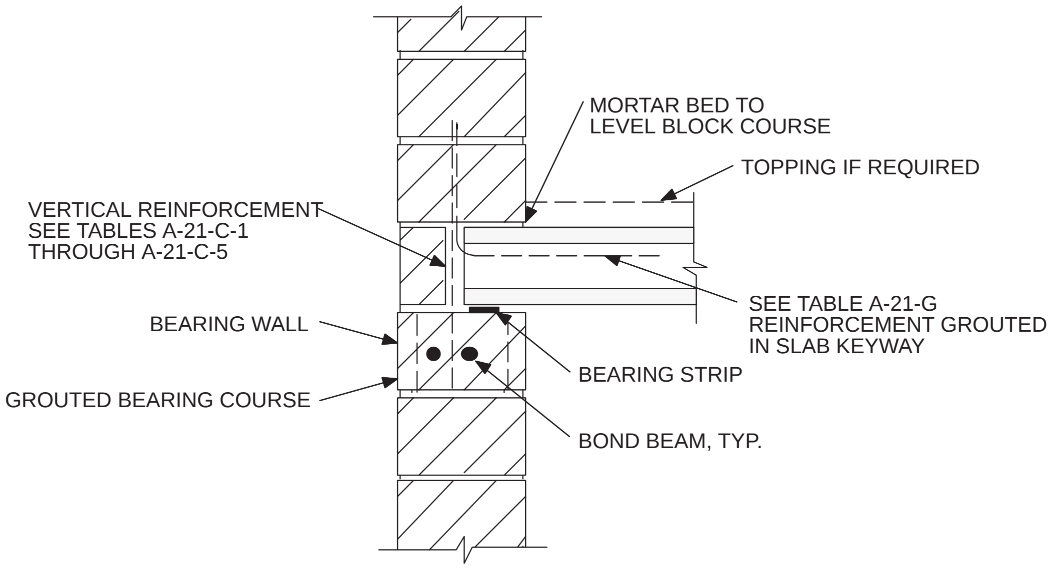


(a) EXTERIOR WALL SUPPORT

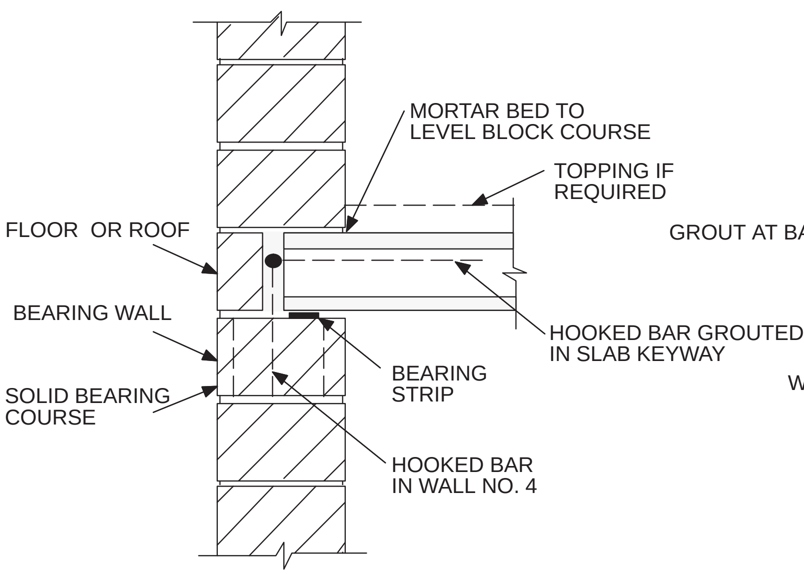


(b) INTERIOR WALL SUPPORT BOND–BEAM SUPPORTS

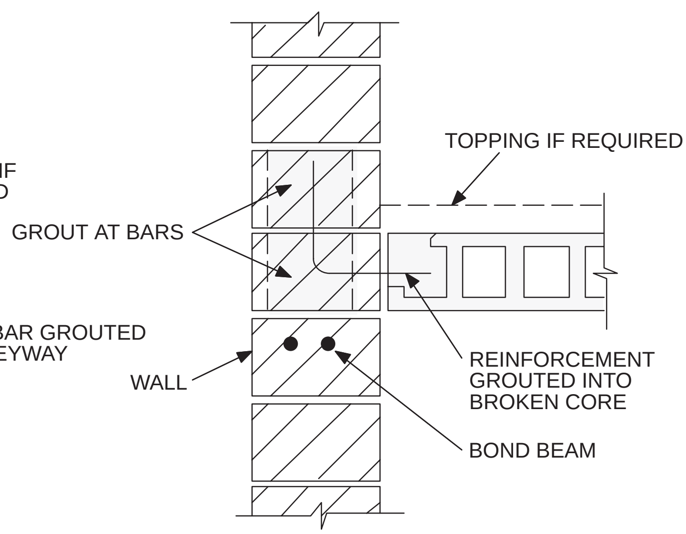
FIGURE A-21-12—ROOF-TO-WALL CONNECTION DETAILS



(a) SLAB PERPENDICULAR TO WALL

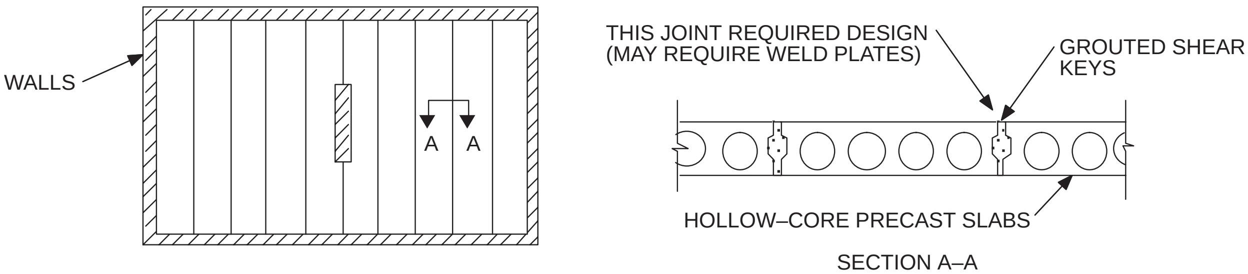


(b) ALTERNATE CONNECTION PERPENDICULAR TO WALL

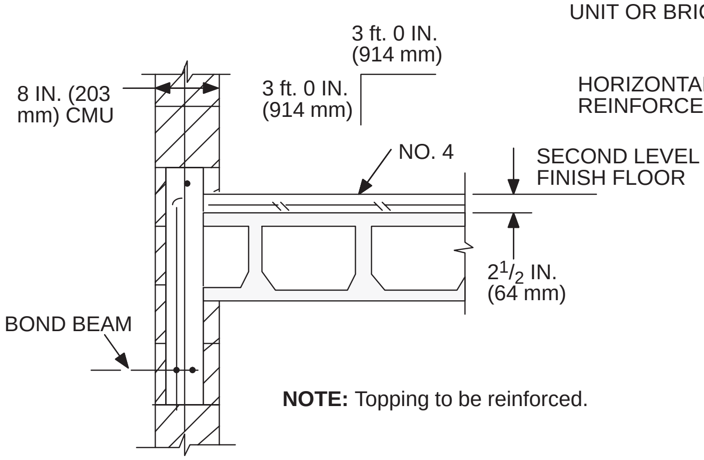


(c) SLAB PARALLEL WITH WALL

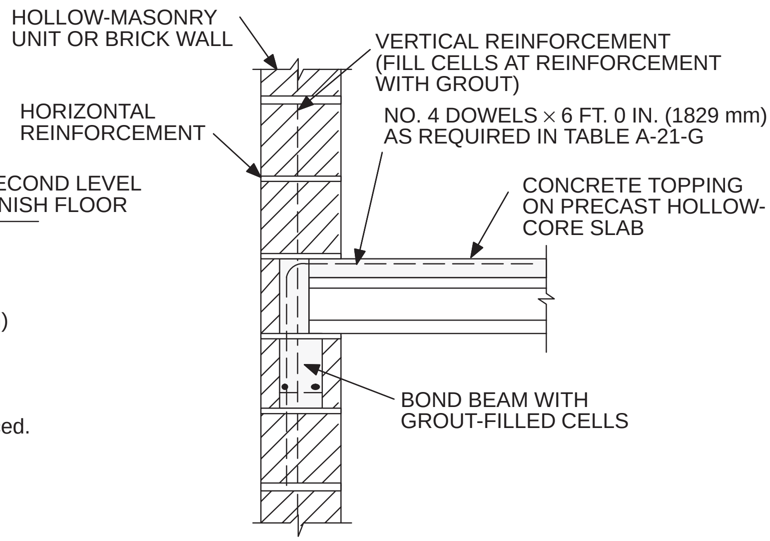
FIGURE A-21-13—VARIOUS TYPES OF WALL CONNECTIONS



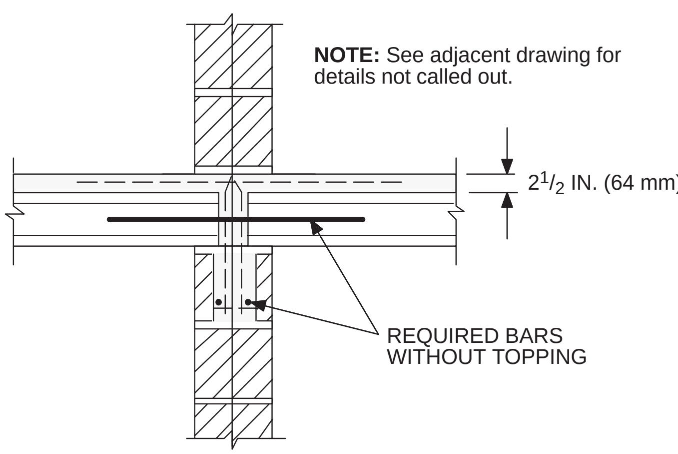
(d) PLAN VIEW OF FLOOR OR ROOF AND CROSS SECTION THROUGH PLANKS



(e) ALTERNATE PLANK PARALLEL
WITH WALL WITH TOPPING



(f) ALTERNATE WITH TOPPING



(g) INTERIOR WALL MINIMUM CONNECTION

FIGURE A-21-13—VARIOUS TYPES OF WALL CONNECTIONS—(Continued)

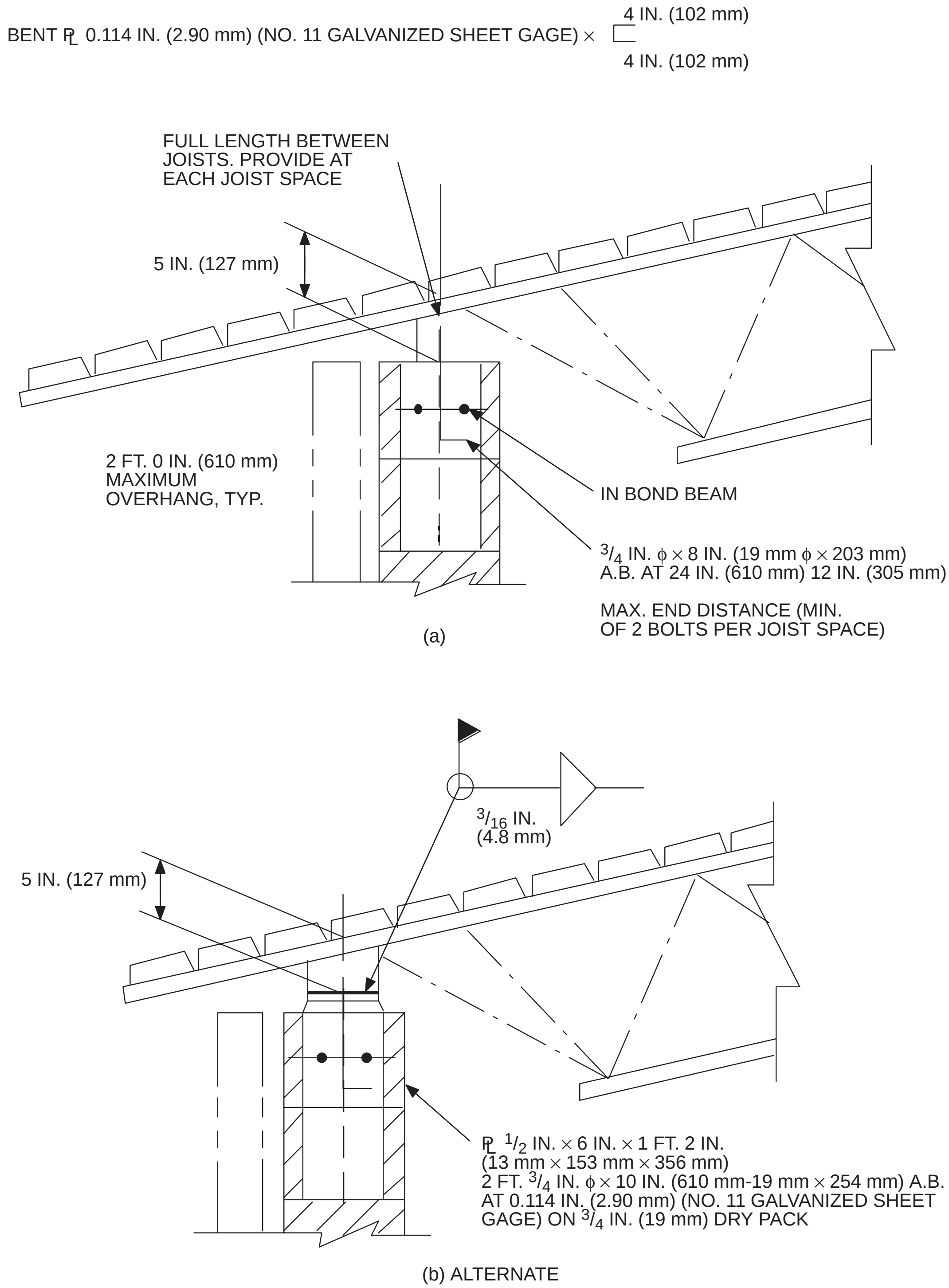
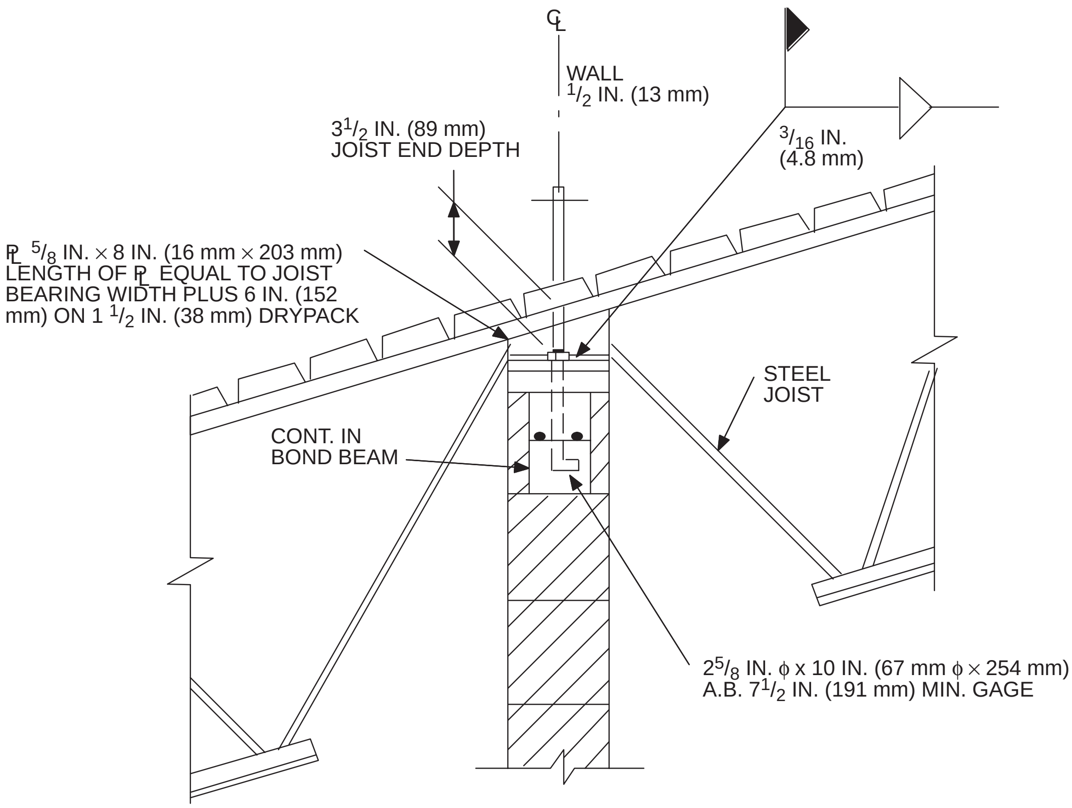


FIGURE A-21-14—EXTERIOR WALL DETAILS



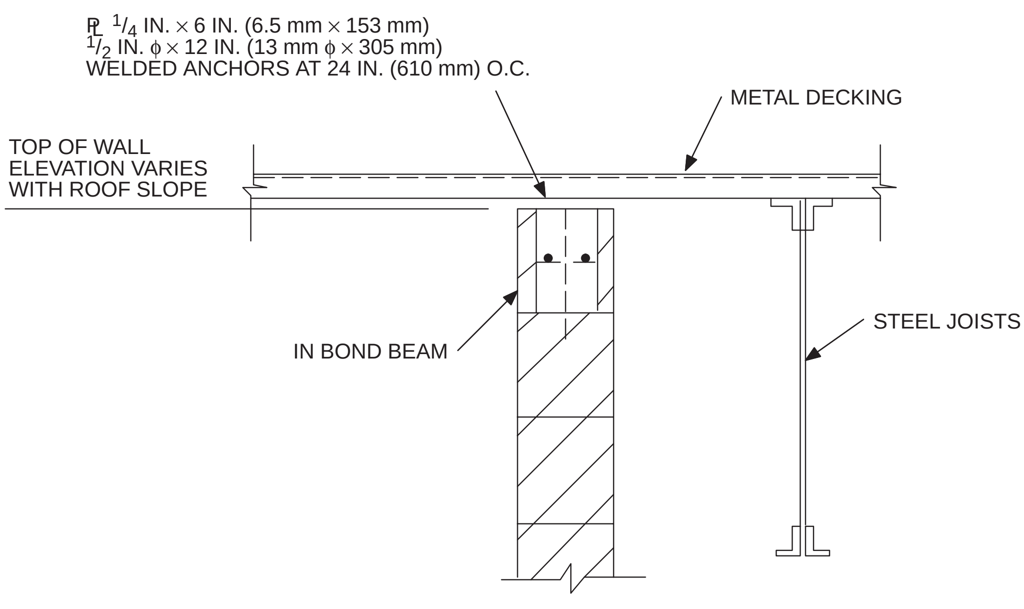


FIGURE A-21-15—INTERIOR WALL DETAILS

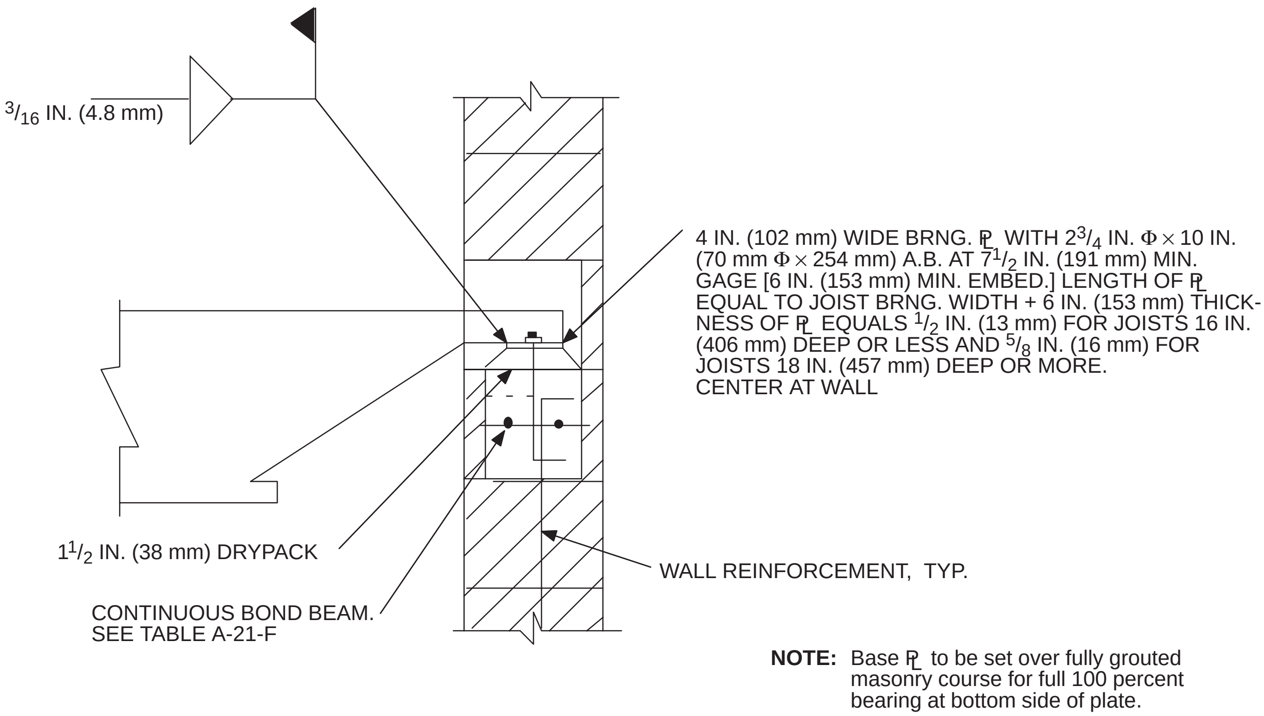
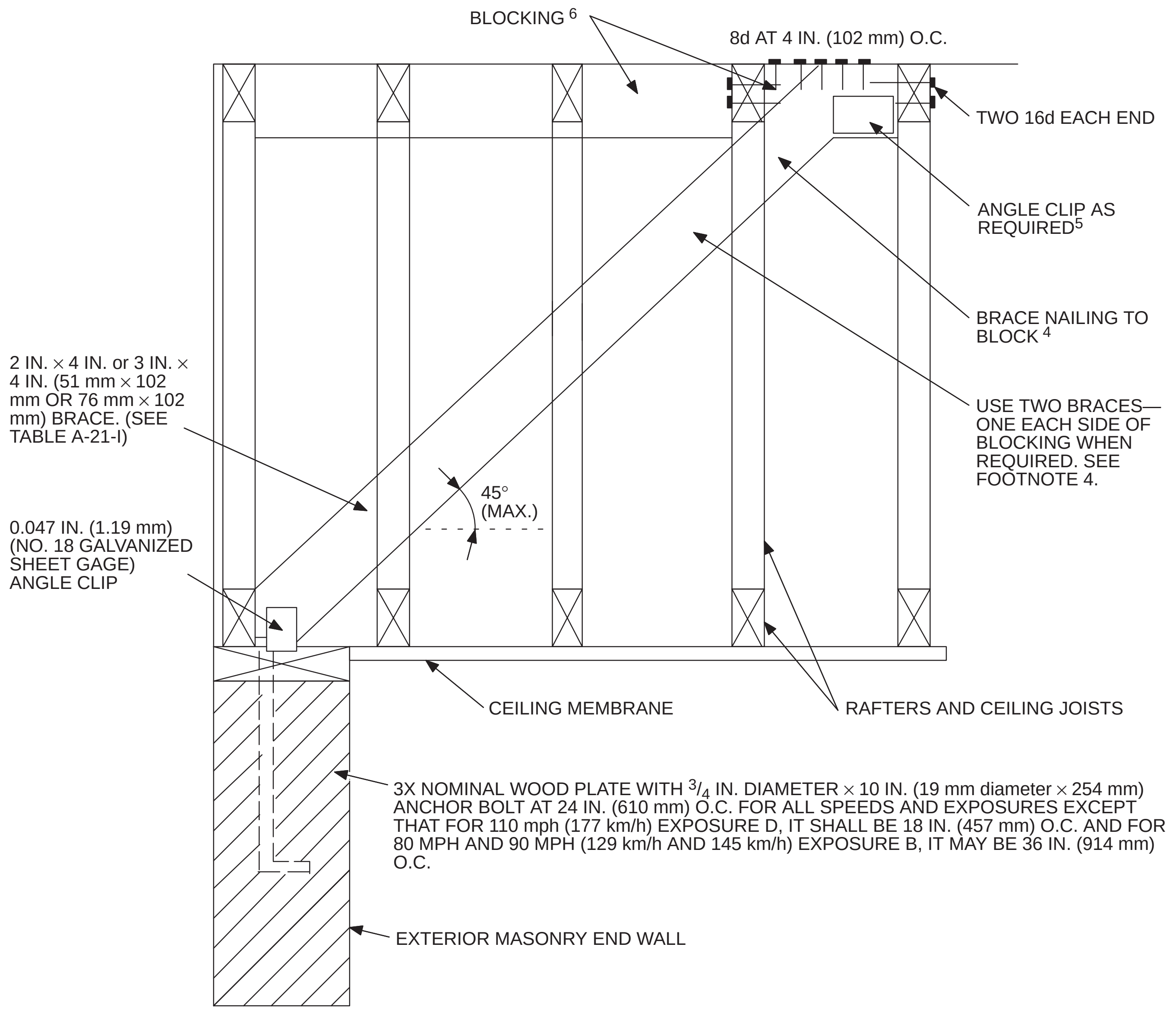
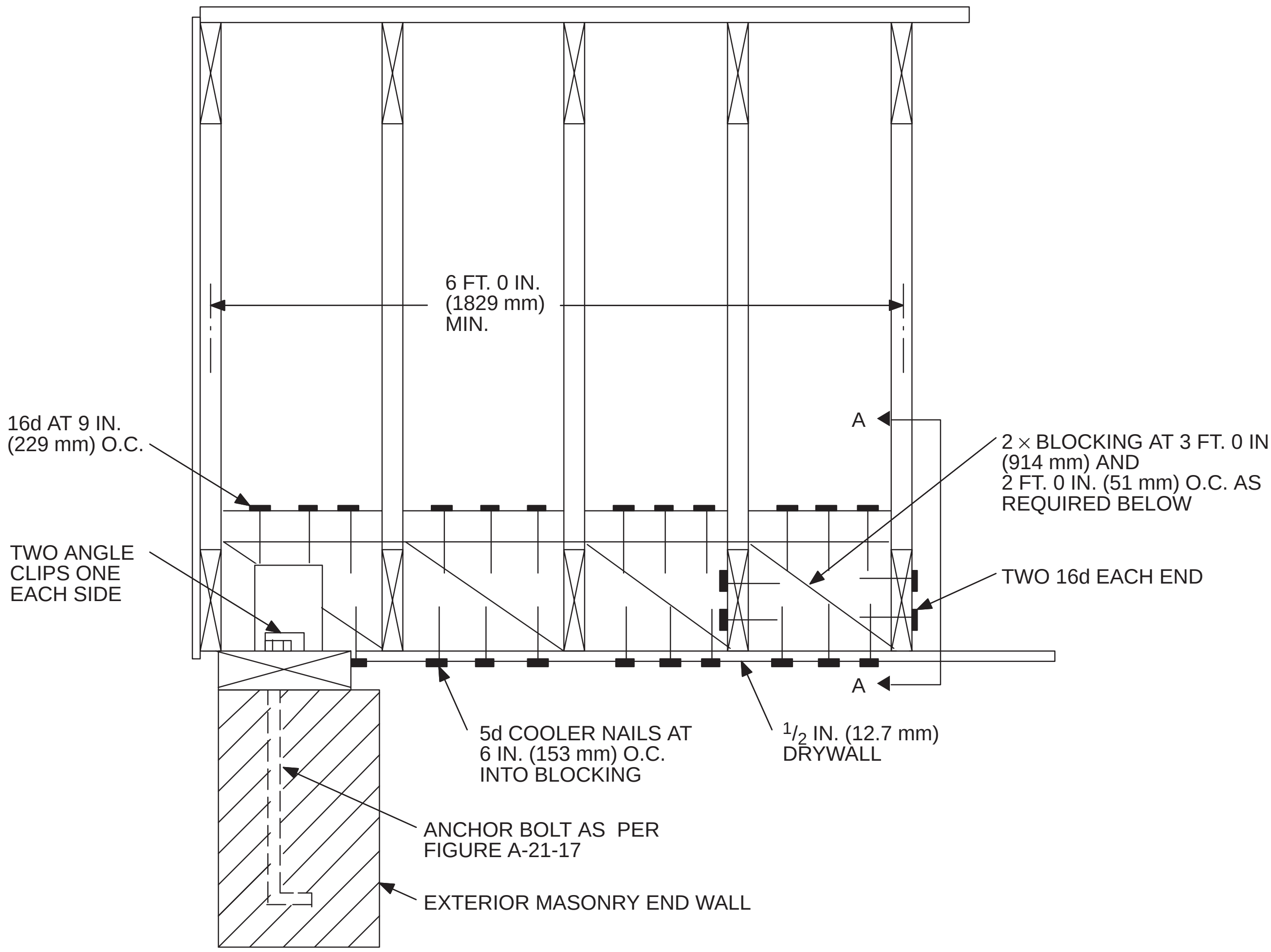


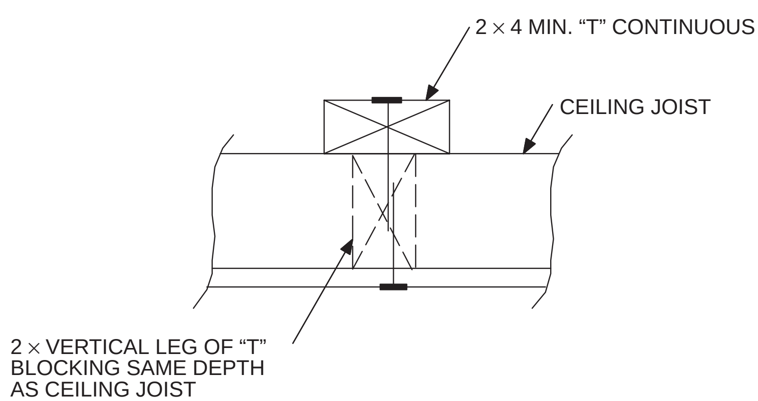
FIGURE A-21-16—FLOOR DETAILS
(Design Required for Joists and Wall)



[1] For roof slopes up to 5 units vertical in 12 units horizontal (42%); see Table A-21-I.
[2] See Detail 2, Table A-21-B, for size of angle clip.
[3] Angle clip one side or both sides as required by Table A-21-I.
[4] Use six 16d nails to fasten brace to block, except use two braces and six 16d nails each for 110 miles per hour (mph) (177 km/h), Exposure D. Place on brace on each side block.
[5] Add angle clip each end of block for 90 mph (145 km/h), Exposure D, and 100 and 110 mph (161 and 177 km/h) for Exposures C and D.
[6] Use 2 in. × 6 in. (51 mm × 153 mm) block with 2 in. (51 mm) × brace, 2 in. × 8 in. (51 mm × 203 mm) block with 3 in. (76 mm) × brace.

FIGURE A-21-17—DIAGONAL BRACING OF GABLE-END WALL[1]





DETAIL A–A

NOTE: This detail may be used for flat roofs also, except use full height blocking connected to roof sheathing in lieu of "T."
2 × 4 "T" at 36 in. (914 mm) on center—90 miles per hour (mph) (145 km/h) Exposure C and less, and 100 mph and 110 mph (161 km/h and 177 km/h), Exposure B.
2 × 4 "T" at 24 in. (610 mm) on center—required for 90 mph (145 mm) exposure.
See Figure A-21-4 for details of clip angle and connections.

FIGURE A-21-18—ALTERNATE HORIZONTAL BRACING OF GABLE-END WALL

Appendix Chapter 23
CONVENTIONAL LIGHT-FRAME CONSTRUCTION IN HIGH-WIND AREAS

SECTION 2337 — GENERAL

2337.1 Purpose. The provisions of this chapter are intended to promote public safety and welfare by reducing the risk of wind-induced damages to conventional light-frame construction.

2337.2 Scope. This chapter applies to regular-shaped buildings which have roof structural members spanning 32 feet (9.75 m) or less, are not more than three stories in height, are of conventional light-frame construction and are located in areas with a basic wind speed from 80 through 110 miles per hour (mph) (129 km/h through 177 km/h).

> **EXCEPTION:** Detached carports and garages not exceeding 600 square feet (55.7 m^2) and accessory to Group R, Division 3 Occupancies need only comply with the roof-member-to-wall-tie requirements of Section 2337.5.8.

2337.3 Definitions. For the purpose of this chapter, certain terms are defined as follows:

CORROSION RESISTANT or **NONCORROSIVE** is material having a corrosion resistance equal to or greater than a hot-dipped galvanized coating of 1.5 ounces of zinc per square foot (4 g/m^2) of surface area.

2337.4 General. The requirements of Section 2320 are applicable except as specifically modified by this chapter. Other methods may be used, provided a satisfactory design is submitted showing compliance with the provisions of Section 1611.4 and other applicable portions of this code.

In addition to the other provisions of this chapter, foundations for buildings in areas subject to wave action or tidal surge shall be designed in accordance with approved national standards.

When an element is required to be corrosion resistant or noncorrosive, all of its parts, such as screws, nails, wire, dowels, bolts, nuts, washers, shims, anchors, ties and attachments, shall also be corrosion resistant or noncorrosive.

2337.5 Complete Load Path and Uplift Ties.

2337.5.1 General. Blocking, bridging, straps, approved framing anchors or mechanical fasteners shall be installed to provide continuous ties from the roof to the foundation system. (See Figure A-23-1.)

Tie straps shall be $1^1/_8$-inch (28.6 mm) by 0.036-inch (0.91 mm) (No. 20 gage) sheet steel and shall be corrosion resistant as herein specified. All metal connectors and fasteners used in exposed locations or in areas otherwise subject to corrosion shall be of corrosion-resistant or noncorrosive material.

2337.5.2 Walls-to-foundation tie. Exterior walls shall be tied to a continuous foundation, or an elevated foundation system in accordance with Section 2337.10.

2337.5.3 Sills and foundation tie. Foundation plates resting on concrete or masonry foundations shall be bolted to the foundation with not less than $^1/_2$-inch-diameter (13 mm) anchor bolts with 7-inch-minimum (178 mm) embedment into the foundation. In areas where the basic wind speed is 90 mph (145 km/h) or greater, the maximum spacing of anchor bolts shall be 4 feet (1219 mm) on center. Structures located where the basic wind speed is less than 90 mph (145 km/h) may have anchor bolts spaced not more than 6 feet (1829 mm) on center.

2337.5.4 Floor-to-foundation tie. The lowest-level exterior wall studs shall be connected to the foundation sill plate or an approved elevated foundation system with bent tie straps spaced not more than 48 inches (1219 mm) on center. Tie straps shall be nailed and installed in accordance with Table A-23-B and Figure A-23-1.

2337.5.5 Wall framing details. The spacing of 2-inch-by-4-inch studs (51 mm by 102 mm) in exterior walls shall not exceed 16 inches (406 mm) on center for areas with a basic wind speed of 90 mph (145 km/h) or greater.

Mechanical fasteners complying with this chapter shall be installed as required to connect studs to the sole plates, foundation sill plate and top plates of the wall.

Interior main cross-stud partitions shall be installed approximately perpendicular to the exterior wall when the length of the structure exceeds the width. The maximum distance between these partitions shall not exceed the width of the structure. Interior main cross-stud partition walls shall be securely fastened to exterior walls at the point of intersection with fasteners as required by Table 23-II-B-1. The main cross-stud partitions shall be covered on both sides by materials as described in Section 2337.5.6.

2337.5.6 Wall sheathing. All exterior walls and required interior main cross-stud partitions shall be sheathed in accordance with Table A-23-A. The total width of sheathed wall elements shall not be less than 50 percent of the exterior wall length or 60 percent of the width of the building for required interior main cross-stud partitions. The exterior wall sheathing or covering shall extend from the foundation sill plate or girder to the top plates at the roof level and shall be adequately attached thereto.

A sheathed wall element not less than 4 feet (1219 mm) in width shall be installed at each corner or as near thereto as possible. There shall not be less than one 4-foot (1219 mm) sheathed wall element for every 20 feet (6096 mm) or fraction thereof of wall length. The height-to-length ratio of required sheathed wall elements shall not exceed 3 for wood structural panel or particleboard and $1^1/_2$ (38 mm) for other sheathing materials listed in Table A-23-A.

2337.5.7 Floor-to-floor tie. Upper-level exterior wall studs shall be aligned and connected to the wall studs below with a tie strap as required by Table A-23-B.

2337.5.8 Roof-members-to-wall tie. Tie straps shall be provided from the side of the roof-framing member to the exterior studs, posts or other supporting members below the roof. The wall studs to which the roof-framing members are tied shall be aligned with the roof-framing member and be connected in accordance with Table A-23-B.

The eave overhang shall not exceed 3 feet (914 mm) unless an analysis is provided showing that the required resistance is provided to prevent uplift.

Where openings exceed 6 feet (1829 mm) in width, the required tie straps shall be doubled at each edge of the opening and connected to a doubled full-height wall stud. When openings exceed 12 feet (3658 mm) in width, ties designed to prevent uplift shall be provided.

> **EXCEPTION:** The opening width may be increased to 16 feet (4877 mm) for garages and carports accessory to Group R, Division 3 Occupancies when constructed in accordance with the following:

1. Approved column bases shall be a minimum $^3/_{16}$-inch (4.8 mm) steel plate embedded not less than 8 inches (203 mm) into the concrete footing and connected to a minimum 4-inch-by-4-inch (102 mm by 102 mm) wood post with two $^5/_8$-inch-diameter (15.9 mm) through bolts.
2. Beams over openings shall be connected to minimum 4-inch by 4-inch (102 mm by 102 mm) wood posts below with an approved $^3/_{16}$-inch (4.8 mm) steel post cap with two $^5/_8$-inch-diameter (15.9 mm) through bolts to the posts and to the beams.

2337.5.9 Ridge ties. Opposing rafters shall be aligned at the ridge and be connected at the rafters with a tie strap in accordance with Table A-23-C.

2337.6 Masonry Veneer. Anchor ties shall be spaced so as to support not more than $1^1/_3$ square feet (860 mm^2) of wall area but not more than 12 inches (305 mm) on center vertically. The materials and connection details shall comply with Chapter 14.

2337.7 Roof Sheathing. Solid roof sheathing shall be applied and shall consist of a minimum 1-inch-thick (25 mm) nominal lumber applied diagonally or a minimum $^{15}/_{32}$-inch-thick (11.9 mm) wood structural panel or particleboard or other approved sheathing applied with the long dimension perpendicular to supporting rafters. Sheathing shall be nailed to roof framing in an approved manner. The end joints of wood structural panels or particleboard shall be staggered and shall occur over blocking, rafters or other supports.

2337.8 Gable-end Walls. The roof overhang at gabled ends shall not exceed 2 feet (610 mm) unless an analysis showing that the required resistance to prevent uplift is provided.

Gable-end wall studs shall be continuous between points of lateral support which are perpendicular to the plane of the wall.

Gable-end wall studs shall be attached with approved mechanical fasteners at the top and bottom.

2337.9 Roof Covering. Roof coverings shall be approved and shall be installed and fastened in accordance with Chapter 15 and with the manufacturer's instructions. In areas with basic wind speeds of 90 mph (145 km/h) or greater strip asphalt shingles shall be fastened with a minimum of six fasteners and hand sealed.

2337.10 Elevated Foundation.

2337.10.1 General. When approved, elevated foundations supporting not more than one story and meeting the provisions of this section may be used. A foundation investigation may be required by the building official.

2337.10.2 Material. All exposed wood-framing members shall be treated wood. All metal connectors and fasteners used in exposed locations shall be corrosion-resistant or noncorrosive steel.

2337.10.3 Wood piles. The spacing of wood piles shall not exceed 8 feet (2438 mm) on center. Square piles shall not be less than 10 inches (254 mm) and tapered piles shall have a tip of not less than 8 inches (203 mm). Ten-inch-square (64 516 mm^2) piles shall have a minimum embedment length of 10 feet (3048 mm) and shall project not more than 8 feet (2438 mm) above undisturbed ground surface. Eight-inch (203 mm) taper piles shall have a minimum embedment length of 14 feet (4267 mm) and shall project not more than 7 feet (2134 mm) above undisturbed ground surface.

2337.10.4 Girders. Floor girders shall be solid sawn timber, built-up 2-inch-thick (51 mm) lumber or trusses. Splices shall occur over wood piles. The floor girders shall span in the direction parallel to the potential floodwater and wave action.

2337.10.5 Connections. Wood piles may be notched to provide a shelf for supporting the floor girders. The total notching shall not exceed 50 percent of the pile cross section. Approved bolted connections with $^1/_4$-inch (6.4 mm) corrosion-resistant or noncorrosive steel plates and $^3/_4$-inch-diameter (19 mm) bolts shall be provided. Each end of the girder shall be connected to the piles using a minimum of two $^3/_4$-inch-diameter (19 mm) bolts.

TABLE A-23-A—WALL SHEATHING AT EXTERIOR WALLS AND INTERIOR MAIN CROSS-STUD PARTITIONS[1]

BASIC WIND SPEED (mph) × 1.61 for km/h	STORIES	LEVEL[2]	EXPOSURE B	EXPOSURE C	EXPOSURE D
80	1		A	A	B
	2	2 1	A C	A D	B D
	3	3 2 1	A C C	A D D	B D E
90	1		A	B	B
	2	2 1	A C	B D	B D
	3	3 2 1	A C D	B D E	Not permitted
100	1		A	C	C
	2	2 1	A C	C D	C E
	3	3 2 1	A C D	Not permitted	Not permitted
110	1		B	C	C
	2	2 1	B D	C E	C E

[1]Sheathing types; exterior walls with sheathing at one face, interior main cross-stud partitions with sheathing at each face. The values for sheathing are listed in order of increased capacity. Sheathing with a capacity greater than required may be substituted for the sheathing listed. Particleboard sheathing in accordance with Table 23-IV-D-2 may be substituted for sheathing Types A and B.

A. One-half-inch (12.7 mm) gypsum board or gypsum sheathing with 5d cooler nails at 7 inches (178 mm) or $^{3}/_{8}$-inch (9.5 mm) gypsum lath and $^{1}/_{2}$-inch (12.7 mm) plaster.

B. One-half-inch (12.7 mm) gypsum board or gypsum sheathing with 5d cooler nails at 4 inches (102 mm).

C. Expanded metal lath and $^{7}/_{8}$-inch (22 mm) portland cement plaster.

D. Three-eighths-inch (9.5 mm) wood structural panel or particleboard sheathing with 8d nails at 6 inches (153 mm) all edges and 12 inches (305 mm) intermediate.

E. Three-eighths-inch (9.5 mm) plywood or particleboard sheathing with 8d nails at 4 inches (102 mm) all edges and 12 inches (305 mm) intermediate.

The application of these sheathing materials shall comply with Section 2513.5 and Table 25-I for Types A, B and C, and Section 2315.1 and Table 23-II-I-1 or 23-II-I-2 for Types D and E. All panel edges of Types D and E shall be backed with 2-inch (51 mm) nominal or wider framing.

[2]Level refers to the space between the upper surface of any floor and upper surface of floor next above. The topmost level shall be the space between upper surface of the topmost floor and the ceiling or roof above. Wall sheathing at useable or unused under-floor space shall be provided as required for the level directly above.

TABLE A-23-B—ROOF AND FLOOR ANCHORAGE AT EXTERIOR WALLS

BASIC WIND SPEED (mph) × 1.61 for km/h	LOCATION[1]	NUMBER OF NAILS[2] Exposure B	Exposure C	Exposure D
80	roof to wall floor to floor floor to foundation	6-8d — —	8-8d 4-10d 4-10d	8-10d 6-10d 4-10d
90	roof to wall floor to floor floor to foundation	8-8d — —	8-10d 6-10d 4-10d	10-10d 8-10d 6-10d
100	roof to wall floor to floor floor to foundation	8-10d 6-10d 4-10d	10-10d 8-10d 6-10d	12-10d 10-10d 8-10d
110	roof to wall floor to floor floor to foundation	10-10d 8-10d 6-10d	12-10d 10-10d 8-10d	12-10d 10-10d 8-10d

[1]For floor-to-foundation anchorage, see Section 2337.5.4.

[2]Number of common nails listed is total required for each tie strap. The tie straps shall be spaced at 48 inches (1219 mm) on center along the length of the wall. The number of nails on each side of the roof or floor plate joints shall be equal. Nails shall be spaced to avoid splitting of the wood. See Figure A-23-1 for illustration of these tie straps.

TABLE A-23-C—RIDGE TIE-STRAP NAILING[1]

BASIC WIND SPEED (mph)	NUMBER OF NAILS[1]		
	Exposure		
× 1.61 for km/h	B	C	D
80	6-10d	8-10d	10-10d
90	8-10d	10-10d	12-10d
100	10-10d	12-10d	14-10d
110	12-10d	14-10d	16-10d

[1]Number of common nails listed is total required for each tie strap. The tie straps shall be spaced at 48 inches (1219 mm) on center along the length of the roof. The number of nails on each side of the rafter/ridge joint shall be equal. Nails shall be spaced to avoid splitting of the wood. See Figure A-23-1 for illustration of these tie straps.

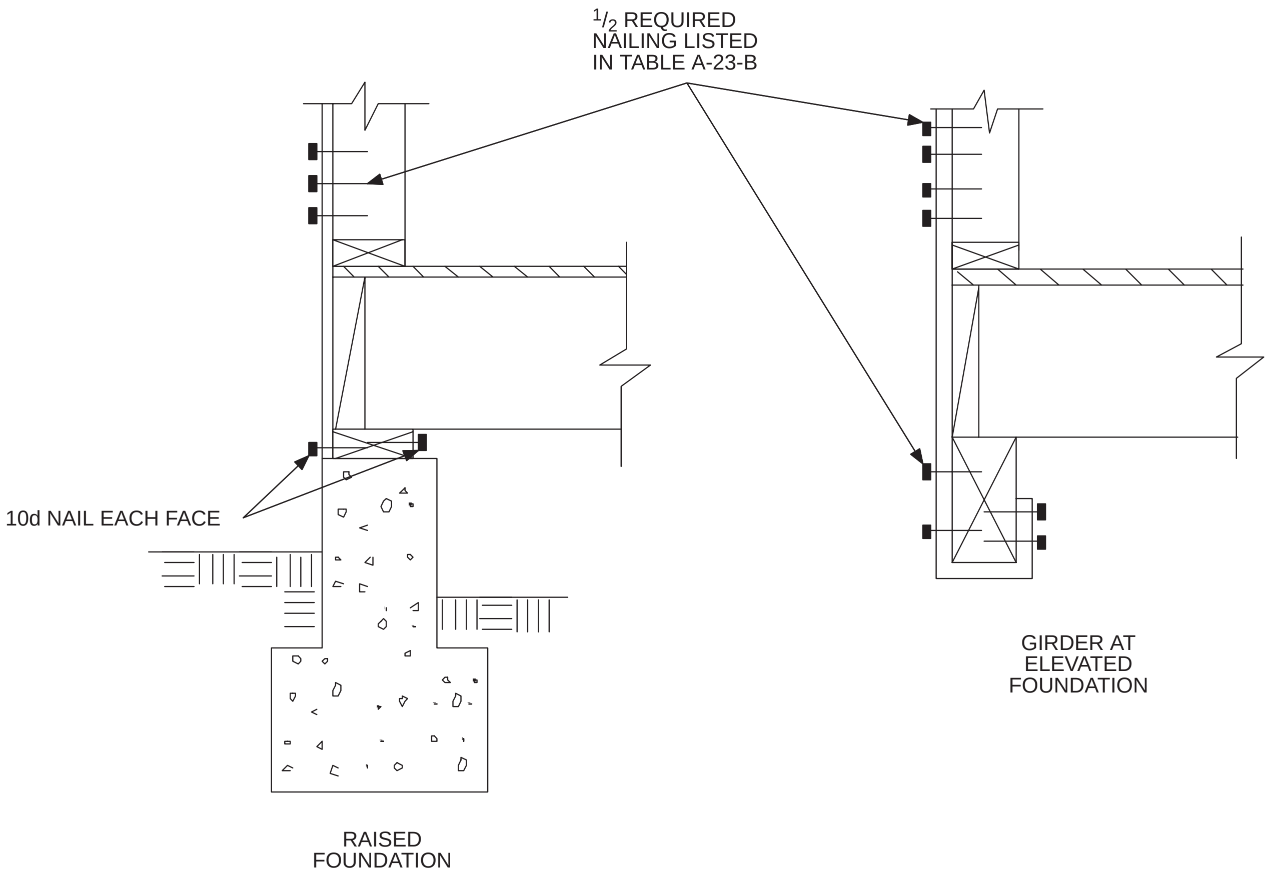


FIGURE A-23-1—COMPLETE LOAD PATH DETAILS

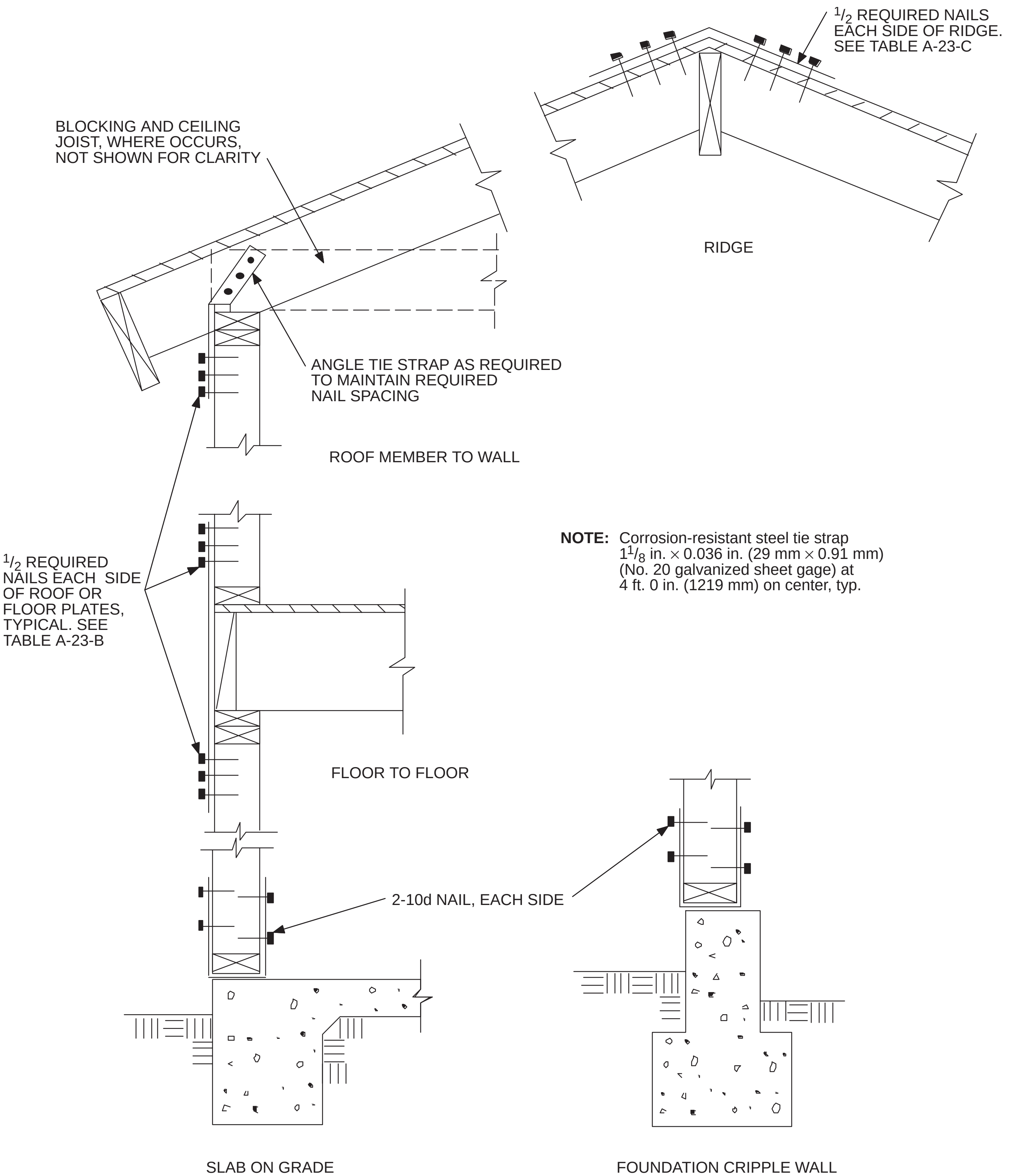


FIGURE A-23-1—COMPLETE LOAD PATH DETAILS—(Continued)

Appendix Chapters 30 through 34 are printed in Volume 1 of the *Uniform Building Code.*

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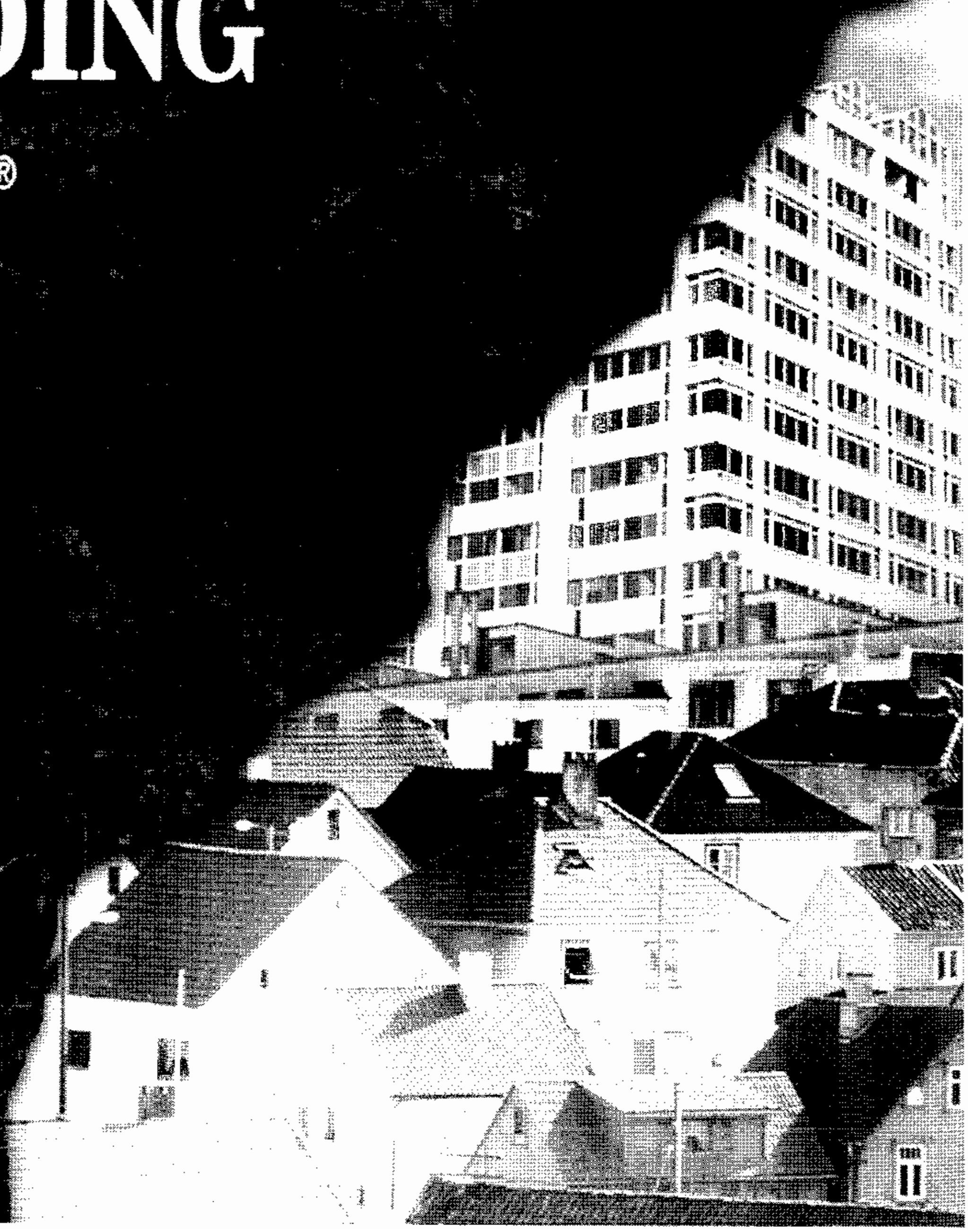

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Preface

The *Uniform Building Code*™ is dedicated to the development of better building construction and greater safety to the public by uniformity in building laws. The code is founded on broad-based principles that make possible the use of new materials and new construction systems.

The *Uniform Building Code* was first enacted by the International Conference of Building Officials at the Sixth Annual Business Meeting held in Phoenix, Arizona, October 18-21, 1927. Revised editions of this code have been published since that time at approximate three-year intervals. New editions incorporate changes approved since the last edition.

The *Uniform Building Code* is designed to be compatible with related publications to provide a complete set of documents for regulatory use. See the publications list following this preface for a listing of the complete family of Uniform Codes and related publications.

Code Changes. The ICBO code development process has been suspended by the Board of Directors and, because of this action, changes to the *Uniform Building Code* will not be processed. For more information, write to the International Conference of Building Officials, 5360 Workman Mill Road, Whittier, California 90601-2298. An analysis of changes between editions is published in the *Analysis of Revisions to the Uniform Codes*.

Marginal Markings. Solid vertical lines in the margins within the body of the code indicate a change from the requirements of the 1994 edition except where an entire chapter was revised, a new chapter was added or a change was minor. Where an entire chapter was revised or a new chapter was added, a notation appears at the beginning of that chapter. The letter **F** repeating in line vertically in the margin indicates that the provision is maintained under the code change procedures of the International Fire Code Institute. Deletion indicators (➧) are provided in the margin where a paragraph or item listing has been deleted if the deletion resulted in a change of requirements.

Three-Volume Set. Provisions of the *Uniform Building Code* have been divided into a three-volume set. Volume 1 accommodates administrative, fire- and life-safety, and field inspection provisions. Chapters 1 through 15 and Chapters 24 through 35 are printed in Volume 1 in their entirety. Any appendix chapters associated with these chapters are printed in their entirety at the end of Volume 1. Excerpts of certain chapters from Volume 2 are reprinted in Volume 1 to provide greater usability.

Volume 2 accommodates structural engineering design provisions, and specifically contains Chapters 16 through 23 printed in their entirety. Included in this volume are design standards that have been added to their respective chapters as divisions of the chapters. Any appendix chapters associated with these chapters are printed in their entirety at the end of Volume 2. Excerpts of certain chapters from Volume 1 are reprinted in Volume 2 to provide greater usability.

Volume 3 contains material, testing and installation standards.

Metrication. The *Uniform Building Code* was metricated in the 1994 edition. The metric conversions are provided in parenthesis following the English units. Where industry has made metric conversions available, the conversions conform to current industry standards.

Formulas are also provided with metric equivalents. Metric equivalent formulas immediately follow the English formula and are denoted by "For **SI:**" preceding the metric equivalent. Some formulas do not use dimensions and, thus, are not provided with a metric equivalent. Multiplying conversion factors have been provided for formulas where metric forms were unavailable. Tables are provided with multiplying conversion factors in subheadings for each tabulated unit of measurement.

CODES AND RELATED PUBLICATIONS

The International Conference of Building Officials (ICBO) publishes a family of codes, each correlated with the *Uniform Building Code*™ to provide jurisdictions with a complete set of building-related regulations for adoption. Some of these codes are published in affiliation with other organizations such as the International Fire Code Institute (IFCI) and the International Code Council (ICC). Reference materials and related codes also are available to improve knowledge of code enforcement and administration of building inspection programs. Publications and products are continually being added, so inquiries should be directed to Conference headquarters for a listing of available products. Many codes and references are also available on CD-ROM or floppy disk. These are denoted by (*). The following publications and products are available from ICBO:

CODES

***Uniform Building Code**, Volumes 1, 2 and 3. The most widely adopted model building code in the United States, the performance-based *Uniform Building Code* is a proven document, meeting the needs of government units charged with the enforcement of building regulations. Volume 1 contains administrative, fire- and life-safety and field inspection provisions; Volume 2 contains structural engineering design provisions; and Volume 3 contains material, testing and installation standards.

***Uniform Mechanical Code™.** Provides a complete set of requirements for the design, construction, installation and maintenance of heating, ventilating, cooling and refrigeration systems; incinerators and other heat-producing appliances.

International Plumbing Code™. Provides consistent and technically advanced requirements that can be used across the country to provide comprehensive regulations of modern plumbing systems. Setting minimum regulations for plumbing facilities in terms of performance objectives, the IPC provides for the acceptance of new and innovative products, materials and systems.

International Private Sewage Disposal Code™. Provides flexibility in the development of safety and sanitary individual sewage disposal systems and includes detailed provisions for all aspects of design, installation and inspection of private sewage disposal systems.

International Mechanical Code™. Establishes minimum regulations for mechanical systems using prescriptive and performance-related provisions. It is founded on broad-based principles that make possible the use of new materials and new mechanical designs.

Uniform Zoning Code™. This code is dedicated to intelligent community development and to the benefit of the public welfare by providing a means of promoting uniformity in zoning laws and enforcement.

***Uniform Fire Code™**, Volumes 1 and 2. The premier model fire code in the United States, the *Uniform Fire Code* sets forth provisions necessary for fire prevention and fire protection. Published by the International Fire Code Institute, the *Uniform Fire Code* is endorsed by the Western Fire Chiefs Association, the International Association of Fire Chiefs and ICBO. Volume 1 contains code provisions compatible with the *Uniform Building Code,* and Volume 2 contains standards referenced from the code provisions.

***Urban-Wildland Interface Code™.** Promulgated by IFCI, this code regulates both land use and the built environment in designated urban-wildland interface areas. This newly developed code is the only model code that bases construction requirements on the fire-hazard severity exposed to the structure. Developed under a grant from the Federal Emergency Management Agency, this code is the direct result of hazard mitigation meetings held after devastating wildfires.

Uniform Housing Code™. Provides complete requirements affecting conservation and rehabilitation of housing. Its regulations are compatible with the *Uniform Building Code.*

Uniform Code for the Abatement of Dangerous Buildings™. A code compatible with the *Uniform Building Code* and the *Uniform Housing Code* which provides equitable remedies consistent with other laws for the repair, vacation or demolition of dangerous buildings.

Uniform Sign Code™. Dedicated to the development of better sign regulation, its requirements pertain to all signs and sign construction attached to buildings.

Uniform Administrative Code™. This code covers administrative areas in connection with adoption of the *Uniform Building Code, Uniform Mechanical Code* and related codes. It contains provisions which relate to site preparation, construction, alteration, moving, repair and use and occupancies of buildings or structures and building service equipment, including plumbing, electrical and mechanical regulations. The code is compatible with the administrative provisions of all codes published by the Conference.

Uniform Building Security Code™. This code establishes minimum standards to make dwelling units resistant to unlawful entry. It regulates swinging doors, sliding doors, windows and hardware in connection with dwelling units of apartment houses or one- and two-family dwellings. The code gives consideration to the concerns of police, fire and building officials in establishing requirements for resistance to burglary which are compatible with fire and life safety.

Uniform Code for Building Conservation™. A building conservation guideline presented in code format which will provide a community with the means to preserve its existing buildings while achieving appropriate levels of safety. It is formatted in the same manner as the *Uniform Building Code,* is compatible with other Uniform Codes, and may be adopted as a code or used as a guideline.

Dwelling Construction under the Uniform Building Code™. Designed primarily for use in home building and apprentice training, this book contains requirements applicable to the construction of one- and two-story dwellings based on the requirements of the *Uniform Building Code.* Available in English or Spanish.

Dwelling Construction under the Uniform Mechanical Code™. This publication is for the convenience of the homeowner or contractor interested in installing mechanical equipment in a one- or two-family dwelling in conformance with the *Uniform Mechanical Code.*

Supplements to UBC and related codes. Published in the years between editions, the Supplements contain all approved changes, plus an analysis of those changes.

Uniform Building Code—1927 Edition. A special 60th anniversary printing of the first published *Uniform Building Code.*

One and Two Family Dwelling Code. Promulgated by ICC, this code eliminates conflicts and duplications among the model codes to achieve national uniformity. Covers mechanical and plumbing requirements as well as construction and occupancy.

Application and Commentary on the One and Two Family Dwelling Code. An interpretative commentary on the *One and Two Family Dwelling Code* intended to enhance uniformity of interpretation and application of the code nationwide. Developed by the three model code organizations, this document includes numerous illustrations of code requirements and the rationale for individual provisions.

Model Energy Code. This code includes minimum requirements for effective use of energy in the design of new buildings and structures and additions to existing buildings. It is based on American Society of Heating, Refrigeration and Air-conditioning Engineers Standard 90A-1980 and was originally developed jointly by ICBO, BOCA, SBCCI and the National Conference of States on Building Codes and Standards under a contract funded by the United States Department of Energy. The code is now maintained by ICC and is adopted by reference in the *Uniform Building Code.*

National Electrical Code®. The electrical code used throughout the United States. Published by the National Fire Protection Association, it is an indispensable aid to every electrician, contractor, architect, builder, inspector and anyone who must specify or certify electrical installations.

TECHNICAL REFERENCES AND EDUCATIONAL MATERIALS

Analysis of Revisions to the Uniform Codes™. An analysis of changes between the previous and new editions of the Uniform Codes is provided. Changes between code editions are noted either at the beginning of chapters or in the margins of the code text.

***Handbook to the Uniform Building Code.** The handbook is a completely detailed and illustrated commentary on the *Uniform Building Code,* tracing historical background and rationale of the codes through the current edition. Also included are numerous drawings and figures clarifying the application and intent of the code provisions. Also available in electronic format.

***Handbook to the Uniform Mechanical Code.** An indispensable tool for understanding the provisions of the current UMC, the handbook traces the historical background and rationale behind the UMC provisions, includes 160 figures which clarify the intent and application of the code, and provides a chapter-by-chapter analysis of the UMC.

***Uniform Building Code Application Manual.** This manual discusses sections of the *Uniform Building Code* with a question-and-answer format, providing a comprehensive analysis of the intent of the code sections. Most sections include illustrative examples. The manual is in loose-leaf format so that code applications published in *Building Standards* magazine may be inserted. Also available in electronic format.

***Uniform Mechanical Code Application Manual.** As a companion document to the *Uniform Mechanical Code,* this manual provides a comprehensive analysis of the intent of a number of code sections in an easy-to-use question-and-answer format. The manual is available in a loose-leaf format and includes illustrative examples for many code sections.

***Uniform Fire Code Applications Manual.** This newly developed manual provides questions and answers regarding UFC provisions. A comprehensive analysis of the intent of numerous code sections, the manual is in a loose-leaf format for easy insertion of code applications published in IFCI's *Fire Code Journal.*

Quick-Reference Guide to the Occupancy Requirements of the 1997 UBC. Code requirements are compiled in this publication by occupancy groups for quick access. These tabulations assemble requirements for each occupancy classification in the code. Provisions, such as fire-resistive ratings for occupancy separations in Table 3-B, exterior wall and opening protection requirements in Table 5-A-1, and fire-resistive ratings for types of construction in Table 6-A, are tabulated for quick reference and comparison.

Plan Review Manual. A practical text that will assist and guide both the field inspector and plan reviewer in applying the code requirements. This manual covers the nonstructural and basic structural aspects of plan review.

Field Inspection Manual. An important fundamental text for courses of study at the community college and trade or technical school level. It is an effective text for those studying building construction or architecture and includes sample forms and checklists for use in the field.

Building Department Administration. An excellent guide for improvement of skills in departmental management and in the enforcement and application of the Building Code and other regulations administered by a building inspection department. This textbook will also be a valuable aid to instructors, students and those in related professional fields.

Building Department Guide to Disaster Mitigation. This new, expanded guide is designed to assist building departments in developing or updating disaster mitigation plans. Subjects covered include guidelines for damage mitigation, disaster-response management, immediate response, mutual aid and inspections, working with the media, repair and recovery policies, and public information bulletins. This publication is a must for those involved in preparing for and responding to disaster.

Building Official Management Manual. This manual addresses the unique nature of code administration and the managerial duties of the building official. A supplementary insert addresses the budgetary and financial aspects of a building department. It is also an ideal resource for those preparing for the management module of the CABO Building Official Certification Examination.

Legal Aspects of Code Administration. A manual developed by the three model code organizations to inform the building official on the legal aspects of the profession. The text is written in a logical sequence with explanation of legal terminology. It is designed to serve as a refresher for those preparing to take the legal module of the CABO Building Official Certification Examination.

Illustrated Guide to Conventional Construction Provisions of the UBC. This comprehensive guide and commentary provides detailed explanations of the conventional construction provisions in the UBC, including descriptive discussions and illustrated drawings to convey the prescriptive provisions related to wood-frame construction.

Introduction to the Uniform Building Code. A workbook that provides an overview of the basics of the UBC.

Uniform Building Code Update Workbook. This manual addresses many of the changes to the administrative, fire- and life-safety, and inspection provisions appearing in the UBC.

UMC Workbook. Designed for independent study or use with instructor-led programs based on the *Uniform Mechanical Code,* this comprehensive study guide consists of 16 learning sessions, with the first two sessions reviewing the purpose, scope, definitions and administrative provisions and the remaining 14 sessions progressively exploring the requirements for installing, inspecting and maintaining heating, ventilating, cooling and refrigeration systems.

UBC Field Inspection Workbook. A comprehensive workbook for studying the provisions of the UBC. Divided into 12 sessions, this workbook focuses on the UBC combustible construction requirements for the inspection of wood-framed construction.

Concrete Manual. A publication for individuals seeking an understanding of the fundamentals of concrete field technology and inspection practices. Of particular interest to concrete construction inspectors, it will also benefit employees of concrete producers, contractors, testing and inspection laboratories and material suppliers.

Reinforced Concrete Masonry Construction Inspector's Handbook. A comprehensive information source written especially for masonry inspection covering terminology, technology, materials, quality control, inspection and standards. Published jointly by ICBO and the Masonry Institute of America.

You Can Build It! Sponsored by ICBO in cooperation with CABO, this booklet contains information and advice to aid "do-it-yourselfers" with building projects. Provides guidance in necessary procedures such as permit requirements, codes, plans, cost estimation, etc.

Guidelines for Manufactured Housing Installations. A guideline in code form implementing the *Uniform Building Code* and its companion code documents to regulate the permanent installation of a manufactured home on a privately owned, nonrental site. A commentary is included to explain specific provisions, and codes applying to each component part are defined.

Accessibility Reference Guide. This guide is a valuable resource for architects, interior designers, plan reviewers and others who design and enforce accessibility provisions. Features include accessibility requirements, along with detailed commentary and graphics to clarify the provisions; cross-references to other applicable sections of the UBC and the Americans with Disabilities Act Accessibility Guidelines; a checklist of UBC provisions on access and usability requirements; and many other useful references.

Educational and Technical Reference Materials. The Conference has been a leader in the development of texts and course material to assist in the educational process. These materials include vital information necessary for the building official and subordinates in carrying out their responsibilities and have proven to be excellent references in connection with community college curricula and higher-level courses in the field of building construction technology and inspection and in the administration of building departments. Included are plan review checklists for structural, nonstructural, mechanical and fire-safety provisions and a full line of videotapes and automated products.

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Volume 3

UNIFORM BUILDING CODE STANDARD 2-1
NONCOMBUSTIBLE MATERIAL—TESTS

Based on Standard Method of Test E 136-79 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 201.2 and 215, *Uniform Building Code*; Section 216, *Uniform Mechanical Code*; and Section 211, *Uniform Sign Code*

SECTION 2.101 — SCOPE

This standard describes a procedure for the determination of noncombustibility of elementary materials of which building materials are composed, to indicate those materials which do not act to aid combustion or add appreciable heat to an ambient fire. It is not intended to apply to laminated or coated materials.

SECTION 2.102 — APPARATUS

The apparatus shall consist primarily of the following:

Refractory tubes. Two 10-inch-long (254 mm), concentric refractory tubes, 3 inches (76 mm) and 4 inches (102 mm) in inside diameter, with axes vertical and with heat applied by electric heating coils outside of the larger tube. A controlled flow of air is admitted tangentially near the top of the annular space between the tubes and passes to the bottom of the inner tube. The outer tube rests on a refractory bottom and the inner tube rests on three spacer blocks so as to afford a total opening under the inner tube equal to or greater than that of the annular space. The refractory bottom plate has a removable plug for cleaning.

Transparent cover. A transparent cover of heat-resisting glass or other transparent material shall be provided over the top of the inner tube with a 1-inch square (645 mm^2) opening over the axis of the tubes. This cover may be in two movable parts.

Thermocouples or other temperature-measuring devices, preferably automatically recording, shall be provided, one for the air in the lower part of the inner tube, another on the specimen in the approximate center of the space, and a third within the interior of the specimen. A thermocouple may be provided in the region of the heating coils for better regulation of the temperature of the air in the furnace space. The two specimen thermocouples shall have a time constant [time to reach 63.2 percent of the furnace air temperature of 1382°F (750°C)] of five to 10 seconds.

SECTION 2.103 — TEST SPECIMENS

All test specimens shall be $1^1/_2$ inches (38 mm) wide by $1^1/_2$ inches (38 mm) thick in cross section perpendicular to the air flow in the furnace and 2 inches (51 mm) long with tolerances on the dimensions of plus or minus $^1/_{10}$ inch (2.5 mm). The specimens shall be dried at 140°F plus or minus 5°F (60°C ± 3°C) for not less than 24 hours nor more than 48 hours before being tested.

Specimens in granular or powder form may be contained in thin-wall, open-top vessels of inert materials whose outside dimensions conform to the specimen shape and maximum size specified in this section. These vessels may have solid walls or be of mesh.

Not less than four identical specimens shall be tested.

SECTION 2.104 — PROCEDURE

Prepare the furnace by bringing the temperature (at the approximate position to be occupied by the center of the specimen) of the air in the furnace tube to 1382°F plus or minus 10°F (750°C ± 6°C), maintaining the furnace setting long enough to ascertain that it will remain at constant temperature in the unloaded furnace for at least 15 minutes while air passes at a velocity of 10 feet per minute (3 m/min.) plus or minus 20 percent past a loaded specimen in the tube, computed on the basis of air supply and velocity at room temperature and pressure.

As rapidly as possible, insert the test specimen into the furnace, with a thermocouple attached to the side surface of the specimen and a thermocouple inserted from the top of the specimen to its approximate volumetric center. Close the top cover to the 1-square-inch (645 mm^2) opening immediately after insertion of the specimen. Readings for the specimen thermocouples shall be made at intervals not to exceed 10 seconds during the first five minutes, and as often afterwards as necessary to produce a smooth curve. Do not change the regulation of the current through the heating coils and the air flow during the test.

Continue the test until the temperatures at the specimen thermocouples have reached maxima or until it is clearly evident that the specimen does not pass this test.

Throughout the test make and record visual observations on the specimens, noting quality, quantity or intensity and duration of flaming or smoking, or both, and change of state.

Weigh each specimen before and after testing and record the weight loss to the nearest 1 percent.

SECTION 2.105 — INTERPRETATION OF RESULTS

Materials subjected to the test described in this method shall be reported as noncombustible if, for three or more of the four specimens tested, (1) the recorded temperatures of the surface and interior thermocouples do not at any time during the test rise to more than 54°F (30°C) above the furnace air temperature at the beginning of the test, (2) if there is no flaming from the specimen after the first 30 seconds and (3) when the weight loss of the specimen during testing exceeds 50 percent, the recorded temperature of the surface and interior thermocouples do not at any time during the test rise above the furnace air temperature at the beginning of the test and there is no flaming of the specimen.

UNIFORM BUILDING CODE STANDARD 4-1
PROSCENIUM FIRESAFETY CURTAINS

Installation Standard of the International Conference of Building Officials

See Sections 303.8 and 405.3.4, *Uniform Building Code*

SECTION 4.101 — GENERAL REQUIREMENTS

Proscenium curtains, when required, shall be made of approved materials constructed and mounted so as to intercept hot gases, flames and smoke, and to prevent a glow from a severe fire on the stage from showing on the auditorium side within a period of 30 minutes. The closing of the curtain from the full-open position shall be effected in less than 30 seconds, but the last 8 feet (2438 mm) of travel shall not require less than five seconds.

SECTION 4.102 — DEFINITIONS

Curtain styles regulated by this standard are defined as follows:

BRAILLE PROSCENIUM FIRESAFETY CURTAIN is a curtain that folds up and stores in a very limited space above the proscenium opening. (See Figure 4-1-1.)

FRAME PROSCENIUM FIRESAFETY CURTAIN is a curtain that has a rigid frame, and stores over the proscenium opening in one flat panel.

MODIFIED FRAME PROSCENIUM FIRESAFETY CURTAIN is a curtain made of various components of both the frame and straight-lift-style curtains, and stores over the proscenium opening in one flat panel.

STRAIGHT-LIFT PROSCENIUM FIRESAFETY CURTAIN is a curtain which stores over the proscenium opening in one flat panel.

SECTION 4.103 — CURTAIN FABRICS

4.103.1 General. A proscenium curtain shall be constructed and installed as specified in this standard.

4.103.2 Fabrics.

4.103.2.1 Asbestos. When not prohibited by federal, state or local law, an existing installed curtain may be made of one or more thicknesses of not less than $2^3/_4$-pound-per-square-yard (1.5 kg/m^2) AAA grade wire-inserted asbestos fabric, or of another wire-inserted asbestos fabric obviously of greater fire resistance than this $2^3/_4$-pound (1.5 kg/m^2) AAA grade wire-inserted fabric. Nonasbestos portions of these fabrics, if any, shall be flame-resistant treated so as not to support combustion.

4.103.2.2 Other fabrics. Curtains not meeting the above criteria shall be made of one or more thicknesses of a noncombustible fabric, or a fabric with a noncombustible base material which may be given a coating provided the modified fabric meets the criteria detailed in this section.

Curtain fabrics shall not weigh less than $2^3/_8$ pounds per square yard (1.3 kg/m^2) unless it can be substantiated by approved tests that the fabric is equivalent in strength and durability.

4.103.3 Tensile Strength. Curtain fabric shall have tensile strength of not less than 400 pounds per inch (70 kN/mm) in both the warp and fill directions.

4.103.4 Wire-insertion Reinforcement. Curtain fabric shall be reinforced with noncorrosive wire intertwined with the base fiber at a minimum rate of one wire per yarn. Wire may be omitted if it can be substantiated by approved tests that it is equivalent in strength and durability.

4.103.5 Fire Test. A sample curtain with a minimum of two vertical seams shall be subjected to the standard fire test specified in UBC Standard 7-1 as applicable to nonbearing walls and partitions for a period of 30 minutes. Surface temperature measurements need not be taken and the hose stream exposure need not be made. The curtain shall overlap the furnace edges an appropriate amount to seal the top and sides. It shall have a bottom pocket containing a minimum 4 pounds per linear foot (5.94 kg/m) of batten. The unexposed surface of the curtain shall not glow, and neither flame nor smoke shall penetrate the curtain during the test period.

4.103.6 Smoke Test. Curtain fabrics shall have a smoke density of no greater than 25 when tested in accordance with UBC Standard 8-1. The curtain fabric shall be tested in the condition in which it is intended to be used.

SECTION 4.104 — DESIGN AND CONSTRUCTION

4.104.1 General. The various style curtains detailed below shall all be acceptable for use, except when the fly space above the stage is sufficient to allow the straight-lift, frame or modified frame styles to be used.

When the fly space is sufficient for these above-mentioned full-lift-style curtains, the straight-lift, frame or modified frame styles shall be used for proscenium openings 50 feet (15 240 mm) wide or less and 30 feet (9144 mm) high or less; and the frame or modified frame styles shall be used for openings over 50 feet (15 240 mm) in width or 30 feet (9144 mm) in height.

Curtain installations in new facilities with openings over 50 feet (15 240 mm) in width or 30 feet (9144 mm) in height shall be the frame or modified frame construction.

Regardless of curtain style, the curtain shall be made of continuous strips of fabric as specified above, sewn together vertically using minimum 1-inch-wide (25 mm) double-needled overlap seams. These vertical seams and all other functional stitching on the curtain shall consist of two rows of lockstitch stitching using flame-resistant thread, conforming to the test requirements of Section 4.103.

The curtain shall overlap the sides of the opening at least 18 inches (457 mm) and the top of the opening at least 24 inches (610 mm).

All style curtains, except the frame style and the modified frame style (unless it has batten pockets and vertical side edge hems), shall have minimum 6-inch (153 mm) flat [12-inch (305 mm) circumference] single-thickness pockets at the top and bottom of the curtain to hold the pipe battens, and double-thick vertical side edge hems each a minimum of $^1/_2$ inch (13 mm) wider than the length of side edge guide brackets being used and width of the metal hem reinforcing pieces being used, if any, except that hems shall not be less than 4 inches (102 mm) in width. Should the curtain fabric being used be an acceptable nonwire-inserted (nonwire reinforced) fabric, batten pockets shall be double thick and vertical side edge hems shall be triple thick or faced with wire-inserted (wire reinforced) webbing or fabric (raw edges turned under). Pockets and vertical side edge hems shall be sewn as specified above. Minimum $1^1/_2$-inch (38 mm) inside diameter metal battens shall be placed in the top and bottom curtain pockets when the proscenium opening height is 18 feet (5486 mm) or less and width is 34 feet (10 363 mm) or less. For openings 50 feet (15 240 mm) or less in width [but more than 34 feet (10 363 mm)], and 30 feet (9144 mm) or less in height [but more than 18 feet [5486 mm)], the top and bottom metal battens shall not be less than 2 inches (51 mm) inside diameter. Metal battens shall be Schedule 40 steel pipe, Schedule 80 steel pipe or other metallic tubing meeting or exceeding the tensile strength and performance standards of Schedule 40 steel pipe. All batten joints shall be reinforced with minimum 18-inch (457 mm) sections of said pipes or tubing internally and shall be riveted.

A minimum 3-inch-thick (76 mm) yield pad made with an outer covering of the curtain fabric, filled with fiberglass or other noncombustible materials, in such a manner so as to achieve a minimum 3-pound-per-cubic-foot (48 kg/m^3) density, shall be sewn beneath the bottom batten pocket with four rows of flame-resistant thread (two on each side of the pocket) in such a manner so as to force the bottom batten to compress the yield pad firmly against the stage floor, producing the best possible seal when the curtain is lowered.

4.104.2 Straight-lift Style. The straight-lift-style curtain shall meet the general requirements detailed above with vertical side edge hems reinforced with one piece of 0.064-inch-thick (1.63 mm) (16 gauge) plated or painted sheet metal on each side of the hem on each side of the curtain for its full vertical height so that both faces are covered $5^1/_2$ inches (140 mm) deep, or with minimum 2-inch-wide by $1^1/_2$-inch (51 mm by 38 mm) projection by $^1/_8$-inch-thick (3.2 mm) steel angle/2-inch-wide (51 mm) by $^1/_8$-inch-thick (3.2 mm) steel flat piece set (plated or painted) clamped on both edges for the curtain's full height. Either edge-reinforcement system shall be fastened to the side edge hems with pairs of minimum $^3/_{16}$-inch (4.8 mm) plated tubular or solid steel rivets, or bolts spaced not more than 6 inches (153 mm) on center vertically.

Curtains for proscenium openings, 50 feet (15 240 mm) or less in width and 30 feet (9144 mm) or less in height, shall use a roller guide/metal track side edge guide system, using guides with at least two roller or ball bearing steel wheels each, and 0.079-inch-thick (2 mm) (14 gage) galvanized steel tracks (installed rigidly in place so that roller guides will operate smoothly with a wind load of 2 pounds per square foot (95.8 Pa) over entire area of curtain). Each guide shall be attached to the curtain's metal stiffened edges by way of three or more minimum $^3/_{16}$-inch (4.8 mm) plated tubular or solid steel rivets, or bolts through a plated steel strap assembly [0.064-inch-thick (1.63 mm) sheet metal stiffening system], a minimum $^3/_8$-inch (9.5 mm) machine screw assembly (attached to the projecting flange of the angle iron/flat steel edge stiffening system), or an equivalent attachment system. Guides shall be on maximum 18-inch (457 mm) vertical centers.

Curtains for proscenium openings 42 feet (12 802 mm) or less in width and 22 feet (6706 mm) or less in height may have a bronze-alloy, oil-impregnated wood, or other spool-type guide wire side edge system, where the guide wires are at least $^1/_4$-inch (6.4 mm) diameter 7 by 19 galvanized aircraft cable installed securely using at least $^3/_8$-inch (9.5 mm) locked turnbuckles, thimbles and three forged wire rope clips (or one swagged fitting) at the end of each guide wire; or the roller guide system with either hem reinforcing/stiffening system as detailed above. Guides shall not be more than 18 inches (457 mm) on vertical centers.

Curtains for proscenium openings less than 34 feet (10 363 mm) in width and less than 18 feet (5486 mm) in height may have a spool-type guide wire side guide system, as detailed in the paragraph above, except neither edge reinforcing/stiffening system is required. Guides shall be on maximum 18-inch (457 mm) vertical centers.

An approximate 3-inch-diameter (76 mm) smoke seal made of the curtain fabric and filled with fiberglass insulation or other noncombustible materials, to a density of not less than 3 pounds per cubic foot (48 kg/m^3), shall be attached to the upstage side of the proscenium wall, above the proscenium opening. The seal shall contact with the curtain's top batten pocket, and compress against it when the curtain is in its deployed position to make as smoke-tight a seal as practical.

4.104.3 Braille Style. The dead hung braille-style curtain shall meet the requirements detailed above in Sections 4.104.1 and 4.104.2, except for the following:

1. Curtain shall have minimum 5 percent fullness in the height only.

2. Side edge guide system shall be bronze spool guides on a maximum 18-inch (457 mm) vertical centers on both of the curtain's vertical edges, without any type of edge reinforcing/stiffening system.

3. Galvanized minimum $^1/_4$-inch (6.4 mm) diameter 7 by 19 aircraft cable vertical life lines shall be located on maximum 10-foot (3048 mm) horizontal centers with the outermost two cables a maximum of 3 feet (914 mm) from either of the curtain's vertical edges. Each life line shall operate on a path reinforced with a layer of the curtain's fabric (raw edges turned under) or equivalent webbing, with plated steel D (dee) rings on maximum 18-inch (457 mm) vertical centers.

4. Seven by 19 aircraft cable for $^3/_8$-inch-diameter (9.5 mm) or smaller sized and 6 by 19 or other flexible independent wire rope core, wire rope for larger sizes, sized using a minimum 8 to 1 safety factor, shall be used for the drive lines which connect the winch to the cable clew.

5. In lieu of the approximate 3-inch-diameter (76 mm) smoke seal detailed in Section 4.104.2 above, an attached fill piece smoke seal made of the curtain fabric, spanning the gap from the curtain to the upstage portion of the proscenium opening's wall above the opening, shall be installed.

The lift lines detailed above in conjunction with the D (dee) rings create an accordion-fold-type storage arrangement.

4.104.4 Frame and Modified Frame Style.

4.104.4.1 Frame-style curtain. The frame-style curtain shall consist of a rigid steel or metallic alloy frame, with a frame thickness not less than $^1/_{120}$ of the width, and $^1/_{96}$ of the height of the proscenium opening, but in no case less than 4 inches (102 mm) in thickness, complete with interior steel or metallic alloy members, such that when the required single thickness is battened to the downstage side (audience side) of the frame, the assembly will operate smoothly, and perform as required, when subjected to a lateral load of 2 pounds per square foot (95.8 N/m^2) over the entire area of the curtain.

The side edge guide system shall consist of vertical steel flat edges parallel to the face of the curtain with bronze bushings on this vertical steel edge on both upstage and downstage surfaces, or in the grooves traveled by these vertical steel edges located in the vertical steel smoke pockets on each side of the proscenium opening.

A separate yield pad, the cross section of which shall be square with each edge measuring approximately the same as the thickness of the frame, shall be made of the curtain fabric and filled with fiberglass or other noncombustible materials to a density of not less than 3 pounds per cubic foot (48 kg/m^3). The yield pad shall be attached beneath the bottom frame member so that it will compress and seal when the curtain is lowered.

A separate upper smoke seal, the same as detailed in Section 4.104.2 above, except that the seal shall be approximately 5 inches (127 mm) in diameter, shall be attached to the top of the frame on the downstage edge (edge facing the audience), and rigged so that the smoke seal is forced to compress against a steel or metallic alloy angle or other solid noncombustible material protruding from the proscenium wall above the opening (optionally, seal may be mounted above the proscenium opening on the upstage side and rigged to force the smoke seal to compress against a steel or metallic alloy member protruding downstage from the top member of the curtain's frame).

This curtain style is rigged like and operates like a straight-lift curtain except that the lift lines, blocks and all other involved operating equipment, shall be sized to accommodate the size and weight of the assembly with a minimum 8 to 1 safety margin.

4.104.4.2 Modified frame-style curtain. The modified frame-style curtain shall be any variation or combination of the frame style immediately above, and the straight-lift-style curtain that minimizes the horizontal movement or bowing of a curtain to a point where the curtain assembly will operate smoothly and perform as required when subjected to a lateral load of 2 pounds per square foot (95.8 N/m^2) over the entire area of the curtain.

This curtain style, like the frame style, is rigged like and operates like a straight-lift curtain, except that the lift lines, blocks and all other involved operating equipment shall be sized to accommodate the size and weight of the assembly with a minimum 8 to 1 safety margin.

SECTION 4.105 — OPERATING EQUIPMENT

Vertical smoke pockets which contain the curtain's vertical edges and guide system shall be fabricated of minimum $^1/_4$-inch-thick (6.4 mm) structural steel shapes and plates (plated or painted), with a bolted construction using minimum $^3/_8$-inch (9.5 mm) diameter Grade 5 bolts spaced not more than 4 feet (1219 mm) on center to attach plates to the steel shapes for the entire height of the smoke pockets, or at least for removable sections at the bottom of each smoke pocket (plate portions only), at least the height of the opening plus 4 feet (1219 mm) for frame and modified frame styles of semirigid construction, or at least 6 feet (1829 mm) for all other styles. These smoke pockets shall extend vertically from the stage floor to a point 1 to 3 feet (305 to 914 mm) above the top of the raised curtain and shall be securely fastened to the upstage side (side away from audience) of the proscenium wall, with minimum $^1/_2$-inch-diameter (13 mm) Grade 5 anchors or bolts in concrete spaced not more than 4 feet (1219 mm) on center, with minimum $^3/_8$-inch-diameter (9.5 mm) Grade 5 anchors or bolts in concrete spaced not more than 2 feet (610 mm) on center, or an anchoring system equivalent in strength on concrete or other surfaces. The smoke pockets may vary in depth and width, depending on the style of curtain and the distance the smoke pockets are set back from the vertical edges. Straight-lift curtains shall not have less than 6-inch-deep (153 mm) pockets, braille curtains shall not have less than 8-inch-deep (203 mm) pockets, and frame and modified frame curtains shall have pockets at least 4 inches (102 mm) deeper than the thickest batten or frame member; the pockets shall be at least 11 inches (279 mm) wide set back a minimum of 6 inches (153 mm) from the vertical edges (stage left/stage right) of the proscenium opening, and contain at least 8 inches (203 mm) of the curtain's vertical edges.

The curtain's side edge guide system shall be as specified in Section 4.104.

Straight-lift and braille curtains for proscenium openings 50 feet (15 240 mm) or less in width and 30 feet (9144 mm) or less in height shall not have less than $^1/_4$-inch-diameter (6.4 mm) 7 by 19 galvanized aircraft cable life lines 10 feet (3048 mm) or less on center, with the end overhang not more than 3 feet (914 mm). Attachment to battens shall be accomplished through the use of two-piece pipe clamps made of minimum 0.105-inch-thick (2.7 mm) (12 gage) steel, or equivalent material (plated or painted) with corners rounded and the entire assembly deburred.

The clamps shall attach to the battens using two minimum $^3/_8$-inch (9.5 mm) Grade 5 bolts, one under the batten and one over the batten, with the lift cable securely attached using a thimble and three forged wire rope clips (or one swagged-type fitting). Other methods of attachment that can be shown to be equivalent shall be acceptable as long as the lift lines are not tied in a clove hitch, and they do not require cutting the curtain fabric and leaving exposed cut edges. Frame and modified frame curtains may require larger diameter lift lines to meet the requirements in Section 4.104.4; galvanized cable or wire rope, 7 by 19 aircraft cable for $^3/_8$-inch (9.5 mm) diameter or smaller sizes, and 6 by 19 or other flexible independent wire rope core rope for larger sizes shall be used.

Straight-lift-style curtains for openings 34 feet (10 363 mm) or less in width and 18 feet (5486 mm) or less in height, and braille-style curtains of all sizes, may be designed to operate using properly sized manual and electric winches of various styles, all with adjustable hydraulic-assisted, speed-governing devices; any model with handles shall be so designed that the handle is removable, with an appropriate sign in English and other languages prevalent to the facility's area, stating DANGER! REMOVE HANDLE AFTER USE! prominently displayed near the location of the winch.

Curtain lift lines shall pass through sheaves in or under the gridiron, over to the counterweight guides or winch clew. Cables shall fasten to the curtain's top batten as detailed above. Connections to the braille curtain's bottom batten shall be accomplished by a loop at the end of each lift line secured with three forged wire rope clips, or minimum $^3/_{16}$-inch-thick (4.8 mm) clam-shell-type steel pipe clamps, and to the counterweight guides or winch drive line clew, using $^3/_8$-inch (9.5 mm) locked turnbuckles, thimbles and three forged wire rope clips (each lift line cable). Swagged-type fittings (one per connection) may be used in lieu of three forged wire rope clips. Clove hitches shall not be used and the batten pocket shall not be cut to facilitate the installation of the lift lines.

Straight-lift- and braille-style curtains shall have safety stay chains of a straight-welded link minimum $^1/_4$-inch (6.4 mm) proof coil chain fastened securely to the curtain's top batten. Frame and modified frame-style curtains shall also have the same type safety stay chains, except they shall be sized to support safely the weight of the curtain. There shall be one more stay chain than the number of supporting cables and, except for the stay chains at the ends of the curtain, all stay chains shall be centered between the supporting cables. One end of each stay chain shall be securely attached to the curtain's top batten (or top of a frame), with the other to the gridiron, if of steel construction; otherwise, the upper stay chain ends shall be fastened to $^3/_4$-inch (19 mm) bolts bolted through the proscenium wall. Safety chains shall be so adjusted that they support the curtain when it is lowered and the bottom batten is resting on the yield pad and supported by the floor. In the case of the braille-style curtain, the safety chains will also be the method of holding the curtain's top batten in its stationary position.

All cables shall be carried overhead using head and loft blocks fitted with precision ball or tapered roller bearings of ample capacity to accommodate the weight at the speeds required. Grooves in the blocks shall be machined properly to cradle and protect the cable. All blocks supporting the proscenium firesafety curtain shall be supported on the proscenium wall by means of steel brackets of suitable size to safely carry the weight, or shall be mounted on structural steel beams and other steel shapes that may be added.

Head and loft blocks shall be installed so as to prevent cable fouling.

For all style curtains using $^1/_4$-inch-diameter (6.4 mm) 7 by 19 galvanized aircraft cable lift lines, the minimum diameter of loft blocks shall be 8 inches (203 mm) when the height of the proscenium is 20 feet (6096 mm) or less, and 12 inches (305 mm) for all others. Curtains using larger diameter lift lines shall use loft blocks with a minimum diameter 38 times the diameter of the cable. Head blocks shall be at least 4 inches (102 mm) greater in diameter than the loft blocks.

The mechanism and devices for controlling the curtain shall be of simple design and positive in operation. Normal day-to-day operation of straight-lift, braille curtains installed on proscenium openings of 1,500 square feet (139.4 m^2) or less may be by manual means as long as operation can be accomplished with relative ease by a single person. Curtains meeting the size criteria in the previous sentence that are difficult for a single person to operate and other curtains not meeting the size criteria shall be operated by electric devices.

Automatic emergency release shall be by gravity obtained by overbalancing the curtain. The emergency control line shall be of minimum $^3/_8$-inch-diameter (9.5 mm) manila rope, or $^3/_{32}$-inch-diameter (2.38 mm) 7 by 19 galvanized aircraft cable, fitted with not less than four 165°F (74°C) or less nonelectric fusible links. One of these fusible links shall be located on each side of the stage and two overhead. When any link in the series separates, or the emergency control line is burned, the curtain shall automatically lower properly to its deployed position (see Section 4.101). This emergency control line shall extend up both sides and above the proscenium opening. As is the case with the manual emergency tripping mechanism detailed below, any attachment to the hand line on any operation machine or device that must be disconnected from the hand line or device for proper curtain deployment shall be a mechanical quick-release device that is easily resettable. The fire curtain emergency-release system shall not be interconnected mechanically, electromechanically, electrically or electronically with the emergency ventilator release system, unless a time delay is incorporated to assure that, in the event of a fire, the fire curtain will be fully deployed before the vents open. The building's fire alarm system shall not be interconnected with the fire curtain emergency-release system.

Manual emergency deployment of the fire curtain shall be accomplished by the activation of one of two mechanical quick-release assemblies (one on each side of the proscenium opening). Activation of either assembly shall be by pulling a minimum $1^1/_2$-inch-diameter (38 mm) red (color) ring, attached to a quick-release pin that is normally pinned through two steel plates housing a minimum 1-inch-diameter (25 mm) ring that is securely attached to the emergency-release line; these quick-release mechanisms shall be such that they can quickly (within a few minutes) and easily be reset in the event of erroneous activations. Other similar activation assemblies that are positive in nature and meet the basic criteria of the quick-release system detailed above may be used. Knife, axe and other emergency-release systems shall be allowable only until a new fire curtain is installed.

Appropriate signs in English and other languages prevalent to the facility's area, shall be prominently displayed near the location of the emergency control line quick-release mechanisms. For the release assembly detailed above, the sign would read IN CASE OF FIRE, PULL RED RING TO LOWER FIRE CURTAIN AUTOMATICALLY! with an arrow pointing to the location of the ring. There shall also be a less prominent sign or instruction pamphlet located on the main control side of the opening only, detailing the procedure required to properly and quickly reset the fire curtain in its raised position (this would include the mechanical quick-release mechanisms mentioned in this paragraph and the paragraph above).

Electric operation shall be from a single station located on either side of the proscenium opening and shall consist of two hold-to-operate-style push buttons, one labeled "Up" and one labeled "Down." Alternately, three push buttons that function from a single push of a button; one button shall be labeled "Up" for raising the curtain, one labeled "Down" for lowering the curtain, and one labeled "Stop" for stopping the curtain at the point it is located when the button is pushed; a sign stating NONEMERGENCY FIRE CURTAIN OPERATION shall be adjacent to the push-button station. Buttons and sign shall be labeled in English only.

All manually rigged counterweight curtains shall have their minimum $^3/_4$-inch (19 mm) manila endless operation hand line securely fastened to both the top and bottom of the counterweight arbor and shall pass under a minimum 12-inch-diameter (305 mm) floor block which is adjustable for tension.

The top and bottom counterweight sections of the arbor shall be of steel, sufficiently heavy to safely accommodate the loads. The top and bottom sections shall be connected with rods not less than $^3/_4$ inch (19 mm) in diameter, with one tie plate for every 4 feet (1219 mm) of rod. Counterweights may be cast iron or flame cut steel with edges deburred. There shall be smooth grooves on the ends of the top and bottom weights which engage the steel guides. The arbor top and bottom shall be provided with an oilless-type bushing.

Counterweight guide tracks shall be structural tees or angles properly tied together and securely anchored to the proscenium wall. All joints where the counterweight travels shall be ground smooth. These guide tracks shall be caged their entire length.

All proscenium firesafety curtains shall have an approved adjustable checking device or system, whether it be a counterweight arrangement, a hydraulic speed-governing system, a hydraulic dash pot shock-absorbing unit, or some other equivalent device or system that will enable the installation to meet the automatic-closing requirements detailed in Section 4.101.

SECTION 4.106 — TESTS

The complete installation of every proscenium firesafety curtain shall be subjected to a minimum of two successful emergency-type operating tests triggered by release of the end of the emergency control line away from the hand line, winch or motor, and an on-site review of specifications by the building official prior to a new facility being issued an occupancy permit, and an existing facility being allowed the use of the newly renovated facilities.

SECTION 4.107 — NEW DESIGNS

A water curtain or deluge system complying with UBC Standard 9-1 may be used in conjunction with an automatically closing opaque noncombustible curtain in lieu of the proscenium firesafety curtain described in UBC Standard 4-1. Both the deluge system and curtain closure shall be actuated by combination rate-of-temperature-rise and temperature devices located on the stage. The water system shall be designed to completely wet the entire curtain.

Curtains of other designs and materials, when not obviously of greater fire resistance than specified in this standard, shall, before acceptance, be subjected to the standard fire test specified in Chapter 7 of the Building Code as applicable to nonbearing partitions, except that such tests shall be continued only for a period of five minutes unless failure shall have occurred previously. The unexposed face of the curtain shall not glow within a period of 30 minutes nor shall there be any passage of smoke or flame through the curtain.

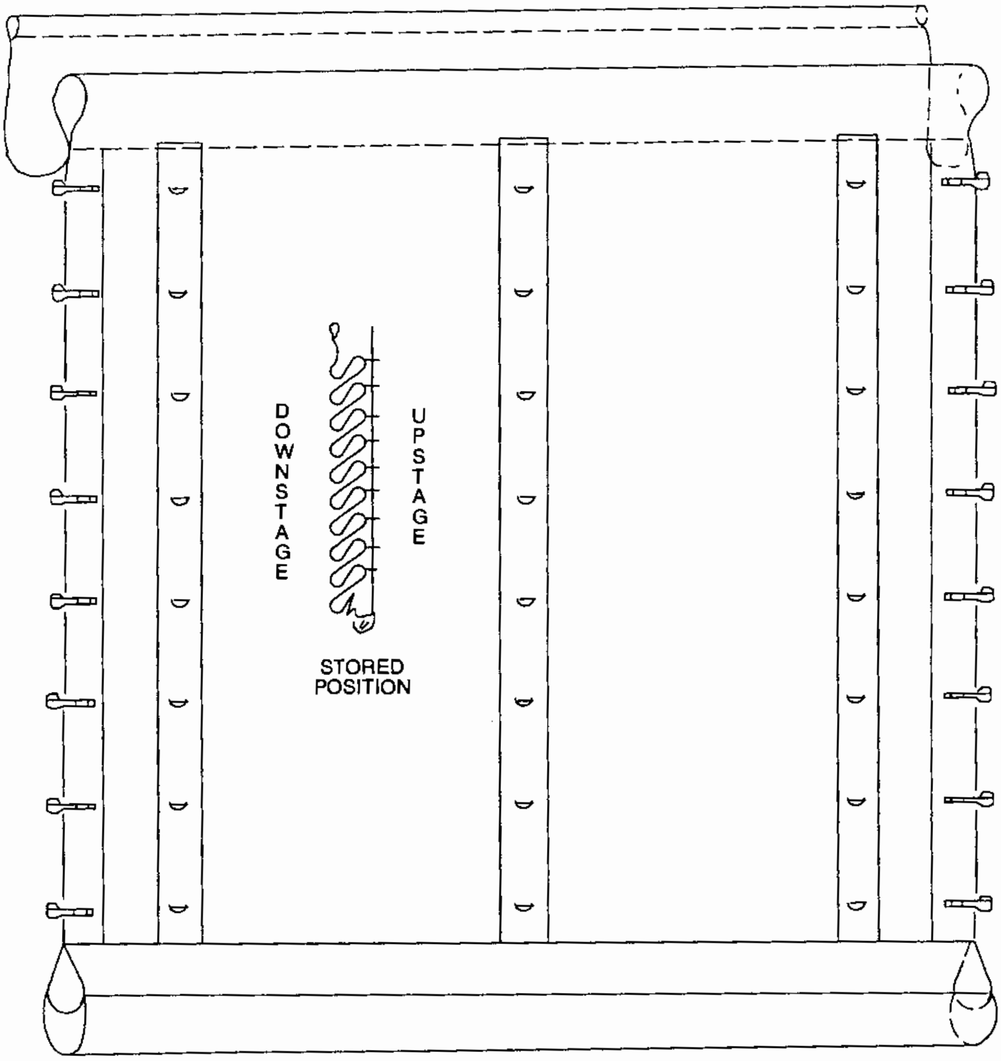


FIGURE 4-1-1—BRAILLE-STYLE PROSCENIUM FIRESAFETY CURTAIN

UNIFORM BUILDING CODE STANDARD 7-1

FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS

Based on Standard Methods E 119-83 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 405.1.1, 601.3, 703.2, 703.4, 706, 709.3.2.2, 709.5, 709.6, 709.7, 710.2, 2602.5.2 and Table 7-A, *Uniform Building Code*

SECTION 7.101 — SCOPE

This standard for fire tests is applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs. They are also applicable to other assemblies and structural units that constitute permanent integral parts of a finished building.

It is the intent that classifications shall register performance during the period of exposure and shall not be construed as having determined suitability for use after fire exposure.

Control of Fire Tests

SECTION 7.102 — TIME-TEMPERATURE CURVE

The conduct of fire tests of materials and construction shall be controlled by the standard time-temperature curve shown in Figure 7-1-1. The points on the curve that determine its character are:

1,000°F (538°C)	at 5 minutes
1,300°F (704°C)	at 10 minutes
1,550°F (843°C)	at 30 minutes
1,700°F (927°C)	at 1 hour
1,850°F (1010°C)	at 2 hours
2,000°F (1093°C)	at 4 hours
2,300°F (1260°C)	at 8 hours or over

SECTION 7.103 — FURNACE TEMPERATURES

The temperature fixed by the curve shall be deemed to be the average temperature obtained from the readings of not less than nine thermocouples for a floor, roof, wall or partition and not less than eight thermocouples for a structural column symmetrically disposed and distributed to shown the temperature near all parts of the sample, the thermocouples being enclosed in protection tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within the range from 5.0 to 7.2 minutes. The exposed length of the pyrometer tube and thermocouple in the furnace chamber shall not be less than 12 inches (305 mm). Other types of protecting tubes or pyrometers may be used that, under test conditions, give the same indications as the above standard within the limit of accuracy that applies for furnace-temperature measurements. For floors and columns, the junction of the thermocouples shall be placed 12 inches (305 mm) away from the exposed face of the sample at the beginning of the test and, during the test, shall not touch the sample as a result of its deflection. In the case of walls and partitions, the thermocouples shall be placed 6 inches (152 mm) away from the exposed face of the sample at the beginning of the test, and shall not touch the sample during the test in the event of deflection.

The temperatures shall be read at intervals not exceeding five minutes during the first two hours, and thereafter the intervals may be increased to not more than 10 minutes.

The accuracy of the furnace control shall be such that the area under the time-temperature curve, obtained by averaging the results from the pyrometer readings, is within 10 percent of the corresponding area under the standard time-temperature curve shown in Figure 7-1-1 for fire tests of one hour or less duration, within 7.5 percent for those over one hour and not more than two hours, and within 5 percent for tests exceeding two hours in duration.

SECTION 7.104 — TEMPERATURES OF UNEXPOSED SURFACES OF FLOORS, WALLS AND PARTITIONS

Temperatures at unexposed surfaces shall be measured with thermocouples or thermometers placed under flexible, dry, felted asbestos pads 6 inches square, 0.4 inch (152 mm square, 10.2 mm) in thickness and weighing not less than 1 nor more than 1.4 pounds per square foot (9.6 kg/m^2). The pads shall be sufficiently soft so that, without breaking, they may be shaped to contact over the whole surface against which they are placed. The wire leads of the thermocouple or the stem of the thermometer shall have an immersion under the pad and be in contact with the unexposed surface for not less than $3^1/_2$ inches (88.9 mm). The hot junction of the thermocouple or the bulb of the thermometer shall be placed approximately under the center of the pad. The outside diameter of protecting or insulating tubes, and of thermometer stems, shall not be more than $^5/_{16}$ inch (7.9 mm). The pad shall be held firmly against the surface and shall fit closely about the thermocouples or thermometer stems. Thermometers shall be of the partial-immersion type with a length of stem between the end of the bulb and the immersion mark of 3 inches (76.2 mm). The wires for the thermocouple in the length covered by the pad shall not be heavier than No. 18 B.&S. gage [0.04 inch (1.02 mm)] and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

Temperature readings shall be taken at not less than nine points on the surface; five of these shall be symmetrically disposed, one to be approximately at the center of the specimens and four at approximately the center of quarter sections. The other four should be located at the discretion of the testing agency to obtain representative information on the performance of the construction under tests. None of the thermocouples shall be located nearer to the edges of the test specimen that one and one-half times the thickness of the construction or 12 inches (305 mm). An exception can be made in those cases where there is an element of the construction that is not otherwise represented in the remainder of the test specimen. None of the thermocouples shall be located opposite or on top of beams, girders, pilasters or other structural members if temperatures at such points will obviously be lower than at more representative locations. None of the thermocouples shall be located opposite or on top of fasteners such as screws, nails or staples that will be obviously higher or lower in temperature than at more representative locations if the aggregate area of any part of such fasteners projected to the unexposed surface is less than 0.8 percent of the area within any 5-inch square (127 mm). Such fasteners shall not extend through the assembly.

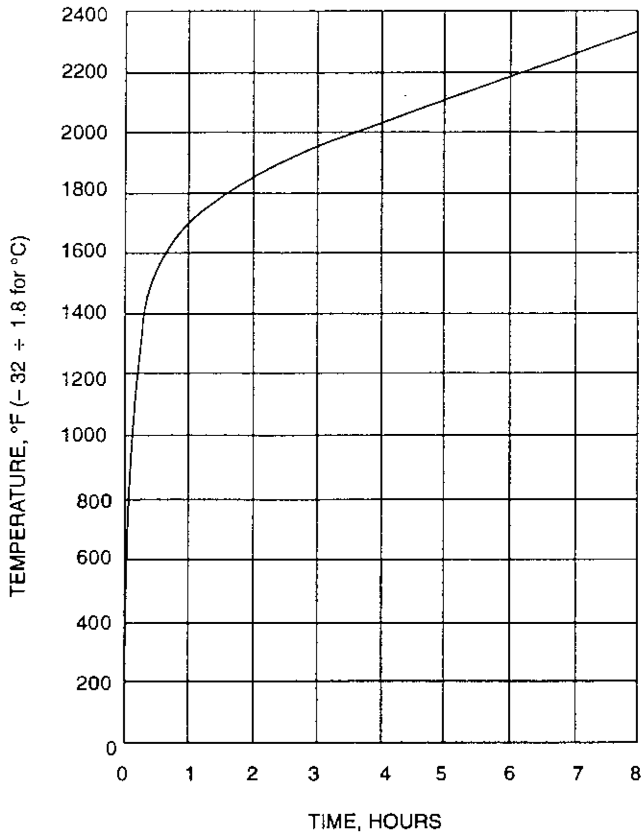


FIGURE 7-1-1—TIME-TEMPERATURE CURVE

Temperature readings shall be taken at intervals not exceeding 15 minutes until a reading exceeding 212°F (100°C) has been obtained at any one point. Thereafter the readings may be taken more frequently at the discretion of the testing body, but the intervals need not be less than five minutes.

Where the conditions of acceptance place a limitation on the rise of temperature of the unexposed surface, the temperature end point of the fire-endurance period shall be determined by the average of the measurements taken at individual points; except that if a temperature rise 30 percent in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire-endurance period judged as ended.

Classification as Determined by Test

SECTION 7.105 — REPORT OF RESULTS

Results shall be reported in accordance with the performance in the tests prescribed in this standard. They shall be expressed in time periods of resistance to the nearest integral minute. Reports shall include observations of significant details of the behavior of the material or construction during the test and after the furnace fire is cut off, including information on deformation, spalling, cracking, burning of the specimen or its component parts, continuance of flaming and production of smoke.

Reports of tests involving wall, floor, beam or ceiling constructions in which restraint is provided against expansion, contraction or rotation of the construction shall describe the method used to provide this restraint.

Reports of tests in which other than maximum load conditions are imposed shall fully define the conditions of loading used in the test and shall be designated in the title of the report of the test as a restricted load condition.

When the indicated resistance period is one-half hour or over, and determined by the average or maximum temperature rise on the unexposed surface or within the test sample, or by failure under load, a correction shall be applied for variation of the furnace exposure from that prescribed where it will affect the classification by multiplying the indicated period by two thirds of the difference in area between the curve of average furnace temperature and the standard curve for the first three fourths of the period and dividing the product by the area between the standard curve and a base line of 68°F (20°C) for the same part of the indicated period, the latter area increased by 54 Fahrenheit-hours (30 centigrade-hours) [3,240 Fahrenheit-minutes (1800 centrigrade-minutes)], to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For fire exposure in the test higher than standard, the indicated resistance period shall be increased by the amount of the correction and be similarly decreased for fire exposure below standard.

NOTE: The correction can be expressed by the following formula:

$$C = \frac{2I\,(A - A_s)}{3\,(A_s + L)}$$

WHERE:

A = area under the curve of indicated average furnace temperature for the first three fourths of the indicated period.

A_s = area under the standard furnace curve for the same part of the indicated period.

C = correction in the same units as I.

I = indicated fire-resistance period.

L = lag correction in the same units as A and A_s [54 Fahrenheit-hours (30 centrigrade-hours) (3,240 Fahrenheit-minutes {1800 centigrade-minutes})].

Walls and partitions of nonsymmetrical construction shall be tested with both faces exposed to the furnace and the report shall indicate the fire-endurance classification applicable to each side. Subject to the approval of the building official based on data submitted by the applicant justifying a single-side test only, unsymmetrical wall assemblies may be tested with the least fire-resistive side exposed in the furnace.

SECTION 7.106 — TEST SPECIMEN

The test sample shall be truly representative of the construction for which classification is desired, as to materials, workmanship, and details such as dimensions of parts, and shall be built under conditions representative of those obtained as practically applied in building construction and operation. The physical properties of the materials and ingredients used in the test sample shall be determined and recorded.

The size and dimensions of the test sample specified herein are intended to apply for rating constructions of dimensions within the usual general range employed in buildings. If the conditions of use limit the construction to smaller dimensions, a proportionate reduction may be made in the dimensions of the samples for a test qualifying them for such restricted use.

When it is desired to include a built-up roof covering, the test specimen shall have a roof covering of three-ply, Type 15 felt not in excess of 120 pounds per square (100 square feet) (6.04 kg/m^2) of hot-mopping asphalt without gravel surfacing. Tests of assemblies with this covering do not preclude the field use of other built-up roof coverings.

Fire Test Procedures

SECTION 7.107 — FIRE-ENDURANCE TEST

The fire-endurance test on the sample with its applied load, if any, shall be continued until failure occurs, or until the sample has withstood the test conditions for a period equal to that herein specified in the conditions of acceptance for the given type of construction.

For the purpose of obtaining additional performance data, the test may be continued beyond the time the fire-endurance classification is determined.

SECTION 7.108 — HOSE STREAM TEST

7.108.1 General. Where required by the conditions of acceptance, a duplicate sample shall be subjected to a fire-exposure test for a period equal to one half of that indicated as the resistance period in the fire-endurance test, but not for more than one hour, immediately after which the sample shall be subjected to the impact, erosion and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed face, changes in direction being made slowly.

7.108.2 Exemption. The hose stream test shall not be required in the case of constructions having a resistance period, indicated in the fire-endurance test, of less than one hour.

7.108.3 Optional Program. The submitter may elect, with the advice and consent of the testing body, to have the hose stream test made on the sample subjected to the fire-endurance test and immediately following the expiration of the fire-endurance test.

7.108.4 Stream Equipment and Details. The stream shall be delivered through a $2^1/_2$-inch (64 mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a $1^1/_8$-inch (28.6 mm) discharge tip of the standard-taper smooth-bore pattern without shoulder at the orifice. The water pressure and duration of application shall be as prescribed in Table 7-1-A.

7.108.5 Nozzle Distance. The nozzle orifice shall be 20 feet (6096 mm) from the center of the exposed surface of the test sample if the nozzle is so located that when directed at the center, its axis is normal to the surface of the test sample. If otherwise located, its distance from the center shall be less than 20 feet (6096 mm) by an amount equal to 1 foot (305 mm) for each 10 degrees of deviation from the normal.

SECTION 7.109 — TIME OF TESTING

The material or construction shall not be tested until a large proportion of its final strength has been attained and, if it contains moisture, until the excess has been removed to achieve an air-dry condition in accordance with the requirements given in this section. Protect the testing equipment and sample undergoing the fire test from any condition of wind or weather that might lead to abnormal results. The ambient air temperature at the beginning of the test shall be within the range of 50°F to 90°F (10°C to 32°C) The velocity of air across the unexposed surface of the sample, measured just before the test begins, shall not exceed 4.4 feet per second (1.3 m/s) as determined by an anemometer placed at right angles to the unexposed surface. If mechanical ventilation is employed during the test, an airstream shall not be directed across the surface of the specimen.

TABLE 7-1-A—CONDITIONS FOR HOSE STREAM TEST

RESISTANCE PERIOD	WATER PRESSURE AT BASE OF NOZZLE (pounds per square inch)	DURATION OF APPLICATION (minutes per 100 square feet) EXPOSED AREA
	× 6.89 for kPa	× 0.0108 for min./m^2
8 hours and over	45	6
4 hours and over if less than 8 hours	45	5
2 hours and over if less than 4 hours	30	$2^1/_2$
$1^1/_2$ hours and over if less than 2 hours	30	$1^1/_2$
1 hour and over if less than $1^1/_2$ hours	30	1
Less than 1 hour, if desired	30	1

Prior to fire test, condition constructions with the objective of providing, within a reasonable time, a moisture condition within the specimen approximately representative of that likely to exist in similar construction in buildings. For purposes of standardization, this condition is to be considered as that which would be established at equilibrium resulting from drying in an ambient atmosphere of 50 percent relative humidity at 73°F (23°C) However, with some constructions, it may be difficult or impossible to achieve such uniformity within a reasonable period of time. Accordingly, where this is the case, specimens may be tested when the dampest portion of the structure, the portion at 6 inches (152 mm) depth below the surface of massive constructions, has achieved a moisture content corresponding to drying to equilibrium with air in the range of 50 to 75 percent relative humidity at 73°F ± 5°F (20°C ± 3°C) In the event that specimens dried in a heated building fail to meet these requirements after a 12-month conditioning period, or in the event that the nature of the construction is such that it is evident that drying of the specimen interior will be prevented by hermetic sealing, these requirements may be waived, except as to attainment of a large portion of final strength, and the specimen tested in the condition in which it then exists.

If during the conditioning of the specimen it appears desirable or is necessary to use accelerated drying techniques, it is the responsibility of the laboratory conducting the test to avoid procedures which will significantly alter the structural or fire-endurance characteristics of the specimen or both from those produced as the result of drying in accordance with procedures given in this section.

Within 72 hours prior to the fire test, information on the actual moisture content and distribution within the specimen shall be obtained. Include this information in the test report.

Tests of Bearing Walls and Partitions

SECTION 7.110 — SIZE OF SAMPLE

The area exposed to fire shall not be less than 100 square feet (9.3 m^2), with neither dimension less than 9 feet (2743 mm). The test specimen shall not be restrained on its vertical edges.

For construction joints, the area of the test specimen may be less than 100 square feet (9.3 m^2) provided the length of the joint is not less than 9 feet (2743 mm). The test specimen shall be of sufficient size so as to produce a representative construction joint for which evaluation is desired.

SECTION 7.111 — LOADING

Throughout the fire-endurance and fire and hose stream tests, apply a constant superimposed load to simulate a maximum load condition. The applied load shall be as nearly as practicable the maximum load allowed by design under design criteria set forth in the Building Code. The tests may also be conducted by applying to the specimen a load less than the maximum. Such tests shall be identified in the test report as having been conducted under restricted load conditions. The applied load, and the applied load expressed as a percentage of the maximum allowable design load, shall be included in the report. A double-wall assembly shall be loaded during the test to simulate field-use conditions, with either side loaded separately or both sides together. (Note: The method used shall be reported.)

The choice depends on the intended use and whether the load on the exposed side, after it has failed, will be transferred to the unexposed side. If, in the intended use, the load from the structure above is supported by both walls as a unit and would be or is transferred to the unexposed side in case of collapse of the exposed side, both walls shall be loaded in the test by a single unit. If in the intended use the load from the structure above each wall is supported by each wall separately, the walls shall be loaded separately in the test by separate load sources. If the intended use of the construction system being tested involved situations of both loading conditions described above, the walls shall be loaded separately in the test by separate load sources. In tests conducted with the walls loaded separately, the condition of acceptance requiring the walls to maintain the applied load shall be based on the time at which the first of either of the walls fails to sustain the load.

SECTION 7.112 — CONDITIONS OF ACCEPTANCE

The test shall be regarded as successful if the following conditions are met:

1. The wall or partition shall have sustained the applied load during the fire-endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

2. The wall or partition shall have sustained the applied load during the fire and hose stream test as specified in Section 7.108, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.

3. Transmission of heat through the wall or partition during the fire-endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

Tests of Nonbearing Walls and Partitions

SECTION 7.113 — SIZE OF SAMPLE

The area exposed to fire shall not be less than 100 square feet (9.3 m^2), with neither dimension less than 9 feet (2734 mm). The test specimen shall be restrained on all four edges.

For construction joints, the area of the test specimen may be less than 100 square feet (9.3 m^2) provided the length of the joint is not less than 9 feet (2734 mm). The test specimen shall be of sufficient size so as to produce a representative construction joint for which evaluation is desired.

SECTION 7.114 — CONDITIONS OF ACCEPTANCE

The test shall be regarded as successful if the following conditions are met:

1. The wall or partition shall have withstood the fire-endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

2. The wall or partition shall have withstood the fire and hose stream test as specified in Section 7.108, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.

3. Transmission of heat through the wall or partition during the fire-endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

Tests of Columns

SECTION 7.115 — SIZE OF SAMPLE

The length of the column exposed to fire shall, when practicable, approximate the maximum clear length contemplated by the design, and for building columns shall not be less than 9 feet (2734 mm). The contemplated details of connections, and their protection, if any, shall be applied according to the methods of acceptable field practice.

SECTION 7.116 — LOADING

During the fire endurance test, the column shall be exposed to fire on all sides and shall be loaded in a manner calculated to develop theoretically, as nearly as practicable, the working stresses contemplated by the design. Provision shall be made for transmitting the load to the exposed portion of the column without unduly increasing the effective column length.

If the submitter and the building official jointly so decide, the column may be subjected to one and three-fourths times its designed working load before the fire-endurance test is undertaken. The fact that such a test has been made shall not be construed as having had a deleterious effect on the fire-endurance test performance.

SECTION 7.117 — CONDITION OF ACCEPTANCE

The test shall be regarded as successful if the column sustains the applied load during the fire-endurance test for a period equal to that for which classification is desired.

Alternate Test of Protection for Structural Steel Columns

SECTION 7.118 — APPLICATION

This test procedure does not require column loading at any time and may be used at the discretion of the testing laboratory to evaluate steel column protections that are not required by design to carry any of the column load.

SECTION 7.119 — SIZE AND CHARACTER OF SAMPLE

The size of the steel column used shall be such as to provide a test specimen that is truly representative of the design, materials and workmanship for which classification is desired. The protection shall be applied according to the methods of acceptable field practice. The length of the protected column shall be at least 8 feet (2438 mm). The column shall be vertical during application of the protection and during the fire exposure.

The applied protection shall be restrained against longitudinal temperature expansion greater than that of the steel column by rigid steel plates or reinforced concrete attached to the ends of the steel column before the protection is applied. The size of the plates or amount of concrete shall be adequate to provide direct bearing for the entire transverse area of the protection.

The ends of the specimen, including the means for restraint, shall be given sufficient thermal insulation to prevent appreciable direct heat transfer from the furnace.

SECTION 7.120 — TEMPERATURE MEASUREMENT

The temperature of the steel in the column shall be measured by at least three thermocouples located at each of four levels. The upper and lower levels shall be 2 feet (610 mm) from the ends of the steel column, and the other two intermediate levels shall be equally spaced. The thermocouples at each level shall be so placed as to measure significant temperatures of the component elements of the steel section.

SECTION 7.121 — EXPOSURE TO FIRE

During the fire-endurance test the specimen shall be exposed to fire on all sides for its full length.

SECTION 7.122 — CONDITIONS OF ACCEPTANCE

The test shall be regarded as successful if the transmission of heat through the protection during the period of fire exposure for which classification is desired does not raise the average (arithmetical) temperature of the steel at any one of the four levels above 1,000°F (538°C), or does not raise the temperature above 1,200°F (649°C) at any one of the measured points.

Tests of Floors and Roofs

SECTION 7.123 — APPLICATION

This procedure is applicable to floor and roof assemblies with or without attached, furred or suspended ceilings and requires application of fire exposure to the underside of the specimen under test.

Two fire-endurance classifications shall be developed for assemblies restrained against thermal expansion, a restrained assembly classification based upon the conditions of acceptance specified in Section 7.127 and an unrestrained assembly classification based upon the conditions of acceptance specified in Section 7.128.

One fire-endurance classification shall be developed from tests of assemblies not restrained against thermal expansion based upon the conditions of acceptance specified in Section 7.128, Items 1 and 2.

Individual unrestrained classifications may be developed for beams tested in accordance with this test method using the conditions of acceptance specified in Section 7.136.

SECTION 7.124 — SIZE AND CHARACTERISTICS OF SPECIMEN

The area exposed to fire shall not be less than 180 square feet (16.7 m^2) with either dimension less than 12 feet (3658 mm). Structural members, if a part of the construction under test, shall lie within the combustion chamber and have a side clearance of not less than 8 inches (203 mm) from its walls.

For construction joints, the area of the test specimen may be less than 180 square feet (16.7 m^2) provided the length of the joint is not less than 12 feet (3658 mm). The test specimen shall be of sufficient size so as to produce a representative construction joint for which evaluation is desired.

The specimen shall be installed in accordance with recommended fabrication procedures for the type of construction and shall be representative of the design for which classification is desired. Where a restrained classification is desired, specimens representing forms of construction in which restraint to thermal expansion occurs shall be reasonably restrained in the furnace.

SECTION 7.125 — LOADING

Throughout the fire-endurance test, apply a superimposed load to the specimen. This load, together with the weight of the specimen, shall be as nearly as practicable the maximum theoretical dead and live loads permitted by this code. A fire-endurance test may be conducted applying a restricted load condition to the specimen which shall be identified for a specific load condition other than the maximum allowed load condition.

SECTION 7.126 — TEMPERATURE MEASUREMENT

For specimens employing structural members (beams, open-web steel joists, etc.) spaced at more than 4 feet (1219 mm) on centers, measure the temperature of the steel in these structural members by thermocouples at three or more sections spaced along the length of the members with one section preferably located at midspan, except that in cases where the cover thickness is not uniform along the specimen length, at least one of the sections at which temperatures are measured shall include the point of minimum cover.

For specimens employing structural members (beams, open-web steel joists, etc.) spaced at 4 feet (1219 mm) on center or less, measure the temperature of the steel in these structural members by four thermocouples placed on each member, except that no more than four members shall be so instrumented. Place the thermocouples at significant locations, such as at midspan, over joints in the ceiling, and over light fixtures, etc.

For steel structural members, there shall be four thermocouples at each section, except that where only four thermocouples are required on a member, the thermocouples may be distributed along the member at significant locations as provided for in the preceding paragraph. Locate two on the bottom of the bottom flange or chord, one on the web at the center, and one on the top flange or chord. The recommended thermocouple distribution at each section is shown in Figure 7-1-2.

For reinforced or prestressed concrete structural members, locate thermocouples on each of the tension-reinforcing elements, unless there are more than eight such elements, in which case place thermocouples on eight elements selected in such a manner as to obtain representative temperatures of all the elements.

For steel floor or roof units, locate four thermocouples on each section (a section to comprise the width of one unit), one on the bottom plane of the unit at an edge joint, one on the bottom plane of the unit remote from the edge, one on the side wall of the unit, and one on the top plane of the unit. The thermocouples should be applied, where practicable, to the surface of the units remote from fire and spaced across the width of the unit. No more than four or less than two sections need be so instrumented in each representative span. Locate the groups of four thermocouples in representative locations. Typical thermocouple locations for a unit section are shown in Figure 7-1-3.

SECTION 7.127 — CONDITIONS OF ACCEPTANCE—RESTRAINED ASSEMBLY

In obtaining a restrained assembly classification, the following conditions shall be met:

1. The specimen shall have sustained the applied load during the classification period without developing unexposed surface conditions which will ignite cotton waste.

2. Transmission of heat through the specimen during the classification period shall not have been such as to raise the average temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

3. For specimens employing steel structural members (beams, open-web joists, etc.) spaced more than 4 feet (1219 mm) on centers, the assembly shall achieve a fire-endurance classification on the basis of the temperature criteria specified in Section 7.128, Item 3, for assembly classifications up to and including one hour. For classifications greater than one hour, the above temperature criteria shall apply for a period of one half the classification of the assembly or one hour, whichever is greater.

4. For specimens employing steel structural members (beams, open-web steel joists, etc.) spaced 4 feet (1219 mm) or less on centers, the assembly shall achieve a fire-endurance classification on the basis of the temperature criteria specified in Section 7.128, Item 4, for assembly classifications up to and including one hour. For classifications greater than one hour, the above temperature criteria shall apply for a period of one half the classification of the assembly or one hour, whichever is greater.

5. For specimens employing conventionally designed concrete beams, spaced more than 4 feet (1219 mm) on centers, the assembly shall achieve a fire-endurance classification on the basis of the temperature criteria specified in Section 7.128, Item 5, for assembly classifications up to and including one hour. For classifications greater than one hour, the above temperature criteria shall apply for a period of one half the classification of the assembly or one hour, whichever is greater.

SECTION 7.128 — CONDITIONS OF ACCEPTANCE—UNRESTRAINED ASSEMBLY

In obtaining a unrestrained assembly classification, the following conditions shall be met:

1. The specimen shall have sustained the applied load during the classification period without developing unexposed surface conditions which will ignite cotton waste.

2. The transmission of heat through the specimen during the classification period shall not have been such as to raise the average temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

3. For specimens employing steel structural members (beams, open-web steel joists, etc.) spaced more than 4 feet (1219 mm) on centers, the temperature of the steel shall not have exceeded 1,300°F (704°C) at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section have exceeded 1,100°F (593°C) during the classification period.

4. For specimens employing steel structural members (beams, open-web steel joists, etc.) spaced 4 feet (1219 mm) or less on center, the average temperature recorded by all joist or beam thermocouples shall not have exceeded 1,100°F (593°C) during the classification period.

5. For specimens employing conventionally designed concrete structural members (excluding cast-in-place concrete roof or floor slabs having spans equal to or less than those tested), the average temperature of the tension steel at any section shall not have exceeded 800°F (427°C) for cold-drawn prestressing steel or 1,100°F (593°C) for reinforcing steel during the classification period.

6. For specimens employing steel floor or roof units intended for use in spans greater than those tested, the average temperature recorded by all thermocouples located on any one span of the floor or roof units shall not have exceeded 1,100°F (593°C) during the classification period.

SECTION 7.129 — REPORT OF RESULTS

The fire-endurance classification of a restrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Section 7.127.

The fire-endurance classification of an unrestrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Section 7.128 to a specimen tested in accordance with this test procedure.

Tests of Loaded Restrained Beams

SECTION 7.130 — APPLICATION

An individual classification of a restrained beam may be obtained by this procedure and based upon the conditions of acceptance specified in Section 7.133. The fire-endurance classification so derived shall be applicable to the beam when used with a floor or roof construction which has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it was tested. The fire-endurance classification developed by this method shall not be applicable to sizes of beams smaller than those tested.

SECTION 7.131 — SIZE AND CHARACTERISTICS OF SPECIMEN

Install the test specimen in accordance with recommended fabrication procedures for the type of construction. It shall be representative of the design for which classification is desired. The length of beam exposed to the fire shall not be less than 12 feet (3658 mm) and the member shall be tested in its normal horizontal position. A section of a representative floor or roof construction not more than 7 feet (2134 mm) wide, symmetrically located with reference to the beam, may be included with the test specimen and exposed to the fire from below. Restrain the beam including that part of the floor or roof element forming the complete beam as designed (such as composite steel or concrete construction) against longitudinal thermal expansion in a manner simulating the restraint in the construction represented. Do not support or restrain the perimeter of the floor or roof element of the specimen, except that part which forms part of a beam as designed.

SECTION 7.132 — LOADING

Throughout the fire-endurance tests, apply a superimposed load to the specimen. This load, together with the weight of the specimen, shall be as nearly as practicable the maximum theoretical dead and live loads permitted by this code.

SECTION 7.133 — CONDITIONS OF ACCEPTANCE

The following conditions shall be met:

1. The specimen shall have sustained the applied load during the classification period.

2. The specimen shall have achieved a fire-endurance classification on the basis of the temperature criteria specified in Section 7.128, Item 3 or 4, of one half the classification of the assembly, or one hour, whichever is greater.

Alternative Classification Procedure for Loaded Beams

SECTION 7.134 — APPLICATION

Individual unrestrained classifications may be developed for beams tested as part of a floor or roof assembly as described in Sections 7.123 through 7.126 (except for the fourth paragraph of Section 7.123) or for restrained beams tested in accordance with the procedure described in Sections 7.130 through 7.132. The fire-endurance classification so derived shall be applicable to beams when used with a floor or roof construction which has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it was tested. The fire-endurance classification developed by this method shall not be applicable to sizes of beams smaller than those tested.

SECTION 7.135 — TEMPERATURE MEASUREMENT

Measure the temperature of the steel in structural members by thermocouples at three or more sections spaced along the length of the members with one section preferably located at midspan, except that in cases where the cover thickness is not uniform along the specimen length, at least one of the sections at which temperatures are measured shall include the point of minimum cover.

For steel beams, there shall be four thermocouples at each section; locate two on the bottom of the bottom flange, one on the web at the center, and one on the bottom of the top flange.

For reinforced or prestressed concrete structural members, locate thermocouples on each of the tension-reinforcing elements unless there are more than eight such elements, in which case place thermocouples on eight elements selected in such a manner as to obtain representative temperatures of all the elements.

SECTION 7.136 — CONDITIONS OF ACCEPTANCE

In obtaining an unrestrained beam classification, the following conditions shall be met:

1. The specimen shall have sustained the applied load during the classification period.

2. For steel beams, the temperature of the steel shall not have exceeded 1,300°F (704°C) at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section have exceeded 1,100°F (593°C) during this period.

3. For conventionally designed concrete beams, the average temperature of the tension steel at any section shall not have exceeded 800°F (427°C) for cold-drawn prestressing steel or 1,100°F (593°C) for reinforcing steel during the classification period.

Alternate Test of Protection for Solid Structural Steel Beams and Girders

SECTION 7.137 — APPLICATION

Where the loading required in Section 7.125 is not feasible, this alternate test procedure may be used to evaluate the protection of steel beams and girders without application of design load, provided that the protection is not required by design to function structurally in resisting applied loads. The conditions of acceptance of this alternate test are not applicable to tests made under design load as provided under tests for floors and roofs in Sections 7.124, 7.127 and 7.128.

SECTION 7.138 — SIZE AND CHARACTER OF SAMPLE

The size of the steel beam or girder shall be such as to provide a test specimen that is truly representative of the design, materials and workmanship for which classification is desired. The protection shall be applied according to the methods of acceptable field practice and the projection below the ceiling, if any, shall be representative of the conditions of intended use. The length of beam or girder exposed to the fire shall not be less than 12 feet (3658 mm) and the member shall be tested in horizontal position. A section of a representative floor construction not less than 5 feet (1524 mm) wide, symmetrically located with reference to the beam or girder and extending its full length, shall be included in the test assembly and exposed to fire from below. The rating of performance shall not be applicable to sizes smaller than those tested.

The applied protection shall be restrained against longitudinal expansion greater than that of the steel beam or girder by rigid steel plates or reinforced concrete attached to the ends of the member before the protection is applied. The ends of the member, including the means for restraint, shall be given sufficient thermal insulation to prevent appreciable direct heat transfer from the furnace to the unexposed ends of the member or from the ends of the member to the outside of the furnace.

SECTION 7.139 — TEMPERATURE MEASUREMENT

The temperature of the steel in the beam or girder shall be measured with not less than four thermocouples at each of four sections equally spaced along the length of the beam and symmetrically disposed and not nearer than 2 feet (610 mm) from the inside face of the furnace. The thermocouples at each section shall be symmetrically placed so as to measure significant temperatures of the component elements of the steel section.

SECTION 7.140 — CONDITIONS OF ACCEPTANCE

The test shall be regarded as successful if the transmission of heat through the protection during the period of fire exposure for which classification is desired does not raise the average (arithmetical) temperature of the steel at any one of the four sections above 1,000°F (649°C), or does not raise the temperature above 1,200°F (649°C) at any one of the measured points.

Determining Conditions of Restraint for Floor and Roof Assemblies and for Individual Beams

SECTION 7.141 — GENERAL

Construction tested in accordance with this standard shall be classified as restrained or unrestrained.

A restrained condition in fire tests, as used in this standard, is one in which expansion at the supports of a load-carrying element resulting from the effects of the fire is resisted by forces external to the element. An unrestrained condition is one in which the load-carrying element is free to expand and rotate at its supports.

For the purpose of this section, restraint in buildings is defined as follows: floor and roof assemblies and individual beams in buildings shall be considered restrained when the surrounding or supporting structure is capable of resisting the thermal expansion throughout the range of anticipated elevated temperatures. Construction not complying with this definition is assumed to be free to rotate and expand and shall be considered as unrestrained.

Restraint may be provided by the lateral stiffness of supports for floor and roof assemblies and intermediate beams forming part of the assembly. In order to develop restraint, connections must adequately transfer thermal thrusts to such supports. The rigidity of adjoining panels or structures shall be considered in assessing the capability of a structure to resist thermal expansion.

Performance of Protective Membranes in Wall, Partition, Floor or Roof Assemblies

SECTION 7.142 — APPLICATION

When the thermal protection afforded by membrane elements in wall, partition, floor or roof assemblies is to be determined, the nonstructural performance of protective membranes shall be obtained by the following procedure. The performance of protective membranes as determined by this procedure is not a substitute for the fire-endurance classification determined by Sections 7.110 through 7.141 of this standard.

SECTION 7.143 — SIZE AND CHARACTER OF SAMPLE

The sample shall conform to the provisions specified in Section 7.106. The size of the sample shall also conform to the provisions specified in Section 7.110 for bearing walls and partitions, Section 7.113 for nonbearing walls and partitions, or Section 7.124 for floors or roofs.

SECTION 7.144 — TEMPERATURE PERFORMANCE OF PROTECTIVE MEMBRANES

The temperature performance of protective membranes shall be measured with thermocouples, the measuring junctions of which are in intimate contact with the exposed surface of the elements being protected. The diameter of the wires used to form the thermo-junction shall not be greater than the thickness of sheet metal framing or panel members to which they are attached, and in no case greater than No. 18 B.&S. gage [0.040 inch (1.02 mm)]. The lead shall be electrically insulated with heat-resistant and moisture-resistant coatings.

For each class of elements being protected, temperature readings shall be taken at not less than five representative points. Thermocouples shall not be located nearer to the edges of the test assembly than 12 inches (305 mm). An exception may be made in those cases when there is an element or feature of the construction that is not otherwise represented in the test assembly. Thermocouples shall not be located opposite, on top of or adjacent to fasteners such as screws, nails or staples when such locations are excluded for thermocouple placement on the unexposed surface of the test assembly as specified in the second paragraph of Section 7.104.

Thermocouples shall be located to obtain representative information on the temperature of the interface between the exposed membrane and the substrate or element being protected.

Temperature readings shall be taken at intervals not exceeding five minutes, but the intervals need not be less than two minutes.

SECTION 7.145 — CONDITIONS OF PERFORMANCE

Unless otherwise specified, the performance of protective membranes shall be determined as the time at which the following conditions occur:

1. The average temperature rise of any set of thermocouples for each class of element being protected is more than 250°F (139°C) above the initial temperature, or

2. The temperature rise of any one thermocouple of the set for each class of element being protected is more than 325°F (181°C) above the initial temperature.

SECTION 7.146 — REPORT OF RESULTS

The protective membrane performance for each class of element being protected shall be reported to the nearest integral minute.

The test report shall identify each class of elements being protected and shall show the location of each thermocouple.

The test report shall show the time-temperature data recorded for each thermocouple and the average temperature for the set of thermocouples on each element being protected.

The test report shall state any visual observations recorded that are pertinent to the performance of the protective membrane.

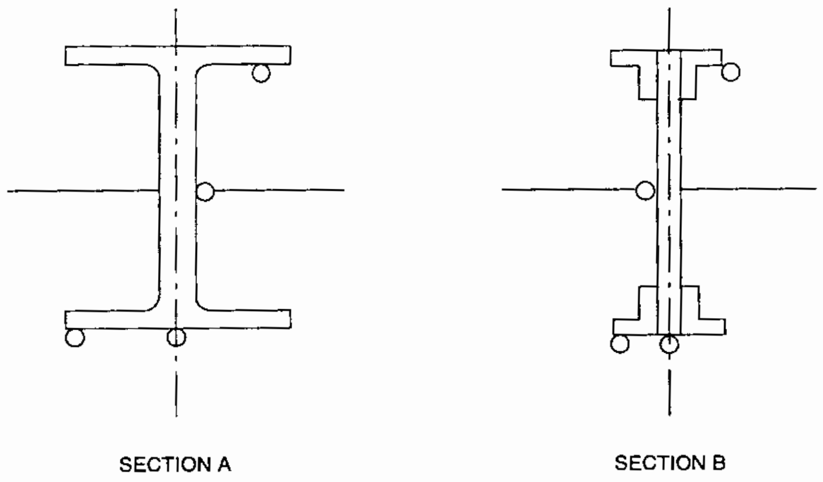


FIGURE 7-1-2—RECOMMENDED THERMOCOUPLE DISTRIBUTION

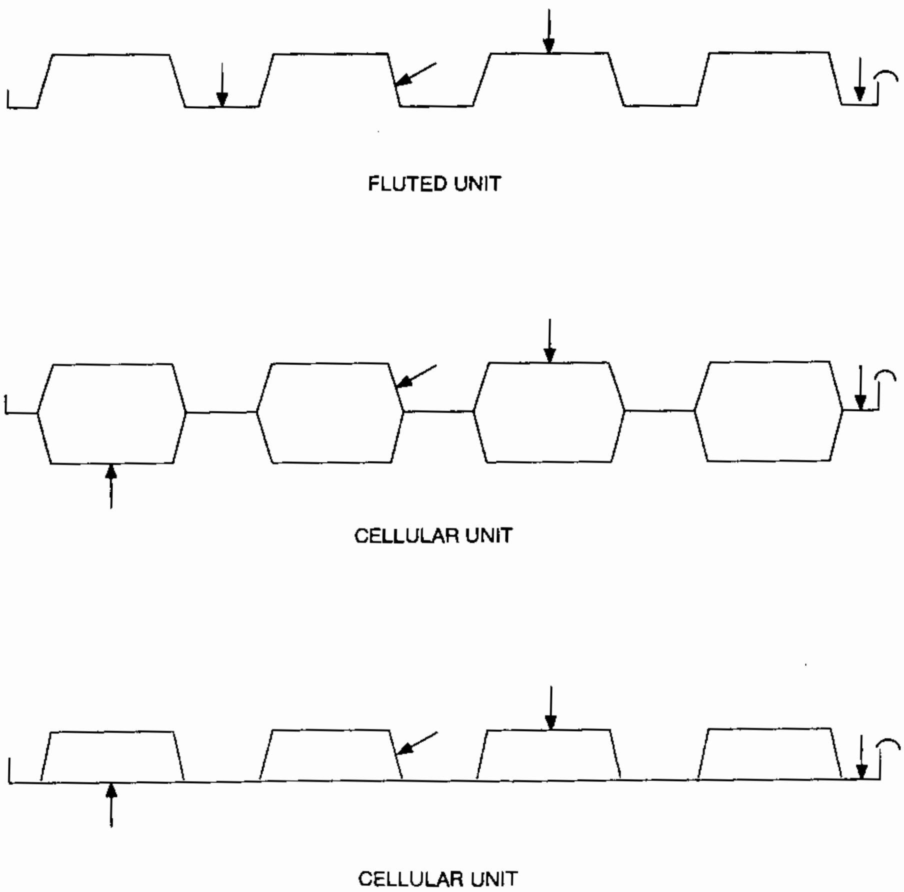


FIGURE 7-1-3—TYPICAL LOCATION OF THERMOCOUPLES

UNIFORM BUILDING CODE STANDARD 7-2
FIRE TESTS OF DOOR ASSEMBLIES

See Sections 302.4, 703.4, 713.5, 713.9, 1004.3.4.3.2 and 1005.3.3.5, *Uniform Building Code*

Part I—Based on Underwriters Laboratories Inc. Standard 10B-1988, Fire Tests of Door Assemblies

SECTION 7.201 — SCOPE

These methods of fire test are applicable for door assemblies of various materials and types of construction, for use in wall openings to retard the passage of fire.

Tests made in conformity with these test methods will register performance during the test exposure; but such tests shall not be construed as determining suitability for use after exposure to fire.

SECTION 7.202 — TIME-TEMPERATURE CURVE

The fire exposure of door assemblies shall be controlled to conform to the applicable portion of the standard time-temperature curve shown in Figure 7-1-1 of UBC Standard 7-1. The points on the curve that determine its character are:

1,000°F (538°C)	at 5 minutes
1,300°F (704°C)	at 10 minutes
1,462°F (794°C)	at 20 minutes
1,550°F (843°C)	at 30 minutes
1,638°F (892°C)	at 45 minutes
1,700°F (927°C)	at 1 hour
1,792°F (978°C)	at $1^1/_2$ hours
1,850°F (1010°C)	at 2 hours
1,925°F (1052°C)	at 3 hours

SECTION 7.203 — FURNACE TEMPERATURES

7.203.1 Test Exposure. The temperatures of the test exposure shall be deemed to be the average temperature obtained from the readings of not less than nine thermocouples symmetrically disposed and distributed to show the temperature near all parts of the test assembly. The thermocouples shall be protected by sealed porcelain tubes having $^3/_4$-inch (19.1 mm) outside diameter and $^1/_8$-inch (3.2 mm) wall thickness; or, as an alternate, in the case of base metal thermocouples shall be protected by $^1/_2$-inch (12.7 mm) wrought steel or wrought-iron pipe of standard weight. The junction of the thermocouples shall be 6 inches (152 mm) from the exposed face of the test assembly or from the masonry in which the assembly is installed during the entire test exposure.

7.203.2 Reading Intervals. The temperatures shall be read at intervals not exceeding five minutes during the first two hours, and thereafter the intervals may be increased to not more than 10 minutes.

7.203.3 Accuracy of Control. The accuracy of furnace control shall be such that the area under the time-temperature curve, obtained by averaging the results from the thermocouple readings, is within 10 percent of the corresponding area under the standard time-temperature curve for fire tests of one hour or less duration, within 7.5 percent of those over one hour and not more than two hours and within 5 percent for tests exceeding two hours in duration.

SECTION 7.204 — UNEXPOSED SURFACE TEMPERATURES

If unexposed surface temperatures are recorded other than for single-layer metal doors, they shall be determined in the following manner:

1. Unexposed surface temperatures shall be taken at not less than three points with at least one thermocouple in each 16-square-foot (1.5 m^2) area of the door.

Thermocouples shall not be located over reinforcements extending through the door, over vision panels or nearer than 12 inches (305 mm) from the edge of the door.

2. Unexposed surface temperatures shall be measured with thermocouples placed under flexible, oven-dry pads, $6^1/_8$ inches square (156 mm square), 0.40 inch ± 0.05 inch (10.2 mm ± 1.3 mm) thick and weighing not less than 1.0 (4.9 kg/m^2) or more than 1.4 pounds per square foot (6.8 kg/m^2). The pads shall be held firmly against the surface of the door and shall fit closely about the thermocouples. The thermocouple leads shall be positioned under the pad for a distance of not less than $3^1/_2$ inches (88.9 mm) with the hot junction under the center of the pad. The thermocouple leads under the pads shall not be heavier than No. 18 AWG [0.04 inch (1.02 mm)] and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

3. Unexposed-surface temperatures shall be read at the same intervals as those for furnace temperatures in Section 7.203.2.

4. The thermocouples and pads shall be removed from the surface of the test assembly after the first 30 minutes of the fire exposure.

EXCEPTION: The thermocouples and pads are permitted to remain if additional temperature rise information beyond the initial 30 minutes of exposure is being sought.

SECTION 7.205 — TEST ASSEMBLIES

7.205.1 Construction and Size. The construction and size of the test door assembly, consisting of single doors or doors in pairs, special purpose doors (such as dutch doors, double egress doors, etc.) or multisection doors shall be representative of that for which classification or rating is desired.

7.205.2 Sills. A floor structure shall be provided as part of the opening to be protected except where such sill interferes with the operation of the door. The sill shall be of noncombustible material and project into the furnace to a distance approximately twice the thickness of the test door or to the limit of the frame, whichever is greater.

SECTION 7.206 — MOUNTING

7.206.1 Side to Be Exposed. Swinging doors shall be mounted so as to open into the furnace chamber.

Sliding and rolling doors, except passenger-elevator shaft doors, shall be mounted on the exposed side of the opening in the wall closing the furnace chamber.

Horizontal slide-type elevator shaft doors shall be mounted on the unexposed side of the opening in the wall closing the furnace chamber.

Access-type doors and chute-type doors and frame assemblies shall be mounted so as to have one assembly open into the furnace chamber and another assembly open away from the furnace chamber.

Dumbwaiter and service-counter doors and frame assemblies shall be mounted on the exposed side of the opening in the wall.

7.206.2 Frames. Door frames shall be evaluated when mounted so as to have the doors open either away from, or into, the furnace chamber at the discretion of the testing agency, to obtain representative information on the performance of the construction under test.

7.206.3 Hardware. Surface-mounted hardware (fire-exit devices) for use on fire doors shall be evaluated by being installed on one door assembly swinging into the furnace chamber and another door assembly swinging away from the furnace chamber.

7.206.4 Anchors. Door frame wall anchors, when used, shall be acceptable for the wall or partition construction.

7.206.5 Fit. The mounting of all doors shall be such that they fit snugly within the frame, against the wall surfaces, or in guides, but such mounting shall not prevent free and easy operation of the test door.

7.206.6 Clearances. Clearances for swinging doors shall be as follows: With a minus $^1/_{16}$-inch (1.6 mm) tolerance—$^1/_8$ inch (3.2 mm) along the top, $^1/_8$ inch (3.2 mm) along the hinge and latch jambs, $^1/_8$ inch (3.2 mm) along the meeting edge of doors in pairs, and $^3/_8$ inch (9.5 mm) at the bottom edge of a single swing door, and $^1/_4$ inch (6.4 mm) at the bottom of a pair of doors.

Clearances for horizontal sliding doors not mounted within guides shall be as follows: With a minus $^1/_8$-inch (3.2 mm) tolerance—$^1/_2$ inch (12.7 mm) between door and wall surfaces, $^3/_8$ inch (9.5 mm) between door and floor structure, and $^1/_4$ inch (6.4 mm) between the meeting edges of center-parting doors. A maximum lap of 4 inches (101.6 mm) of the door over the wall opening at sides and top shall be provided.

Clearances for vertical sliding doors moving within guides shall be as follows: With a minus $^1/_8$-inch (3.2 mm) tolerance—$^1/_2$ inch (12.7 mm) between door and wall surfaces along top and/or bottom door edges with guides mounted directly to the wall surface and $^3/_{16}$ inch (4.8 mm) between meeting edges of biparting doors or $^3/_{16}$ inch (4.8 mm) between door and floor structure or sill.

Clearances for horizontal slide-type elevator doors shall be as follows: With a minus $^1/_8$-inch (3.2 mm) tolerance—$^3/_8$ inch (9.5 mm) between door and wall surfaces, $^3/_8$ inch (9.5 mm) between multisection door panels and $^3/_8$ inch (9.5 mm) from the bottom of the panel to the sill. Multisection door panels shall overlap $^3/_4$ inch (19.1 mm). Door panels shall lap the wall opening $^3/_4$ inch (19.1 mm) at sides and top.

SECTION 7.207 — CONDUCT OF TEST

7.207.1 Time of Testing. Masonry settings shall have sufficient strength to retain the assembly securely in position throughout the fire and hose stream tests.

7.207.2 Fire-endurance Test. After five minutes into the test, the neutral pressure level in the furnace shall be established at 40 inches (1016 mm) or less above the sill for side-hinged or pivoted swinging doors. For other types of doors, including swinging elevator doors, the pressure in the furnace shall be maintained as nearly equal to the atmosphere's pressure as possible. The pressure shall be maintained during the entire test period.

The test shall be continued until the exposure period of the desired classification or rating is reached unless the conditions of acceptance specified in Section 7.209 are exceeded in a shorter period.

7.207.3 Hose Stream Test. Immediately following the fire-endurance test, the test assembly shall be subjected to the impact, erosion and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed surface, changes in direction being made slowly.

The hose stream shall be delivered through a $2^1/_2$-inch (63.5 mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a $1^1/_8$-inch (28.6 mm) discharge tip of standard-taper smoothbore pattern without shoulder at the orifice. The water pressure at the base of the nozzle and the duration of application in seconds per square foot (square meter) of exposed area shall be as set forth in Table 7-2-A.

The tip of the nozzle shall be located 20 feet (6096 mm) from and on a line normal to the center of the test door. If impossible to be so located, the nozzle may be on a line deviating not to exceed 30 degrees from the line normal to the center of the test door.

When so located, the distance from the center shall be less than 20 feet (6096 mm) by an amount equal to 1 foot (305 mm) for each 10 degrees of deviation from the normal.

7.207.4 Cotton Pad Test. For doors rated for a temperature rise of 650°F (361°C) or less, a cotton pad test shall be required during and at the end of the first 30 minutes of fire test. This test, for the passage of gases hot enough to ignite a cotton pad (absorbent cotton U.S.P. sterilized dried at 100°C for 24 hours) 4 inches by 4 inches (100 mm by 100 mm) in size, $^3/_4$ inch (19 mm) thick, weighing not less than 3 nor more than 4 grams. The pad shall be mounted in a steel device which will hold the pad parallel to, and 1 inch (25.4 mm) away from, the unexposed surface of the door. The cotton pad is to be held in position on the door for a minimum period of 20 seconds at such locations where cracks, seams or similar openings appear to have developed.

SECTION 7.208 — REPORT AND LABELING

7.208.1 Report. Results shall be reported in accordance with the performance in the tests prescribed in these test methods. The report shall show the performance under an exposure period chosen from the following: 20 minutes, 30 minutes, three-fourths hour, one hour, one and one-half hours, or three hours. The report shall include the temperature measurements of the furnace and, if determined, of the unexposed side of the test assembly. It shall also contain a record of all observations having a bearing on the performance of the test assembly including:

1. Any flaming on the unexposed surface of the door leaf.

2. The amount of movement of any portion of the edges of the door adjacent to the door frame from the original position.

3. The materials and construction of the door and frame and the details of the installation, hardware, hangers, guides, trim, finish and clearance or lap shall also be recorded or appropriately referenced to provide positive identification or duplication in all respects.

4. It shall also contain pressure measurements relative to the elevation of the top of the door.

7.208.2 Label. The classification marking or label on the door shall indicate the temperature rise developed on the unexposed surface of the door after the first 30 minutes of fire exposure as follows:

250°F (138°C) maximum
450°F (250°C) maximum

650°F (361°C) maximum
More than 650°F (361°C)

All doors with glass lights in excess of 100 square inches (64 516 mm^2) are not eligible for a temperature rise rating.

SECTION 7.209 — CONDITIONS OF ACCEPTANCE

7.209.1 General. A door assembly shall be considered as meeting the requirements for acceptable performance when it remains in the opening during the fire-endurance test and hose stream test within the following limitations:

1. The movement of swinging doors shall not result in any portion of the edges adjacent to the door frame moving from the original position in a direction perpendicular to the plane of the door more than the thickness of the door, during the entire classification period or more than $1^1/_2$ times the door thickness as a result of the hose stream test.

2. An assembly consisting of a pair of swinging doors shall not separate more than $^3/_4$ inch (19.1 mm) or a distance equal to the throw of the latch bolt at the latch location.

3. An assembly consisting of a single swinging door shall not separate more than $^1/_2$ inch (12.7 mm) at the latch location.

4. The lap edges of passenger (horizontal slide-type) elevator doors, including the lap edges of multisection doors, shall not move from the wall or adjacent panel surfaces sufficiently to develop a separation of more than $2^7/_8$ inches (73.0 mm) during the entire classification period, or immediately following the hose stream test. The meeting edges of center-parting elevator door assemblies, for a fire and hose stream exposure of one and one-half hours or less, shall not move apart more than $1^1/_4$ inches (31.8 mm) as measured in any horizontal plane during the entire classification period or immediately following the hose stream test.

5. Doors mounted in guides shall not release from guides and guides shall not loosen from fastenings.

6. The test assembly shall have withstood the fire-endurance test and the hose stream test without developing openings anywhere through the assembly; except that dislodging of small portions of glass by the hose stream and within the limits specified in these requirements shall remain in place.

7. An opening is defined as a through hole in the assembly that can be seen from the unexposed side when viewed from the direction perpendicular to the plane of the assembly at the location of the suspected opening.

8. Ignition of the cotton pad shall be considered as failure.

7.209.2 Specific, All Doors.

1. Light intermittent flaming not exceeding 10-second duration and 6 inches (152 mm) in length shall be permitted during the first 30 minutes of the classification period.

2. After 30 minutes, some intermittent light flames [approximately 6 inches (152.4 mm) long], for periods not exceeding five-minute intervals, may occur along the edges of doors.

3. Light flaming may occur during the last 15 minutes of the classification period on the unexposed surface area of the door, provided it is contained within a distance of $1^1/_2$ inches (38.1 mm) from a vertical door edge and within 3 inches (76.2 mm) from the top edge of the door and within 3 inches (76.2 mm) from the top edge of the frame of a vision panel.

4. When hardware is to be evaluated for use on fire doors, it shall hold the door closed in accordance with the conditions of acceptance for the intended door assembly classification period and, in addition, the latch bolt shall remain projected and shall be intact after the test. The hardware need not be operable after test.

5. The door itself shall not emit excessive amounts of smoke during the fire test.

7.209.3 Swinging Doors. The movement of swinging doors shall not result in any portion of the door edges adjacent to the door frame moving from the original position in a direction perpendicular to the plane of the door more than the thickness of the door during the entire classification period, or more than one and one-half times the door thickness as a result of the hose stream test.

An assembly consisting of a pair of swinging doors incorporating an astragal shall not separate in a direction parallel to the plane of the doors more than $^3/_4$ inch (19.1 mm) or a distance equal to the throw of a latch bolt at the latch location.

An assembly consisting of a pair of swinging doors, without an overlapping astragal, for a fire and hose stream exposure of one and one-half hours or less, shall not separate along the meeting edges more than $^3/_8$ inch (9.5 mm), including the initial clearance between doors.

An assembly consisting of a single swinging door shall not separate more than $^1/_2$ inch (12.7 mm) at the latch location.

Door frames to be evaluated with doors shall remain securely fastened to the wall on all sides and shall not permit through openings between frame and doors or between frame and adjacent wall.

7.209.4 Sliding Doors. Doors mounted on the face of the wall shall not move from the wall sufficiently to develop a separation of more than $2^7/_8$ inches (73.0 mm) during the entire classification period or as a result of the hose stream test.

Doors mounted in guides shall not release from the guides, and the guides shall not loosen from fastenings.

The bottom bar of rolling steel doors shall not separate from the floor structure more than $^3/_4$ inch (19.1 mm) during the entire classification period or as a result of the hose stream test.

The meeting edge of center-parting horizontal sliding doors and biparting vertical sliding doors shall not separate more than the door thickness in a direction perpendicular to the plane of the doors. The meeting edges of center-parting horizontal sliding doors and biparting vertical sliding doors without an overlapping astragal, for a fire and hose stream exposure of one and one-half hours or less, shall not separate in a direction parallel to the plane of the doors more than $^3/_8$ inch (9.5 mm) along the meeting edges, including the initial clearance between doors.

The meeting edges of center-parting horizontal sliding doors incorporating an astragal shall not separate in a direction parallel to the plane of the doors more than $^3/_4$ inch (19.1 mm) nor a distance equal to the throw of the latch bolt along the meeting edges.

The bottom edge of service-counter doors or single-slide dumbwaiter doors shall not separate from the sill more than $^3/_8$ inch (9.5 mm).

A resilient astragal, if provided, shall not deteriorate sufficiently to result in through openings during the fire-endurance test, but small portions may be dislodged during the hose stream test.

TABLE 7-2-A—WATER PRESSURE AT BASE OF NOZZLE AND DURATION OF APPLICATION

DESIRED RATING	WATER PRESSURE AT BASE OF NOZZLE (pounds per square inch)	DURATION OF APPLICATION (seconds per square foot of exposed area)
	× 6.89 for kPa	× 10.76 for sec./m²
3 hrs.	45	3
$1^1/_2$ hrs. and over, if less than 3 hrs.	30	1.5
1 hr. and over, if less than $1^1/_2$ hrs.	30	0.9
Less than 1 hr.	30	0.6

Part II—Test Standard for Smoke- and Draft-control Assemblies of the International Conference of Building Officials

SECTION 7.210 — SMOKE- AND DRAFT-CONTROL DOOR ASSEMBLIES

7.210.1 Scope. This method of test measures air leakage through door assemblies to determine the resistance of the door assembly in the closed position to the passage of smoke. The door assembly does not include a transom or sidelights.

7.210.2 Fire-endurance Test. The method of test for 20-minute smoke- and draft-control assemblies shall be as required for swinging doors under Part I of this standard. The fire-endurance test for these door assemblies shall be for an exposure period of not less than 20 minutes, except that the hose stream test required by Section 7.207.3 need not be applied.

7.210.3 Mounting.

7.210.3.1 Test chamber. The air leakage test chamber shall consist of a well-sealed chamber or box with an opening large enough to accommodate the test sample. A means of access into the chamber shall be permitted to facilitate adjustments and observations of the installed test sample.

At least one static pressure tap shall be provided to measure the chamber pressure. It shall be located so that readings are unaffected by the velocity of the air supplied to, or existing from, the chamber.

7.210.3.2 Test sample. The test sample shall be representative of production design. It shall be installed in accordance with manufacturers' instructions.

Test samples shall be tested swinging away from the positive pressure of the test chamber, or swinging toward the positive pressure, depending on which direction causes the most air infiltration for the type of door tested. Where representative test data exists to verify the ambient temperature results in higher leakage rates, additional tests for warm temperature measurements need not be conducted.

7.210.3.3 Conditioning. Test samples containing hygroscopic materials or other materials that can be affected by moisture shall be conditioned in an environment having a dry bulb temperature of 77 ± 5°F (25 ± 3°C) and a relative humidity of 40 to 65 percent until reaching equilibrium.

7.210.3.4 Gasketing. Gasketing may or may not not be installed in the test sample.

7.210.3.5 Bottom seal. An artificial bottom seal shall be installed across the full width of the bottom of the assembly.

7.210.4 Conduct of Test.

7.210.4.1 Chamber leakage test. Prior to the air leakage test, the clearances between the test sample and the chamber opening shall be measured at three points on each vertical and horizontal edge. Extraneous chamber leakage shall be measured using an air-impermeable sheet to cover the entire test sample. It shall be measured prior to the ambient temperature exposure tests specified in Section 7.210.4.2 and after the elevated temperature tests specified in Section 7.210.4.3 after the temperatures at the face of the test sample have returned to within 20°F (11°C) of their temperatures prior to the test. Chamber leakage shall be subtracted from the measured test sample leakage.

7.210.4.2 Ambient temperature test. The temperature of the exposed face of the test sample shall be 75 ± 20°F (24 ± 11°C), and each door face shall be ± 5°F (± 3°C) of each other prior to the conduct of the test. The air flow in the chamber shall be adjusted to provide a positive test pressure differential of 0.05-inch water (12.5 Pa) between the test chamber and the area immediately outside the chamber. The difference shall be within a tolerance of ± 0.005-inch water (1.25 Pa). After test conditions are stabilized, the air flow through the air flow metering system and the test pressure difference shall be measured and recorded. This measured air flow is designated the total metered air flow. The total measured air flow is then determined and recorded at test pressure differentials of 0.10-inch water (25 Pa), 0.20-inch water (50 Pa) and 0.30-inch water (75 Pa).

7.210.4.3 Elevated temperature test. The temperature of the exposed face of the test sample shall be 75 ± 20°F (24 ± 11°C), and each door face shall be ± 5°F (± 3°C) of each other prior to the conduct of the test. The test at ambient temperatures in Section 7.210.4.2 shall be repeated at a test chamber temperature of 400 ± 10°F (204 ± 5°C). The chamber temperature is to be increased so that it reaches 350°F (177°C) within 15 minutes and 400°F (204°C) within 30 minutes. When stabilized at 400°F ± 10°F (204 ± 5°C), metered air flow is determined and recorded to exceed 30 minutes.

7.210.5 Report. The air flow through the test sample shall be determined with an error not greater than ± 5 percent when the air flow equals or exceeds 2 cubic feet per minute (cfm) (9.44×10^{-4} m^3), or 10 percent when the air flow is less than 2 cfm (9.44×10^{-4} m^3) but more than 0.5 cfm (2.36×10^{-4} m^3). At lower rates, a greater percentage of error is acceptable.

The barometric pressure, temperature and relative humidity of the supply air shall be measured at the test sample and recorded. The air supply flow values shall be corrected to normal temperature and pressure standard conditions for reporting purposes.

7.210.6 Conditions of Acceptance. A smoke- and draft-control door meeting the requirements of Section 7.209.2 as modified herein shall be considered as meeting the requirements for acceptable performance when the air leakage rate of the door assembly does not exceed 3.0 cfm (14.16×10^{-4} m^3) per square foot of door opening at 0.10-inch water (25 Pa).

7.210.7 Marking. Door assemblies shall bear fire-rating labels issued by a listing agency showing compliance with this part. The hourly fire rating shall be followed by the letter "S." Label markings shall include the following:

1. Name and address of the listee.
2. Model number of type.
3. Symbol, serial or issue number of the listing agency.

UNIFORM BUILDING CODE STANDARD 7-3
TINCLAD FIRE DOORS

Based on Tinclad Fire Doors Standard ANSI/UL 10 A-1979 (R 1985)

See Sections 703.4, Item 1 and 713.5, *Uniform Building Code*

Part I—General

SECTION 7.301 — SCOPE

This standard covers the design and construction of tinclad fire doors which have been shown by fire tests to possess sufficient fire-retardant values to warrant classification as three, one and one-half or three-fourths-hour assemblies, when tested in accordance with the Standard Specification for Fire Tests of Door Assemblies. Doors complying with these requirements are classified in two temperature-rise groups:

1. Temperature rise on the unexposed side at the end of 30 minutes, 250°F (139°C) maximum.

2. Temperature rise on the unexposed side at the end of 30 minutes in excess of 650°F (361°C).

SECTION 7.302 — REQUIREMENTS

A door conforming to these specifications consists essentially of a core made up of layers of boards nailed to each other, encased in terne or zinc-coated steel in the form of sections jointed together at their edges and nailed through the seams to the core.

SECTION 7.303 — SIZES AND RATINGS

The sizes and ratings for three-ply and two-ply doors are given in Table 7-3-A.

Doors exceeding the sizes in Table 7-3-A have not been subjected to standard fire tests, and certificates on such doors indicate that the units conform to construction requirements of this standard, except in size.

It should be noted that Table 7-3-A pertains to maximum size of opening. Doors limited in size by this table fall into two categories: (1) swinging doors intended to be installed within an opening, and (2) all sliding doors and those swinging doors intended for surface mounting outside of the opening. Swinging doors in the first category are limited in size to the maximum dimensions specified for the opening. Doors in the second category must be larger than the maximum opening dimensions to provide the minimum 4-inch (101.6 mm) lap at each side and the top of the door. Doors exceeding these two basic dimension considerations are termed "Oversize," the design and construction of which are not necessarily fully covered in these requirements.

Part II—Materials

SECTION 7.304 — LUMBER

7.304.1 Species and Condition. The following soft woods may be used, provided only one kind of lumber is used in the assembly of a single core:

Cedars—All classes	Redwood
Cypress—All classes	Sitka Spruce
Douglas Fir	Tupelo Gum
Eastern Spruce	Yellow Poplar
Northern White Pine	Western White Pine

Other kinds of lumber may be added to the foregoing list, provided the kind of wood to be used has properties equivalent to the above species with respect to low resin content, light weight, resistance to fungus and decay, and ability to withstand nailing without splitting or splintering.

Lumber shall have a moisture content of 19 percent or less at the time of manufacturing door cores. Tests for moisture content shall be made using the oven-drying or the electrical meter method in accordance with approved methods for tests for moisture content of wood.

Stocks of lumber shall be stored under cover in the premises of the fire-door manufacturer for at least one month before being used in the manufacture of fire-door cores and, while in storage, shall be piled in such a manner that the air has free access to all surfaces of each board. Kiln drying will be accepted for the 30-day drying period.

7.304.2 Size. The boards shall be nominal 1-inch (25 mm) lumber, surfaced on two sides and matched. They shall be without beading, beveling, painting or other treatment.

The actual thickness of the boards shall not be less than $^3/_4$ inch (19.1 mm).

The boards shall not be less than 4 inches (102 mm) or more than 8 inches (203 mm) in nominal width.

The nominal width (or stock width) is greater than the actual width over the tongue and groove.

7.304.3 Grading. The boards shall be free from wane (bark), decay, knots or other holes, loose knots, unsound knots or knots exceeding $2^1/_2$ inches (63.5 mm) in any dimension.

Lumber of a No. 2 Common or Construction grade or better will generally meet these requirements. However, because some pieces of No. 2 grade could be unacceptable, the kind of lumber used and its condition shall be judged from characteristic properties of the wood as commonly known. These characteristics include:

1. **Decay**—Destruction of the wood substance due to the action of wood destroying fungi.

NOTE: "Dote" and "rot" are synonymous with "decay" and are any form of decay which may be evident either as a dark red discoloration, not found in the sound wood, or the presence of white or red rotten spots.

2. **Advanced (typical decay)**—The older stage of decay in which the destruction is readily recognized because the wood has become punky, soft and spongy, stringy, ring shaped, pitted or crumbly.

3. **Incipient decay**—The early stage of decay which has not proceeded far enough to soften or otherwise perceptibly impair the hardness of the wood.

4. **Knot**—That portion of a branch which has become incorporated in the body of a tree.

5. **Loose knot**—A knot which is not firmly held in place by growth or position.

6. **Tight knot**—A knot so fixed by growth or position that it will firmly retain its place in the wood piece.

7. **Hollow knot**—A hollow knot is an apparently sound knot except it contains a hole over $^1/_4$ inch (6.4 mm) in diameter or a void area behind the knot.

8. **Check**—A separation along the grain, the greater part of which occurs across the rings of annual growth.

9. **Wane**—The lack of wood from any cause, or bark on the surface of lumber.

To permit judging of the several characteristics of knots, oval and circular knots are to be measured across their lines of growth. For spike knots, the measurement is to be parallel to the lines of growth. In all cases, the measured distance is to be the visible portion of the knot which is normally darker or lighter than the coloring of the board.

The following characteristics are to be judged as unacceptable:

1. Oval, circular or spike knots exceeding $2^1/_2$ inches (63.5 mm) in any direction.

2. Loose knots, open knots or any knot over 1 inch (25.4 mm) in any direction located on the tongue or lip.

3. Loose knots, open knots, through holes and surface pits [deeper than $^1/_{16}$ inch (1.6 mm)] in the central portion of the boards.

4. Hollow and decayed knots.

5. Checks, advanced (typical) and incipient decay.

6. Warpage which would prevent the boards from being nailed flat or which would affect the flatness of the nailed core.

7. Cluster knots or knots in groups [less than $^5/_8$ inch (15.9 mm) apart].

Tight knots on the lips or tongue of a board may be judged acceptable if, due to manufacturing, the lips or tongue have been chipped, but only to the extent that (1) the dimensions of the damage do not exceed $^3/_8$ inch (9.5 mm) in length and $^3/_{16}$ inch (4.8 mm) in diameter, and (2) the lip or tongue with a chip cannot be easily broken, such as upon exerting direct hand pressure.

SECTION 7.305 — METAL COVERINGS

7.305.1 General. The terne or zinc-coated steel sections shall have straight edges and square corners. A deviation of $^1/_{32}$ inch per foot (2.6 mm per meter) from square shall be accepted, provided the door manufacturer is able to obtain true, straight joints and to avoid patching the rows of sheets in the covering.

7.305.2 Terne-coated Sheet Steel. Only prime terne plate shall be used. For the purpose of these requirements, "terne" shall be understood as indicating an alloy of tin and lead in the proportion of 80 percent lead and 20 percent tin, hot-dipped applied. The terne coating shall be uniformly applied on both sides of sheet steel having an uncoated thickness of not less than 0.010 inch (0.254 mm). The terne coating shall not crack, peel or flake when formed.

The sheet steel shall be coated with not less than 0.55 ounce per square foot (0.168 kg/m^2) average of terne coating (total both sides) by triple spot test and not less than 0.40 ounce per square foot (0.122 kg/m^2) of terne coating (total both sides) by the single spot test, with not less than 40 percent of the coating of any side, by the single spot test requirement. The weight of terne coating shall be determined by approved nationally recognized methods.

A determination for percent tin shall be made on a portion of the solution containing the stripped terne coating, using standard laboratory analytical methods. The amount of tin in the coating shall not be less than 20 percent.

A determination for percent lead may be made on a portion of the solution containing the stripped terne coating, using standard laboratory analytical methods, or the percent of lead in coating may be determined by subtracting the percent of tin from 100 percent.

7.305.3 Zinc-coated (Galvanized) Sheet Steel. Zinc-coated sheet steel shall have an uncoated thickness of not less than 0.010 inch (0.254 mm). The zinc coating shall not crack or flake when formed.

Finished doors shall be painted with a good grade of corrosion-resisting paint before shipment. Before painting, zinc surfaces shall be thoroughly cleaned and pretreated to provide for adherence of the paint coating.

The protective coating of zinc shall be as applied to hot-dipped, mill galvanized sheet steel, with not less than 40 percent of the zinc on any side, based on the single spot requirement. The weight of zinc coating, minimum 0.5 oz./ft.^{2} (0.153 kg/m^2), shall be determined by approved nationally recognized methods.

SECTION 7.306 — NAILS

Core nails shall be cut nails of the clinch type or duck-bill point-type power-driven nails that clinch. For three-ply cores, the nails shall not be less than $2^7/_8$ inches (73 mm) or more than 3 inches (76.2 mm) long. For two-ply cores, the nails shall not be less than $1^{11}/_{16}$ inches (42.9 mm) or more than 2 inches (50.8 mm) long. The shank diameters of duckbill-point nails shall be 0.130 inch to 0.140 inch (3.3 mm to 3.6 mm) for three-ply doors and 0.100 inch to 0.110 inch (2.5 mm to 2.8 mm) for two-ply doors.

Nails for applying the metal covering shall be wire nails with flat heads. The shank of the nails shall not be less than 0.091 inch (2.3 mm) nor more than 0.109 inch (2.8 mm) in diameter. The nails for three-ply cores shall be 2 inches (50.8 mm) long, and for two-ply cores shall not be less than $1^1/_4$ inches (31.8 mm) or more than $1^1/_2$ inches (38.1 mm) long.

Part III—Construction

SECTION 7.307 — ASSEMBLY OF BOARDS

The details for the assembly of boards are shown in Figures 7-3-1 and 7-3-2.

Only one stock width of board shall be used in any one core, except that the edge board and the stock board immediately adjacent to the edge board may differ in width from the remaining stock boards. Edge boards shall not finish less than 3 inches (76.2 mm) in width and the exposed edges shall not be tongued or grooved.

Boards shall not be less than 1 foot (305 mm) in length, with ends cut square. Not more than two pieces shall be used in any continuous strip in any outside layer of a two-ply or three-ply core, nor more than three pieces in any middle layer strip of a three-ply core. At least alternate strips in outside layers shall be full-length boards.

If glass panels are provided and the panel opening is of such a size that the distance between the opening and the edges of the door is less than 2 feet (609.6 mm), all boards bordering the vertical edges of the opening may be laid vertically, and all boards bordering the horizontal edges of the opening may be laid horizontally.

If glass panels are provided, the boards in the normally vertical layers bordering the sides of the panel opening shall be continuous from top to bottom of the door, and boards in the normally horizontal layer bordering the top or bottom of the panel opening shall be continuous from side to side of the door. The distance between the panel opening and the side of the door shall not be less than 7 inches (177.8 mm). See Figure 7-3-2.

Outside layers in a three-ply core and one layer of a two-ply core shall be vertical, and the other layer horizontal. The several boards in each layer and the ends of pieces of boards in strips shall make tight joints at edges and ends of boards.

The top edge for a sliding door designed to close by gravity shall conform to an incline of $^3/_4$ inch per foot (62.5 mm per meter). The minimum face width of the top horizontal board of a core having the top edge inclined shall not be less than 3 inches (76.2 mm). See Figures 7-3-3, 7-3-4 and 7-3-5.

SECTION 7.308 — NAILING OF CORES

7.308.1 General. The boards shall be nailed so that the several layers are fastened tightly together, with the points of the nails turning back and clinching thoroughly in the face of the core and with no portion of the nails projecting beyond the surfaces of the core. See Figure 7-3-6.

7.308.2 Two-ply and Three-ply Cores of Boards 3 Inches to 4 Inches (76.2 mm to 101.6 mm) (Inclusive) Stock Width. The details for nailing of boards 3 inches to 4 inches (76.2 mm to 101.6 mm), inclusive, stock width are shown in Figure 7-3-3.

Horizontal rows of nails shall be about the center of each horizontal layer board. Vertical rows of nails shall be about the center of each vertical layer of board. Nails in horizontal and vertical rows shall be spaced not more than five times the face width of each board. Rows of nails at edges of core shall be about $1^1/_2$ inches (38 mm) from each edge. Nails in vertical edge rows shall be placed not more than the face width of each board and shall be about the center of each horizontal board. Nails in horizontal edge rows shall be spaced not more than the face width of each board and shall be about the center of each vertical board.

7.308.3 Two-ply and Three-ply Cores of Boards $4^1/_2$ Inches to 8 Inches (114.3 mm to 203.2 mm) (Inclusive) Stock Width. The details for nailing of boards $4^1/_2$ inches to 8 inches (114.3 mm to 203.2 mm), inclusive, stock width are shown in Figure 7-3-4.

Horizontal rows of nails shall be about 1 inch (25 mm) from each edge of each horizontal layer board (two horizontal rows of nails through each horizontal board). Vertical rows of nails shall be about 1 inch (25 mm) from each edge of each vertical layer board (two vertical rows of nails through each vertical board). Nails in horizontal and vertical rows shall be spaced not more than twice the face width of each board.

Rows of nails at edges of core shall be about $1^1/_2$ inches (38 mm) from each edge. Nails in vertical-edge rows shall be spaced not more than the face width of each board and shall be about the center of each horizontal board. Nails in horizontal edge rows shall be spaced not more than the face width of each board and shall be about the center of each vertical board, except that the nails in the top edge row of a core having the top edge inclined shall be spaced not more than $4^1/_2$ inches (114.3 mm).

7.308.4 Three-ply Cores Only of Boards $4^1/_2$ Inches to 8 Inches (114.3 mm to 203.2 mm) (Inclusive) Stock Width. The details for nailing of boards $4^1/_2$ inches to 8 inches (114.3 mm to 203.2 mm), inclusive, stock width for three-ply core only are shown in Figure 7-3-5.

Horizontal rows of nails shall be about the center of each horizontal layer board. Vertical rows of nails shall be about 1 inch (25 mm) from each edge of each vertical layer board (two vertical rows of nails through each vertical board). Nails in horizontal rows shall be spaced not more than the face width of each board. Nails in vertical rows shall be spaced not more than twice the face width of each board.

Rows of nails at edges of core shall be about $1^1/_2$ inches (38 mm) from each edge. Nails in vertical edge rows shall be spaced not more than the face width of each board and shall be about the center of each horizontal board. Nails in horizontal edge rows shall be spaced about 1 inch (25 mm) from each edge of each vertical board, except that each vertical edge board shall have only one nail, which should be placed about the center of the board.

SECTION 7.309 — FINISHED CORES

A finished three-ply core shall not be less than $2^1/_4$ inches (57.2 mm) nor more than $2^5/_8$ inches (66.7 mm) in thickness, and a finished two-ply core shall not be less than $1^1/_2$ inches (38.1 mm) nor more than $1^3/_4$ inches (44.5 mm) in thickness.

> **EXCEPTION:** A finished three-ply core door which is less than $2^1/_4$ inches (57.2 mm) thick may be marked in accordance with the schedule for two-ply doors.

The cores shall have true corners. All edges shall be finished smooth and square, except that meeting edges of swinging doors may be beveled $^1/_4$ inch (6.4 mm) (not rabbeted).

SECTION 7.310 — SIZES OF STEEL SECTIONS

Coated steel sections shall not be larger than the 14- by 20-inch (355.6 mm by 508 mm) size. Corner sections shall not be over 14 inches (355.6 mm) wide and of any length that will avoid joints with edge sections coming under miter fold. Edge sections (excepting "cap" sections) shall be of the same width as corner sections and of any convenient length. Cap sections shall be of any convenient length and equal in width to thickness of core plus $3^1/_2$ inches (88.9 mm).

SECTION 7.311 — FORMING OF STEEL SECTIONS

Turned edges of coated steel sections shall be parallel to cut edges. Turned-up portions of all sections shall be of uniform width.

Face sections, excepting the face sections used in the row forming the closure, shall have one vertical edge turned $^5/_8$ inch (15.9 mm) and the other vertical edge doubled under $1^3/_{16}$ inches (30.2 mm) and the doubled edge then turned up $^5/_8$ inch (15.9 mm) from cut edge as shown in Figure 7-3-7, Section A-B.

Face sections, excepting face sections forming top horizontal seams, shall have both horizontal seams, shall have both horizontal edges turned $^5/_8$ inch (15.9 mm) to lock with edge and other face sections shown in Figure 7-3-7, Section C-D.

Face sections forming top horizontal seams, excepting seams formed with a cap, shall have the lower horizontal edge turned $^5/_8$ inch (15.9 mm) to lock with other face sections, and the other horizontal edge doubled under $1^3/_{16}$ inches (30.2 mm) and the doubled edge then turned up $^5/_8$ inch (15.9 mm) from cut edge.

Face sections forming top horizontal seams with a cap shall have both horizontal edges turned up $^5/_8$ inch (15.9 mm) to lock with cap and other face sections.

Corner sections shall have all edges turned $^5/_8$ inch (15.9 mm) so as to lock with edge and face sections as shown in Figure 7-3-8.

Edge sections, excepting cap sections, shall have all edges turned $^5/_8$ inch (15.9 mm) so as to lock with corner, face and other edge sections as shown in Figure 7-3-9.

Cap sections shall have edges forming seams with other cap sections turned $^5/_8$ inch (15.9 mm). Cap sections shall have edges forming top horizontal seams with face and edge sections doubled under $1^3/_{16}$ inches (30.2 mm) and the portion next to the cut edge turned down $^5/_8$ inch (15.9 mm) so as to lap the edge and face sections as shown in Figure 7-3-10.

SECTION 7.312 — APPLICATION OF STEEL SECTIONS

The sections shall fit the core as flatly and tightly as practicable. Any air space created as the result of bulging shall not exceed $^3/_{16}$ inch (4.8 mm).

The sections shall be locked together not less than $^1/_2$ inch (12.7 mm). Both faces of the core shall be covered with sections laid with their longer sides vertical, except that the sections in one vertical row on each face of the core may be laid horizontally.

Vertical seams formed with face sections shall be hook seams with the upper section having a fold for covering the heads of the nails in the seam as shown in Figure 7-3-11.

Horizontal seams formed with face sections, excepting top horizontal seams, shall be hook seams as shown in Figure 7-3-12. Top horizontal seams, excepting seams formed with a cap, shall have a fold for covering the heads of the nails in the seam as shown in Figure 7-3-11. Top horizontal seams formed with a cap shall be lock seams with the locking portion of the cap having a fold for covering the heads of the nails in the seam as shown in Figure 7-3-10.

The upper ends of vertical seams shall be covered by the doubled edges of the top horizontal seams.

Each bottom corner of the core shall be covered with a section bent over the edges of the core and lapped an equal distance on both faces of the core, making a miter fold (without cutting) on each face, the folds on a door for use at an opening in an exterior wall being arranged to shed water as shown in Figure 7-3-8.

Each upper corner shall be covered the same as bottom corners if a cap is not used for covering the top edge of the core.

The bottom edge and the vertical edges of the core shall be covered with sections bent over edges of the core and lapped an equal distance on both faces. The sections shall be joined to each other and to the corners with hook seams, the seams being made so as to shed water when the door is for use at an opening in an exterior wall as shown in Figures 7-3-7 and 7-3-9.

The top edge of the core shall be covered the same as the bottom and vertical edges if a cap is not used. The top edge of a core shall be covered with a cap when the door is for use at an opening in an exterior wall or when the door has a segmental head. The cap shall be formed of sections joined to each other with hook seams as shown in Figure 7-3-13.

If glass panels are provided and band or angle iron reinforcement for glass grooves is used, the vertical edges of the panel openings shall be covered with terne or zinc-coated steel secured to the face sections by vertical seams. The covering at the horizontal edges of the opening shall be cap seams as shown in Figure 7-3-14.

SECTION 7.313 — NAILING OF STEEL SECTIONS

The nails shall pass straight into the core and as near as possible through the center of the lock in the seams as shown in Figures 7-3-10, 7-3-11 and 7-3-12.

Full-sized face sections shall be held to the core by 18 nails in the seams, with nails near but not in the corners, and with four nails along each short side and five along each long side of each section.

Face sections smaller than 14- by 20-inch (355.6 mm by 508 mm) size shall be held to the core by nails in the seams placed near but not in the corners, with at least two nails along each side and with nails spaced not over 3 inches (76.2 mm) apart in horizontal seams and not over 4 inches (101.6 mm) apart in vertical seams.

Vertical seams formed with face sections shall have nails through two thicknesses of each section as shown in Figure 7-3-11.

Horizontal seams formed with face sections, except top horizontal seams, shall have nails through two thicknesses of lower sections and one thickness of upper section forming the seams as shown in Figure 7-3-12. Top horizontal seams, except seams made with a cap, shall have nails through two thicknesses of each section forming the seams as shown in Figure 7-3-11. Top horizontal seams formed with a cap shall have nails through one thickness of each plate forming the seams as shown in Figure 7-3-10.

Each corner section shall be held to the core with two nails on each side near the edge of the core as shown in Figure 7-3-8.

If glass panels are provided and band or angle-iron reinforcement for glass grooves is used, nails securing seams between face sections and strips covering edges of panel opening shall be spaced at intervals not exceeding 3 inches (76.2 mm) in horizontal seams and 4 inches (101.6 mm) in vertical seams, with one nail near but not in each corner.

SECTION 7.314 — PROTECTION OF NAILHEADS

Heads of nails in vertical seams formed with face sections shall be covered by the doubled edges of face sections as shown in Figure 7-3-11. Heads of nails in horizontal seams formed with face sections, except top horizontal seams, shall be covered by the face sections as shown in Figure 7-3-12. Heads of nails in top horizontal seams formed with face sections shall be covered by the doubled edges of face sections or cap as shown in Figures 7-3-10 and 7-3-11. Heads of nails in corner sections shall be covered by the miter fold as shown in Figure 7-3-8.

SECTION 7.315 — ASTRAGALS

Swinging doors to be mounted in pairs shall be provided with at least one astragal extending the full height of the doors. Sliding doors to be mounted in pairs shall be provided with only one astragal extending to within 4 inches (101.6 mm) of the top and bottom of the doors. Astragals shall be of steel not less than $^3/_{16}$ inch (4.8 mm) thick and 3 inches (76.2 mm) wide. The astragal shall be fastened to the door, when installed, by not less than $^1/_4$-inch (6.4 mm) carriage or stove bolts spaced at intervals not exceeding 12 inches (304.8 mm). Top bolts shall not be over 5 inches (127 mm) from the end of the astragal and bottom bolts not over 3 inches (76.2 mm). Bolts shall pass through the astragal and be secured by nuts on the opposite side of the door. Washers shall be used under nuts. Bolt holes in the astragal and door shall be located so that the astragal will extend at least $^3/_4$ inch (19.1 mm) beyond the edge of the door to which it is attached.

In case the astragal is to be attached in the field, the bolt holes in the astragal shall be drilled by the manufacturer to ensure proper spacings, fit, etc. In such case it will not be necessary to drill the door for the bolts.

SECTION 7.316 — GLASS PANELS

7.316.1 General. The construction details for any one of the following types of glass panel construction shall not be used in or combined with any of the other types described.

7.316.2 Reinforcements for Grooves. In all doors provided with grooves constructed of angles, the opening shall be reinforced either by means of a band-iron strip not less than $^1/_8$ inch

(3.2 mm) in thickness and equal in width to the thickness of the core or by means of $^1/_8$-by-$1^3/_8$-by-$^7/_8$-inch (3.2 mm by 34.9 mm by 22.2 mm) angles bolted together through the door. See Figures 7-3-14, 7-3-16 and 7-3-15.

The band-iron strip shall be secured to the inner edges of the panel opening by not less than two wood screws and shall be provided with threaded holes for receiving the bolts which secure the angles forming the glass grooves.

The $^1/_8$-by-$1^3/_8$-by-$^7/_8$-inch (3.2 mm by 34.9 mm by 22.2 mm) angles shall be bolted together through the door by $^3/_{16}$-inch (4.8 mm) stove bolts spaced at intervals not exceeding 12 inches (304.8 mm) and not more than 2 inches (50.8 mm) from each end. They shall be provided with threaded holes for receiving the bolts which secure angles forming the glass groove.

7.316.3 Glass Grooves Constructed of Angles. The angles used in forming the glass grooves shall not be less than $^1/_8$ inch (3.2 mm) in thickness and shall be of such other dimensions as to provide a groove not less than $^3/_4$ inch (19.1 mm) deep by $^3/_8$ inch (9.5 mm) wide as shown by Figures 7-3-14, 7-3-15 and 7-3-16.

Rivets or screws used to secure the groove angles to the reinforcement shall be spaced at intervals not exceeding 12 inches (304.8 mm) and not more than 2 inches (50.8 mm) from each end.

7.316.4 Grooves Constructed of Formed Sheet Metal. Grooves of this type shall be formed of a single piece of galvanized or terne-coated sheet steel having an uncoated thickness of not less than 0.020 inch (0.508 mm) as shown by Figures 7-3-17, 7-3-18 and 7-3-19 and shall not be less than $^3/_4$ inch (19.1 mm) deep by $^3/_8$ inch (9.5 mm) wide.

The edges of this formed strip shall be secured to the face sections of the door by vertical seams at the vertical edges of the opening as shown by Figure 7-3-19, Section B-B, and by cap seams at the horizontal edges of the opening as shown by Figure 7-3-19, Section D-D.

The edges of this formed strip shall be secured to the face plates of the door by vertical seams at the vertical edges of the opening as shown by Figure 7-3-19, Section B-B, and by cap seams at the horizontal edges of the opening as shown by Figure 7-3-19, Section D-D.

In the case of glass openings employing only one light, the sheet-metal glass groove may be constructed as shown by Figure 7-3-19, Section A-A. In this type of glass groove the reinforcing strip shall be $^1/_8$-inch (3.2 mm) band iron and shall either be continuous for the full length of the groove or consist of individual reinforcing strips not less than 1 inch (25 mm) long for each screw securing the removable molding. The reinforcing strip shall be secured to the fixed part of the glass groove by rivets or screws, independent of the screws fastening the removable molding. Rivets or screws used to secure the reinforcing strip or the removable molding shall be spaced at intervals not exceeding 12 inches (304.8 mm) and not more than 2 inches (50.8 mm) from each end.

Nails securing seams between molding strips and face sections shall be spaced at intervals not exceeding 3 inches (76.2 mm) in horizontal seams and 4 inches (101.6 mm) in vertical seams, with one nail near, but not in, each corner.

7.316.5 Muntins. Muntins may be of any of the constructions shown by Figures 7-3-12 through 7-3-19. In all cases, fixed parts of muntins shall be firmly secured to glass moldings at ends and at intersections with each other. Rivets, screws, welds or clips may be employed. Rivets, screws, etc., shall be spaced at intervals not exceeding 12 inches (304.8 mm).

When muntins are formed of sheet metal, the reinforcing plate shall be $^1/_8$-inch (3.2 mm) band iron which may be either continuous for the full length of the muntin or may consist of individual reinforcing strips not less than 1 inch (25 mm) long for each screw securing the removable part of the muntin.

7.316.6 Screws and Rivets. Screw sizes shall be $^3/_{16}$ inch (4.8 mm) (10-24) spaced 10 inches (254 mm) on centers; $^1/_8$ inch (3.2 mm) (either 6-32 or 8-32) spaced 8 inches (203.2 mm) on centers. Rivets shall not be less than $^1/_8$ inch (3.2 mm) in diameter.

7.316.7 Glass Sizes. Individual lights in doors bearing the marking "Rating: $^3/_4$-Hr. (C) or (E)" shall not exceed 1,296 square inches (0.836 m^2) in exposed area or 54 inches (1371.6 mm) in either dimension.

Area of exposed glass light per door leaf in doors bearing the marking "Rating: $1^1/_2$-Hr. (B), Temp. Rise—30 Min.—250°F (139°C) Max." shall not exceed 100 square inches (0.064 m^2), neither length nor width to exceed 12 inches (304.8 mm).

Glass lights shall not be used in doors bearing the marking "Rating: 3-Hr. (A) or $1^1/_2$-Hr. (D)."

SECTION 7.317 — SPLICING OF DOORS MADE IN SECTIONS

If doors are made in sections to be assembled as a single unit in the field, each section shall be constructed and marked in accordance with the requirements for a completed door.

Sections less than 10 feet (3048 mm) in height (not more than two) shall be joined together vertically by attaching to each face of the completed door a strip of galvanized sheet steel having a minimum thickness of not less than 0.056 inch (1.42 mm), not less than 6 inches (152.4 mm) in width and of a length corresponding to the height of the door. The splice metal sections shall be attached to each section of the door by not less than $^1/_4$-inch (6.4 mm) through bolts spaced on not more than 12-inch (304.8 mm) centers and not to exceed 3 inches (76.2 mm) from the top and bottom edges of the door. Through bolts shall extend through both splice plates and the door body and shall thread into nuts.

Sections over 10 feet (3048 mm) in height (not more than two) may be joined together vertically by attaching to each face of the completed door not more than two strips of sheet steel having a minimum thickness of 0.12 inch (3.05 mm), painted on both sides, or galvanized sheet steel having a minimum thickness of 0.126 inch (3.20 mm) not less than 6 inches (152.4 mm) in width and of a length corresponding to the height of the door. The meeting edges of such splice sections on one side of the door section shall be at least 2 feet (610 mm) higher or lower than those on the opposite side.

On three-ply doors, 2-by-2-by-$^3/_{16}$-inch (50.8 mm by 50.8 mm by 4.8 mm) angles or $2^1/_2$-by-$^5/_8$-by-$^3/_{16}$-inch (63.5 mm by 15.9 mm by 4.8 mm) channels shall be attached horizontally across the width of the door and not to exceed 18 inches (457.2 mm) from the bottom edge and the lowest corner of the top edge by not less than $^3/_8$-inch (9.5 mm) through bolts spaced on not more than 18-inch (457.2 mm) centers and at not more than 6 inches (152.4 mm) from each edge of the assembled door. On two-ply doors, 2-by-$1^1/_2$-by-$^3/_{16}$-inch (50.8 mm by 38.1 mm by 4.8 mm) angles or $1^1/_2$-by-$^5/_8$-by-$^3/_{16}$-inch (38.1 mm by 15.9 mm by 4.8 mm) channels shall be attached in a like manner.

Angle- and channel-iron reinforcements and both splice plates may be shipped separately, but through bolts shall be secured to them before shipment. Both sections of the door shall be drilled at the factory to receive through bolts for attachment of splice metal sections and angle- and channel-iron reinforcements.

SECTION 7.318 — WICKETS

Doors or door sections shall not be provided with wickets or openings for same.

SECTION 7.319 — APPLIED METALS

Doors or door sections shall not be provided with kick plates or metals applied over the standard construction.

Part IV—Marking

SECTION 7.320 — MARKING

7.320.1 Content. Each door shall be marked with:

1. The manufacturer's or vendor's name or identifying symbol.
2. The words "Tinclad Fire Door."
3. The appropriate hourly rating and temperature rise for the classification and any glass panels.

If a door has been provided with edge notches to clear conveyor rails, for example, it becomes ineligible to carry the marking outlined in Section 7.320, Item 3; but it shall be otherwise identified with the following statement:

> "This door(s) violates one of the fundamental principles of wall opening protection in that it (they) does not provide for a continuous lap of the door over the edge of the opening to oppose the passage of flame and therefore cannot be provided with an hourly classification."

If a manufacturer produces doors at more than one factory, each door shall have a distinctive marking to identify it as the product of a particular factory.

7.320.2 Application. Markings shall be permanent to the degree afforded by a lithographed metal plate, a pressure-sensitive label, or stamping. All markings on one door shall be grouped in one location.

TABLE 7-3-A—SIZES AND RATINGS

TYPE, METHOD OF OPERATION AND MAXIMUM SIZE OF OPENING	RATING AND CLASS OF OPENING	MAXIMUM EXPOSED GLASS AREA × 645 for mm²
Three-ply		
Swinging single 6′ 0″ × 12′ 0″ (1829 × 3658 mm)	3-hr. (A)[1]	None
Swinging in pairs 10′ 0″ × 12′ 0″ (3048 × 3658 mm)	$1^1/_2$-hr. (B)[1]	100 square inches per door
Sliding single and center-parting 120 square feet (11.15 m^2) with maximum dimension 12′ 0″ (3658 mm)	$^3/_4$-hr. (C)[2]	1,296 square inches per light
	$1^1/_2$-hr. (D)[1]	None
Vertically sliding 80 square feet (7.43 m^2) with maximum dimension 10′ 0″ (3048 mm)	$^3/_4$-hr. (E)[2]	1,296 square inches per light
Two-ply	$1^1/_2$-hr. (B)[1]	100 square inches per door
Swinging single 6′ 0″ × 10′ 0″ (1829 × 3048 mm)	$^3/_4$-hr. (C)[2]	1,296 square inches per light
Swinging in pairs 10′ 0″ × 10′ 0″ (3048 × 3048 mm)	$1^1/_2$-hr. (D)[1]	None
Sliding single and 80 square feet (7.43 m^2) with maximum dimension 10′ 0″ (3048 mm)	$^3/_4$-hr. (E)[2]	1,296 square inches per light

[1]Three-hour (A), one- and one-half-hour (B) and one- and one-half hour (D) doors have a temperature rise of 250°F (139°C) maximum at 30 minutes.

[2]Three-fourths-hour (C) and three-fourths-hour (E) doors with large glass lights may permit a temperature rise in excess of 650°F (361°C) on the unexposed side at 30 minutes.

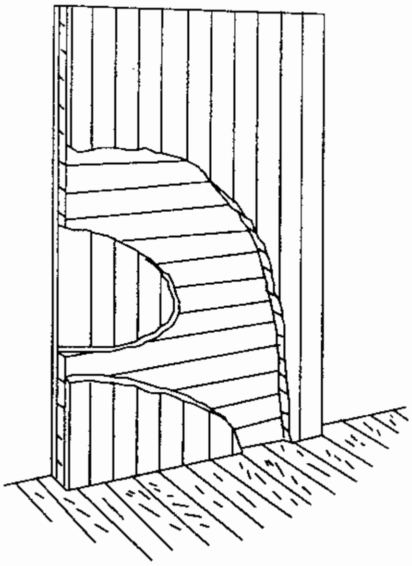


FIGURE 7-3-1—ASSEMBLY OF BOARDS IN THREE-PLY CORE

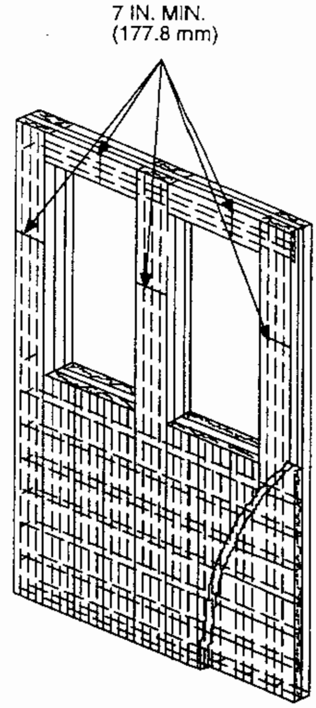


FIGURE 7-3-2—ASSEMBLY OF BOARDS IN THREE-PLY CORE WITH GLASS OPENINGS

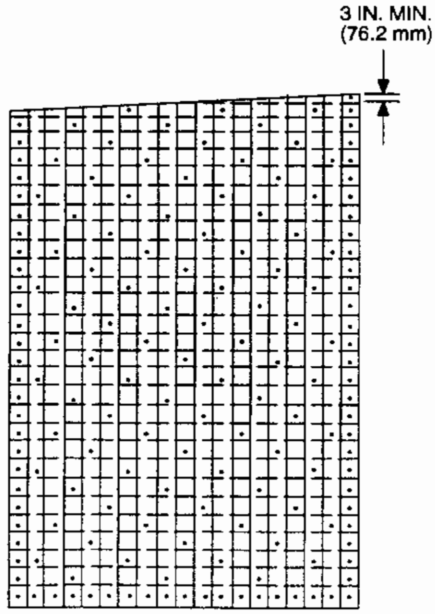


FIGURE 7-3-3—NAILING FOR 3- TO 4-INCH (76.2 to 101.6 mm) STOCK

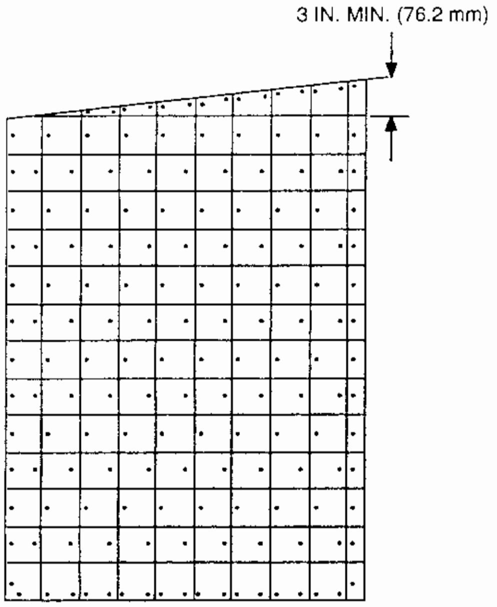


FIGURE 7-3-4—NAILING FOR $4^1/_2$- TO 8-INCH (114.3 to 203.2 mm) STOCK

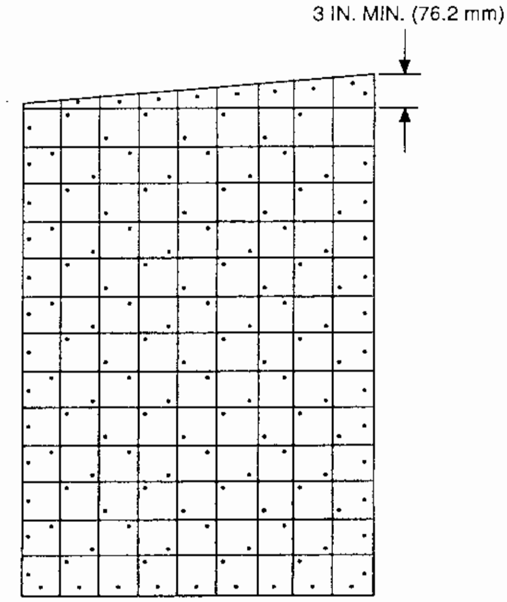


FIGURE 7-3-5—NAILING FOR THREE-PLY CORES ONLY $4^1/_2$- TO 8-INCH (114.3 to 203.2 mm) STOCK

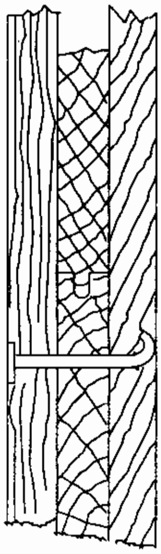


FIGURE 7-3-6—NAILING IN THREE-PLY CORE SHOWING CLINCHING

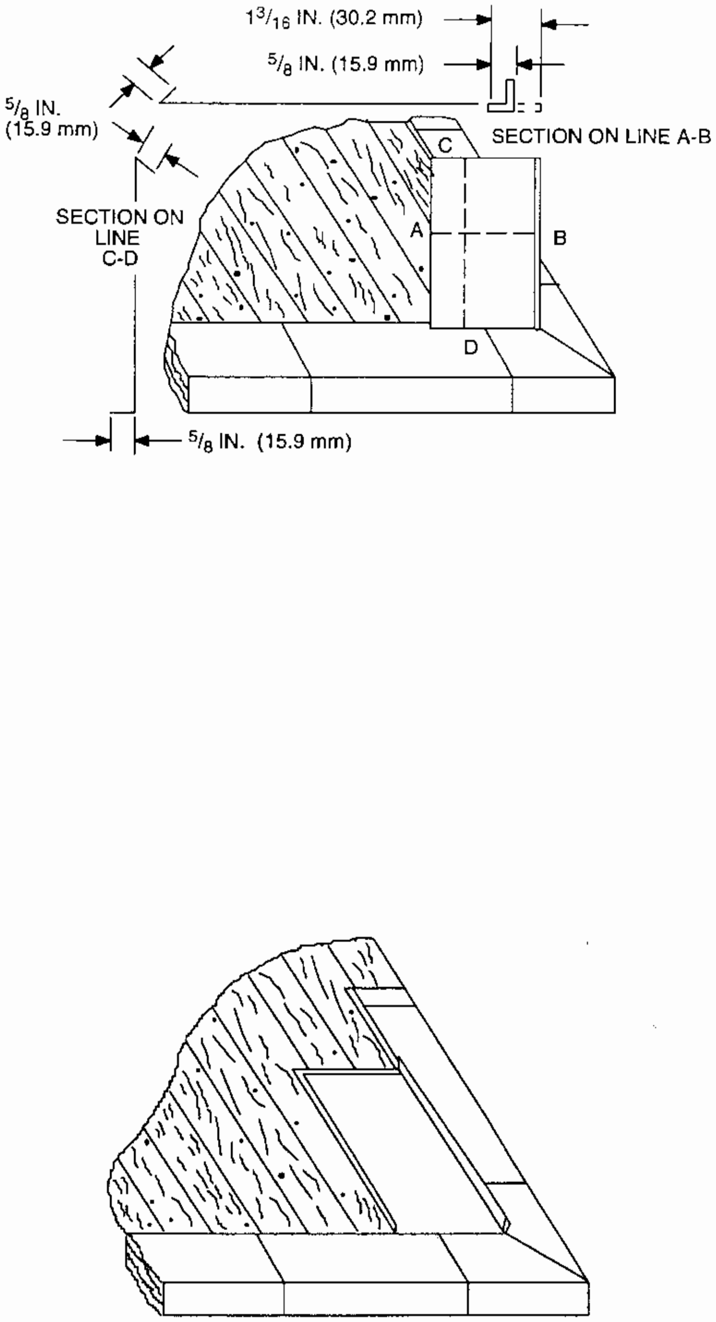


FIGURE 7-3-7—APPLICATION OF METAL SECTIONS ON FACE OF CORE

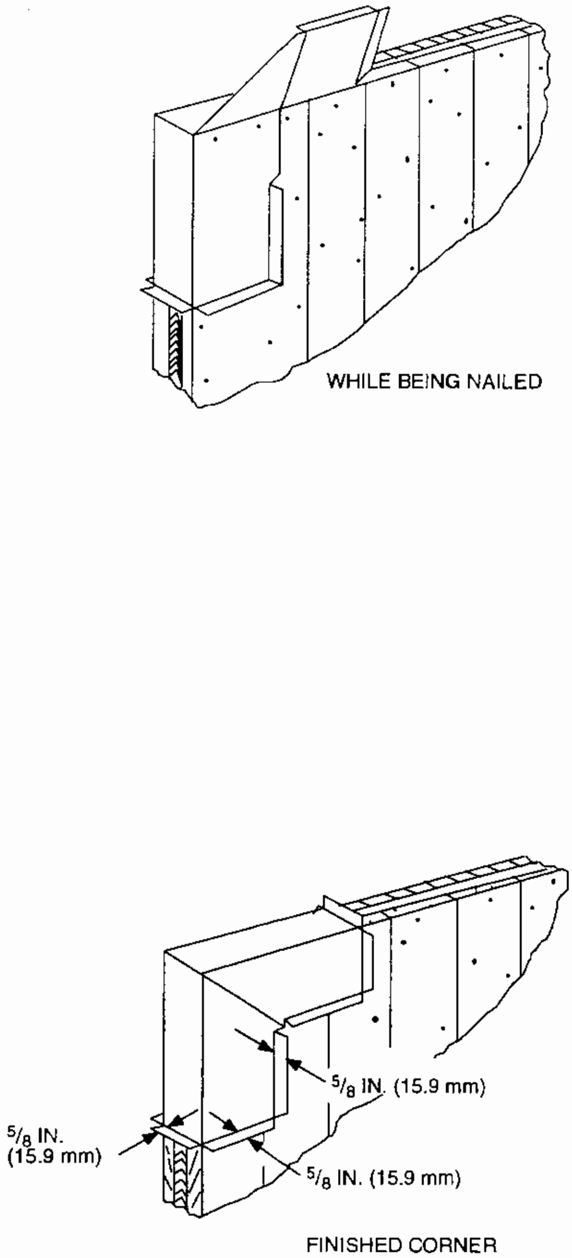


FIGURE 7-3-8—APPLICATION OF METAL SECTIONS AT CORNER OF CORE

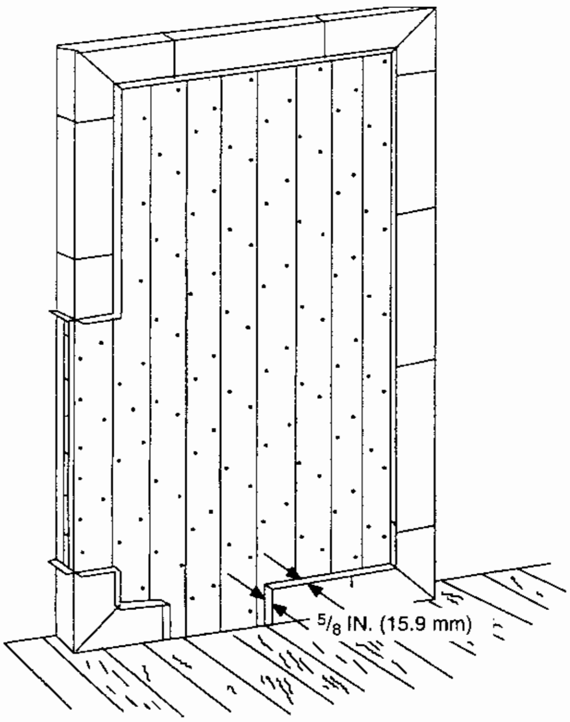


FIGURE 7-3-9—APPLICATION OF METAL SECTIONS AT EDGES OF CORE

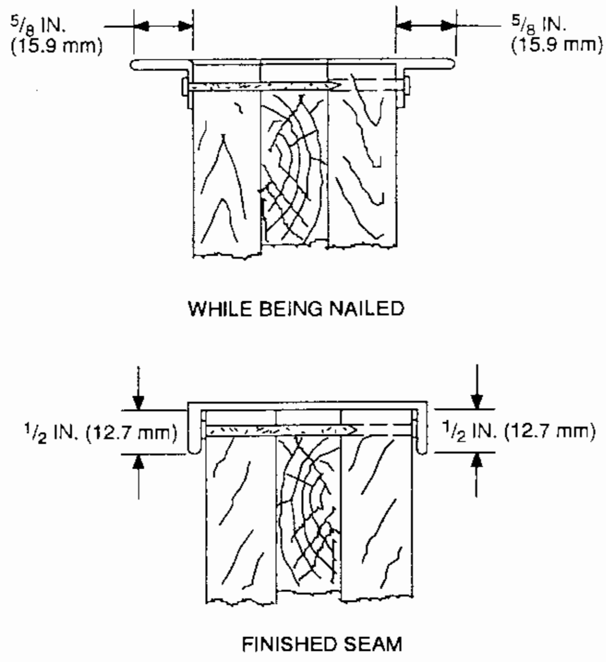


FIGURE 7-3-10—APPLICATION OF CAP METAL SECTIONS AT TOP EDGE OF CORE

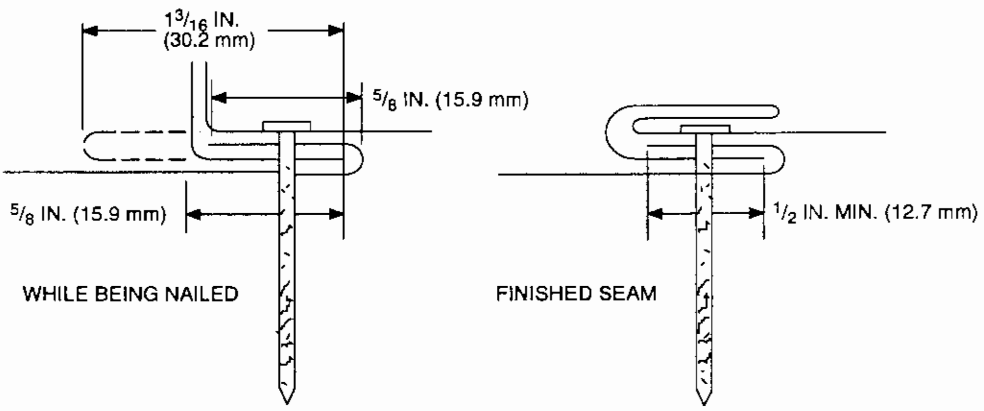


FIGURE 7-3-11—VERTICAL SEAMS OF FACE SECTIONS (TOP VIEW)

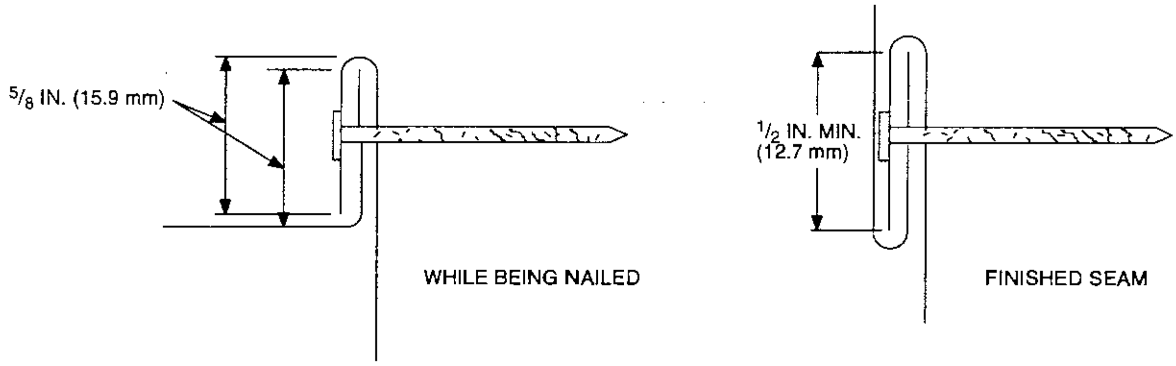


FIGURE 7-3-12—HORIZONTAL SEAMS OF FACE SECTIONS (SIDE VIEW)

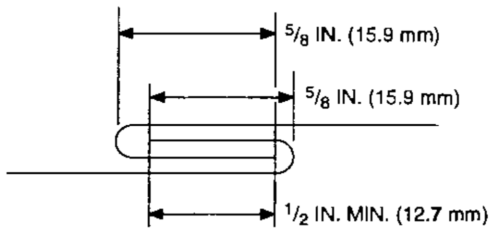


FIGURE 7-3-13—SEAMS BETWEEN CORNER AND EDGE SECTIONS

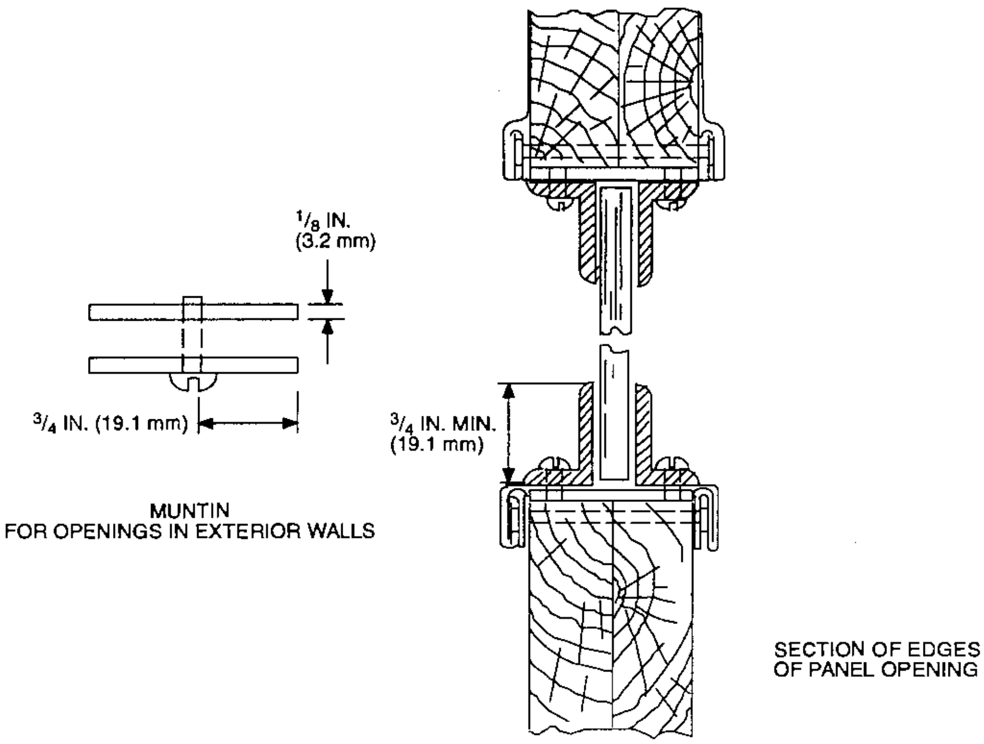


FIGURE 7-3-14—GLASS OPENING DETAILS

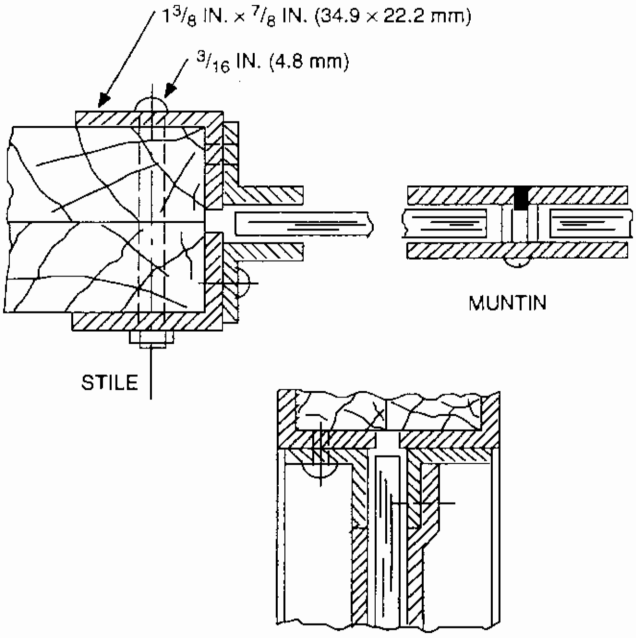


FIGURE 7-3-15—GLASS OPENING DETAILS

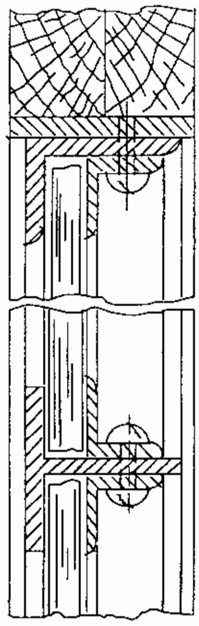


FIGURE 7-3-16—GLASS OPENING DETAILS

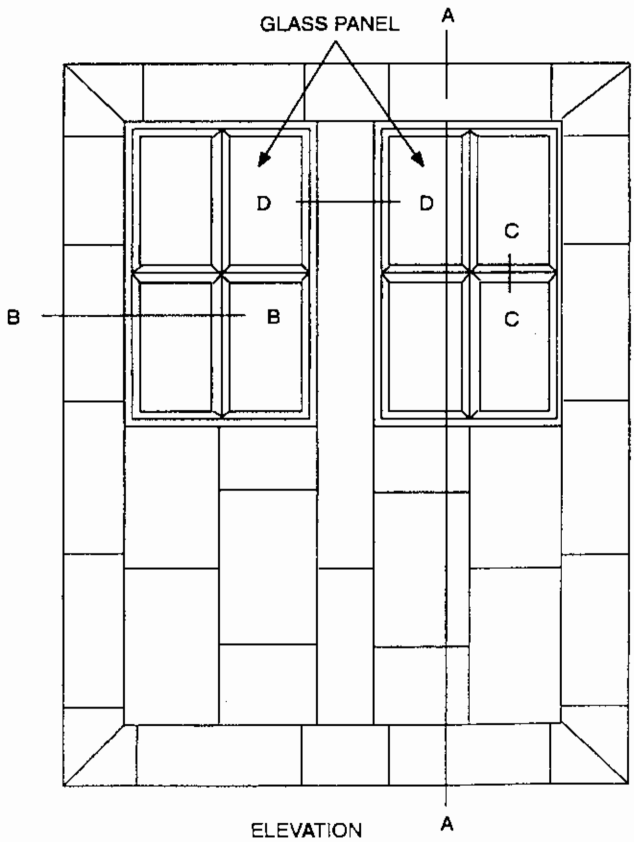


FIGURE 7-3-17—ASSEMBLY—GLASS GROOVES, FORMED SHEET METAL

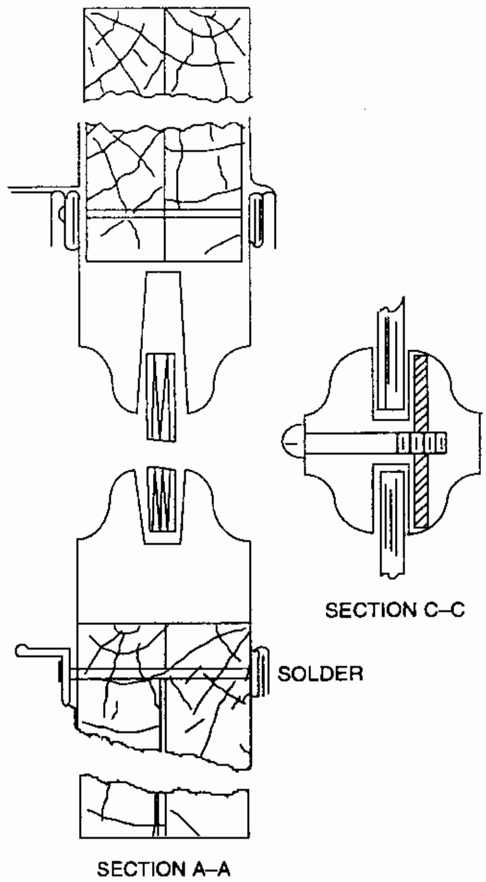
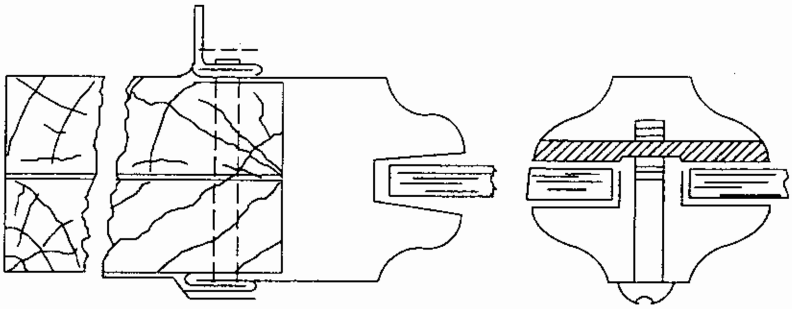
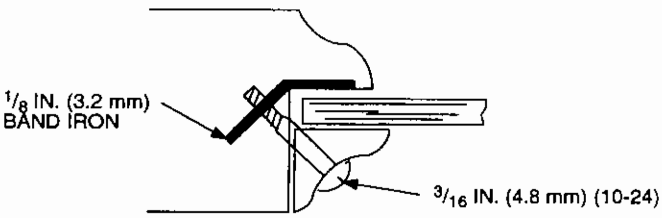


FIGURE 7-3-18—GLASS OPENING DETAILS



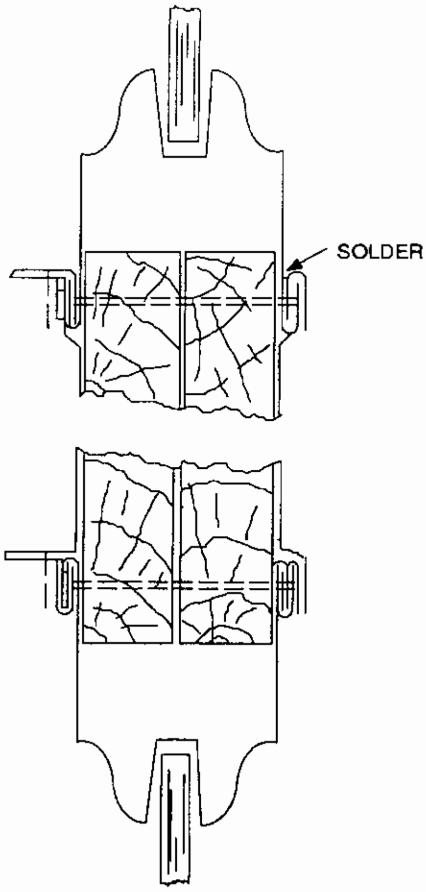
SECTION B–B

NOTE: For sash having more than one light in width.



SECTION A–A

NOTE: For sash having one light in width.



SECTION D–D

FIGURE 7-3-19—GLASS OPENING DETAILS

UNIFORM BUILDING CODE STANDARD 7-4
FIRE TESTS OF WINDOW ASSEMBLIES

Based on Standard Methods E 163-76 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 703.4, 713.5 and 713.9, *Uniform Building Code*

SECTION 7.401 — SCOPE

These methods of fire tests are applicable to window assemblies, including glass block and other light-transmitting assemblies, for use in wall openings to retard the passage of fire. Test methods in this standard are intended to evaluate the ability of a window or other light-transmitting assembly to remain in an opening during a predetermined test exposure of 45-minute duration.

Tests made in conformity with these test methods will register performance during the test exposure and develop data to determine the suitability of window assemblies for use in wall openings where fire protection is required. Such tests shall not be construed as determining suitability of window assemblies for continued use after fire exposure.

SECTION 7.402 — CONTROL OF FIRE TESTS

7.402.1 Time-temperature Curve. The fire exposure of window assemblies shall be controlled to conform to the standard time-temperature curve shown in Figure 7-1-1.

7.402.2 Furnace Temperatures. The temperatures of the test exposure shall be the average temperature obtained from the readings of not less than nine thermocouples symmetrically disposed and distributed to show the temperature near all parts of the test assembly. The thermocouples shall be protected by sealed porcelain tubes having $^3/_4$-inch (19.1 mm) outside diameter and $^1/_8$-inch (3.2 mm) wall thickness or, as an alternate, in the case of base metal thermocouples, protected by sealed $^1/_2$-inch (12.7 mm) wrought-steel or wrought-iron pipe of standard weight. The exposed length of the thermocouple protection tube in the furnace chamber shall not be less than 12 inches (304.8 mm). The junction of the thermocouples shall be 6 inches (152.4 mm) from the exposed face of the test assembly or from the masonry in which the assembly is installed during the entire test exposure.

The temperature shall be read at intervals not exceeding five minutes.

The furnace shall be controlled so that the maximum temperature at individual points shall not exceed 1,650°F* (899°C) and the area under the time-temperature curve, obtained by averaging the results from the temperature readings, is within 10 percent of the corresponding area under the standard time-temperature curve.

SECTION 7.403 — TEST ASSEMBLIES

7.403.1 Construction and Size. The design, construction, material, workmanship and hardware of the test window assembly shall be representative of that for which approval is desired. A record of materials and construction details adequate for identification shall be made.

The area of the test assembly shall not be less than 100 square feet (9.29 m^2), with neither dimension less than 9 feet (2743 mm). If the conditions of use limit the construction to smaller dimensions, a proportionate reduction may be made in the dimensions of the test assembly for tests qualifying them for such restricted use.

7.403.2 Mounting. The test assembly shall be installed in the manner in which it is to be used. It shall be mounted so that the latches and fasteners other than hinges shall be on the unexposed side, and the mounting shall not prevent the free and easy operation of all openable components such as ventilators and sash.

SECTION 7.404 — CONDUCT OF TESTS: TIME OF TESTING

Masonry settings shall be allowed to season at least seven days, and reinforced concrete settings at least 28 days, before fire tests are made.

SECTION 7.405 — FIRE-ENDURANCE TEST

The pressure in the furnace shall be so managed that the upper two thirds of the test specimen is above the neutral pressure plane.

The test shall be continued for 45 minutes unless the conditions of acceptance specified in Section 7.407 are exceeded in a shorter period.

SECTION 7.406 — HOSE STREAM TEST

Immediately following the fire-endurance test and within one and one-half minutes, the fire exposed side of the test assembly shall be subjected to the impact, erosion and cooling effects of the hose stream.

The hose stream shall be delivered through a $2^1/_2$-inch (63.5 mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a $1^1/_8$-inch (28.6 mm) discharge tip of the standard-taper, smooth-bore pattern without shoulder at the orifice.

The tip of the nozzle shall be located 20 feet (6.1 m) from and on a line normal to the center of the test assembly. If impossible to be so located, the nozzle may be on a line deviating not to exceed 30 degrees from the line normal to the center of the test assembly. When so located, the distance from the plane of the surface of the test assembly shall be less than 20 feet (6.1 m) by an amount equal to 1 foot (304.8 mm) for each 10 degrees of deviation from the normal.

The hose stream shall be directed around the periphery of the test assembly starting upward from a lower corner. When the circuit is about 1 foot (304.8 mm) from the starting point, the hose stream shall be applied in paths about 1 foot (304.8 mm) apart up and down the assembly across the entire width and then back and forth horizontally across the entire height.

The water pressure at the base of the nozzle shall be 30 psi (207 kPa) and the hose stream shall be applied $^6/_{10}$ second for each square foot (0.0929 m^2) of area of the test assembly.

* In case the temperature at any point does exceed 1,650°F (899°C), the performance of the glass in that area shall be disregarded.

SECTION 7.407 — CONDITIONS OF ACCEPTANCE

7.407.1 Window Assemblies. A window assembly shall be considered as meeting the requirements for acceptable performance when it remains in the opening during the fire-endurance and hose stream tests within the following limitations:

1. The window assembly shall not be loosened from its fastenings.

2. Movement at the perimeter of openable components, from the initial closed position, shall not exceed the thickness of the frame member at any point.

3. At least 70 percent of the edges of each individual glass light shall remain in position through the hose stream test. The dislodging of small fragments from the central areas of individual lights shall be disregarded.

7.407.2 Glass Block Assemblies. A glass block assembly shall be considered as meeting the requirements for acceptable performance when it remains in the opening during the fire-endurance and hose stream tests within the following limitations:

1. The glass block assembly shall not be loosened from the frame.

2. At least 70 percent of the glass blocks shall not develop through openings.

UNIFORM BUILDING CODE STANDARD 7-5
FIRE TESTS OF THROUGH-PENETRATION FIRE STOPS

Based on Standard Method E 814-88 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 714, *Uniform Building Code*

Part I—General

SECTION 7.501 — SCOPE

This method is applicable to penetration fire stops as defined in this code. Part I of this standard is applicable to both through-penetration and membrane-penetration fire stops. Part II contains additional criteria applicable to through-penetration fire stops.

In addition to evaluating the fire-resistive characteristics of penetration fire stops, this test method considers the resistance of penetration fire stops to an external force simulated by a hose stream. However, this method shall not be construed as determining the performance of the fire stop during actual fire conditions when subjected to forces such as failure of support systems and falling debris.

SECTION 7.502 — SIGNIFICANCE AND USE

This method is used to determine the performance of a penetration fire stop with respect to exposure to a standard temperature-time fire test and hose stream test. The performance of a penetration fire stop is dependent upon the specific assembly of materials tested, including the number, type and size of penetrations and the floors or walls in which it is installed.

SECTION 7.503 — DEFINITIONS

For the purpose of this standard, certain terms are defined as follows:

TEST ASSEMBLY is the wall or floor into which the test sample is mounted or installed.

TEST SAMPLE is the fire stop being tested.

SECTION 7.504 — CONTROL OF FIRE TESTS

7.504.1 Temperature-time Curve. The fire environment within the furnace shall be in accordance with the standard temperature-time curve shown in UBC Standard 7-1, Figure 7-1-1. The points on the curve that determine its character are set forth in Section 7.504.2.

7.504.2 Furnace Temperatures. The temperature fixed by the curve shall be the average temperature obtained from the readings of thermocouples symmetrically disposed and distributed within the test furnace to show the temperature near all parts of the assembly. Use a minimum of three thermocouples, with not fewer than five thermocouples per 100 square feet (9.29 m^2) of floor surface, and not fewer than nine thermocouples per 100 square feet (9.29 m^2) of wall specimen surface.

Enclose the thermocouples in sealed protection tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within the range from 300 to 400 seconds. The exposed length of the pyrometer tube and thermocouple in the furnace chamber shall not be less than 12 inches (300 mm). Other types of protection tubes of pyrometers may be used, provided that temperature measurements obtained in accordance with Figure 7-1-1 are within the limit of accuracy that applies for furnace temperature measurements.

For floors, place the junction of the thermocouples 12 inches (300 mm) away from the exposed face of the assembly. In the case of walls, place the thermocouples 6.0 inches (150 mm) away from the exposed face.

Read the temperature at intervals not exceeding five minutes during the first 120 minutes. Thereafter, the intervals may be increased to not more than 10 minutes.

The accuracy of the furnace control shall be such that the area under the temperature-time curve, obtained by averaging the results from the pyrometer or thermoelectric device readings, is within 10 percent of the corresponding area under the standard temperature-time curve shown in Figure 7-1-1 for fire tests of 60 minutes or less duration; within 7.5 percent for those over 60 minutes and not more than 120 minutes; and within 5 percent for tests exceeding 120 minutes in duration.

7.504.3 Unexposed Surface Temperatures. Measure temperatures on the unexposed surface of the test sample and assembly with thermocouples placed under flexible pads.

The pads shall be of suitable inorganic material and shall exhibit the following properties:

1. **Length and width:** 2.00 ± 0.04 inch (50 ± 1.02 mm).
2. **Thickness:** 0.04 ± 0.05 inch (10.2 ± 1.27 mm).
3. **Density:** 31.2 ± 0.6 pounds/cubic feet (499.2 ± 9.6 kg/m^3).
4. **Thermal conductivity (k) at 150°F (65.6°C):** 0.380 ± 0.027 Btu × inches/hour × square feet °F [0.0548 ± 0.0039 W/(m·k)].

The pads shall be sufficiently soft so that, without breaking, they may be shaped to contact over the whole surface against which they are placed.

The pads shall be held firmly against the surface; they shall fit closely about the thermocouples. The thermocouple junction shall be located under the center of the pads. The thermocouple leads under the pads shall not be heavier than No. 18 B.&S. gage (0.040 inches) (1.02 mm) and shall be electrically insulated with heat-resistant, moisture-resistant coverings.

Read temperatures at intervals not exceeding 15 minutes until a reading exceeding 212°F (100°C) has been obtained at any one point. Thereafter, the readings may be taken more frequently, but the intervals need not be less than five minutes.

For specific locations of thermocouples, see Part II.

Additional temperature measurements may be made at the discretion of the testing agency to obtain representative information on the performance of the test sample.

7.504.4 Differential Pressure. Measure the pressure differential between the exposed and unexposed surfaces of the test assembly required in Section 7.507.2 at three points 0.78 inch (20 mm) from the surface and locate as follows:

1. **Walls**—At the center and quarter points on the vertical center line.

2. Floors—At the center and quarter points along the longitudinal center line.

The pressure-measuring probe tip shall be as shown in Figure 7-5-2, manufactured from stainless steel or other suitable material.

Measure the pressure by means of a manometer or equivalent transducer. The manometer or transducer shall be capable of reading 0.01-inch of water (2.5 Pa) increments.

SECTION 7.505 — TEST SAMPLE

The construction of the test sample shall be of sufficient size and include all conduits, pipes, cables (jacket types, sizes, conductor types, percent fills), required supports or other penetrating items so as to produce a representative penetration fire stop for which evaluation is desired. Penetration fire stops shall be installed and tested in each representative construction for which ratings are desired.

The periphery of the test sample shall not be closer than one and one-half times the thickness of the test assembly or a minimum of 12 inches (300 mm) to the furnace edge, whichever is greater.

The distance between test sample periphery and furnace edge may be reduced if the testing agency demonstrates and reports that the edge effects do not affect the results.

SECTION 7.506 — PROTECTING AND CONDITIONING

Prior to fire test, condition the floor or wall assembly and test samples to provide, within a reasonable time, a moisture condition approximately representative of that likely to exist in similar construction in buildings. This moisture condition is considered as that which would be established at equilibrium resulting from drying in an ambient atmosphere of 50 percent relative humidity at 73°F (23°C). However, with some assemblies and test samples it may be difficult or impossible to achieve the equilibrium moisture condition within a reasonable period of time. Therefore, floor or wall assemblies and test samples may be tested when their dampest portion has achieved a moisture content corresponding to drying to equilibrium with air in the range from 50 to 75 percent relative humidity at 73°F ± 5°F (23°C ± 3°C). If the assembly or test sample dried in a heated building fails to meet these requirements after a 12-month conditioning period, or if the nature of the construction is such that drying of the assembly or test sample interior will be prevented by hermetic sealing, these requirements may be waived, except as to attainment of the required strength as described in Section 7.507.1, and the assembly or test sample may be tested in the condition in which it then exists.

Protect the testing equipment, sample and assembly undergoing the fire test from any condition of wind or weather that might lead to abnormal results. The ambient air temperature at the beginning of the test shall be within the range from 50°F to 90°F (10°C to 32°C). The velocity of air across the unexposed surface measured just before the test begins shall not exceed 4.4 feet/seconds (1.3 m/s) as determined by an anomometer placed at right angles to the unexposed surface. If mechanical ventilation is employed during the test, an airstream shall not be directed across the surface of the sample.

SECTION 7.507 — CONDUCT OF TESTS

7.507.1 Time of Testing. The test sample shall not be tested until the test assembly has developed sufficient strength to retain the test sample securely in position.

7.507.2 Fire Test. After the first 10 minutes, the test sample shall be subject to a minimum positive pressure differential of 0.01 inch of water (2.5 Pa).

Continue the test until the desired evaluation period is reached or until the rating criteria are satisfied.

7.507.3 Hose Stream Test. Subject a duplicate test sample to a fire exposure test for a period equal to one half of that indicated as the resistance period in the fire test, but not more than 60 minutes, immediately after which subject the sample to the impact, erosion and cooling effects of a hose stream as described in Table 7-5-A directed first at the middle and then at all parts of the exposed face, with changes in direction being made slowly.

The test sponsor may elect, with the advice and consent of the testing body, to have a hose stream test made on the sample subjected to the fire test immediately following the fire test.

The stream shall be delivered through a $2^1/_2$-inch (63.5 mm) hose and discharged through a National Standard Playpipe of corresponding size equipped with a $1^1/_8$-inch (28.6 mm) discharge tip of the standard-taper, smooth-bore pattern without a shoulder at the orifice. The water pressure shall be 30 psi ± 2 psi as (207 kPa ± 13.8 kPa) measured at the base of the nozzle.

The nozzle orifice shall be 20 feet (6096 mm) from the center of the exposed surface of the test sample if the nozzle is so located that when directed at the center its axis is normal to the surface of the test sample. If otherwise located, its distance from the center shall be less than 20 feet (6096 mm) by an amount equal to 1 foot (300 mm) for each 10 degrees of deviation from the normal.

SECTION 7.508 — REPORT

Results expressed as F and T ratings, as appropriate, shall be reported in accordance with the performance in the tests prescribed in this method. They shall be expressed in hours and minutes to the nearest integral minute. Reports shall include the following:

1. The assembly, materials and penetrating items of the tested penetration fire stop, clearly identified and described. Drawings depicting geometry, exact size (length, width, thickness) and location of penetration fire stops within the test assembly.

2. The relative humidities of the test assembly and test sample materials, if applicable.

3. The furnace and the unexposed side temperatures for the duration of the standard fire test.

4. The measurement of differential pressure between the exposed and unexposed test assembly surface during the fire test.

5. Observations of significant details of the behavior of the test sample during the test and after the furnace fire is extinguished. These shall include cracks, deformation, flaming and smoke issuance. Also, these include continued burning within the test sample after termination of the fire test.

When the indicated, penetration fire-stop rating period is 60 minutes or over, a correction shall be applied for variation of the furnace exposure from that prescribed, where it will affect the rating, by multiplying the indicated period by two thirds of the difference in area between the curve of average furnace temperature and the standard curve for the first three fourths of the period, and dividing the product by the area between the standard curve above a base line of 68°F (20°C) for the same part of the indicated period, the latter areas increased by 54°F × hours (30°C × hours) [3,240°F × minutes (1800°C × minutes)]; to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For higher-than-standard fire exposure in the test, the indicated rating period shall be increased by the amount of the correction and similarly decreased for fire exposure below surface. The correction can be expressed as follows:

$$C = \frac{2I(A - A_s)}{3(A_s + L)}$$

WHERE:

A = area under the curve of indicated average furnace temperature for the first three fourths of the indicated period.

A_s = area under the standard furnace curve for the same part of the indicated period.

C = correction in the same units as I.

I = indicated fire-resistance period.

L = lag correction in the same units as A and A_s [54°F × hours (30°C × hours); 3,240°F × minutes (1800°C × minutes)].

Part II—Through-penetration Fire Stops

SECTION 7.509 — SCOPE

This part of this standard contains specific criteria for testing and rating through-penetration fire stops.

Two ratings are established for each through-penetration fire stop. An F rating is based on flame occurrence on the unexposed surface, while the T rating is based on the temperature rise on the unexposed side of the through-penetration fire stop.

SECTION 7.510 — UNEXPOSED SURFACE AND PENETRATION TEMPERATURES

Measurements shall be made at the locations on the unexposed surface of the test sample and floor or wall assembly as shown in Figure 7-5-1 and as described in the following:

Measure temperatures of each type and size of penetrating item with at least one thermocouple located 1 inch (25.4 mm) from the unexposed surface of the test sample. Where a thermal protection assembly is used to wrap around the penetrating items on the unexposed side, an additional thermocouple shall be located on the penetrating items 1 inch (25.4 mm) from the end of the thermal-protection assembly. The thermocouple lead shall be held firmly against the penetrating item. The thermocouple leads shall not be heavier than No. 22 B.&S. gage (0.0253 inches) (300 mm) and shall be electrically insulated with heat-resistant and moisture-resistant coverings. The pads as described in Part I shall be held firmly against the penetrating item and shall fit closely about the thermocouples.

SECTION 7.511 — INSTALLATION OF PENETRATING ITEMS

Penetrating items shall be installed so that they extend a minimum of 12 inches (300 mm) on the exposed side and a minimum of 36 inches (900 mm) on the unexposed side. The extended portion of the penetrating items on the unexposed side shall be supported in the same manner as methods employed in field installation. When the end use of the penetrating items precludes the minimum projections specified, the penetrating items shall be installed in the end-use configuration.

Individual ends of the penetrating items shall be covered and sealed by suitable means on the exposed side to prevent excessive transfer of gases through the test sample. When the penetrating item is intended to be representative of a closed system that is not normally vented or open to the atmosphere, the penetrating item may also be capped or sealed on the unexposed side. Otherwise, the penetrating items shall not be capped or sealed on the unexposed side.

SECTION 7.512 — RATING CRITERIA

7.512.1 F Rating. A through-penetration fire stop shall be considered as meeting the requirements for an F rating when it remains in the test assembly during the fire test and hose stream test within the following limitations:

1. The through-penetration fire stop shall have withstood the fire test for the rating period without permitting the passage of flame through openings or the occurrence of flaming on any element of the unexposed side of the test sample.

2. During the hose stream test, the test sample shall not develop any opening that would permit a projection of water from the stream beyond the unexposed side.

7.512.2 T Rating. A through-penetration fire stop shall be considered as meeting the requirements for a T rating when it remains in the test assembly during the fire test and hose stream test so as to meet the requirements for an F rating and it performs within the following limitations:

1. The transmission of heat through the test sample during the rating period shall not have been such as to raise the temperature of any thermocouple on the unexposed surface of the test sample or any penetrating item more than 325°F (181°C) above its initial temperature.

SECTION 7.513 — REPORT

In addition to the information required in Section 7.508, the following shall be included in the report:

1. The F and T ratings for each through-penetration fire stop in the time period of resistance.

TABLE 7-5-A—HOSE STREAM TEST PRESSURE AND DURATION

RESISTANCE PERIOD	DURATION OF APPLICATION (seconds per square foot of exposed area[1])
	× 10.76 for sec./m²
120 minutes and over	1.5
90 minutes and over if less than 120 minutes	0.9
Less than 90 minutes	0.6

[1]The exposed area shall be calculated using the area of the wall or floor assembly in which the penetration fire stop is mounted.

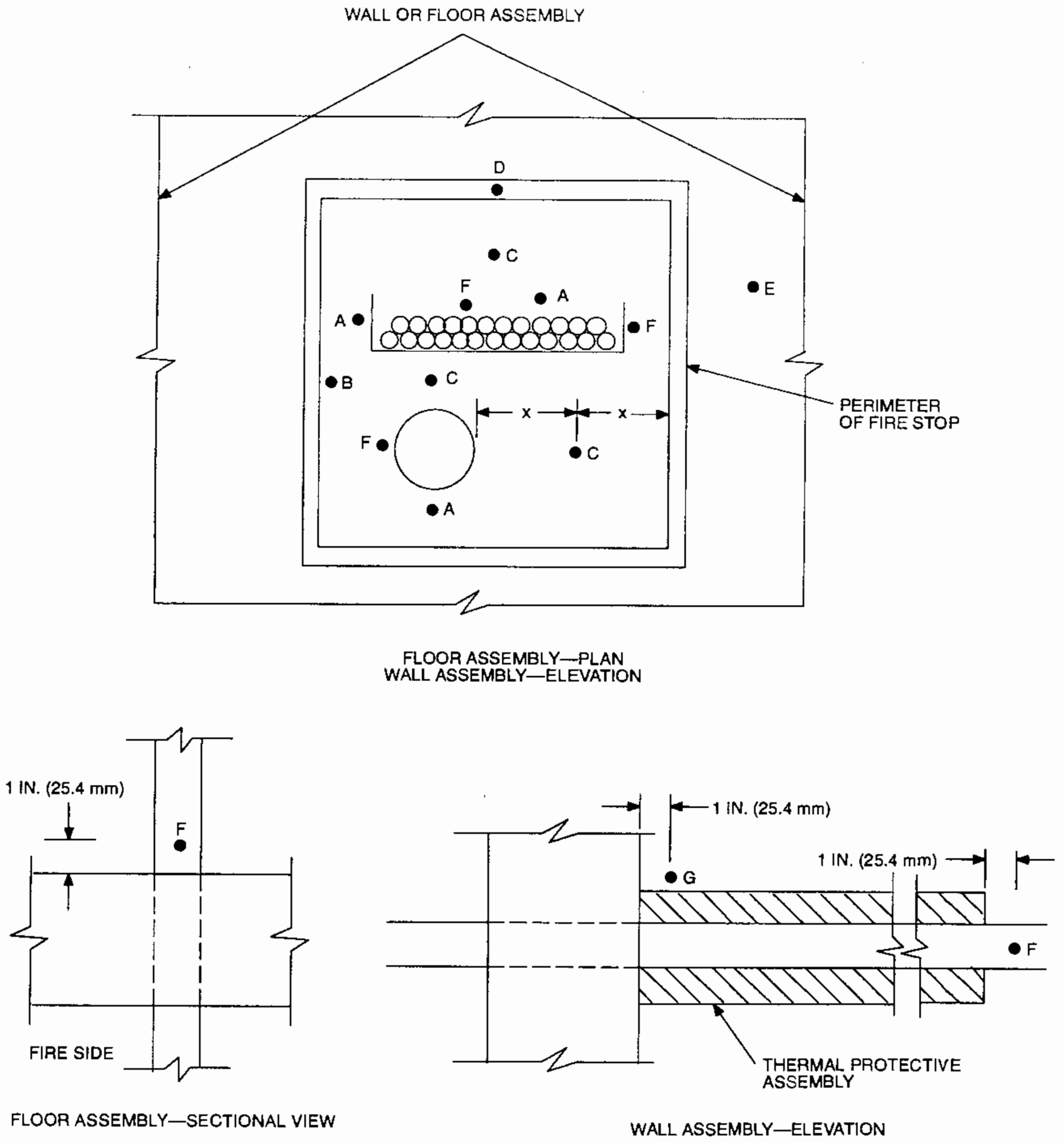


FIGURE 7-5-1—TEMPERATURE MEASUREMENT LOCATIONS

LEGEND:

A—At a point on the surface of the fire stop 1 inch (25.4 mm) from one through-penetrating item for each type of penetrating item employed in the field of the fire stop. If the grouping of penetrating items through the test sample prohibits placement of the thermocouple pad, the thermocouple shall not be required.

B—At a point on the fire stop surface at the periphery of the fire stop.

C—At a minimum of three points on the fire stop surface approximately equidistant from a penetrating item or group of penetrating items in the field of the fire stop and the periphery.

D—At one point on any frame that is installed about the perimeter of the opening.

E—At one point on the unexposed surface of the wall or floor that is not less than 12 inches (300 mm) from any opening.

F—At one point on each type of through-penetrating item, 1 inch (25.4 mm) beyond test sample or thermal protective assembly.

G—At one point on the surface of thermal protective assembly, 1 inch (25.4 mm) beyond test sample.

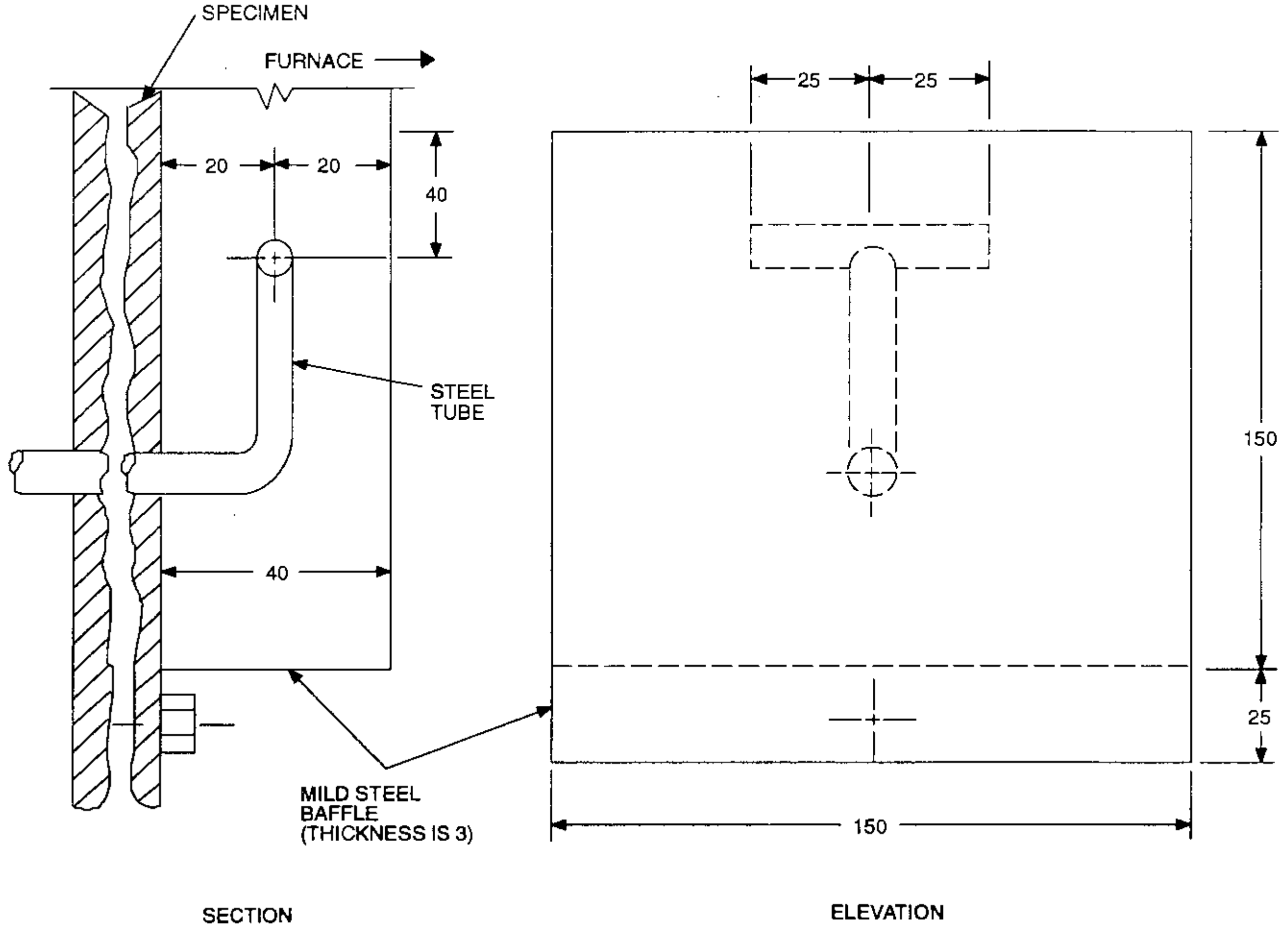


FIGURE 7-5-2—STATIC PRESSURE-MEASURING DEVICE DIMENSIONS IN MILLIMETERS

UNIFORM BUILDING CODE STANDARD 7-6
THICKNESS, DENSITY DETERMINATION AND COHESION/ADHESION FOR SPRAY-APPLIED FIRE-RESISTIVE MATERIAL

Test Standard of the International Conference of Building Officials

See Sections 703.4, 704.6 and 1701.4, *Uniform Building Code*

SECTION 7.601 — SCOPE

These methods cover procedures for obtaining the thickness, density and cohesion/adhesion for sprayed fibrous and cementitious fire-resistive materials. In addition, provisions for field inspection procedures by a special inspector employed by an approved agency on a random basis are included.

SECTION 7.602 — APPLICATIONS

These test methods require that the application of the field-applied, sprayed, fire-resistive material be in accordance with the manufacturer's published instructions. The apparatus, materials and procedure used to apply the fire-resistive material shall be the same as the procedure used to prepare the test specimens which were subjected to the fire tests set forth in UBC Standard 7-1.

SECTION 7.603 — TEST METHODS FOR THICKNESS

7.603.1 General. The following tests, based on samplings as described in this standard, shall be conducted by a special inspector employed by an approved agency.

7.603.2 Substrate Condition. The condition of the substrate on each floor shall be inspected prior to application of the spray-applied fire-resistive material. The substrate shall be prepared in accordance with the manufacturer's instructions and shall be free of dirt, grease, oil, loose scale, loose paint or primer and other materials which may prevent adequate adhesion.

7.603.3 Thickness Measurement and Acceptance Criteria. The thickness of the spray-applied fire-resistive material shall be measured by either of the following methods:

1. A steel rule graduated in at least $^1/_{16}$-inch (1.6 mm) increments, a depth gage consisting of a movable needle or pin and a disc perpendicular to the needle as shown in Figure 7-6-1.

The pin shall be of sufficient length to penetrate the material to be measured. The disc shall be perpendicular to the needle at all times and shall have a friction device to grip the pin unless purposely moved. The disc shall have a diameter of $1^1/_8$ inches (28.6 mm) to permit complete contact with the surface of the specimen to be measured. In materials not readily penetrated by the depth gage, other suitable approved measuring devices may be used.

The thickness shall be determined by inserting the penetrating pin of the depth gage perpendicular to and through the sprayed fire-resistive material to the substrate. When the point of the pin touches the substrate, the disc shall be moved against the fire-resistive material with sufficient force on the disc to register the average plane of the surface. The gage shall be withdrawn to read the thickness in $^1/_{16}$-inch (1.6 mm) increments as shown by the position of the sliding clip indicator. The acceptance of measurements with a minus tolerance greater than $^1/_4$ inch (6.4 mm) shall not be permitted. If design thickness is less than 1 inch (25.4 mm), no more than 25 percent less thickness shall be permitted. Measurements greater than $^1/_4$ inch (6.4 mm) for thickness over 1 inch (25.4 mm), or 25 percent for thickness less than 1 inch (25.4 mm) above the required thickness, shall not be used to determine the thickness average.

2. As an alternate to the method described above, the thickness of the spray-applied fire-resistive material may be measured by a fixed probe with a $1^1/_8$-inch-diameter (28.6 mm) disc set to the required thickness. If any measurement is less than that required, the thickness shall be increased or measurement shall be taken as required in Method 1.

Where thickness is less than that required, the condition shall be corrected. The location of any uncorrected areas shall be reported to the building official.

7.603.4 Thickness Determination for Structural Frame Members. Twenty-five percent of the structural frame, columns and beams as defined in Section 601.4 of this code in each story shall be inspected for thickness determination. Five measurements at a single cross section shall be made and averaged on structural frame beams, and six measurements shall be made and averaged at a single cross section on columns as shown in Figure 7-6-2.

Where open flutes or valley of steel deck sections occur over beams, they shall be filled solid unless the flutes were unfilled in the fire-tested assembly.

7.603.5 Thickness Determination for Beams Other than Structural Frame. Ten percent of beams (other than structural frame members) on each floor shall be selected at random and shall be measured for thickness as required for structural frame members in Section 7.603.4.

7.603.6 Thickness Determination for Floor Sections. Ten floor thickness measurements for each prescribed thickness shall be made on a random basis for each 10,000 square feet (929 m^2). At each area selected, a rectangle having an area of 144 square inches (0.0929 m^2) and a minimum width of 6 inches (152.4 mm) where possible shall be laid out, and a thickness measurement shall be taken at the center and at each corner. The five measurements shall be averaged and shall be reported as a single measurement of the area. The average thickness as determined by Section 7.603.3, Item 1, shall not be less than that specified. If the method for thickness determination as described in Section 7.603.3, Item 2 is used, the thickness at any location shall not be less than the required thickness.

SECTION 7.604 — TEST METHODS FOR DENSITY

7.604.1 General. The test to determine the density of spray-applied fire-resistive material shall be conducted by a special inspector employed by an approved agency.

7.604.2 Density Sample Groups. There shall be density test specimens taken from a column, a beam and a deck for each 10,000 square feet (929 m^2) of floor area or fraction thereof, or from each floor if the floor area is smaller than 10,000 square feet (929 m^2).

7.604.3 Density Determination. The density of each sample shall be determined as follows:

1. Utilizing a rectangular template as described in Section 7.603.6, a known area of the test sample shall be marked off.

2. Utilizing the procedure described in Section 7.603.6 and Section 7.603.3, Method 1, at least five thickness measurements

shall be taken. One measurement shall be taken at the center of the specimen and one at each of the four corners approximately $1^1/_2$ (38 mm^2) inches from adjacent sides. The thickness measurement shall be determined prior to removing the sample, and the average of these five measurements shall be considered as the thickness of the specimen.

3. The specimen shall be cut along the perimeter of the template. All of the in-place material shall be carefully removed from the substrate and dried at 120°F (49°C) at a relative humidity of not less than 50 percent until a constant weight is obtained. The constant weight of the dried material shall be measured.

4. The density shall be calculated in accordance with the following formula:

Density in pounds per cubic foot:

$$\frac{W \times 1,728}{l \times w \times t}$$

For **SI:** (Density in kilograms per cubic meter)

$$\frac{W \times (10^9)}{l \times w \times t}$$

WHERE:

l = length of the specimen, inches (mm).

t = thickness of the specimen, inches (mm).

W = weight of the dried material, pounds (kg).

w = width of the specimen, inches (mm).

7.604.4 Alternative Density Displacement Method.

1. This is an alternative method for determining the in-place density of specimens with irregular surfaces or dimensions or for specimens that are difficult to remove from the substrate.

2. The minimum sample size recommended is 131 cm^3 (8 in.^{3}).

3. The sample shall be cut to a uniform size, removing all uneven edges.

4. Cure the specimen in accordance with Section 7.604.3.3.

5. Determine weight.

6. Use the following apparatus to determine volume:

6.1 Unexpanded polystyrene beads, 500 mL—Designation C bead with a nominal diameter of 1.0 mm (0.04 in.) (preferred) or lead shot-size No. 8 (alternate).

6.2 Graduated cylinders, two 250 cm^3 (15 in.^{3}).

6.3 Funnel—Polypropylene funnel having a top diameter of 150 mm (6 in.) and a bottom diameter of 28 mm (1.1 in.).

6.4 Beaker, 400 mL smooth wall type.

6.5 Screed, minimum 150 mm (6 in.) long rigid straight edge.

6.6 Pan—Two flat pans minimum 150 mm (6 in.) diameter with minimum 150 mm (6 in.) high rim.

7. Determine volume as follows:

7.1 Place the empty 400 mL beaker in the center of the flat pan and pour the unexpanded polystyrene beads or shot through the funnel until the excess beads (shot) fall over the rim of the beaker.

7.2 Hold the screed perpendicular to the rim or the beaker. Begin at the edge opposite the spout and screed off the excess beads (shot). Only one pass is needed.

7.3 Discard the overflow that collects in the pan.

7.4 Pour all the beads (shot) remaining in the beaker into the graduated cylinders.

7.5 Return the empty beaker into the center of the pan and pour about 100 mL of beads (shot) poured from the graduated cylinder(s) into the beaker. Do not shake the beaker in any way.

7.6 Place the sample to be tested in the center of the beaker, making sure no edge touches the side of the glass. Gently twist the sample if required.

7.7 Pour the remainder of the beads from the graduated cylinders over the sample, letting the excess beads (shot) flow over the top of the beaker into the pan. Do not leave any beads (shot) in the graduated cylinders.

7.8 Screed the excess beads (shot) off the top of the beaker (8.3.7.a) and remove the beaker from the pan.

7.9 Using the funnel, pour the beads (shot) collected in the pan into the empty graduated cylinder and read the volume displaced by the sample. Do not tap or shake the graduated cylinder when reading.

8. Calculate density as follows:

$$D = W \times 62.43/V$$

For **SI:** 1 pcf = 16.0 kg/m^3.

WHERE:

D = density in pounds per cubic foot (kg/m^3).

V = volume of sample dried in cm^3 (equal to the volume of beads displaced by the sample).

W = constant weight of dried material, g.

7.604.5 Density Acceptance Criteria. No sample shall have a density less than 5 percent below the specified density. Where the density is less than the 5 percent tolerance allowed above, the work shall be corrected to the satisfaction of the building official.

SECTION 7.605 — TEST METHOD FOR COHESION/ADHESION

7.605.1 General. The test to determine the cohesion/adhesion of spray-applied fire-resistive material shall be conducted by an approved agency.

7.605.2 Adhesive/Cohesive Samples. There shall not be less than one cohesion/adhesion test taken from a column, a beam and a deck for each 10,000 square feet (929 m^2) of floor area or fraction thereof, or from each floor if the floor is smaller than 10,000 square feet (929 m^2).

7.605.3 Adhesive/Cohesive Determination.

1. Use the following equipment:

1.1 Bottle screw cap, metal or rigid plastic 51 mm to 83 mm (2 inches to $3^1/_4$ inches) in diameter and 12 mm ($^1/_2$ inch) in nominal depth. A hook shall be attached at the center. Where deck profile does not allow the use of an 83 mm ($3^1/_4$ inch) diameter cap, a smaller cap shall be used.

1.2 Adhesive, single or two component, suitable for adhering cap to the spray-applied fire-resistive material.

1.3 Weighing scale, spring-type (fish hook), with a capacity suitable for the spray-applied fire-resistive material being tested [typically 12 kg to 30 kg (26 to 66 pounds) capacity]. The accuracy shall be within 0.1 kg ($^1/_4$ pound).

2. The test specimen shall be the in-place spray-applied fire-resistive material as applied to any field condition surface. Where

a 300-by-300 mm (12 by 12 inch) area is not available, such as on beams and fluted deck, use the width of the beam or the width of a flute by 300 mm (12 inch) length. The area shall be at least 100 by 300 mm (4 by 12 inches). See Item 1.1 for exceptions.

3. Condition the specimen at atmospheric conditions or in accordance with the manufacturer's recommendations for a period sufficient to be considered dry.

4. Apply adhesive sufficient to fill the metal or plastic cap, and immediately place the cap against the surface of the spray-applied fire-resistive material.

5. Support the cap at the surface until the adhesive has adequately cured. Wipe away any excess adhesive around the cap before it cures or carefully cut it away after it cures.

6. Engage the scale with the hook and exert an increasing force at a minimum uniform or incremental rate of approximately 5 kg (11 pounds)/minutes perpendicular to the surface.

7. Force shall be applied until failure occurs, a predetermined value is reached, or until the capacity of the scale is reached.

8. Record the force in newtons or points-force at the time failure occurs or other end point is reached.

9. A field test may be performed by replacing the scale (Item 1.3) with a fixed weight sufficient to exert the minimum force specified in Section 7.605.4. The weight must be supported for a minimum one minute duration.

10. Calculate the cohesive/adhesive force (bond strength) as follows:

$$CA = F/A$$

WHERE:

A = area of the cap, m^2 ($ft.^2$).

CA = cohesive/adhesive force, Pa ($lbs./ft.^2$).

F = recorded force, N (lbs.).

7.605.4 Cohesive/Adhesive Acceptance Criteria. No sample shall have a cohesive/adhesive force of less than 150 pounds per square foot (7.18 kN/m^2). Where the cohesive/adhesive force is less than 150 pounds per square foot (7.18 kN/m^2), the work shall be corrected to the satisfaction of the building official.

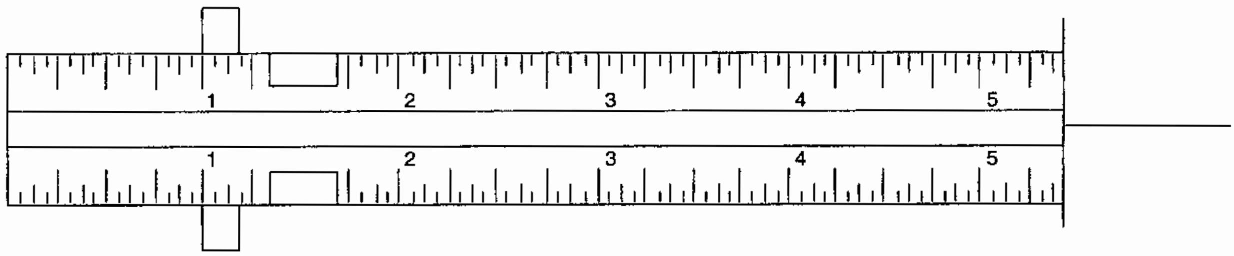


FIGURE 7-6-1—THICKNESS GAGE

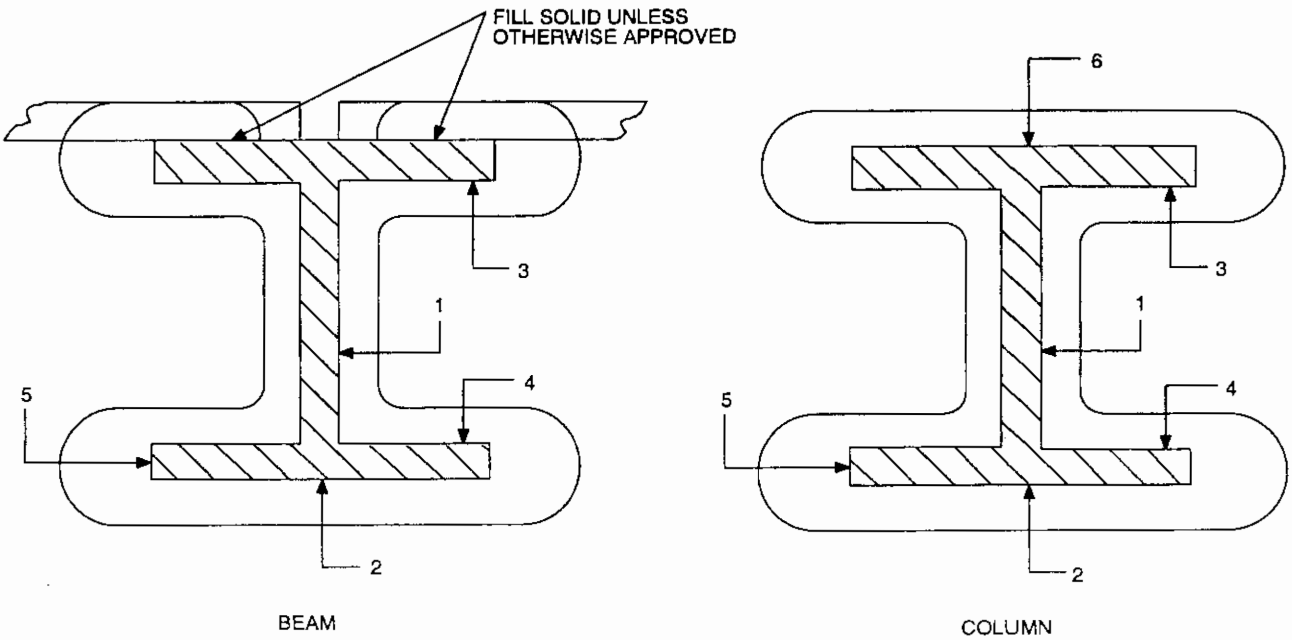


FIGURE 7-6-2—THICKNESS MEASUREMENT LOCATIONS

UNIFORM BUILDING CODE STANDARD 7-7

METHODS FOR CALCULATING FIRE RESISTANCE OF STEEL, CONCRETE, WOOD, CONCRETE MASONRY AND CLAY MASONRY CONSTRUCTION

Standard of the International Conference of Building Officials

Part I—Method for Calculating the Fire Resistance of Steel Construction

See Sections 703.3 and 703.4, *Uniform Building Code*

SECTION 7.701 — SCOPE

This part of this standard contains procedures by which the fire resistance of steel columns, beams, girders and trusses protected by specific materials or combinations of materials can be established by calculations. These procedures apply to the material contained in this part only.

SECTION 7.702 — DEFINITION

CERAMIC FIBER BLANKET is a mineral wool insulation material made of alumina-silica fibers and weighing 4 to 10 pounds per cubic foot (64 to 160 kg/m^3).

SECTION 7.703 — STRUCTURAL STEEL COLUMN PROTECTION

7.703.1 Procedures. These procedures establish a basis for determining the fire resistance of column assemblies as a function of the thickness of fire-resistive material, the weight (W) or cross-sectional area (A) of steel columns and the heated perimeter (D or P) of steel columns. As used in these sections, W is the average weight of a structural steel column in pounds per linear foot (kg/m) and A is the cross-sectional area of a structural steel column in square inches (mm^2). The heated perimeter (D) is the inside perimeter of the fire-resistive material in inches (mm) as illustrated in Figure 7-7-S-1.

Application of these procedures shall be limited to column assemblies in which the fire-resistive material is not designed to carry any of the load acting on the column. In the absence of substantiating fire-endurance test results, ducts, conduit, piping and similar mechanical, electrical and plumbing installations shall not be embedded in any required fire-resistive materials of assemblies designed in accordance with this standard. Table 7-7-S-A1 contains weight-to-heated-perimeter ratios (W/D) for both contour and box fire-protection profiles for the wide-flange shapes most often used as columns. For different fire-resistive design profiles or column cross sections, the weight-to-heated-perimeter ratios (W/D) and cross-sectional-area-to-heated-perimeter ratios (A/P) shall be determined in accordance with the definitions given in this section.

7.703.2 Gypsum Wallboard (Wide-flange, Pipe and Tubular Columns). The fire resistance of structural steel columns with weight-to-heated-perimeter ratios (W/D) less than or equal to 3.65 (0.215) and which are protected with Type X gypsum wallboard may be determined from the following expression:

$$R = 130\left[\frac{h\,(W'/D)}{2}\right]^{0.75}$$

For SI: $$R = 96\left[\frac{h\,(W'/D)}{2}\right]^{0.75}$$

WHERE:

D = heated perimeter of the structural steel column, inches (mm).

h = total thickness of gypsum wallboard, inches (mm).

R = fire resistance (minutes).

W' = total weight of the structural steel column and gypsum wallboard protection, pounds per linear foot (kg/m).

$$= W + \frac{50\,h\,D}{144}$$

For SI: $= W + 0.0008\,hD$

The gypsum wallboard shall be supported and fastened as illustrated in either Figure 7-7-S-2 for fire-resistance ratings of four hours or less, or Figure 7-7-S-3 for fire-resistance ratings of three hours or less. The fire resistance of structural steel columns can be determined from Figure 7-7-S-4 for various thicknesses of gypsum wallboard as a function of the weight-to-heated-perimeter ratio (W/D) of the column. For structural steel columns with weight-to-heated- perimeter ratios (W/D) greater than 3.65 (0.215), the thickness of gypsum wallboard required for specified fire-resistance ratings shall be the same as the thickness determined for a W14 × 233-wide (W 360 × 347) flange shape.

7.703.3 Spray-applied Fire-resistive Materials (Wide-flange Columns). The fire resistance of wide-flange structural steel columns protected with spray-applied fire-resistive materials, as illustrated in Figure 7-7-S-5, may be determined from the following expression:

$$R = (C_1 \frac{W}{D} + C_2)\,h$$

WHERE:

C_1 and

C_2 = material-dependent constants.

D = heated perimeter of the structural steel column, inches (mm).

h = thickness of spray-applied fire-resistive material, inches (mm).

R = fire resistance, minutes.

W = average weight of steel column, pounds per linear foot (kg/m).

The material-dependent constants, C_1 and C_2, shall be determined for specific spray-applied fire-resistive materials on the basis of standard fire-endurance tests in accordance with Section 703.2. These constants shall be determined from results of at least four fire-endurance tests in accordance with requirements set forth in UBC Standard 7-1. At least two tests shall be conducted on the largest and two on the smallest columns which establish the limits of applicability to the resulting equation. Test data shall be evaluated with respect to the assumption that the ratio of fire endurance to fire-resistive material thickness (R/h) is reasonably constant for a given column shape (W/D ratio). The tests conducted on columns of the same shape shall be designed so that the resulting fire-endurance times are approximately one and one-half hours and three and one-half hours. In evaluating the R/h ratios resulting from tests on the same column shape, differences in the range of 10 percent are typical. Differences greater than 20 percent may, however, suggest that the equation is not applicable to the specific fire-resistive material under consideration and further examination of the test data is warranted.

Unless evidence is submitted to the building official substantiating a broader application, this expression shall be limited to determining the fire resistance of structural steel columns with weight-to-heated-perimeter ratios (W/D) between the largest and smallest columns for which standard fire-endurance test results are available.

7.703.4 Spray-applied Fire-resistive Materials (Pipe and Tubular Columns). The fire resistance of pipe and tubular steel columns protected with spray-applied fire-resistive materials may be determined from the following expressions:

$$R = C_3 \, (A/P) \, h + C_4$$

WHERE:

A = cross-sectional area of the structural steel column, square inches (mm^2).

C_3 and
C_4 = material-dependent constants.

h = thickness of spray-applied fire-resistive material, inches (mm).

P = heated perimeter of the structural steel column, inches (mm).

R = fire resistance, hours.

The material-dependent constants (C_3 and C_4) shall be determined for specific spray-applied fire-resistive materials on the basis of standard fire-resistance tests in accordance with Section 703.2. These constants shall be determined from the results of at least four fire-endurance tests in accordance with requirements set forth in UBC Standard 7-1. At least two tests shall be conducted on each of two different column sizes as follows:

1. For the smaller of the two columns, one of the test specimens shall be protected so as to develop the minimum desired fire-resistance rating, and the second specimen shall be protected with the maximum intended thickness of fire-resistive material.

2. For the larger of the two columns, one of the test specimens shall be protected with the minimum intended thickness of fire-resistive material, and the second specimen shall be protected so as to develop the maximum desired fire-resistance rating.

These four tests shall establish limits governing the use of the resulting equation. These limits shall define the minimum and maximum permitted thicknesses of the fire-resistive material and the minimum and maximum fire-resistance ratings. Additional tests may be conducted to modify any of these four limits and these additional tests may involve different column sizes. The material-dependent constants shall be determined based on all applicable test data using a linear, least-squares curve-fitting technique or similar statistical analysis.

Unless evidence is submitted to the building official substantiating a broader application, this expression shall be limited to determining the fire resistance of structural steel columns with cross-sectional-area-to-heated-perimeter ratios (A/P) between the largest and smallest columns for which standard fire-endurance test results are available.

Table 7-7-S-A2 contains area-to-heated-perimeter ratios (A/P) for circular, square and rectangular tubes most often used as columns.

7.703.5 Concrete. The fire-resistance rating of structural steel columns protected with concrete, as illustrated in Figure 7-7-S-6, may be determined from the following expression:

$$R = R_o (1 + 0.03m)$$

$$R_o = 10\left(\frac{W}{D}\right)^{0.7} + 17\,\frac{h^{1.6}}{k_c^{\;0.2}}\left[1 + 26\left(\frac{H}{\rho_c\, c_c h (L + h)}\right)^{0.8}\right]$$

For SI: $$R_o = 73\left(\frac{W}{D}\right)^{0.7} + 0.16\,\frac{h^{1.6}}{k_c^{\;0.2}}\left[1 + 30984\left(\frac{H}{\rho_c\, c_c h (L + h)}\right)^{0.8}\right]$$

WHERE:

c_c = ambient temperature specific heat of concrete, Btu/lb.°F (KJ/kg·K).

D = heated perimeter of the steel column, inches (mm).

H = ambient temperature thermal capacity of the steel column.

= $0.11W$, Btu/ft.°F [$0.46W$(kJ/m·k)].

h = thickness of the cover for concrete, inches (mm).

k_c = ambient temperature thermal conductivity of the concrete, Btu/hr. ft.°F (W/m·K).

L = interior dimension of one side of a square concrete, inches (mm).

m = equilibrium moisture content of the concrete by volume, percentage.

R = fire endurance at equilibrium moisture conditions, minutes.

R_o = fire endurance at zero moisture content, minutes.

W = average weight of the steel column, pounds per linear foot (kg/m).

ρ_c = concrete density, pounds per cubic foot (kg/m^3).

For wide-flange steel columns completely encased in concrete with all reentrant spaces filled (Figure 7-7-S-6, Detail C), the thermal capacity of the concrete with the reentrant spaces may be added to the thermal capacity of the steel column, and the total thermal capacity may be determined by the expression:

$$H = 0.11W + \frac{\rho_c\, c_c\,(b_f d - A_s)}{144}$$

For SI: $$H = 0.46W + \frac{\rho_c\, c_c\,(b_f d - A_s)}{1{,}000{,}000}$$

WHERE:

A_s = cross-sectional area of the steel column, square inches (mm^2).

b_f = flange width of the steel column, inches (mm).

d = depth of the steel column, inches (mm).

If specific data on the properties of concrete or concrete masonry are not available, the values given in Table 7-7-S-B may be used.

For structural steel columns encased in concrete with all reentrant spaces filled (Figure 7-7-S-6, Detail C), Tables 7-7-S-C and 7-7-S-D give the thickness of concrete cover required for various fire-resistance ratings for typical wide-flange sections. The thicknesses of concrete given in these tables also apply to structural steel columns larger than those listed.

For structural steel columns protected with precast concrete column covers (Figure 7-7-S-6, Detail A), Tables 7-7-S-E and 7-7-S-F give the thickness of the column covers required for various fire-resistance ratings for typical wide-flange shapes. The thicknesses of concrete given in these tables also apply to structural steel columns larger than those listed.

For structural steel columns protected with concrete masonry (Figure 7-7-S-7), Tables 7-7-S-G and 7-7-S-H give the equivalent thickness of concrete masonry required for various fire-resistance ratings for typical wide-flange shapes. The equivalent thicknesses given in these tables also apply to structural steel columns larger than those listed.

Head and bed joints shall be fully mortared. Design and anchorage of concrete masonry shall be in accordance with Chapter 21. The thickness of column units (Figure 7-7-S-7) shall not be less than $1^1/_2$ inches (38 mm). The nominal thickness of hollow or solid units (Figure 7-7-S-7) shall not be less than 4 inches (102 mm).

7.703.6 Concrete Masonry. The fire-resistance rating of structural steel columns protected with concrete masonry, as illustrated in Figure 7-7-S-7, may be determined in accordance with the following expression:

$$R = 0.401(A_s/p_s)^{0.7} + 0.285(T_{ea}^{\ 1.6}/K^{0.2}) \times [1.0 + 42.7\{(A_s/DT_{ea})/(0.25p + T_{ea})\}^{0.8}]$$

For **SI:**

$$R = 0.042(A_s/p_s)^{0.7} + 0.0018(T_{ea}^{\ 1.6}/K^{0.2}) \times [1.0 + 384\{(A_s/DT_{ea})/(0.25p + T_{ea})\}^{0.8}]$$

WHERE:

A_s = cross-sectional area of the steel column, square inches (mm^2).

D = density of the concrete masonry protection, pounds per cubic foot (kg/m^3).

K = ambient thermal conductivity of concrete masonry. See Table 7-7-S-J, Btu/hr.ft.°F (W/m·k).

p = inner perimeter of concrete masonry protection, inches (mm).

p_s = heated perimeter of steel column, inches (mm).

R = fire-resistance rating of the column assembly, hours.

T_{ea} = equivalent thickness of concrete masonry protection assembly, inches (mm).

SECTION 7.704 — PROTECTED STEEL BEAMS, GIRDERS AND TRUSSES

7.704.1 Beams and Girders.

7.704.1.1 General. These procedures establish a basis for determining the fire resistance of structural beams and girders which differ in size from that specified in approved fire-resistant assemblies as a function of the thickness of fire-resistive material and the weight W and heated perimeter D of the beam or girder. The use of the methodology in this section is limited to unrestrained conditions. As used in these sections, W is the average weight of a structural steel member in pounds per linear foot (kg/m). The heated perimeter D is the inside perimeter of the fire-resistive material in inches (mm) as illustrated in Figure 7-7-S-8. The weight-to-heated-perimeter ratios (W/D) for both contour and box fire-resistive design profiles for the wide-flange shapes most often used as beams or girders are given in Table 7-7-S-I. For different shapes, the weight-to-heated-perimeter ratios (W/D) shall be determined in accordance with the definitions given in this section. Except as provided for in Section 7.704.1, structural steel beams in approved fire-resistant assemblies shall be considered the minimum permissible size. Other beam or girder shapes may be substituted, provided that the weight-to-heated-perimeter ratio (W/D) of the substitute beam is equal to or greater than that of the beam specified in the approved assembly.

7.704.1.2 Spray-applied fire-resistive materials. The provisions in this section apply to unrestrained structural steel beams and girders protected with spray-applied cementitious or mineral fiber materials. Larger or smaller unrestrained beam and girder shapes may be substituted for beams specified in approved unrestrained fire-resistant assemblies, provided that the thickness of fire-resistive materials is adjusted in accordance with the following expression:

$$h_2 = \left[\frac{W_1/D_1 + 0.60}{W_2/D_2 + 0.60}\right] h_1$$

For **SI:**

$$h_2 = \left[\frac{W_1/D_1 + 0.036}{W_2/D_2 + 0.036}\right] h_1$$

WHERE:

D = heated perimeter of the structural steel beam or girder, in inches (mm).

h = thickness of spray-applied fire-resistive material, in inches (mm).

W = weight of the structural steel beam or girder in pounds per linear foot (kg/m).

Subscript 1 refers to the beam and fire-resistive material thickness in the approved assembly.

Subscript 2 refers to the substitute beam or girder and the required thickness of fire-resistive materials.

This equation is limited to beams with a weight-to-heated-perimeter ratio (W/D) of 0.37 (0.022) or greater. The thickness of protection shall not be less than $^3/_8$ inch (9.5 mm).

7.704.2 Structural Steel Trusses. The fire resistance of structural steel trusses protected with cementitious or mineral fiber materials spray applied to each of the individual truss elements may be determined in accordance with this section. The thickness of the fire-resistive material shall be determined in accordance with Section 7.703.3. The weight-to-heated-perimeter ratio (W/D) of truss elements which can be simultaneously exposed to fire on all sides shall be determined on the same basis as columns, as specified in Section 7.703.1. The weight-to-heated-perimeter ratio (W/D) of truss elements which directly support floor or roof construction shall be determined on the same basis as beams and girders, as specified in Section 7.704.1, Item 1.

TABLE 7-7-S-A1—WEIGHT-TO-HEATED-PERIMETER RATIOS (*W/D*)
FOR TYPICAL STRUCTURAL STEEL WIDE FLANGE COLUMNS

STRUCTURAL SHAPE	STRUCTURAL SHAPE	CONTOUR PROFILE (*W/D*)	BOX PROFILE[1] (*W/D*)
in. × lb./ft.	mm × kg/m	× 0.059 for metric *W/D*	
W14 × 730	W360 × 1086	6.62	9.05
W14 × 665	W260 × 990	6.14	8.46
W14 × 605	W360 × 900	5.69	7.89
W14 × 550	W360 × 818	5.26	7.35
W14 × 500	W360 × 744	4.86	6.83
W14 × 455	W360 × 677	4.49	6.35
W14 × 426	W360 × 634	4.24	6.02
W14 × 398	W360 × 592	4.00	5.71
W14 × 370	W360 × 551	3.76	5.38
W14 × 342	W360 × 509	3.51	5.04
W14 × 311	W360 × 463	3.23	4.66
W14 × 283	W360 × 421	2.97	4.31
W14 × 257	W360 × 382	2.72	3.97
W14 × 233	W360 × 347	2.49	3.65
W14 × 211	W360 × 314	2.28	3.35
W14 × 193	W360 × 287	2.10	3.09
W14 × 176	W360 × 262	1.93	2.85
W14 × 159	W360 × 237	1.75	2.60
W14 × 145	W360 × 216	1.61	2.39
W14 × 132	W360 × 196	1.52	2.25
W14 × 120	W360 × 179	1.39	2.06
W14 × 109	W360 × 162	1.27	1.88
W14 × 99	W360 × 147	1.16	1.72
W14 × 90	W360 × 134	1.06	1.58
W14 × 82	W360 × 122	1.20	1.68
W14 × 74	W360 × 110	1.09	1.53
W14 × 68	W360 × 101	1.01	1.41
W14 × 61	W360 × 91	0.91	1.28
W14 × 53	W360 × 79	0.89	1.21
W14 × 48	W360 × 72	0.81	1.10
W14 × 43	W360 × 64	0.73	0.99
W12 × 336	W310 × 500	4.02	5.56
W12 × 305	W310 × 454	3.70	5.16
W12 × 279	W310 × 415	3.44	4.81
W12 × 252	W310 × 375	3.15	4.43
W12 × 230	W310 × 342	2.91	4.12
W12 × 210	W310 × 313	2.68	3.82
W12 × 190	W310 × 283	2.46	3.51
W12 × 170	W310 × 253	2.22	3.20
W12 × 152	W310 × 226	2.01	2.90
W12 × 136	W310 × 202	1.82	2.63
W12 × 120	W310 × 179	1.62	2.36
W12 × 106	W310 × 158	1.44	2.11
W12 × 96	W310 × 143	1.32	1.93
W12 × 87	W310 × 129	1.20	1.76
W12 × 79	W310 × 117	1.10	1.61
W12 × 72	W310 × 107	1.00	1.48
W12 × 65	W310 × 97	0.91	1.35
W12 × 58	W310 × 86	0.91	1.31
W12 × 53	W310 × 79	0.84	1.20
W12 × 50	W310 × 74	0.89	1.23
W12 × 45	W310 × 67	0.81	1.12
W12 × 40	W310 × 60	0.72	1.00
W10 × 112	W250 × 167	1.78	2.57
W10 × 100	W250 × 149	1.61	2.33
W10 × 88	W250 × 131	1.43	2.08
W10 × 77	W250 × 115	1.26	1.85
W10 × 68	W250 × 101	1.13	1.66
W10 × 60	W250 × 89	1.00	1.48
W10 × 54	W250 × 80	0.91	1.34
W10 × 49	W250 × 73	0.83	1.23
W10 × 45	W250 × 67	0.87	1.24
W10 × 39	W250 × 58	0.76	1.09
W10 × 33	W250 × 49	0.65	0.93
W8 × 67	W200 × 100	1.34	1.94
W8 × 58	W200 × 86	1.18	1.71
W8 × 48	W200 × 71	0.99	1.44
W8 × 40	W200 × 59	0.83	1.23
W8 × 35	W200 × 52	0.73	1.08
W8 × 31	W200 × 46	0.65	0.97
W8 × 28	W200 × 42	0.67	0.96
W8 × 24	W200 × 36	0.58	0.83
W8 × 21	W200 × 31	0.57	0.77
W8 × 18	W200 × 27	0.49	0.67

(Continued)

TABLE 7-7-S-A1—WEIGHT-TO-HEATED-PERIMETER RATIOS (*W/D*) FOR TYPICAL STRUCTURAL STEEL WIDE FLANGE COLUMNS—(Continued)

STRUCTURAL SHAPE	STRUCTURAL SHAPE	CONTOUR PROFILE (*W/D*)	BOX PROFILE[1] (*W/D*)
in. × lb./ft.	mm × kg/m	× 0.059 for metric *W/D*	
W6 × 25	W150 × 37	0.69	1.00
W6 × 20	W150 × 30	0.56	0.82
W6 × 16	W150 × 24	0.57	0.78
W6 × 15	W150 × 22	0.42	0.63
W6 × 12	W150 × 18	0.43	0.60
W6 × 9	W150 × 13	0.33	0.46
W5 × 19	W130 × 28	0.64	0.93
W5 × 16	W130 × 24	0.54	0.80
W4 × 13	W130 × 19	0.54	0.79

[1]See Section 7.703.2 for *W/D* limitations for gypsum wallboard protected assemblies.

TABLE 7-7-S-A2—AREA-TO-HEATED-PERIMETER RATIOS (*A/P*) FOR TYPICAL ROUND AND SQUARE STRUCTURAL TUBING

ROUND PIPE COLUMNS STANDARD STEEL PIPE				
Nominal Diameter (inches)	**Thickness (inches)**	***A/P* Ratio (× 25.4 for metric *A/P*)**	**Nominal Diameter (mm)**	**Thickness (mm)**
12	0.375	0.36	310	9.52
10	0.365	0.35	254	9.27
8	0.322	0.31	203	8.18
6	0.280	0.27	152	7.11
5	0.258	0.25	127	6.55
4	0.237	0.22	102	6.02
3.5	0.226	0.21	89	5.74
3	0.216	0.20	75	5.49
EXTRA-STRONG STEEL PIPE COLUMNS				
Nominal Diameter (inches)	**Thickness (inches)**	***A/P* Ratio (× 25.4 for metric *A/P*)**	**Nominal Diameter (mm)**	**Thickness (mm)**
12	0.500	0.48	310	12.70
10	0.500	0.48	254	12.70
8	0.500	0.47	203	12.70
6	0.432	0.40	152	10.97
5	0.375	0.35	127	9.52
4	0.337	0.31	102	8.56
3.5	0.318	0.29	89	8.08
3	0.300	0.27	75	7.62
DOUBLE EXTRA-STRONG STEEL PIPE COLUMNS				
Nominal Diameter (inches)	**Thickness (inches)**	***A/P* Ratio (× 25.4 for metric *A/P*)**	**Nominal Diameter (mm)**	**Thickness (mm)**
8	0.875	0.79	203	22.23
6	0.864	0.75	152	21.95
5	0.750	0.65	127	19.05
4	0.647	0.57	102	17.12
3	0.600	0.50	75	15.24
SQUARE STRUCTURAL TUBING				
Nominal Size Each Side (inches)	**Thickness (inches)**	***A/P* Ratio (× 25.4 for metric *A/P*)**	**Nominal Size Each Side (mm)**	**Thickness (mm)**
16	$^5/_8$	0.58	406	15.9
16	$^1/_2$	0.48	406	12.7
14	$^5/_8$	0.58	356	15.9
14	$^1/_2$	0.47	356	12.7
14	$^3/_8$	0.36	356	9.5
12	$^5/_8$	0.57	305	15.9
12	$^1/_2$	0.47	305	12.7
12	$^3/_8$	0.36	305	9.5
10	$^5/_8$	0.56	254	15.9
10	$^9/_{16}$	0.51	254	14.3
10	$^1/_2$	0.46	254	12.7
10	$^3/_8$	0.35	254	9.5
10	$^5/_{16}$	0.30	254	7.9

(Continued)

TABLE 7-7-S-A2—AREA-TO-HEATED-PERIMETER RATIOS (*A/P*) FOR TYPICAL ROUND AND SQUARE STRUCTURAL TUBING—(Continued)

SQUARE STRUCTURAL TUBING				
Nominal Size Each Side (inches)	Thickness (inches)	*A/P* Ratio (× 25.4 for metric *A/P*)	Nominal Size Each Side (mm)	Thickness (mm)
9	5/8	0.55	229	15.9
9	9/16	0.51	229	14.3
9	1/2	0.46	229	12.7
9	3/8	0.35	229	9.5
9	5/16	0.29	229	7.9
8	5/8	0.54	203	15.9
8	9/16	0.50	203	14.3
8	1/2	0.45	203	12.7
8	3/8	0.35	203	9.5
8	5/16	0.29	203	7.9
8	1/4	0.24	203	6.4
7	9/16	0.49	178	14.3
7	1/2	0.44	178	12.7
7	3/8	0.34	178	9.5
7	5/16	0.29	178	7.9
7	1/4	0.24	178	6.4
6	9/16	0.48	152	14.3
6	1/2	0.43	152	12.7
6	3/8	0.34	152	9.5
6	5/16	0.29	152	7.9
6	1/4	0.23	152	6.4
6	3/16	0.18	152	4.8
5	1/2	0.42	127	12.7
5	3/8	0.33	127	9.5
5	5/16	0.28	127	7.9
5	1/4	0.23	127	6.4
5	3/16	0.18	127	4.8
4	1/2	0.40	102	12.7
4	3/8	0.32	102	9.5
4	5/16	0.27	102	7.9
4	1/4	0.22	102	6.4
4	3/16	0.17	102	4.8
3	5/16	0.26	76	7.9
3	1/4	0.22	76	6.4
3	3/16	0.17	76	4.8
RECTANGULAR STRUCTURAL TUBING				
Nominal Size (inches)	**Thickness (inches)**	***A/P* Ratio (× 25.4 for metric *A/P*)**	**Nominal Size (mm)**	**Thickness (mm)**
16 × 12	5/8	0.58	406 × 305	15.9
16 × 12	1/2	0.47	406 × 305	12.7
16 × 8	1/2	0.47	406 × 203	12.7
14 × 10	5/8	0.57	356 × 254	15.9
14 × 10	1/2	0.47	356 × 254	12.7
14 × 10	3/8	0.36	356 × 254	9.5
12 × 8	5/8	0.56	305 × 203	15.9
12 × 8	9/16	0.51	305 × 203	14.3
12 × 8	1/2	0.46	305 × 203	12.7
12 × 8	3/8	0.35	305 × 203	9.5
12 × 6	5/8	0.55	305 × 152	15.9
12 × 6	9/16	0.51	305 × 152	14.3
12 × 6	1/2	0.46	305 × 152	12.7
12 × 6	3/8	0.35	305 × 152	9.5
10 × 8	5/8	0.55	254 × 203	15.9
10 × 8	9/16	0.51	254 × 203	14.3
10 × 8	1/2	0.46	254 × 203	12.7
10 × 8	3/8	0.35	254 × 203	9.5
10 × 8	5/16	0.29	254 × 203	7.9
10 × 8	1/4	0.24	254 × 203	6.4

(Continued)

TABLE 7-7-S-A2—AREA-TO-HEATED-PERIMETER RATIOS (*A/P*) FOR TYPICAL ROUND AND SQUARE STRUCTURAL TUBING—(Continued)

RECTANGULAR STRUCTURAL TUBING				
Nominal Size (inches)	Thickness (inches)	*A/P* Ratio (× 25.4 for metric *A/P*)	Nominal Size (mm)	Thickness (mm)
10 × 6	5/8	0.54	254 × 152	15.9
10 × 6	9/16	0.50	254 × 152	14.3
10 × 6	1/2	0.45	254 × 152	12.7
10 × 6	3/8	0.35	254 × 152	9.5
10 × 6	5/16	0.29	254 × 152	7.9
10 × 5	5/8	0.54	254 × 127	15.9
10 × 5	9/16	0.49	254 × 127	14.3
10 × 5	1/2	0.45	254 × 127	12.7
10 × 5	3/8	0.34	254 × 127	9.5
10 × 5	5/16	0.29	254 × 127	7.9
9 × 7	5/8	0.50	229 × 178	15.9
9 × 7	9/16	0.45	229 × 178	14.3
9 × 7	1/2	0.35	229 × 178	12.7
9 × 7	3/8	0.29	229 × 178	9.5
9 × 7	5/16	0.24	229 × 178	7.9
9 × 6	5/8	0.54	229 × 152	15.9
9 × 6	9/16	0.49	229 × 152	14.3
9 × 6	1/2	0.45	229 × 152	12.7
9 × 6	3/8	0.34	229 × 152	9.5
9 × 6	5/16	0.29	229 × 152	7.9
9 × 5	9/16	0.49	229 × 127	14.3
9 × 5	1/2	0.44	229 × 127	12.7
9 × 5	3/8	0.34	229 × 127	9.5
9 × 5	5/16	0.29	229 × 127	7.9

RECTANGULAR STRUCTURAL TUBING				
Nominal Size (inches)	Thickness (inches)	*A/P* Ratio (× 25.4 for metric *A/P*)	Nominal Size (mm)	Thickness (mm)
8 × 6	9/16	0.49	203 × 152	14.3
8 × 6	1/2	0.44	203 × 152	12.7
8 × 6	3/8	0.34	203 × 152	9.5
8 × 6	5/16	0.29	203 × 152	7.9
8 × 6	1/4	0.24	203 × 152	6.4
8 × 4	9/16	0.48	203 × 102	14.3
8 × 4	1/2	0.43	203 × 102	12.7
8 × 4	3/8	0.34	203 × 102	9.5
8 × 4	5/16	0.29	203 × 102	7.9
8 × 4	1/4	0.23	203 × 102	6.4
7 × 5	1/2	0.43	178 × 127	12.7
7 × 5	3/8	0.34	178 × 127	9.5
7 × 5	5/16	0.29	178 × 127	7.9
7 × 5	1/4	0.23	178 × 127	6.4
6 × 5	1/2	0.43	152 × 127	12.7
6 × 5	3/8	0.33	152 × 127	9.5
6 × 5	5/16	0.28	152 × 127	7.9
6 × 5	1/4	0.23	152 × 127	6.4
6 × 5	3/16	0.18	152 × 127	4.8
6 × 4	1/2	0.42	152 × 102	12.7
6 × 4	3/8	0.33	152 × 102	9.5
6 × 4	5/16	0.28	152 × 102	7.9
6 × 4	1/4	0.23	152 × 102	6.4
6 × 4	3/16	0.18	152 × 102	4.8
6 × 3	3/8	0.32	152 × 76	9.5
6 × 3	5/16	0.28	152 × 76	7.9
6 × 3	1/4	0.23	152 × 76	6.4
6 × 3	3/16	0.17	152 × 76	4.8
5 × 3	1/2	0.40	127 × 76	12.7
5 × 3	3/8	0.32	127 × 76	9.5
5 × 3	5/16	0.27	127 × 76	7.9
5 × 3	1/4	0.22	127 × 76	6.4
5 × 3	3/16	0.17	127 × 76	4.8
4 × 3	5/16	0.27	102 × 76	7.9
4 × 3	1/4	0.22	102 × 76	6.4
4 × 3	3/16	0.17	102 × 76	4.8
4 × 2	5/16	0.26	102 × 51	7.9
4 × 2	1/4	0.22	102 × 51	6.4
4 × 2	3/16	0.17	102 × 51	4.8
3.5 × 2.5	1/4	0.22	89 × 64	6.4
3.5 × 2.5	3/16	0.17	89 × 64	4.8
3 × 2	1/4	0.21	76 × 51	6.4
3 × 2	3/16	0.16	76 × 51	4.8

TABLE 7-7-S-B—PROPERTIES OF CONCRETE

PROPERTIES OF CONCRETE AND CONCRETE MASONRY				
	Concrete		Concrete Masonry	
Thermal Conductivity Metric W/m•k	Normal-Weight	Structural Lightweight	Normal-Weight	Structural Lightweight
Thermal conductivity, k_c (Btu/h ft. °F) (× 1.73 for KJ/kg·K)	0.95	0.35	0.51	0.33
Specific heat, c_c (Btu/h/lb. °F) (× 4.187 for KJ/kg·K)	0.20	0.20	0.20	0.20
Density, p_c (pcf) (× 16 for kg/m^3)	145	110	125	105
Equilibrium (free) moisture content, *m*, percent by volume	4	5	4	5

TABLE 7-7-S-C—THICKNESS OF NORMAL-WEIGHT CONCRETE[1] FOR VARIOUS FIRE-RESISTANCE RATINGS FOR TYPICAL WIDE-FLANGE STRUCTURAL STEEL COLUMNS ENCASED IN CONCRETE [Inches (mm)] (Figure 7-7-S-6, Detail C)

<table>
<tr><th colspan="3">STRUCTURAL STEEL COLUMN SHAPES</th><th colspan="4">FIRE-RESISTANCE RATING (hours)</th></tr>
<tr><th>(mm)</th><th></th><th>(kg/m)</th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td rowspan="7">W14X (W360)</td><td>233</td><td>347</td><td rowspan="7">1</td><td rowspan="3">1</td><td rowspan="2">1 1/2</td><td>2</td></tr>
<tr><td>176</td><td>262</td><td rowspan="3">2 1/2</td></tr>
<tr><td>132</td><td>196</td><td rowspan="3">2</td></tr>
<tr><td>90</td><td>134</td><td rowspan="4">1 1/2</td></tr>
<tr><td>61</td><td>91</td><td rowspan="3">3</td></tr>
<tr><td>48</td><td>72</td><td rowspan="2">2 1/2</td></tr>
<tr><td>43</td><td>64</td></tr>
<tr><td rowspan="5">W12X (W310)</td><td>152</td><td>226</td><td rowspan="5">1</td><td>1</td><td rowspan="3">2</td><td rowspan="2">2 1/2</td></tr>
<tr><td>96</td><td>143</td><td rowspan="4">1 1/2</td></tr>
<tr><td>65</td><td>97</td><td rowspan="3">3</td></tr>
<tr><td>50</td><td>74</td><td rowspan="2">2 1/2</td></tr>
<tr><td>40</td><td>60</td></tr>
<tr><td rowspan="5">W10X (W250)</td><td>88</td><td>131</td><td rowspan="5">1</td><td rowspan="4">1 1/2</td><td>2</td><td rowspan="3">3</td></tr>
<tr><td>49</td><td>73</td><td rowspan="4">2 1/2</td></tr>
<tr><td>45</td><td>67</td></tr>
<tr><td>39</td><td>58</td><td rowspan="2">3 1/2</td></tr>
<tr><td>33</td><td>49</td><td>2</td></tr>
<tr><td rowspan="6">W8X (W200)</td><td>67</td><td>100</td><td rowspan="6">1</td><td rowspan="3">1 1/2</td><td rowspan="4">2 1/2</td><td rowspan="2">3</td></tr>
<tr><td>58</td><td>86</td></tr>
<tr><td>48</td><td>71</td><td rowspan="3">3 1/2</td></tr>
<tr><td>31</td><td>46</td><td rowspan="3">2</td></tr>
<tr><td>21</td><td>31</td><td rowspan="2">3</td></tr>
<tr><td>18</td><td>27</td><td>4</td></tr>
<tr><td rowspan="5">W6X (W150)</td><td>25</td><td>37</td><td rowspan="4">1</td><td rowspan="2">2</td><td rowspan="4">3</td><td>3 1/2</td></tr>
<tr><td>20</td><td>30</td><td rowspan="4">4</td></tr>
<tr><td>16</td><td>24</td><td rowspan="3">2 1/2</td></tr>
<tr><td>15</td><td>22</td></tr>
<tr><td>9</td><td>13</td><td>1 1/2</td><td>3 1/2</td></tr>
</table>

[1]The tabulated thicknesses are based on the assumed properties of normal-weight concrete given in Table 7-7-S-B.

TABLE 7-7-S-D—THICKNESS OF LIGHTWEIGHT CONCRETE[1] FOR VARIOUS FIRE-RESISTANCE RATINGS FOR TYPICAL WIDE-FLANGE STRUCTURAL STEEL COLUMNS ENCASED IN CONCRETE [Inches (mm)] (Figure 7-7-S-6, Detail C)

<table>
<tr><th colspan="3">STRUCTURAL STEEL COLUMN SHAPES</th><th colspan="4">FIRE-RESISTANCE RATING (hours)</th></tr>
<tr><th>(mm)</th><th></th><th>(kg/m)</th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td rowspan="5">W14X (W360)</td><td>233</td><td>347</td><td rowspan="5">1</td><td rowspan="4">1</td><td>1</td><td rowspan="2">1½</td></tr>
<tr><td>193</td><td>287</td><td rowspan="3">1½</td></tr>
<tr><td>74</td><td>110</td><td>2</td></tr>
<tr><td>61</td><td>91</td><td rowspan="2">2½</td></tr>
<tr><td>43</td><td>64</td><td>1½</td><td>2</td></tr>
<tr><td rowspan="3">W12X (W310)</td><td>65</td><td>97</td><td rowspan="3">1</td><td rowspan="2">1</td><td>1½</td><td>2</td></tr>
<tr><td>53</td><td>79</td><td rowspan="2">2</td><td rowspan="2">2½</td></tr>
<tr><td>40</td><td>60</td><td>1½</td></tr>
<tr><td rowspan="4">W10X (W250)</td><td>112</td><td>167</td><td rowspan="4">1</td><td rowspan="3">1</td><td rowspan="2">1½</td><td rowspan="2">2</td></tr>
<tr><td>88</td><td>131</td></tr>
<tr><td>60</td><td>89</td><td rowspan="2">2</td><td rowspan="2">2½</td></tr>
<tr><td>33</td><td>49</td><td>1½</td></tr>
<tr><td rowspan="4">W8X (W200)</td><td>35</td><td>52</td><td rowspan="4">1</td><td rowspan="4">1½</td><td rowspan="2">2</td><td>2½</td></tr>
<tr><td>28</td><td>42</td><td rowspan="3">3</td></tr>
<tr><td>24</td><td>36</td><td rowspan="2">2½</td></tr>
<tr><td>18</td><td>27</td></tr>
</table>

[1]The tabulated thicknesses are based on the assumed properties of structural lightweight concrete given in Table 7-7-S-B.

TABLE 7-7-S-E—THICKNESS OF NORMAL-WEIGHT CONCRETE[1] PRECAST CONCRETE COVERS FOR VARIOUS FIRE-RESISTANCE RATINGS FOR TYPICAL WIDE-FLANGE STRUCTURAL STEEL COLUMNS [Inches (mm)] (Figure 7-7-S-6, Detail A)

<table>
<tr><th colspan="3">STRUCTURAL STEEL COLUMN SHAPES</th><th colspan="4">FIRE-RESISTANCE RATING (hours)</th></tr>
<tr><th>(mm)</th><th></th><th>(kg/m)</th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td rowspan="8">W14X (W360)</td><td>233</td><td>347</td><td rowspan="8">1½</td><td rowspan="2">1½</td><td rowspan="3">2½</td><td>3</td></tr>
<tr><td>211</td><td>314</td><td rowspan="2">3½</td></tr>
<tr><td>176</td><td>262</td><td rowspan="3">2</td></tr>
<tr><td>145</td><td>216</td><td rowspan="3">3</td><td rowspan="3">4</td></tr>
<tr><td>109</td><td>162</td></tr>
<tr><td>99</td><td>147</td><td rowspan="3">2½</td></tr>
<tr><td>61</td><td>91</td><td rowspan="2">3½</td></tr>
<tr><td>43</td><td>64</td><td>4½</td></tr>
<tr><td rowspan="7">W12X (W310)</td><td>190</td><td>283</td><td rowspan="7">1½</td><td>1½</td><td rowspan="2">2½</td><td rowspan="3">3½</td></tr>
<tr><td>152</td><td>226</td><td rowspan="3">2</td></tr>
<tr><td>120</td><td>179</td><td rowspan="3">3</td></tr>
<tr><td>96</td><td>143</td><td rowspan="3">4</td></tr>
<tr><td>87</td><td>129</td><td rowspan="3">2½</td></tr>
<tr><td>58</td><td>86</td><td rowspan="2">3½</td></tr>
<tr><td>40</td><td>60</td><td>4½</td></tr>
<tr><td rowspan="5">W10X (W250)</td><td>112</td><td>167</td><td rowspan="5">1½</td><td rowspan="2">2</td><td rowspan="3">3</td><td>3½</td></tr>
<tr><td>88</td><td>131</td><td rowspan="3">4</td></tr>
<tr><td>77</td><td>115</td><td rowspan="3">2½</td></tr>
<tr><td>54</td><td>80</td><td rowspan="2">3½</td></tr>
<tr><td>33</td><td>49</td><td>4½</td></tr>
<tr><td rowspan="6">W8X (W200)</td><td>67</td><td>100</td><td rowspan="6">1½</td><td>2</td><td>3</td><td rowspan="3">4</td></tr>
<tr><td>58</td><td>86</td><td rowspan="3">2½</td><td rowspan="4">3½</td></tr>
<tr><td>48</td><td>71</td></tr>
<tr><td>28</td><td>42</td><td rowspan="3">4½</td></tr>
<tr><td>21</td><td>31</td><td rowspan="2">3</td></tr>
<tr><td>18</td><td>27</td><td>4</td></tr>
<tr><td rowspan="5">W6X (W150)</td><td>25</td><td>37</td><td rowspan="3">1½</td><td>2½</td><td rowspan="2">3½</td><td rowspan="4">4½</td></tr>
<tr><td>20</td><td>30</td><td rowspan="4">3</td></tr>
<tr><td>16</td><td>24</td><td rowspan="3">4</td></tr>
<tr><td>12</td><td>18</td><td rowspan="2">2</td></tr>
<tr><td>9</td><td>13</td><td>5</td></tr>
</table>

[1]The tabulated thicknesses are based on the assumed properties of normal-weight concrete given in Table 7-7-S-B.

TABLE 7-7-S-F—THICKNESS STRUCTURAL OF LIGHTWEIGHT[1] PRECAST CONCRETE COVERS FOR VARIOUS FIRE-RESISTANCE RATINGS FOR TYPICAL WIDE-FLANGE STRUCTURAL STEEL COLUMNS [Inches (mm)] (Figure 7-7-S-6, Detail A)

<table>
<tr><th colspan="3">STRUCTURAL STEEL COLUMN SHAPES</th><th colspan="4">FIRE-RESISTANCE RATING (hours)</th></tr>
<tr><th>(mm)</th><th></th><th>(kg/m)</th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td rowspan="8">W14X
(W360)</td><td>233</td><td>347</td><td rowspan="8">1 1/2</td><td>1 1/2</td><td rowspan="3">2</td><td rowspan="2">2 1/2</td></tr>
<tr><td>176</td><td>262</td><td rowspan="4">1 1/2</td></tr>
<tr><td>145</td><td>216</td><td rowspan="4">3</td></tr>
<tr><td>132</td><td>196</td><td rowspan="4">2 1/2</td></tr>
<tr><td>109</td><td>162</td></tr>
<tr><td>99</td><td>147</td><td rowspan="3">2</td></tr>
<tr><td>68</td><td>101</td><td rowspan="2">3 1/2</td></tr>
<tr><td>43</td><td>64</td><td>3</td></tr>
<tr><td rowspan="8">W12X
(W310)</td><td>190</td><td>283</td><td rowspan="8">1 1/2</td><td>1 1/2</td><td rowspan="3">2</td><td rowspan="2">2 1/2</td></tr>
<tr><td>152</td><td>226</td><td rowspan="4">1 1/2</td></tr>
<tr><td>136</td><td>202</td><td rowspan="4">3</td></tr>
<tr><td>106</td><td>158</td><td rowspan="4">2 1/2</td></tr>
<tr><td>96</td><td>143</td></tr>
<tr><td>87</td><td>129</td><td rowspan="3">2</td></tr>
<tr><td>65</td><td>97</td><td rowspan="2">3 1/2</td></tr>
<tr><td>40</td><td>60</td><td>3</td></tr>
<tr><td rowspan="7">W10X
(W250)</td><td>112</td><td>167</td><td rowspan="7">1 1/2</td><td rowspan="3">1 1/2</td><td>2</td><td rowspan="4">3</td></tr>
<tr><td>100</td><td>149</td><td rowspan="4">2 1/2</td></tr>
<tr><td>88</td><td>131</td></tr>
<tr><td>77</td><td>115</td><td rowspan="4">2</td></tr>
<tr><td>60</td><td>89</td><td rowspan="3">3 1/2</td></tr>
<tr><td>39</td><td>58</td><td rowspan="2">3</td></tr>
<tr><td>33</td><td>49</td></tr>
<tr><td rowspan="5">W8X
(W200)</td><td>67</td><td>100</td><td rowspan="5">1 1/2</td><td>1 1/2</td><td rowspan="2">2 1/2</td><td>3</td></tr>
<tr><td>48</td><td>71</td><td rowspan="3">2</td><td rowspan="3">3 1/2</td></tr>
<tr><td>35</td><td>52</td><td rowspan="3">3</td></tr>
<tr><td>28</td><td>42</td></tr>
<tr><td>18</td><td>27</td><td>2 1/2</td><td>4</td></tr>
<tr><td rowspan="3">W6X
(W150)</td><td>25</td><td>37</td><td rowspan="3">1 1/2</td><td>2</td><td rowspan="2">3</td><td>3 1/2</td></tr>
<tr><td>15</td><td>22</td><td rowspan="2">2 1/2</td><td rowspan="2">4</td></tr>
<tr><td>9</td><td>13</td><td>3 1/2</td></tr>
</table>

[1]The tabulated thicknesses are based on the assumed properties of structural lightweight concrete given in Table 7-7-S-B.

TABLE 7-7-S-G—EQUIVALENT THICKNESS OF NORMAL-WEIGHT CONCRETE MASONRY FIRE PROTECTION FOR TYPICAL WIDE-FLANGE STRUCTURAL STEEL COLUMNS[1, 2] [Inches (mm)] (See Figure 7-7-S-7)

STRUCTURAL STEEL COLUMN SHAPES			FIRE-RESISTANCE RATING (hours)			
(mm)		(kg/m)	1	2	3	4
W14X (W360)	233	347	0.4	1.1	1.8	2.5
	176	262	0.6	1.4	2.1	2.8
	145	216	0.7	1.5	2.3	3.0
	132	196	0.7	1.6	2.4	3.1
	109	162	0.8	1.7	2.5	3.3
	99	147	0.9	1.8	2.6	3.4
	68	101	1.0	2.0	2.9	3.6
	43	64	1.2	2.3	3.1	3.9
W12X (W310)	190	283	0.4	1.2	1.9	2.6
	152	226	0.6	1.4	2.1	2.8
	136	202	0.6	1.5	2.2	2.9
	106	158	0.8	1.7	2.5	3.2
	96	143	0.8	1.7	2.5	3.3
	87	129	0.9	1.8	2.6	3.4
	65	97	1.0	2.0	2.8	3.6
	40	60	1.0	2.2	3.1	3.8
W10X (W250)	112	167	0.6	1.5	2.3	3.0
	100	149	0.7	1.6	2.4	3.1
	88	131	0.8	1.7	2.5	3.2
	77	115	0.8	1.8	2.6	3.3
	60	89	1.0	1.9	2.8	3.5
	39	58	1.2	2.2	3.0	3.8
	33	49	1.2	2.3	3.1	3.9
W8X (W200)	67	100	0.8	1.7	2.6	3.3
	48	71	1.0	2.0	2.8	3.6
	35	52	1.1	2.2	3.0	3.8
	28	42	1.2	2.3	3.1	3.9
	18	27	1.4	2.3	3.3	4.0
W6X (W150)	25	37	1.2	2.2	3.1	3.8
	15	22	1.4	2.4	3.3	4.0
	9	13	1.5	2.6	3.4	4.2

[1]The tabulated thicknesses are based on the assumed properties of normal-weight concrete masonry given in Table 7-7-S-B.
[2]The thicknesses of concrete masonry units shall not be less than set forth in Section 7.703.4.

TABLE 7-7-S-H—EQUIVALENT THICKNESS OF LIGHTWEIGHT CONCRETE MASONRY FIRE PROTECTION FOR TYPICAL WIDE-FLANGE STRUCTURAL STEEL COLUMNS[1, 2] [Inches (mm)] (See Figure 7-7-S-7)

STRUCTURAL STEEL COLUMN SHAPES			FIRE-RESISTANCE RATING (hours)			
(mm)		(kg/m)	1	2	3	4
W14X (W360)	233	347	0.3	0.9	1.5	2.1
	176	262	0.4	1.1	1.8	2.4
	145	216	0.5	1.3	1.9	2.6
	132	196	0.6	1.3	2.0	2.7
	109	162	0.7	1.5	2.2	2.9
	99	147	0.7	1.5	2.3	2.9
	68	101	0.9	1.8	2.5	3.2
	43	64	1.1	2.0	2.8	3.5
W12X (W310)	190	283	0.3	0.9	1.5	2.1
	152	226	0.4	1.1	1.8	2.4
	136	202	0.5	1.2	1.9	2.5
	106	158	0.6	1.4	2.1	2.8
	96	143	0.7	1.5	2.2	2.8
	87	129	0.7	1.5	2.3	2.9
	65	97	0.8	1.7	2.5	3.2
	40	60	1.1	2.0	2.8	3.5
W10X (W250)	112	167	0.5	1.2	1.9	2.5
	100	149	0.5	1.3	2.0	2.7
	88	131	0.6	1.4	2.1	2.8
	77	115	0.7	1.5	2.2	2.9
	60	89	0.8	1.7	2.4	3.1
	39	58	1.0	1.9	2.7	3.4
	33	49	1.1	2.0	2.8	3.5
W8X (W200)	67	100	0.6	1.5	2.2	2.9
	48	71	0.8	1.7	2.5	3.2
	35	52	1.0	1.9	2.7	3.4
	28	42	1.1	2.0	2.8	3.5
	18	27	1.2	2.2	3.0	3.7
W6X (W150)	25	37	1.0	2.0	2.7	3.4
	15	22	1.2	2.2	3.0	3.7
	9	13	1.4	2.3	3.1	3.8

[1]The tabulated thicknesses are based on the assumed properties of normal-weight concrete masonry given in Table 7-7-S-B.

[2]The thicknesses of concrete masonry units shall not be less than set forth in Section 7.703.4.

TABLE 7-7-S-I—WEIGHT-TO-HEATED-PERIMETER RATIOS *W/D* FOR TYPICAL WIDE-FLANGE BEAM AND GIRDER SHAPES

STRUCTURAL SHAPE		CONTOUR PROFILE	BOX PROFILE
in. × lb./ft.	mm × kg/m	× 0.059 for metric *W/D*	
W36 × 300	W920 × 446	2.47	3.33
× 280	× 417	2.31	3.12
× 260	× 387	2.16	2.92
× 245	× 365	2.04	2.76
× 230	× 342	1.92	2.61
× 210	× 313	1.94	2.45
× 194	× 289	1.80	2.28
× 182	× 271	1.69	2.15
× 170	× 253	1.59	2.01
× 160	× 238	1.50	1.90
× 150	× 223	1.41	1.79
× 135	× 201	1.28	1.63
W33 × 241	W840 × 359	2.11	2.86
× 221	× 329	1.94	2.64
× 201	× 299	1.78	2.42
× 154	× 226	1.51	1.94
× 141	× 210	1.41	1.80
× 130	× 193	1.31	1.67
× 118	× 176	1.19	1.53
W30 × 211	W760 × 314	2.00	2.74
× 191	× 284	1.82	2.50
× 173	× 257	1.66	2.28
× 132	× 196	1.45	1.85
× 124	× 185	1.37	1.75
× 116	× 173	1.28	1.65
× 108	× 161	1.20	1.54
× 99	× 147	1.10	1.42
W27 × 178	W690 × 265	1.85	2.55
× 161	× 240	1.68	2.33
× 146	× 217	1.53	2.12
× 114	× 170	1.36	1.76
× 102	× 152	1.23	1.59
× 94	× 140	1.13	1.47
× 84	× 125	1.02	1.33
W24 × 162	W610 × 241	1.85	2.57
× 146	× 217	1.68	2.34
× 131	× 195	1.52	2.12
× 117	× 174	1.36	1.91
× 104	× 155	1.22	1.71
× 94	× 140	1.26	1.63
× 84	× 125	1.13	1.47
× 76	× 113	1.03	1.34
× 68	× 101	0.92	1.21
× 62	× 92	0.92	1.14
× 55	× 82	0.82	1.02
W21 × 147	W530 × 219	1.83	2.60
× 132	× 196	1.66	2.35
× 122	× 182	1.54	2.19
× 111	× 165	1.41	2.01
× 101	× 150	1.29	1.84
× 93	× 138	1.38	1.80
× 83	× 123	1.24	1.62
× 68	× 101	1.03	1.35
× 62	× 92	0.94	1.23
× 57	× 85	0.93	1.17
× 50	× 74	0.83	1.04
× 44	× 66	0.73	0.92

(Continued)

TABLE 7-7-S-I—WEIGHT-TO-HEATED-PERIMETER RATIOS *W/D* FOR TYPICAL WIDE-FLANGE BEAM AND GIRDER SHAPES—(Continued)

STRUCTURAL SHAPE		CONTOUR PROFILE	BOX PROFILE
in. × lb./ft.	mm × kg/m	× 0.059 for metric *W/D*	
W18 × 119	W460 × 177	1.69	2.42
× 106	× 158	1.52	2.18
× 97	× 144	1.39	2.01
× 86	× 128	1.24	1.80
× 76	× 113	1.11	1.60
× 71	× 106	1.21	1.59
× 65	× 97	1.11	1.47
× 60	× 89	1.03	1.36
× 55	× 82	0.95	1.26
× 50	× 74	0.87	1.15
× 46	× 68	0.86	1.09
× 40	× 60	0.75	0.96
× 35	× 52	0.66	0.85
W16 × 100	W410 × 149	1.56	2.25
× 89	× 132	1.40	2.03
× 77	× 114	1.22	1.78
× 67	× 100	1.07	1.56
× 57	× 85	1.07	1.43
× 50	× 75	0.94	1.26
× 45	× 67	0.85	1.15
× 40	× 60	0.76	1.03
× 36	× 53	0.69	0.93
× 31	× 46	0.65	0.83
× 26	× 39	0.55	0.70
W14 × 132	W360 × 196	1.83	3.00
× 120	× 179	1.67	2.75
× 109	× 162	1.53	2.52
× 99	× 147	1.39	2.31
× 90	× 134	1.27	2.11
× 82	× 122	1.41	2.12
× 74	× 110	1.28	1.93
× 68	× 101	1.19	1.78
× 61	× 91	1.07	1.61
× 53	× 79	1.03	1.48
× 48	× 72	0.94	1.35
× 43	× 64	0.85	1.22
× 38	× 58	0.79	1.09
× 34	× 51	0.71	0.98
× 30	× 44	0.63	0.87
× 26	× 39	0.61	0.79
× 22	× 33	0.52	0.68
W12 × 87	W310 × 129	1.44	2.34
× 79	× 117	1.32	2.14
× 72	× 107	1.20	1.97
× 65	× 97	1.09	1.79
× 58	× 86	1.08	1.69
× 53	× 79	0.99	1.55
× 50	× 74	1.04	1.54
× 45	× 67	0.95	1.40
× 40	× 60	0.85	1.25
× 35	× 52	0.79	1.11
× 30	× 45	0.69	0.96
× 26	× 39	0.60	0.84
× 22	× 33	0.61	0.77
× 19	× 28	0.53	0.67
× 16	× 24	0.45	0.57
× 14	× 21	0.40	0.50

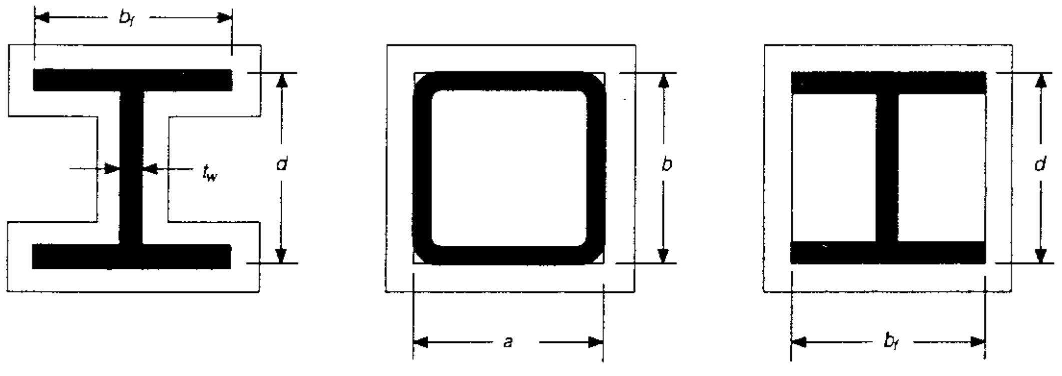
(Continued)

TABLE 7-7-S-I—WEIGHT-TO-HEATED-PERIMETER RATIOS *W/D* FOR TYPICAL WIDE-FLANGE BEAM AND GIRDER SHAPES—(Continued)

STRUCTURAL SHAPE		CONTOUR PROFILE	BOX PROFILE
in. × lb./ft.	mm × kg/m	× 0.059 for metric *W/D*	
W10 × 112	W250 × 167	2.14	3.38
× 100	× 149	1.93	3.07
× 88	× 131	1.72	2.75
× 77	× 115	1.52	2.45
× 68	× 101	1.35	2.20
× 60	× 89	1.20	1.97
× 54	× 80	1.09	1.79
× 49	× 73	0.99	1.64
× 45	× 67	1.03	1.59
× 39	× 58	0.90	1.40
× 33	× 49	0.77	1.20
× 30	× 45	0.79	1.12
× 26	× 39	0.69	0.98
× 22	× 33	0.59	0.84
× 19	× 28	0.59	0.78
× 17	× 25	0.54	0.70
× 15	× 22	0.48	0.63
× 12	× 18	0.38	0.51
W8 × 67	W200 × 100	1.61	2.55
× 58	× 86	1.41	2.26
× 48	× 71	1.18	1.91
× 40	× 59	1.00	1.63
× 35	× 52	0.88	1.44
× 31	× 46	0.79	1.29
× 28	× 42	0.80	1.24
× 24	× 36	0.69	1.07
× 21	× 31	0.66	0.96
× 18	× 27	0.57	0.84
× 15	× 22	0.54	0.74
× 13	× 19	0.47	0.65
× 10	× 15	0.37	0.51
W6 × 25	W150 × 37	0.82	1.33
× 20	× 30	0.67	1.09
× 16	× 24	0.66	0.96
× 15	× 22	0.51	0.83
× 12	× 18	0.51	0.75
× 9	× 13	0.39	0.57
W5 × 19	W130 × 28	0.76	1.24
× 16	× 24	0.65	1.07
W4 × 13	W100 × 19	0.65	1.05

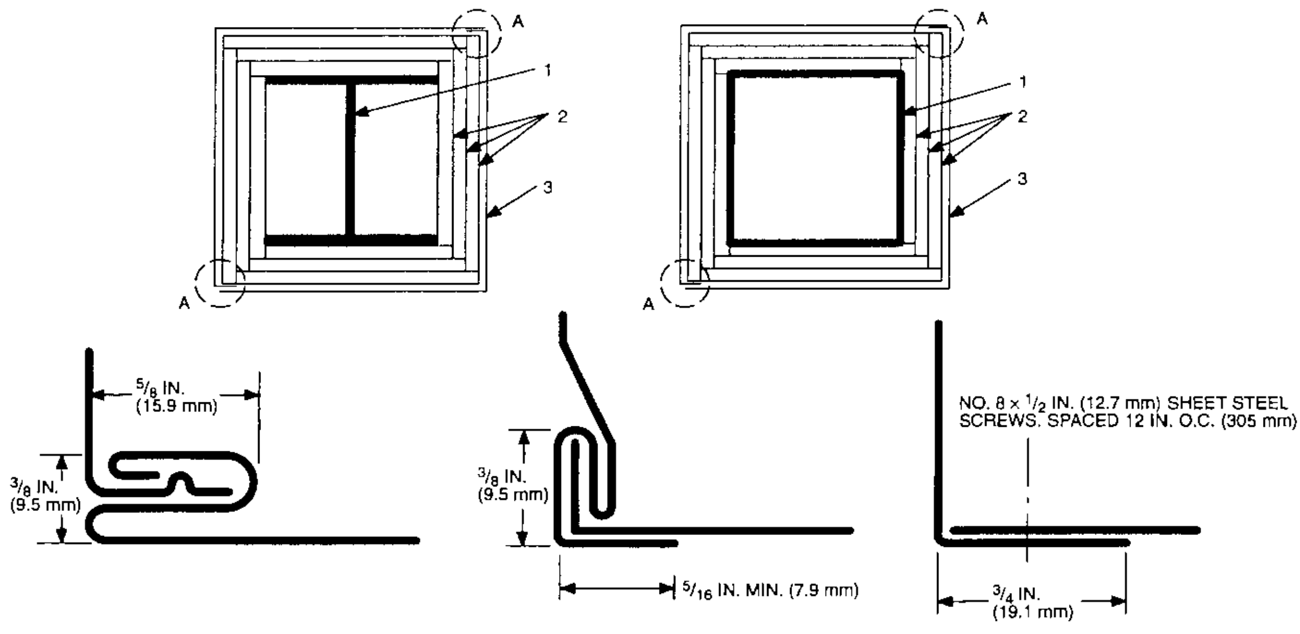
TABLE 7-7-S-J—THERMAL CONDUCTIVITY OF CONCRETE MASONRY UNITS AT 70°F (21°C)

DENSITY (*D*) (pcf)	THERMAL CONDUCTIVITY (*K*) (Btu/hr.ft .°F)
× 16 for kg/m³	× 1.73 for W/m•K
80	0.207
85	0.228
90	0.252
95	0.278
100	0.308
105	0.340
110	0.376
115	0.416
120	0.459
125	0.508
130	0.561
135	0.620
140	0.685
145	0.758
150	0.837



$D = 4b_f + 2d - 2t_w$ $D = 2(a + b)$ $D = 2(b_f + d)$

FIGURE 7-7-S-1—DETERMINATION OF THE HEATED PERIMETER OF STRUCTURAL STEEL COLUMNS



CORNER JOINT DETAILS (A)

NOTES:

1. Structural steel column, either wide-flange or tubular shapes.
2. Type X gypsum wallboard. For single-layer applications, the wallboard shall be applied vertically with no horizontal joints. For multiple-layer applications, horizontal joints are permitted at a minimum spacing of 8 feet (2438 mm), provided that the joints in successive layers are staggered at least 12 inches (305 mm). The total required thickness of wallboard shall be determined on the basis of the specified fire-resistance rating and the weight and heated perimeter of the column. For fire-resistance ratings of two hours or less, one of the required layers of gypsum wallboard may be applied to the exterior of the sheet steel column covers with 1-inch-long (25.4 mm) Type S screws spaced 1 inch (25.4 mm) from the wallboard edge and 8 inches (203.2 mm) on center. For such installations, 0.016-inch-minimum-thickness (0.4 mm) galvanized steel corner beads with $1^1/_2$-inch (38.1 mm) legs shall be attached to the wallboard with Type S screws spaced 12 inches (305 mm) on center.
3. For fire-resistance ratings of three hours or less, the column covers shall be fabricated from 0.024-inch-minimum-thickness (0.6 mm) galvanized or stainless steel. For four-hour fire-resistance ratings, the column covers shall be fabricated from 0.024-inch-minimum-thickness (0.6 mm) stainless steel. The column covers shall be erected with the snap lock or Pittsburgh joint details.

   For fire-resistance ratings of two hours or less, column covers fabricated from 0.027-inch-minimum-thickness (0.7 mm) galvanized or stainless steel may be erected with lap joints. The lap joints may be located anywhere around the perimeter of the column cover. The lap joints shall be secured with $^1/_2$-inch-long (12.7 mm) No. 8 sheet metal screws spaced 12 inches (305 mm) on center.

   The column covers shall be provided with a minimum expansion clearance of $^1/_8$ inch (10.4 mm) per linear foot (m) between the ends of the cover and any restraining construction.

FIGURE 7-7-S-2—GYPSUM WALLBOARD PROTECTED STRUCTURAL STEEL COLUMNS WITH SHEET STEEL COLUMN COVERS (FOUR HOURS OR LESS)

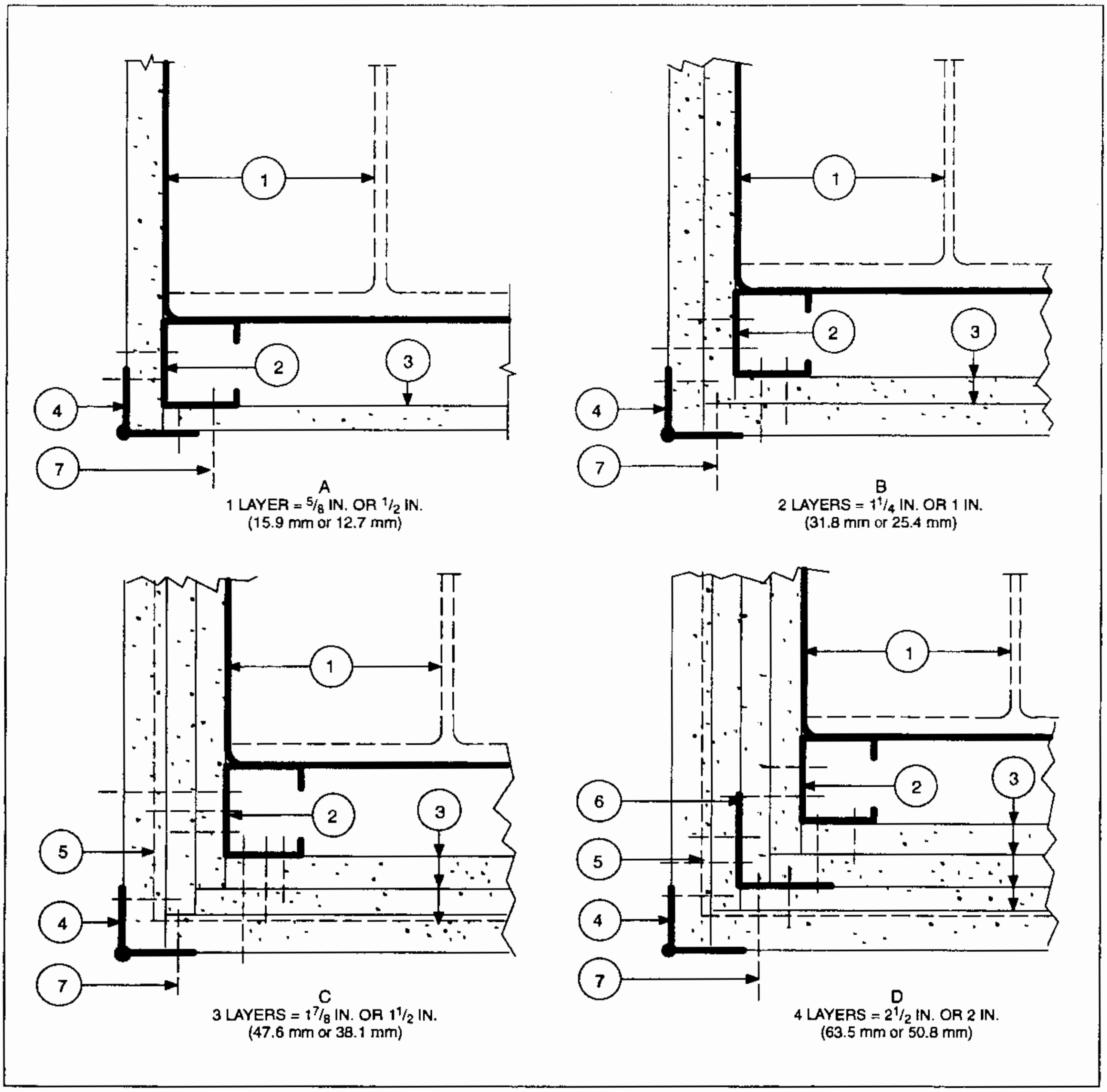
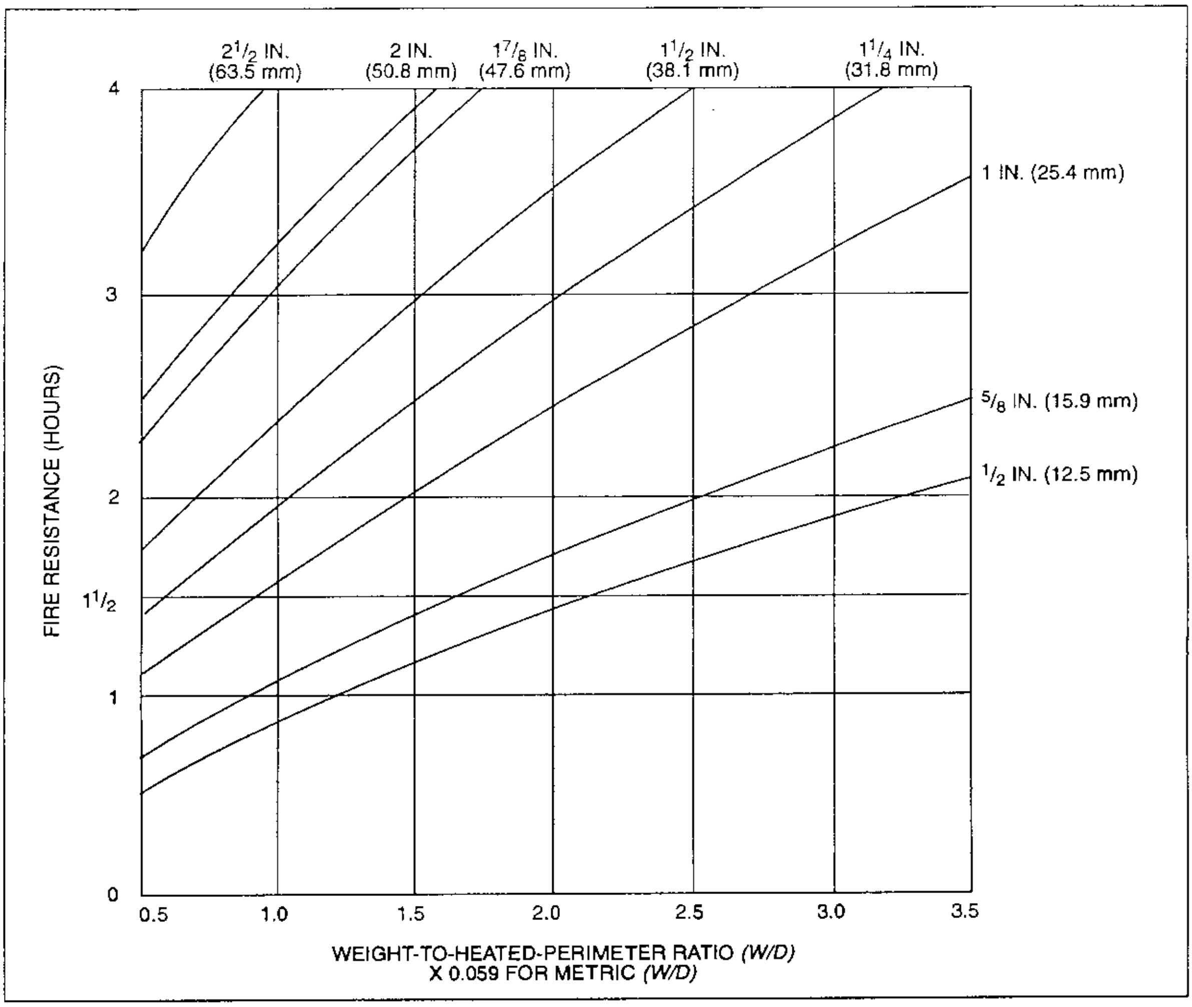


FIGURE 7-7-S-3—GYPSUM WALLBOARD PROTECTED STRUCTURAL STEEL COLUMNS WITH STEEL STUD/SCREW ATTACHMENT SYSTEM (THREE HOURS OR LESS)

NOTES:

1. Structural steel column, either wide-flange or tubular shapes.
2. One and five-eighths-inch-deep (41.3 mm) studs fabricated from 0.021-inch-minimum-thickness (0.5 mm) galvanized steel with $1^5/_{16}$- or $1^7/_{16}$-inch (33.3 mm or 36.5 mm) legs and $^1/_4$-inch (6.4 mm) stiffening flanges. The length of the steel studs shall be $^1/_2$ inch (12.7 mm) less than the height of the assembly.
3. Type X gypsum wallboard. For single-layer applications, the wallboard shall be applied vertically with no horizontal joints. For multiple-layer applications, horizontal joints are permitted at a minimum spacing of 8 feet (2438 mm), provided that the joints in successive layers are staggered at least 12 inches (305 mm). The total required thickness of wallboard shall be determined on the basis of the specified fire-resistance rating and the weight and heated perimeter of the column.
4. Galvanized steel corner beads [0.016-inch (0.4 mm) minimum thickness] with $1^1/_2$-inch (38.1 mm) legs attached to the wallboard with 1-inch-long (25.4 mm) Type S screws spaced 12 inches (305 mm) on center.
5. No. 18 SWG steel tie wires spaced 24 inches (610 mm) on center.
6. Sheet metal angles with 2-inch (50.8 mm) legs fabricated from 0.021-inch-minimum-thickness (0.5 mm) galvanized steel.
7. Type S screws 1-inch (25.4 mm) long shall be used for attaching the first layer of wallboard to the steel studs and the third layer to the sheet metal angles at 24 inches (610 mm) on center. Type S screws $1^3/_4$ inches (44.5 mm) long shall be used for attaching the second layer of wallboard to the steel studs and the fourth layer to the sheet metal angles at 12 inches (305 mm) on center. Type S screws $2^1/_4$ inches (57.1 mm) long shall be used for attaching the third layer of wallboard to the steel studs at 12 inches (305 mm) on center.



NOTE: The *W/D* ratios for typical wide-flange columns are listed in Table 7-7-S-A1. For other column shapes, the *W/D* ratios shall be determined in accordance with Section 7.703.

FIGURE 7-7-S-4—FIRE RESISTANCE OF STRUCTURAL STEEL COLUMNS PROTECTED WITH VARIOUS THICKNESSES OF TYPE X GYPSUM WALLBOARD

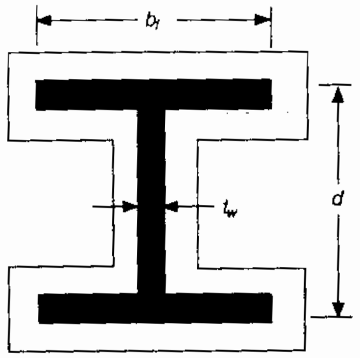
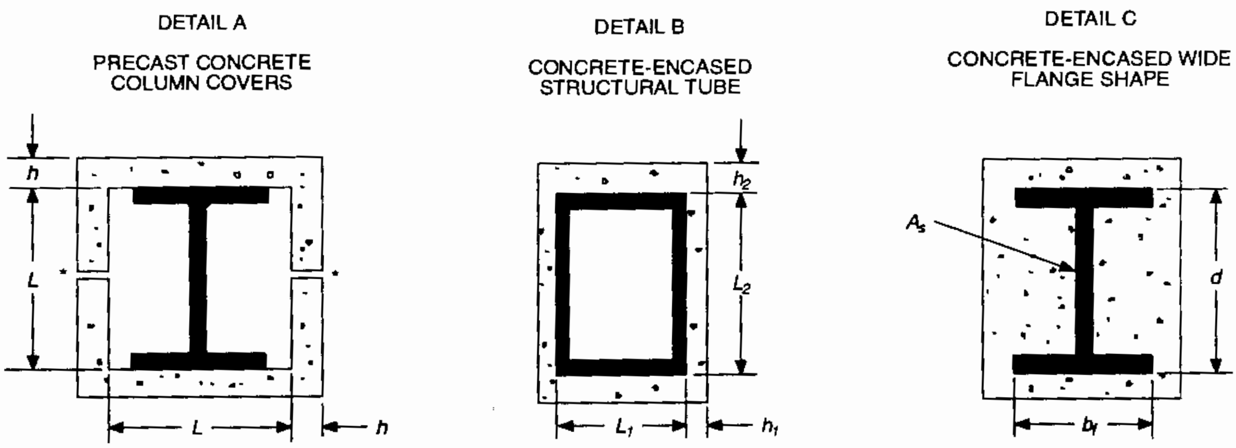


FIGURE 7-7-S-5—WIDE FLANGE STRUCTURAL STEEL COLUMN WITH SPRAY-APPLIED FIRE-RESISTIVE MATERIAL



NOTE: When the inside perimeter of the concrete protection is not square, L shall be taken as the average of L_1 and L_2. When the thickness of concrete cover is not constant, h shall be taken as the average of h_1 and h_2.
*Joints shall be protected with a minimum 1 inch (25.4 mm) thickness of ceramic fiber blanket, but in no case less than one half the thickness of the column cover. The joint width shall not exceed 1 inch (25.4 mm) maximum.

FIGURE 7-7-S-6—CONCRETE-PROTECTED STRUCTURAL STEEL COLUMNS

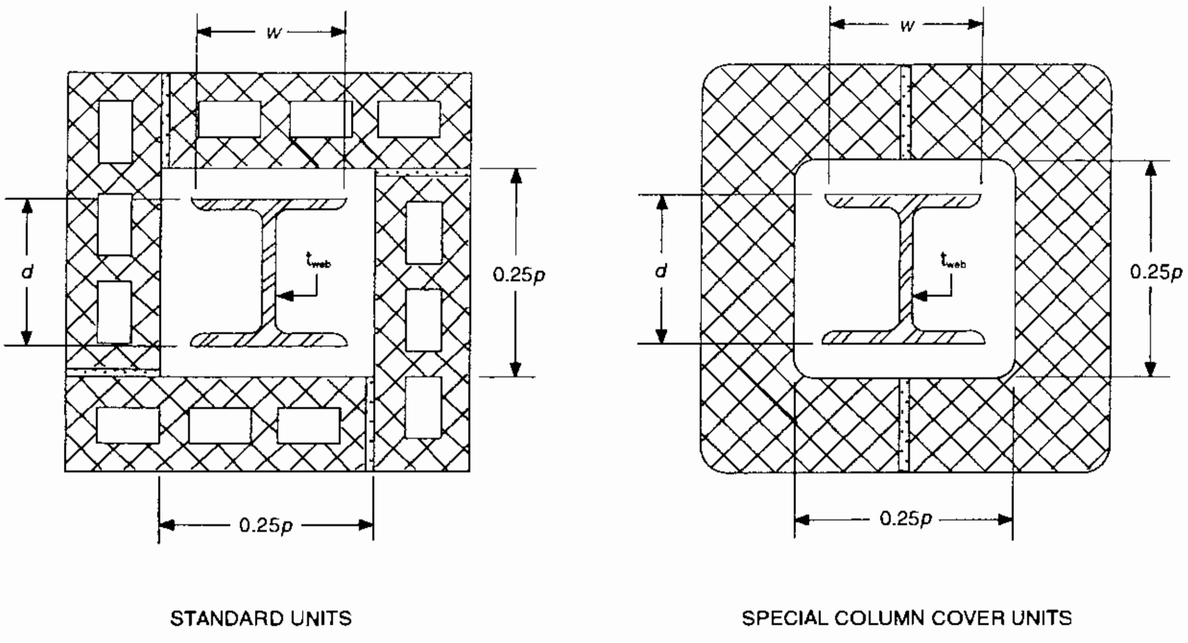


FIGURE 7-7-S-7—CONCRETE MASONRY PROTECTED STRUCTURAL STEEL COLUMNS

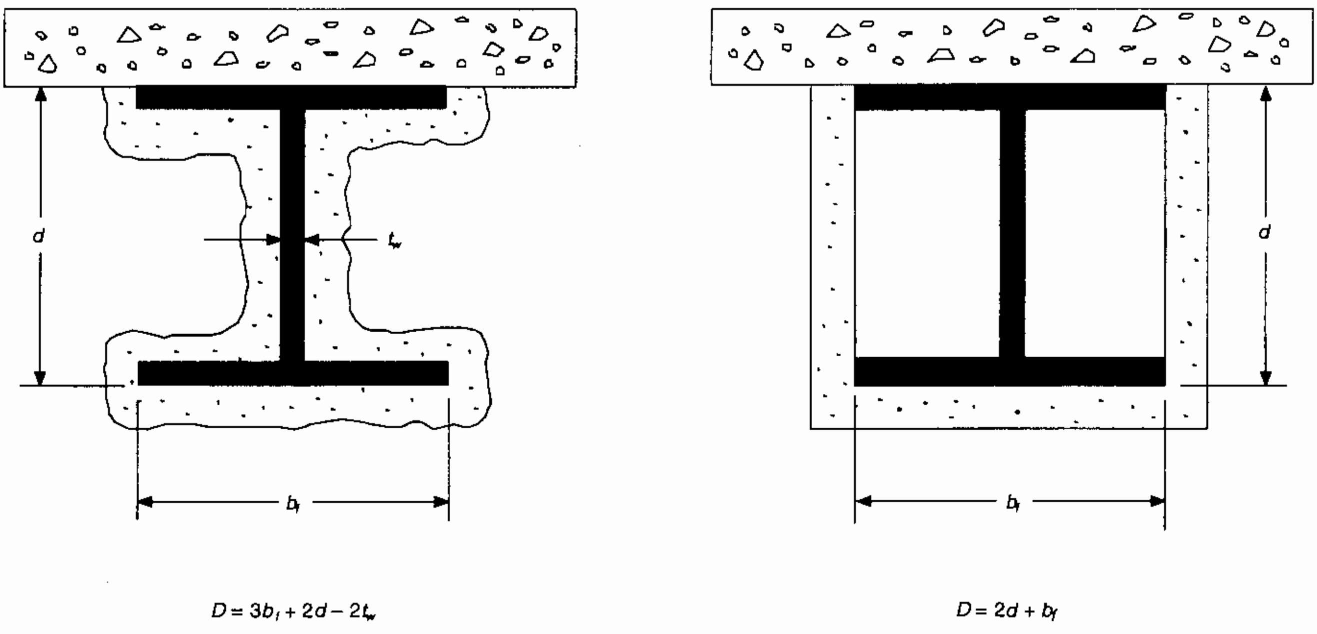


FIGURE 7-7-S-8—DETERMINATION OF THE HEATED PERIMETER OF STRUCTURAL STEEL BEAMS AND GIRDERS

Part II—Method for Calculating the Fire Resistance of Concrete Construction

See Section 703.3, *Uniform Building Code*

SECTION 7.705 — SCOPE

This part of this standard contains procedures by which the fire resistance of concrete of specific materials or combinations of materials can be established by calculations. These procedures apply to the material contained in this part only. Procedures shown in this standard for calculating the fire resistance of concrete construction shall apply to all cast-in-place and precast concrete, conventionally reinforced or prestressed. The procedures shall not apply to single or double "T" precast, prestressed (pretensioned) units in wall or floor-roof assemblies.

SECTION 7.706 — DEFINITIONS

CARBONATE AGGREGATE CONCRETE is concrete made with aggregates consisting mainly of calcium or magnesium carbonate, e.g., limestone or dolomite.

CELLULAR CONCRETE is a lightweight insulating concrete made by mixing a preformed foam with portland cement slurry and having a dry unit weight of approximately 30 pounds per cubic foot (pcf).

CERAMIC FIBER BLANKET is a mineral wool insulation material made of alumina-silica fibers and weighing 4 to 10 pcf (64 to 160 kg/m^3).

GLASS FIBER BOARD is fibrous glass roof insulation consisting of inorganic glass fibers formed into rigid boards using a binder. The board has a top surface faced with asphalt and kraft paper reinforced with glass fibers.

LIGHTWEIGHT AGGREGATE CONCRETE is concrete made with aggregates of expanded clay, shale, slag or slate or sintered fly ash and weighing 85 to 115 pcf (1362 to 1842 kg/m^3).

MINERAL BOARD is a rigid felted thermal insulation board consisting of either felted mineral fiber or cellular beads of expanded aggregate formed into flat rectangular units.

PERLITE CONCRETE is a lightweight insulating concrete having a dry unit weight of approximately 30 pcf (482 kg/m^3) made with perlite concrete aggregate. Perlite aggregate is produced from a volcanic rock which, when heated, expands to form a glass-like material of cellular structure.

SAND-LIGHTWEIGHT CONCRETE is concrete made with a combination of expanded clay, shale, slag or slate or sintered fly ash and natural sand. Its unit weight is generally between 105 and 120 pcf (1682 to 1930 kg/m^3).

SILICEOUS AGGREGATE CONCRETE is concrete made with normal-weight aggregates consisting mainly of silica or compounds other than calcium or magnesium carbonate.

VERMICULITE CONCRETE is a lightweight insulating concrete made with vermiculite concrete aggregate, which is laminated micaceous material produced by expanding the ore at high temperatures. When added to a portland cement slurry, the resulting concrete has a dry unit weight of approximately 30 pcf (482 kg/m^3).

SECTION 7.707 — CONCRETE WALLS

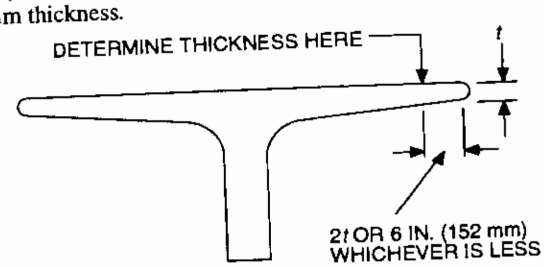
7.707.1 Walls, Cast-in-place or Precast.

1. The minimum equivalent thicknesses of cast-in-place or precast concrete walls for fire-resistance ratings from one to four hours are shown in Table 7-7-C-A. For solid walls with flat vertical surfaces, the equivalent thickness is the same as the thickness. The values in Table 7-7-C-A apply to plain, reinforced or prestressed concrete walls.

2. For hollow-core precast concrete wall panels in which the cores are of constant cross section throughout the length, the equivalent thickness may be calculated by dividing the net cross-sectional area (the gross cross section minus the area of the cores) of the panel by its width.

3. Where all of the core spaces of hollow-core wall panels are filled with loose-fill material, such as expanded shale, clay or slag, or vermiculite or perlite, the fire-resistance rating of the wall is the same as that of a solid wall of the same concrete type and of the same overall thickness.

4. The thickness of panels with tapered cross sections shall be that determined at a distance $2t$ or 6 inches (152 mm), whichever is less, from the point of minimum thickness, where t is the minimum thickness.



5. The equivalent thickness of panels with ribbed or undulating surfaces shall be determined by one of the following expressions, whichever is applicable:

for $s \geq 4t$, the thickness to be used shall be t

for $s \leq 2t$, the thickness to be used shall be t_e

for $4t > s > 2t$, the thickness to be used shall be

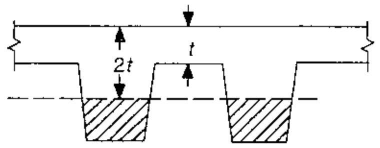
$$t + \left(\frac{4t}{s} - 1\right)(t_e - t)$$

WHERE:

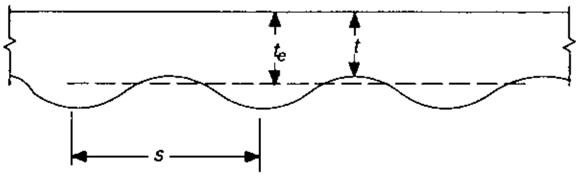
s = spacing of ribs or undulations.

t = minimum thickness.

t_e = equivalent thickness of the panel calculated as the net cross-sectional area of the panel divided by the width in which the maximum thickness used in the calculation shall not exceed $2t$.



NEGLECT SHADED AREA
IN CALCULATION OF
EQUIVALENT THICKNESS



7.707.2 Multiwythe Walls.

1. For walls which consist of two wythes of different types of concrete, the fire-resistance ratings may be determined from Figure 7-7-C-1.

2. The fire-resistance rating for wall panels consisting of two or more wythes may be determined by the formula:

$$R = (R_1{}^{0.59} + R_2{}^{0.59} + \ldots R_n{}^{0.59})^{1.7} \qquad (7\text{-}1)$$

Formula (7-1) can also be expressed as:

$$R^{0.59} = R_1{}^{0.59} + R_2{}^{0.59} + \ldots \; R_n{}^{0.59}$$

WHERE:

R = the fire endurance of the assembly, minutes.

R_1,

R_2

and

R_n = the fire endurances of the individual wythes, minutes.

Values of $R_n{}^{0.59}$ for use in Formula (7-1) are given in Table 7-7-C-B.

R_1 MINUTES	$R^{0.59}$
60	11.20
90	14.22
120	16.85
180	21.41
240	25.37

3. The fire-resistance ratings of precast concrete wall panels consisting of a layer of foam plastic insulation sandwiched between two wythes of concrete may be determined by use of Formula (7-1). Foam plastic insulation with a total thickness of less than 1 inch (25 mm) shall be disregarded. The R_n value for thickness of foam plastic insulation of 1 inch (25 mm) or greater, for use in the calculation, is five minutes; therefore, $R_n{}^{0.59} = 2.5$.

7.707.3 Joints between Precast Concrete Wall Panels. Where openings in exterior walls are required to be protected, or where openings are not permitted in walls, the provisions of this section shall be used to determine the amount of joint insulation required.

Figure 7-7-C-2 shows thicknesses of ceramic fiber blankets to be used to protect joints between precast concrete wall panels for various panel thicknesses. For joint widths of $^3/_8$ inch and 1 inch (10 mm and 25 mm) for fire-resistance ratings of one hour to four hours for joint widths between $^3/_8$ inch and 1 inch (10 mm and 25 mm), the thickness of ceramic fiber blanket may be determined by direct interpolation. Other approved tested and labeled materials may be used in place of ceramic fiber blankets.

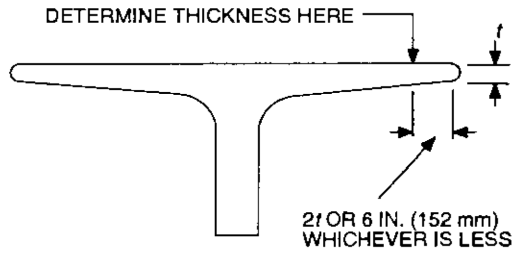
SECTION 7.708 — CONCRETE FLOOR AND ROOF SLABS

7.708.1 Reinforced and Prestressed Concrete Floor and Roof Slabs.

1. The minimum thickness of reinforced and prestressed concrete floor or roof slabs for fire-resistance ratings from one to four hours are shown in Table 7-7-C-C.

2. For hollow-core prestressed concrete slabs in which the cores are of constant cross section throughout the length, the equivalent thickness may be obtained by dividing the net cross-sectional area of the slab, including grout in the joints, by its width.

3. The thickness of slabs with sloping soffits shall be determined at a distance of $2t$ or 6 inches (152 mm), whichever is less, from the point of minimum thickness, where t is the minimum thickness.



4. The thickness of slabs with ribbed or undulating soffits shall be determined by one of the following expressions, whichever is applicable:

for $s \geq 4t$, the thickness to be used shall be t

for $s \leq 2t$, the thickness to be used shall be t_e

for $4t > s > 2t$, the thickness to be used shall be

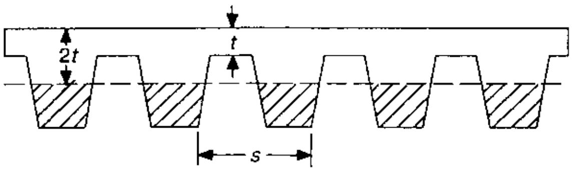
$$t + \left(\frac{4t}{s} - 1\right)(t_e - t)$$

WHERE:

s = spacing of ribs or undulations.

t = minimum thickness.

t_e = equivalent thickness of the panel calculated as the net cross-sectional area of the panel divided by the width in which the maximum thickness used in the calculation shall not exceed $2t$.



NEGLECT SHADED AREA
IN CALCULATION OF
EQUIVALENT THICKNESS

7.708.2 Multicourse Floors and Roofs.

1. Figure 7-7-C-3A gives information on the fire-resistance ratings of floors which consist of a base slab of concrete with a topping (overlay) of a different type of concrete.

2. Figure 7-7-C-3B gives information on the fire-resistance ratings of roofs which consist of a base slab of concrete with a topping (overlay) of an insulating concrete or with an insulating board and built-up roofing. Three-ply built-up roofing contributes 10 minutes to the fire-resistance rating; therefore, 10 minutes can be added to the assemblies shown in Figure 7-7-C-3B, Details (a), (b) and (c), but not to those shown in Figure 7-7-C-3B, Details (d) and (e).

7.708.3 Joints in Precast Slabs. Joints between adjacent precast concrete slabs may be ignored in calculating the slab thickness, provided that a concrete topping at least 1 inch (25 mm) thick is used. Where no concrete topping is used, joints must be grouted to a depth of at least one third the slab thickness at the joint, but not less than 1 inch (25 mm), or the joints must be made fire resistive by other approved methods.

SECTION 7.709 — MINIMUM CONCRETE COVER REQUIREMENTS

7.709.1 Slabs. The minimum thickness of concrete cover to the positive moment reinforcement is given in Table 7-7-C-D for reinforced concrete and Table 7-7-C-E for prestressed concrete. Tables 7-7-C-D and 7-7-C-E are applicable for solid- or hollow-core one-way or two-way slabs with flat undersurfaces. Slabs may be cast-in-place or precast.

7.709.2 Beams.

1. The minimum thickness of concrete cover to the positive moment reinforcement (bottom steel) for reinforced concrete beams is shown in Table 7-7-C-F for fire-resistance ratings from one to four hours.

2. The minimum thickness of concrete cover to the positive moment prestressing tendon (bottom steel) for prestressed concrete beams is shown in Table 7-7-C-G for fire-resistance ratings from one to four hours.

SECTION 7.710 — CONCRETE COLUMNS

7.710.1 Minimum Size. Table 7-7-C-H shows the minimum overall dimensions of reinforced concrete columns for fire-resistance ratings from one to four hours.

7.710.2 Minimum Cover for Reinforced Concrete Columns. The minimum cover to the main reinforcement in columns for fire-resistance ratings of one hour, one and one-half hours, two hours and three hours shall be $1^1/_2$ inches (38 mm); for a four-hour rating, the minimum cover to the main reinforcement shall be 2 inches (51 mm) for siliceous aggregate concrete and $1^1/_2$ inches (38 mm) for carbonate aggregate concrete or sand-lightweight concrete.

TABLE 7-7-C-A—MINIMUM EQUIVALENT THICKNESS, INCHES, OF CAST-IN-PLACE OR PRECAST CONCRETE WALLS, LOAD BEARING OR NONLOAD BEARING

CONCRETE TYPE	MINIMUM WALL THICKNESS (INCHES) FOR FIRE-RESISTANCE RATING OF × 25.4 for mm				
	1 Hr.	$1^1/_2$ Hr.	2 Hr.	3 Hr.	4 Hr.
Siliceous[1]	3.5	4.3	5.0	6.2	7.0
Carbonate	3.2	4.0	4.6	5.7	6.6
Sand-lightweight	2.7	3.3	3.8	4.6	5.4
Lightweight concrete	2.5	3.1	3.6	4.4	5.1

[1]The equivalent thickness may include the thickness of portland cement plaster or 1.5 times the thickness of gypsum plaster applied in accordance with the requirements of Chapter 25.

TABLE 7-7-C-B—VALUES OF $R_n^{0.59}$ FOR USE IN FORMULA 1

TYPE OF MATERIAL	VALUES OF $R_n^{0.59}$ FOR USE IN EQUATION 1 FOR THICKNESS OF											
	$1^1/_2$ in. (38 mm)	2 in. (51 mm)	$2^1/_2$ in. (64 mm)	3 in. (76 mm)	$3^1/_2$ in. (89 mm)	4 in. (102 mm)	$4^1/_2$ in. (114 mm)	5 in. (127 mm)	$5^1/_2$ in. (140 mm)	6 in. (152 mm)	$6^1/_2$ in. (165 mm)	7 in. (178 mm)
Siliceous aggregate concrete	5.3	6.5	8.1	9.5	11.3	13.0	14.9	16.9	18.8	20.7	22.8	25.1
Carbonate aggregate concrete	5.5	7.1	8.9	10.4	12.0	14.0	16.2	18.1	20.3	21.9	24.7	27.2[3]
Sand-lightweight concrete	6.5	8.2	10.5	12.8	15.5	18.1	20.7	23.3	26.0[3]	[3]	[3]	[3]
Lightweight concrete	6.6	8.8	11.2	13.7	16.5	19.1	21.9	24.7	27.8[3]	[3]	[3]	[3]
Insulating concrete[1]	9.3	13.3	16.6	18.3	23.1	26.5[3]	[3]	[3]	[3]	[3]	[3]	[3]
Air space[2]	—	—	—	—	—	—	—	—	—	—	—	—

[1]Dry unit weight of 35 pcf (563 kg/m^3) or less and consisting of cellular, perlite or vermiculite concrete.
[2]The $R_n^{0.59}$ value for $^1/_2$ inch to $3^1/_2$ inches (13 mm to 89 mm) air space is 3.3. The $R_n^{0.59}$ value for $2^1/_2$ inches to $3^1/_2$ inches (64 mm to 89 mm) air space is 6.7.
[3]The fire-resistance rating for this thickness exceeds four hours.

TABLE 7-7-C-C—MINIMUM SLAB THICKNESS FOR CONCRETE FLOORS OR ROOFS

CONCRETE TYPE	MINIMUM WALL THICKNESS (INCHES) FOR FIRE-RESISTANCE RATING OF × 25.4 for mm				
	1 Hr.	$1^1/_2$ Hr.	2 Hr.	3 Hr.	4 Hr.
Siliceous[1]	3.5	4.3	5.0	6.2	7.0
Carbonate	3.2	4.0	4.6	5.7	6.6
Sand-lightweight	2.7	3.3	3.8	4.6	5.4
Lightweight	2.5	3.1	3.6	4.4	5.1

[1]The equivalent thickness may include the thickness of portland cement plaster or 1.5 times the thickness of gypsum plaster applied in accordance with the requirements of Chapter 25.

TABLE 7-7-C-D—COVER THICKNESS FOR REINFORCED CONCRETE FLOOR OR ROOF SLABS

CONCRETE AGGREGATE TYPE	THICKNESS OF COVER (INCHES) FOR FIRE-RESISTANCE RATING OF × 25.4 for mm									
	Restrained[1]					Unrestrained[1]				
	1 Hr.	1 1/2 Hr.	2 Hr.	3 Hr.	4 Hr.	1 Hr.	1 1/2 Hr.	2 Hr.	3 Hr.	4 Hr.
Siliceous	3/4	3/4	3/4	3/4	3/4	3/4	3/4	1	1 1/4	1 5/8
Carbonate	3/4	3/4	3/4	3/4	3/4	3/4	3/4	3/4	1 1/4	1 1/4
Sand-lightweight	3/4	3/4	3/4	3/4	3/4	3/4	3/4	3/4	1 1/4	1 1/4
Lightweight	3/4	3/4	3/4	3/4	3/4	3/4	3/4	3/4	1 1/4	1 1/4

[1]See Section 7.141 of UBC Standard 7-1 for guidance on restrained and unrestrained assemblies.

TABLE 7-7-C-E—COVER THICKNESS FOR PRESTRESSED CONCRETE FLOOR OR ROOF SLABS

CONCRETE AGGREGATE TYPE	THICKNESS OF COVER (INCHES) FOR FIRE-RESISTANCE RATING OF × 25.4 for mm									
	Restrained[1]					Unrestrained[1]				
	1 Hr.	1 1/2 Hr.	2 Hr.	3 Hr.	4 Hr.	1 Hr.	1 1/2 Hr.	2 Hr.	3 Hr.	4 Hr.
Siliceous	3/4	3/4	3/4	3/4	3/4	1 1/8	1 1/2	1 3/4	2 3/8	2 3/4
Carbonate	3/4	3/4	3/4	3/4	3/4	1	1 3/8	1 5/8	2 1/8	2 1/4
Sand-lightweight	3/4	3/4	3/4	3/4	3/4	1	1 3/8	1 1/2	2	2 1/4
Lightweight	3/4	3/4	3/4	3/4	3/4	1	1 3/8	1 1/2	2	2 1/4

[1]See Section 7.141 of UBC Standard 7-1 for guidance on restrained and unrestrained assemblies.

TABLE 7-7-C-F—MINIMUM COVER TO MAIN REINFORCING BARS FOR REINFORCED CONCRETE BEAMS (APPLICABLE TO ALL TYPES OF STRUCTURAL CONCRETE)

RESTRAINED OR UNRESTRAINED[1]	BEAM WIDTH[2] (Inches) × 25.4 for mm	COVER THICKNESS (INCHES) FOR FIRE-RESISTANCE RATING OF × 25.4 for mm				
		1 Hr.	1 1/2 Hr.	2 Hr.	3 Hr.	4 Hr.
Restrained	5	3/4	3/4	3/4	1[1]	1 1/4[1]
Restrained	7	3/4	3/4	3/4	3/4	3/4
Restrained	≥ 10	3/4	3/4	3/4	3/4	3/4
Unrestrained	5	3/4	1	1 1/4	—	—
Unrestrained	7	3/4	3/4	3/4	1 3/4	3
Unrestrained	≥ 10	3/4	3/4	3/4	1	1 3/4

[1]See Section 7.141 of UBC Standard 7-1 for guidance on restrained and unrestrained assemblies. Tabulated values for restrained assemblies apply to beams spaced more than 4 feet (1219 mm) on centers; for restrained beams spaced 4 feet (1219 mm) or less on centers, minimum cover of 3/4 inch (19.1 mm) is adequate for ratings of four hours or less.

[2]For beam widths between the tabulated values, the minimum cover thickness can be determined by direct interpolation.

TABLE 7-7-C-G—MINIMUM COVER FOR PRESTRESSED CONCRETE BEAMS[1]

RESTRAINED OR UNRESTRAINED[2]	CONCRETE AGGREGATE TYPE[3]	BEAM WIDTH[4] (Inches) × 25.4 for mm	COVER THICKNESS[5] (INCHES) FOR FIRE-RESISTANCE RATING OF × 25.4 for mm				
			1 Hr.	1 1/2 Hr.	2 Hr.	3 Hr.	4 Hr.
Restrained	Carb or Sil	8	1 1/2	1 1/2	1 1/2	1 3/4[2]	2 1/2[2]
Restrained	Carb or Sil	≥ 12	1 1/2	1 1/2	1 1/2	1 1/2	1 7/8[2]
Restrained	Sand LW	8	1 1/2	1 1/2	1 1/2	1 1/2	2[2]
Restrained	Sand LW	≥ 12	1 1/2	1 1/2	1 1/2	1 1/2	1 5/8[2]
Unrestrained	Carb or Sil	8	1 1/2	1 3/4	2 1/2	5[6]	—
Unrestrained	Carb or Sil	≥ 12	1 1/2	1 1/2	1 7/8	2 1/2	3
Unrestrained	Sand LW	8	1 1/2	1 1/2	2	3 1/4	—
Unrestrained	Sand LW	≥ 12	1 1/2	1 1/2	1 5/8	2	2 1/2

[1]This table shall not apply to I-shaped beams.

[2]See Section 7.141 of UBC Standard 7-1 for guidance on restrained and unrestrained assemblies. Tabulated values for restrained assemblies apply to beams spaced more than 4 feet on center.

[3]Carb = carbonate aggregate concrete; Sil = siliceous aggregate concrete; Sand LW = sand lightweight concrete.

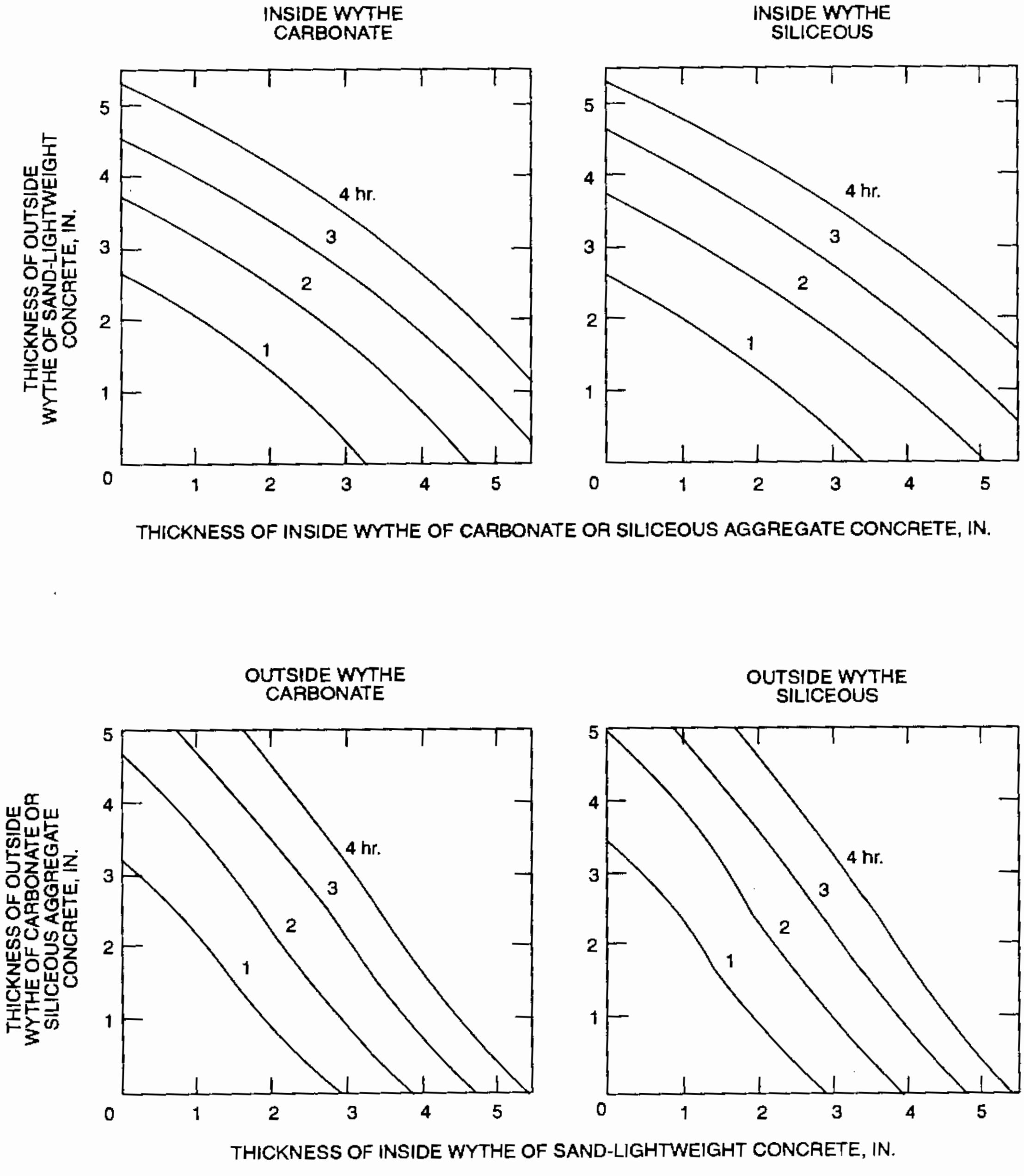
[4]For beam widths between 8 inches and 12 inches (203 mm and 305 mm), minimum cover thickness can be determined by direct interpolation.

[5]The cover for an individual tendon is the minimum thickness of concrete between the surface of the tendon and the fire-exposed surface of the beam, except that the ungrouted ducts the assumed cover thickness is the minimum thickness of concrete between the surface of the duct and the surface of the beam. For beams in which several tendons are used, the cover is assumed to be the average of the minimum cover of the individual tendons. The cover for any individual tendon must not be less than one half of the value given in this table or less than 1 inch (25 mm).

[6]Not practical for 8-inch-wide (203 mm) beam, but shown for purposes of interpolation.

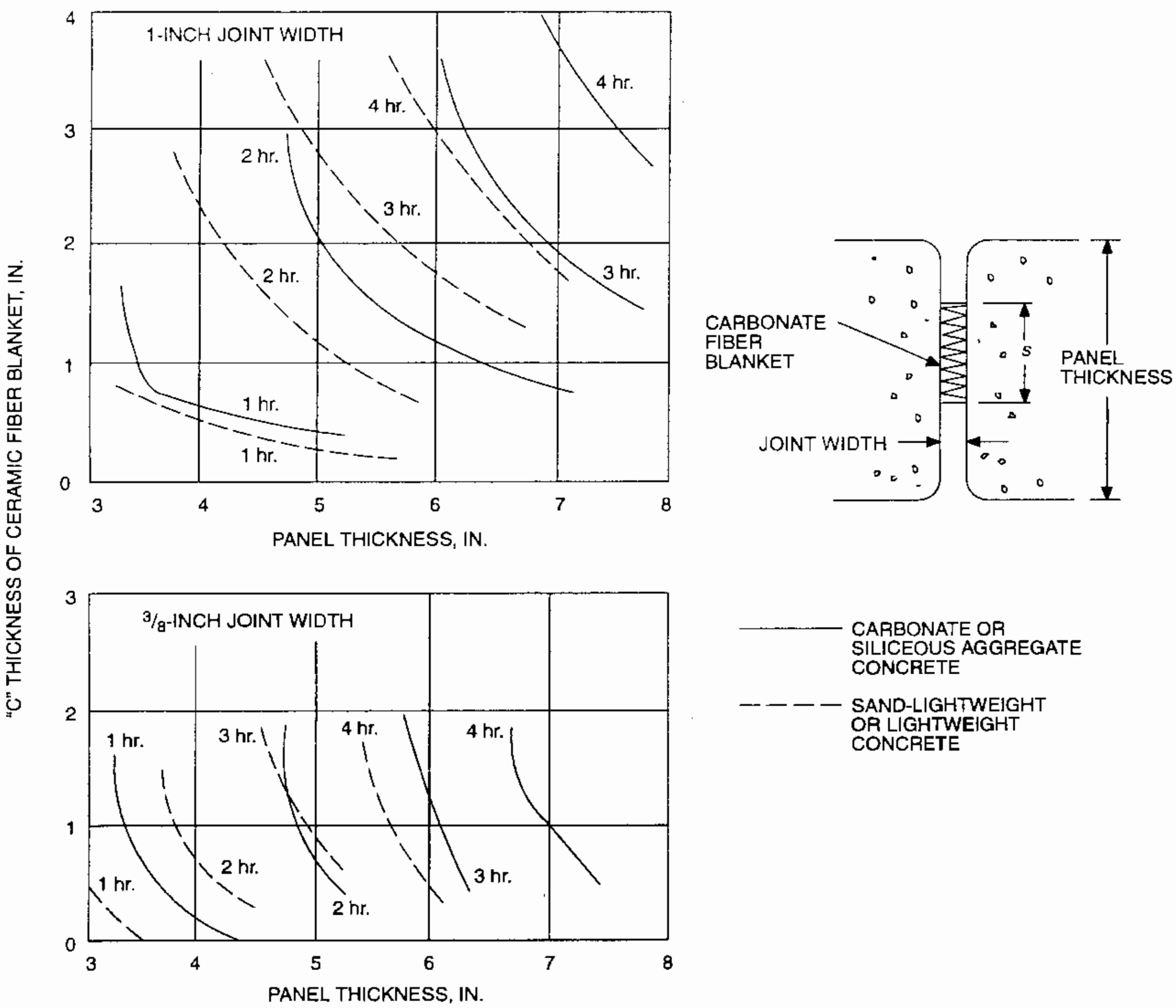
TABLE 7-7-C-H—MINIMUM SIZES OF CONCRETE COLUMNS

TYPE OF CONCRETE	MINIMUM COLUMN DIMENSION (INCHES) FOR FIRE-RESISTANCE RATING OF × 25.4 for mm				
	1 Hr.	$1^1/_2$ Hr.	2 Hr.	3 Hr.	4 Hr.
Siliceous	8	8	10	12	14
Carbonate	8	8	10	12	14
Sand-lightweight	8	8	9	10.5	12



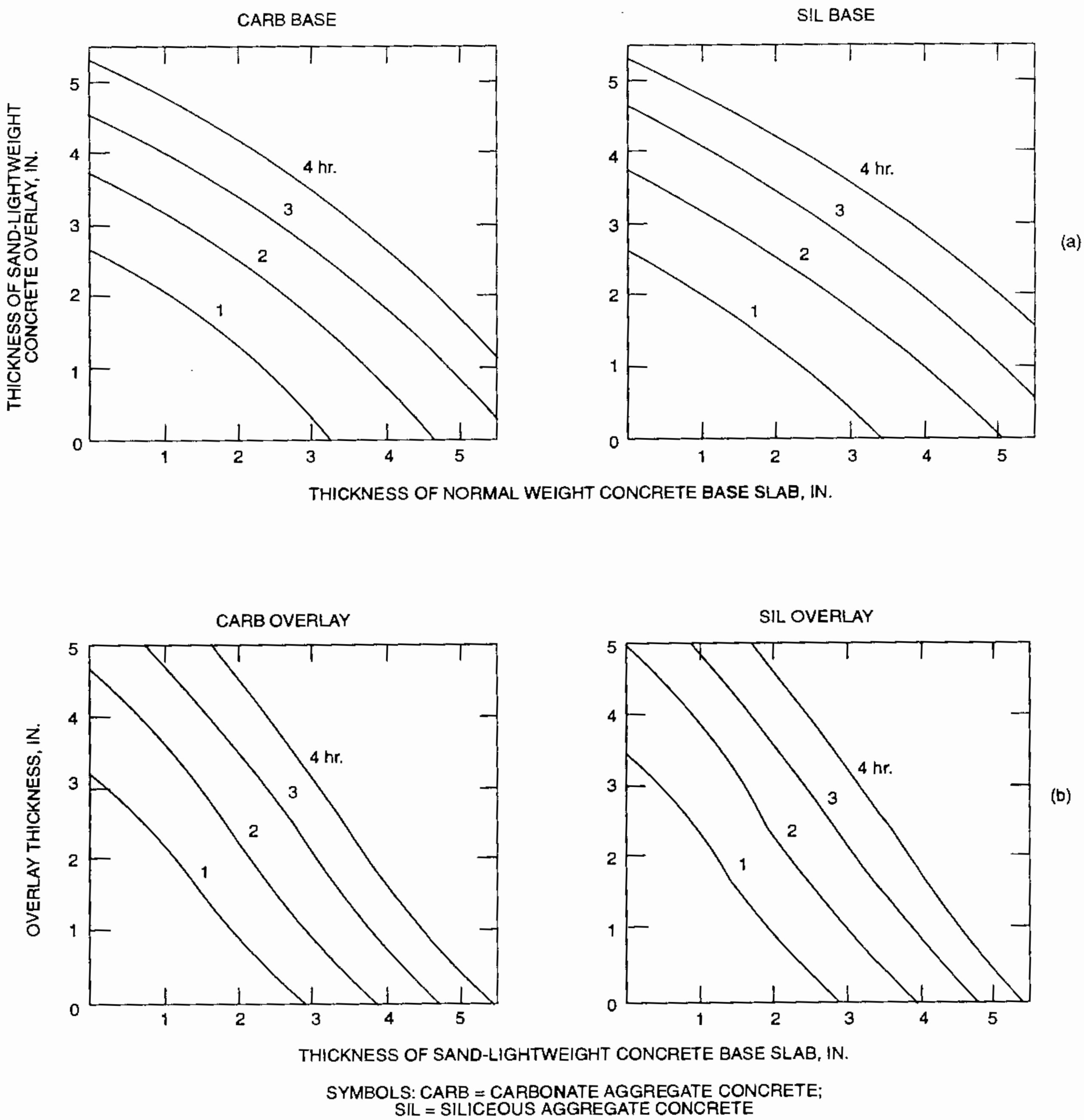
For **SI:** 1 inch = 25.4 mm.

FIGURE 7-7-C-1—FIRE-RESISTANCE RATINGS OF TWO-WYTHE CONCRETE WALLS CONSISTING OF WYTHES OF DIFFERENT TYPES OF CONCRETE



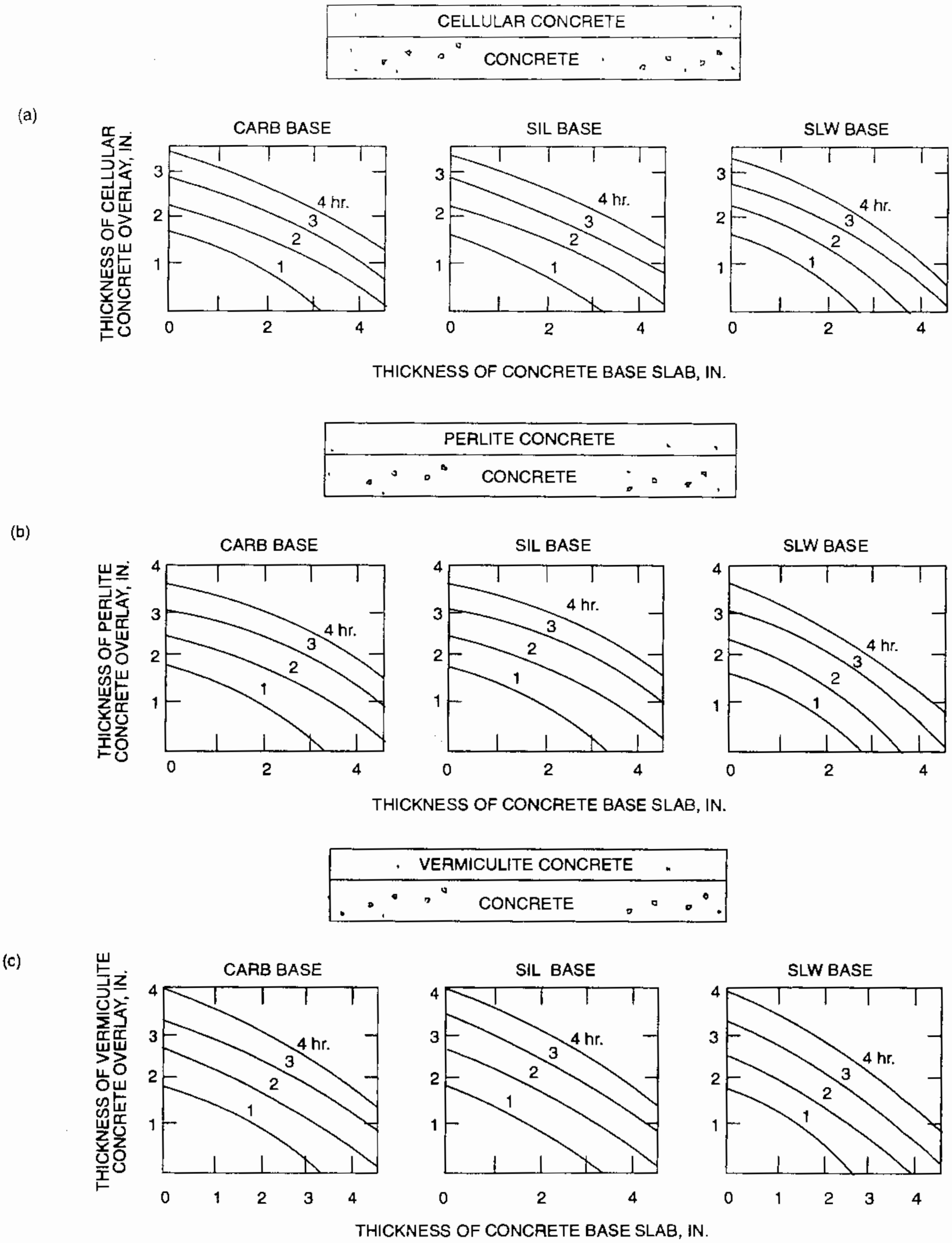
For **SI:** 1 inch = 25.4 mm.

FIGURE 7-7-C-2—MINIMUM THICKNESS OF CERAMIC FIBER BLANKET REQUIRED BETWEEN PRECAST CONCRETE WALL PANELS TO PROVIDE FIRE-RESISTANCE RATINGS OF ONE HOUR TO FOUR HOURS



For **SI:** 1 inch = 25.4 mm.

FIGURE 7-7-C-3A—FIRE-RESISTANCE RATINGS FOR TWO-COURSE CONCRETE FLOORS



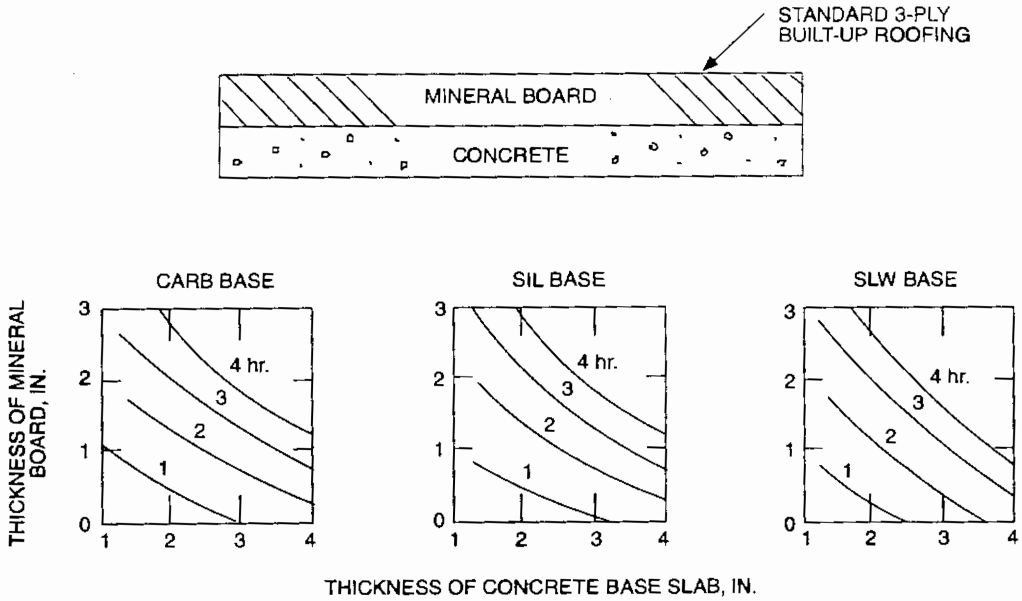
SYMBOLS: CARB = CARBONATE AGGREGATE CONCRETE;
SIL = SILICEOUS AGGREGATE CONCRETE;
SLW = SAND-LIGHTWEIGHT CONCRETE

For SI: 1 inch = 25.4 mm.

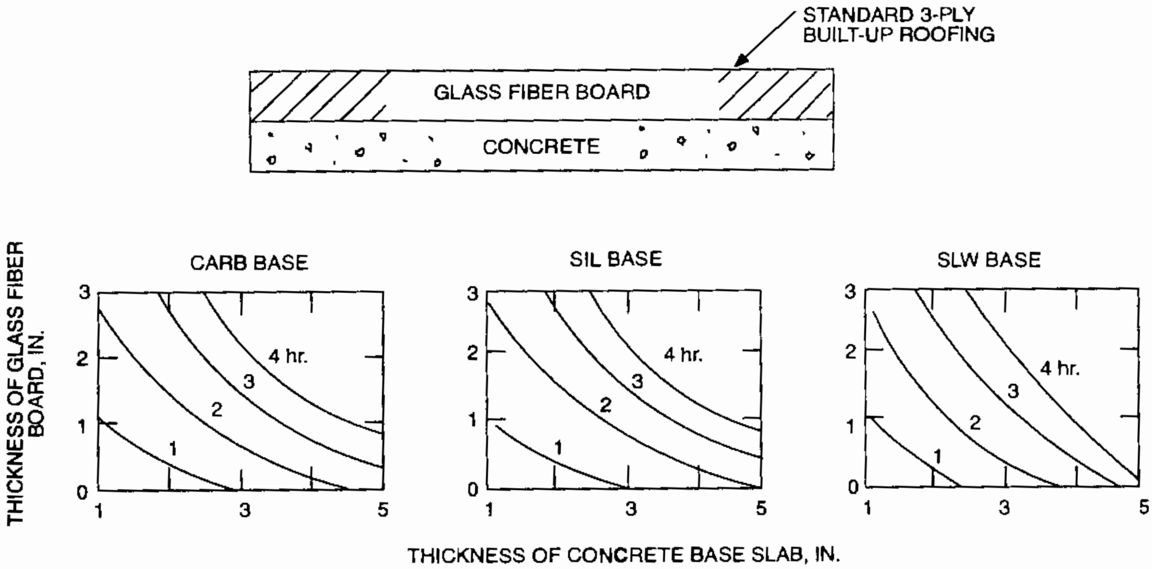
FIGURE 7-7-C-3B—FIRE-RESISTANCE RATINGS FOR CONCRETE ROOF ASSEMBLIES

(Continued)

(d)



(e)



For SI: 1 inch = 25.4 mm.

FIGURE 7-7-C-3B—FIRE-RESISTANCE RATINGS FOR CONCRETE ROOF ASSEMBLIES—(Continued)

Part III—Methods for Calculating the Fire-resistance Rating of Concrete Masonry

SECTION 7.711 — SCOPE

This part of this standard contains procedures by which the fire-resistance rating of concrete masonry assemblies can be established by calculations. It is applicable to concrete masonry walls, concrete masonry columns, concrete masonry lintels and steel columns protected with concrete masonry.

SECTION 7.712 — MATERIAL REQUIREMENTS

Materials used in accordance with this standard shall comply with the following:

7.712.1 Concrete Masonry Units.

UBC Standard 21-2, Standard Specification for Calcium Silicate Face Brick (Sand-lime Brick)

UBC Standard 21-3, Standard Specification for Concrete Building Brick

UBC Standard 21-4, Standard Specification for Hollow and Solid Load-bearing Concrete Masonry Units

UBC Standard 21-5 Standard Specification for Nonload-bearing Concrete Masonry Units

7.712.2 Mortar.

UBC Standard 21-15, Standard Specifications for Mortar for Unit Masonry and Reinforced Masonry Other Than Gypsum

7.712.3 Grout.

UBC Standard 21-19, Standard Specification for Grout for Masonry

7.712.4 Material for Filling Cells of Units.

Sand or slag having a maximum particle size of $^3/_8$ inch (9.5 mm).

ASTM C 33-86, Standard Specification for Aggregate

ASTM C 144-89, Standard Specification for Aggregate for Masonry Mortar

ASTM C 330-85 and C 332-83, Standard Specifications for Lightweight Aggregates for Structural and Insulating Concrete

ASTM C 549-81, Perlite Loose-fill Insulation (Type II)

ASTM C 516-80, Vermiculite Loose-fill Insulation (Type I and Type II)

7.712.5 Material for Surface Coverings.

ASTM C 28-76a, Gypsum Plasters

ASTM C 36-76a, Gypsum Wallboard

SECTION 7.713 — CONCRETE MASONRY WALLS

7.713.1 General. The fire-resistance rating of concrete masonry walls shall be determined in accordance with this section. The wall shall have the minimum equivalent thickness for the desired fire-resistive rating as specified in Table 7-7-M-A. The equivalent thickness of the wall may be increased by adding finishes in accordance with Section 7.713.3 and may be modified by combining more than one type of aggregate in the manufacture of the concrete masonry units in accordance with Section 7.713.4.

7.713.2 Determining Equivalent Thickness. Equivalent thickness of concrete masonry walls shall be determined in accordance with Formula (13-1) for units composed of a single aggregate and by Formula (13-2) for units composed of combined aggregates. When a plaster or gypsum wallboard finish material is applied over an entire face of a concrete masonry wall, the equivalent thickness of the wall assembly shall be determined in accordance with Formula (13-1). Equivalent thickness of units filled with grout or 100 percent solid units shall be the specified thickness.

$$T_E = \frac{V}{(L \times H)} + T_F \qquad (13\text{-}1)$$

WHERE:

H = height of block or brick using specified dimensions as defined in Chapter 21, inches (mm).

L = length of block or brick using specified dimensions as defined in Chapter 21, inches (mm).

T_E = equivalent thickness of wall, inches (mm).

T_F = equivalent thickness of finishes in Table 7-7-M-B.

V = net volume of unit, cubic inch (mm^3) (See ASTM C 140).

7.713.3 Finishes. When a plaster or gypsum wallboard finish is applied over an entire face of the concrete masonry wall, the equivalent thickness of finish shall be determined in accordance with Table 7-7-M-B. The calculated equivalent thickness of the finish can then be added to the calculated equivalent thickness of the concrete masonry wall to determine the total equivalent thickness in accordance with Formula (13-1).

7.713.4 Minimum Required Equivalent Thickness for a Combination of Aggregates. The fire-resistance rating of concrete masonry units composed of a combination of aggregate types shall be based on equivalent thickness values determined as follows:

Determine equivalent thickness values for each tabular column of the desired fire-resistance rating in Table 7-7-M-A by interpolating between equivalent thickness values for aggregate types in proportion to the percentage by volume of each aggregate used in accordance with Formula (13-2).

$$T_R = T_1 \times V_1 + T_2 \times V_2 \ldots T_n \times V_n \qquad (13\text{-}2)$$

WHERE:

$T_1, T_2 \ldots$

T_n = equivalent thickness for each aggregate Type 1, 2, . . . *n*, respectively, used as indicated in Table 7-7-M-A for the desired fire-resistance rating.

T_R = minimum required equivalent thickness corresponding to the desired fire-resistance rating as listed in Table 7-7-M-A for concrete masonry units manufactured with a particular combination of aggregate types.

$V_1, V_2, \ldots$

V_n = percentage by volume of each aggregate Type 1, 2, . . . *n*, respectively, which is used in the manufacture of the concrete masonry unit.

7.713.5 Fire-resistance Increase. When the calculated fire-resistance rating of the concrete masonry wall without fill materials or finishes is not less than two hours, the fire-resistance rating may be increased to four hours provided the cells are completely filled with any of the materials specified in the Building Code and the minimum specified thickness of the concrete masonry units is $7^5/_8$ inches (193.7 mm) as determined in accordance with Chapter 21 of the Building Code.

7.713.6 Framing into Wall. Combustible members framed into a wall shall be protected at their ends by not less than one half the required equivalent thickness of such wall.

7.713.7 Multiwythe. The fire-resistance rating of multiwythe walls, such as illustrated in Figure 7-7-M-1, shall be based on the fire-resistance rating of each wythe and the continuous air space between each wythe in accordance with Formula (13-3).

$$R = (R_1{}^{0.59} + R_2{}^{0.59} + R_n{}^{0.59} + A_1, + A_2 + \ldots A_n)^{1.7} \quad (13\text{-}3)$$

WHERE:

$A_1, A_2, \ldots$

A_n = 0.30, factor for each continuous air space (1,2, . . . n, respectively) having a depth of $^1/_2$ inch or more between wythes.

$R_1, R_2, \ldots$

R_n = fire-resistance rating of wythe 1, 2, . . . n (hours), respectively.

SECTION 7.714 — CONTROL JOINTS

7.714.1 Design. Control joints installed in fire-resistance-rated concrete masonry walls may be designed in accordance with this section to maintain the fire-resistance rating of the wall in which they are installed.

7.714.2 Materials. The control joints shall be sealed with approved caulk, grout or gaskets in accordance with the details provided in Figure 7-7-M-2.

SECTION 7.715 — STEEL COLUMNS PROTECTED BY CONCRETE MASONRY

7.715.1 The fire-resistance rating of steel columns illustrated in Figure 7-7-S-7, protected by concrete masonry shall be determined in accordance with Part I of this standard.

SECTION 7.716 — CONCRETE MASONRY COLUMNS

7.716.1 Concrete masonry columns shall be designed and reinforced in accordance with the requirements of this code. The fire-resistance rating of concrete masonry columns shall be determined based on the least dimension of the column faces in accordance with the requirements of Table 7-7-M-C.

SECTION 7.717 — CONCRETE MASONRY LINTELS

7.717.1 The fire-resistance rating of concrete lintels shall be determined based on the nominal thickness of the lintel and the minimum thickness of concrete or concrete masonry or any combination thereof, covering the reinforcing steel as determined in accordance with Table 7-7-M-D.

TABLE 7-7-M-A—FIRE-RESISTANCE RATING OF CONCRETE MASONRY WALLS

AGGREGATE TYPE	MINIMUM REQUIRED EQUIVALENT THICKNESS, T_R (inches) × 25.4 for mm			
	4 Hours	3 Hours	2 Hours	1 Hour
Calcareous or siliceous gravel	6.2	5.3	4.2	2.8
Limestone, cinders or slag	5.9	5.0	4.0	2.7
Expanded clay, shale or slate	5.1	4.4	3.6	2.6
Expanded slag or pumice	4.7	4.0	3.2	2.1

NOTE: The minimum required equivalent thickness of concrete masonry units made with a combination of aggregates shall be determined by linear interpolation of the values shown for each aggregate type in accordance with Formula (13-2) and Section 7.713.4.

TABLE 7-7-M-B—EQUIVALENT THICKNESS FOR EACH INCH OF FINISH THICKNESS (inches)

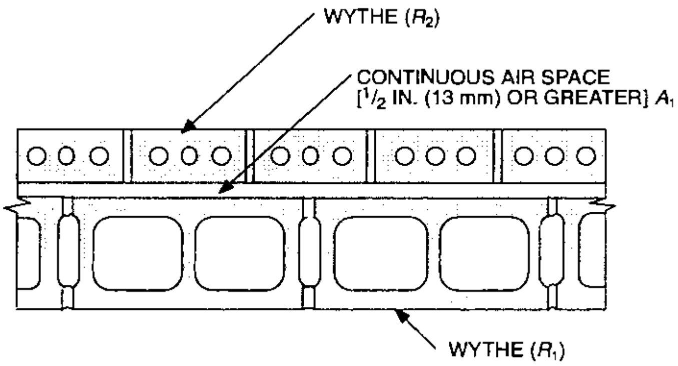
FINISH	AGGREGATE TYPE			
	Siliceous or Calcareous Gravel	Limestone Cinders or Slag	Expanded Shale, Clay or Slate	Expanded Slag or Pumice
	× 25.4 for mm			
Portland cement-sand plaster	1.00	0.75	0.75	0.50
Gypsum-sand plaster or gypsum wallboard	1.25	1.00	1.00	1.00
Gypsum-vermiculite or perlite plaster	1.75	1.50	1.25	1.25

TABLE 7-7-M-C—MINIMUM SIZES OF CONCRETE MASONRY COLUMNS

MINIMUM COLUMN DIMENSIONS, INCHES, FOR FIRE-RESISTANCE RATING OF			
1 Hour	2 Hours	3 Hours	4 Hours
× 25.4 for mm			
8	10	12	14

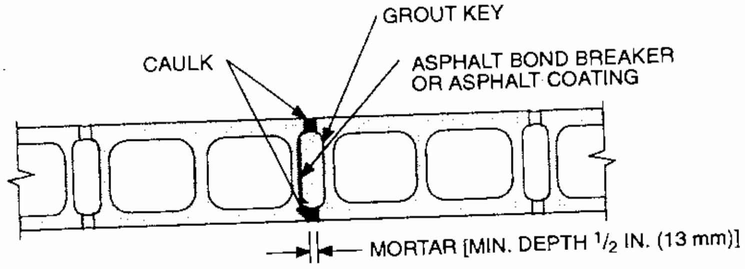
TABLE 7-7-M-D—MINIMUM COVER ON MAIN REINFORCING BARS FOR REINFORCED CONCRETE MASONRY LINTELS

LINTEL THICKNESS (inches) (Nominal)	COVER THICKNESS (inches) FOR FIRE-RESISTANCE RATING OF			
	× 25.4 for mm			
× 25.4 for mm	1 Hour	2 Hours	3 Hours	4 Hours
6	1	$1^1/_4$	—	—
8	1	1	$1^3/_4$	3
10 or more	1	1	1	$1^3/_4$

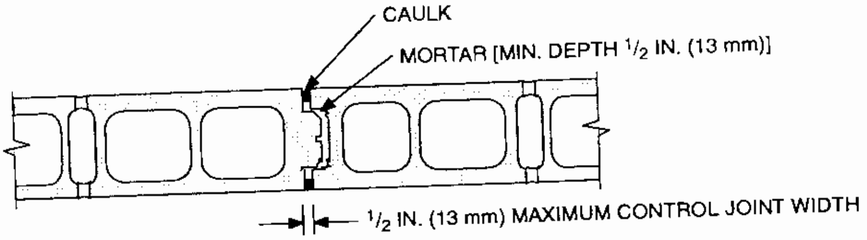


A_1 = FIRE-RESISTANCE RATING FACTOR OF AIR SPACE
R_1 = FIRE-RESISTANCE RATING OF WYTHE 1
R_2 = FIRE-RESISTANCE RATING OF WYTHE 2

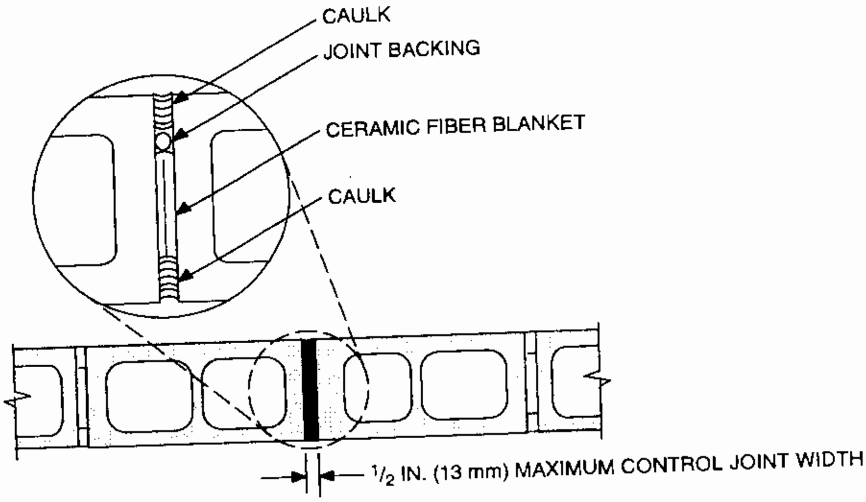
FIGURE 7-7-M-1—MULTIWYTHE WALL



FOR RATINGS UP TO AND INCLUDING 4 HOURS



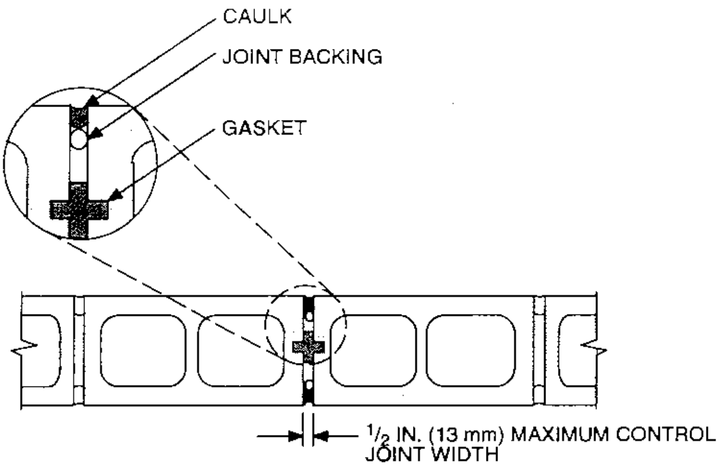
FOR RATINGS UP TO AND INCLUDING 4 HOURS



FOR RATINGS UP TO AND INCLUDING 4 HOURS

FIGURE 7-7-M-2—TYPES OF CONTROL JOINTS FOR FIRE-RESISTANCE-RATED CONCRETE MASONRY WALLS

(Continued)



FOR RATINGS UP TO AND INCLUDING 2 HOURS

FIGURE 7-7-M-2—TYPES OF CONTROL JOINTS FOR FIRE-RESISTANCE-RATED CONCRETE MASONRY WALLS—(Continued)

Part IV—Methods of Calculating the Fire-resistance Rating of Clay Masonry

SECTION 7.718 — SCOPE

This standard provides methods for calculating the fire-resistance-rating periods of clay and shale masonry. This standard is applicable to clay and tile masonry walls.

SECTION 7.719 — GENERAL

Clay masonry construction shall comply with the applicable requirements of this code.

SECTION 7.720 — CLAY MASONRY WALLS

7.720.1 General. The rated fire-resistive period of clay masonry walls shall be determined in accordance with this section. The fire-resistance periods of clay masonry units shall be determined from Tables 7-7-B-A, 7-7-B-B and 7-7-B-C. When sanded gypsum plaster is applied over the entire face of the clay masonry wall, the rated fire-resistive period shall be determined in accordance with Section 7.720.2. When continuous air spaces separate multiwythe walls, the rated fire-resistive period shall be determined in accordance with Section 7.720.4. The rated fire-resistive period of multiwythe walls shall be determined in accordance with Section 7.720.4. Hollow clay masonry walls shall have a minimum equivalent thickness for the desired fire-resistive rating as specified in Section 7.720.5.

7.720.2 Plaster Finishes. The fire-resistive rating period of sanded gypsum plastered clay masonry walls shall be based in accordance with Formula (20-1).

$$R = (R_n^{0.59} + Pl)^{1.7} \qquad (20\text{-}1)$$

WHERE:

Pl = thickness coefficient of sanded gypsum plaster.

R = fire-resistive rating of the assembly, hours.

R_n = fire-resistive period of wythe, hours.

Coefficients for thickness of sanded gypsum plaster shall be selected from Table 7-7-B-D, based on the actual thickness of plaster applied to the clay masonry wall and whether one or two sides of the wall are plastered.

7.720.3 Continuous Air Spaces. The fire-resistive rating period of multiwythe clay masonry walls separated by a continuous air space between each wythe shall be based in accordance with Formula (20-2).

$$R = (R_1^{0.59} + R_2^{0.59} + \ldots R_n^{0.59} + A_s)^{1.7} \qquad (20\text{-}2)$$

WHERE:

A_s = 0.30 factor for each continuous air space having a depth of 1/2 inch to 3 1/2 inches (12.7 mm to 88.9 mm) between wythes.

R = fire-resistive rating of the assembly, hours.

$R_1, R_2,$

R_n = fire-resistive period of each individual wythe, hours.

7.720.4 Multiwythe Walls. The fire-resistive rating period of multiwythe walls consisting of two or more dissimilar wythes shall be based on the fire-resistive periods of each wythe and shall be based in accordance with Formula (20-3).

$$R = (R_1^{0.59} + R_2^{0.59} + R_n^{0.59})^{1.7} \qquad (20\text{-}3)$$

WHERE:

R = fire-resistive rating of the assembly, hours.

$R_1, R_2, \ldots$

R_n = fire-resistive period of each individual wythe, hours.

For walls which consist of two or more wythes of dissimilar materials (concrete or concrete masonry units) in combination with clay masonry units, the fire-resistive period of the dissimilar materials shall be based in accordance with Table 7-7-C-B for concrete, Table 7-7-M-A for concrete masonry units or Table 7-7-B-A, 7-7-B-B or 7-7-B-C for clay masonry units.

7.720.5 Hollow Clay Masonry Walls. The rated fire-resistive period of hollow clay masonry units shall be based on the equivalent thickness in accordance with Formula (20-4).

$$T_E = \frac{V_n}{L \times H} \qquad (20\text{-}4)$$

WHERE:

H = height of brick using the specified dimensions as defined in Chapter 21 of the Building Code, inches (mm).

L = length of brick using the specified dimensions as defined in Chapter 21 of the Building Code, inches (mm).

T_E = equivalent thickness of wall, inches (mm).

V_n = net volume of unit, cubic inches (mm^3).

The fire-resistive rating for hollow clay brick shall be determined from Table 7-7-B-C based on the equivalent thickness. The fire-resistive rating determined from Table 7-7-B-C may be used in the calculated fire-resistance procedure of Sections 7.720.1, 7.720.2, 7.720.3 and 7.720.4.

TABLE 7-7-B-A—FIRE-RESISTIVE PERIODS FOR NONLOAD-BEARING AND LOAD-BEARING CLAY MASONRY WALLS[1]

WALL OR PARTITION ASSEMBLY, MINIMUM NOMINAL THICKNESS × 25.4 for mm × 0.093 for m²	FIRE-RESISTIVE PERIOD (hours)
CLAY OR SHALE, SOLID	
4-inch brick	1.25
6-inch brick	2.55
8-inch brick	4.00
CLAY OR SHALE, HOLLOW	
8-inch brick, 71% solid	3.00
12-inch brick, 64% solid	4.00
8-inch brick, 60% solid, cells filled with loose fill insulation	4.00
CLAY OR SHALE, ROLOK	
8-inch Hollow Rolok	2.50
12-inch Hollow Rolok	4.00
CAVITY WALLS, CLAY OR SHALE	
8-inch wall; two 3-inch (actual) brick wythes separated by 2-inch air space; masonry joint reinforcement spaced 16 inches on center vertically	3.00
10-inch wall; two nominal 4-inch wythes separated by 2-inch air space; $^1/_4$-inch metal ties for each 3 square feet of wall area	4.00
CLAY OR SHALE BRICK, METAL FURRING CHANNELS	
5-inch wall, 4-inch nominal brick (75% solid) backed with a hat-shaped metal furring channel $^3/_4$ inch thick formed from 0.021 inch sheet metal attached to brick wall on 24 inch centers with approved fasteners; and $^1/_2$-inch Type X gypsum board attached to the metal furring strips with 1-inch-long Type S screws spaced 8 inches on center	2.00
HOLLOW CLAY TILE, BRICK FACING	
8-inch wall; 4-inch units (40% solid)[2] plus 4-inch solid brick	3.50
12-inch wall; 8-inch units (40% solid)[2] plus 4-inch solid brick	4.00

[1]Units shall comply with the requirements of UBC Standard 21-1 or ASTM C 126.

[2]Units shall comply with the requirements of ASTM C 34.

TABLE 7-7-B-B—FIRE-RESISTIVE PERIODS FOR NONLOAD-BEARING AND LOAD-BEARING CLAY TILE MASONRY WALLS[1]

WALL OR PARTITION ASSEMBLY, MINIMUM NOMINAL THICKNESS × 25.4 for mm	FIRE-RESISTIVE PERIOD (hours)
HOLLOW CLAY TILE	
8-inch unit; 2 cells in wall thickness, 40% solid	1.25
8-inch unit; 2 cells in wall thickness, 43% solid	1.50
8-inch unit; 2 cells in wall thickness, 46% solid	1.75
8-inch unit; 2 cells in wall thickness, 49% solid	2.00
8-inch unit; 3 or 4 cells in wall thickness, 40% solid	1.75
8-inch unit; 3 or 4 cells in wall thickness, 43% solid	2.00
8-inch unit; 3 or 4 cells in wall thickness, 48% solid	2.50
8-inch unit; 3 or 4 cells in wall thickness, 53% solid	3.00
12-inch unit; 3 cells in wall thickness, 40% solid	2.50
12-inch unit; 3 cells in wall thickness, 45% solid	3.00
12-inch unit; 3 cells in wall thickness, 49% solid	3.50
12-inch wall; 2 units with 3 or 4 cells in wall thickness, 40% solid	3.50
12-inch wall; 2 units with 3 or 4 cells in wall thickness, 45% solid	4.00
12-inch wall; 2 units with 3 or 4 cells in wall thickness, 53% solid	4.00
16-inch wall; 2 or 3 units with 4 or 5 cells in wall thickness, 40% solid	4.00
CLAY TILE	
4-inch unit; 1 cell in wall thickness, 40% solid[2,3]	1.25
6-inch unit; 1 cell in wall thickness, 30% solid[2,3]	2.00
6-inch unit; 2 cell in wall thickness, 45% solid[4]	1.00
4-inch unit; 1 cell in wall thickness, 40% solid[3,4]	1.25
6-inch unit; 1 cell in wall thickness, 40% solid[3,4]	2.00
HOLLOW STRUCTURAL CLAY TILE	
8-inch unit; 2 cells in wall thickness, 40% solid	1.25
8-inch unit; 2 cells in wall thickness, 49% solid	2.00
8-inch unit; 3 or 4 cells in wall thickness, 53% solid	3.00
8-inch unit; 2 cells in wall thickness, 46% solid	1.75
12-inch unit; 3 cells in wall thickness, 40% solid	2.50
12-inch wall; 2 units, with 3 cells in wall thickness, 40% solid	3.50
12-inch wall; 2 units with 3 or 4 cells in wall thickness, 45% solid	4.00
12-inch unit, 3 cells in wall thickness, 45% solid	3.00
12-inch unit, 3 cells in wall thickness, 49% solid	3.50
16-inch wall, 2 units with 4 cells in wall thickness, 43% solid	4.00
16-inch wall; 2 or 3 units with 4 or 5 cells in wall thickness, 40% solid	4.00

[1]Units shall comply with the requirements of ASTM C 34, C 56, C 212 or C 530.
[2]Ratings are for dense hard-burned clay or shale tile.
[3]Cells filled with tile, stone, slag, cinders or sand mixed with mortar.
[4]Ratings are for medium-burned clay tile.

TABLE 7-7-B-C—MINIMUM EQUIVALENT THICKNESS[1] (inches) OF LOAD-BEARING OR NONLOAD-BEARING HOLLOW CLAY MASONRY WALLS[2,3,4]

TYPE OF MATERIAL	FIRE-RESISTIVE PERIOD (hours)			
	1	2	3	4
	× 25.4 for mm			
Brick of clay or shale, unfilled	2.3	3.4	4.3	5.0
Brick of clay or shale, grouted or filled with perlite, vermiculite or expanded shale aggregate	3.0	4.4	5.5	6.6

[1]Equivalent thickness as determined for UBC Standard 7-7, Section 7.720.5.
[2]Values between those shown can be determined by direct interpolation.
[3]Where combustible members are framed in the wall, the thickness of solid material between the end of each member and the opposite face of the wall, or between members set in from opposite sides, shall not be less than 93 percent of the thickness shown in the table.
[4]Units shall comply with the requirements of UBC Standard 21-1, Section 21.107.

TABLE 7-7-B-D—COEFFICIENTS FOR PLASTER (PI)[1]

THICKNESS OF PLASTER (inch) × 25.4 for mm	ONE-SIDE	TWO-SIDE
$^1/_2$	0.30	0.60
$^5/_8$	0.37	0.75
$^3/_4$	0.45	0.90

[1]Values listed are for 1:3 sanded gypsum plaster.

Part V—Methods for Calculating One-hour Fire-resistive Ratings of Wood-framed Walls, Floors and Roofs

See Section 703.3, *Uniform Building Code*

SECTION 7.721 — SCOPE

This part establishes acceptable calculation methods for determining the fire-resistive classification of structural parts, walls and partitions and floor-ceiling or roof-ceiling assemblies. It is intended for use in cases where fire test results specified in UBC Standard 7-1 are not available and the specific assembly of materials is not among those listed in Tables 7-A, 7-B and 7-C.

Wood-framed Walls, Floors and Roofs

SECTION 7.722 — GENERAL

These procedures apply to both load-bearing and nonbearing construction. The calculated fire-resistive ratings shall only apply to one-hour construction. When the wall construction is nonsymmetrical, the provisions of Section 709.5 of the Building Code apply.

SECTION 7.723 — PROCEDURES

The fire-resistive rating of wood-framed construction is equal to the sum of the time assigned to the membrane on the fire-exposed side (Table 7-7-W-A), the time assigned to the framing members (Table 7-7-W-C), and the time assigned for other protective measures, such as insulation (Table 7-7-W-D). The membrane on the unexposed side shall not be included in determining the fire resistance of the assembly. When more than one membrane is installed on the wall surface exposed to fire, ratings of each membrane may be added.

SECTION 7.724 — WALLS AND PARTITIONS

Table 7-7-W-A lists the time of fire resistance accredited to the materials used on the fire-exposed side of walls and partitions.

SECTION 7.725 — ROOF-CEILING AND FLOOR-CEILING ASSEMBLIES

Table 7-7-W-B specifies the various acceptable membranes and limits the structural frame to wood joists installed on no more than 16-inch (406 mm) spacings. Ratings for roof-ceiling and floor-ceiling assemblies are based on the membranes listed in Table 7-7-W-A being installed on the fire-exposed side in combination with membranes listed in Table 7-7-W-B being installed on the side not exposed to furnace temperatures.

SECTION 7.726 — MEMBRANE FASTENING

Fastening the membrane to the supporting construction shall be as specified in Tables 7-B, 7-C and 23-II-B-1 of the Building Code for corresponding membrane materials.

TABLE 7-7-W-A—TIME ASSIGNED TO WALLBOARD MEMBRANES[1, 2, 3]

DESCRIPTION OF FINISH	TIME, MINUTES
$^3/_8$-inch (9.5 mm) Exterior-glue plywood	5
$^1/_2$-inch (12.7 mm) Exterior-glue plywood	10
$^5/_8$-inch (15.9 mm) Exterior-glue plywood	15
$^3/_8$-inch (9.5 mm) gypsum wallboard	10[4]
$^1/_2$-inch (12.7 mm) gypsum wallboard	15
$^5/_8$-inch (15.9 mm) gypsum wallboard	30
$^1/_2$-inch (12.7 mm) Type X gypsum wallboard	25
$^5/_8$-inch (15.9 mm) Type X gypsum wallboard	40
Double $^3/_8$-inch (9.5 mm) gypsum wallboard	25
$^1/_2$ + $^3/_8$-inch (12.7 + 9.5 mm) gypsum wallboard	35
Double $^1/_2$-inch (12.7 mm) gypsum wallboard	40

[1]All wall panels shall be installed with the long dimension parallel to framing members or shall be backed with at least 2-inch-thick (51 mm) framing and gypsum panels.
[2]These values apply only when framing members are spaced a maximum of 16 inches (406 mm) on center.
[3]Plywood membranes shall be limited to nonbearing applications. Other membranes shall be limited to the design stress for studs shown by Footnote 19 to Table 7-B.
[4]Membrane rating combined with stud rating is 25.

TABLE 7-7-W-B—FLOORING OR ROOFING OVER WOOD FRAMING

ASSEMBLY	STRUCTURAL MEMBERS	SUBFLOOR OR ROOF DECK	FINISH FLOORING OR ROOFING
Floor	Wood joists	$^1/_2$-inch (12.7 mm) plywood or $^{11}/_{16}$-inch (17.5 mm) tongue-and-groove softwood	Hard or softwood flooring on building paper. Resilient flooring, parquet floor, felted-synthetic-fiber floor coverings, carpeting or ceramic tile on $^5/_8$-inch-thick (15.9 mm) panel-type underlay Ceramic tile on $1^1/_4$-inch (32 mm) mortar bed.
Roof	Wood joists	$^1/_2$-inch (12.7 mm) plywood or $^{11}/_{16}$-inch (17.5 mm) tongue-and-groove softwood	Finish roofing material with or without insulation. See Section 710.1 for the addition of insulation.

TABLE 7-7-W-C—TIME ASSIGNED FOR CONTRIBUTION OF WOOD FRAME[1, 2]

DESCRIPTION OF FRAME	TIME ASSIGNED TO FRAME, MINUTES
Wood studs 16 inches (406 mm) on center	20
Wood floor and roof joists 16 inches (406 mm) on center	10

[1]This table does not apply to studs or joists spaced more than 16 inches (406 mm) on center.

[2]All studs shall be nominal 2 inches by 4 inches (51 mm by 102 mm) and all joists shall have a nominal thickness of at least 2 inches (51 mm).

TABLE 7-7-W-D—TIME ASSIGNED FOR ADDITIONAL PROTECTION

DESCRIPTION OF ADDITIONAL PROTECTION	FIRE RESISTANCE, MINUTES
Add to the fire-resistance rating of wood stud walls if the spaces between the studs are filled with rock-wool batts weighing not less than 1.0 lb./ft.^{2} (4.9 kg/m^2) [3.3 lb.ft.^{3} (52.8 kg/m^3)] or glass-wool batts at 0.6 lb./ft.^{2} (2.9 kg/m^2) [2.0 lb./ft.^{3} (32 kg/m^3)] wall surface.	15

Part VI—Method for Design of One-hour Fire-resistive Exposed Wood Member [6-inch (152 mm) Nominal or Greater]

See Section 703.3, *Uniform Building Code*

SECTION 7.727 — SCOPE

Part IV of this standard applies to the design of one-hour fire-resistive exposed solid-sawn and glued-laminated timbers described in Chapter 23. The timbers shall have a minimum nominal thickness of 6 inches (152 mm).

This design method for one-hour fire-resistive exposed wood members is an accepted method of determining fire-resistive construction as specified in Section 703.3 of the Building Code.

SECTION 7.728 — DESIGN PROCEDURES

Design procedures, loads and allowable design stresses shall be as specified in Chapters 16 and 23. In addition, the column or beam shall be analyzed to determine the size required to sustain the design load at the end of a one-hour fire. This design procedure is specified in Section 7.729.

SECTION 7.729 — CALCULATION OF TIMBER SIZE

The following procedure shall be used to establish the fire rating of columns or beams and to determine the size required to be treated as one hour.

The fire-resistance rating, in minutes, of timber beams and columns with a minimum nominal dimension of 6 inches (152 mm) is equal to:

Beams—

1. $2.54\ Zb\ [4 - 2(b/d)]$ {For **SI:** $0.10\ Zb\ [4 - 2(b/d)]$} for beams which may be exposed to fire on four sides.
2. $2.54\ Zb\ [4 - (b/d)]$ {For **SI:** $0.10\ Zb\ [4 - (b/d)]$} for beams which may be exposed on three sides.

Columns—

3. $2.54\ Zd\ [3 - (d/b)]$ {For **SI:** $0.10\ Zd\ [3 - (d/b)]$} for columns which may be exposed to fire on four sides.
4. $2.54\ Zd\ [4 - (d/2b)]$ {For **SI:** $0.10\ Zd\ [4 - (d/2b)]$} for columns which may be exposed on three sides. (Applies only when the smaller side of the column is the exposed face.)

WHERE:

b = the breadth (width) of a beam or larger side of a column before exposure to fire, inches (mm).

d = the depth of a beam or smaller side of a column before exposure to fire, inches (mm).

K_e = the effective length factor (Figure 7-7-2).

l = the unsupported length of column, inches (mm) (Figure 7-7-1).

Z = the load factor (Figure 7-7-1).

If a column is recessed into a wall and protected, its minimum dimension need not be calculated using this procedure.

SECTION 7.730 — ACCEPTANCE CRITERIA OF CONSTRUCTION

In addition to sizing the timber, the following conditions shall be met:

1. The minimum nominal width or thickness is 6 inches (152 mm).

2. Connectors and fasteners relating to the support of the member shall be protected for equivalent fire resistance. When the minimum one-hour fire resistance is required, connectors and fasteners shall be protected from fire exposure by not less than $1^1/_2$ inches (38 mm) of wood, appropriate thickness or layers of Type X gypsum board, or any coating approved for one-hour rating.

3. For structural integrity of glued-laminated timbers, one additional lamination of 2-inch (51 mm) thickness shall be placed on the tension face of the beam and shall be equivalent in quality to that required by the design for the outer tensile lamination. The additional lamination n the tension face shall replace a core lamination to maintain the same design depth required in Section 7.729.

4. Glued-laminated timber shall be marked "Fire-rated One-hour" by the manufacturer to indicate compliance with Item 3.

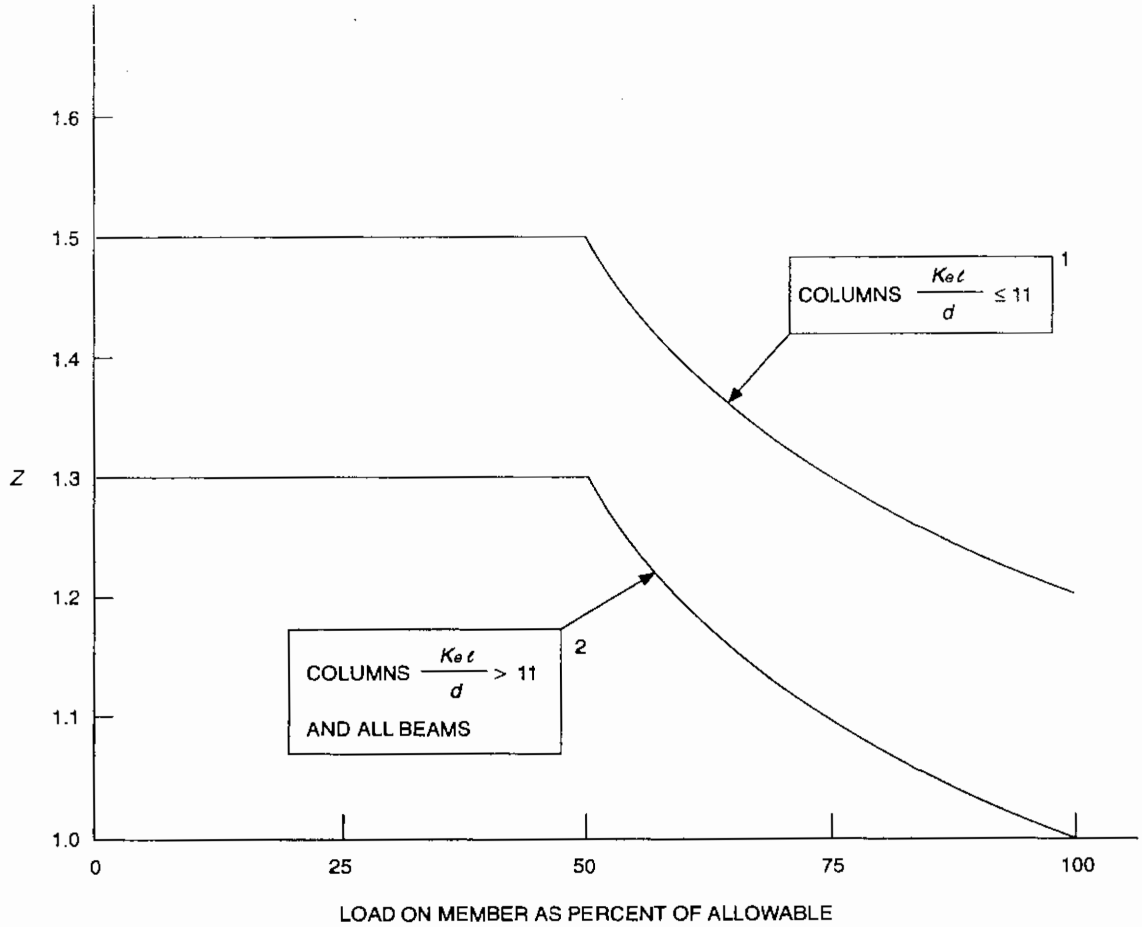


FIGURE 7-7-1—LOAD FACTOR

1 For columns having a $K_e \ell/d \leq 11$, Z shall be determined as follows:
Where the ratio of applied load to allowable load is equal to or less than 50, $Z = 1.5$.
Where the ratio of applied load to allowable load is greater than 50, Z shall be determined in accordance with the following formula.
$Z = 0.9 + 30/r$, where r = ratio of applied load to allowable load expressed as a percent of allowable.

2 For columns having a $K_e \ell/d > 11$ and all beams, Z shall be determined as follows:
Where the ratio of applied load to allowable load is equal to or less than 50, $Z = 1.3$.
Where the ratio of applied load to allowable load is greater than 50, Z shall be determined in accordance with the following formula:
$Z = 0.7 + 30/r$, where r = ratio of applied load to allowable load expressed as a percent of allowable.

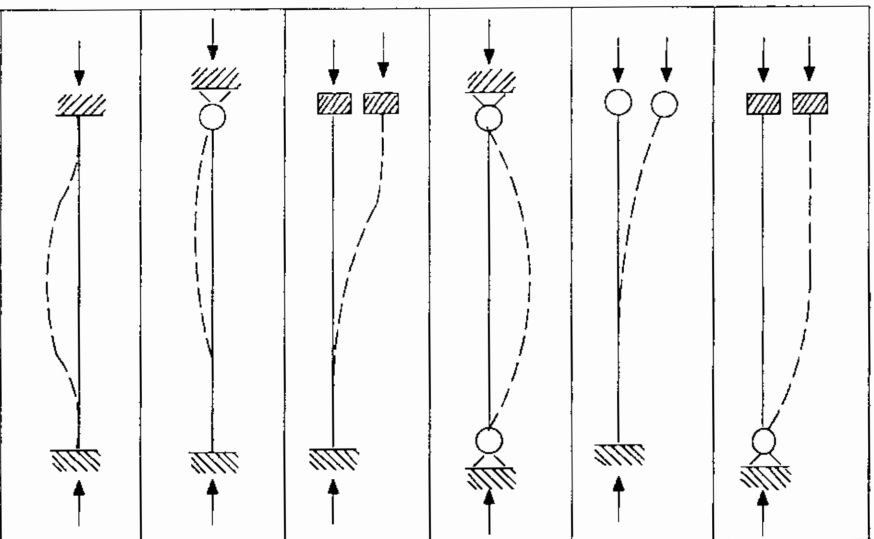
BUCKLING MODES						
THEORETICAL K_e VALUE	0.5	0.7	1.0	1.0	2.0	2.0
RECOMMENDED DESIGN K_e WHEN IDEAL CONDITIONS APPROXIMATED	0.65	0.8	1.2	1.0	2.1	2.4
END CONDITION CODE		ROTATION FIXED, TRANSLATION FIXED ROTATION FREE, TRANSLATION FIXED ROTATION FIXED, TRANSLATION FREE ROTATION FREE, TRANSLATION FREE				

FIGURE 7-7-2—EFFECTIVE COLUMN LENGTH

UNIFORM BUILDING CODE STANDARD 7-8
HORIZONTAL SLIDING FIRE DOORS USED IN A MEANS OF EGRESS

Test Standard of the International Conference of Building Officials

See Sections 308.2.2.1 and 1004.3.4.3.2, Uniform Building Code

SECTION 7.801 — SCOPE

This standard covers performance criteria and conditions for horizontal sliding fire doors in means of egress.

SECTION 7.802 — APPLICATION

Compliance with these conditions permits use of horizontal fire doors in areas specifically authorized by the code.

SECTION 7.803 — GENERAL

Installation shall be in accordance with manufacturer's instructions and nationally recognized standards.

SECTION 7.804 — CONSTRUCTION

Door assemblies shall be fire rated in accordance with UBC Standard 7-2, and shall have a Class I interior finish rating. The door's power operating system shall be approved and listed. The power operating system shall be housed in a fire-resistive enclosure of the same rating as the door.

SECTION 7.805 — OPERATION

The door shall be power operated, be capable of manual operation in the event of power failure and be self-closing or smoke-detector-activated automatic closing. The door's power supply shall be capable of being electrically supervised at a constantly attended location and the door shall have an emergency power supply. Actuating devices shall be installed on both sides of the door and shall be inhibited from opening the door if the temperature on either side exceeds 500°F (260°C). The door shall be equipped with sensors capable of detecting obstructions in its closing path and of signaling such detection at the door location or at a constantly attended location. Automatic closing of the door or trouble conditions shall cause an audible alarm to be sounded at the door location. The alarm shall also be capable of being sounded at a constantly attended location. Operation of the activating device while the door is opening shall cause it to return to the closed position.

SECTION 7.806 — PERFORMANCE

7.806.1 Power Operation. The power operating system shall be examined in accordance with nationally recognized standards and shall be listed. The test report shall contain engineering data relative to tests for normal operation, electrical supervision, input and output, jarring, temperature, charging current, battery charger, undervoltage and overvoltage, standby operating power, variable ambient temperature, humidity, leakage current, transient, overload, endurance, dielectric withstand and abnormal operation. The report shall describe the mechanical operation of the power operating system in sequence as the door opens and closes under both normal and emergency conditions. It shall set forth the tests performed in accordance with nationally recognized standards and the results thereof. Additionally, the report shall contain an analysis comparing each feature of the design against the performance test procedures.

7.806.2 Automatic-closing Test. Upon receipt of the initiating device signal, the power operating system shall move the door to the closed position. The door shall begin closing within 10 seconds of receiving the signal. Closing speed shall not be less than 6 inches (152 mm) or more than 24 inches (610 mm) per second.

7.806.3 Ease of Operation Test. Manufacturers shall provide a test report from an approved independent authority that the door is easily recognized and operable for its intended usage without a key, special knowledge or effort.

The actuating device shall be subjected to a measurable force load. The force shall be applied to the actuating device in the direction of egress travel (perpendicular to the door). The force causing the actuating device to signal the power operating system to open the door shall not be more than 15 pounds (67 N).

7.806.4 Self-contained Power Test. Doors equipped with a self-contained power supply shall be subjected to cycle testing. One cycle shall be defined as the time to completely close the door from the open position and return it to the open position. The self-contained power supply shall have sufficient capacity to operate the door 50 cycles without the aid of outside power.

7.806.5 Manual Operation Test. With all power disconnected, and with the door in the closed position, 30 pounds (134 N) of force or less shall be applied in the direction of door travel to initiate the door opening. With a sustained force of 15 pounds (67 N) or less, the door shall open to the specified open distance but not less than 44 inches (1118 mm).

7.806.6 Temperature Override Test. The door shall include temperature-sensing devices installed at the leading edge approximately 12 inches (305 mm) from the top of the door. These devices shall be subjected to a measurable temperature. When the temperature exceeds 500°F (260°C), the actuating devices shall be deactivated and shall not cause the door to open.

7.806.7 Lateral Load Test. A lateral load shall be applied to the door in the direction of egress travel. The total load shall be equivalent to 250 pounds (1113 N) of force distributed over a minimum of five points over the total area of the closed door at locations at least 3 feet (914 mm), but not more than 6 feet (1829 mm), from the floor. Under this condition, the door must meet the conditions of the ease of operation test outlined in Section 7.806.3.

7.806.8 Opening Speed. The door shall open to a distance of 88 inches (2235 mm) within 10 seconds after activation of the actuating device.

SECTION 7.807 — CONDITIONS OF ACCEPTANCE

A door shall be considered as meeting the requirements for acceptable performance when it conforms to the tests under Section 7.806.

SECTION 7.808 — MARKING

7.808.1 Label. Doors shall bear fire-rating labels issued by a listing agency showing compliance with UBC Standards 7-2 and

7-8. The label shall be of metal attached to the assembly by welding, brazing, riveting or contact adhesive.

7.808.2 Label Markings. The markings on the label shall include the following:

1. Name and address of the listee.
2. Model number or type.
3. Symbol, serial or issue number issued by the listing agency.

UNIFORM BUILDING CODE STANDARD 8-1
TEST METHOD FOR SURFACE-BURNING CHARACTERISTICS OF BUILDING MATERIALS

Based on Standard Test Method E 84-84 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 201.2; 207; 215; 217; 405.1; 405.3.4; 601.3; 707.2; 707.3; 801.1, Items 1 and 2; 802.2; 2602.3; 2602.5.2 and 2602.6, *Uniform Building Code;* Section 216, Table 3-A, and Section 1201.1, *Uniform Mechanical Code;* and Sections 202 and 211, *Uniform Sign Code*

SECTION 8.101 — SCOPE

This method for surface-burning characteristics of building materials is applicable to any type of building material that, by its own structural quality or the manner in which it is applied, is capable of supporting itself in position or may be supported in the test furnace to a thickness comparable to its recommended use.

EXCEPTION: This test method shall not apply to cellulose loose-fill insulation.

The purpose of the test is to determine the comparative burning characteristics of the material under test by evaluating the flame spread over its surface when exposed to a test fire and thus to establish a basis on which surface-burning characteristics of different materials may be compared, without specific consideration of all the end-use parameters that might affect the surface-burning characteristics.

Smoke density as well as the flame-spread rate are recorded in this test. However, there is not necessarily a relationship between these measurements.

It is the intent of this method to register performance during the period of exposure, and not to determine suitability for use after the test exposure.

This standard shall be used to measure and describe the properties of materials, products or assemblies in response to heat and flame under controlled laboratory conditions and is not to describe or appraise the fire hazard or fire risk of materials, products or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.

This method is intended to provide only comparative measurements of surface flame-spread and smoke-density measurements with that of Select grade red oak and asbestos-cement board surfaces under the specific fire exposure conditions described herein.

The test exposes a nominal 24-foot-long (7315 mm) by 20-inch-wide (508 mm) specimen to a controlled airflow and flaming fire exposure adjusted to spread the flame along the entire length of the Select grade red oak specimen in $5^1/_2$ minutes.

The test method does not provide for the following:

Measurement of heat transmission through the tested surface.

The effect of aggravated flame-spread behavior of an assembly resulting from the proximity of combustible walls and ceilings.

Classifying or defining a material as noncombustible, by means of a flame-spread index by itself.

SECTION 8.102 — FIRE TEST CHAMBER

The fire test chamber, Figures 8-1-1 and 8-1-2, shall consist of a horizontal duct having an inside width of $17^3/_4$ inches $\pm\ ^1/_4$ inch (451 mm ± 6.3 mm) measured at ledge location along side walls and $17^5/_8$ inches $\pm\ ^3/_8$ inch (448 mm ± 10 mm) at all other points; a depth of 12 inches $\pm\ ^1/_2$ inch (305 mm ± 13 mm) measured from the bottom of the test chamber to the ledge of the inner walls on which the sample is supported [including the $^1/_8$-inch (3.2 mm) thickness of asbestos fabric gasketing tape]; and a length of 25 feet (7620 mm). The sides and base of the duct are to be lined with insulating masonry as illustrated in Figure 8-1-2 consisting of A. P. Green, G-26 refractory firebrick. The operation and calibration of this equipment is based on the use of A. P. Green Refractories. One side is to be provided with a double window with the inside pane flush mounted (see Figure 8-1-2) pressure tight as described in Section 8.104. Exposed inside glass shall be $2^3/_4$ inches $\pm ^3/_8$ inch by 11 inches plus 1 inch minus 2 inches (70 mm ± 10 mm by 279 mm + 25 mm – 50 mm). The center line of the exposed area of the inside glass shall be in the upper half of the furnace wall, with the upper edge not less than 2.5 inches (63 mm) below the furnace ledge. The window shall be located such that not less than 12 inches (305 mm) of the specimen width can be observed. Multiple windows shall be located along the tunnel so that the entire length of the test sample may be observed from outside the fire chamber.

The ledges shall be fabricated of structural material capable of withstanding the abuse of continuous testing, level with respect to length and width of the chamber and each other and maintained in a state of repair commensurate with the frequency, volume and severity of testing occurring at any time.

To provide air turbulance for proper combustion, turbulence baffling is to be provided as necessary by positioning six A. P. Green, G-26, refractory firebricks [long dimension vertical $4^1/_2$-inch (114 mm) dimension along the wall] along the sidewalls of the chamber at distances of 7 feet, 12 feet and 20 feet ± 0.5 foot (2.1 m, 3.7 m and 6.1 m ± 0.2 m) on the window side and $4^1/_2$ feet, $9^1/_2$ feet and 16 feet ± 0.5 foot (1.3 m, 2.9 m and 4.9 m ± 0.2 m) on the opposite side.

The top shall consist of a removable noncombustible (metal and mineral composite) structure, insulated with nominal 2-inch-thick (51 mm) mineral composition material as shown in Figure 8-1-2 and of a size necessary to completely cover the fire test chamber and the test samples. The mineral composition material shall have physical characteristics comparable to the following:

Maximum effective temperature—1,200°F (650°C)

Bulk density—12.5 ± 1.5 lb/ft.^{3} (200 ± 24 kg/m^3)

Thermal conductivity—0.45-0.65 Btu in./h. ft.^{2} °F at 300-700°F (0.065 – 0.094 W/m·k at 149 – 371°C)

The entire lid assembly shall be protected with flat sections of high density [nominal 110 lb./ft.^{3} (1761 kg/m^3)] $^1/_4$-inch (6.3 mm) asbestos-cement board maintained in an unwarped and uncracked condition through continued replacement. When in place, the top is to be completely sealed against the leakage of air into the fire test chamber during the test.

One end of the test chamber, designated as the "fire end," shall be provided with two gas burners delivering flames upward against the surface of the test sample. The burners are to be spaced

12 inches (305 mm) from the fire end of the test chamber sample and $7^1/_2$ inches ± $^1/_2$ inch (190 mm ± 13 mm) below the under surface of the test sample. The air intake shutter is to be located 54 inches ± 5 inches (1372 mm ± 127 mm) upstream of the burner, as measured from the burners' center line to the outside surface of the shutter. Gas to the burners shall be provided through a single inlet pipe, distributed to each port burner through a tee section. The outlet shall be a $^3/_4$-inch (19 mm) elbow. The plane of the port shall be parallel to the furnace floor, such that the gas is directed upward toward the specimen. Each part shall be positioned transversely approximately 4 inches ± $^1/_2$ inch (102 mm ± 13 mm) on each side of the center line of the furnace so that the flame is evenly distributed over the width of the exposed sample surface. See Figure 8-1-2. The controls used to assure constant flow of gas to the burners during periods of use are to consist of a pressure regulator, a gas meter calibrated to read in increments of not more than 0.1 ft.^{3} (2.8 L), a manometer to indicate gas pressure in inches of water, a quick-acting gas shutoff valve, a gas-metering valve and an orifice plate in combination with a water manometer to assist in maintaining uniform gas-flow conditions. An air intake fitted with a vertically sliding shutter extending the entire width of the test chamber is to be provided at the fire end. The shutter is to be positioned so as to provide an air-inlet port 3 inches ± $^1/_{16}$ inch (76 mm ± 2 mm) high measured from the floor level of the test chamber at the air-intake point.

The other end of the test chamber, designated as the "vent end," is to be fitted with a gradual rectangular-to-round transition piece, not less than 20 inches (508 mm) in length with a minimum cross-sectional area of 200 square inches (0.129 m^2) at any point. The transition piece shall in turn be fitted to a 16-inch-diameter (406 mm) flue pipe. The movement of air is to be by induced draft system, and the draft-inducing system is to have a total draft capacity of at least 0.15-inch (3.8 mm) water column with the sample in place, the shutter at the fire end open to normal 3 inches ± $^1/_{16}$ inch (76 mm ± 2 mm), and the damper in the wide-open position. A draft gage tap to indicate static pressure shall be inserted through the top at the midwidth of the tunnel, 1 inch ± 0.5 inch (25 mm ± 12 mm) below the ceiling, 15 inches ± 0.5 inch (381 mm ± 13 mm) downstream from the inlet shutter.

A light source shall be mounted on a horizontal section of the 16-inch-diameter (406 mm) horizontal vent pipe at a point where it will be preceded by a straight run of pipe [at least 12 diameters or 16 feet (4880 mm) and not more than 30 diameters or 40 feet (12 190 mm)], from the vent end of the chamber, with the light beam directed upward along the vertical axis of the vent pipe. The vent pipe is to be insulated with at least 2 inches (51 mm) of high-temperature mineral composition material from the vent end of the chamber to the photometer location. A photoelectric cell of which the output is directly proportional to the amount of light received is to be mounted over the light source and connected to a recording device for indicating changes in the attenuation of incident light by passing smoke, particulate and other effluent. The distance between the light source lens and the photocell lens shall be 36 inches ± 4 inches (914 mm ± 102 mm). The cylindrical light beam shall pass through 3-inch-diameter (76 mm) openings at the top and bottom of the 16-inch-diameter (406 mm) duct, with the resultant light beam centered on the photocell.

Linearity of the photometer system shall be verified periodically by interrupting the light beam with calibrated neutral density filters. The filters shall cover the full range of the recording instrument. Transmittance values measured by the photometer, using neutral density filters, shall be within ± 3 percent of the calibrated value for each filter.

An automatically controlled damper to regulate the draft pressure shall be installed in the vent pipe downstream of the smoke-indicating attachment. The damper shall be provided with a manual override.

Other manual or automatic draft regulation devices, or both, may be incorporated to maintain fan characterization and airflow control throughout test periods.

A No. 18 AWG (1.02 mm) thermocouple, with $^3/_8$ inch ± $^1/_8$ inch (9.5 mm ± 3.2 mm) of the junction exposed in the air, shall be inserted through the floor of the test chamber so that the tip is 1 inch ± $^1/_{32}$ inch (25.4 mm ± 0.8 mm) below the top surface of the asbestos gasketing tape and 23 feet ± $^1/_2$ inch (7010 mm ± 13 mm) from the center line of the burner ports at the center of its width.

A No. 18 AWG (1.02 mm) thermocouple embedded $^1/_8$ inch (3.2 mm) below the floor surface of the test chamber is to be mounted in refractory or portland cement carefully dried to avoid cracking at distances of 13 feet ± $^1/_2$ inch (3962 mm ± 13 mm) and $23^1/_4$ feet ± $^1/_2$ inch (7087 mm ± 13 mm) from the center line of the burner ports.

The room in which the test chamber is located is to have provision for a free inflow of air during test to maintain the room at atmospheric pressure during the entire test run.

SECTION 8.103 — TEST SPECIMENS

The test specimen shall be at least 2 inches (51 mm) wider [nominally $20^1/_4$ inches ± $^3/_4$ inch (514 mm ± 19 mm)] than the interior width of the tunnel and total 24 feet ± $^1/_2$ inch (7315 mm ± 13 mm) in length. The specimen may consist of a continuous, unbroken length or of sections joined end-to-end. A 14-inch ± $^1/_8$-inch (356 mm ± 3 mm) length of uncoated 16-gage (0.053-inch to 0.060-inch) steel sheet shall be placed on specimen mounting ledge in front of and under the specimen in the upstream end of the tunnel. Specimens shall truly represent the materials for which classification is desired. Properties adequate for identification of the materials or ingredients, or both, of which the test specimen is made are to be determined and recorded.

The test specimen shall be conditioned to a constant weight at a temperature of 73.4°F ± 5°F (23°C ± 2.8°C) and at a relative humidity of 50 ± 5 percent.

SECTION 8.104 — CALIBRATION OF TEST EQUIPMENT

A $^1/_4$-inch (6.3 mm) asbestos-cement board shall be placed on the ledge of the furnace chamber. The removable top of the test chamber shall be placed in position.

With the $^1/_4$-inch (6.3 mm) asbestos-cement board in position on top of the ledge of the furnace chamber, and with the removable top in place, the draft is to be established so as to produce a 0.15-inch (3.8 mm) water-column reading on the draft manometer, with the fire-end shutter open 3 inches ± $^1/_{16}$ inch (76 mm ± 1.6 mm) by manually setting the damper as a characterization of fan performance. The fire-end shutter shall be closed and sealed without changing the damper position. The manometer reading shall increase to at least 0.375-inch (9.53 mm) water column, indicating that no excessive air leakage exists.

In addition, a supplemental leakage test is to be conducted periodically with the fire shutter and exhaust duct beyond the differential manometer tube sealed, by placing a smoke bomb in the chamber. The bomb shall be ignited and the chamber pressurized to 0.375 inch ± 0.15-inch (9.53 mm ± 3.18 mm) water column. All points of leakage observed in the form of escaping smoke particles shall be sealed.

A draft reading shall be established within the range 0.055-inch to 0.100-inch (1.40 to 2.54 mm) water column. The required draft gage reading shall be maintained by the automatic damper. Record the air velocity at seven points, 23 feet (7010 mm) from the center line of the burner ports, 6 inches ± $^1/_4$ inch (168 mm ± 7 mm) below the plane of the specimen mounting ledge. Determine these seven points by dividing the width of the tunnel into seven equal sections and recording the velocity at the geometrical center of each section. During the measurement of velocity, remove the turbulence bricks and exposed 23-foot (7010 mm) thermocouple and place 24-inch-long (670 mm) straightening vanes between 16 feet and 18 feet (4876 mm and 5486 mm) from the burner. The straightening vanes shall divide the furnace cross section into nine uniform sections. Determine the velocity with furnace air temperature at 73.4°F ± 5°F (23°C ± 2.8°C) using a velocity transducer. The velocity, determined as the arithmetic average of the seven readings, shall be 240 feet ± 5 feet (7.32 m ± 1.5 m) per minute.

Maintain the air supply at a temperature of 73.4°F ± 5°F (23°C ± 2.8°C) and a relative humidity of 50 ± 5 percent.

The fire test chamber shall be suppled with natural (city) or methane (bottled) gas fuel of uniform quality with a heating value of nominally 1,000 Btu/ft^3 (37.3 MJ/m^3). The gas supply is to be initially adjusted at approximately 5,000 Btu/min. (5.3 MJ/min.) The gas pressure, the pressure differential across the orifice plate and the volume of gas used shall be recorded in each test. Unless otherwise corrected for, when bottled methane is employed, a length of coiled copper tubing is to be inserted into the gas line between the supply and metering connection to compensate for possible errors in the flow indicated due to reductions in gas temperature associated with the pressure drop and expansion across the regulator. With the draft and gas supply adjusted as indicated in this section, the test flame is to extend downstream to a distance of 4$^1/_2$ feet (1372 mm) over the specimen surface, with negligible upstream coverage.

The test chamber shall be preheated with the $^1/_4$-inch (6.3 mm) asbestos-cement board and the removable top in place and with the fuel supply adjusted to the required flow. The preheating shall be continued until the temperature indicated by the floor thermocouple at 23$^1/_4$ feet (7087 mm) reaches 150°F ± 5°F (66°C ± 2.8°C). During the preheat test, the temperatures indicated by the thermocouple at the vent end of the chamber shall be recorded at 15-second intervals and compared to the preheat temperature shown in the time-temperature curve, Figure 8-1-3. The preheating is for the purpose of establishing the conditions that will exist following the successive tests and to indicate the control of the heat input into the test chamber. If the appreciable variation from the temperatures shown in the representative preheat curve is observed, because of variation in the characteristics of the gas used, adjustments in the fuel supply may be made prior to proceeding with the red oak calibration tests.

The furnace shall be allowed to cool after each test. When the floor thermocouple at 13 feet (3962 mm) shows a temperature of 105°F ± 5°F (40.5°C ± 2.8°C), the next specimen shall be placed in position for test.

With the test equipment adjusted and conditioned as described in this section, a test or series of tests shall be made, using nominal $^{23}/_{32}$-inch (18.3 mm) Select grade red oak flooring as the sample, conditioned to 6 to 8 percent moisture content as determined by the 221°F (105°C) oven-dry method in accordance with approved nationally recognized standards. Observations shall be made at distance intervals of not more than 2 feet (610 mm) and time intervals of not more than 30 seconds and the time recorded when the flame reaches the end of the specimen, that is, 19$^1/_2$ feet (5944 mm) from the end of the ignition fire. The end of the ignition fire shall be considered as being 4$^1/_2$ feet (1372 mm) from the burners. The flame shall reach the end point in five and one-half minutes ± 15 seconds. The temperature measured by the thermocouple near the vent end shall be automatically recorded at least every 15 seconds. The photoelectric cell output shall be automatically recorded immediately prior to the test and at least every 15 seconds during the test.

The results of tests of Select grade red oak flooring in which the flame spreads 19$^1/_2$ feet (5944 mm) from the end of the igniting flame in five and one-half minutes shall be considered as representing a classification of 100. Plot the flame spread distance, temperature, and change in photoelectric cell readings separately on suitable coordinate paper. Figures 8-1-4, 8-1-5 and 8-1-6 are representative curves for red oak flame spread distance, time-temperature development, and smoke density, respectively. Flame-spread distance shall be determined as the observed distance minus 4$^1/_2$ feet (1372 mm).

Following the calibration tests for red oak, a similar test(s) is to be conducted on samples of $^1/_4$-inch (6.3 mm) asbestos-cement board. The results are to be considered as representing a classification of zero. The temperature readings shall be plotted separately on coordinate paper. Figure 8-1-7 is a representative curve for fuel contribution of asbestos-cement board.

SECTION 8.105 — MOUNTING METHODS

8.105.1 General.

8.105.1.1 Purpose. The methods specified in this section have been compiled as an aid in selecting a means for mounting and supporting various building materials in the fire test chamber for test method uniformity and convenience. They are not meant to imply restriction in the specific details of field installation.

8.105.1.2 Application. These methods shall apply to (i) materials that, in and of themselves, are not self-supporting when installed in the test chamber in accordance with Section 8.106, and (ii) materials that are self-supporting as indicated herein, but which become dislodged from their mounting position or otherwise separate or distort so that they fall to the floor of the test chamber during the test. Materials that are installed and perform as described in (ii) above shall be retested when mounted and supported in accordance with the applicable method specified in this section.

8.105.1.3 Alternates. For some building materials, none of the methods described may be applicable. In such cases, other means of mounting and support shall be devised to minimize the effect of the mounting and support method on the performance of the material when tested in accordance with this standard.

8.105.1.4 Format. These mounting methods are grouped according to building materials to be tested, which are broadly described either by usage or by form of the material.

8.105.1.5 Cement board backing. Whenever inorganic reinforced cement board is specified as a backing in this section, the material shall be nominal $^1/_4$-inch (6.3 mm) thick, high density [110 ± 5 lb./ft.^{3} (1792 ± 80 kg/m^3)] and uncoated.

8.105.1.6 Use of metal rods. When metal rods or bars are specified in this section as supports, they shall be:

Steel rods, $^1/_4$-inch (6.3 mm) diameter
Steel bars, $^3/_{16}$ inch by 2 inches (5 mm by 51 mm)

The rods or bars shall span the width of the tunnel. Rods shall be placed approximately 2 inches (51 mm) from each end of each panel and at approximately 2-foot (610 mm) intervals starting with the fire end of each panel.

Bars shall be used instead of rods only when they are required to support the sample. The bars shall be placed approximately 2 inches (51 mm) from each end of each panel and at approximately 2-foot (610 mm) intervals starting with the fire end of each panel.

8.105.1.7 Use of netting. Whenever netting is specified as a support in this section, the material shall be 20-gage, 2-inch (51 mm), hexagonal galvanized steel netting (chicken wire).

8.105.2 Acoustical and Other Similar Panel Products Less Than 20 Inches (508 mm).

8.105.2.1 For acoustical materials and other similar panel products whose maximum dimension is less than 20 inches (508 mm), metal splines or wood furring strips and metal fasteners shall be used.

8.105.2.2 Steel tee splines for mounting kerfed-acoustical tile shall be nominal $^1/_2$-inch (13 mm) web by $^3/_4$-inch (19 mm) flange, formed No. 24 gage [0.021-inch (0.53 mm) minimum thickness] sheet metal.

8.105.2.3 Wood furring frames for mounting acoustical materials and other similar panel products whose maximum dimension is less than 20 inches (508 mm) shall be nominal 1-inch-by-2-inch (25 mm by 51 mm) wood furring joined with corrugated-metal fasteners. Use two frames as shown in Figure 8-1-9.

8.105.3 Adhesives. To determine the surface-burning characteristics of adhesives, they shall be mixed as specified in the manufacturer's instructions and shall be applied to inorganic reinforced cement board in the thickness or at the coverage rate recommended by the manufacturer. The adhesive application shall be cured prior to testing.

8.105.4 Batt or Blanket-type Insulating Materials. Batt or blanket materials that do not have sufficient rigidity or strength to support themselves shall be supported by metal rods inserted through the material and positioned such that the bottom of the rod is approximately $^1/_4$ inch (6.3 mm) from the surface to be exposed to the flame. Batt or blanket materials less than 1-inch (25.4 mm) thick shall not be mounted for testing in this manner.

8.105.5 Coating Materials, Cementitious Mixtures and Sprayed Fibers. Coating materials, cementitious mixtures and sprayed fibers shall be mixed and applied as specified in the manufacturer's instructions.

8.105.6 Loose-fill Insulation. Loose-fill insulation, other than cellulose loose-fill insulation, shall be placed on the floor of the tunnel at an approximate thickness of 2 inches (51 mm) by length of the tunnel, packed to the density specified by the manufacturer. Ceramic paper with a nominal density of 0.7 kg/m^2 shall be laid on the floor of the tunnel beneath the insulation, with appropriate cutouts being made to accommodate the burners and thermocouple.

The following modifications to the tunnel shall be made:

Inside windows shall be removed, leaving only the outside windows.

The burners shall be capable of vertical movement upwards and adjusted so that their center line is 2 inches ± $^1/_8$ inch (50.8 mm ± 3.2 mm) above the nominal level of the top of the test sample. The elbows constituting the burner ports shall be rotated until they are pointed downwards at an angle of 45 degrees to the horizontal in the direction of the air flow (see Figure 8-1-12).

To reduce (air) eddies and possible ablation of low-density materials in the burner vicinity, an air ramp (see Figure 8-1-13) shall be placed as shown with the downstream end of the ramp terminating beneath the center line of the burner tee and overlapping the specimen 1 inch (25.4 mm). The ramp shall be made of No. 304 stainless steel, minimum thickness $^1/_{16}$ inch (1.6 mm), 26 inches (660 mm) long and sized to fit within $^1/_8$ inch (3.2 mm) of the furnace width.

Flame Spread Index shall be determined as follows:

If the total area (A_T) is less than or equal to 97.5 feet·min., the Flame Spread Index shall be 0.564 times the total area (FSI = 0.564_T) (For **SI:** If $A_T \leq 29.7$ m·min., FSI = 1.85 A_T).

If the total area (A_T) is greater than 97.5 feet·min., the Flame Spread Index shall be 5363, divided by the difference of 195 minus the total area (A_T). [FSI = 5363/(195 – A_T)] [For **SI:** If $A_T >$ 29.7 m·min., FSI = 1640/(59.4 – A_T)].

Smoke developed is determined as stated in Section 8.104.

8.105.7 Plastics. Plastics shall be supported by metal rods or bars, or by netting supported with metal bars or rods, spanning the width of the tunnel in accordance with Section 8.105.1.6.

8.105.8 Thin Membranes. Single-layer membranes or thin laminates consisting of a limited number of similar or dissimilar layers shall be supported on netting placed on metal rods in accordance with Section 8.105.1.6.

8.105.9 Wall Coverings. Wall coverings of various types intended for application directly to a noncombustible wall surface shall be mounted to $^1/_4$-inch (6.4 mm) inorganic-cement board with the adhesive specified by the manufacturer in a manner consistent with field practice.

If intended to be applied over gypsum wallboard, the wall coverings shall be tested on that substrate.

If intended for application over a combustible substrate, the wall coverings shall be tested on that substrate.

Wall coverings not intended to be adhered directly to a wall surface, but hung or otherwise supported by framing or a track system, shall be mounted for test in a manner that is representative of their installation. Where this is not practical, the sample shall be supported on netting placed on metal rods as provided.

8.105.10 Mounting Method for Heavy Textile Materials. When the surface-burning characteristics of the material itself are required, specimens shall be mounted on inorganic reinforced cement board with high-temperature bonding mortar or the equivalent.

The application shall be determined by a $^3/_{32}$-inch (2.4 mm) notched trowel held at an 80-degree to 90-degree angle using a random pattern. The adhesive shall be applied only to the specimen back. The specimen shall then be placed on the smooth side of the inorganic reinforced-cement board and rolled using a 100-pound (45.4 kg) roller [nominal 5-inch (127 mm) diameter, three 5-inch-long (127 mm) sections placed end-to-end for a total length of 15 inches (381 mm)]. The prepared samples can be dead stacked overnight but should be transferred to separate storage racks until tested. Each sample shall be vacuumed prior to test.

SECTION 8.106 — TEST PROCEDURE

With the furnace draft operating, the test specimen shall be placed on the test chamber ledges which have been completely covered with nominal $^1/_8$-inch-thick (3.2 mm) by $1^1/_2$-inch-wide (38 mm) woven asbestos tape. The removable top shall be placed in position over the specimen.

The completely mounted specimen is to remain in position in the chamber with the furnace draft operating for 120 ± 15 seconds prior to application of the test flame.

The igniting flame shall be lighted and adjusted. The distance and time of maximum flame front travel is to be observed and recorded. The test shall be continued for a 10-minute period unless the sample is completely consumed in the fire area before that time, in which case the test is to be ended after no further progressive burning is evident and the photoelectric cell reading has returned to the base line.

The photoelectric cell output shall be recorded immediately prior to the test and at least every 15 seconds during test.

The gas pressure, the pressure differential across the orifice plate and the volume of gas used shall be recorded in each test.

When the test is ended, the gas supply shall be shut off. Smoldering and other conditions within the test duct are to be observed and the sample removed for further examination.

The temperature, flame-spread distance and change in photoelectric cell readings shall be plotted separately on the same coordinate paper as used for those graphs required in Section 8.104 for use in determining the flame-spread and smoke-developed indexes as outlined in Section 8.106. Flame front advancement shall be recorded at the time of occurrence or at least every 30 seconds if no advancement is noted. Flame-spread distance shall be determined as the observed distance minus $4^1/_2$ feet (1372 mm).

SECTION 8.107 — INTERPRETATION OF RESULTS

The flame-spread index (FSI) shall be the value as determined below rounded to the nearest multiple of 5 points:

In plotting the flame-spread distance-time relationship, all progressive flaming as previously recorded shall be included at the time of occurrence. A straight line shall be used to connect successive points. The total area (A_T) under the flame-spread distance-time plot shall be determined by ignoring any flame front recession. For example, in Figure 8-1-8 the flame spreads 10 feet (3048 mm) in $2^1/_2$ minutes and then recedes. The area is calculated as if the flame had spread to 10 feet (3048 mm) in $2^1/_2$ minutes and then remained at 10 feet (3048 mm) for the remainder of the test or until the flame front again passed 10 feet (3048 mm). This is shown by the dashed line in Figure 8-1-8. The area (A_T) used for calculating the flame-spread index is the sum of areas A_1 and A_2 in Figure 8-1-8.

If this total area (A_T) is less than or equal to 97.5 feet·min., the flame-spread index shall be 0.515 times the total area (FSI = 0.515 A_T) (For **SI:** If $A_T \leq 29.7$ m·min., FSI = 1.85 A_T).

If this total area (A_T) is greater than 97.5 feet·min., the flame-spread index shall be 4,900 divided by the difference of 195 minus the total area (A_T). [FSI = 4,900/(195 – A_T)] [For **SI:** If $A_T > 29.7$ m·min., FSI = 1640/(59.4 – A_T)].

The test results for smoke shall be plotted, using the same coordinates as in Section 8.104. The area under the curve shall be divided by the area under the curve for red oak, and multiplied by 100, and rounded to the nearest multiple of 5 points to establish a smoke-developed index by which the performance of the material may be compared with that of inorganic reinforced cement board and Select grade red oak flooring, which has been arbitrarily established as 0 and 100, respectively. For smoke-developed indexes 200 or over, the calculated value shall be rounded to the nearest 50 points.

When multiple test data are provided, the flame-spread index and smoke-developed index shall be determined as follows:

Flame-spread Index (FSI)

The individual flame-spread data values shall be rounded to the nearest multiple of 5 points. If the rounded values do not exceed a 10-point range, the original values shall be averaged and the resultant average shall be rounded to the nearest multiple of 5 points and considered as the FSI.

Where the individual rounded values do exceed a 10-point range, the highest individual value shall be rounded to the nearest multiple of 5 points and considered as the FSI.

Smoke-developed Index (SDI)—All Rounded Smoke Values 200 or under

The individual smoke-developed data values shall be each rounded to the nearest multiple of 5 points. If the rounded values do not exceed a 20-point range, the original values shall be averaged and the resultant average shall be rounded to the nearest multiple of 5 points and considered as the SDI.

Where the individual rounded values do exceed a 20-point range, the highest individual value shall be rounded to the nearest multiple of 5 points and considered as the SDI.

Smoke-developed Index (SDI)—All Rounded Smoke Values 200 or over

The individual smoke-developed data values shall be each rounded to the nearest multiple of 5 points. If the rounded values do not exceed a 50-point range, the original values shall be averaged and the resultant average shall be rounded to the nearest multiple of 50 points and considered as the SDI.

Where the individual rounded values do exceed a 50-point range, the highest individual value shall be rounded to the nearest multiple of 50 points and considered as the SDI.

Rounded Smoke Values both under and over 200

The calculated smoke-developed data values shall each be rounded to the nearest multiple of 5 points. If the rounded values do not exceed a 20-point range, the SDI value shall be considered as 200.

Where the individual rounded values do exceed a 20-point range, the highest individual value shall be rounded to the nearest multiple of 50 points and considered as the SDI.

SECTION 8.108 — ANALYSIS OF PRODUCTS OF COMBUSTION

Samples for combustion product analysis, when analysis is requested, shall be taken downstream from the photometer, or shall consist of not more than 1 percent of the total flow. It should be noted that analysis of the products of combustion is not required in this method.

SECTION 8.109 — REPORT

The report shall include the following:

1. Description of the material being tested,
2. Test results as calculated in Section 8.106,
3. Details of the method used in placing the specimen in the test chamber,
4. Observations of the burning characteristics of the specimen during test exposure, such as delamination, sagging, shrinkage, fallout, etc., and
5. Graphical plots of flame-spread and smoke-developed data.

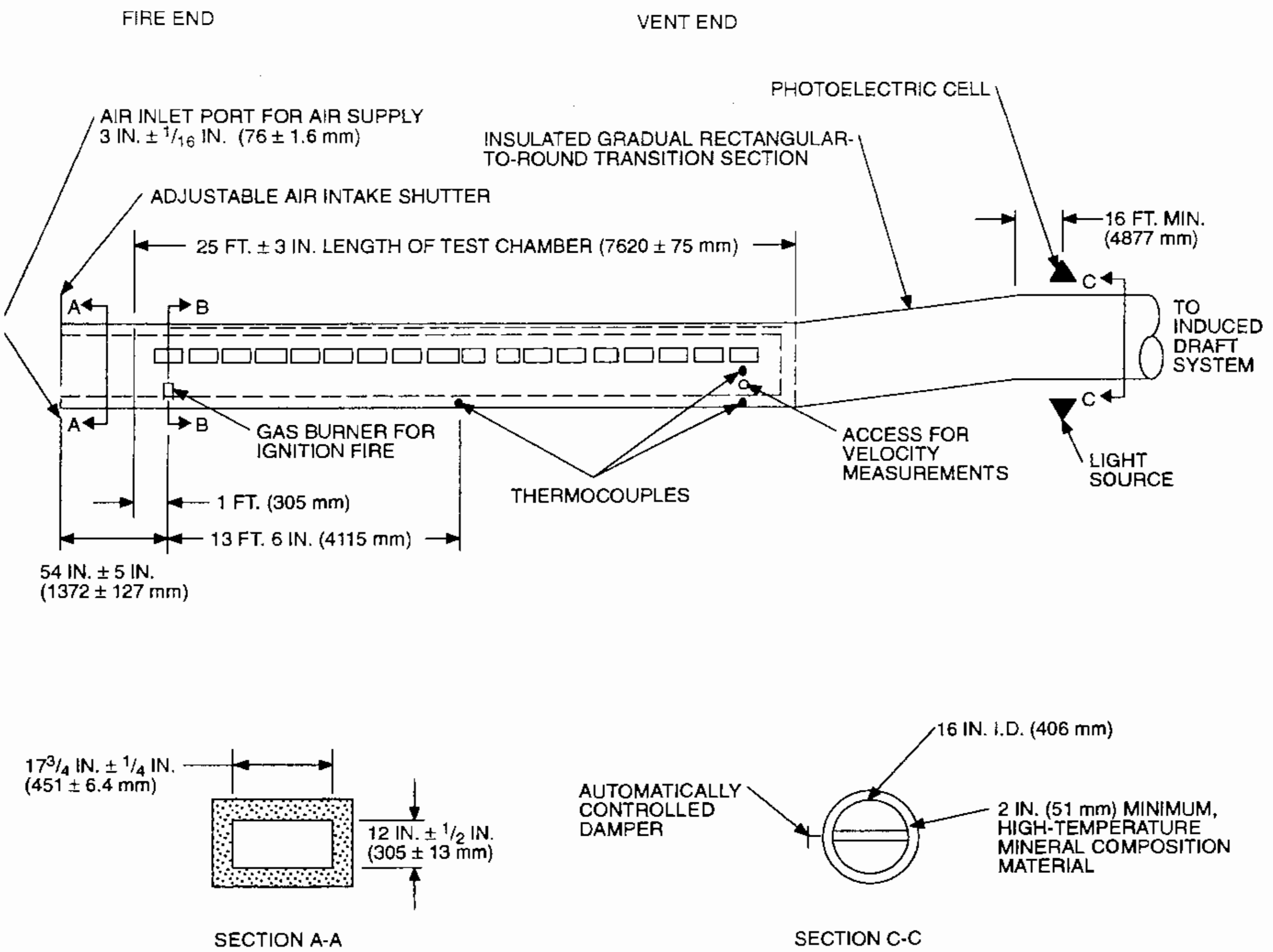


FIGURE 8-1-1—DETAILS OF TEST FURNACE

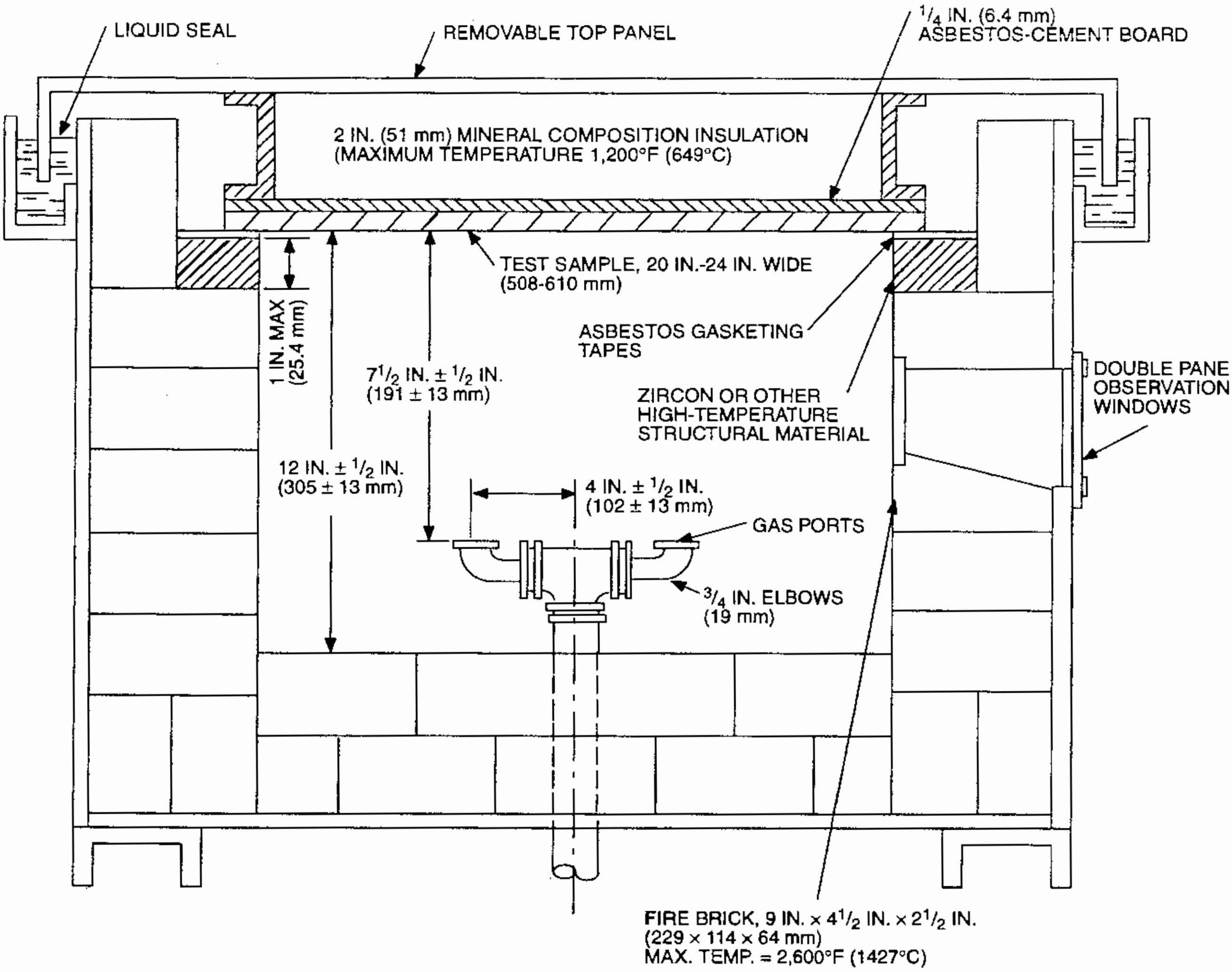


FIGURE 8-1-2—SECTION B-B

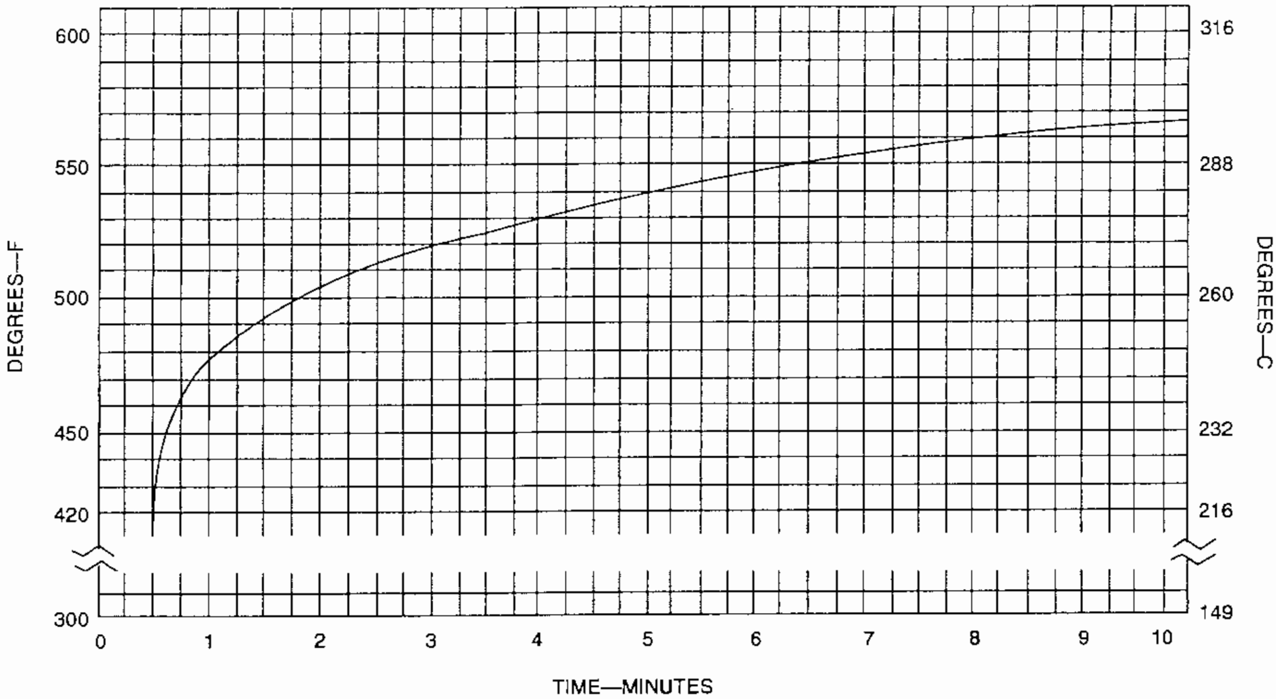
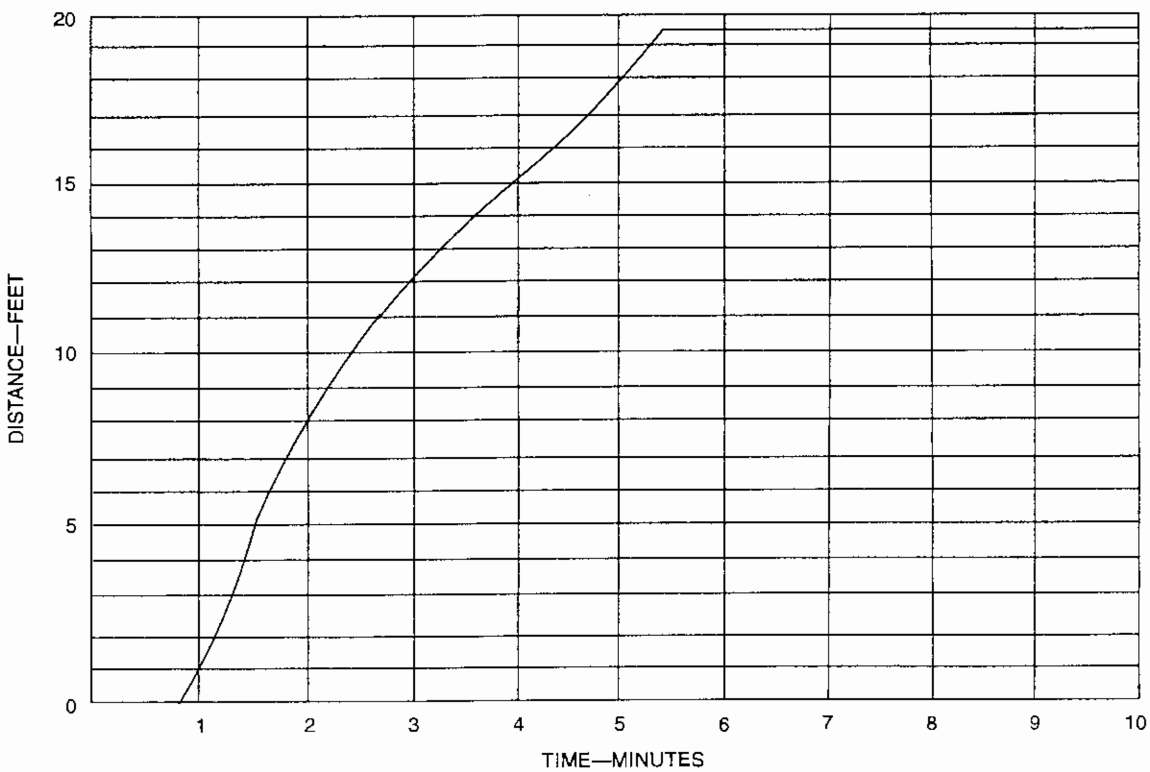


FIGURE 8-1-3—TIME-TEMPERATURE FOR PREHEAT TEMPERATURE



For SI: 1 foot = 0.3048 m.

FIGURE 8-1-4—REPRESENTATIVE TIME-DISTANCE CURVE FOR FLAME SPREAD OF RED OAK

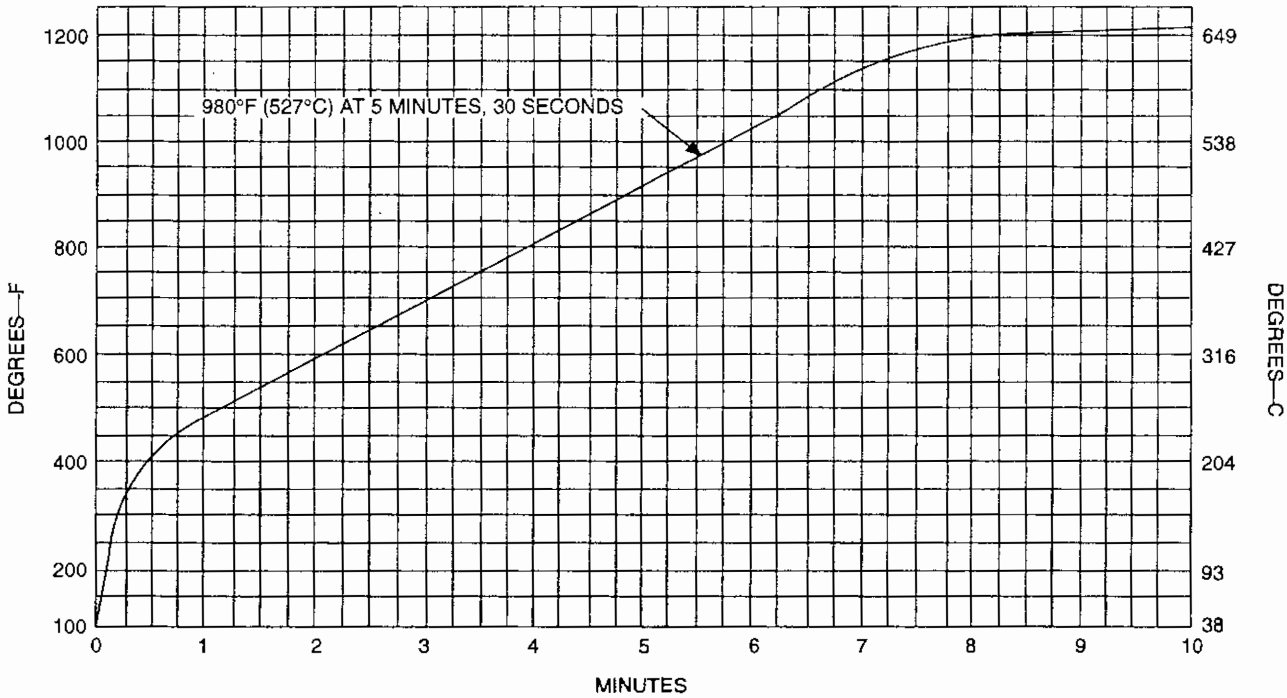


FIGURE 8-1-5—TIME-TEMPERATURE CURVE FOR FUEL CONTRIBUTION OF RED OAK

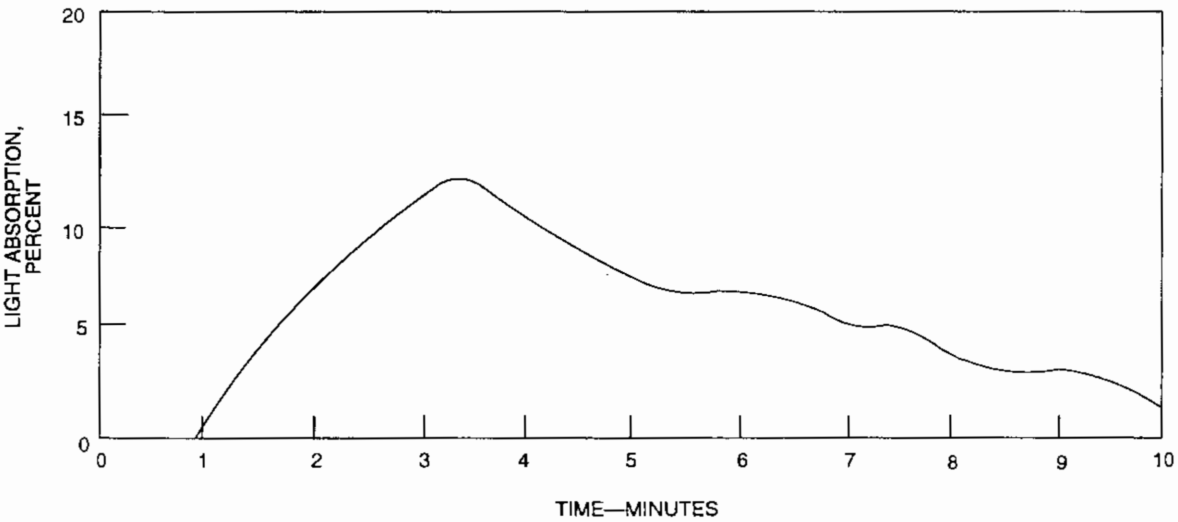


FIGURE 8-1-6—SMOKE DENSITY—RED OAK

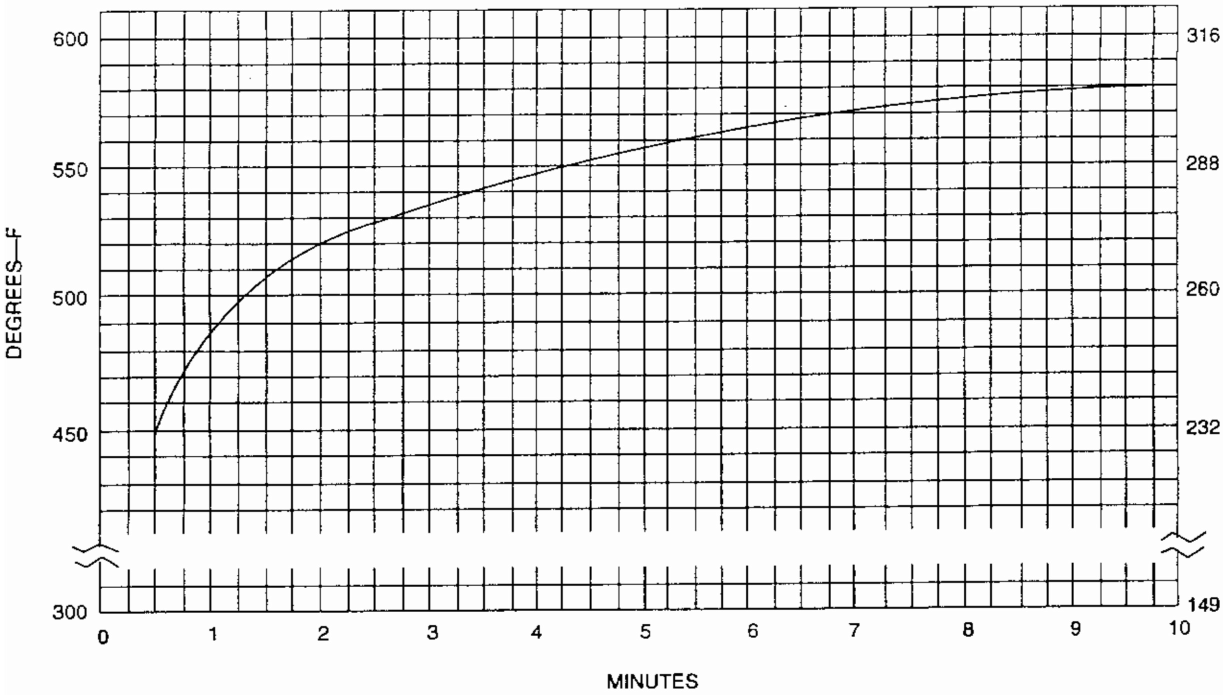
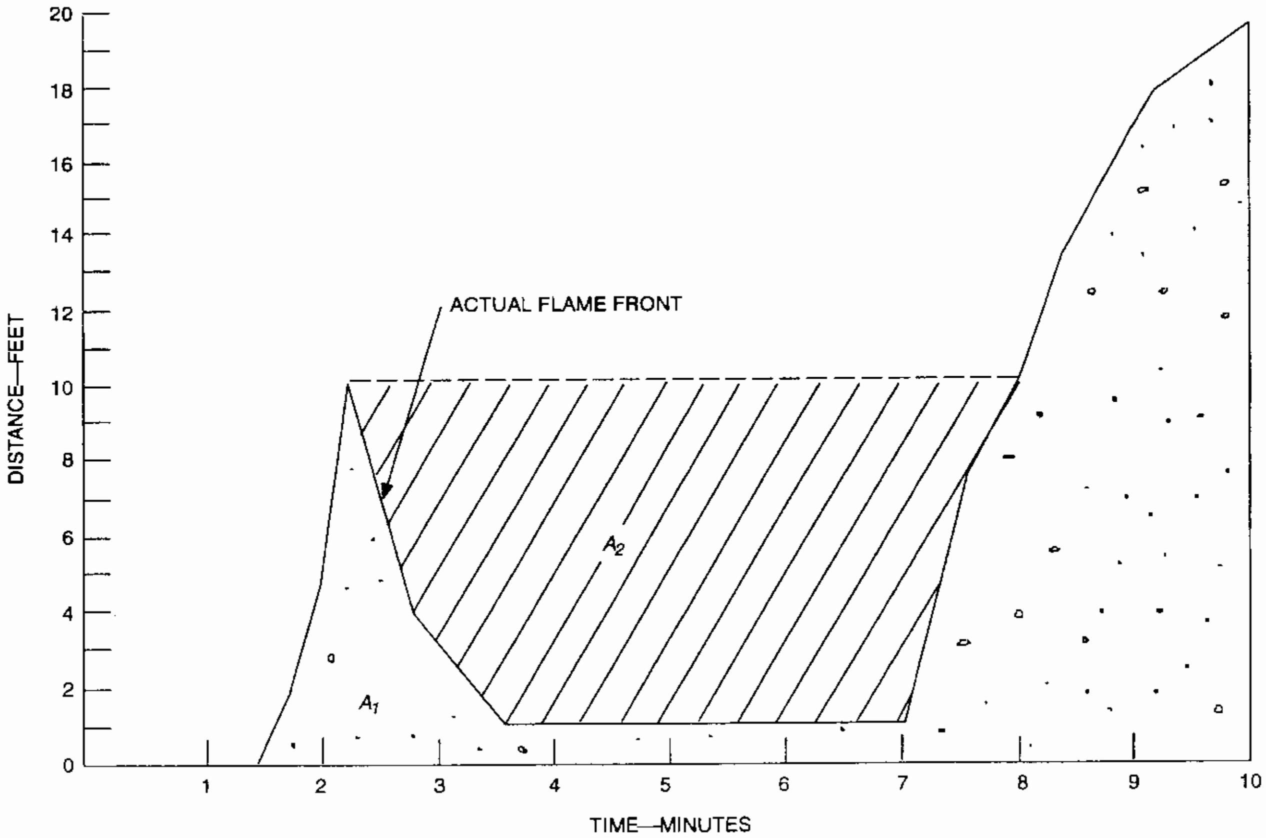


FIGURE 8-1-7—TIME-TEMPERATURE CURVE FOR FUEL CONTRIBUTION ASBESTOS-CEMENT BOARD



For **SI:** 1 foot = 0.3048 m.

FIGURE 8-1-8—EXAMPLE OF TIME-DISTANCE RELATIONSHIP WITH FLAME FRONT RECESSION
(Total Area, $A_T = A_1 + A_2$)

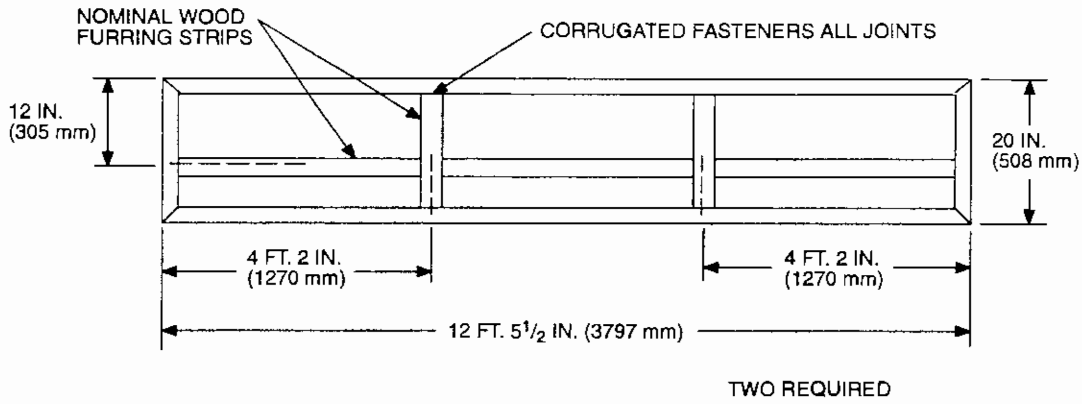


FIGURE 8-1-9—WOOD FRAME FOR ACOUSTICAL MATERIALS AND OTHER SIMILAR PANEL PRODUCTS LESS THAN 20 INCHES (508 mm)

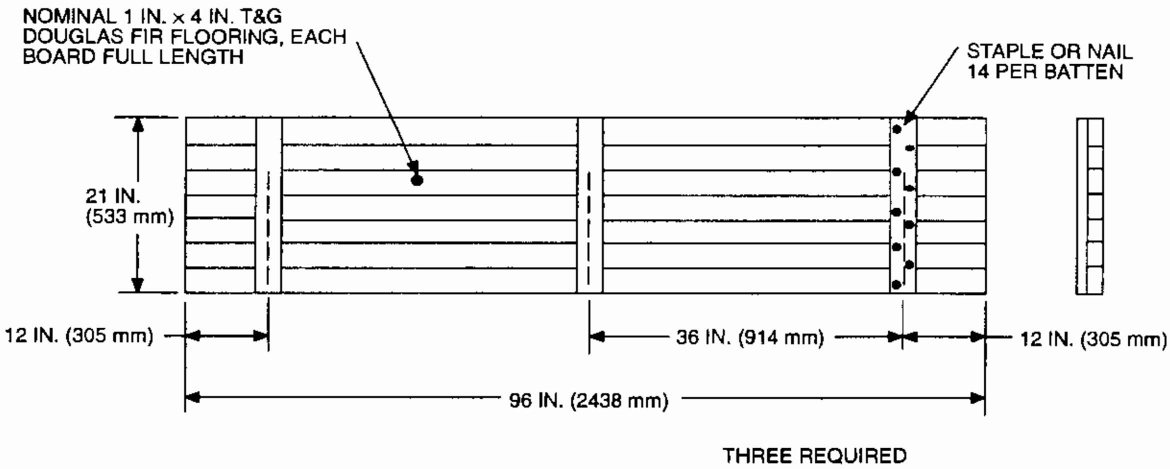


FIGURE 8-1-10—WOOD DECK FOR COATING MATERIAL

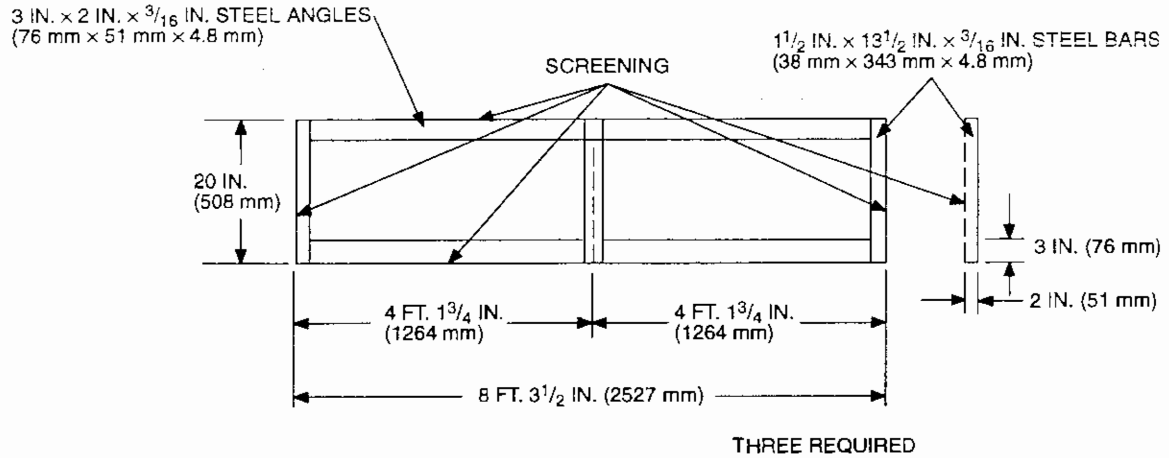


FIGURE 8-1-11—STEEL FRAME FOR LOOSE FILL MATERIALS

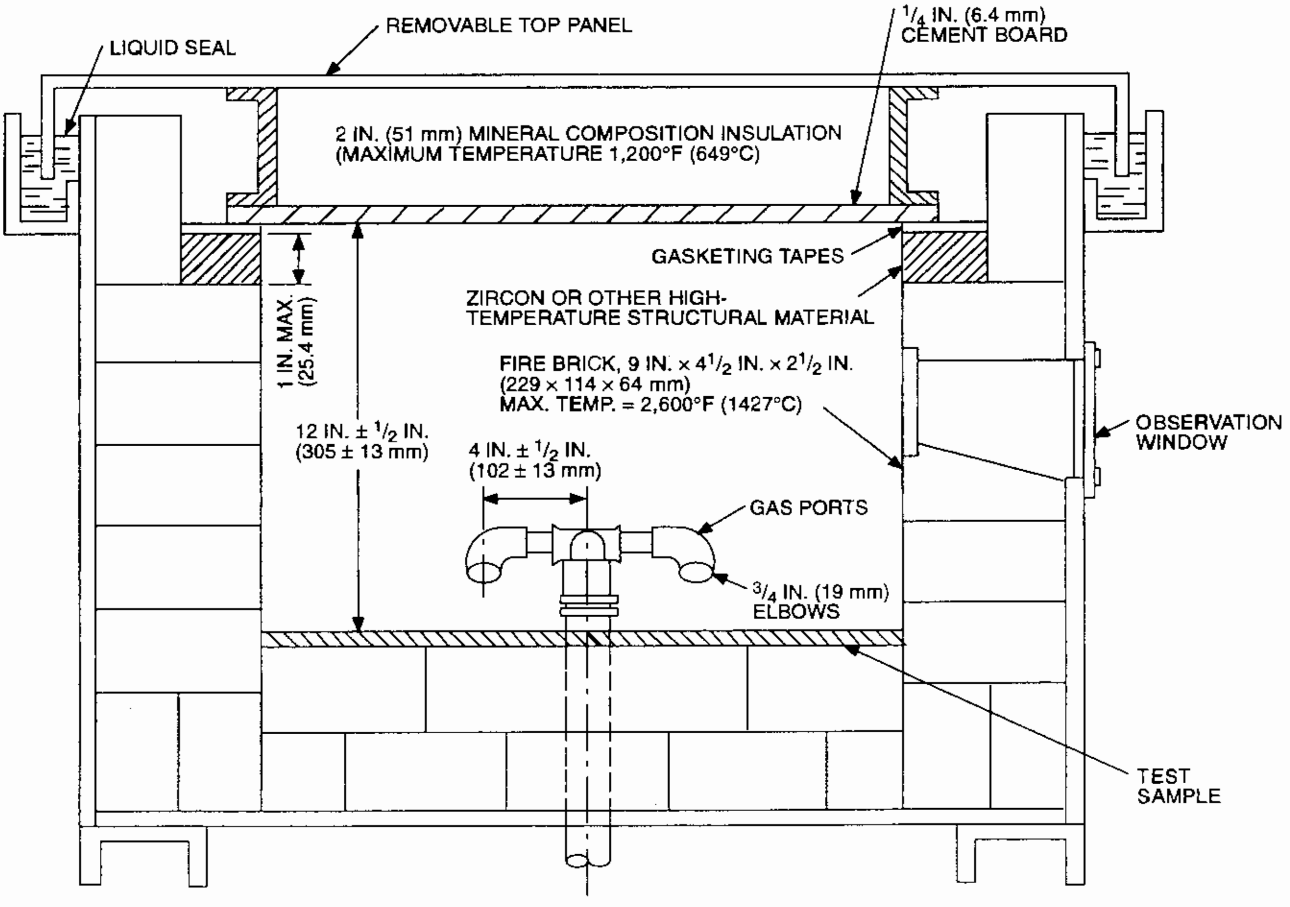


FIGURE 8-1-12—SECTION B-B

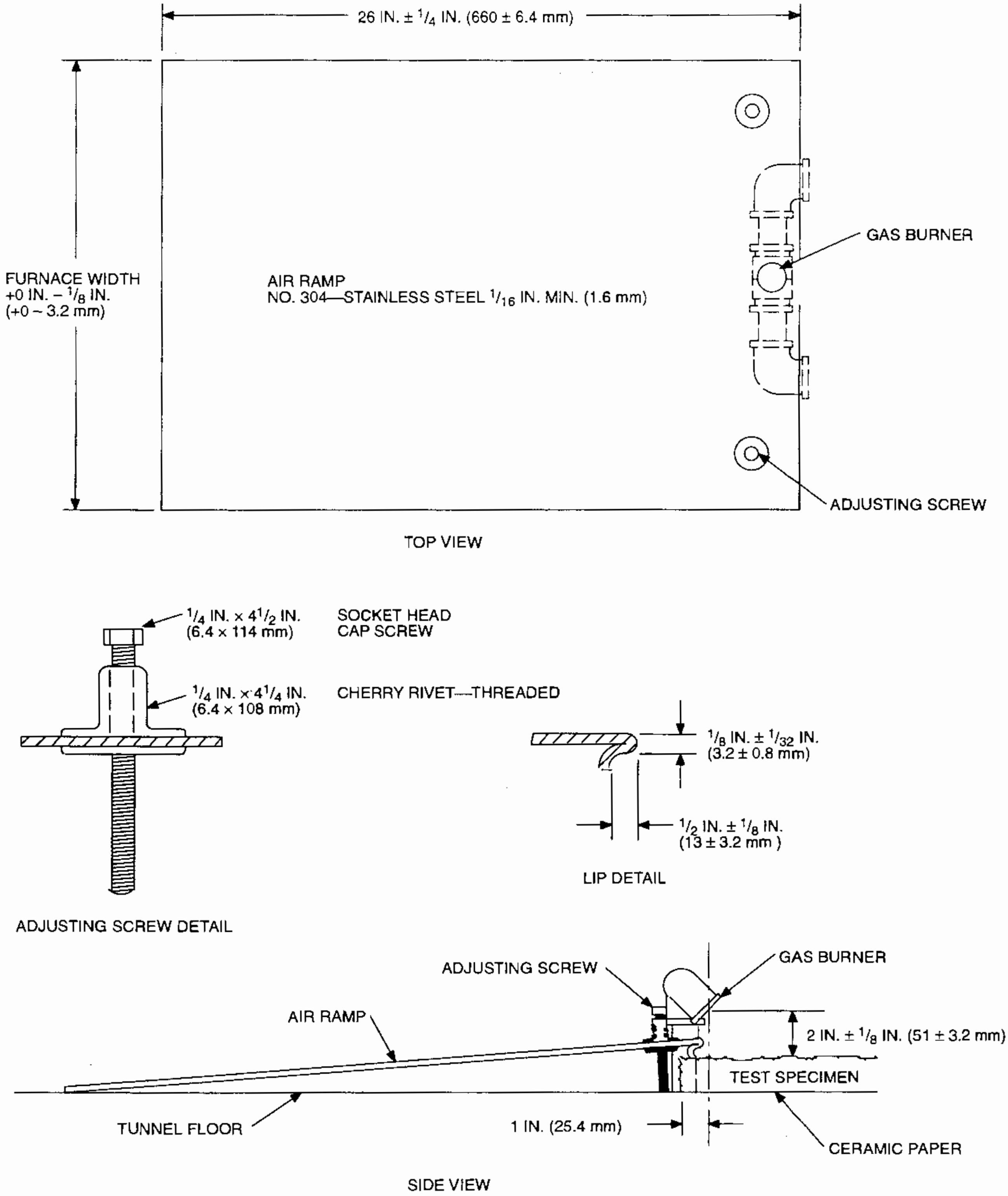


FIGURE 8-1-13—AIR RAMP

UNIFORM BUILDING CODE STANDARD 8-2
STANDARD TEST METHOD FOR EVALUATING ROOM FIRE GROWTH CONTRIBUTION OF TEXTILE WALL COVERING

Test Method of the International Conference of Building Officials

See Sections 801.2 and 805, *Uniform Building Code*

SECTION 8.201 — SCOPE

This standard describes a method for determining the contribution of textile wall covering to room fire growth during specified fire exposure conditions. This method is not intended to evaluate the fire endurance of assemblies, nor is it able to evaluate the effect of fires originating within the wall assembly. The method is not intended for the evaluation of floor or ceiling finishes.

This method is to be used to evaluate the flammability characteristics of textile wall coverings when such materials constitute the exposed interior surfaces of buildings. This test method does not apply to fabric covered less than ceiling height; freestanding, prefabricated panel furniture systems; or demountable, relocatable, full-height partitions used in open building interiors. Freestanding panel furniture systems include all freestanding panels that provide visual and/or acoustical separation and are intended to be used to divide space and may support components to form complete work stations. Demountable, relocatable, full-height partitions include demountable, relocatable, full-height partitions that fill the space between the finished floor and the finished ceiling.

This method is to be used to evaluate the flammability characteristics of textile wall coverings when required by this code.

SECTION 8.202 — SIGNIFICANCE AND USE

This fire test measures certain fire performance characteristics of textile wall covering materials in an enclosure under specified fire exposure conditions. It determines the extent to which the textile wall covering materials may contribute to fire growth in a room and the potential for fire spread beyond the room under the particular conditions simulated. The test indicates the maximum extent of fire growth in a room, the rate of heat release, and if they occur, the time to flashover and the time to flame extension beyond the doorway following flashover. It does not measure the fire growth in, or the contribution of, the room contents. Time to flashover is defined herein as either the time when the radiant flux onto the floor reaches 20 kW/m^2 or the temperature of the upper air reaches 600°C. A crumpled single sheet of newspaper shall be placed on the floor 3 feet (914 mm) out from the center of the rear wall. The spontaneous ignition of this newspaper provides the visual indication of flashover.

The potential for spread of fire to other objects in the room, remote from the ignition source, is evaluated by measurements of:

1. The total heat flux incident on the center of the floor.
2. A characteristic upper-level gas temperature in the room.
3. Instantaneous net peak rate of heat release.

The potential for the spread of fire to objects outside the room of origin is evaluated by the measurement of the total heat release of the fire.

Measurements of the rate of production of carbon monoxide and carbon dioxide are taken.

The overall performance of the test specimen is to be visually documented by full-color photographic records. Videotaping of the complete fire test may be done as an alternative to the photographic record. Such records shall show when each area of the test specimen becomes involved in the fire.

SECTION 8.203 — SUMMARY OF METHOD

The test method has two types of protocols. One is a "screening test" protocol and the second is the "fully lined test" protocol. The "screening test" protocol utilizes a corner test exposure of relatively small specimens mounted on the walls of the test compartment. The "fully lined test" protocol involves the same test in a compartment having three fully lined walls.

This method uses a gas burner to produce a diffusion flame to expose the walls in the corner of an 8- by 12- by 8-foot-high (2348 mm by 3658 mm by 2438 mm) room. The burner produces a prescribed rate of heat output of 40 kW for five minutes followed by 150 kW for 10 minutes, for a total exposure period of 15 minutes. The contribution of the textile wall covering to fire growth is measured via constant monitoring of the incident heat flux on the center of the floor, the temperature of the gases in the upper part of the room, the rate of heat release and the time to flashover. The test is conducted with natural ventilation to the room provided through a single doorway 30 inches by 80 inches (762 mm by 2032 mm) in width and height. The combustion products are collected in a hood feeding into a plenum connected to an exhaust duct in which measurements are made of the gas velocity, temperature, and concentrations of selected gases.

SECTION 8.204 — IGNITION SOURCE

The ignition source for the test shall be a gas burner with a nominal 12-inch-by-12-inch (305 mm by 305 mm) porous top surface of a refractory material. See Figure 8-2-1. A burner may be constructed with 1-inch-thick (25.4 mm) porous ceramic-fiberboard over a 6-inch (152 mm) plenum, or, alternatively, a minimum 4-inch (102 mm) layer of Ottawa sand can be used to provide the horizontal surface through which the gas is supplied.

The top surface of the burner through which the gas is applied shall be 12 inches (305 mm) above the floor, and the burner enclosure shall be located such that the edge of the diffusion surface is located 2 inches (51 mm) from both walls in the left corner of the room opposite from the door. See Figure 8-2-3.

The gas supply to the burner (see Figure 8-2-1) shall be of C.P. grade propane (99 percent purity). The burner shall be capable of producing a gross heat output of 40 ± 1 kW for five minutes followed by 150 ± 5 kW for 10 minutes. The flow rate shall be metered throughout the test. Flow rates may be calculated using propane's gross heat of combustion as 2,480 Btu/foot^3 (92.5 MJ/m^3) at 68°F (20°C) and 14.70 psia (101.4 kPa). The burner design shall permit switching from 40 kW to 150 kW within 10 seconds. Burner controls should be provided for automatic shutoff of the gas supply if flameout occurs. Two arrangements for gas supply that have been used are shown in Figures 8-2-2A and 8-2-2B.

The burner shall be ignited by a pilot burner or a remotely controlled spark igniter.

SECTION 8.205 — COMPARTMENT GEOMETRY AND CONSTRUCTION

The interior dimensions of the floor of the fire room, when the specimens are in place, shall measure 8 feet ± 1 inch by 12 feet ± 1 inch (2438 mm ± 25 mm by 3658 mm ± 25 mm). The finished ceiling shall be 8 feet ± 0.5 inch (2438 mm ± 13 mm) above the floor. There shall be four walls at right angles defining the compartment.

There shall be a (30- ± 0.25- by 80- ± 0.25-inch) (762 mm ± 6 mm by 2032 mm ± 6 mm) doorway in the center of one of the 8-foot-by-8-foot (2438 mm by 2438 mm) walls, and no other wall, floor or ceiling openings that allow ventilation.

The inside surface of the wall containing the door shall be of calcium-silicate board of 46 pounds per cubic foot (737 kg/m^3) density and 0.5 inch (12.7 mm) in nominal thickness or 0.5-inch (12.7 mm) gypsum wallboard. The door frame shall be constructed to remain unchanged during the test period to a tolerance of ± 1 percent in height and width.

The test compartment may be framed or a concrete block structure. If self-supporting panels are tested, a separate exterior frame or block compartment may not be required.

The floor, ceiling and walls of the test compartment shall be covered by calcium-silicate board or by gypsum wallboard.

SECTION 8.206 — SPECIMEN MOUNTING

Test specimens shall be mounted on a framing or support system comparable to that intended for their actual use, using backing materials, insulation or air gaps as appropriate to the intended application and representing a typical value of thermal resistance for the wall system. Where a manufacturer specifies use of an adhesive, specimens shall be mounted using the adhesive and application rate as recommended by the manufacturer and comparable to actual field installations. The adhesive utilized shall be the same as that intended for actual use.

Where a textile wall covering has a distinct directionality, the sample shall be mounted such that the machine direction is vertical unless the manufacturer indicates a different method of mounting will be used in actual installations.

For the screening test protocol, specimens shall be mounted on the left side and rear walls (as viewed from the room door) and as illustrated in Figure 8-2-3. Vertically mounted portions of test specimens shall extend 2 feet (610 mm) from the room corner on the left side and rear walls. Horizontally mounted specimens on the rear and left sidewalls shall extend 2 feet (610 mm) down from the ceiling and be installed for the full 8-foot (2438 mm) width of the rear wall and the full 12-foot (3658 mm) wall length of the left sidewall.

In the fully lined room protocol test, specimens shall be mounted to fully cover both 8-foot-by-12-foot (2438 mm by 3658 mm) walls and the 8-foot-by-8-foot (2438 mm by 2438 mm) wall, which does not have a door in it.

SECTION 8.207 — FIRE ROOM ENVIRONMENT

8.207.1 General. The test building in which the fire room is located shall have vents for the discharge of the combustion products and have provisions for fresh air intake so that no oxygen-deficient air shall be introduced into the fire room during the test. Prior to the start of the test, the ambient air at the mid-height entrance to the compartment shall have a velocity in any direction of less than 100 feet per minute (30.5 m/min.). The building shall be of adequate size so that there shall be no smoke accumulation in the building below the level of the top of the fire compartment.

8.207.2 Ambient Conditions in Test Building. The ambient temperature in the test building at locations around the fire compartment shall be above 40°F (4.4°C) and the relative humidity shall be less than 75 percent for the duration of the test.

8.207.3 Ambient Conditions in Fire Room. If test samples are installed within the test room two or more hours prior to test, the following ambient conditions shall be maintained:

1. The ambient temperature in the fire room measured by one of the thermocouples in Section 42.208 shall be from 65°F to 75°F (18.3°C to 23.9°C).

2. The ambient relative humidity in the fire room shall be within the range of 50 ± 5 percent.

8.207.4 Specimen Conditioning. Prior to testing, mounted specimens shall be conditioned for a minimum of seven days and until the sample reaches a rate of weight change of less than 0.1 percent per day at a temperature of 70°F ± 5°F (21.1°C ± 2.8°C) and at a relative humidity of 50 ± 5 percent.

SECTION 8.208 — INSTRUMENTATION

The following are minimum requirements for instrumentation for this test:

8.208.1 Total Heat Flux Gage.

8.208.1.1 Location. A gage shall be mounted a maximum of 2 inches (51 mm) above the floor surface, facing upward in the geometric center of the test room (see Figure 8-2-4).

8.208.1.2 Specification. The gage shall be of the Gardon type, with a flat black surface, and a 180 degree view angle. In operation, it shall be maintained at a constant temperature [within ± 5 percent °F (± 2.8 percent °C)] above the dew point by water supplied at a temperature from 120°F to 150°F (48.9°C to 65.6°C). This will normally require a flow rate of at least 0.1 gallon per minute (6.31 mL/s). The full-scale output range shall be 50 kW/m^2 for the gage.

8.208.2 Gas Temperature Thermocouples.

8.208.2.1 Specification. Bare chromel-alumel thermocouples 20 mil in diameter shall be used at each required location. The thermocouple wire, within 0.5 inch (13 mm) of the bead, should be run along expected isotherms to minimize conduction errors. The insulation between the chromel and alumel wires shall be stable to at least 2,000°F (1093°C) or the wires shall be separated. Metal-clad thermocouples with ceramic-powder filling shall be used.

8.208.2.2 Location in doorway. A thermocouple shall be located in the interior plane of the door opening on the door center line, 4 inches (102 mm) down from the top. (See Figure 8-2-5.)

8.208.2.3 Locations for room. Thermocouples shall be located 4 inches (102 mm) below the ceiling at the center of the ceiling, the center of each of the four ceiling quadrants and directly over the center of the ignition burner. The thermocouples shall be mounted on supports or penetrate through the ceiling with their junctions 4 inches (102 mm) away from a solid surface. (See Figure 8-2-5.) Any ceiling penetration shall be just large enough to permit passage of the thermocouples. Spackling compound or ceramic fiber insulation shall be used to backfill the holes around the thermocouple wires.

8.208.2.4 Location in canopy hood and duct system. One pair of thermocouples shall be placed a minimum of 8.25 exhaust duct diameters downstream of the entrance to the horizontal duct. The pair of thermocouples shall straddle the center of the duct and be separated 2 inches (51 mm) from each other. (See Figure 8-2-6.)

8.208.3 Canopy Hood and Exhaust Duct.

8.208.3.1 Location and design. A hood shall be installed immediately adjacent to the door of the fire room. The bottom of the hood shall be level with the top surface of the room. The face dimensions of the hood shall be at least 8 feet by 8 feet (2438 mm by 2438 mm) and the depth shall be 3.5 feet (1067 mm) minimum. The hood shall feed into a plenum having a 3-foot-by-3-foot (914 mm by 914 mm) cross-section minimum. The plenum shall have a minimum height of 3 feet (914 mm) and a maximum height of 6 feet (1829 mm). The exhaust duct connected to the plenum shall be at least 16 inches (406 mm) in diameter, horizontal, and shall have a circular aperture of between one-half and three-fourths of the duct diameter at its entrance. (See Figures 8-2-6 and 8-2-7.)

8.208.3.2 Draft. The hood shall have sufficient draft to collect all of the combustion products leaving the room. [This draft should be capable of moving up to 7,000 standard cubic feet per minute (3303 L/s) equivalent to 16,000 acfm at 750°F (7550 L/s at 399°C) during the test.] Provisions shall be made so that the draft can operate at either 1,000 or 7,000 standard cubic feet per minute (472 L/s or 3303 L/s). Mixing vanes may also be required in the duct if concentration gradients are found to exist.

8.208.3.3 Alternate exhaust system. An alternative exhaust system design may be used if it has been shown to produce equivalent results. (Equivalency may be shown in meeting the requirements of Section 8.209.)

8.208.4 Duct Gas Velocity. A bidirectional probe or an equivalent measuring system shall be used to measure gas velocity in the duct. The probe shown in Figure 8-2-8 consists of a short stainless steel cylinder 1.75 inches (44 mm) long and 0.875 inch (22.2 mm) inside diameter with a solid diaphragm in the center. The pressure taps on either side of the diaphragm support the probe. The axis of the probe shall be along the center line of the duct a minimum of 8.25 duct diameters downstream from the entrance. The taps shall be connected to a pressure transducer that shall be able to resolve pressure differences of 0.001-inch water (0.25 Pa). Capacitance transducers have been found to be most stable for this application.

8.208.5 Oxygen-depletion Measurements.

8.208.5.1 Determination of rate of heat release. A stainless steel gas sampling tube shall be located 2 feet (610 mm) downstream from the bidirectional probe at the geometric center of the duct ± $^1/_2$ inch (± 13 mm) to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time. A suitable filter and cold trap shall be placed in the line ahead of the analyzer to remove particulates and water. The oxygen analyzer shall be of the paramagnetic or polarographic type and shall be capable of measuring the oxygen concentration in the range from 21 percent down to 15 percent with a relative accuracy of ± 2 percent in this concentration range. The signal from the oxygen analyzer shall be within 5 percent of its final value in 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

8.208.5.2 Duct carbon dioxide concentration: specification. The gas-sampling tube described in Section 8.208 may be used to provide a continuous sample for the measurement of the carbon dioxide concentration using an analyzer with a range of not more than 0 to 6 percent (vol.), with a maximum relative error of 2 percent of full scale. The total system response time between the sampling inlet and the meter shall be no greater than 30 seconds.

8.208.5.3 Duct carbon monoxide concentration: specification. The gas-sampling tube defined in Section 8.208 shall provide a continuous sample for the measurement of the carbon monoxide concentration using an analyzer with a range from not more than 0 to 1 percent (vol.) with a maximum relative error of 2 percent of full scale. The signal from the analyzer shall be within 5 percent of its final value in 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

8.208.6 Photographic Records. Photographic or video equipment shall be used to record the fire spread in the room and the fire projection from the door of the room. The location of the camera shall avoid interference with the air inflow. The interior wall surfaces of the test room, adjacent to the corner in which the burner is located, shall be clearly marked with a 12-inch (305 mm) grid. A clock shall appear in all photographic records, giving time to the nearest 1 second or 0.01 minimum from the start of the test. This clock shall be accurately synchronized with all other measurements, or other provisions shall be made to correlate the photo record with time. Color slides shall be taken at 30-second intervals from the duration of the test or a continuous video recording shall be made.

SECTION 8.209 — CALIBRATION AND DOCUMENTATION OF IGNITION SOURCE AND TEST EQUIPMENT

A calibration test shall have been performed prior to and within 30 days of any fire test. The calibration test, to last for 15 minutes, shall use the standard ignition source with inert wall and ceiling materials [calcium-silicate board of 46 pounds per cubic foot (737 kg/m^3) density, 0.50 inch (12.7 mm) in thickness]. The following data shall be reported:

1. The output as a function of time, after the burner is activated, of all instruments normally used for the standard fire test.

2. The maximum extension of the burner flame, as recorded by still photographs taken at 30-second intervals or continuous video recording.

3. The calibration constant shall be determined as follows:

3.1 Estimate the initial calibration constant for C in the Heat Release Rate Equations using the product 22.1 × A, where A is the area of the duct (in m^2). This gives a good estimation (generally within about 20 percent) of the final value one can expect for C.

3.2 Burn 99 percent purity propane or methane fuel at a constant rate corresponding to 150 kW for 10 minutes. Measure the heat release rate using oxygen consumption calorimetry and the "initial" value for C estimated in Item 3.1. Use the appropriate constants for the fuel being used as follows:

Procedure	α	E
Methane calibration	1.105	12.5 MJ/kg
Propane calibration	1.084	12.8 MJ/kg

3.3 Calculate the total heat released from the mass loss of the fuel and its heat of combustion. The heat of combustion for 99 percent purity propane is 46.5 MJ/kg. The heat of combustion for 99 percent purity methane is 50.0 MJ/kg.

3.4 Adjust the calibration constant C so that the total rate of heat released, as determined by the oxygen consumption calculation, agrees with that from the mass of fuel consumed to within 5 percent.

$$C_{new} = \left[\frac{A(\text{MJ/kg}) \times B(\text{kg})}{\int_0^T \dot{q}\,(t)\,(MW)^{dt}} \right] \times C_{old} \quad \pm\ 5\%$$

A is the heat of combustion of the fuel being used and B is the total mass of fuel burned in the period T. Use the new constant for subsequent tests for calculation of the heat release rate and flow rate.

3.5 **Example:** An initial value of 6.6 is assigned to C. A 10-minute calibration burn uses 1.80 kg of methane (50 MJ/kg), which corresponds to a burning rate of 150 kW. The oxygen consumption calculations reveal an average heat release rate of 160 kW during the burn period. Integrating the the heat release rate curve over the 10-minute burn period, one calculates the total heat released as 96.0 MJ. Applying the formula above, one finds

$$C_{new} = [0.94] \times C_{old}$$

SECTION 8.210 — PROCEDURE

The screening test protocol and the fully lined test protocol, except for specimen mounting, follow the same test procedure. Where indicated by Section 8.211, the fully lined test protocol shall be followed.

Establish an initial volumetric flow rate of 1,000 cubic feet per minute (472 L/s) through the duct and increase the volume flow rate to 7,000 cubic feet per minute (3303 L/s) when the oxygen content falls below 14 percent.

Turn on all sampling and recording devices, and establish steady-state baseline readings for at least three minutes.

Ignite the gas burner and simultaneously start the clock and increase gas flow rate to provide a rate of heat release of 40 kW ± 1 kW by the burner. Continue the exposure at the 40 kW ± 1 kW level for five minutes. Within 10 seconds following the five-minute exposure, increase the gas flow to provide a rate of heat release by the burner of 150 kW ± 5 kW exposure for 10 minutes.

Take 35mm color photographs at 30-second intervals or provide a continuous video recording to document the growth of the fire.

Provide a continuous voice or written record of the fire, which will give times of all significant events, such as time of ignition, flames out the doorway, flashover, etc.

The ignition burner shall be shut off at 15 minutes after start of the test and the test terminated at that time, unless safety considerations dictate an earlier termination.

Document damage after the test, using words, pictures and drawings.

SECTION 8.211 — ACCEPTANCE CRITERIA

Textile wall coverings shall be considered as demonstrating satisfactory performance if, during the screening test protocol, the following conditions are met:

Flame shall not spread to the ceiling during the 40 kW exposure.

During the 150 kW exposure, the following criteria shall be met:

1. Flame shall not spread to the outer extremity of the sample on the 8-foot-by-12-foot (2438 mm by 3658 mm) wall.

2. The specimen shall not burn to the outer extremity of the 2-foot-wide (610 mm) samples mounted vertically in the corner of the room.

3. Burning droplets shall not be formed and drop to the floor which are judged to be capable of igniting the textile wall covering or which persist in burning for 30 seconds or more.

4. Flashover shall not occur. Flashover may be judged to occur when heat flux at floor level exceeds 20 kW/m^2, upper-level air temperatures within the room exceed 1,100°F (593°C) or flames project out the room door opening.

5. The maximum instantaneous net peak rate of heat release shall not exceed 300 kW. Textile wall coverings in the screening test protocol developing a maximum, instantaneous net peak rate of heat release of 300 kW may or may not cause flashover in a fully lined room. A fully lined room test protocol shall be used to judge acceptability of such products. The maximum instantaneous net peak rate of heat release shall be derived by taking the measured maximum rate of heat release and subtracting the burner output.

Textile wall coverings which fail to meet the criteria of Section 8.211 may be judged to perform satisfactorily when tested following the fully lined test protocol and when meeting the following criteria:

A. Flame shall not spread to the ceiling during the 40 kW exposure.

During the 150 kW exposure, the following criteria shall be met:

(i) Flame shall not spread to the outer extremities of the samples on the 8-foot-by-12-foot (2438 mm by 3658 mm) walls.

(ii) Flashover shall not occur. Flashover shall be judged to have occurred when heat flux at floor level exceeds 20 kW/m^2, upper-level air temperatures exceed 1,100°F (593°C) or flames project out the room door opening.

SECTION 8.212 — REPORT

The report shall include the following:

8.212.1 Materials:

1. **Material description.** The name, thickness, density and size of the material to be listed, along with other identifying characteristics or labels.

2. Materials mounting and conditioning.

3. Layout of specimens and attachments in test room (include appropriate drawings).

4. Relative humidity and temperature of the room and the test building prior to and during the test.

8.212.2 Burner Gas Flow. The fuel gas flow to the ignition burner and its calculated rate of heat output.

8.212.3 Time History of the Total Heat Flux to Floor. The total incident heat flux at the center of the floor for the heat flux gage as a function of time starting three minutes prior to the test.

8.212.4 Time History of the Gas Temperature. The temperature of gases in the room, the doorway, and in the exhaust duct for each thermocouple as a function of time starting three minutes prior to the test.

8.212.5 Time History of the Total Rate of Heat Production of the Fire. The total of heat production shall be calculated from the measured oxygen and carbon monoxide concentrations or measured oxygen, carbon monoxide and carbon dioxide concentrations and the temperature and volumetric flow rate of the gas in the duct. The calculations shall be based on the method shown in Section 8.213.

8.212.6 Time History of the Fire Growth. A transcription of the visual, photographic, audio and written records of the fire test. The records shall indicate the time of ignition of the wall finish, the approximate location of the flame front most distant from the ignition source, at intervals not exceeding 15 seconds during the fire test, the time of flashover, and the time at which flames extend outside the doorway. In addition, still photographs taken at intervals not exceeding 30 seconds or continuous video recordings shall be supplied. Drawings and photographs or video recordings showing the extent of the damage of the materials after the test shall also be supplied.

8.212.7 Discussion of Performance. Complete discussion of sample performances related to acceptance criteria within Section 8.211.

SECTION 8.213 — CALCULATIONS

Calculate mass flow rate using Formula (13-1), using the calibration constant C as described in Section 8.209 — Calibration and Documentation of Ignition Source and Test Equipment.

$$\dot{m} = C\sqrt{\frac{\Delta P}{T}} \qquad (13\text{-}1)$$

The heat release formulas are a function of the oxygen depletion factor ϕ. Three cases exist for calculating ϕ depending on the gas analysis equipment being used. Use the formula below for Case 1 or 2 to calculate the heat release rate.

$$\dot{q} = E\left(\frac{M_{O_2}}{M_a}\right)\left(\frac{\phi}{1+\phi(\alpha-1)}\right)\dot{m}\,X^o_{O_2} \qquad (13\text{-}2)$$

Case 1: Only O_2 measurements are made.

Use:

$$\phi = \frac{X^o_{O_2} - X_{O_2}}{(1 - X_{O_2})X^o_{O_2}} \qquad (13\text{-}3)$$

NOTE: Water vapor and CO_2 must be removed before introducing the sample air into the O_2 analyzer. Use a water trap and desiccant to remove water and use soda lime to remove the CO_2. The concentration range of CO in most fires is a small fraction of the concentration range of CO_2, hence, the correction for the heat release rate is generally less than 5 percent. Therefore, CO measurements can be ignored.

Case 2: O_2 and CO_2 measurements are made.

Use:

$$\phi = \frac{X^o_{O_2}(1-X_{CO_2}) - X_{O_2}(1-X^o_{CO_2})}{X^o_{O_2}(1-X_{O_2}-X_{CO_2})} \qquad (13\text{-}4)$$

NOTE: Water vapor must be removed before introducing the sample air into the O_2 analyzer. Use a water trap and desiccant to remove water. The concentration range of CO in most fires is a small fraction of the concentration range of CO_2, hence, the correction for the heat release rate is generally less than 5 percent. Therefore, CO measurements can be ignored.

In Case 3, the heat release rate is calculated using the following formula:

$$\dot{q} = \left[E\phi - (E_{CO}-E)\frac{(1-\phi)}{2}\frac{X_{CO}}{X_{O_2}}\right]\left(\frac{M_{O_2}}{M_a}\right)\left(\frac{\dot{m}}{1+\phi(\alpha-1)}\right)X^o_{O_2} \qquad (13\text{-}5)$$

Case 3: O_2, CO_2 and CO_0 measurements are made.

Use:

$$\phi = \frac{X^o_{O_2}(1-X_{CO_2}-X_{CO}) - X_{O_2}(1-X^o_{CO_2})}{X^o_{O_2}(1-X_{O_2}-X_{CO_2}-X_{CO})} \qquad (13\text{-}6)$$

NOTE: Water vapor must be removed before introducing the sample air into the O_2 analyzer. Use a water trap and desiccant to remove water.

It is important that one choose the correct constants for calculating heat release rates.

Note that the formulas incorporate α (the chemical expansion factor) and E (net heat released for complete combustion per unit of oxygen consumed). Use $\alpha = 1.105$ and $E = 13.1$ MJ/kg for testing.

WHERE:

C = calibration factor for orifice plate or bidirectional probe.
E = average heat released for complete combustion per unit of oxygen consumed (13.1 MJ/kg).
E_{CO} = heat released for complete combustion per unit of oxygen consumed, for CO (17.6 MJ/kg).
M_{O_2} = molecular weight of oxygen (32 kg/kmol).
M_a = molecular weight of air (29 kg/kmol).
$\dot{m}$ = mass flow rate in the duct (kg/s).
$\dot{q}$ = heat release rate (MW).
T = temperature of air near measurement probe (K.).
X_{CO} = measured mole fraction of carbon monoxide.
X_{CO_2} = measured mole fraction of carbon dioxide.
X_{O_2} = measured mole fraction of oxygen.
$X^o_{O_2}$ = ambient mole fraction of oxygen (0.2095).
α = chemical expansion factor.
ΔP = pressure across orifice plate or bidirectional probe (Pa).
ϕ = oxygen depletion factor.

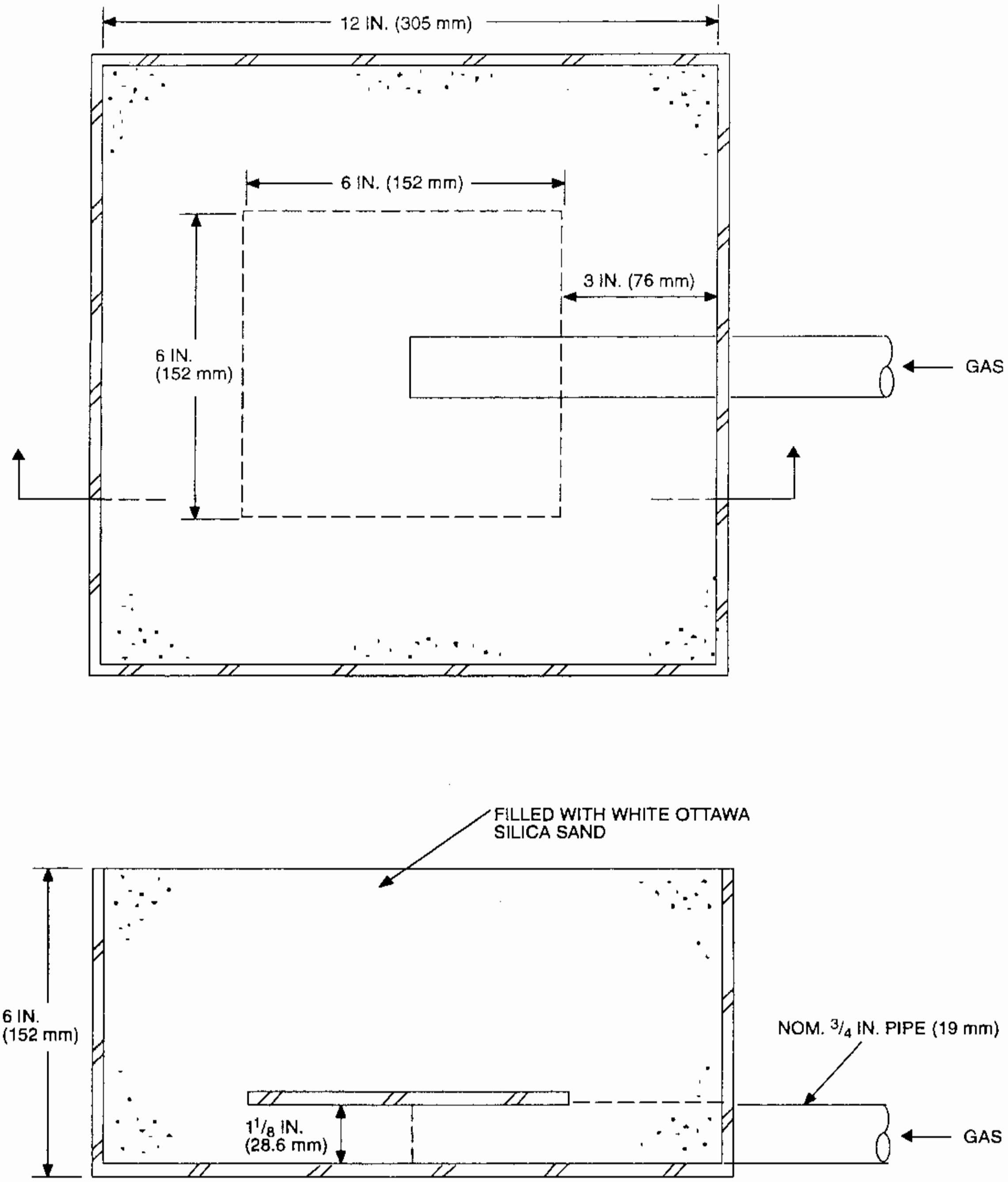


FIGURE 8-2-1—GAS BURNER

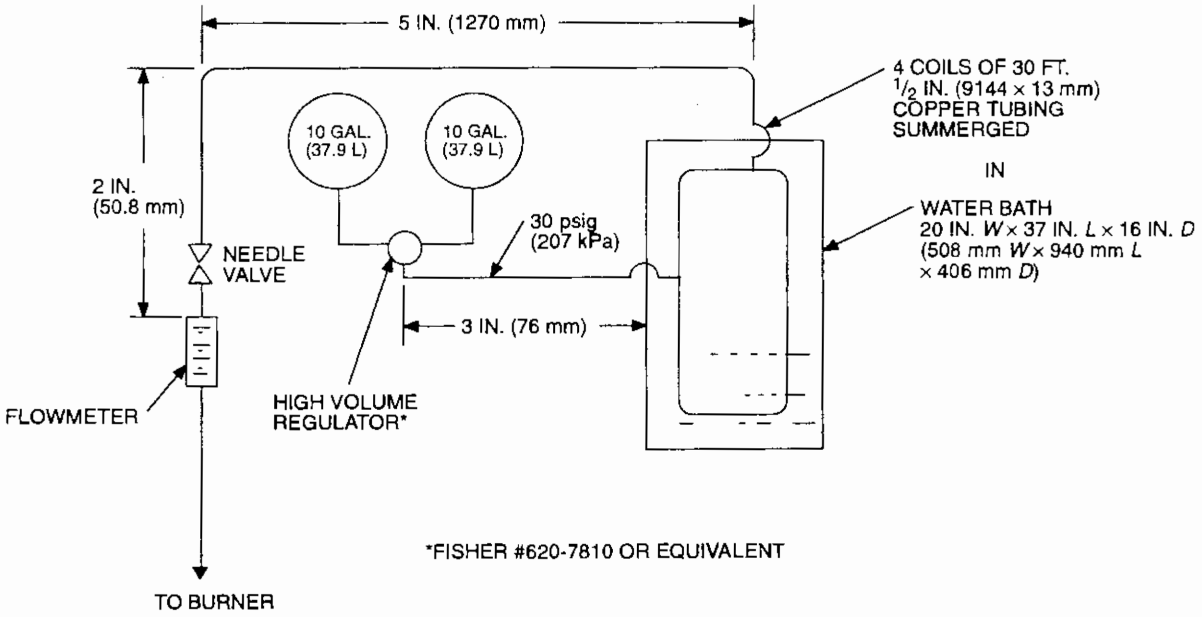
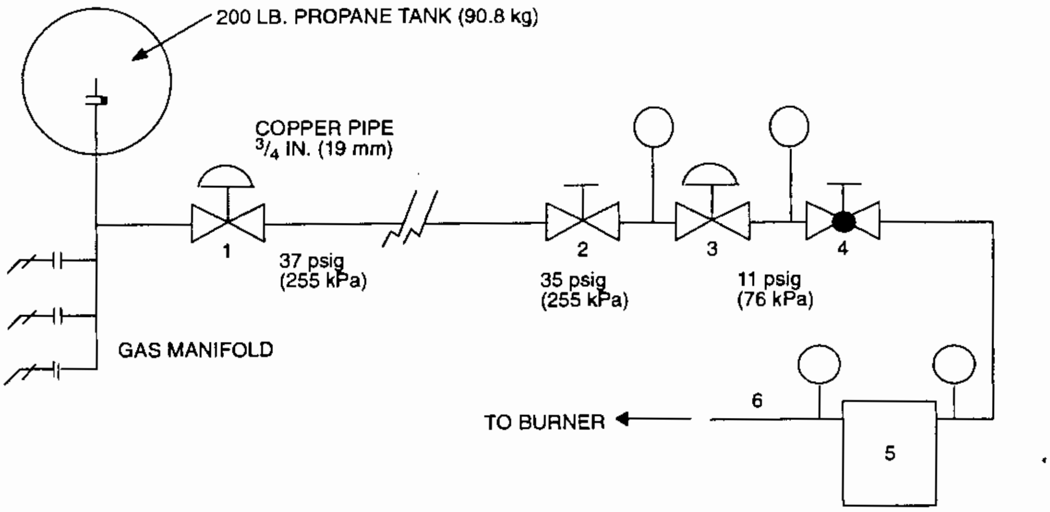


FIGURE 8-2-2A—TYPICAL GAS FLOW REGULATION SYSTEM



1—PROPANE GAS REGULATOR (HIGH PRESSURE) (MAIN GAS SUPPLY)
2—SHUTOFF VALVE
3—REGULATOR (LOW PRESSURE)
4—ADJUSTABLE VALVE FOR FLOW IMPENDANCE
5—VOLUME METER
6—STEEL BRAID OVER TUBING TO BURNER
*—LINE PRESSURES ARE SHOWN

FIGURE 8-2-2B—TYPICAL GAS FLOW REGULATION SYSTEM

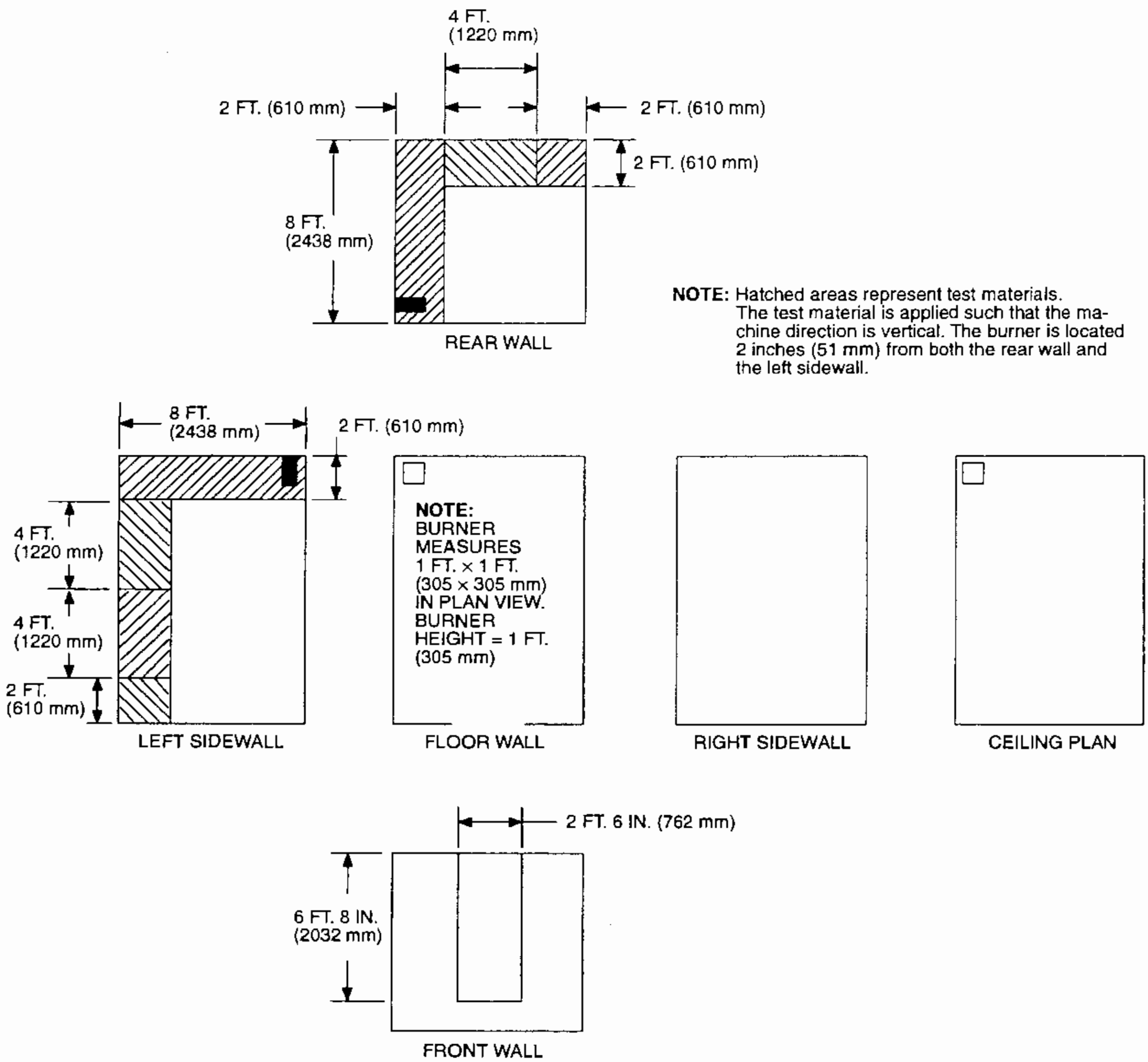


FIGURE 8-2-3—MOUNTING OF SPECIMEN

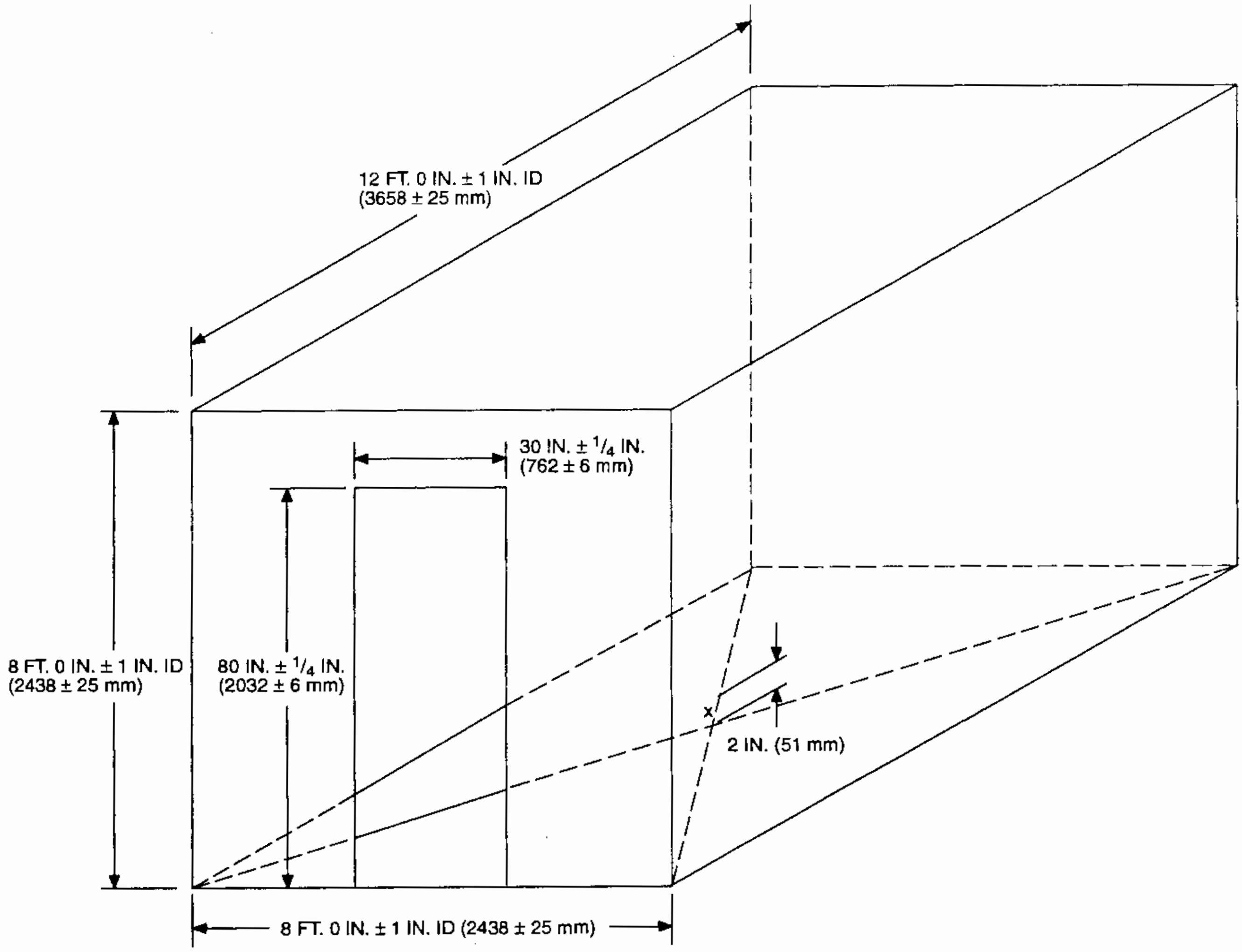


FIGURE 8-2-4—ROOM RADIOMETER LOCATION

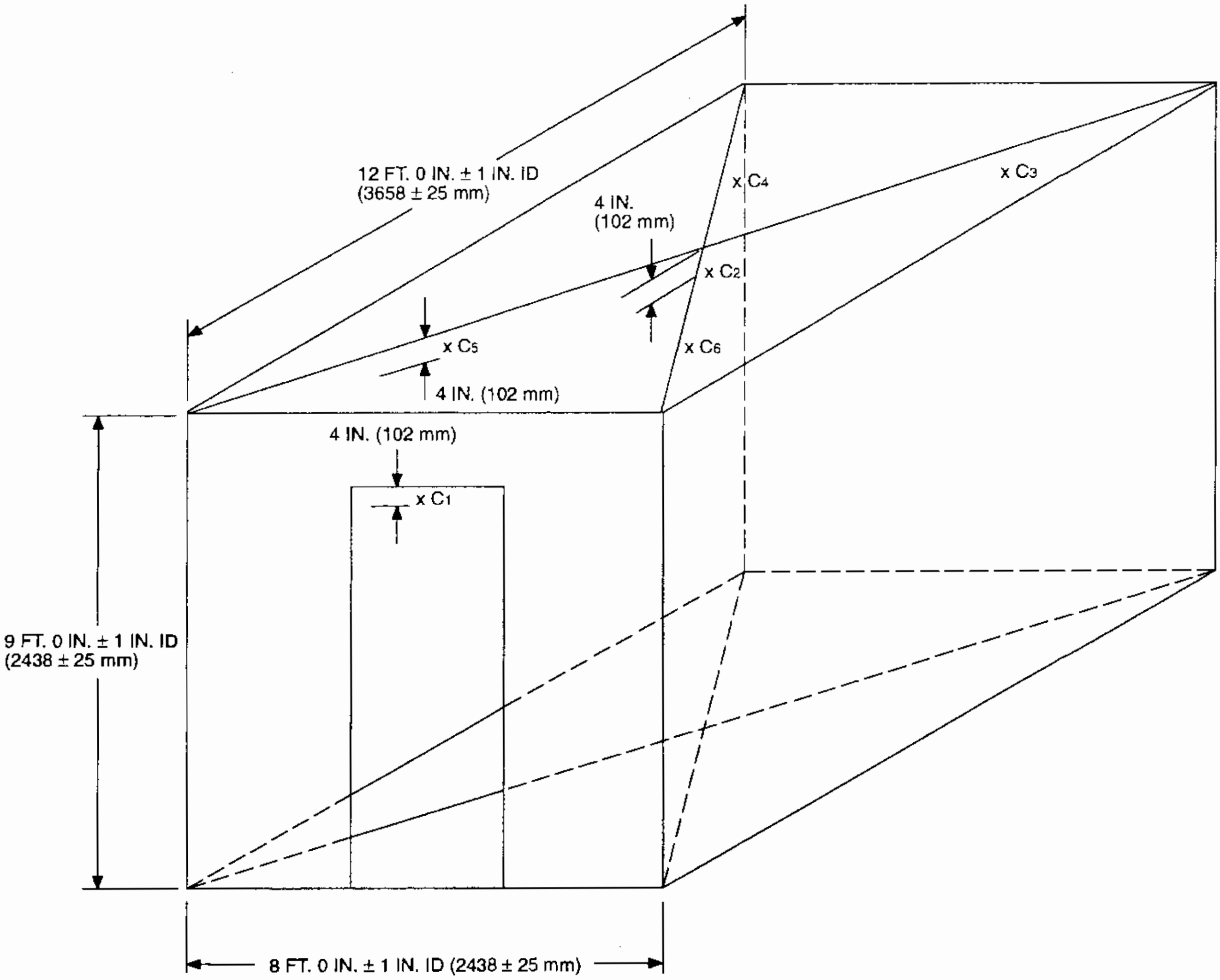


FIGURE 8-2-5—ROOM THERMOCOUPLE LOCATIONS

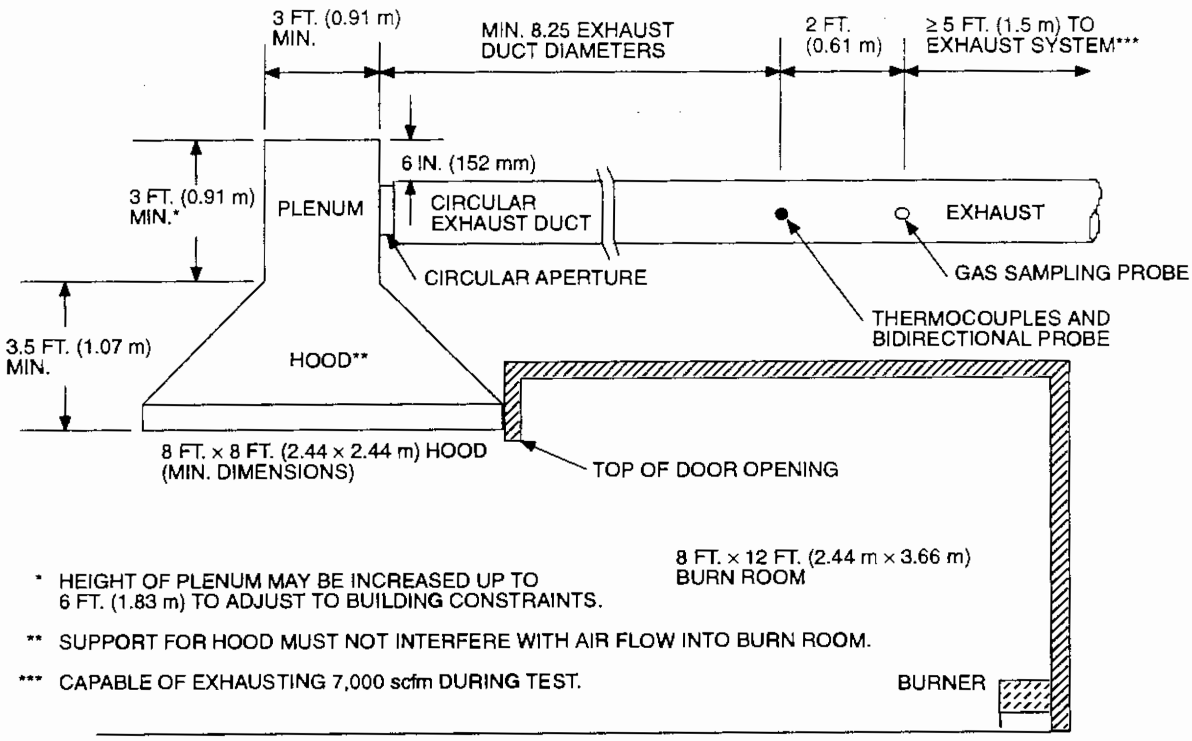


FIGURE 8-2-6—CANOPY HOOD AND EXHAUST DUCT

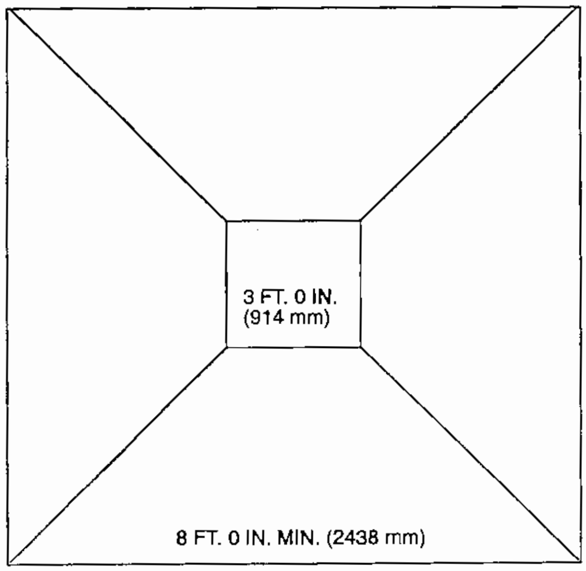


FIGURE 8-2-7—PLAN VIEW OF CANOPY HEAD

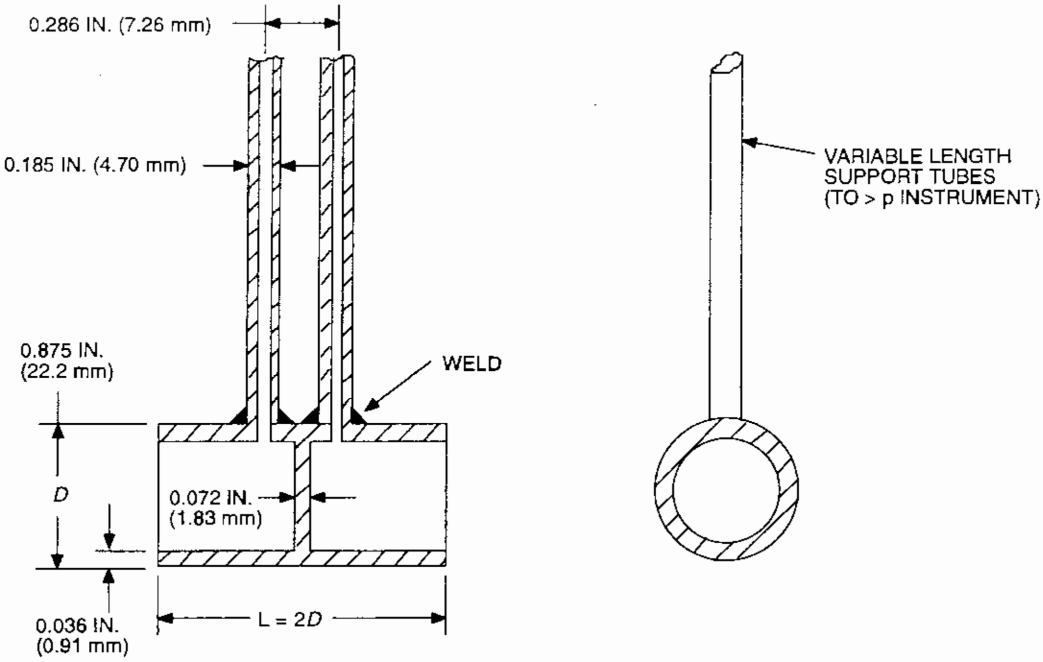


FIGURE 8-2-8—BIDIRECTIONAL PROBE

UNIFORM BUILDING CODE STANDARD 9-1
INSTALLATION OF SPRINKLER SYSTEMS

See Sections 307.11.3; 404.3.1; 405.1.1; 405.3.4; 804.1; 902; 904.1.2; 904.1.3; 904.2.6.3; 904.2.8; 904.2.9; 2603.7.1; 2603.8.1, Item 4; Appendix 327.2, *Uniform Building Code*

This standard, with certain exceptions, is based on the National Fire Protection Association Standard for the Installation of Sprinkler Systems, NFPA 13-1991[1].

Part I of this standard contains the exceptions to NFPA 13-1991[1]. Part II of this standard contains NFPA 13-1991[1] reproduced in its entirety with permission of the publisher.

[1]The current edition is NFPA 13-1996.

Part I

SECTION 9.101 — AMENDMENTS

The National Fire Protection Association standard adopted by this standard applies to the selection, installation, acceptance inspection and acceptance testing of sprinkler systems, except as follows:

1. Sec. 1-1 is amended by changing the note to read as follows:

Consult other recognized and accepted standards for additional requirements relating to water supplies.

2. Sec. 1-4 is amended by changing the definition of "authority having jurisdiction" to read as follows:

Authority Having Jurisdiction is the building official.

The definitions of "approved" and "listed" shall be as set forth in Volume 1 of this code.

Sec. 1-4.1 is amended by deleting the definitions of the terms "limited combustible material," "noncombustible material," "should" and "standard;" by deleting the note following the definition of "sprinkler system;" and by adding definitions for "acceptance," "building official" and "thermal barrier" to read as follows:

Acceptance is acceptance by the building official.

Building Official is the officer or other designated authority charged with the administration and enforcement of this standard, or the officer's or other designated authority's duly authorized representative.

Thermal Barrier is a material that will limit the average temperature rise of the unexposed surface to not more than 250°F (121°C) after 15 minutes of fire exposure complying with nationally recognized standards.

3. Sec. 1-4.7 is amended to read as follows:

1-4.7. For the purpose of determining the level of protection to be provided by required sprinkler system installations, Table 1.4.7 shall be used.

For hazard classifications other than those indicated, see appropriate nationally recognized standards for design criteria.

When fire sprinkler systems are required in buildings of undetermined use, they shall be designed and installed to have a sprinkler density of not less than that required for an Ordinary Hazard Group 2 use with a minimum design area of 3,000 square feet (279 m^2).

Use is considered undetermined if not specified at time permit is issued.

Where a subsequent occupancy requires a system with greater capability, it shall be the responsibility of the occupant to upgrade the system to the required density for the new occupancy.

Other Uniform Codes or standards contain sprinkler system design criteria for fire control or suppression of specific hazards.

TABLE 1.4.7—HAZARD CLASSIFICATION

OCCUPANCY OF BUILDING OR PORTION THEREOF	HAZARD CLASSIFICATION
Group A Occupancies used as meeting rooms, library reading rooms, restaurant seating areas, clubs, theaters, museums, health clubs, educational classrooms and churches. Group B Occupancies used as offices, data processing areas, colleges and universities. Group E Occupancies other than shops and laboratories. Group I Occupancy living and sleeping areas. Group R, Division 1 Occupancies.[1] Typically these uses are such that the quantity and combustibility of contents is such that relatively low-rate-of-heat-release fires would be expected.	Light
Groups B, F and S Occupancies used for light manufacturing, commercial kitchens, laundries, automobile parking garages, bakeries, canneries, electronic plants, beverage manufacturing and glass products manufacturing plants not producing dust or fibers. Typically these uses are such that the quantity of combustibles is relatively low, the combustibility of contents is moderate, storage does not exceed 8 feet (2438 mm) in height, and moderate-rate-of-heat-release fires would be expected.	Ordinary Group 1
Groups B, F, M and S Occupancies used for chemical plant laboratories, mercantile, machine shops, printing, plants, library stack areas, metal working, wood product assembly, textile manufacturing, confectionery products, cold storage warehouses,[2] cereal mills, service stations and repair garages. Typically these uses are such that the quantity of combustibles is moderate. The combustibility of contents is moderate, storage does not exceed 12 feet (3658 mm) in height[2] and moderate-rate-of-heat-release fires would be expected. **Also:** Group A Occupancies such as exhibition halls. Groups B, F and S Occupancies used as to tobacco products manufacturing, paper and pulp mills, piers and wharfs, and warehousing[2] of higher combustible contents (including packaging). Group H Occupancies used as fee mills, tire manufacturing, chemical plants, repair garages and woodworking. Group H, Division 6 Occupancies (except extra-hazard areas). Typically these uses are such that high-rate-of-heat-release fires would be expected and the spread of fire would be rapid.	Ordinary Group 2
Group H Occupancies used for printing [using inks with flash points below 100°F (38°C)], combustible hydraulic fluid-use areas such as die casting and metal extruding, upholstering with plastic foam, rubber reclaiming, compounding, drying, milling, vulcanizing, plywood and particle board manufacturing, saw mills, textile picking, opening, blending, garnetting, carding and combining of cotton, synthetics, wool shoddy or burlap. Typically these uses are such that a significant fire hazard exists.	Extra Hazard Group 1
Group H Occupancies used as asphalt saturating, flammable liquids spraying, flow coating, open oil quenching, varnish and paint dipping, solvent cleaning, and manufactured home or modular building manufacturing (where the finished building enclosure is present and has combustible interiors). These uses are such that a severe fire hazard exists.	Extra Hazard Group 2[3]

[1]See also Section 5-3.2
[2]For high-piled storage, see UFC Article 81.
[3]For additional or more stringent criteria, see UFC Article 79 or 80.

4. Sec. 2-1.1 is revised to read as follows:

2-1.1 All materials and devices shall be listed and approved.

5. Sec. 2-3.5 is revised to read as follows:

2-3.5. Other types of pipe or tube, such as plastic, may be used if it is investigated and found to be listed for this service.

6. Sec. 2-8.1 is revised to read as follows:

2-8.1. The fire department connection(s) shall be internal swivel fittings having national standard hose thread or as approved by the chief.

7. Sec. 2-9.1 is revised by changing the last line as follows: "on the premises within two minutes after such flow begins."

8. Sec. 2-9.5.1 is revised to read as follows:

Electrically operated alarm attachments forming part of an auxiliary, proprietary, remote station or local signalling system shall be installed in accordance with Uniform Fire Code Standard 10-2.

9. Sec. 3-9.1 is revised by deleting the last sentence.

10. Sec. 4-2-1 is revised by changing the last item to read as follows:

Storage—High piled storage (as defined in *Uniform Fire Code*)—40,000 square feet (3716 m^2).

(Exception to remain unchanged.)

11. Table 4-2.2 is revised by substituting "Uniform Fire Code Standards 81-1 and 81-2" for "NFPA 231 and 231C" in Footnote 6, Item 1, and by deleting "NFPA" in Footnote 6, Item 2.

12. Sec. 4-3.6.1 is revised by substituting "UBC Standard 9-3" for "NFPA 13R, Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and including Four Stories in Height," and by deleting references to NFPA 13D.

13. Sec. 4-4.1.4.2 is revised by adding Exception 3 to read as follows:

Exception No. 3: Where sprinklers are installed under composite wood joists less than 16 inches (406 mm) in depth, sprinkler deflectors shall be a minimum of 1 inch (25 mm) and a maximum of 6 inches (152 mm) below the bottom of the composite wood joist and the joist channels shall be fire-stopped the full depth of the joist with a material equivalent to the web construction so that individual channel areas do not exceed 300 square feet (27.9 m^2). Where the depth of the composite wood joist is 16 inches (406 mm) or greater, protection shall be provided by using one or more of the following methods:

(a) Provide a sprinkler in each joist channel. The distance between sprinklers within the joist channel shall not exceed 15 feet (4572 mm).

(b) Protect the composite wood joist with $^5/_8$-inch (16 mm) Type X gypsum wallboard attached directly to the bottom of the composite wood joist. Joist channels shall be fire-stopped the full depth of the joist with a material equivalent to the web construction so that the volume of individual channels do not exceed 160 cubic feet (4.53 m^3).

(c) Completely fill the channel with noncombustible insulation. The insulation shall be secured to prevent the insulation from falling. Joist channels shall be fire-stopped the full depth of the joist with a material equivalent to the web construction so that the volume of individual channels does not exceed 160 cubic feet (4.53 m^3).

14. Sec. 4-4.1.7.17 is revised to read as follows:

Rack Storage. For sprinklers in rack storage, see Uniform Fire Code Standard 81-2.

15. Sec. 4-5.2.1.2 is revised to read as follows:

When sprinkler piping is installed in storage racks as defined in UFC Standard 81-2, piping shall be substantially supported from the storage rack structure or building in accordance with all applicable provisions of Sections 4-5.2 and 4-5.4.3.

16. Sec. 4-6.1.1.1 is revised to read as follows:

Local water-flow alarms shall be provided on each sprinkler system having more than five sprinklers and shall be located in an area approved by the chief.

17. Sec. 5-2.3.1.1 is revised by substituting "nationally recognized" for "NFPA" in the first line of Exception 1.

18. Sec. 5-2.3.1.3 (e) is revised by substituting the phrase "*Uniform Building Code*" for "NFPA 14, Standard for the Installation of Standpipe and Hose Systems" in the fourth line of the text and where located in the two exceptions.

19. Sec. 5-3.4.1 is revised by substituting "nationally recognized" for "NFPA" in the second line of the text.

20. Sec. 6-1.1.1.1 (l) is revised to read as follows:

6-1.1.1.1 (l). Manufacturing data sheets for sprinkler head which contain at least the following information:

-Make

-Type

-K-factor

-Nominal office size

-Temperature rating

-Minimum operating pressures and discharge rates for proposed area of coverage.

21. Sec. 7-2.1 is revised by deleting "See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances."

22. Sec. 7-2.2.1 is revised by substituting "nationally recognized standards" for "NFPA 20, Standard for the Installation of Centrifugal Pumps."

23. Sec. 7-2.3.1.1 is revised by substituting "nationally recognized standards" for "NFPA 22, Standard for Water Tanks for Private Fire Protection."

24. Sec. 7-2.4 is revised by substituting "nationally recognized standards" for "NFPA 22, Standard for Water Tanks for Private Fire Protection."

25. Sec. 8-2.2.5 is revised by substituting "nationally recognized standards" for "NFPA 24, Standard for the Installation of Private Fire Service Mains and their Appurtenances" in the first sentence.

26. Sec. 8-2.2.5 is revised by substituting "nationally recognized standards" for "NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances" in the first sentence and by deleting "by NFPA 24 and" from the second sentence.

27. Sec. 8-4.1 is revised to read as follows:

8-4.1. The installer of the system shall provide the owner with written instructions and information relating to the care and maintenance of the sprinkler system, with special attention given to the sprinkler system devices.

Subsections (a) and (b) are deleted.

28. Sec. 9-1.1 is revised to read as follows:

9-1.1. A sprinkler system installed under this standard shall be maintained in accordance with the UFC Article 10.

29. Sec. 9-3.1 is revised by deleting "(See NFPA 24, standard for the installation of private Fire Service Mains and Their Appurtenances.)"

30. Chapter 10 is deleted.

Part II

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[1]The current edition is NFPA 13-1996.

NOTE: See page 3–239 for errata to NFPA 13-1991.

Contents

NFPA 13

Standard for the

Installation of Sprinkler Systems

1991 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 10 and Appendix C.

Chapter 1 General Information

1-1 Scope. This standard provides the minimum requirements for the design and installation of automatic fire sprinkler systems and exposure protection sprinkler systems, including the character and adequacy of water supplies and the selection of sprinklers, piping, valves, and all materials and accessories, but not including the installation of private fire service mains and water supplies.

NOTE: Consult other NFPA standards for additional requirements relating to water supplies.

NOTE: See Tentative Interim Amendment on page 131.

1-2 Purpose. The purpose of this standard is to provide a reasonable degree of protection for life and property from fire through standardization of design, installation, and testing requirements for sprinkler systems based upon sound engineering principles, test data, and field experience. This standard endeavors to continue the excellent record that has been established by sprinkler systems while meeting the needs of changing technology. Nothing in this standard is intended to restrict new technologies or alternate arrangements, providing the level of safety prescribed by this standard is not lowered. Materials or devices not specifically designated by this standard shall be utilized in complete accord with all conditions, requirements, and limitations of their listings.

NOTE 1: A sprinkler system is a specialized fire protection system and requires knowledgeable and experienced design and installation.

NOTE 2: Since its inception, this document has been developed on the basis of standardized materials, devices, and design practices. However, certain paragraphs, such as 2-3.5, 4-3.2, and this one, allow the use of materials and devices not specifically designated by this standard, provided such use is within parameters established by a listing organization. In using such materials or devices, it is important that all conditions, requirements, and limitations of the listing be fully understood and accepted and that the installation is in complete accord with such listing requirements.

1-3 Retroactivity Clause. The provisions of this document are considered necessary to provide a reasonable level of protection from loss of life and property from fire. They reflect situations and the state of the art at the time the standard was issued.

Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of this document.

Exception: In those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or property, this standard shall apply.

1-4 Definitions.

1-4.1 NFPA Definitions.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installation, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the most current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard. A document containing only mandatory provisions, using the word shall to indicate requirements. Explanatory material may be included only in the form of fine print notes, in footnotes, or in an appendix.

1-4.2 General Definitions.

Compartment. As used in 4-3.6.3 and 6-4.4.4, a space completely enclosed by walls and a ceiling. The compartment enclosure may have openings to an adjoining space if the openings have a minimum lintel depth of 8 in. (203 mm) from the ceiling.

Drop-Out Ceiling. A suspended ceiling system with listed translucent or opaque panels that are heat sensitive and fall from their setting when exposed to heat. This ceiling system is installed below the sprinklers.

Dwelling Unit. One or more rooms arranged for the use of one or more individuals living together as in a single housekeeping unit normally having cooking, living, sanitary, and sleeping facilities.

For purposes of this standard, dwelling unit includes hotel rooms, dormitory rooms, apartments, condominiums, sleeping rooms in nursing homes, and similar living units.

Fire Control. Limiting the size of a fire by distribution of water so as to decrease the heat release rate and pre-wet adjacent combustibles, while controlling ceiling gas temperatures to avoid structural damage.

Fire Suppression. Sharply reducing the heat release rate of a fire and preventing its regrowth by means of direct and sufficient application of water through the fire plume to the burning fuel surface.

High Challenge Fire Hazard. A fire hazard typical of that produced by fires in combustible high-piled storage.

High-Piled Storage. Solid piled, palletized, rack storage, bin box, and shelf storage in excess of 12 ft (3.7 m) in height. (*See 5-2.3.1.1.*)

Hydraulically Designed System. A calculated sprinkler system in which pipe sizes are selected on a pressure loss basis to provide a prescribed water density, in gallons per minute per square foot [(L/min)/m^2], or a prescribed minimum discharge pressure or flow per sprinkler, distributed with a reasonable degree of uniformity over a specified area.

Limited-Combustible Material. As applied to a building construction material, a material, not complying with the definition of noncombustible material, that, in the form in which it is used, has a potential heat value not exceeding 3500 Btu per lb (8141 kJ/kg) and complies with one of the following paragraphs, (a) or (b). Materials subject to increase in combustibility or flame spread rating beyond the limits herein established through the effects of age, moisture, or other atmospheric condition shall be considered combustible.

(a) Materials having a structural base of noncombustible material, with a surfacing not exceeding a thickness of $^1/_8$ in. (3.2 mm) that has a flame spread rating not greater than 50.

(b) Materials, in the form and thickness used, other than as described in (a), having neither a flame spread rating greater than 25 nor evidence of continued progressive combustion and of such composition that surfaces that would be exposed by cutting through the material on any plane would have neither a flame spread rating greater than 25 nor evidence of continued progressive combustion.

Miscellaneous Storage.* Storage that does not exceed 12 ft (3.7 m) in height and is incidental to another occupancy use group as defined in 1-4.7 (see 5-2.3.1.1). Protection criteria for miscellaneous storage are within the scope of this standard.

Noncombustible Material. A material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials that are reported as passing ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible materials.

Pipe Schedule System. A sprinkler system in which the pipe sizing is selected from a schedule that is determined by the occupancy classification. A given number of sprinklers are allowed to be supplied from specific sizes of pipe.

Small Rooms. Rooms of light hazard occupancy classification having unobstructed construction and floor areas not exceeding 800 sq ft (74.3 m^2). (*See 1-4.7.1.*)

Sprinkler System.* For fire protection purposes, an integrated system of underground and overhead piping designed in accordance with fire protection engineering standards. The installation includes one or more automatic water supplies. The portion of the sprinkler system aboveground is a network of specially sized or hydraulically designed piping installed in a building, structure, or area, generally overhead, and to which sprinklers are attached in a systematic pattern. The valve controlling each system riser is located in the system riser or its supply piping. Each sprinkler system riser includes a device for actuating an alarm when the system is in operation. The system is usually activated by heat from a fire and discharges water over the fire area.

NOTE: The design and installation of water supply facilities such as gravity tanks, fire pumps, reservoirs or pressure tanks, and underground piping are covered by the following NFPA standards: NFPA 22, *Standard for Water Tanks for Private Fire Protection*; NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*; and NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

Thermal Barrier. A material that will limit the average temperature rise of the unexposed surface to not more than 250°F (121°C) after 15 minutes of fire exposure complying with the standard time-temperature curve of NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*.

1-4.3 Sprinkler System Type Definitions.

Wet Pipe System. A sprinkler system employing automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers opened by heat from a fire.

Dry Pipe System. A sprinkler system employing automatic sprinklers attached to a piping system containing air or nitrogen under pressure, the release of which (as from the opening of a sprinkler) permits the water pressure to open a valve known as a dry pipe valve. The water then flows into the piping system and out the opened sprinklers.

Preaction System. A sprinkler system employing automatic sprinklers attached to a piping system containing air that may or may not be under pressure, with a supplemental detection system installed in the same areas as the sprinklers. Actuating means of the valve are described in 3-3.2.1. Actuation of the detection system opens a valve that permits water to flow into the sprinkler piping system and to be discharged from any sprinklers that may be open.

Deluge System. A sprinkler system employing open sprinklers attached to a piping system connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers. When this valve opens, water flows into the piping system and discharges from all sprinklers attached thereto.

Combined Dry Pipe-Preaction System. A sprinkler system employing automatic sprinklers attached to a piping system containing air under pressure with a supplemental detection system installed in the same areas as the sprinklers. Operation of the detection system actuates tripping devices that open dry pipe valves simultaneously and without loss of air pressure in the system. Operation of the detection system also opens listed air exhaust valves at the end of the feed main, which usually precedes the opening of sprinklers. The detection system also serves as an automatic fire alarm system.

Antifreeze System. A wet pipe sprinkler system employing automatic sprinklers attached to a piping system containing an antifreeze solution and connected to a water supply. The antifreeze solution is discharged, followed by water, immediately upon operation of sprinklers opened by heat from a fire.

Circulating Closed-Loop System. A wet pipe sprinkler system having non-fire-protection connections to automatic sprinkler systems in a closed-loop piping arrangement for the purpose of utilizing sprinkler piping to conduct water for heating or cooling. Water is not removed or used from the system, but only circulated through the piping system.

1-4.4* System Component Definitions.

Branch Lines. The pipes in which the sprinklers are placed, either directly or through risers.

Cross Mains. The pipes supplying the branch lines, directly or through risers.

Feed Mains. The pipes supplying risers or cross mains.

Risers. The vertical supply pipes in a sprinkler system.

Supervisory Devices. Devices arranged to supervise the operative condition of automatic sprinkler systems.

System Riser. The aboveground supply pipe directly connected to the water supply.

1-4.5 Sprinkler Definitions.

1-4.5.1 Sprinklers defined according to design and performance characteristics:

Spray Sprinkler. A type of sprinkler listed for its capability to provide fire control for a wide range of fire hazards.

Old-Style/Conventional Sprinkler. Sprinklers that direct from 40 to 60 percent of the total water initially in a downward direction and that are designed to be installed with the deflector either upright or pendent.

Fast Response Sprinkler. A type of sprinkler with a high level of thermal sensitivity, enabling it to respond at an early stage of fire development. This includes ESFR, QR, QREC, QRES, and residential sprinklers.

Residential Sprinkler. A type of fast response sprinkler specifically listed for use in protection against the fire hazards typically found in dwelling units.

Extended Coverage (EC) Sprinkler. A type of spray sprinkler listed as a special sprinkler with extended maximum protection area.

Quick-Response (QR) Sprinkler. A type of sprinkler that is both a fast response and a spray sprinkler.

Quick-Response Extended Coverage (QREC) Sprinkler. Sprinklers that are listed as both quick-response and extended coverage sprinklers.

Quick-Response Early Suppression (QRES) Sprinkler.* Fast response sprinklers that are listed for their capability to provide fire suppression of specific fire hazards.

Large-Drop Sprinkler. A type of sprinkler that is capable of producing characteristic large water droplets and that is listed for its capability to provide fire control of specific high challenge fire hazards.

Early Suppression Fast Response (ESFR) Sprinkler.* A type of fast response sprinkler listed for its capability to provide fire suppression of specific high challenge fire hazards.

Open Sprinkler. Sprinklers from which the heat responsive and actuating elements have been removed.

Nozzles. Devices for use in applications requiring special water discharge patterns, directional spray, or other unusual discharge characteristics.

Special Sprinkler. Sprinklers that have been tested and listed as prescribed in 4-3.2.

1-4.5.2 Sprinklers defined according to orientation:

Concealed Sprinkler. Recessed sprinklers with cover plates.

Flush Sprinkler. Sprinklers in which all or part of the body, including the shank thread, is mounted above the lower plane of the ceiling.

Pendent Sprinkler. Sprinklers designed to be installed in such a way that the water stream is directed downward against the deflector.

Recessed Sprinkler. Sprinklers in which all or part of the body, other than the shank thread, is mounted within a recessed housing.

Sidewall Sprinkler. Sprinklers having special deflectors that are designed to discharge most of the water away from the nearby wall in a pattern resembling one quarter of a sphere, with a small portion of the discharge directed at the wall behind the sprinkler.

Upright Sprinkler. Sprinklers designed to be installed in such a way that the water spray is directed upwards against the deflector.

1-4.5.3 Sprinklers defined according to special application or environment:

Corrosion-Resistant Sprinkler. Sprinklers fabricated with corrosion-resistant material or with special coatings or platings to be used in an atmosphere that would normally corrode sprinklers.

Dry Sprinkler.* Sprinklers secured in an extension nipple that has a seal at the inlet end to prevent water from entering the nipple until the sprinkler operates. Dry sprinklers are intended to extend into an unheated area from a wet pipe system or (for dry-pendent sprinklers) to be used on a dry pipe system in the pendent position.

Intermediate Level Sprinkler/Rack Storage Sprinkler. Sprinklers equipped with integral shields to protect their operating elements from the discharge of sprinklers installed at higher elevations.

Ornamental/Decorative Sprinkler. Sprinklers that have been painted or plated by the manufacturer.

1-4.6* Construction Definitions.

Obstructed Construction. Construction where beams, trusses, or other members impede heatflow or water distribution in a manner that materially affects the ability of sprinklers to control or suppress a fire.

Unobstructed Construction. Construction where beams, trusses, or other members do not impede heatflow or water distribution in a manner that materially affects the ability of sprinklers to control or suppress a fire. Unobstructed construction has horizontal structural members that are not solid, where the openings are at least 70 percent of the cross section area, and the depth of the member does not exceed the least dimension of the openings, or all construction types where the spacing of structural members exceed 7 ½ ft (2.3 m) on center.

For descriptions of construction types, see A-1-4.6(a) and (b).

1-4.7* Classification of Occupancies. Occupancy classifications for this standard relate to sprinkler installations and their water supplies only. They are not intended to be a general classification of occupancy hazards.

1-4.7.1* Light Hazard Occupancies. Occupancies or portions of other occupancies where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected.

1-4.7.2 Ordinary Hazard Occupancies.

1-4.7.2.1* Ordinary Hazard (Group 1). Occupancies or portions of other occupancies where combustibility is low, quantity of combustibles is moderate, stockpiles of combustibles do not exceed 8 ft (2.4 m), and fires with moderate rates of heat release are expected.

1-4.7.2.2* Ordinary Hazard (Group 2). Occupancies or portions of other occupancies where quantity and combustibility of contents is moderate to high, stockpiles do not exceed 12 ft (3.7 m), and fires with moderate to high rates of heat release are expected.

1-4.7.3 Extra Hazard Occupancies.

1-4.7.3.1* Occupancies or portions of other occupancies where quantity and combustibility of contents is very high and flammable and combustible liquids, dust, lint, or other materials are present, introducing the probability of rapidly developing fires with high rates of heat release.

1-4.7.3.2 Extra hazard occupancies involve a wide range of variables that may produce severe fires. The following shall be used to evaluate the severity of Extra Hazard Occupancies:

Extra Hazard (Group 1) includes occupancies described in 1-4.7.3.1 with little or no flammable or combustible liquids.

Extra Hazard (Group 2) includes occupancies described in 1-4.7.3.1 with moderate to substantial amounts of flammable or combustible liquids or where shielding of combustibles is extensive.

1-4.7.4 Special Occupancy Hazards.

1-4.7.4.1* Other NFPA standards contain sprinkler system design criteria for fire control or suppression of specific hazards. These are listed in Chapter 10 and include but are not limited to NFPA 30, *Flammable and Combustible Liquids Code*; NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*; NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*; NFPA 81, *Standard for Fur Storage, Fumigation and Cleaning*; NFPA 231, *Standard for General Storage*; NFPA 231C, *Standard for Rack Storage of Materials*; NFPA 231D, *Standard for Storage of Rubber Tires*; NFPA 231E, *Recommended Practice for the Storage of Baled Cotton*; NFPA 231F, *Standard for the Storage of Roll Paper*; NFPA 232, *Standard for the Protection of Records*; and NFPA 409, *Standard on Aircraft Hangars*.

1-4.7.4.2 Miscellaneous storage as defined herein shall be classified as to occupancy group in accordance with Table 1-4.7.4.2.

Table 1-4.7.4.2 Occupancy Group Classification for Miscellaneous Storage 12 ft (3.7 m) or Less in Height

Commodity Classification	Palletized and Bin Box	Rack
I	OH-1	OH-1
II	OH-1	OH-1
III	OH-2	OH-2
IV	OH-2	OH-2
Group A Plastic	EH-1	EH-2

NOTE: See Tentative Interim Amendment on page 131.

1-4.7.4.2.1 The commodity classifications and storage characteristics in Table 1-4.7.4.2 shall be as defined in NFPA 231 and NFPA 231C.

1-5 Abbreviations. The standard abbreviations in Table 1-5 shall be used on the hydraulic calculation form.

Table 1-5

Symbol or Abbreviation	Item
p	Pressure in psi
gpm	U.S. Gallons per minute
q	Flow increment in gpm to be added at a specific location
Q	Summation of flow in gpm at a specific location
P_t	Total pressure in psi at a point in a pipe
P_f	Pressure loss due to friction between points indicated in location column
P_e	Pressure due to elevation difference between indicated points. This can be a plus value or a minus value. Where minus, the (−) shall be used; where plus, no sign need be indicated
P_v	Velocity pressure in psi at a point in a pipe
P_n	Normal pressure in psi at a point in a pipe
E	90° Ell
EE	45° Ell
Lt.E	Long Turn Elbow
Cr	Cross
T	Tee—flow turned 90°
GV	Gate Valve
BV	Butterfly (Wafer) Check Valve
Del V	Deluge Valve
ALV	Alarm Valve
DPV	Dry Pipe Valve
CV	Swing Check Valve
WCV	Butterfly (Wafer) Check Valve
St	Strainer
psi	Pounds per square inch
v	Velocity of water in pipe in feet per second

1-6 Level of Protection.

1-6.1 A building, when protected by an automatic sprinkler system installation, shall be provided with sprinklers in all areas.

Exception: Where specific sections of this standard permit the omission of sprinklers.

1-6.2 Limited Area Systems. When partial sprinkler systems are installed, the requirements of this standard shall be used insofar as they are applicable. The authority having jurisdiction shall be consulted in each case.

Chapter 2 System Components and Hardware

2-1 General. This chapter provides requirements for correct use of sprinkler system components.

2-1.1* All materials and devices essential to successful system operation shall be listed.

Exception No. 1: Equipment as permitted in Table 2-3.1, Table 2-4.1, and the Exceptions to 2-6.1 and 2-6.1.1 need not be listed.

Exception No. 2: Components that do not affect system operation such as drain valves and signs need not be listed. The use of reconditioned valves and devices other than sprinklers as replacement equipment in existing systems shall be permitted.

2-1.2 System components shall be rated for the maximum working pressure to which they are exposed but not less than 175 psi (12.1 bars).

2-2 Sprinklers.

2-2.1 Only new sprinklers shall be installed.

2-2.2 Sprinkler Discharge Characteristics. The K factor, relative discharge, and identification for sprinklers having different orifice sizes shall be in accordance with Table 2-2.2 on the following page.

Exception: Listed sprinklers having pipe threads different from those shown in Table 2-2.2 shall be permitted.

2-2.2.1 For Light Hazard Occupancies not requiring as much water as is discharged by a nominal 1/2-in. (12.7-mm) orifice sprinkler operating at 7 psi (0.5 bar), sprinklers having a smaller orifice shall be permitted subject to the following restrictions:

(a) The system shall be hydraulically calculated. (*See Chapter 6.*)

(b) Small orifice sprinklers shall be installed in wet systems only.

Exception: Small orifice outside sprinklers for protection from exposure fires installed in conformance with Section 3-7 shall be permitted.

(c) A listed strainer shall be provided on the supply side of sprinklers having orifices smaller than 3/8 in. (9.5 mm).

2-2.2.2 Sprinklers having orifice sizes exceeding 1/2 in. (12.7 mm) and having 1/2 in. NPT shall not be installed in new sprinkler systems.

2-2.3* Temperature Characteristics.

2-2.3.1 The standard temperature ratings of automatic sprinklers are shown in Table 2-2.3.1 on the following page. Automatic sprinklers shall have their frame arms colored in accordance with the color code designated in Table 2-2.3.1.

Exception No. 1: A dot on the top of the deflector, or the color of the coating material, or colored frame arms shall be permitted for color identification of corrosion-resistant sprinklers.

Table 2-2.2 Sprinkler Discharge Characteristics Identification

Nominal Orifice Size (in.)	Orifice Type	K Factor[1]	Percent of Nominal 1/2 in. Discharge	Thread Type	Pintle	Nominal Orifice Size Marked On Frame
1/4	Small	1.3-1.5	25	1/2 in. NPT	Yes	Yes
5/16	Small	1.8-2.0	33.3	1/2 in. NPT	Yes	Yes
3/8	Small	2.6-2.9	50	1/2 in. NPT	Yes	Yes
7/16	Small	4.0-4.4	75	1/2 in. NPT	Yes	Yes
1/2	Standard	5.3-5.8	100	1/2 in. NPT	No	No
17/32	Large	7.4-8.2	140	3/4 in. NPT or 1/2 in. NPT	No	No
5/8	Extra Large	11.0-11.5	200	1/2 in. NPT or 3/4 in. NPT	Yes	Yes
5/8	Large-Drop	11.0-11.5	200	1/2 in. NPT or 3/4 in. NPT	Yes	Yes
3/4	ESFR	13.5-14.5	250	3/4 in. NPT	Yes	No

[1]K factor is the constant in the formula $Q = K\sqrt{p}$
Where Q = Flow in gpm
p = Pressure in psi

For SI Units: $Q_m = K_m\sqrt{p_m}$
Where Q_m = Flow in L/min
P_m = Pressure in bars
K_m = 14 K

Exception No. 2: Color identification shall not be required for ornamental sprinklers such as factory plated or factory painted sprinklers or for recessed, flush, or concealed sprinklers.

Exception No. 3: The frame arms of bulb type sprinklers need not be color coded.

2-2.3.2 The liquid in bulb type sprinklers shall be color coded in accordance with Table 2-2.3.1.

2-2.4 Special Coatings.

2-2.4.1* Listed corrosion-resistant sprinklers shall be installed in locations where chemicals, moisture, or other corrosive vapors sufficient to cause corrosion of such devices exist.

2-2.4.2* Corrosion-resistant coatings shall be applied only by the manufacturer of the sprinkler.

Exception: Any damage to the protective coating occurring at the time of installation shall be repaired at once using only the coating of the manufacturer of the sprinkler in the approved manner so that no part of the sprinkler will be exposed after installation has been completed.

2-2.4.3* Unless applied by the manufacturer, sprinklers shall not be painted, and any sprinklers that have been painted shall be replaced with new listed sprinklers of the same characteristics, including orifice size, thermal response, and water distribution.

Exception: Factory-applied paint or coating to sprinkler frames in accordance with 2-2.3.1 shall be permitted.

2-2.4.4 Ornamental finishes shall not be applied to sprinklers by anyone other than the sprinkler manufacturer, and only sprinklers listed with such finishes shall be used.

2-2.5 Escutcheon Plates.

2-2.5.1 Nonmetallic escutcheon plates shall be listed.

2-2.5.2* Escutcheon plates used with a recessed or flush type sprinkler shall be part of a listed sprinkler assembly.

2-2.6* Guards and Shields. Sprinklers subject to mechanical injury shall be protected with listed guards.

2-2.7 Stock of Spare Sprinklers.

2-2.7.1 A supply of spare sprinklers (never less than 6) shall be maintained on the premises so that any sprinklers that have operated or been damaged in any way can be

Table 2-2.3.1 Temperature Ratings, Classifications, and Color Codings

Max. Ceiling Temp. °F	°C	Temperature Rating °F	°C	Temperature Classification	Color Code	Glass Bulb Colors
100	38	135 to 170	57 to 77	Ordinary	Uncolored or Black	Orange or Red
150	66	175 to 225	79 to 107	Intermediate	White	Yellow or Green
225	107	250 to 300	121 to 149	High	Blue	Blue
300	149	325 to 375	163 to 191	Extra High	Red	Purple
375	191	400 to 475	204 to 246	Very Extra High	Green	Black
475	246	500 to 575	260 to 302	Ultra High	Orange	Black
625	329	650	343	Ultra High	Orange	Black

promptly replaced. These sprinklers shall correspond to the types and temperature ratings of the sprinklers in the property. The sprinklers shall be kept in a cabinet located where the temperature to which they are subjected will at no time exceed 100°F (38°C).

2-2.7.2 A special sprinkler wrench shall also be provided and kept in the cabinet to be used in the removal and installation of sprinklers.

2-2.7.3 The stock of spare sprinklers shall include all types and ratings installed and shall be as follows:

(a) For systems with not over 300 sprinklers, not less than 6 sprinklers.

(b) For systems with 300 to 1000 sprinklers, not less than 12 sprinklers.

(c) For systems with over 1000 sprinklers, not less than 24 sprinklers.

2-3 Pipe and Tube.

2-3.1 Pipe or tube used in sprinkler systems shall meet or exceed one of the standards in Table 2-3.1 or be in accordance with 2-3.2 through 2-3.5.

Table 2-3.1 Pipe or Tube Materials and Dimensions

Materials and Dimensions	Standard
Ferrous Piping (Welded and Seamless)	
† Spec. for Black and Hot-Dipped Zinc Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use	ASTM A795
† Spec. for Welded and Seamless Steel Pipe	ANSI/ ASTM A53
Wrought Steel Pipe	ANSI B36.10M
Spec. for Elec.-Resistance Welded Steel Pipe	ASTM A135
Copper Tube (Drawn, Seamless)	
† Spec. for Seamless Copper Tube	ASTM B75
† Spec. for Seamless Copper Water Tube	ASTM B88
Spec. for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube	ASTM B251
Brazing Filler Metal (Classification BCuP-3 or BCuP-4)	AWS A5.8
Solder Metal, 95-5 (Tin-Antimony-Grade 95TA)	ASTM B32

† Denotes pipe or tubing suitable for bending (see 2-3.6) according to ASTM standards.

2-3.2* When steel pipe listed in Table 2-3.1 is used and joined by welding as referenced in 2-5.2 or by roll grooved pipe and fittings as referenced in 2-5.3, the minimum nominal wall thickness for pressures up to 300 psi (20.7 bars) shall be in accordance with Schedule 10 for sizes up to 5 in. (127 mm); 0.134 in. (3.40 mm) for 6 in. (152 mm); and 0.188 in. (4.78 mm) for 8 and 10 in. (203 and 254 mm) pipe.

Exception: Pressure limitations and wall thickness for steel pipe listed in accordance with 2-3.5 shall be in accordance with the listing requirements.

2-3.3 When steel pipe listed in Table 2-3.1 is joined by threaded fittings referenced in 2-5.1 or by fittings used with pipe having cut grooves, the minimum wall thickness shall be in accordance with Schedule 30 [in sizes 8 in. (203 mm) and larger] or Schedule 40 [in sizes less than 8 in. (203 mm)] pipe for pressures up to 300 psi (20.7 bars).

Exception: Pressure limitations and wall thickness for steel pipe specially listed in accordance with 2-3.5 shall be in accordance with the listing requirements.

2-3.4* Copper tube as specified in the standards listed in Table 2-3.1 shall have a wall thickness of Type K, L, or M where used in sprinkler systems.

2-3.5* Other types of pipe or tube investigated for suitability in automatic sprinkler installations and listed for this service, including but not limited to polybutylene, chlorinated polyvinyl chloride (CPVC), and steel differing from that provided in Table 2-3.1, shall be permitted when installed in accordance with their listing limitations, including installation instructions. Pipe or tube shall not be listed for portions of an occupancy classification.

2-3.6 Pipe Bending. Bending of Schedule 40 steel pipe and Types K and L copper tube shall be permitted when bends are made with no kinks, ripples, distortions, reductions in diameter, or any noticeable deviations from round. The minimum radius of a bend shall be 6 pipe diameters for pipe sizes 2 in. (51 mm) and smaller, and 5 pipe diameters for pipe sizes $2^1/_2$ in. (64 mm) and larger.

2-4 Fittings.

2-4.1 Fittings used in sprinkler systems shall meet or exceed the standards in Table 2-4.1 or be in accordance with 2-4.2.

Table 2-4.1 Fittings Materials and Dimensions

Materials and Dimensions	Standard
Cast Iron	
Cast Iron Threaded Fittings, Class 125 and 250	ANSI B16.4
Cast Iron Pipe Flanges and Flanged Fittings	ANSI B16.1
Malleable Iron	
Malleable Iron Threaded Fittings, Class 150 and 300	ANSI B16.3
Steel	
Factory-made Wrought Steel Buttweld Fittings	ANSI B16.9
Buttwelding Ends for Pipe, Valves, Flanges, and Fittings	ANSI B16.25
Spec. for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures	ASTM A234
Steel Pipe Flanges and Flanged Fittings	ANSI B16.5
Forged Steel Fittings, Socket Welded and Threaded	ANSI B16.11
Copper	
Wrought Copper and Bronze Solder-Joint Pressure Fittings	ANSI B16.22
Cast Bronze Solder-Joint Pressure Fittings	ANSI B16.18

2-4.2* Other types of fittings investigated for suitability in automatic sprinkler installations and listed for this service, including but not limited to polybutylene, chlorinated polyvinyl chloride (CPVC), and steel differing from that provided in Table 2-4.1, shall be permitted when installed in accordance with their listing limitations, including installation instructions.

2-4.3 Fittings shall be extra-heavy pattern where pressures exceed 175 psi (12.1 bars).

Exception No. 1: Standard weight pattern cast-iron fittings 2 in. (51 mm) in size and smaller shall be permitted where pressures do not exceed 300 psi (20.7 bars).

Exception No. 2: Standard weight pattern malleable iron fittings 6 in. (152 mm) in size and smaller shall be permitted where pressures do not exceed 300 psi (20.7 bars).

Exception No. 3: Fittings shall be permitted for system pressures up to the limits specified in their listings.

2-4.4* Couplings and Unions. Screwed unions shall not be used on pipe larger than 2 in. (51 mm). Couplings and unions of other than screwed-type shall be of types listed specifically for use in sprinkler systems.

2-4.5 Reducers and Bushings. A one-piece reducing fitting shall be used wherever a change is made in the size of the pipe.

Exception No. 1: Hexagonal or face bushings shall be permitted in reducing the size of openings of fittings when standard fittings of the required size are not available.

Exception No. 2: Hexagonal bushings as permitted in 4-4.1.7.21.1 are acceptable.

2-5 Joining of Pipe and Fittings.

2-5.1 Threaded Pipe and Fittings.

2-5.1.1 All threaded pipe and fittings shall have threads cut to ANSI/ASME B1.20.1.

2-5.1.2* Steel pipe with wall thicknesses less than Schedule 30 [in sizes 8 in. (203 mm) and larger] or Schedule 40 [in sizes less than 8 in. (203 mm)] shall not be joined by threaded fittings.

Exception: A threaded assembly investigated for suitability in automatic sprinkler installations and listed for this service shall be permitted.

2-5.1.3 Joint compound or tape shall be applied only to male threads.

2-5.2* Welded Pipe and Fittings.

2-5.2.1 Welding methods that comply with all of the requirements of AWS D10.9, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*, Level AR-3, are acceptable means of joining fire protection piping.

2-5.2.2* Sprinkler piping shall he shop welded.

Exception: Welding of sprinkler piping in place inside new buildings under construction shall be permitted only when the construction is noncombustible and no combustible contents are present and when the welding process is performed in accordance with NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes.

2-5.2.3 Fittings used to join pipe shall be listed fabricated fittings or manufactured in accordance with Table 2-4.1. Such fittings joined in conformance with a qualified welding procedure as set forth in this section are an acceptable product under this standard, provided that materials and wall thickness are compatible with other sections of this standard.

Exception: Fittings are not required when pipe ends are buttwelded.

2-5.2.4 No welding shall be performed if there is impingement of rain, snow, sleet, or high wind on the weld area of the pipe product.

2-5.2.5 When welding is performed:

(a)* Holes in piping for outlets shall be cut to the full inside diameter of fittings prior to welding in place of the fittings.

(b) Discs shall be retrieved.

(c) Openings cut into piping shall be smooth bore, and all internal slag and welding residue shall be removed.

(d) Fittings shall not penetrate the internal diameter of the piping.

(e) Steel plates shall not be welded to the ends of piping or fittings.

(f) Fittings shall not be modified.

(g) Nuts, clips, eye rods, angle brackets, or other fasteners shall not be welded to pipe or fittings.

Exception: Only tabs welded to pipe for longitudinal earthquake braces shall be permitted. (See 4-5.4.3.5.1.)

2-5.2.6 When reducing the pipe size in a run of piping, a reducing fitting designed for that purpose shall be used.

2-5.2.7 Torch cutting and welding shall not be permitted as a means of modifying or repairing sprinkler systems.

2-5.2.8 Qualifications.

2-5.2.8.1 A welding procedure shall be prepared and qualified by the contractor or fabricator before any welding is done. Qualification of the welding procedure to be used and the performance of all welders and welding operators is required and shall meet or exceed the requirements of American Welding Society Standard AWS D10.9, Level AR-3.

2-5.2.8.2 Contractors or fabricators shall be responsible for all welding they produce. Each contractor or fabricator shall have an established written quality assurance procedure ensuring compliance with the requirements of 2-5.2.5 available to the authority having jurisdiction.

2-5.2.9 **Records.**

2-5.2.9.1 Welders or welding machine operators shall, upon completion of each weld, stamp an imprint of their identification into the side of the pipe adjacent to the weld.

2-5.2.9.2 Contractors or fabricators shall maintain certified records, which are available to the authority having jurisdiction, of the procedures used and the welders or welding machine operators employed by them along with their welding identification imprints. Records shall show the date and the results of procedure and performance qualifications.

2-5.3 Groove Joining Methods.

2-5.3.1 Pipe joined with grooved fittings shall be joined by a listed combination of fittings, gaskets, and grooves. Grooves cut or rolled on pipe shall be dimensionally compatible with the fittings.

2-5.3.2 Grooved fittings including gaskets used on dry pipe systems shall be listed for dry pipe service.

2-5.4* Brazed and Soldered Joints. Joints for the connection of copper tube shall be brazed.

Exception No. 1: Solder joints shall be permitted for exposed wet pipe systems in Light Hazard Occupancies where the temperature classification of the installed sprinklers is ordinary or intermediate.

Exception No. 2: Solder joints shall be permitted for wet pipe systems in Light Hazard and Ordinary Hazard (Group 1) Occupancies where the piping is concealed, irrespective of sprinkler temperature ratings.

2-5.4.1* Highly corrosive fluxes shall not be used.

2-5.5 Other Types. Other joining methods investigated for suitability in automatic sprinkler installations and listed for this service shall be permitted when installed in accordance with their listing limitations, including installation instructions.

2-5.6 End Treatment. After cutting, pipe ends shall have burrs and fins removed.

2-5.6.1 Pipe used with listed fittings and its end treatment shall be in accordance with the fitting manufacturer's installation instructions and the fitting's listing.

2-6 Hangers.

2-6.1* General. Types of hangers shall be in accordance with the requirements of Section 2-6.

Exception: Hangers certified by a registered professional engineer to include all of the following shall be acceptable:

(a) Hangers are designed to support five times the weight of the water-filled pipe plus 250 lb (114 kg) at each point of piping support.

(b) These points of support are adequate to support the sprinkler system.

(c) Hanger components shall be ferrous.

Detailed calculations shall be submitted, when required by the reviewing authority, showing stresses developed both in hangers and piping and safety factors allowed.

2-6.1.1 The components of hanger assemblies that directly attach to the pipe or to the building structure shall be listed.

Exception: Mild steel hangers formed from rods need not be listed.

2-6.1.2 Hangers and their components shall be ferrous.

Exception: Nonferrous components that have been proven by fire tests to be adequate for the hazard application, that are listed for this purpose, and that are in compliance with the other requirements of this section shall be acceptable.

2-6.1.3 Sprinkler piping shall be substantially supported from the building structure, which must support the added load of the water-filled pipe plus a minimum of 250 lb (114 kg) applied at the point of hanging.

2-6.1.4 When sprinkler piping is installed below ductwork, piping shall be supported from the building structure or from the ductwork supports, provided such supports are capable of handling both the load of the ductwork and the load specified in 2-6.1.3.

2-6.1.5* For trapeze hangers, the minimum size of steel angle or pipe span between purlins or joists shall be such that the available section modulus of the trapeze member from Table 2-6.1.5(b) equals or exceeds the section modulus required in Table 2-6.1.5(a). (*See following pages.*)

Any other sizes or shapes giving equal or greater section modulus shall be acceptable. All angles shall be used with the longer leg vertical. The trapeze member shall be secured to prevent slippage. When a pipe is suspended from a pipe trapeze of a diameter less than the diameter of the pipe being supported, ring, strap, or clevis hangers of the size corresponding to the suspended pipe shall be used on both ends.

2-6.1.6 The size of hanger rods and fasteners required to support the steel angle iron or pipe indicated in Table 2-6.1.5(a) shall comply with 2-6.4.

2-6.1.7* Sprinkler piping or hangers shall not be used to support nonsystem components.

2-6.2 Hangers in Concrete.

2-6.2.1 The use of listed inserts set in concrete to support hangers shall be permitted.

2-6.2.2 Listed expansion shields for supporting pipes under concrete construction shall be permitted to be used in a horizontal position in the sides of beams. In concrete

Table 2-6.1.5(a) Section Modulus Required for Trapeze Members (in.^{3})

Span of Trapeze	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.	8 in.	10 in.
1 ft 6 in.	.08	.09	.09	.09	.10	.11	.12	.13	.15	.18	.24	.32
	.08	.09	.09	.10	.11	.12	.13	.15	.18	.22	.30	.41
2 ft 0 in.	.11	.12	.12	.13	.13	.15	.16	.17	.20	.24	.32	.43
	.11	.12	.12	.13	.15	.16	.18	.20	.24	.29	.40	.55
2 ft 6 in.	.14	.14	.15	.16	.17	.18	.20	.21	.25	.30	.40	.54
	.14	.15	.15	.16	.18	.21	.22	.25	.30	.36	.50	.68
3 ft 0 in.	.17	.17	.18	.19	.20	.22	.24	.26	.31	.36	.48	.65
	.17	.18	.18	.20	.22	.25	.27	.30	.36	.43	.60	.82
4 ft 0 in.	.22	.23	.24	.25	.27	.29	.32	.34	.41	.48	.64	.87
	.22	.24	.24	.26	.29	.33	.36	.40	.48	.58	.80	1.09
5 ft 0 in.	.28	.29	.30	.31	.34	.37	.40	.43	.51	.59	.80	1.08
	.28	.29	.30	.33	.37	.41	.45	.49	.60	.72	1.00	1.37
6 ft 0 in.	.33	.35	.36	.38	.41	.44	.48	.51	.61	.71	.97	1.30
	.34	.35	.36	.39	.44	.49	.54	.59	.72	.87	1.20	1.64
7 ft 0 in.	.39	.40	.41	.44	.47	.52	.55	.60	.71	.83	1.13	1.52
	.39	.41	.43	.46	.51	.58	.63	.69	.84	1.01	1.41	1.92
8 ft 0 in.	.44	.46	.47	.50	.54	.59	.63	.68	.81	.95	1.29	1.73
	.45	.47	.49	.52	.59	.66	.72	.79	.96	1.16	1.61	2.19
9 ft 0 in.	.50	.52	.53	.56	.61	.66	.71	.77	.92	1.07	1.45	1.95
	.50	.53	.55	.59	.66	.74	.81	.89	1.08	1.30	1.81	2.46
10 ft 0 in.	.56	.58	.59	.63	.68	.74	.79	.85	1.02	1.19	1.61	2.17
	.56	.59	.61	.65	.74	.82	.90	.99	1.20	1.44	2.01	2.74

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Top values are for Schedule 10 pipe; bottom values are for Schedule 40 pipe.
Note: The table is based on a maximum allowable bending stress of 15 KSI and a midspan concentrated load from 15 ft of water-filled pipe, plus 250 lb.

having gravel or crushed stone aggregate, expansion shields shall be permitted to be used in the vertical position to support pipes 4 in. (102 mm) or less in diameter.

2-6.2.3 For the support of pipes 5 in. (127 mm) and larger, expansion shields, if used in the vertical position, shall alternate with hangers connected directly to the structural members, such as trusses and girders, or to the sides of concrete beams. In the absence of convenient structural members, pipes 5 in. (127 mm) and larger shall be permitted to be supported entirely by expansion shields in the vertical position, but spaced not over 10 ft (3 m) apart.

2-6.2.4 Expansion shields shall not be used in ceilings of gypsum or similar soft material. In cinder concrete, expansion shields shall not be used except on branch lines where they shall alternate with through bolts or hangers attached to beams.

2-6.2.5 When expansion shields are used in the vertical position, the holes shall be drilled to provide uniform contact with the shield over its entire circumference. Depth of the hole shall not be less than specified for the type of shield used.

2-6.2.6 Holes for expansion shields in the side of concrete beams shall be above the center line of the beam or above the bottom reinforcement steel rods.

2-6.3 Powder-Driven Studs and Welding Studs.

2-6.3.1* Powder-driven studs, welding studs, and the tools used for installing these devices shall be listed. Pipe size, installation position, and construction material into which they are installed shall be in accordance with individual listings.

2-6.3.2* Representative samples of concrete into which studs are to be driven shall be tested to determine that the studs will hold a minimum load of 750 lb (341 kg) for 2-in. (51-mm) or smaller pipe, 1000 lb (454 kg) for 2½-, 3-, or 3½-in. (64-, 76-, or 89-mm) pipe, and 1200 lb (545 kg) for 4- or 5-in. (102- or 127-mm) pipe.

2-6.3.3 Increaser couplings shall be attached directly to the powder-driven studs or welding studs.

2-6.3.4 Welding studs or other hanger parts shall not be attached by welding to steel less than U.S. Standard, 12 gauge.

2-6.4 Rods and "U" Hooks.

2-6.4.1 Hanger rod size shall be the same as that approved for use with the hanger assembly, and the size of rods shall not be less than that given in Table 2-6.4.1.

Exception: Rods of smaller diameter shall be permitted when the hanger assembly has been tested and listed by a testing laboratory and installed within the limits of pipe sizes expressed in individual listings. For rolled threads, the rod size shall not be less than the root diameter of the thread.

2-6.4.2 U-Hooks. The size of the rod material of U-hooks shall not be less than that given in Table 2-6.4.2. Drive screws shall be used only in a horizontal position as in the side of a beam in conjunction with U-hangers only.

2-6.4.3 The size of the rod material for eye rods shall not be less than specified in Table 2-6.4.3. When eye rods are fastened to wood structural members, the eye rod shall be backed with a large flat washer bearing directly against the structural member, in addition to the lock washer.

Table 2-6.1.5(b) Available Section Moduli of Common Trapeze Hangers

Pipe	Modulus	Angles					Modulus
Schedule 10							
1 in.	.12	1½	×	1½	×	3/16	.10
1¼ in.	.19	2	×	2	×	1/8	.13
1½ in.	.26	2	×	1½	×	3/16	.18
2 in.	.42	2	×	2	×	3/16	.19
2½ in.	.69	2	×	2	×	1/4	.25
3 in.	1.04	2½	×	1½	×	3/16	.28
3½ in.	1.38	2½	×	2	×	3/16	.29
4 in.	1.76	2	×	2	×	5/16	.30
5 in.	3.03	2½	×	2½	×	3/16	.30
6 in.	4.35	2	×	2	×	3/8	.35
		2½	×	2½	×	1/4	.39
		3	×	2	×	3/16	.41
Schedule 40		3	×	2½	×	3/16	.43
1 in.	.13	3	×	3	×	3/16	.44
1¼ in.	.23	2½	×	2½	×	5/16	.48
1½ in.	.33	3	×	2	×	1/4	.54
2 in.	.56	2½	×	2	×	3/8	.55
2½ in.	1.06	2½	×	2½	×	3/8	.57
3 in.	1.72	3	×	3	×	1/4	.58
3½ in.	2.39	3	×	3	×	5/16	.71
4 in.	3.21	2½	×	2½	×	1/2	.72
5 in.	5.45	3½	×	2½	×	1/4	.75
6 in.	8.50	3	×	2½	×	3/8	.81
		3	×	3	×	3/8	.83
		3½	×	2½	×	5/16	.93
		3	×	3	×	7/16	.95
		4	×	4	×	1/4	1.05
		3	×	3	×	1/2	1.07
		4	×	3	×	5/16	1.23
		4	×	4	×	5/16	1.29
		4	×	3	×	3/8	1.46
		4	×	4	×	3/8	1.52
		5	×	3½	×	5/16	1.94
		4	×	4	×	1/2	1.97
		4	×	4	×	5/8	2.40
		4	×	4	×	3/4	2.81
		6	×	4	×	3/8	3.32
		6	×	4	×	1/2	4.33
		6	×	4	×	3/4	6.25
		6	×	6	×	1	8.57

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

2-6.4.3.1 Eye rods shall be secured with lock washers to prevent lateral motion.

2-6.4.4 Threaded sections of rods shall not be formed or bent.

2-6.4.5 Screws. For ceiling flanges and U-hooks, screw dimensions shall not be less than those given in Table 2-6.4.5.

Exception: When the thickness of planking and thickness of flange do not permit the use of screws 2 in. (51 mm) long, screws 1¾ in. (44 mm) long shall be permitted with hangers spaced not over 10 ft (3 m) apart. When the thickness of beams or joists does not permit the use of screws 2½ in. (64 mm) long, screws 2 in. (51 mm) long shall be permitted with hangers spaced not over 10 ft (3 m) apart.

Table 2-6.4.1 Hanger Rod Sizes

Pipe Size	Diam. of Rod in.	Diam. of Rod mm	Pipe Size	Diam. of Rod in.	Diam. of Rod mm
Up to and including 4 in.	3/8	9.5	5, 6, and 8 in.	1/2	12.7
			10 and 12 in.	5/8	15.9

For SI Units: 1 in. = 25.4 mm.

Table 2-6.4.2 U-Hook Rod Sizes

Pipe Size	Hook Material Diameter in.	Hook Material Diameter mm
Up to 2 in.	5/16	7.9
2½ in. to 6 in.	3/8	9.5
8 in.	1/2	12.7

For SI Units: 1 in. = 25.4 mm.

Table 2-6.4.3 Eye Rod Sizes

Pipe Size	Diameter of Rod With Bent Eye in.	With Bent Eye mm	With Welded Eye in.	With Welded Eye mm
Up to 4 in.	3/8	9.5	3/8	9.5
5-6 in.	1/2	12.7	1/2	12.7
8 in.	3/4	19.1	1/2	12.7

For SI Units: 1 in. = 25.4 mm.

Table 2-6.4.5 Screw Dimensions for Ceiling Flanges and U-Hooks

Pipe Size	2 Screw Flanges
Up to 2 in.	Wood Screw No. 18 × 1½ in.
Pipe Size	**3 Screw Flanges**
Up to 2 in.	Wood Screw No. 18 × 1½ in.
2½ in., 3 in., 3½ in.	Lag Screw 3/8 in. × 2 in.
4 in., 5 in., 6 in.	Lag Screw 1/2 in. × 2 in.
8 in.	Lag Screw 5/8 in. × 2 in.
Pipe Size	**4 Screw Flanges**
Up to 2 in.	Wood Screw No. 18 × 1½ in.
2½ in., 3 in., 3½ in.	Lag Screw 3/8 in. × 1½ in.
4 in., 5 in., 6 in.	Lag Screw 1/2 in. × 2 in.
8 in.	Lag Screw 5/8 in. × 2 in.
Pipe Size	**U-Hooks**
Up to 2 in.	Drive Screw No. 16 × 2 in.
2½ in., 3 in., 3½ in.	Lag Screw 3/8 in. × 2½ in.
4 in., 5 in., 6 in.	Lag Screw 1/2 in. × 3 in.
8 in.	Lag Screw 5/8 in. × 3 in.

For SI Units: 1 in. = 25.4 mm.

2-6.4.6 The size bolt or lag (coach) screw used with an eye rod or flange on the side of the beam shall not be less than specified in Table 2-6.4.6.

Exception: When the thickness of beams or joists does not permit the use of screws 2 1/2 in. (64 mm) long, screws 2 in. (51 mm) long shall be permitted with hangers spaced not over 10 ft (3 m) apart.

Table 2-6.4.6 Minimum Bolt or Lag Screw Sizes

Size of Pipe	Size of Bolt or Lag Screw		Length of Lag Screw Used with Wood Beams	
	in.	mm	in.	mm
Up to and including 2 in.	3/8	9.5	2 1/2	64
2 1/2 to 6 in. (inclusive)	1/2	12.7	3	76
8 in.	5/8	15.9	3	76

2-6.4.7 Wood screws shall be installed with a screwdriver. Nails are not acceptable for fastening hangers.

2-6.4.8 Screws in the side of a timber or joist shall be not less than 2 1/2 in. (64 mm) from the lower edge when supporting branch lines and not less than 3 in. (76 mm) when supporting main lines.

Exception: This requirement shall not apply to 2 in. (51 mm) or thicker nailing strips resting on top of steel beams.

2-6.4.9 The minimum plank thickness and the minimum width of the lower face of beams or joists in which lag screw rods are used shall be as given in Table 2-6.4.9.

Table 2-6.4.9 Minimum Plank Thicknesses and Beam or Joist Widths

Pipe Size	Nominal Plank Thickness		Nominal Width of Beam or Joist Face	
	in.	mm	in.	mm
Up to 2 in.	3	76	2	51
2 1/2 in. to 3 1/2 in.	4	102	2	51
4 in. and 5 in.	4	102	3	76
6 in.	4	102	4	102

2-6.4.10 Lag screw rods shall not be used for support of pipes larger than 6 in. (152 mm). All holes for lag screw rods shall be predrilled 1/8 in. (3.2 mm) less in diameter than the maximum root diameter of the lag screw thread.

2-7 Valves.

2-7.1 Types of Valves to Be Used.

2-7.1.1 All valves controlling connections to water supplies and to supply pipes to sprinklers shall be listed indicating valves. Such valves shall not close in less than 5 seconds when operated at maximum possible speed from the fully open position.

Exception No. 1: A listed underground gate valve equipped with a listed indicator post shall be permitted.

Exception No. 2: A listed water control valve assembly with a reliable position indication connected to a remote supervisory station shall be permitted.

Exception No. 3: A nonindicating valve, such as an underground gate valve with approved roadway box complete with T-wrench, accepted by the authority having jurisdiction, shall be permitted.

2-7.1.2 When water pressures exceed 175 psi (12.1 bars), valves shall be used in accordance with their pressure ratings.

2-7.1.3 Wafer type valves with components that extend beyond the valve body shall be installed in a manner that does not interfere with the operation of any system components.

2-7.2 Drain Valves and Test Valves. Drain valves and test valves shall be approved.

2-7.3 Identification of Valves. All control, drain, and test connection valves shall be provided with permanently marked weather-proof metal or rigid plastic identification signs. The sign shall be secured with corrosion-resistant wire, chain, or other approved means.

2-8 Fire Department Connections.

2-8.1 The fire department connection(s) shall be internal threaded swivel fitting(s) having threads compatible with those of the local fire department.

2-8.2 Connections shall be equipped with listed plugs or caps.

2-9 Waterflow Alarms.

2-9.1 Waterflow alarm apparatus shall be listed for the service and so constructed and installed that any flow of water from a sprinkler system equal to or greater than that from a single automatic sprinkler of the smallest orifice size installed on the system will result in an audible alarm on the premises within 5 minutes after such flow begins.

2-9.2 Waterflow Detecting Devices.

2-9.2.1 Wet Pipe Systems. The alarm apparatus for a wet pipe system shall consist of a listed alarm check valve or other listed waterflow detecting alarm device with the necessary attachments required to give an alarm.

2-9.2.2 Dry Pipe Systems. The alarm apparatus for a dry pipe system shall consist of listed alarm attachments to the dry pipe valve. When a dry pipe valve is located on the system side of an alarm valve, connection of the actuating device of the alarms for the dry pipe valve to the alarms on the wet pipe system is permitted.

2-9.2.3 Preaction and Deluge Systems. The alarm apparatus for deluge and preaction systems shall consist of alarms actuated independently by the detection system and the flow of water.

2-9.2.4* Paddle-type waterflow alarm indicators shall be installed in wet systems only.

2-9.3 Attachments — General.

2-9.3.1* An alarm unit shall include a listed mechanical alarm, horn, or siren or a listed electric gong, bell, speaker, horn, or siren.

2-9.3.2* Outdoor water motor operated or electrically operated bells shall be weatherproofed and guarded.

2-9.4 All piping to water motor operated devices shall be galvanized or brass or other corrosion-resistant material acceptable under this standard and of a size not less than $^3/_4$ in. (19 mm).

2-9.5 Attachments — Electrically Operated.

2-9.5.1* Electrically operated alarm attachments forming part of an auxiliary, central station, local protective, proprietary, or remote station signaling system shall be installed in accordance with the following applicable NFPA standards:

(a) NFPA 71, *Standard for the Installation, Maintenance, and Use of Signaling Systems for Central Station Service,*

(b) NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems.*

Exception: Sprinkler waterflow alarm systems that are not part of a required protective signaling system need not be supervised and shall be installed in accordance with NFPA 70, National Electrical Code,® Article 760.

2-9.5.2 Outdoor electric alarm devices shall be listed for outdoor use.

2-9.6 Drains from alarm devices shall be so arranged that there will be no overflowing at the alarm apparatus, at domestic connections, or elsewhere with the sprinkler drains wide open and under system pressure. (*See 4-5.3.6.1.*)

Chapter 3 System Requirements

3-1 Wet Pipe Systems.

3-1.1 Pressure Gauges. A listed pressure gauge conforming to 4-6.3.2 shall be installed in each system riser. Pressure gauges shall be installed above and below each alarm check valve when such devices are present.

3-1.2 Relief Valves. A gridded wet pipe system shall be provided with a relief valve not less than $^1/_4$ in. (6.4 mm) in size set to operate at pressures not greater than 175 psi (12.1 bars).

Exception No. 1: When the maximum system pressure exceeds 165 psi (11.4 bars), the relief valve shall operate at 10 psi (0.7 bars) in excess of the maximum system pressure.

Exception No. 2: When auxiliary air reservoirs are installed to absorb pressure increases, a relief valve shall not be required.

3-1.3 Auxiliary Systems. A wet pipe system shall be permitted to supply an auxiliary dry pipe, preaction, or deluge system, provided the water supply is adequate.

3-2* Dry Pipe Systems.

3-2.1 Pressure Gauges. Listed pressure gauges conforming to 4-6.3.2 shall be connected:

(a) On the water side and air side of the dry pipe valve,

(b) At the air pump supplying the air receiver where one is provided,

(c) At the air receiver where one is provided,

(d) In each independent pipe from air supply to dry pipe system, and

(e) At exhausters and accelerators.

3-2.2 Dry-Pendent Sprinklers. Automatic sprinklers installed in the pendent position shall be of the listed dry-pendent type.

Exception: Pendent sprinklers installed on return bends are permitted when both the sprinklers and the return bends are located in a heated area.

3-2.3* Size of Systems.

3-2.3.1 Volume Limitations. Not more than 750 gal (2839 L) system capacity shall be controlled by one dry pipe valve.

Exception: Piping volume may exceed 750 gal (2839 L) for nongridded systems if the system design is such that water is delivered to the system test connection in not more than 60 seconds, starting at the normal air pressure on the system and at the time of fully opened inspection test connection.

3-2.3.2 Gridded dry pipe systems shall not be installed. (*See 4-5.3.5.3.3.*)

3-2.4 Quick-Opening Devices.

3-2.4.1 Dry pipe valves shall be provided with a listed quick-opening device when system capacity exceeds 500 gal (1893 L).

Exception: A quick-opening device shall not be required if the requirements of 3-2.3.1 Exception can be met without such a device.

3-2.4.2 The quick-opening device shall be located as close as practical to the dry pipe valve. To protect the restriction orifice and other operating parts of the quick-opening device against submergence, the connection to the riser shall be above the point at which water (priming water and back drainage) is expected when the dry pipe valve and quick-opening device are set, except where design features of the particular quick-opening device make these requirements unnecessary.

3-2.4.3 A soft disc globe or angle valve shall be installed in the connection between the dry pipe sprinkler riser and the quick-opening device.

3-2.4.4 A check valve shall be installed between the quick-opening device and the intermediate chamber of the dry pipe valve. If the quick-opening device requires pressure feedback from the intermediate chamber, a valve type that will clearly indicate whether it is opened or closed shall be permitted in place of that check valve. This valve shall be constructed so that it may be locked or sealed in the open position.

3-2.4.5 A listed antiflooding device shall be installed in the connection between the dry pipe sprinkler riser and the quick-opening device.

Exception: Where the quick-opening device has built-in anti-flooding design features.

3-2.5* Location and Protection of Dry Pipe Valve.

3-2.5.1 The dry pipe valve and supply pipe shall be protected against freezing and mechanical injury.

3-2.5.2 Valve rooms shall be lighted and heated. The source of heat shall be of a permanently installed type. Heat tape shall not be used in lieu of heated valve enclosures to protect the dry pipe valve and supply pipe against freezing.

3-2.5.3 The supply for the sprinkler in the dry pipe valve enclosure shall be from the dry side of the system.

3-2.5.4 Protection against accumulation of water above the clapper shall be provided for a low differential dry pipe valve. An automatic high water level signaling device or an automatic drain device is acceptable.

3-2.6 Air Pressure and Supply.

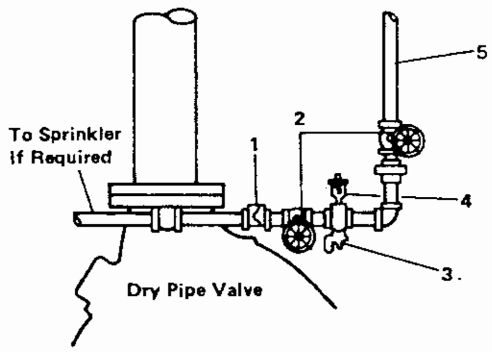
3-2.6.1 Maintenance of Air Pressure. Air or nitrogen pressure shall be maintained on dry pipe systems throughout the year.

3-2.6.2* Air Supply. The compressed air supply shall be from a source available at all times and having a capacity capable of restoring normal air pressure in the system within 30 minutes.

3-2.6.3 Air Filling Connection. The connection pipe from the air compressor shall not be less than 1/2 in. (13 mm) in diameter and shall enter the system above the priming water level of the dry pipe valve. A check valve shall be installed in this air line, and a shutoff valve of the renewable disc type shall be installed on the supply side of this check valve and shall remain closed unless filling the system.

3-2.6.4 Relief Valve. A listed relief valve shall be provided between the compressor and controlling valve, set to relieve at a pressure 5 psi (0.3 bars) in excess of maximum air pressure carried in the system.

3-2.6.5 Shop Air Supply. When the air supply is taken from a shop system having a normal pressure greater than that required for dry pipe systems and an automatic air maintenance device is not used, the relief valve shall be installed between two control valves in the air line, and a small air cock, which is normally left open, shall be installed in the fitting below the relief valve. (*See Figure 3-2.6.5.*)



1. Check Valve
2. Control Valve (Renewable Disc Type)
3. Small Air Cock (Normally Open)
4. Relief Valve
5. Air Supply

Figure 3-2.6.5 Air supply from shop system.

3-2.6.6 Automatic Air Compressor. When a dry pipe system is supplied by an automatic air compressor or plant air system, any device or apparatus used for automatic maintenance of air pressure shall be of a type specifically listed for such service and capable of maintaining the required air pressure on the dry pipe system. Automatic air supply to more than one dry pipe system shall be connected to enable individual maintenance of air pressure in each system. A check valve or other positive backflow prevention device shall be installed in the air supply to each system to prevent air- or waterflow from one system to another.

3-2.6.7 System Air Pressure. The system air pressure shall be maintained in accordance with the instruction sheet furnished with the dry pipe valve, or 20 psi (1.4 bars) in excess of the calculated trip pressure of the dry pipe valve, based on the highest normal water pressure of the system supply. The permitted rate of air leakage shall be as specified in 8-2.3.

3-2.6.8 Nitrogen. When used, nitrogen shall be introduced through a pressure regulator set to maintain system pressure in accordance with 3-2.6.7.

3-3 Preaction Systems and Deluge Systems.

3-3.1* General.

3-3.1.1 All components of pneumatic, hydraulic, or electrical systems shall be compatible.

3-3.1.2 The automatic water control valve shall be provided with manual means for operation that is independent of detection devices and of the sprinklers.

3-3.1.3 Pressure Gauges. Listed pressure gauges conforming to 4-6.3.2 shall be installed as follows:

(a) Above and below preaction valve and below deluge valve.

(b) On air supply to preaction and deluge valves.

3-3.1.4 A supply of spare fusible elements for heat-responsive devices, not less than two of each temperature rating, shall be maintained on the premises for replacement purposes.

3-3.1.5 Hydraulic release systems shall be designed and installed in accordance with manufacturer's requirements and listing for height limitations above deluge valves or deluge valve actuators to prevent water column.

3-3.1.6 Location and Spacing of Detection Devices. Spacing of detection devices, including automatic sprinklers used as detectors, shall be in accordance with their listing and manufacturer's specifications.

3-3.1.7 Devices for Test Purposes and Testing Apparatus.

3-3.1.7.1 When detection devices installed in circuits are located where not readily accessible, an additional detection device shall be provided on each circuit for test purposes at an accessible location and shall be connected to the circuit at a point that will assure a proper test of the circuit.

3-3.1.7.2 Testing apparatus capable of producing the heat or impulse necessary to operate any normal detection device shall be furnished to the owner of the property with each installation. Where explosive vapors or materials are present, hot water, steam, or other methods of testing not involving an ignition source shall be used.

3-3.1.8 Location and Protection of System Water Control Valves.

3-3.1.8.1 System water control valves and supply pipes shall be protected against freezing and mechanical injury.

3-3.1.8.2 Valve rooms shall be lighted and heated. The source of heat shall be of a permanently installed type. Heat tape shall not be used in lieu of heated valve enclosure rooms to protect preaction and deluge valves and supply pipe against freezing.

3-3.2 Preaction Systems.

3-3.2.1 Preaction systems shall operate by one of the means described in (a) through (c) below.

(a) Systems that admit water to sprinkler piping upon operation of detection devices.

(b) Systems that admit water to sprinkler piping upon operation of detection devices or automatic sprinklers.

(c)* Systems that admit water to sprinkler piping upon operation of both detection devices and automatic sprinklers.

3-3.2.2 Size of Systems. Not more than 1000 automatic sprinklers shall be controlled by any one preaction valve.

Exception: For preaction system types described in 3-3.2.1(c), system volume shall not exceed 750 gal (2839 L) controlled by one preaction valve unless the system is designed to deliver water to the system test connection in not more than 60 seconds, starting at the normal air pressure on the system with the detection system operated and at the time of fully opened inspection test connection. Air pressure and supply shall comply with 3-2.6.

3-3.2.3 Supervision. Sprinkler piping and fire detection devices shall be automatically supervised when there are more than 20 sprinklers on the system.

3-3.2.4 Pendent Sprinklers. Automatic sprinklers on preaction systems installed in the pendent position shall be of the listed dry-pendent type.

Exception: Pendent sprinklers installed on return bends are permitted when both the sprinklers and the return bends are located in a heated area.

3-3.3* Deluge Systems.

3-3.3.1 The detection devices or systems shall be automatically supervised.

3-3.3.2 Deluge systems shall be hydraulically calculated.

3-4 Combined Dry Pipe and Preaction Systems.

3-4.1* General.

3-4.1.1* Combined automatic dry pipe and preaction systems shall be so constructed that failure of the detection system shall not prevent the system from functioning as a conventional automatic dry pipe system.

3-4.1.2 Combined automatic dry pipe and preaction systems shall be so constructed that failure of the dry pipe system of automatic sprinklers shall not prevent the detection system from properly functioning as an automatic fire alarm system.

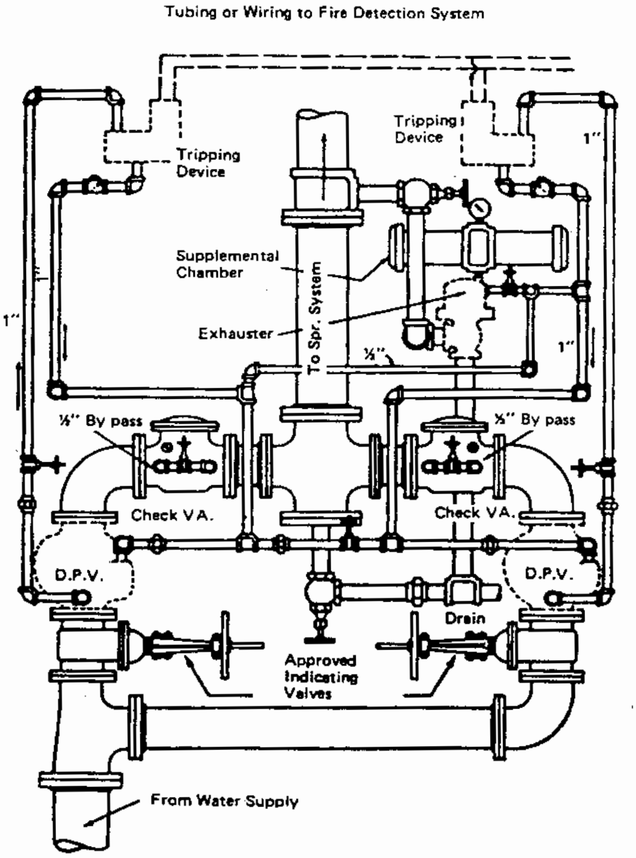
3-4.1.3 Provisions shall be made for the manual operation of the detection system at locations requiring not more than 200 ft (61 m) of travel.

3-4.1.4 Dry-Pendent Sprinklers. Automatic sprinklers installed in the pendent position shall be of the listed dry-pendent type.

Exception: Pendent sprinklers installed on return bends are permitted when both the sprinklers and the return bends are located in a heated area.

3-4.2 Dry Pipe Valves in Combined Systems.

3-4.2.1 Where the system consists of more than 600 sprinklers or has more than 275 sprinklers in any fire area, he entire system shall be controlled through two 6-in. (152-mm) dry pipe valves connected in parallel and shall feed into a common feed main. These valves shall be checked against each other. (*See Figure 3-4.2.*)



For SI Units: 1 in. = 25.4 mm.

Figure 3-4.2 Header for dry pipe valves installed in parallel for combined systems, standard trimmings not shown.

3-4.2.2 Each dry pipe valve shall be provided with a listed tripping device actuated by the detection system. Dry pipe valves shall be cross-connected through a 1-in. (25.4-mm) pipe connection to permit simultaneous tripping of both dry pipe valves. This 1-in. (25.4-mm) pipe connection shall be equipped with an indicating valve so that either dry pipe valve can be shut off and worked on while the other remains in service.

3-4.2.3 The check valves between the dry pipe valves and the common feed main shall be equipped with $^1/_2$-in. (13-mm) bypasses so that a loss of air from leakage in the trimmings of a dry pipe valve will not cause the valve to rip until the pressure in the feed main is reduced to the tripping point. An indicating valve shall be installed in each of these bypasses so that either dry pipe valve can be completely isolated from the main riser or feed main and from the other dry pipe valve.

3-4.2.4 Each combined dry pipe and preaction system shall be provided with listed quick-opening devices at the dry pipe valves.

3-4.3* Air Exhaust Valves. One or more listed air exhaust valves of 2-in. (51-mm) or larger size controlled by operation of a fire detection system shall be installed at the end of the common feed main. These air exhaust valves shall have soft-seated globe or angle valves in their intakes; also, approved strainers shall be installed between these globe valves and the air exhaust valves.

3-4.4 Subdivision of System Using Check Valves.

3-4.4.1 Where more than 275 sprinklers are required in a single fire area, the system shall be divided into sections of 275 sprinklers or less by means of check valves. If the system is installed in more than one fire area or story, not more than 600 sprinklers shall be supplied through any one check valve. Each section shall have a $1^1/_4$-in. (33-mm) drain on the system side of each check valve supplemented by a dry pipe system auxiliary drain.

3-4.4.2 Section drain lines and dry pipe system auxiliary drains shall be located in heated areas or inside of heated cabinets to enclose drain valves and auxiliary drains for each section.

3-4.4.3 Air exhaust valves at the end of a feed main and associated check valves shall be protected against freezing.

3-4.5 Time Limitation. The sprinkler system shall be so constructed and the number of sprinklers controlled shall be so limited that water shall reach the farthest sprinkler within a period of time not exceeding 1 minute for each 400 ft (122 m) of common feed main from the time the heat-responsive system operates. Maximum time permitted shall not exceed 3 minutes.

3-4.6 System Test Connection. The end section shall have a system test connection as required for dry pipe systems.

3-5 Antifreeze Systems.

3-5.1* Where Used. The use of antifreeze solutions shall be in conformity with state and local health regulations.

3-5.2* Antifreeze Solutions.

3-5.2.1 When sprinkler systems are supplied by potable water connections, the use of antifreeze solutions other than water solutions of pure glycerine (C.P. or U.S.P. 96.5 percent grade) or propylene glycol shall not be permitted. Suitable glycerine-water and propylene glycol-water mixtures are shown in Table 3-5.2.1.

Table 3-5.2.1 Antifreeze Solutions to Be Used if Potable Water Is Connected to Sprinklers

Material	Solution (by Volume)	Specific Gravity at 60°F (15.6°C)	Freezing Point °F	°C
Glycerine	50% Water	1.133	−15	−26.1
C.P. or U.S.P. Grade*	40% Water	1.151	−22	−30.0
	30% Water	1.165	−40	−40.0
Hydrometer Scale 1.000 to 1.200				
Propylene Glycol	70% Water	1.027	+ 9	−12.8
	60% Water	1.034	− 6	−21.1
	50% Water	1.041	−26	−32.2
	40% Water	1.045	−60	−51.1
Hydrometer Scale 1.000 to 1.200 (Subdivisions 0.002)				

*C.P.—Chemically Pure. U.S.P.—United States Pharmacopoeia 96.5%.

3-5.2.2 If potable water is not connected to sprinklers, the commercially available materials indicated in Table 3-5.2.2 (*see page 25*) are permitted for use in antifreeze solutions.

3-5.2.3* An antifreeze solution shall be prepared with a freezing point below the expected minimum temperature for the locality. The specific gravity of the prepared solution shall be checked by a hydrometer with suitable scale or refractometer having a scale calibrated for the antifreeze solution involved. [*See Figures 3-5.2.3(a) and (b).*]

3-5.3* **Arrangement of Supply Piping and Valves.** Sprinklers shall be below the interface between the water and antifreeze solutions.

Exception: Sprinklers are permitted to be above the water/antifreeze interface when a check valve with a 1/32-in. (0.8-mm) hole in the clapper is provided in a U-loop. In most cases, this necessitates the use of a 5-ft (1.5-m) drop pipe or U-loop as illustrated in Figure 3-5.3.

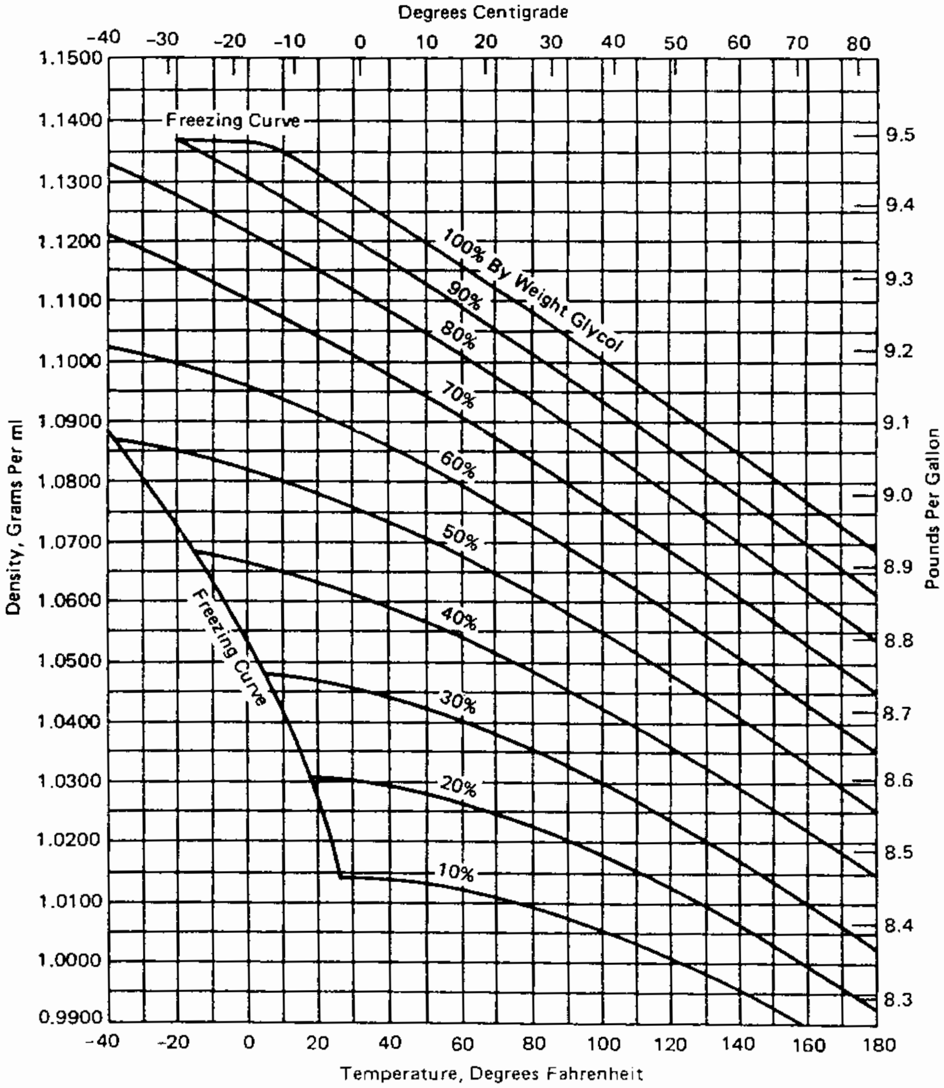


Figure 3-5.2.3(a) Densities of aqueous ethylene glycol solutions (percent by weight).

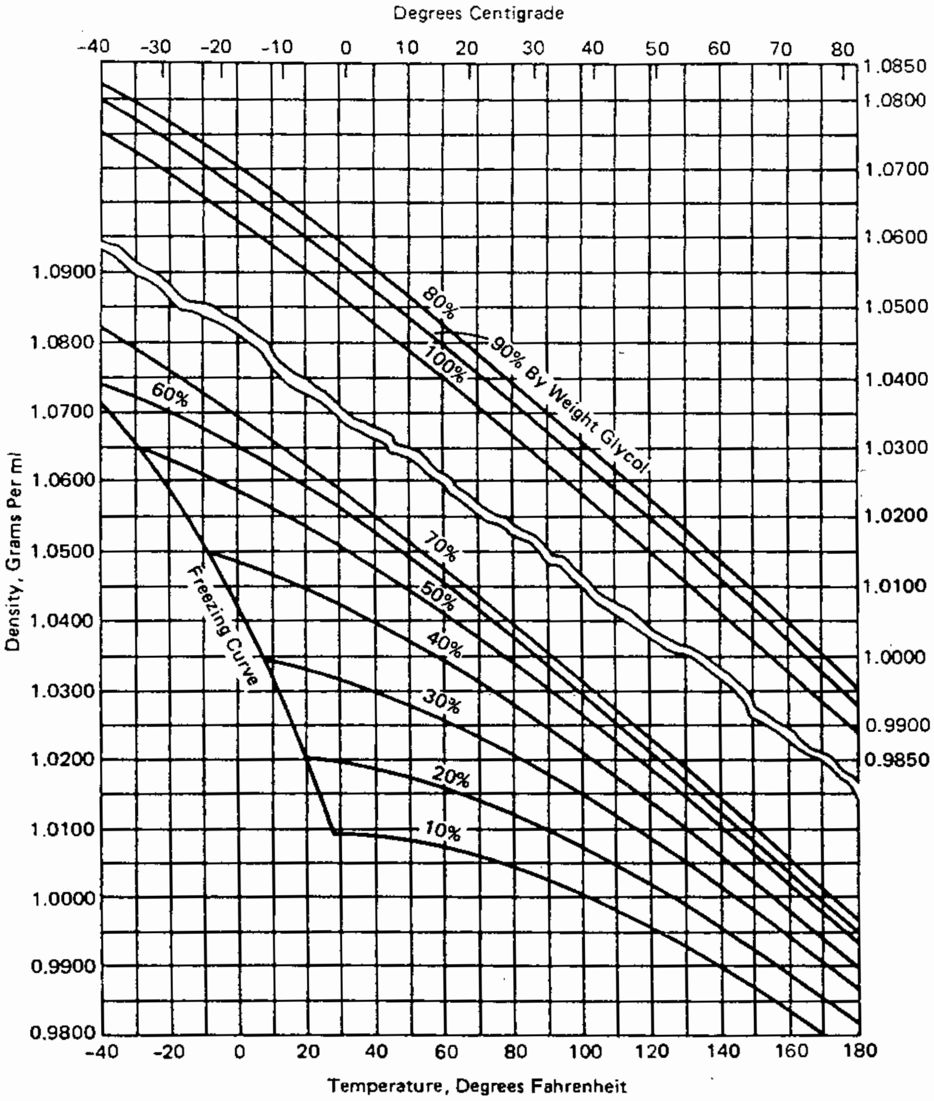


Figure 3-5.2.3(b) Densities of aqueous propylene glycol solutions (percent by weight).

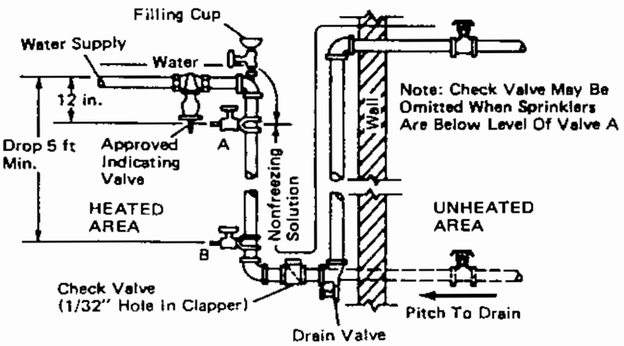
Table 3-5.2.2 Antifreeze Solution to Be Used if Nonpotable Water Is Connected to Sprinklers

Material	Solution (by Volume)	Specific Gravity at 60°F (15.6°C)	Freezing Point °F	Freezing Point °C
Glycerine	If glycerine is used, see Table 3-5.2.1			
Diethylene Glycol	50% Water	1.078	−13	−25.0
	45% Water	1.081	−27	−32.8
	40% Water	1.086	−42	−41.1
Hydrometer Scale 1.000 to 1.120 (Subdivisions 0.002)				
Ethylene Glycol	61% Water	1.056	−10	−23.3
	56% Water	1.063	−20	−28.9
	51% Water	1.069	−30	−34.4
	47% Water	1.073	−40	−40.0
Hydrometer Scale 1.000 to 1.120 (Subdivisions 0.002)				
Propylene Glycol	If propylene glycol is used, see Table 3-5.2.1			
Calcium Chloride 80% "Flake"	lb $CaCl_2$ per gal of Water			
Fire Protection Grade†	2.83	1.183	0	−17.8
Add corrosion inhibitor	3.38	1.212	−10	−23.3
of sodium bichromate	3.89	1.237	−20	−28.9
1/4 oz per gal water	4.37	1.258	−30	−34.4
	4.73	1.274	−40	−40.0
	4.93	1.283	−50	−45.6

† Free from magnesium chloride and other impurities.

3-5.3.1 A water control valve and two small solution test valves shall be provided as illustrated in Figure 3-5.3.

Exception: When the connection between the antifreeze system and the wet pipe system incorporates a backflow prevention device, an expansion chamber shall be provided to compensate for the expansion of the antifreeze solution.



NOTE: The 1/32-in. (0.8-mm) hole in the check valve clapper is needed to allow for expansion of the solution during a temperature rise and thus prevent damage to sprinklers.

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure 3-5.3 Arrangement of supply piping and valves.

3-6 Automatic Sprinkler Systems with Nonfire Protection Connections.

3-6.1 Circulating Closed-Loop Systems.

3-6.1.1 System Components.

3-6.1.1.1 A circulating closed-loop system is primarily a sprinkler system and shall comply with all provisions of this standard such as those for control valves, area limitations of a system, alarms, fire department connections, sprinkler spacing, etc.

Exception: Items as specifically detailed within 3-6.1.

3-6.1.1.2 Piping, fittings, valves, and pipe hangers shall meet requirements specified in Chapter 2.

3-6.1.1.3 A dielectric fitting shall be installed in the junction where dissimilar piping materials are joined, e.g., copper to steel.

Exception: Dielectric fittings are not required in the junction where sprinklers are connected to piping.

3-6.1.1.4 It is not required that other auxiliary devices be listed for sprinkler service; however, these devices, such as pumps, circulating pumps, heat exchangers, radiators, and luminaries, shall be pressure rated at 175 or 300 psi (12.1 or 20.7 bars) (rupture pressure of 5 times rated water working pressure) to match the required rating of sprinkler system components.

3-6.1.1.5 Auxiliary devices shall incorporate materials of construction and be so constructed that they will maintain their physical integrity under fire conditions to avoid impairment to the fire protection system.

3-6.1.1.6 Auxiliary devices, where hung from the building structure, shall be supported independently from the sprinkler portion of the system, following recognized engineering practices.

3-6.1.2* Hydraulic Characteristics. Piping systems for attached heating and cooling equipment shall have auxiliary pumps or an arrangement made to return water to the piping system in order to assure the following:

(a) Water for sprinklers shall not be required to pass through heating or cooling equipment. At least one direct path shall exist for waterflow from the sprinkler water supply to every sprinkler. Pipe sizing in the direct path shall be in accordance with design requirements of this standard.

(b) No portions of the sprinkler piping shall have less than the sprinkler system design pressure regardless of the mode of operation of the attached heating or cooling equipment.

(c) There shall be no loss or outflow of water from the system due to or resulting from the operation of heating or cooling equipment.

(d) Shutoff valves and a means of drainage shall be provided on piping to heating or cooling equipment at all points of connection to sprinkler piping and shall be installed in such a manner as to make possible repair or removal of any auxiliary component without impairing the serviceability and response to the sprinkler system. All auxiliary components, including the strainer, shall be installed on the auxiliary equipment side of the shutoff valves.

3-6.1.3 Water Temperature.

3-6.1.3.1 Maximum. In no case shall maximum water temperature flowing through the sprinkler portion of the system exceed 120°F (49°C). Protective control devices listed for this purpose shall be installed to shut down heating or cooling systems when temperature of water flowing through the sprinkler portion of the system exceeds 120°F (49°C). When water temperature exceeds 100°F (37.8°C), intermediate or higher temperature rated sprinklers shall be used.

3-6.1.3.2 Minimum. Precautions shall be taken to ensure that temperatures below 40°F (4°C) are not permitted.

3-6.1.4 Obstruction to Discharge. Automatic sprinklers shall not be obstructed by auxiliary devices, piping, insulation, etc., from detecting fire or from proper distribution of water.

3-6.1.5 Signs. Caution signs shall be attached to all valves controlling sprinklers. The caution sign shall be worded as follows:

"This valve controls fire protection equipment. Do not close until after fire has been extinguished. Use auxiliary valves when necessary to shut off supply to auxiliary equipment.

CAUTION: Automatic alarm will be sounded if this valve is closed."

3-6.1.6 Water Additives. Materials added to water shall not adversely affect the fire fighting properties of the water and shall be in conformity with any state or local health regulations. Due care and caution shall be given to the use of additives that may remove or suspend scale from older piping systems. When additives are necessary for proper system operation, due care shall be taken to ensure that additives are replenished after alarm testing or whenever water is removed from the system.

3-6.1.7 Waterflow Detection. The supply of water from sprinkler piping through auxiliary devices, circulatory piping, and pumps shall not under any condition or operation, transient or static, cause false sprinkler waterflow signals.

3-6.1.7.1 A sprinkler waterflow signal shall not be impaired when water is discharged through an opened sprinkler or through the system test connection while auxiliary equipment is in any mode of operation (on, off, transient, stable).

3-7 Outside Sprinklers for Protection against Exposure Fires.

3-7.1 Applications. Exposure protection systems shall be permitted on buildings regardless of whether the building's interior is protected by a sprinkler system.

3-7.2 Water Supply and Control.

3-7.2.1* Sprinklers installed for protection against exposure fires shall be supplied from a standard water supply as outlined in Chapter 7.

Exception: When approved, other supplies, such as manual valves or pumps or fire department connections, shall be acceptable.

3-7.2.2 When fire department connections are used for water supply, they shall be so located that they will not be affected by the exposing fire.

3-7.3 Control.

3-7.3.1 Each system of outside sprinklers shall have an independent control valve.

3-7.3.2 Manually controlled open sprinklers shall be used only where constant supervision is present.

3-7.3.3 Sprinklers may be of the open or automatic type. Automatic sprinklers in areas subject to freezing shall be on dry pipe systems conforming to Section 3-2 or antifreeze systems conforming to Section 3-5.

3-7.3.4 Automatic systems of open sprinklers shall be controlled by the operation of fire detection devices designed for the specific application.

3-7.4 System Components.

3-7.4.1 Drain Valves. Each system of outside sprinklers shall have a separate drain valve installed on the system side of each control valve.

Exception: Open sprinkler-top fed systems arranged to facilitate drainage.

3-7.4.2 Check Valves. When sprinklers are installed on two adjacent sides of a building, protecting against two separate and distinct exposures, with separate control valves for each side, the end lines shall be connected with check valves located so that one sprinkler around the corner will operate. The intermediate pipe between the two check valves shall be arranged to drain. As an alternate solution, an additional sprinkler shall be installed on each system located around the corner from the system involved.

3-7.4.3 System Arrangement. When one exposure affects two sides of the protected structure, the system shall not be subdivided between the two sides, but rather shall be arranged to operate as a single system.

3-7.5 Pipe and Fittings. Pipe and fittings installed on the exterior of the building shall be corrosion resistant.

3-7.6 Strainers. A listed strainer shall be provided in the riser or feed main that supplies sprinklers having orifices smaller than $^3/_8$ in. (9.5 mm).

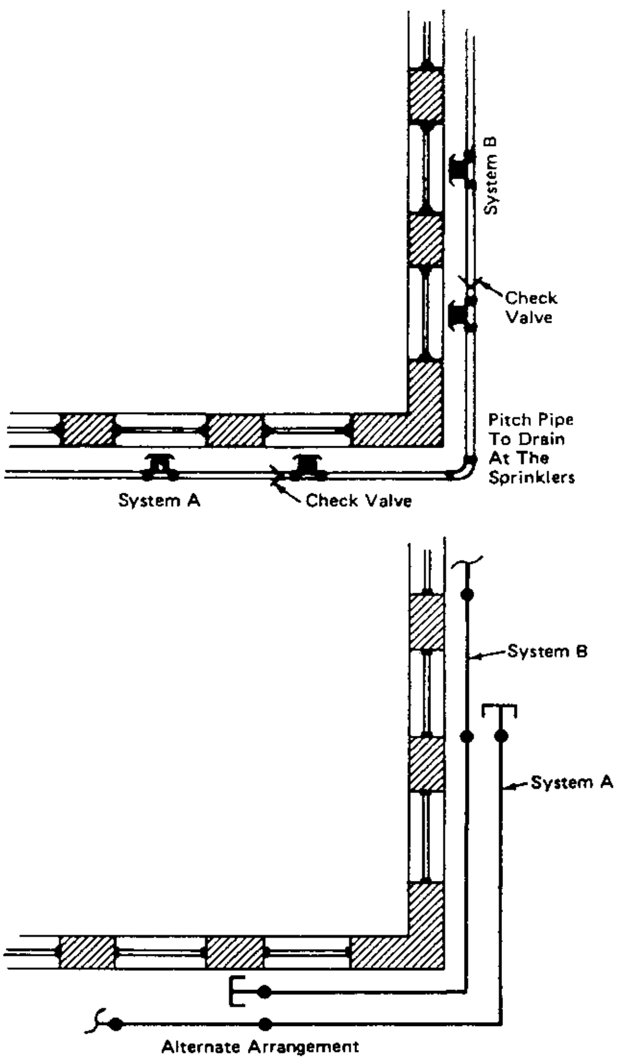


Figure 3-7.4.2 Arrangement of check valves.

3-7.7 Gauge Connections. A listed pressure gauge conforming to 4-6.3.2 shall be installed immediately below the control valve of each system.

3-7.8 Sprinklers. Only sprinklers of such type as are listed for window, cornice, sidewall, or ridge pole service shall be installed for such use except where adequate coverage by use of other types of listed sprinklers and/or nozzles has been demonstrated. Small orifice or large orifice sprinklers shall be permitted.

3-8* Cold Storage Rooms.

3-8.1* Fittings for visual internal inspection of piping in cold storage rooms shall be provided whenever the following occurs:

(a)* A cross main connects to a riser or feed main,

(b)* Feed mains change direction,

(c)* A riser or feed main passes through a wall or floor from a warm room to a cold room.

3-8.2 A local low air-pressure alarm shall be installed on sprinkler systems supplying freezer sections.

3-8.3 Piping in cold storage rooms shall be installed with pitch, as outlined in 4-5.3.3.

3-8.4* The air supply for systems shall be taken from the room of lowest temperature, or through a chemical dehydrator, to eliminate introducing moisture. Compressed nitrogen gas from cylinders shall be acceptable in lieu of air.

3-9 Commercial-Type Cooking Equipment and Ventilation.

3-9.1 In cooking areas protected by automatic sprinklers, additional sprinklers or automatic spray nozzles shall be provided to protect commercial-type cooking equipment and ventilation systems that are designed to carry away grease-laden vapors unless otherwise protected. (*See NFPA 96, Standard for the Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment.*)

3-9.2* Standard sprinklers or automatic spray nozzles shall be so located as to provide for the protection of exhaust ducts, hood exhaust duct collars, and hood exhaust plenum chambers.

Exception: Sprinklers or automatic spray nozzles in ducts, duct collars, and plenum chambers may be omitted when all cooking equipment is served by listed grease extractors.

3-9.3 Exhaust ducts shall have one sprinkler or automatic spray nozzle located at the top of each vertical riser and at the midpoint of each offset. The first sprinkler or automatic spray nozzle in a horizontal duct shall be installed at the duct entrance. Horizontal exhaust ducts shall have such devices located on 10-ft (3-m) centers beginning no more than 5 ft (1.5 m) from the duct entrance. Sprinkler(s) or automatic spray nozzle(s) in exhaust ducts subject to freezing shall be properly protected against freezing by approved means. (*See 4-5.4.1.*)

Exception: Sprinklers or automatic spray nozzles may be omitted from a vertical riser located outside of a building provided the riser does not expose combustible material or provided the interior of a building and the horizontal distance between the hood outlet and the vertical riser is at least 25 ft (7.6 m).

3-9.4 Each hood exhaust duct collar shall have one sprinkler or automatic spray nozzle located 1 in. minimum to 12 in. maximum (25.4 mm min. to 305 mm max.) above the point of duct collar connection in the hood plenum. Hoods that have listed fire dampers located in the duct collar shall be protected with a sprinkler or automatic spray nozzle located on the discharge side of the damper and be so positioned as not to interfere with damper operation.

3-9.5 Hood exhaust plenum chambers shall have one sprinkler or automatic spray nozzle centered in each chamber not exceeding 10 ft (3 m) in length. Plenum chambers eater than 10 ft (3 m) in length shall have two sprinklers automatic spray nozzles evenly spaced with the maximum distance between the two sprinklers not to exceed 10 ft (3 m).

3-9.6 Sprinklers or automatic spray nozzles being used in duct, duct collar, and plenum areas shall be of the extra gh temperature classification [325 to 375°F (163 to 91°C)] and have orifice sizes not less than 1/4 in. (6.4 mm) and not more than 1/2 in. (13 mm).

Exception: When use of a temperature measuring device indicates temperatures above 300°F (149°C), a sprinkler or automatic spray nozzle of higher classification shall be used.

3-9.7 Access must be provided to all sprinklers or automatic spray nozzles for examination and replacement.

3-9.8 Cooking Equipment.

3-9.8.1 Cooking equipment (such as deep fat fryers, ranges, griddles, and broilers) that may be a source of ignition shall be protected in accordance with the provisions of 3-9.1.

3-9.8.2 A sprinkler or automatic spray nozzle used for protection of deep fat fryers shall be listed for that application. The position, arrangement, location, and water pply for each sprinkler or automatic spray nozzle shall e in accordance with its listing.

3-9.8.3 The operation of any cooking equipment sprinkler or automatic spray nozzle shall automatically shut off all sources of fuel and heat to all equipment requiring protection. Any gas appliance not requiring protection but located under ventilating equipment shall also be shut off. All shutdown devices shall be of the type that requires manual resetting prior to fuel or power being restored.

3-9.9 A listed indicating valve shall be installed in the water supply line to the sprinklers and spray nozzles protecting the cooking and ventilating system.

3-9.10 An approved line strainer shall be installed in the main water supply preceding sprinklers or automatic spray nozzles having orifices smaller than 3/8 in. (9.5 mm).

3-9.11 A system test connection shall be provided to verify proper operation of equipment specified in 3-9.8.3.

3-9.12 Sprinklers and automatic spray nozzles used for protecting commercial-type cooking equipment and ventilating systems shall be replaced annually.

Exception: When automatic bulb-type sprinklers or spray nozzles are used and annual examination shows no build-up of grease or other material on the sprinklers or spray nozzles.

Chapter 4 Installation Requirements

4-1* Basic Requirements.

4-1.1* The requirements for spacing, location, and position of sprinklers are based on the following principles:

(a) Sprinklers installed throughout the premises,

(b) Sprinklers located so as not to exceed maximum protection area per sprinkler,

(c) Sprinklers positioned and located so as to provide satisfactory performance with respect to activation time and distribution.

Exception No. 1: For locations permitting omission of sprinklers see 4-4.1.7.1, 4-4.1.7.2, 4-4.1.7.7.

Exception No. 2: When sprinklers are specifically tested and test results demonstrate that deviations from clearance requirements to structural members do not impair the ability of the sprinkler to control or suppress a fire, their positioning and locating in accordance with the test results shall be permitted.

Exception No. 3: Clearance between sprinklers and ceilings exceeding the maximum specified in 4-4.1.4 shall be permitted provided that tests or calculations demonstrate comparable sensitivity and performance of the sprinklers to those installed in conformance with 4-4.1.4.

4-2 Protection Area Limitations.

4-2.1 Systems. The maximum floor area on any one floor to be protected by sprinklers supplied by any one sprinkler system riser or combined system riser shall be as follows:

Light Hazard	52,000 sq ft (4831 m²)
Ordinary Hazard	52,000 sq ft (4831 m²)
Extra Hazard	
Pipe Schedule	25,000 sq ft (2323 m²)
Hydraulically Calculated	40,000 sq ft (3716 m²)
Storage — High-piled storage (as defined in 1-4.2) and storage covered by other NFPA standards	40,000 sq ft (3716 m²)

Exception No. 1: The floor area occupied by mezzanines shall not be included in the above area.

Exception No. 2: When single systems protect extra hazard, high-piled storage, or storage covered by other NFPA standards and ordinary or light hazard areas, the extra hazard or storage area coverage shall not exceed the floor area specified for that hazard and the total area coverage shall not exceed 52,000 sq ft (4831 m²).

4-2.2* Sprinklers. The maximum protection area per sprinkler shall comply with Table 4-2.2.

4-2.2.1 The protection area per sprinkler shall be determined as follows:

4-2.2.1.1 Along Branch Lines. Determine distance to next sprinkler (or to wall or obstruction in case of end sprinkler on branch line) upstream and downstream. Choose the larger of either twice the distance to the wall or the distance to the next sprinkler. Call this *S*.

Table 4-2.2 Maximum Sprinkler Protection Areas (sq ft)[8]

	Light Hazard	Ordinary Hazard	Extra Hazard[5]	High-Piled Storage[6]	Large-Drop Sprinklers[7]	Early Suppression Fast Response Sprinklers[7]
Unobstructed Construction[1]	225[2]	130	100	100	130	100
Noncombustible Obstructed Construction	225[2]	130	100	100	130	100
Combustible Obstructed Construction	168[3,4]	130	100	100	100	N/A

Note 1: Wood truss construction as defined in A-1-4.6(b)(v) is classified as obstructed construction for the purpose of determining sprinkler protection areas.
Note 2: For Light Hazard Occupancies, the protection area per sprinkler for pipe schedule systems shall not exceed 200 sq ft per sprinkler.
Note 3: For light combustible framing members spaced less than 3 ft on center, maximum spacing is 130 sq ft [for examples, see A-1-4.6(a)(ii), A-1-4.6(a)(v) and A-1-4.6(b)(v)].
Note 4: For heavy combustible framing members spaced 3 ft or more on center, maximum spacing is 225 sq ft [for examples, see A-1-4.6(a)(i)].
Note 5: For Extra Hazard Occupancies:
1) The protection area per sprinkler for pipe schedule systems shall not exceed 90 sq ft.
2) The protection area per sprinkler for hydraulically designed systems with densities below 0.25 gpm/ft^2 may exceed 100 sq ft, but shall not exceed 130 sq ft.
Note 6: For high-piled storage occupancies:
1) The protection area per sprinkler may exceed 100 sq ft but shall not exceed 130 sq ft for systems hydraulically designed in accordance with NFPA 231 and 231C for densities below 0.25 gpm/sq ft.
2) Where protection areas are specifically indicated in the design criteria of other portions of this standard or other NFPA standards, those protection areas shall be used.
3) For protection involving large-drop sprinklers use the large-drop sprinkler column in the table.
Note 7: For large-drop and ESFR sprinklers, the minimum spacing is 80 sq ft per sprinkler.
Note 8: For special sprinkler protection areas see 4-3.2.
N/A Denotes data not available in current standard.
For SI Units: 1 sq ft = 0.0929 m^2; 1 ft = 0.3048 m; 1 gpm/ft^2 = 40.746 L/min/m^2.

4-2.2.1.2 Between Branch Lines. Determine perpendicular distance to sprinkler on branch lines (or to wall or obstruction in the case of the last branch line) on each side of the branch line on which the subject sprinkler is positioned. Choose the larger of either twice the distance to the wall or obstruction or the distance to the next sprinkler. Call this *L*.

4-2.2.1.3 Protection area of the sprinkler = S × L.

Exception: In a small room as defined in 1-4.2, the protection area of each sprinkler in the small room shall be the area of the room divided by the number of sprinklers in the room.

4-3 Use of Sprinklers.

4-3.1 General.

4-3.1.1* Sprinklers shall be installed in accordance with their listing.

Exception: When construction features or other special situations require unusual water distribution, listed sprinklers shall be permitted to be installed in positions other than anticipated by their listing to achieve specific results.

4-3.1.2* Upright sprinklers shall be installed with the frame arms parallel to the branch line.

4-3.1.3 Temperature Ratings.

4-3.1.3.1 Ordinary-temperature rated sprinklers shall be used throughout buildings.

Exception No. 1: Where maximum ceiling temperatures exceed 100°F (38°C), sprinklers with temperature ratings in accordance with the maximum ceiling temperatures of Table 2-2.3.1 shall be used.

Exception No. 2: Intermediate- and high-temperature sprinklers shall be permitted to be used throughout Ordinary and Extra Hazard Occupancies.

Exception No. 3: Sprinklers of intermediate and high temperature classifications shall be installed in specific locations as required by 4-3.1.3.2.

4-3.1.3.2 The following practices shall be observed to provide sprinklers of other than ordinary temperature classification unless other temperatures are determined or unless high-temperature sprinklers are used throughout [*see Tables 4-3.1.3.2(a) and (b) and Figure 4-3.1.3.2 on the following pages*].

(a) Sprinklers in the heater zone shall be of the high temperature classification, and sprinklers in the danger zone of the intermediate temperature classification.

(b) Sprinklers located within 12 in. (305 mm) to one side or 30 in. (762 mm) above an uncovered steam main, heating coil, or radiator shall be of the intermediate temperature classification.

(c) Sprinklers within 7 ft (2.1 m) of a low-pressure blow-off valve that discharges free in a large room shall be of the high temperature classification.

(d) Sprinklers under glass or plastic skylights exposed to the direct rays of the sun shall be of the intermediate temperature classification.

(e) Sprinklers in an unventilated, concealed space, under an uninsulated roof, or in an unventilated attic shall be of the intermediate temperature classification.

(f) Sprinklers in unventilated show windows having high powered electric lights near the ceiling shall be of the intermediate temperature classification.

(g) Sprinklers protecting commercial-type cooking equipment and ventilation systems shall be of the high or

Table 4-3.1.3.2(a) Temperature Ratings of Sprinklers Based on Distance from Heat Sources

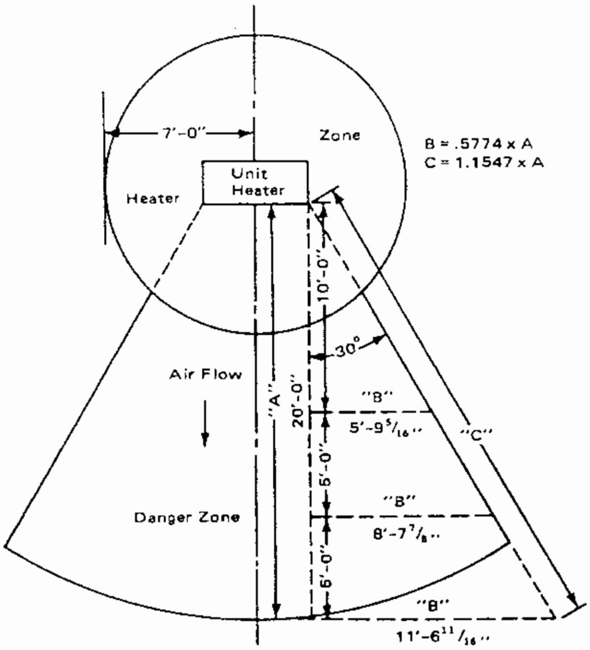
Type of Heat Condition	Ordinary Degree Rating	Intermediate Degree Rating	High Degree Rating
1. Heating Ducts (a) Above	More than 2 ft 6 in.	2 ft 6 in. or less	—
(b) Side and Below	More than 1 ft 0 in.	1 ft 0 in. or less	—
(c) Diffuser Downward Discharge Horizontal Discharge	Any distance except as shown under Intermediate	*Downward:* Cylinder with 1 ft 0 in. radius from edge, extending 1 ft 0 in. below and 2 ft 6 in. above *Horizontal:* Semi-cylinder with 2 ft 6 in. radius in direction of flow, extending 1 ft 0 in. below and 2 ft 6 in. above	—
2. Unit Heater (a) Horizontal Discharge	—	*Discharge Side:* 7 ft 0 in. to 20 ft 0 in. radius pie-shaped cylinder [see Figure 4-3.1.3.2] extending 7 ft 0 in. above and 2 ft 0 in. below heater; also 7 ft 0 in. radius cylinder more than 7 ft 0 in. above unit heater	7 ft 0 in. radius cylinder extending 7 ft 0 in. above and 2 ft 0 in. below unit heater
(b) Vertical Downward Discharge [Note: For sprinklers below unit heater, see Figure 4-3.1.3.2.]	—	7 ft 0 in. radius cylinder extending upward from an elavation 7 ft 0 in. above unit heater	7 ft 0 in. radius cylinder extending from the top of the unit heater to an elevation 7 ft 0 in. above unit heater
3. Steam Mains (Uncovered) (a) Above	More than 2 ft 6 in.	2 ft 6 in. or less	—
(b) Side and Below	More than 1 ft 0 in.	1 ft 0 in. or less	—
(c) Blowoff Valve	More than 7 ft 0 in.	—	7 ft 0 in. or less

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Table 4-3.1.3.2(b) Ratings of Sprinklers in Specified Locations

Location	Ordinary Degree Rating	Intermediate Degree Rating	High Degree Rating
Skylights	—	Glass or plastic	—
Attics	Ventilated	Unventilated	—
Peaked Roof: Metal or thin boards; concealed or not concealed; insulated or uninsulated	Ventilated	Unventilated	—
Flat Roof: Metal, not concealed; insulated or uninsulated	Ventilated or unventilated	Note: For uninsulated roof, climate and occupancy may necessitate Intermediate sprinklers. Check on job.	—
Flat Roof: Metal; concealed; insulated or uninsulated	Ventilated	Unventilated	—
Show Windows	Ventilated	Unventilated	—

Note: A check of job condition by means of thermometers may be necessary.



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure 4-3.1.3.2 Heater and danger zones at unit heaters.

extra high temperature classification as determined by use of a temperature measuring device. (*See 3-9.6.*)

4-3.1.3.3 In case of occupancy change involving temperature change the sprinklers shall be changed accordingly.

4-3.2 Special Sprinklers. Installation of special sprinklers with protection areas, locations, and distances between sprinklers differing from those specified in Table 4-2.2 and Section 4-4 shall be permitted when found suitable for such use based on: fire tests related to the hazard category; tests to evaluate distribution, wetting of floors and walls, and interference to distribution by structural elements; and tests to characterize response sensitivity.

Exception No. 1: The maximum protection area for special sprinklers shall not exceed 400 sq ft (36 m²) per sprinkler.

Exception No. 2: Maximum area of coverage for individual extended coverage pendent and upright sprinklers shall be limited to areas having equal-sided dimensions.

4-3.3 Old-Style Sprinklers. Old-style sprinklers shall not be used in a new installation.

Exception No. 1: Old-style sprinklers shall be installed in fur storage vaults. See 4-4.1.7.15.

Exception No. 2: Use of old-style sprinklers shall be permitted when construction features or other special situations require unique water distribution.

4-3.4 Sidewall Spray Sprinklers. Sidewall sprinklers shall be installed only in Light Hazard Occupancies.

Exception: Sidewall sprinklers shall be permitted to be used in Ordinary Hazard Occupancies when specifically listed for such use.

4-3.5 Open Sprinklers. Open sprinklers shall be permitted to protect special hazards, for protection against exposures, or in other special locations.

4-3.6 Residential Sprinklers.

4-3.6.1* Residential sprinklers shall be permitted in dwelling units and their adjoining corridors located in any occupancy provided they are installed in conformance with their listing and the positioning requirements of NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Mobile Homes*, or NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height.*

4-3.6.2 Residential sprinklers shall be used only in wet systems.

Exception: Residential sprinklers shall be permitted for use in dry systems if specifically listed for such service.

4-3.6.3 When residential sprinklers are installed within a compartment as defined in 1-4.2, all sprinklers shall be from the same manufacturer and have the same heat-response thermal characteristic.

4-3.7 Early Suppression Fast Response (ESFR) Sprinklers.

4-3.7.1 ESFR sprinklers shall be used only in wet pipe systems.

4-3.7.2 ESFR sprinklers shall be installed only in buildings with roof or ceiling slope not exceeding 1 in. per ft (84 mm/m).

4-3.7.3 ESFR sprinklers shall be permitted for use in buildings with the following types of construction:

(a) Smooth ceiling, joists consisting of steel truss shaped member, wood truss shaped members that consist of wood top and bottom chord members not exceeding 4 in. (102 mm) in depth with steel tube or bar web.

(b) Wood beams of 4 in. by 4 in. (102 mm by 102 mm) or greater nominal dimension, concrete or steel beams spaced $3^1/_2$ to $7^1/_2$ ft (0.9 to 2.3 m) on centers and either supported on or framed into girders. Ceiling panels formed by members capable of trapping heat to aid the operation of sprinklers with members spaced greater than $7^1/_2$ ft (2.3 m) and limited to a maximum of 300 sq ft (27.9 m²) in area.

(c) Paragraphs (a) and (b) apply to construction with noncombustible or combustible roof or decks.

(d) Construction with ceiling panels formed by members capable of trapping heat to aid the operation of sprinklers with members spaced greater than $7^1/_2$ ft (2.3 m) and limited to a maximum of 300 sq ft (27.9 m²) in area.

4-3.7.4 Temperature Rating. Sprinkler temperature ratings shall be nominal 165°F (74°C).

Exception: Sprinklers of intermediate and high temperature ratings shall be installed in specific locations as required by 4-3.1.3.

4-3.8 Large-Drop Sprinklers.

4-3.8.1 Large-drop sprinklers shall be permitted to be used in wet, dry, or preaction systems.

4-3.8.2* In preaction and dry pipe systems, piping materials shall be limited to internally galvanized steel or copper.

Exception: Nongalvanized fittings shall be permitted.

4-3.8.3 Sprinkler temperature ratings shall be the same as those indicated in Tables 4-3.1.3.2(a) and (b) or those used in large scale fire testing to determine the protection requirements for the hazard involved.

Exception: Sprinklers of intermediate and high temperature ratings shall be installed in specific locations as required by 4-3.1.3.

4-3.9 Quick Response Early Suppression (QRES) Sprinklers. (Reserved)

4-4 Sprinkler Spacing and Location.

4-4.1 Upright and Pendent Spray Sprinkler.

4-4.1.1 Sprinkler Spacing Limitations. The maximum distance between sprinklers, either on branch lines or between branch lines, shall be as follows:

Light Hazard Occupancies	15 ft
Ordinary Hazard Occupancies	15 ft
Extra Hazard Occupancies	12 ft
High-Piled Storage	12 ft

When sprinklers are spaced less than 6 ft (1.8 m) on center see 4-4.1.7.8.

Exception No. 1: For Extra Hazard Occupancies and high-piled storage in bays 25 ft (7.6 m) wide, a spacing of 12 ft 6 in. (3.8 m) shall be permitted.

Exception No. 2: For densities less than 0.25 gpm per sq ft [10.2 (L/min)/m²)] spacing of 15 ft (4.6 m) shall be permitted.

4-4.1.2 Distance from Walls.

4-4.1.2.1 The distance from sprinklers to walls shall not exceed one-half of the allowable distance between sprinklers.

Exception: Within small rooms, sprinklers shall be permitted to be located not more than 9 ft (2.7 m) from any single wall. Sprinkler spacing limitations of 4-4.1.1 and area limitations of Table 4-2.2 shall not be exceeded.*

4-4.1.2.2 Sprinklers shall be located a minimum of 4 in. (102 mm) from a wall.

4-4.1.3 Obstructions to Sprinkler Discharge

4-4.1.3.1* Obstructions Located at the Ceiling. Noncontinuous obstructions at the ceiling or roof such as columns, bar joists, truss webs, and light fixtures shall be treated as vertical obstructions.

Exception: Obstructions that can meet the separation requirements for horizontal obstructions in 4-4.1.3.1.2.

4-4.1.3.1.1 Vertical Obstructions. The minimum separation between vertical obstructions and a sprinkler shall be as shown in Table 4-4.1.3.1.1 and Figures 4-4.1.3.1.1(a), (b), (c), and (d).

Exception: Sprinklers shall be permitted to be spaced on opposite sides of the obstruction providing the distance from the centerline of the obstruction to the sprinklers does not exceed one-half the allowable distance between sprinklers.

Table 4-4.1.3.1.1 Minimum Distance from Vertical Obstructions

Maximum Dimension of Obstruction	Minimum Horizontal Distance
½ – 1 in.	6 in.
>1 in. – 4 in.	12 in.
>4 in.	24 in.

For SI Units: 1 in. = 25.4 mm.

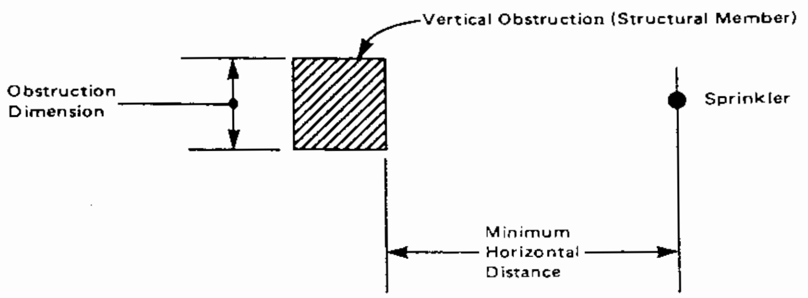


Figure 4-4.1.3.1.1(a).

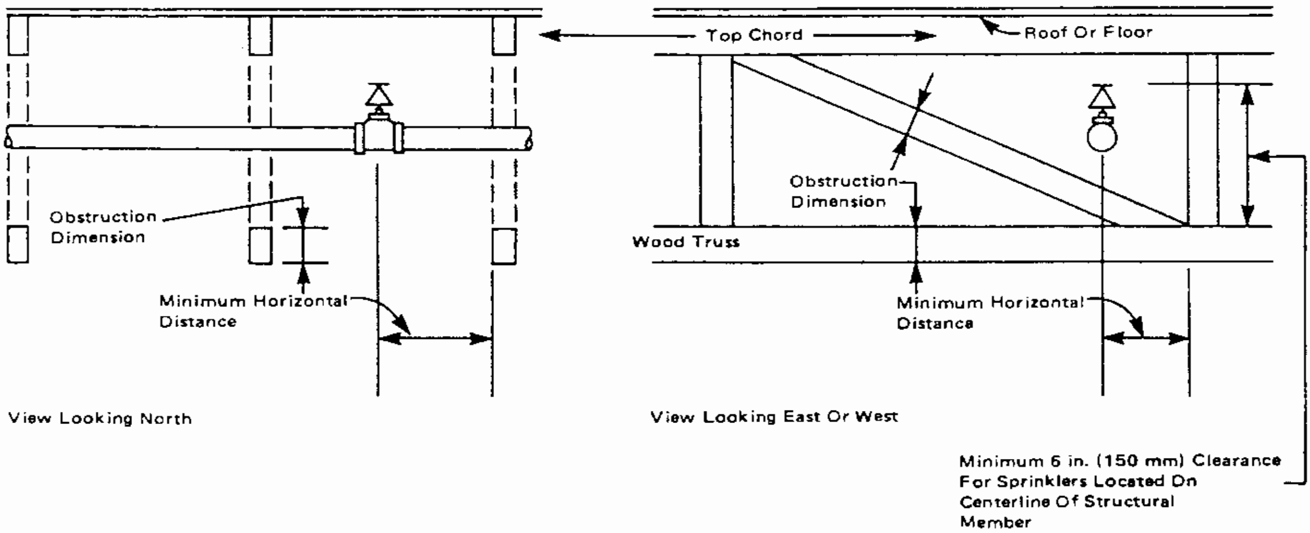


Figure 4-4.1.3.1.1(b).

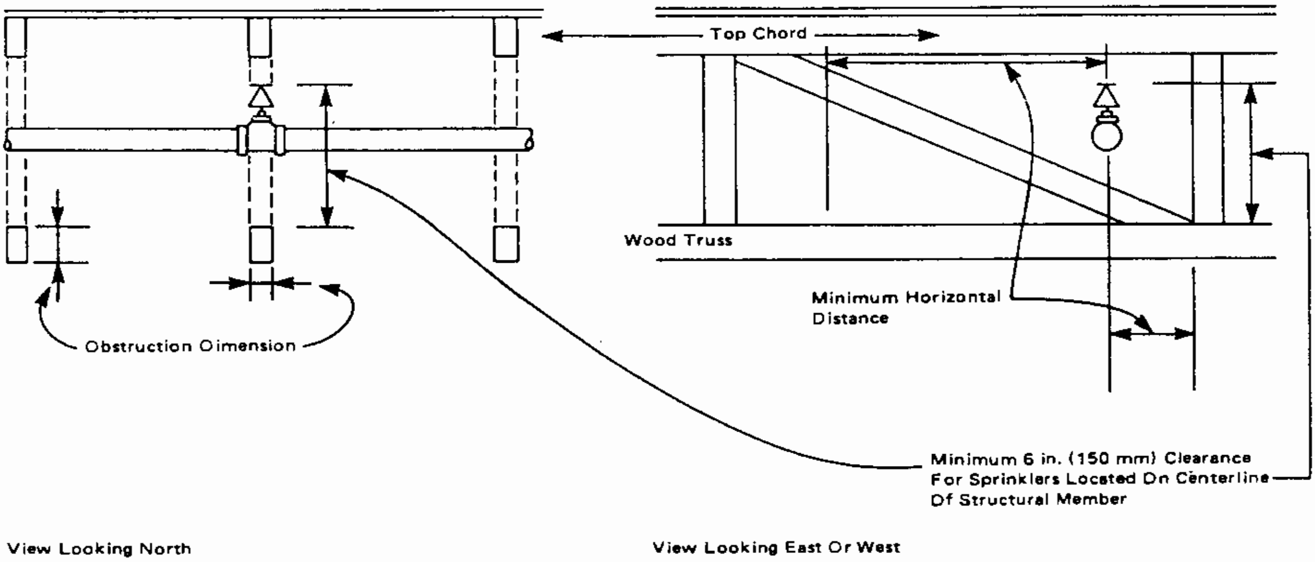


Figure 4-4.1.3.1.1(c).

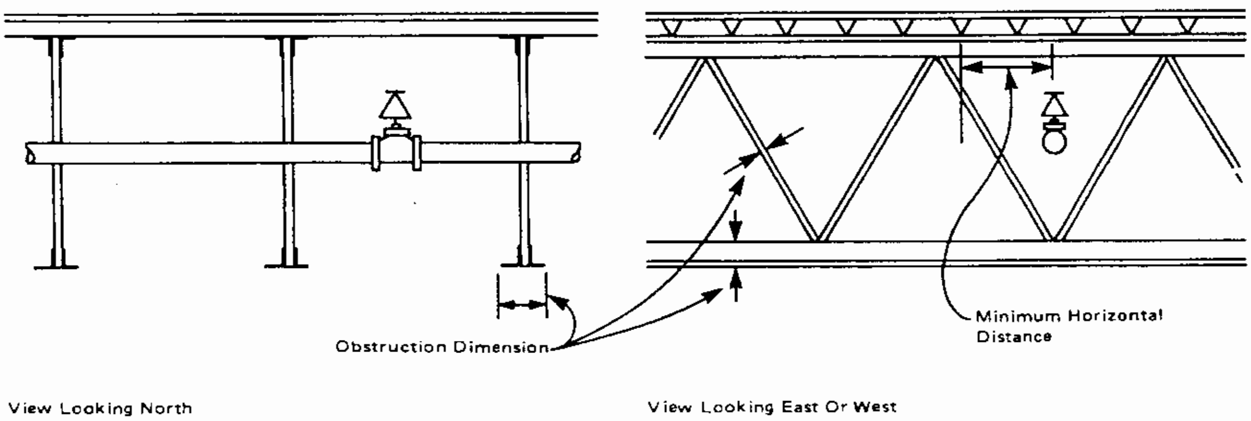


Figure 4-4.1.3.1.1(d).

4-4.1.3.1.2 Horizontal Obstructions. The minimum separation of a sprinkler from a horizontal obstruction shall be determined by the height of the deflector above the bottom of the obstruction as shown in Table 4-4.1.3.1.2 and Figure 4-4.1.3.1.2.

Exception: Sprinklers shall be permitted to be spaced on opposite sides of the obstruction providing the distance from the centerline of the obstruction to the sprinklers does not exceed one-half the allowable distance between sprinklers.

Table 4-4.1.3.1.2 Position of Deflector when Located above Bottom of Obstruction

Distance from Sprinkler to Side of Obstruction	Maximum Allowable Distance Deflector above Bottom of Obstruction
Less than 1 ft	0 in.
1 ft to less than 2 ft	1 in.
2 ft to less than 2 ft 6 in.	2 in.
2 ft 6 in. to less than 3 ft	3 in.
3 ft to less than 3 ft 6 in.	4 in.
3 ft 6 in. to less than 4 ft	6 in.
4 ft to less than 4 ft 6 in.	7 in.
4 ft 6 in. to less than 5 ft	9 in.
5 ft to less than 5 ft 6 in.	11 in.
5 ft 6 in. to less than 6 ft	14 in.

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

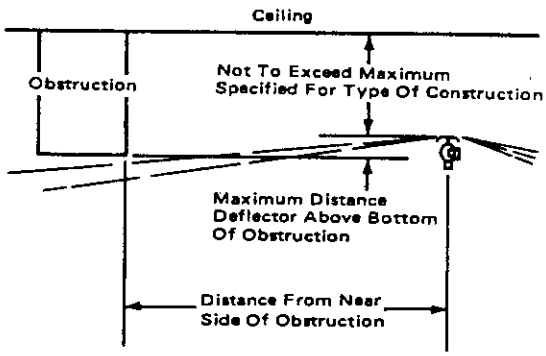


Figure 4-4.1.3.1.2 Position of deflector, upright, or pendent sprinkler when located above bottom of obstructions.

4-4.1.3.2 Obstructions Located below Sprinklers

4-4.1.3.2.1* Sprinklers shall be installed under ducts, decks, and other obstructions over 4 ft (1.2 m) wide.

Exception: Ceiling sprinklers shall be permitted to be spaced in accordance with Table 4-4.1.3.1.2.

4-4.1.3.2.2 Sprinklers installed under open gratings shall be of the intermediate level/rack storage type or otherwise shielded from the discharge of overhead sprinklers.

4-4.1.3.2.3 Sprinklers shall be permitted to be installed on the centerline of a truss or directly above a beam provided the truss chord or beam dimension is not more than 8 in. (203 mm) and the sprinkler deflector is located at least 6 in. (152 mm) above the structural member.

4-4.1.3.3* Suspended or Floor Mounted Vertical Obstructions. The distance from sprinklers to privacy curtains, free-standing partitions, room dividers, and similar obstructions in Light Hazard Occupancies shall be as shown in Table 4-4.1.3.3 and Figure 4-4.1.3.3.

Table 4-4.1.3.3 Horizontal and Minimum Vertical Distances for Sprinklers

Horizontal Distance	Minimum Vertical Distance below Deflector
6 in. or less	3 in.
More than 6 in. to 9 in.	4 in.
More than 9 in. to 12 in.	6 in.
More than 12 in. to 15 in.	8 in.
More than 15 in. to 18 in.	9½ in.
More than 18 in. to 24 in.	12½ in.
More than 24 in. to 30 in.	15½ in.
More than 30 in.	18 in.

For SI Units: 1 in. = 25.4 mm.

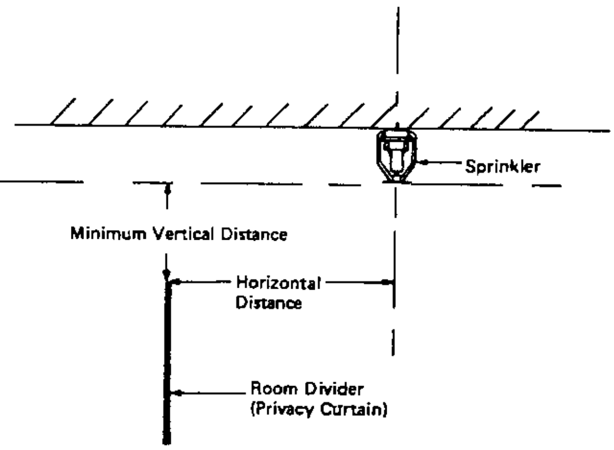
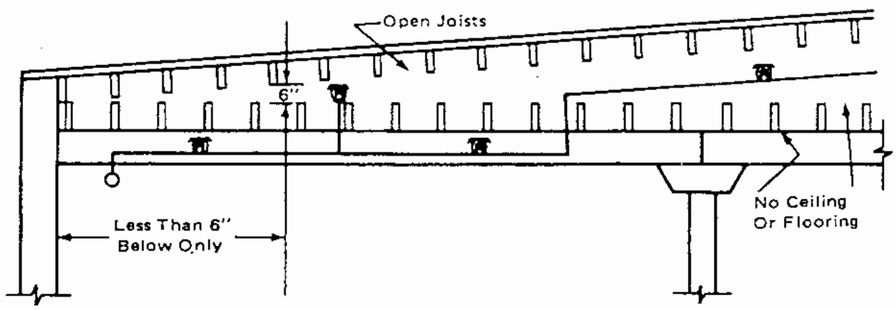


Figure 4-4.1.3.3 Sprinklers installed near privacy curtains, free-standing partitions, or room dividers.

4-4.1.3.4 Double Joist Obstructions. Where there are two sets of joists under a roof or ceiling, and there is no flooring over the lower set, sprinklers shall be installed above and below the lower set of joists where there is a clearance of 6 in. (152 mm) or more between the top of the lower joist and the bottom of the upper joist. (*See Figure 4-4.1.3.4.*)

Exception: Sprinklers are permitted to be omitted from below the lower set of joists where at least 18 in. (457 mm) is maintained between the sprinkler deflector and the top of the lower joist.



For SI Units: 1 in. = 25.4 mm.

Figure 4-4.1.3.4 Arrangement of sprinklers under two sets of open joists — no sheathing on lower joists.

4-4.1.4 Distance below Ceilings.

4-4.1.4.1 Under unobstructed construction, the distance between the sprinkler deflector and the ceiling shall be a minimum of 1 in. (25.4 mm) and a maximum of 12 in (305 mm).

Exception: Special ceiling-type sprinklers (concealed, recessed, and flush types) shall be permitted to have the operating element above the ceiling and the deflector located nearer to the ceiling when installed in accordance with their listing.

4-4.1.4.2 Under obstructed construction, the sprinkler deflector shall be located 1 to 6 in. (25.4 to 152 mm) below the structural members and a maximum distance of 22 in. (559 mm) below the ceiling/roof deck.

Exception No. 1: Sprinklers shall be permitted to be installed with the deflector at or above the bottom of the structural member to a maximum of 22 in. (559 mm) below the ceiling/roof deck when the sprinkler is installed in conformance with 4-4.1.3.1.2.

Exception No. 2: Where sprinklers are installed in each bay of obstructed construction, deflectors shall be a minimum of 1 in. (25.4 mm) and a maximum of 12 in. (152 mm) below the ceiling.

4-4.1.4.3 Deflectors of sprinklers under concrete tee construction with stems spaced less than 7½ ft (2.3 m) but more than 3 ft (0.9 m) on centers shall, regardless of the depth of the tee, be located at or above the plane 1 in. (25.4 mm) below the bottom of the stems of the tees and shall comply with Table 4-4.1.3.1.2.

4-4.1.5* Position of Deflectors. Deflectors of sprinklers shall be parallel to ceilings, roofs, or the incline of stairs.

Exception No. 1: When sprinklers are installed in the peak of a pitched roof, the sprinkler shall be installed with the deflector horizontal.

Exception No. 2: Pitched roofs having slopes less than 1 in. per ft (83 mm/m) are considered level in the application of this rule, and sprinklers shall be permitted to be installed with deflectors horizontal.

4-4.1.6* Clear Space below Sprinklers. A minimum of 18 in. (457 mm) clearance shall be maintained between top of storage and ceiling sprinkler deflectors.

Exception: Where other standards specify greater minimums, they shall be followed.

4-4.1.7 Special Situations.

4-4.1.7.1 Concealed Spaces.

4-4.1.7.1.1* All concealed spaces enclosed wholly or partly by exposed combustible construction shall be protected by sprinklers.

Exception No. 1: Concealed spaces formed by studs or joists with less than 6 in. (152 mm) between the inside or near edges of the studs or joists. (See Figure 4-4.1.3.4.)

Exception No. 2: Concealed spaces formed by bar joists with less than 6 in. (152 mm) between the roof or floor deck and ceiling.

Exception No. 3: Concealed spaces formed by ceilings attached directly to or within 6 in. (152 mm) of wood joist construction.

Exception No. 4: Concealed spaces formed by ceilings attached directly to the underside of composite wood joist construction, provided the joist channels are fire-stopped into volumes each not exceeding 160 cu ft (4.53 m^3) using materials equivalent to the web construction.

Exception No. 5: Concealed spaces entirely filled with noncombustible insulation.

Exception No. 6: Concealed spaces within wood joist construction and composite wood joist construction having noncombustible insulation filling the space from the ceiling up to the bottom edge of the joist of the roof or floor deck, provided that in composite wood joist construction the joist channels are fire-stopped into volumes each not exceeding 160 cu ft (4.53 m^3). The joists shall be fire-stopped to the full depth of the joist with material equivalent to the web construction.

Exception No. 7: Concealed spaces over isolated small rooms not exceeding 55 sq ft (4.6 m^2) in area.

Exception No. 8: When the exposed surfaces have a flame spread rating of 25 or less and the materials have been demonstrated not to propagate fire in the form in which they are installed in the space.

Exception No. 9: Noncombustible concealed spaces having exposed combustible insulation when the heat content of the facing and substrate of the insulation material does not exceed 1000 Btu per sq ft (11 356 kJ/m^2).

4-4.1.7.1.2 Sprinklers in concealed spaces having no access for storage or other use shall be installed in accordance with requirements of Light Hazard Occupancy.

4-4.1.7.1.3 When heat-producing devices such as furnaces or process equipment are located in the joist channels above a ceiling attached directly to the underside of composite wood joist construction that would not otherwise require sprinkler protection of the spaces, the joist channel containing the heat-producing devices shall be sprinklered by installing sprinklers in each joist channel, on each side, adjacent to the heat-producing device.

4-4.1.7.2 Vertical Shafts.

4-4.1.7.2.1 One sprinkler shall be installed at the top of shafts.

Exception No. 1: Noncombustible, nonaccessible vertical duct shafts.

Exception No. 2: Noncombustible, nonaccessible vertical electrical shafts.

Exception No. 3: Noncombustible, nonaccessible vertical pipe shafts.

4-4.1.7.2.2* Where vertical shafts have combustible surfaces, one sprinkler shall be installed at each alternate floor level. Where a shaft having combustible surfaces is trapped, an additional sprinkler shall be installed at the top of each trapped section.

4-4.1.7.2.3 Where accessible vertical shafts have noncombustible surfaces, one sprinkler shall be installed near the bottom.

4-4.1.7.2.4 Where vertical openings are not protected by fire rated enclosures, sprinklers shall be placed so as to fully protect the openings.

4-4.1.7.3 Stairways.

4-4.1.7.3.1 Sprinklers shall be installed beneath all stairways of combustible construction.

4-4.1.7.3.2 In noncombustible stair shafts with noncombustible stairs, sprinklers shall be installed at the top of the shaft and under the first landing above the bottom of the shaft.

Exception: Sprinklers shall be installed beneath landings or stairways when the area beneath is used for storage.

4-4.1.7.3.3* Sprinklers shall be installed in the stair shaft at each floor landing serving two or more separate fire divisions located at the same level as the landing.

4-4.1.7.3.4* Where moving stairways, staircases, or similar floor openings are unenclosed, the floor openings involved shall be protected by closely spaced sprinklers in combination with draft stops.

The draft stops shall be located immediately adjacent to the opening, shall be at least 18 in. (457 mm) deep, and shall be of noncombustible or limited-combustible material that will stay in place before and during sprinkler operation. Sprinklers shall be spaced not more than 6 ft (1.8 m) apart and placed 6 to 12 in. (152 to 305 mm) from the draft stop on the side away from the opening. When sprinklers are closer than 6 ft (1.8 m), cross baffles shall be provided in accordance with 4-4.1.7.8.

Exception: Closely spaced sprinklers and draft stops are not required around large openings such as those found in shopping malls, atrium buildings, and similar structures where all adjoining levels and spaces are protected by automatic sprinklers in accordance with this standard and where the openings have all horizontal dimensions between opposite edges of 20 ft (6 m) or greater and an area of 1000 sq ft (93 m^2) or greater.

4-4.1.7.4* Building Service Chutes. Building service chutes (linen, rubbish, etc.) shall be protected internally by automatic sprinklers. A sprinkler shall be provided above the top service opening of the chute, above the lowest service opening, and above service openings at alternate levels in buildings over two stories in height. The room or area into which the chute discharges shall also be protected by automatic sprinklers.

4-4.1.7.5 Spaces under Ground Floors, Exterior Docks, and Platforms. Sprinklers shall be installed in spaces under all ground floors, exterior docks, and platforms.

Exception: Sprinklers shall be permitted to be omitted when all of the following conditions prevail:

(a) The space is not accessible for storage purposes and is protected against accumulation of wind-borne debris;

(b) The space contains no equipment such as steam pipes, electric wiring, or conveyors;

(c) The floor over the space is of tight construction;

(d) No combustible or flammable liquids or materials that under fire conditions may convert into combustible or flammable liquids are processed, handled, or stored on the floor above the space.

4-4.1.7.6* Exterior Roofs or Canopies.

4-4.1.7.6.1 Sprinklers shall be installed under roofs or canopies over areas where combustibles are stored or handled.

Exception: Sprinklers are permitted to be omitted where construction is noncombustible and areas under the roofs or canopies are not used for storage or handling of combustibles.

4-4.1.7.6.2 Sprinklers shall be installed under exterior combustible roofs or canopies exceeding 4 ft (1.2 m) in width.

4-4.1.7.7 Dwelling Units.

4-4.1.7.7.1 Sprinklers are not required in bathrooms that are located within dwelling units, that do not exceed 55 sq ft (5.1 m^2), and that have walls and ceilings of noncombustible or limited-combustible materials with a 15 minute thermal barrier rating including the walls and ceilings behind fixtures.

Exception: Sprinklers are required in bathrooms of nursing homes and in bathrooms opening directly onto public corridors or exitways.

4-4.1.7.7.2 Sprinklers are not required in clothes closets, linen closets, and pantries within dwelling units in hotels and motels where the area of the space does not exceed 24 sq ft (2.2 m^2), the least dimension does not exceed 3 ft (0.9 m), and the walls and ceilings are surfaced with noncombustible or limited-combustible materials.

4-4.1.7.8 **Baffles.** Baffles shall be installed whenever sprinklers are less than 6 ft (1.8 m) apart to prevent operating sprinklers from wetting adjacent sprinklers, thus delaying or preventing their operation. Baffles shall be located midway between sprinklers and arranged to protect the actuating elements. Baffles shall be of noncombustible or limited-combustible material that will stay in place before and during sprinkler operation. The baffles shall be approximately 8 in. (203 mm) wide and 6 in. (152 mm) high. The tops of baffles shall extend 2 to 3 in. (51 to 76 mm) above the deflectors of upright sprinklers. The bottoms of baffles shall extend downward to a level at least even with the deflectors of pendent sprinklers. (*See A-4-4.1.7.3.4.*)

Exception No. 1: For in-rack sprinklers, see NFPA 231C, Standard for Rack Storage of Materials.

Exception No. 2: Baffles are not required for old-style sprinklers protecting fur storage vaults.

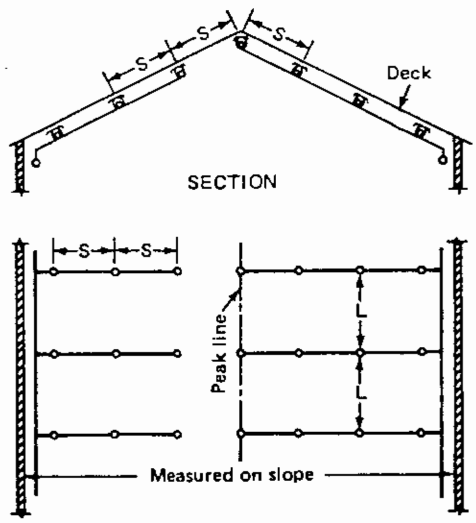
4-4.1.7.9 **Spacing under Pitched Surfaces.**

4-4.1.7.9.1 The distance between sprinklers either on the branch lines or between the branch lines, running up or down the slope of a pitched surface, shall be measured along the slope.

4-4.1.7.9.2* Sprinklers under or near the peak shall have deflectors located not more than 3 ft (0.9 m) vertically down from the peak. [*See Figures 4-4.1.7.9.2(a) and 4-4.1.7.9.2(b).*]

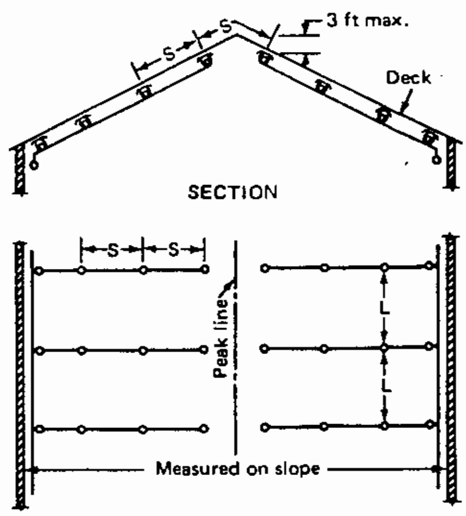
Exception No. 1: Under saw-toothed roofs, sprinklers at the highest elevation shall not exceed a distance of 3 ft (0.9 m) measured down the slope from the peak.

Exception No. 2: Under a steeply pitched surface, the distance from the peak to the deflectors shall be permitted to be increased to maintain a horizontal clearance of not less than 2 ft (0.6 m) from other structural members. [See Figure 4-4.1.7.9.2(c).]



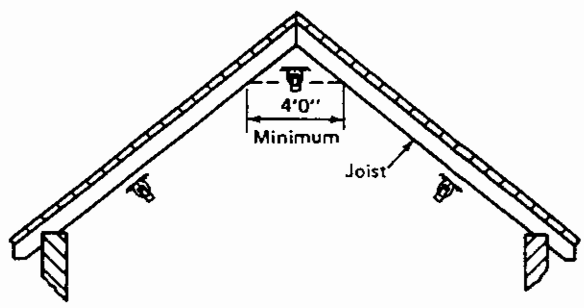
For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure 4-4.1.7.9.2(a) Sprinklers at pitched roofs; branch lines run up the slope.



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure 4-4.1.7.9.2(b) Sprinklers at pitched roofs; branch lines run up the slope.



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure 4-4.1.7.9.2(c) Desirable horizontal clearance for sprinklers at peak of pitched roof.

4-4.1.7.10 Spacing of Sprinklers under Curved Roof Buildings.

4-4.1.7.10.1 Under curved surfaces, the horizontal distance measured at the floor level from the wall to the nearest sprinkler shall not be greater than one-half the allowable distance between sprinklers.

4-4.1.7.10.2 Deflectors of sprinklers shall be parallel with the curve of the surface.

4-4.1.7.10.3 When Extra Hazard Occupancy spacing of sprinklers is used under curved ceilings of other than fire resistive construction, the sprinkler spacing as projected on the floor shall not be greater than that required for Extra Hazard Occupancies, but in no case shall the spacing at the roof or ceiling be wider than that required for Ordinary Hazard Occupancies.

4-4.1.7.11 Library Stack Rooms. Sprinklers shall be installed in every aisle and at every tier of stacks with distance between sprinklers along aisles not to exceed 12 ft (3.6 m). [*See Figure 4-4.1.7.11(a).*]

Exception No. 1: When vertical shelf dividers are incomplete and allow water distribution to adjacent aisles, sprinklers are permitted to be omitted in alternate aisles on each tier. Where ventilation openings are also provided in tier floors, sprinklers shall be staggered vertically. [See Figure 4-4.1.7.11(b).]

Exception No. 2: Sprinklers are permitted to be installed without regard to aisles when there is 18 in. (457 mm) or more clearance between sprinkler deflectors and tops of racks.

4-4.1.7.12 Electrical Equipment. When sprinkler protection is provided in generator or transformer rooms, hoods or shields installed to protect important electrical equipment from sprinkler discharge shall be noncombustible.

4-4.1.7.13* Open-Grid Ceilings. Open-grid ceilings shall not be installed beneath sprinklers.

Exception No. 1: Open-grid ceilings in which the openings are $^1/_4$ in. (6.4 mm) or larger in the least dimension, when the thickness or depth of the material does not exceed the least dimension of the opening, and when such openings constitute 70 percent of the area of the ceiling material. The spacing of the sprinklers over the open grid ceiling shall then comply with the following:

(a) In Light Hazard Occupancies when sprinkler spacing (either spray or old-style sprinklers) is less than 10 ft by 10 ft (3 m by 3 m), a minimum clearance of at least 18 in. (457 mm) shall be provided between the sprinkler deflectors and the upper surface of the open-grid ceiling. When spacing is greater than 10 ft by 10 ft (3 m by 3 m) but less than 10 ft by 12 ft (3 m by 3.7 m), a clearance of at least 24 in. (610 mm) shall be provided from spray sprinklers and at least 36 in. (914 mm) from old-style sprinklers. When spacing is greater than 10 ft by 12 ft (3 m by 3.7 m), a clearance of at least 48 in. (1219 mm) shall be provided.

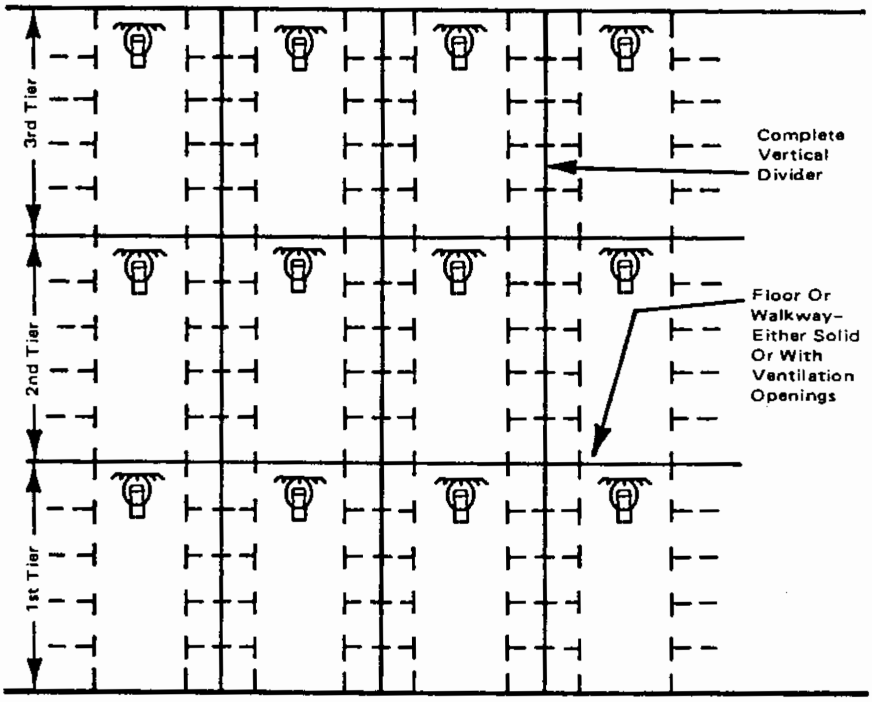


Figure 4-4.1.7.11(a) Sprinklers in multitier library bookstacks with complete vertical dividers.

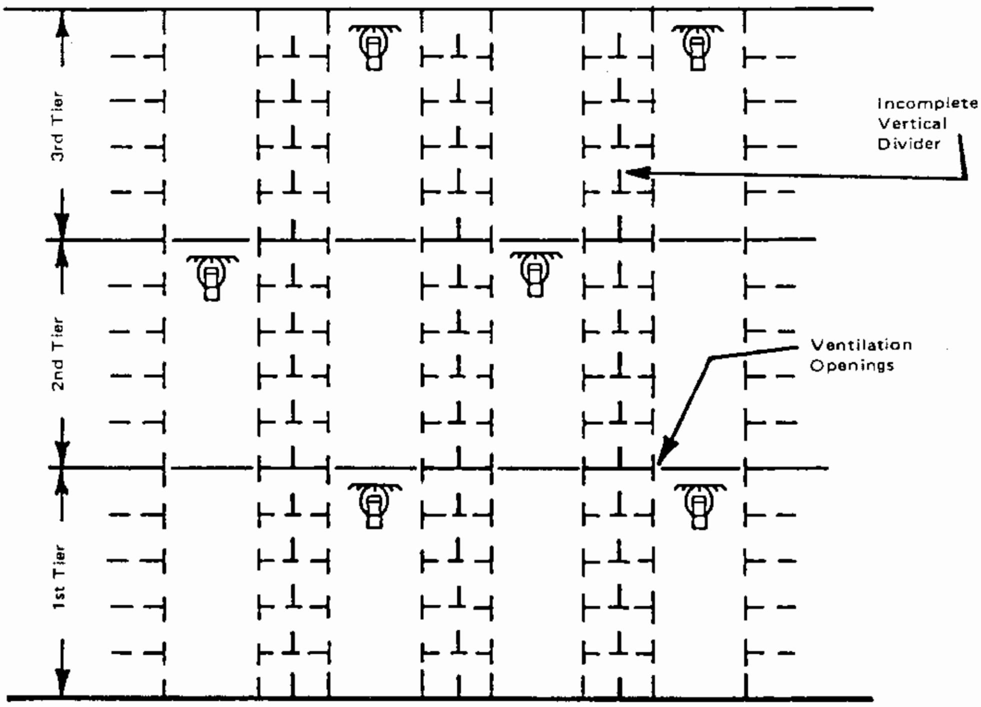


Figure 4-4.1.7.11(b) Sprinklers in multitier library bookstacks with incomplete vertical dividers.

(b) In Ordinary Hazard Occupancies, open-grid ceilings shall be permitted to be installed beneath spray sprinklers only. When sprinkler spacing is less than 10 ft by 10 ft (3 m by 3 m), a minimum clearance of at least 24 in. (610 mm) shall be provided between the sprinkler deflectors and the upper surface of the open-grid ceiling. When spacing is greater than 10 ft by 10 ft (3 m by 3 m), a clearance of at least 36 in. (914 mm) shall be provided.

Exception No. 2: Other types of open-grid ceilings shall not be installed beneath sprinklers unless they are listed for such service and are installed in accordance with instructions contained in each package of ceiling material.

4-4.1.7.14 Drop-Out Ceilings.

4-4.1.7.14.1 Drop-out ceilings shall be permitted to be installed beneath sprinklers when ceilings are listed for that service and are installed in accordance with their listings.

Exception: Special sprinklers shall not be installed above drop-out ceilings unless specifically listed for this purpose.

4-4.1.7.14.2 Drop-out ceilings shall not be considered ceilings within the context of this standard.

4-4.1.7.14.3* Piping installed above drop-out ceilings shall not be considered concealed piping (*see 2-5.4, Exception No. 2*).

4-4.1.7.14.4* Sprinklers shall not be installed beneath drop-out ceilings.

4-4.1.7.15* Fur Vaults.

4-4.1.7.15.1 Sprinklers shall be listed old-style having orifice sizes selected to provide as closely as possible but not less than 20 gal per min (76 L/min) per sprinkler, for four sprinklers, based on the water pressure available.

4-4.1.7.15.2 Sprinklers in fur storage vaults shall be located centrally over the aisles between racks and shall be spaced not over 5 ft (1.5 m) apart along the aisles.

4-4.1.7.15.3 When sprinklers are spaced 5 ft (1.5 m) apart along the sprinkler branch lines, pipe sizes shall be in accordance with the following schedule:

1 in.	4 sprinklers	2 in.	20 sprinklers
$1^1/_4$ in.	6 sprinklers	$2^1/_2$ in.	40 sprinklers
$1^1/_2$ in.	10 sprinklers	3 in.	80 sprinklers

4-4.1.7.16 Stages. Sprinklers shall be installed under the roof at the ceiling, in spaces under the stage either containing combustible materials or constructed of combustible materials, and in all adjacent spaces and dressing rooms, storerooms, and workshops.

4-4.1.7.16.1 When proscenium opening protection is required, a deluge system shall be provided with open sprinklers located not more than 3 ft (0.9 m) away from the stage side of the proscenium arch and spaced up to a maximum of 6 ft (1.8 m) on center. (*See Chapter 5 for design criteria.*)

4-4.1.7.17 Rack Storage. For sprinklers in storage racks see NFPA 231C, *Standard for Rack Storage of Materials.*

4-4.1.7.18 Provision for Flushing Systems. All sprinkler systems shall be arranged for flushing. Readily removable fittings shall be provided at the end of all cross mains. All cross mains shall terminate in 1¼-in. (33-mm) or larger pipe. All branch lines on gridded systems shall be arranged to facilitate flushing.

4-4.1.7.19 Stair Towers. Stairs, towers, or other construction with incomplete floors, if piped on independent risers, shall be treated as one area with reference to pipe sizes.

4-4.1.7.20 Return Bends. Return bends shall be used when pendent sprinklers are supplied from a raw water source, mill pond, or from open-top reservoirs. Return bends shall be connected to the top of branch lines in order to avoid accumulation of sediment in the drop nipples.

Exception No. 1: Return bends are not required for deluge systems.

Exception No. 2: Return bends are not required when dry-pendent sprinklers are used.

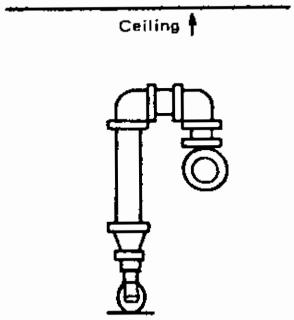


Figure 4-4.1.7.20 Return bend arrangement.

4-4.1.7.21 Piping to Sprinklers below Ceilings.

4-4.1.7.21.1 In new installations expected to supply sprinklers below a ceiling, minimum 1 in. (25 mm) outlets shall be provided.

Exception: Hexagonal bushings may be used to accommodate temporary sprinklers and shall be removed with the temporary sprinklers when the permanent ceiling sprinklers are installed.

4-4.1.7.21.2 In revamping existing systems, a nipple not exceeding 4 in. (102 mm) in length and of the same pipe thread size as the sprinkler being removed shall be permitted to be installed in the branch line fitting. All other piping shall be 1 in. (25 mm) where it supplies a single sprinkler in an area.

Exception: When it is necessary to pipe two new ceiling sprinklers from an existing outlet in an overhead system, the use of a nipple not exceeding 4 in. (102 mm) in length and of the same pipe thread size as the existing outlet shall be permitted, provided that a hydraulic calculation verifies that the design flow rate will be achieved.

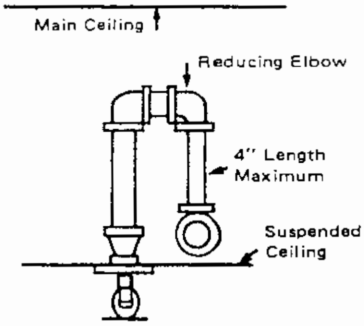


Figure 4-4.1.7.21.2(a) Nipple and reducing elbow supplying sprinkler below ceiling.

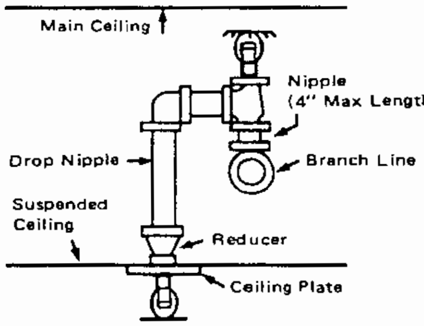


Figure 4-4.1.7.21.2(b) Sprinklers in concealed space and below ceiling.

4-4.1.7.22 Dry Pipe Underground. When necessary to place pipe that will be under air pressure underground, the pipe shall be protected against corrosion (*see 4-5.4.2*), or unprotected cast or ductile iron pipe may be used when joined with a gasketed joint listed for air service underground.

4-4.1.7.23* One and One-Half-Inch Hose Connections. One and one-half-inch [1½-in. (38-mm)] hose used for fire purposes only shall be permitted to be connected to wet sprinkler systems only, subject to the following restrictions:

(a) Hose station's supply pipes shall not be connected to any pipe smaller than 2½ in. (64 mm).

Exception: For hydraulically designed loops and grids the minimum size pipe between the hose station's supply pipe and the source shall be permitted to be 2 in. (51 mm).

(b) For piping serving a single hose station, pipe shall be minimum 1 in. (25 mm) for horizontal runs up to 20 ft (6.1 m), minimum 1¼ in. (33 mm) for the entire run for runs between 20 and 80 ft (6.1 and 24.4 m), and minimum 1½ in. (38 mm) for the entire run for runs greater than 80 ft (24.4 m). For piping serving multiple hose stations, runs shall be a minimum of 1½ in. (38 mm) throughout.

(c) Piping shall be at least 1 in. (25 mm) for vertical runs.

(d) When the pressure at any hose station outlet exceeds 100 psi (6.9 bars), an approved device shall be installed at the outlet to reduce the pressure at the outlet to 100 psi (6.9 bars).

4-4.1.7.24* Hose Connections for Fire Department Use. In buildings of Light or Ordinary Hazard Occupancy, $2^1/_2$ in. (64 mm) hose valves for fire department use may be attached to wet pipe sprinkler system risers. [*See 5-2.3.1.3(d).*] The following restrictions shall apply:

(a) Sprinklers shall be under separate floor control valves.

(b) The minimum size of the riser shall be 4 in. (102 mm) unless hydraulic calculations indicate a smaller size riser will satisfy sprinkler and hose stream demands.

(c) Each combined sprinkler and standpipe riser shall be equipped with a riser control valve to permit isolating a riser without interrupting the supply to other risers from the same source of supply.

(d) For fire department connections serving standpipe and sprinkler systems, refer to Section 2-8.

4-4.1.7.25* When individual floor/zone control valves are not provided, a flanged joint or mechanical coupling shall be used at the riser at each floor for connections to piping serving floor areas in excess of 5000 sq ft (465 m^2).

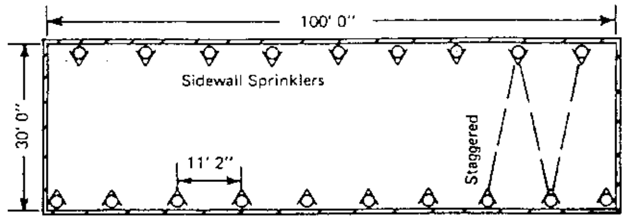
4-4.2 Sidewall Spray Sprinklers.

4-4.2.1 Distance between Sprinklers on Branch Lines. Sidewall sprinklers shall be installed along the length of a single wall of rooms or bays not exceeding the width dimension specified in Table 4-4.2.1.

Exception: Where the width of the room or bay exceeds the maximum allowed, up to 30 ft (9.1 m) for Light Hazard Occupancy, or 20 ft (6.1 m) for Ordinary Hazard Occupancy, sidewall sprinklers on a staggered basis shall be provided on two opposite walls or sides of bays with spacing as required by Table 4-4.2.1. (See Figure 4-4.2.1.)

4-4.2.2 Protection Area Limitations.

4-4.2.2.1* Protection area limitations for sidewall sprinklers shall be in conformity with Table 4-4.2.1.



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure 4-4.2.1 Spacing of sidewall sprinklers under unobstructed construction in Light Hazard Occupancies.

4-4.2.2.2 The distance from a sidewall sprinkler to an end wall shall not exceed one-half the allowable distance between sidewall sprinklers.

4-4.2.3 Position of Sidewall Sprinklers.

4-4.2.3.1 Sidewall sprinklers shall only be installed along walls, lintels, or soffits where the distance from the ceiling to the bottom of the lintel or soffit is at least 2 in. (51 mm) greater than the distances from the ceiling to sidewall sprinkler deflector.

4-4.2.3.2 Sidewall sprinklers shall not be installed back to back without being separated by a continuous lintel or soffit.

4-4.2.3.3 Sidewall sprinkler deflectors (vertical type) shall be located not more than 6 in. (152 mm) or less than 4 in. (102 mm) from walls and ceilings.

Exception No. 1: Horizontal sidewall sprinklers are permitted to be located 6 to 12 in. (152 to 305 mm) below noncombustible ceilings when listed for these positions.

Exception No. 2: Horizontal sidewall sprinklers are permitted to be located with their deflectors less than 4 in. (102 mm) from the wall on which they are mounted.

Table 4-4.2.1 Dimensions for Sidewall Sprinkler Installation for Various Ceiling Types

	Light Hazard Occupancy			Ordinary Hazard Occupancy	
	Combustible sheathing	**Combustible construction with noncombustible or limited combustible sheathing, wood lath and plaster**	**Noncombustible construction with noncombustible or limited combustible sheathing**	**Combustible sheathing**	**Noncombustible or limited combustible sheathing**
Maximum distance between sprinklers on branch line	14	14	14	10	10
Maximum room width for single branch line along wall (ft)	12	12	14	10	10
Maximum area coverage (ft^2)	120	168	196	80	100

For SI Units: 1 ft = 0.3048 m; 1 ft^2 = 0.0929 m^2.

4-4.2.3.4 Sidewall sprinklers, when installed under a sloped ceiling, shall be located at the high point of the slope and positioned to discharge downward, and the deflector shall be parallel to the sloped ceiling.

4-4.2.3.5 When soffits are used for the installation of sidewall sprinklers, they shall not exceed 8 in. (203 mm) in width or projection from the wall.

Exception: When soffits exceed 8 in., additional sprinklers shall be installed below the soffit.

4-4.2.4 Obstructions to Sidewall Sprinklers. Sidewall sprinklers shall be installed where no beams or similar obstructions are located closer than 4 ft (2.3 m) from the sprinkler. Beams or similar obstructions located greater than 4 ft (2.3 m) from the sprinkler shall be in conformity with Table 4-4.2.4.

Table 4-4.2.4 Sidewall Sprinkler Clearance

Distance from Sidewall Sprinkler to Side of Obstruction	Maximum Allowable Distance of Deflector above Bottom of Obstruction (in.)
Less than 4 ft	0
4 ft to less than 5 ft	1
5 ft to less than 5 ft 6 in.	2
5 ft 6 in. to less than 6 ft	3
6 ft to less than 6 ft 6 in.	4
6 ft 6 in. to less than 7 ft	6
7 ft to less than 7 ft 6 in.	7
7 ft 6 in. to less than 8 ft	9
8 ft to less than 8 ft 6 in.	11
8 ft 6 in. to less than 9 ft	14

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

4-4.3 Large-Drop Sprinklers.

4-4.3.1* Spacing. The distance between sprinklers shall be limited to not more than 12 ft (3.7 m) or less than 8 ft (2.4 m).

Exception: Under obstructed combustible construction, the maximum distance shall be limited to 10 ft (3.0 m).

4-4.3.2 Clear Space below Sprinklers. A minimum of 36 in. (914 mm) shall be maintained between the top of storage and ceiling sprinkler deflectors.

4-4.3.3* Distance below Ceiling.

4-4.3.3.1 Under unobstructed construction, the distance between the sprinkler deflector and the ceiling shall be a minimum of 6 in. and a maximum of 8 in.

4-4.3.3.2 Under obstructed construction, the distance between the sprinkler deflector and the ceiling shall be a minimum of 6 in. and a maximum of 12 in.

Exception: Under wood joist or composite wood joist construction, the sprinklers shall be located 1 to 6 in. below the structural members to a maximum distance of 22 in. below the ceiling/roof or deck.

4-4.3.4* Obstructions to Distribution.

4-4.3.4.1 Obstructions Located at the Ceiling. When sprinkler deflectors are located above the bottom of obstructions such as beams, girders, ducts, fluorescent lighting fixtures, etc., located at the ceiling, the sprinklers shall be positioned so that the maximum distance from the bottom of the obstruction to the deflectors does not exceed the values specified in 4-4.1.3.

4-4.3.4.2 Obstructions Located below the Sprinklers.

4-4.3.4.2.1 Sprinklers shall be positioned with respect to fluorescent lighting fixtures, ducts, and obstrucions more than 24 in. (610 mm) wide and located entirely below the sprinklers so that the minimum horizontal distance from the near side of the obstruction to the center of the sprinkler is not less than the value specified in Table 4-4.3.4.2.1. (*See Figure 4-4.3.4.2.1.*)

Table 4-4.3.4.2.1 Position of Sprinklers in Relation to Obstruction Located Entirely Below the Sprinklers

Distance of Deflector above Bottom of Obstruction	Minimum Distance to Side of Obstruction, ft (m)
Less than 6 in. (152 mm)	1½ (0.5)
6 in. (152 mm) to less than 12 in. (305 mm)	3 (0.9)
12 in. (305 mm) to less than 18 in. (457 mm)	4 (1.2)
18 in. (457 mm) to less than 24 in. (610 mm)	5 (1.5)
24 in. (610 mm) to less than 30 in. (660 mm)	6 (1.8)

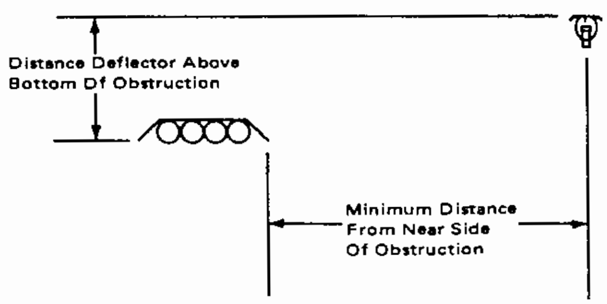


Figure 4-4.3.4.2.1 Position of sprinklers in relation to obstructions located entirely below the sprinklers. (To be used with Table 4-4.3.4.2.1.)

4-4.3.4.2.2 When the bottom of the obstruction is located 24 in. (610 mm) or more below the sprinkler deflectors:

(a) Sprinklers shall be positioned so that the obstruction is centered between adjacent sprinklers. (*See Figure 4-4.3.4.2.2.*)

(b) The obstruction shall be limited to a maximum width of 24 in. (610 mm). (*See Figure 4-4.3.4.2.2.*)

Exception: When obstruction is greater than 24 in. (610 mm) wide, one or more lines of sprinklers shall be installed below the obstruction.

(c) The obstruction shall not extend more than 12 in. (305 mm) to either side of the midpoint between sprinklers. (*See Figure 4-4.3.4.2.2.*)

Exception: When the extensions of the obstruction exceed 12 in. (305 mm), one or more lines of sprinklers shall be installed below the obstruction.

(d) At least 18 in. (457 mm) clearance shall be maintained between the top of storage and the bottom of the obstruction. (*See Figure 4-4.3.4.2.2.*)

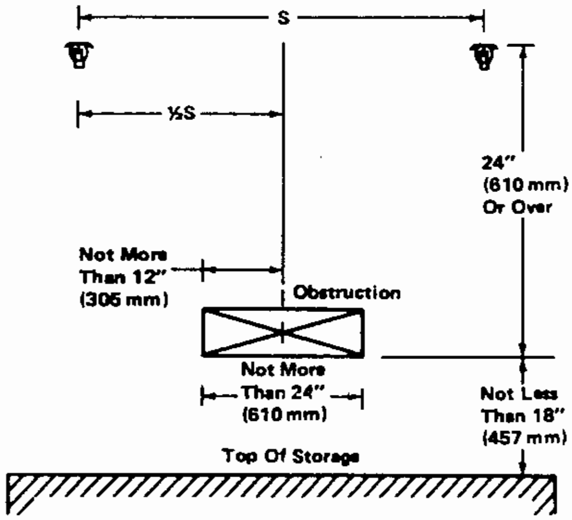


Figure 4-4.3.4.2.2 Position of sprinklers in relation to obstructions located 24 in. (610 mm) or more below deflectors.

4-4.3.4.2.3 Obstructions Parallel to and Directly below Branch Lines. In the special case of an obstruction running parallel to and directly below a branch line:

(a) The sprinkler shall be located at least 36 in. (914 mm) above the top of the obstruction. (*See Figure 4-4.3.4.2.3.*)

(b) The obstruction shall be limited to a maximum width of 12 in. (305 mm). (*See Figure 4-4.3.4.2.3.*)

(c) The obstruction shall be limited to a maximum extension of 6 in. (152 mm) to either side of the center line of the branch line. (*See Figure 4-4.3.4.2.3.*)

4-4.4 Quick Response Early Suppression (QRES) Sprinklers. (Reserved)

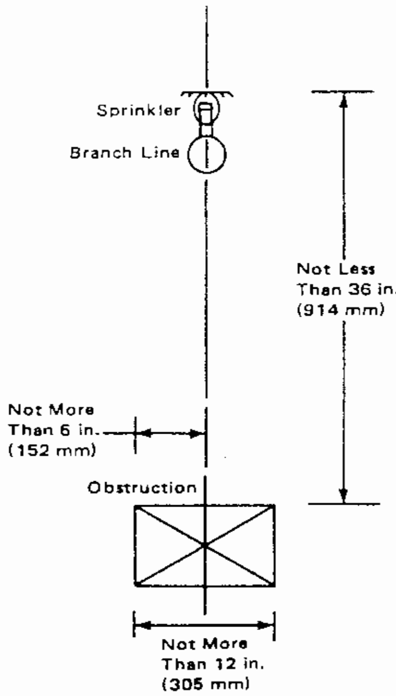


Figure 4-4.3.4.2.3 Position of sprinklers in relation to obstructions running parallel to and directly below branch lines.

4-4.5 Early Suppression Fast Response (ESFR) Sprinklers.

4-4.5.1 Spacing. The distance between sprinklers shall be limited to not more than 12 ft (3.7 m) or less than 8 ft (2.4 m).

4-4.5.2 Distances.

4-4.5.2.1 Distance from Walls. The distance from walls to sprinklers shall not exceed one-half of the allowable distance between sprinklers.

4-4.5.2.2 Clear Space below Sprinklers. At least 36 in. (914 mm) shall be maintained between sprinkler deflectors and the top of storage.

4-4.5.2.3 Distances below Ceiling. Sprinklers shall be positioned so that deflectors are a maximum 14 in. (356 mm) and a minimum 6 in. (152 mm) below the ceiling.

4-4.5.3 Location of Sprinklers in Obstructed Construction. With obstructed construction, the branch lines shall be permitted to be installed across the beams, but sprinklers shall be located in the bays and not under the beams.

4-4.5.4 Obstruction to Discharge.

4-4.5.4.1 Obstructions Located at or near the Ceiling. When sprinkler deflectors are located above the bottom of beams, girders, ducts, fluorescent lighting fixtures, or other obstructions located at the ceiling, the sprinklers shall be positioned so that the maximum distance from the bottom of the obstruction to the deflector does not exceed the value specified in 4-4.1.3.

4-4.5.4.2 Obstructions Located Entirely below the Sprinklers. Sprinklers shall be positioned with respect to any fluorescent lighting fixtures, ducts, or any other obstruction more than 12 in. (305 mm) wide and located entirely below the sprinklers so that the minimum horizontal distance from the near side of the obstruction to the center of the sprinkler is not less than the value specified in Table 4-4.3.4.2.1. (*See Figure 4-4.3.4.2.1.*)

4-5 Piping Installation.

4-5.1 Valves.

4-5.1.1* Valves Controlling Sprinkler Systems. (*See 2-7.1.*)

4-5.1.1.1* Each system shall be provided with a listed indicating valve in an accessible location, so located as to control all automatic sources of water supply.

4-5.1.1.2 At least one listed indicating valve shall be installed in each source of water supply.

Exception: There shall be no shutoff valve in the fire department connection.

4-5.1.1.3 Valves on connections to water supplies, sectional control valves, and other valves in supply pipes to sprinklers shall be supervised open by one of the following methods:

(a) Central station, proprietary, or remote station signaling service.

(b) Local signaling service that will cause the sounding of an audible signal at a constantly attended point.

(c) Valves locked in the open position.

(d) Valves located within fenced enclosures under the control of the owner, sealed in the open position, and inspected weekly as part of an approved procedure.

Floor control valves in high-rise buildings and valves controlling flow to sprinklers in circulating closed loop systems shall comply with (a) or (b) above.

Exception: Supervision of underground gate valves with roadway boxes shall not be required.

4-5.1.1.4 When there is more than one source of water supply, a check valve shall be installed in each connection.

4-5.1.1.5 Check valves shall be installed in a vertical or horizontal position in accordance with their listing.

4-5.1.1.6* When a single wet pipe sprinkler system is equipped with a fire department connection, the alarm valve is considered a check valve and an additional check valve shall not be required.

4-5.1.1.7* In a city connection serving as one source of supply, the city valve in the connection shall be acceptable as one of the required valves. A listed indicating valve or an indicator post valve shall be installed on the system side of the check valve required in 4-5.1.1.4.

Exception: When a wet pipe sprinkler system is equipped with an (alarm) check valve, a gate valve is not required on the system side of the (alarm) check valve.

4-5.1.2 Pressure Reducing Valves.

4-5.1.2.1 In portions of systems where all components are not listed for pressure greater than 175 psi (12.1 bars) and the potential exists for normal (nonfire condition) water pressure in excess of 175 psi (12.1 bars), a listed pressure reducing valve shall be installed and set for an outlet pressure not exceeding 165 psi (11.4 bars) at the maximum inlet pressure.

4-5.1.2.2 Pressure gauges shall be installed on the inlet and outlet sides of each pressure reducing valve.

4-5.1.2.3* A relief valve of not less than 1/2 in. (13 mm) in size shall be provided on the discharge side of the pressure reducing valve set to operate at a pressure not exceeding 175 psi (12.1 bars).

4-5.1.2.4 A listed indicating valve shall be provided on the inlet side of each pressure reducing valve.

Exception: A listed indicating valve is not required where the pressure reducing valve meets the listing requirements for use as an indicating valve.

4-5.2 Pipe Support.

4-5.2.1 General

4-5.2.1.1 Sprinkler piping shall be supported independently of the ceiling sheathing.

Exception: Toggle hangers shall be permitted only for the support of pipe 1 1/2 in. (38 mm) or smaller in size under ceilings of hollow tile or metal lath and plaster.

4-5.2.1.2 When sprinkler piping is installed in storage racks as defined in NFPA 231C, *Standard for Rack Storage of Materials*, piping shall be supported from the storage rack structure or building in accordance with all applicable provisions of 4-5.2 and 4-5.4.3.

4-5.2.2 Maximum Distance between Hangers.

4-5.2.2.1* The maximum distance between hangers shall not exceed that in Table 4-5.2.2.1.

Exception No. 1: The maximum distance between hangers for steel pipe and copper tube shall be modified as specified in 4-5.2.1 and 4-5.2.2.

Exception No. 2: The maximum distance between hangers for CPVC pipe and polybutylene pipe shall be modified as specified in the individual product listings.

Table 4-5.2.2.1 Maximum Distance between Hangers (ft - in.)

Nominal Pipe Size (in.)	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8
Steel Pipe Except Threaded Light-wall	N/A	12-0	12-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0
Threaded Light-wall Steel Pipe	N/A	12-0	12-0	12-0	12-0	12-0	12-0	N/A	N/A	N/A	N/A	N/A
Copper Tube	8-0	8-0	10-0	10-0	12-0	12-0	12-0	15-0	15-0	15-0	15-0	15-0
CPVC	5-6	6-0	6-6	7-0	8-0	9-0	10-0	N/A	N/A	N/A	N/A	N/A
Polybutylene (IPS)	N/A	3-9	4-7	5-0	5-11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Polybutylene (CTS)	2-11	3-4	3-11	4-5	5-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Exception No. 3: Holes through concrete beams shall be acceptable for the support of steel pipe as a substitute for hangers.

4-5.2.3 Location of Hangers on Branch Lines. This subsection applies to the support of steel pipe or copper tube as specified in 2-3.1 and subject to the provisions of 4-5.2.2.

4-5.2.3.1 There shall be not less than one hanger for each section of pipe.

Exception No. 1: When sprinklers are spaced less than 6 ft (1.8 m) apart, hangers spaced up to a maximum of 12 ft (3.7 m) shall be permitted.*

Exception No. 2: Starter lengths less than 6 ft (1.8 m) shall not require a hanger, unless on the end line of a sidefeed system or where an intermediate cross main hanger has been omitted.

4-5.2.3.2 The distance between a hanger and the centerline of an upright sprinkler shall not be less than 3 in. (76 mm).

4-5.2.3.3* The unsupported length between the end sprinkler and the last hanger on the line shall not be greater than 36 in. (914 mm) for 1-in. (2.5-cm) pipe or 48 in. (1219 mm) for 1 1/4-in. (3.2-cm) pipe, and 60 in. (15.2 cm) for 1 1/2-in. (3.8-cm) or larger pipe. When any of these limits is exceeded, the pipe shall be extended beyond the end sprinkler and shall be supported by an additional hanger.

Exception No. 1: When the maximum pressure at the sprinkler exceeds 100 psi (6.9 bars), and a branch line above a ceiling supplies sprinklers in a pendent position below the ceiling, the hanger assembly supporting the pipe supplying an end sprinkler in a pendent position shall be of a type that prevents upward movement of the pipe.*

Exception No. 2: When the maximum pressure at the sprinkler exceeds 100 psi (6.9 bars), the unsupported length between the end sprinkler in a pendent position or drop nipple and the last hanger on the branch line shall not be greater than 12 in. (305 mm) for steel pipe or 6 in. (152 mm) for copper pipe. When this limit is exceeded, the pipe shall be extended beyond the end sprinkler and supported by an additional hanger. The hanger closest to the sprinkler shall be of a type that clamps to and prevents upward movement of the piping.*

4-5.2.3.4* The length of an unsupported armover to a sprinkler shall not exceed 24 in. (610 mm) for steel pipe or 12 in. (305 mm) for copper tube.

Exception: When the maximum pressure at the sprinkler exceeds 100 psi (6.9 bars) and a branch line above a ceiling supplies sprinklers in a pendent position below the ceiling, the length of an unsupported armover to a sprinkler and drop nipple shall not exceed 12 in. (305 mm) for steel pipe and 6 in. (152 mm) for copper tube.*

When the limits of the unsupported armover lengths of 4-5.2.3.4 or this Exception are exceeded, the hanger closest to the sprinkler shall be of a type that prevents upward movement of the piping.

4-5.2.3.5 Wall mounted sidewall sprinklers shall be restrained to prevent movement.

4-5.2.4 Location of Hangers on Cross Mains. This subsection applies to the support of steel pipe only as specified in 4-5.2.3, subject to the provisions of 4-5.2.2.

4-5.2.4.1 On cross mains there shall be at least one hanger between each two branch lines.

Exception No. 1: In bays having two branch lines, the intermediate hanger shall be permitted to be omitted provided that a hanger attached to a purlin is installed on each branch line located as near to the cross main as the location of the purlin permits. Remaining branch line hangers shall be installed in accordance with 4-5.2.3.

Exception No. 2: In bays having three branch lines, either side or center feed, one (only) intermediate hanger shall be permitted to be omitted provided that a hanger attached to a purlin is installed on each branch line located as near to the cross main as the location of the purlin permits. Remaining branch line hangers shall be installed in accordance with 4-5.2.3.

Exception No. 3: In bays having four or more branch lines, either side or center feed, two intermediate hangers shall be permitted to be omitted provided the maximum distance between hangers does not exceed the distances specified in 4-5.2.2.1 and a hanger attached to a purlin on each branch line is located as near to the cross main as the purlin permits.

4-5.2.4.2 Intermediate hangers shall not be omitted for copper tube.

4-5.2.4.3 At the end of the cross main, intermediate trapeze hangers shall be installed unless the cross main is extended to the next framing member with a hanger installed at this point, in which event an intermediate hanger shall be permitted to be omitted in accordance with 4-5.2.4.1, Exceptions No. 1, No. 2, and No. 3.

4-5.2.5 Support of Risers.

4-5.2.5.1 Risers shall be supported by pipe clamps or by hangers located on the horizontal connections close to the riser.

4-5.2.5.2 Clamps supporting pipe by means of setscrews shall not be used.

4-5.2.5.3 In multistory buildings, riser supports shall be provided at the lowest level, at each alternate level above, above and below offsets, and at the top of the riser. Supports above the lowest level shall also restrain the pipe to prevent movement by an upward thrust when flexible fittings are used. Where risers are supported from the ground, the ground support constitutes the first level of riser support. Where risers are offset or do not rise from the ground, the first ceiling level above the offset constitutes the first level of riser support.

4-5.2.5.4 Risers in vertical shafts, or in buildings with ceilings over 25 ft (7.6 m) high, shall have at least one support for each riser pipe section.

4-5.3 Drainage.

4-5.3.1* All sprinkler pipe and fittings shall be so installed that the system can be drained.

4-5.3.2 On wet pipe systems, sprinkler pipes shall be permitted to be installed level. Trapped piping shall be drained in accordance with 4-5.3.5.

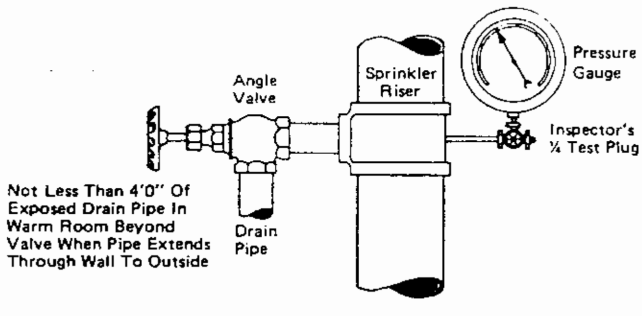
4-5.3.3 In dry pipe systems and portions of preaction systems subject to freezing, branch lines shall be pitched at least 1/2 in. per 10 ft (4 mm/m) and mains shall be pitched at least 1/4 in. per 10 ft (2 mm/m).

Exception: Mains shall be pitched at least 1/2 in. per 10 ft (4 mm/m) in refrigerated areas.

4-5.3.4 System, Main Drain, or Sectional Drain Connections. [*See Figures 4-5.3.4 and A-4-6.4.2(b).*]

4-5.3.4.1 Provisions shall be made to properly drain all parts of the system.

4-5.3.4.2 Drain connections for systems supply risers and mains shall be sized as shown in Table 4-5.3.4.2.



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure 4-5.3.4 Drain connection for system riser.

Table 4-5.3.4.2

Riser or Main Size	Size of Drain Connection
Up to 2 in.	3/4 in. or larger
2 1/2 in., 3 in., 3 1/2 in.	1 1/4 in. or larger
4 in. and larger	2 in. only

4-5.3.4.3 When interior sectional or floor control valve(s) are provided, they shall be provided with a drain connection sized as shown in Table 4-5.3.4.2 to drain that portion of the system controlled by the sectional valve. Drains shall discharge outside or to a drain connection. [*See Figure A-4-6.4.2(b).*]

4-5.3.4.4 The test connections required by 4-6.4.1 shall be permitted to be used as main drain connections.

Exception: When drain connections for floor control valves are tied into a common drain riser, the drain riser shall be one pipe size larger than the largest size drain connection tying into it.

4-5.3.5 Auxiliary Drains.

4-5.3.5.1 Auxiliary drains shall be provided when a change in piping direction prevents drainage of system piping through the main drain valve.

4-5.3.5.2 Auxiliary Drains for Wet Pipe Systems and Preaction Systems in Areas Not Subject to Freezing.

4-5.3.5.2.1 When the capacity of trapped sections of pipes in wet systems is less than 5 gal (18.9 L), the auxiliary drain shall consist of a nipple and cap or plug not less than 1/2 in. (12 mm) in size.

Exception: Auxiliary drains are not required for system piping that can be drained by removing a single pendent sprinkler.

4-5.3.5.2.2 When the capacity of isolated trapped sections of pipe is more than 5 gal (18.9 L) and less than 50 gal (189 L), the auxiliary drain shall consist of a valve 3/4 in. or larger and a plug or a nipple and cap.

4-5.3.5.2.3* When the capacity of isolated trapped sections of pipe is 50 gal (18.9 L) or more, the auxiliary drain shall consist of a valve not smaller than 1 in. (25.4 mm), piped to an accessible location.

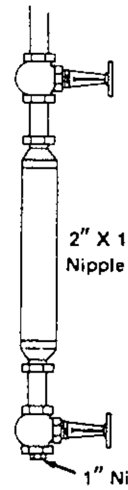
4-5.3.5.2.4 Tie-in drains are not required on wet pipe and preaction systems.

4-5.3.5.3 Auxiliary Drains for Dry Pipe Systems and Preaction Systems in Areas Subject to Freezing.

4-5.3.5.3.1 When capacity of trapped sections of pipe is less than 5 gal (18.9 L), the auxiliary drain shall consist of a valve not smaller than 1/2 in. (12 mm) and a plug or a nipple and cap.

Exception: Auxiliary drains are not required for pipe drops supplying dry-pendent sprinklers installed in accordance with 3-2.2.

4-5.3.5.3.2 When the capacity of isolated trapped sections of system piping is more than 5 gal (18.9 L), the auxiliary drain shall consist of two 1-in. (25-mm) valves and one 2-in. by 12-in. (51-mm by 305-mm) condensate nipple or equivalent, accessibly located. (*See Figure 4-5.3.5.3.2.*)



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure 4-5.3.5.3.2 Dry system auxiliary drain.

4-5.3.5.3.3 Tie-in drains shall be provided for multiple adjacent trapped branch pipes and shall only be 1 in. (25.4 mm). Tie-in drain lines shall be pitched a minimum of 1/2 in. per 10 ft (4 mm/m).

4-5.3.6 Discharge of Drain Valves.

4-5.3.6.1* Direct interconnections shall not be made between sprinkler drains and sewers. The drain discharge shall conform to any health or water department regulations.

4-5.3.6.2 When drain pipes are buried underground, approved corrosion-resistant pipe shall be used.

4-5.3.6.3 Drain pipes shall not terminate in blind spaces under the building.

4-5.3.6.4 When exposed to the atmosphere, drain pipes shall be fitted with a turned down elbow.

4-5.3.6.5 Drain pipes shall be arranged to avoid exposing any part of the sprinkler system to freezing conditions.

4-5.4 Protection of Piping.

4-5.4.1 Protection of Piping against Freezing.

4-5.4.1.1 When portions of systems are subject to freezing and temperatures cannot reliably be maintained at or above 40°F (4°C), sprinklers shall be installed as a dry pipe or preaction system.

Exception: Small unheated areas are permitted to be protected by antifreeze systems or by other systems specifically listed for this purpose. (See 3-5.2.)

4-5.4.1.2 When water-filled supply pipes, risers, system risers, or feed mains pass through open areas, cold rooms, passageways, or other areas exposed to freezing, the pipe shall be protected against freezing by insulating coverings, frostproof casings, or other reliable means capable of maintaining a minimum temperature of 40°F (4°C).

4-5.4.2 Protection of Piping against Corrosion.

4-5.4.2.1* When corrosive conditions are known to exist due to moisture or fumes from corrosive chemicals or both, special types of fittings, pipes, and hangers that resist corrosion shall be used or a protective coating shall be applied to all unprotected exposed surfaces of the sprinkler system. (*See 2-2.4.*)

4-5.4.2.2 When water supplies are known to have unusual corrosive properties and threaded or cut groove steel pipe is to be used, wall thickness shall be in accordance with Schedule 30 [in sizes 8 in. (203 mm) or larger] or Schedule 40 [in sizes less than 8 in. (203 mm)].

4-5.4.2.3 Steel pipe, when exposed to weather, shall be externally galvanized or otherwise protected against corrosion.

4-5.4.2.4 When steel pipe is used underground the pipe shall be protected against corrosion.

4-5.4.3 Protection of Piping against Damage Where Subject to Earthquakes.

4-5.4.3.1* **General.** Sprinkler systems shall be protected to prevent pipe breakage where subject to earthquakes in accordance with the requirements of 4-5.4.3.

Exception: Alternative methods of providing earthquake protection of sprinkler systems based on a dynamic seismic analysis certified by a registered professional engineer such that system performance will be at least equal to that of the building structure under expected seismic forces.

4-5.4.3.2* Couplings. Listed flexible pipe couplings joining grooved end pipe shall be provided as flexure joints to allow individual sections of piping $3^1/_2$ in. (89 mm) or larger to move differentially with the individual sections of the building to which it is attached. Couplings shall be arranged to coincide with structural separations within a building. They shall be installed:

(a) Within 24 in. (610 mm) of the top and bottom of all risers.

Exception No. 1: In risers less than 3 ft (0.9 m) in length flexible couplings are permitted to be omitted.

Exception No. 2: In risers 3 to 7 ft (0.9 to 2.1 m) in length, one flexible coupling is adequate.

(b) Within 12 in. (305 mm) above or below the floor in multistory buildings.

(c) On one side of concrete or masonry walls within 3 ft (0.9 m) of the wall surface.

(d)* At or near building expansion joints.

(e) Within 24 in. of the ceiling at the top of drops to hose lines, rack sprinklers, and mezzanines, regardless of pipe size.

(f) Within 24 in. of the ceiling at the top of drops exceeding 15 ft (4.6 m) in length to portions of systems supplying more than one sprinkler, regardless of pipe size.

4-5.4.3.3* Seismic Separation Assembly. Seismic separation assemblies with flexible fittings shall be installed where sprinkler piping, regardless of size, crosses building seismic separation joints above ground level.

4-5.4.3.4* Clearance. Clearance shall be provided around all piping extending through walls, floors, platforms, and foundations, including drains, fire department connections, and other auxiliary piping.

(a) Minimum clearance on all sides shall be not less than 1 in. (25 mm) for pipes 1 in. (25 mm) through $3^1/_2$ in. (89 mm), and 2 in. (51 mm) for pipe sizes 4 in. (102 mm) and larger.

Exception No. 1: When clearance is provided by a pipe sleeve, a nominal diameter 2 in. (51 mm) larger than the nominal diameter of the pipe is acceptable for pipe sizes 1 in. (25 mm) through $3^1/_2$ in. (89 mm), and the clearance provided by a pipe sleeve of nominal diameter 4 in. (102 mm) larger than the nominal diameter of the pipe is acceptable for pipe sizes 4 in. (102 mm) and larger.

Exception No. 2: No clearance is necessary for piping passing through gypsum board or equally frangible construction that is not required to have a fire-resistance rating.

Exception No. 3: No clearance is necessary if flexible couplings or swing joints are located within 1 ft (0.3 m) of each side of a wall.

(b) When required the clearance shall be filled with a flexible material such as mastic.

4-5.4.3.5 Sway Bracing.

4-5.4.3.5.1* Both lateral and longitudinal sway braces shall be sized and fastened to the structure such that the horizontal loads assigned to the braces in Table 4-5.4.3.5.1(a) do not exceed the allowable loads on the braces as shown in Table 4-5.4.3.5.1(b) and the allowable loads on fasteners as shown in Table 4-5.4.3.5.1(c). Sway bracing shall be tight and concentric. All parts and fittings of a brace shall lie in a straight line to avoid eccentric loadings on fittings and fasteners. For longitudinal braces only, the brace shall be permitted to be connected to a tab welded to the pipe in conformance with 2-5.2. The structural component shall be capable of carrying the added applied loads.

Exception: In lieu of using Table 4-5.4.3.5.1(a), horizontal loads for braces shall be permitted to be determined by analysis. Sway braces shall be designed to withstand a force in tension or compression equivalent to not less than half the weight of water-filled piping. For lateral braces, the load shall include all branch lines and mains within the zone of influence of the brace. For longitudinal braces, the load shall include all mains within the zone of influence of the brace. For individual braces the slenderness ratio l/r shall not exceed 200, where l is the length of the brace and r is the least radius of gyration, both in inches.

Table 4-5.4.3.5.1(a) Assigned Load Table (Based on half the weight of the water-filled pipe)

Spacing of Lateral Braces (ft)	Spacing of Longitudinal Braces** (ft)	Assigned Load for Pipe Size to Be Braced (lb) 2	$2^1/_2$	3	4	5	6	8
10	20	380	395	410	435	470	655	915
20	40	760	785	815	870	940	1305	1830
25	50	950	980	1020	1090	1175	1630	2290
30	60	1140	1180	1225	1305	1410	1960	2745
40	80	1515	1570	1630	1740	1880	2610	3660
50*		1895	1965	2035	2175	2350	3260	4575

*Permitted only under Exception No. 4 to 4-5.4.3.5.4

**If branch lines are provided with lateral bracing or hung with U-hooks bent out at least 30 degrees from vertical, half the assigned load may be used for longitudinal braces.

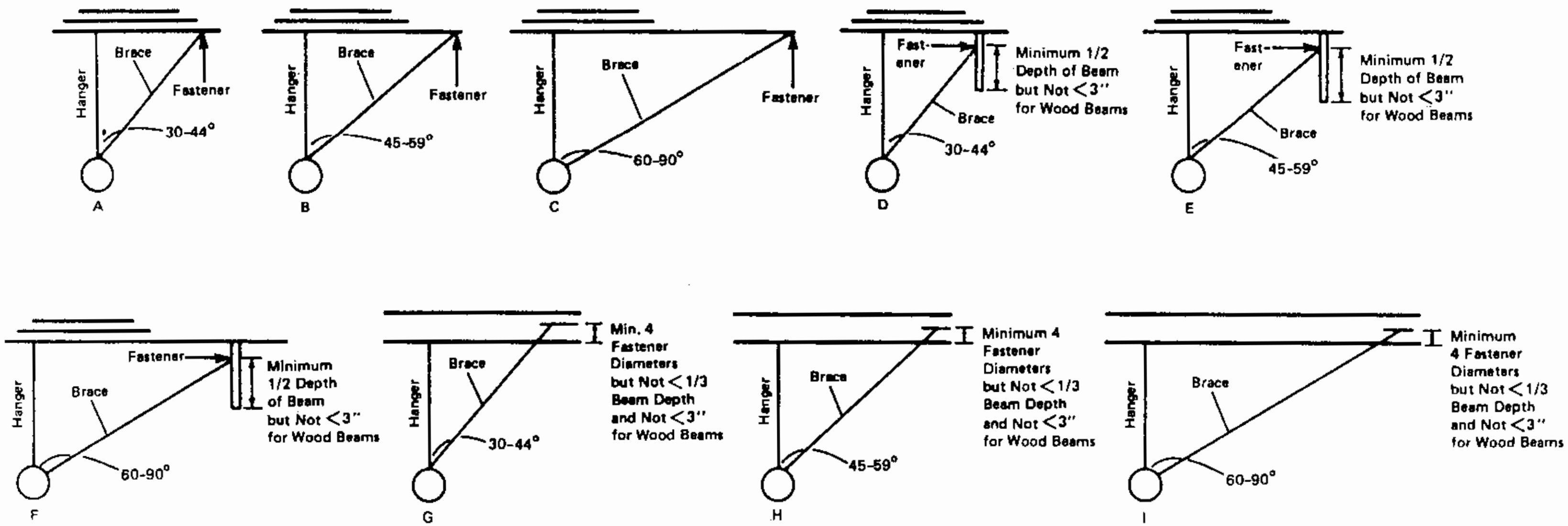
Table 4-5.4.3.5.1(b)

Shape and Size	Least Radius of Gyration	Maximum Length for l/r = 200	Maximum Horizontal Load (lb) 30° Angle from Vertical	45° Angle from Vertical	60° Angle from Vertical
Pipe (Schedule 40)	$= \frac{\sqrt{r_0^2 + r_i^2}}{2}$				
1 in.	.42	7 ft 0 in.	1767	2500	3061
1¼ in.	.54	9 ft 0 in.	2393	3385	4145
1½ in.	.623	10 ft 4 in.	2858	4043	4955
2 in.	.787	13 ft 1 in.	3828	5414	6630
Pipe (Schedule 10)	$= \frac{\sqrt{r_0^2 + r_i^2}}{2}$				
1 in.	.43	7 ft 2 in.	1477	2090	2559
1¼ in.	.55	9 ft 2 in.	1900	2687	3291
1½ in.	.634	10 ft 7 in.	2194	3103	3800
2 in.	.802	13 ft 4 in.	2771	3926	4803
Angles					
1½ × 1½ × ¼	.292	4 ft 10 in.	2461	3481	4263
2 × 2 × ¼	.391	6 ft 6 in.	3356	4746	5813
2½ × 2 × ¼	.424	7 ft 0 in.	3792	5363	6569
2½ × 2½ × ¼	.491	8 ft 2 in.	4257	6021	7374
3 × 2½ × ¼	.528	8 ft 10 in.	4687	6628	8118
3 × 3 × ¼	.592	9 ft 10 in.	5152	7286	8923
Rods	$= \frac{r}{2}$				
⅜	.094	1 ft 6 in.	395	559	685
½	.125	2 ft 6 in.	702	993	1217
⅝	.156	2 ft 7 in.	1087	1537	1883
¾	.188	3 ft 1 in.	1580	2235	2737
⅞	.219	3 ft 7 in.	2151	3043	3726
Flats	= 0.29 h (where h is smaller of two side dimensions)				
1½ × ¼	.0725	1 ft 2 in.	1118	1581	1936
2 × ¼ in.	.0725	1 ft 2 in.	1789	2530	3098
2 × ⅜	.109	1 ft 9 in.	2683	3795	4648

Table 4-5.4.3.5.1(c) Maximum Loads for Various Types of Structure

Maximum Loads for Various Types of Fasteners to Structure

NOTE: Loads (given in pounds) are keyed to vertical angles of braces and orientation of connecting surface. These values are based on concentric loadings of the fastener. Use figures to determine proper reference within table. For angles between those shown, use most restrictive case. Braces should not be attached to light structure members.



Lag Screws in Wood (load perpendicular to grain—holes predrilled using good practice)
Shank Diameter of Lag (in.)

Length Under Head (in.)	3/8 A	B	C	D	E	F	G	H	I
3	304	325	292	168	325	526	230	324	400
4	392	354	517	183	354	678	250	352	435
5	476	375	336	194	375	824	265	373	461
6	564	382	342	196	382	976	270	380	470
8	—	—	—	—	—	—	—	—	—

Length Under Head (in.)	1/2 A	B	C	D	E	F	G	H	I
3	366	—	—	—	—	834	—	—	—
4	473	509	456	264	509	818	360	507	626
5	582	545	488	282	545	1008	385	542	670
6	689	559	501	209	559	1192	395	556	687
8	905	573	513	296	573	1586	405	570	704

Length Under Head (in.)	5/8 A	B	C	D	E	F	G	H	I
3	410	—	—	—	—	716	—	—	—
4	538	—	—	—	—	532	—	—	—
5	687	728	653	277	728	1154	515	725	896
6	791	778	697	403	778	1360	550	775	957
8	1044	806	723	416	806	1807	570	803	991

Length Under Head (in.)	7/8 A	B	C	D	E	F	G	H	I
3	487	—	—	—	—	843	—	—	—
4	548	—	—	—	—	1122	—	—	—
5	813	—	—	—	—	1407	—	—	—
6	971	—	—	—	—	1630	—	—	—
8	1297	1365	1223	685	1365	2244	965	1359	1678

Table 4-5.4.3.5.1(c) Maximum Loads for Various Types of Structure (cont.)

Through Bolts in wood (load perpendicular to grain)
Diameter of Bolt (in.)

Length of Bolt in Timber (in.)	3/8 ABCE	3/8 D	3/8 F	3/8 G	3/8 H	3/8 I	1/2 ABCE	1/2 D	1/2 F	1/2 G	1/2 H	1/2 I
1½	300	173	519	150	211	261	340	197	589	170	239	296
2	370	214	641	185	261	322	420	243	727	210	296	365
2½	460	266	796	230	324	400	550	318	952	275	387	478
3	480	277	831	240	338	417	630	364	1091	315	444	548
3⅝	460	268	797	230	324	400	720	416	1247	360	507	626
5½	—	—	—	—	—	—	680	393	1177	340	479	591

Length of Bolt in Timber (in.)	5/8 ABCE	5/8 D	5/8 F	5/8 G	5/8 H	5/8 I	7/8 ABCE	7/8 D	7/8 F	7/8 G	7/8 H	7/8 I
1½	390	225	675	195	275	339	470	272	614	235	331	409
2	470	272	814	235	331	409	580	335	1004	290	408	504
2½	620	358	1074	310	437	539	760	439	1316	380	535	661
3	710	410	1229	355	500	617	870	503	1506	435	613	757
3⅝	850	491	1472	425	599	739	1050	607	1818	525	739	913
5½	1020	590	1766	510	718	887	1580	913	2736	790	1113	1374

Expansion Shields in Concrete
Diameter of Bolt (in.)

Min. Depth of Hole (in.)	3/8 A	3/8 B	3/8 C	3/8 D	3/8 E	3/8 F	3/8 G	3/8 H	3/8 I	1/2 A	1/2 B	1/2 C	1/2 D	1/2 E	1/2 F	1/2 G	1/2 H	1/2 I
2½	498	962	1173	678	962	962	925	1303	1609	-	-	-	-	-	-	1638	2306	2848
3¼	-	-	-	-	-	-	925	1303	1609	923	1782	2076	1200	1782	1597	1638	2306	2848
3¾	-	-	-	-	-	-	925	1303	1609	-	-	-	-	-	-	1638	2306	2848
4½	-	-	-	-	-	-	925	1303	1609	-	-	-	-	-	-	1638	2306	2848

Min. Depth of Hole (in.)	5/8 A	5/8 B	5/8 C	5/8 D	5/8 E	5/8 F	5/8 G	5/8 H	5/8 I	7/8 A	7/8 B	7/8 C	7/8 D	7/8 E	7/8 F	7/8 G	7/8 H	7/8 I
2½	-	-	-	-	-	-	2080	2930	3617	-	-	-	-	-	-	2470	4113	5078
3¼	-	-	-	-	-	-	2080	2930	3617	-	-	-	-	-	-	2970	4113	5078
3¾	1480	2857	2637	1524	2857	2581	2080	2930	3617	-	-	-	-	-	-	2970	4113	5078
4½	-	-	-	-	-	-	2080	2930	3617	3070	4130	3702	2139	4130	5312	2970	4113	5078

Connections to Steel (values assume bolt perpendicular to mounting surface)
Diameter of Unfinished Steel Bolt (in.)

Diameter	A	B	C	D	E	F	G	H	I
1/4	400	500	600	300	500	650	325	458	565
3/8	900	1200	1400	800	1200	1550	735	1035	1278
1/2	1600	2050	2550	1450	2050	2850	1300	1830	2260
5/8	2500	3300	3950	2250	3300	4400	2045	2880	3557

For SI Units: 1 in. = 25.4 mm.

4-5.4.3.5.2 Longitudinal sway bracing spaced at a maximum of 80 ft (24 m) on center shall be provided for feed and cross mains.

4-5.4.3.5.3* Tops of risers shall be secured against drifting in any direction, utilizing a four-way sway brace.

4-5.4.3.5.4 Lateral sway bracing spaced at a maximum of 40 ft (12 m) on center shall be provided for feed and cross mains.

Exception No. 1: Lateral sway bracing shall be permitted to be omitted on pipes individually supported by rods less than 6 in. (152 mm) long.

Exception No. 2: Wraparound U-type hangers used to support the mains shall be permitted to be used to satisfy the requirements for lateral sway bracing provided the legs are bent out at least 30 degrees from the vertical and the maximum length of each leg satisfies the conditions of Table 4-5.4.3.5.1(b).

Exception No. 3: When flexible couplings are installed on mains other than as required in 4-5.4.3.2, a lateral brace shall be provided within 24 in. (610 mm) of every other coupling, but not more than 40 ft (12 m) on center.

Exception No. 4: When building primary structural members exceed 40 ft (12 m) on center, lateral braces shall be permitted to be spaced up to 50 ft (15.2 m) on center.

4-5.4.3.5.5 Bracing shall be attached directly to feed and cross mains.

4-5.4.3.5.6 A length of pipe shall not be braced to sections of the building that will move differentially.

4-5.4.3.5.7 The last length of pipe at the end of a feed or cross main shall be provided with a lateral brace. Lateral braces may also act as longitudinal braces if they are within 24 in. (610 mm) of the center line of the piping braced longitudinally.

4-5.4.3.5.8* Sway bracing is not required for branch lines.

Exception No. 1: The end sprinkler on a line shall be restrained against excessive movement by use of a wraparound U-hook (see Figure A-2-6.1) or by other approved means.

Exception No. 2: Branch lines $2^1/_2$ in. (64 mm) or larger shall be provided with lateral bracing in accordance with 4-5.4.3.5.4.

Exception No. 3: Where upward or lateral movement of sprinklers would result in an impact against the building structure, equipment, or finish materials, branch lines shall be provided at intervals not exceeding 30 ft (9 m) with a wraparound U-hook, lateral sway brace, or #12, 440 lb (200 kg) splayed seismic brace wire installed at least 45 degrees from the vertical plane and anchored on both sides of the pipe. This bracing shall be located within 2 ft (610 mm) of a hanger. The hanger closest to a splayed wire restraint shall be of a type that resists upward movement of a branch line.

4-5.4.3.5.9 C-type clamps (including beam and large flange clamps) used to attach hangers to the building structure in areas subject to earthquakes shall be equipped with a retaining strap or other approved means to prevent movement. (*See Figure A-2-6.1.*)

4-5.4.3.5.10 C-type clamps (including beam and large flange clamps), with or without retaining straps, shall not be used to attach braces to the building structure.

4-6 System Attachments.

4-6.1 Sprinkler Alarms.

4-6.1.1* Waterflow Alarms.

4-6.1.1.1 Local waterflow alarms shall be provided on all sprinkler systems having more than 20 sprinklers.

4-6.1.1.2 On each alarm check valve used under conditions of variable water pressure, a retarding device shall be installed. Valves shall be provided in the connections to retarding devices to permit repair or removal without shutting off sprinklers; these valves shall be so arranged that they may be locked or sealed in the open position.

4-6.1.1.3 Alarm, dry pipe, preaction, and deluge valves shall be fitted with an alarm bypass test connection for an electric alarm switch, water motor gong, or both. This pipe connection shall be made on the water supply side of the system and provided with a control valve and drain for the alarm piping. A check valve shall be installed in the pipe connection from the intermediate chamber of a dry pipe valve.

4-6.1.1.4 An indicating control valve shall be installed in the connection to pressure-type contactors or water-motor-operated alarm devices. Such valves shall be locked or sealed in the open position. The control valve for the retarding chamber on alarm check valves shall be accepted as complying with this paragraph.

4-6.1.1.5* Attachments — Mechanically Operated. For all types of sprinkler systems employing water-motor-operated alarms, a listed $^3/_4$-in. (19-mm) strainer shall be installed at the alarm outlet of the waterflow detecting device.

Exception: When a retarding chamber is used in connection with an alarm valve, the strainer shall be located at the outlet of the retarding chamber unless the retarding chamber is provided with an approved integral strainer in its outlet.

4-6.1.1.6* Alarm Attachments — High-Rise Buildings. When a fire must be fought internally due to the height of a building, the following additional alarm apparatus shall be provided:

(a) When each sprinkler system on each floor is equipped with a separate waterflow device, it shall be connected to an alarm system in such a manner that operation of one sprinkler will actuate the alarm system and the location of the operated flow device shall be indicated on an annunciator and/or register. The annunciator or register shall be located at grade level at the normal point of fire department access, at a constantly attended building security control center, or at both locations.

Exception: When the location within the protected buildings where supervisory or alarm signals are received is not under constant supervision by qualified personnel in the employ of the owner, a connection shall be provided to transmit a signal to a remote central station.

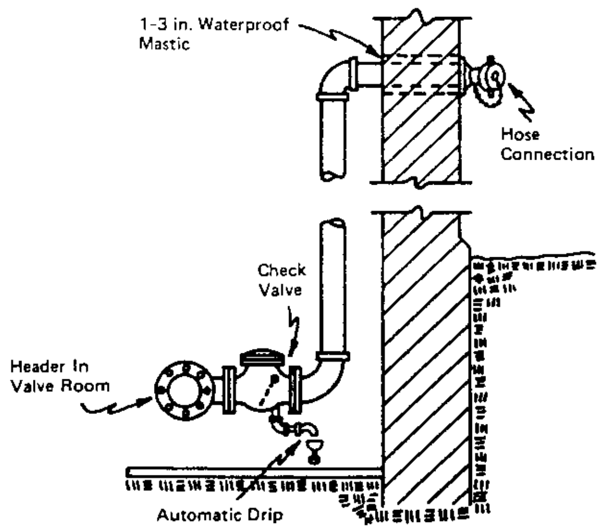
(b) A distinct trouble signal shall be provided to indicate a condition that will impair the satisfactory operation of the sprinkler system.

4-6.2* Fire Department Connections.

4-6.2.1* A fire department connection shall be provided as described in this section. (*See Figure 4-6.2.1.*)

Exception No. 1: Omission of the fire department connection shall be permitted for systems having 20 sprinklers or less.

Exception No. 2: Omission of the fire department connection shall be permitted when approved by the authority having jurisdiction.



For SI Units: 1 in. = 25.4 mm.

Figure 4-6.2.1 Fire department connection.

4-6.2.2 Size. Pipe size shall be 4 in. (102 mm) for fire engine connections and 6 in. (152 mm) for fire boat connections.

Exception No. 1: For hydraulically calculated systems, fire department connection pipe as small as the system riser shall be permitted when serving one system riser.

Exception No. 2: A single outlet fire department connection shall be acceptable when piped to a 3-in. (76-mm) or smaller riser.

4-6.2.3* Arrangement. (*See Figure 4-6.2.1.*)

4-6.2.3.1 The fire department connection shall be on the system side of the water supply check valve.

4-6.2.3.2 For single systems, the fire department connection shall be installed as follows:

(a) *Wet System.* On the system side of system control, check, and alarm valves. (*See Figure A-4-5.1.1.*)

(b) *Dry System.* Between the system control valve and the dry pipe valve.

(c) *Preaction System.* Between the preaction valve and the check valve on the system side of the preaction valve.

(d) *Deluge System.* On the system side of the deluge valve.

Exception: Connection of the fire department connection to underground piping is acceptable.

4-6.2.3.3 For multiple systems, the fire department connection shall be connected between the supply control valves and the system control valves.

Exception: Connection of the fire department connection to underground piping is acceptable.

4-6.2.3.4 Fire department connections shall be located and arranged so that hose can be readily and conveniently attached.

Each fire department connection to sprinkler systems shall be designated by a sign having raised letters at least 1 in. (25.4 mm) in height cast on plate or fitting reading service design, e.g., "AUTOSPKR.," "OPEN SPKR. AND STANDPIPE."

4-6.2.3.5 Fire department connections shall not be connected on the suction side of fire pumps.

4-6.2.4 Valves.

4-6.2.4.1 A listed check valve shall be installed in each fire department connection.

4-6.2.4.2 There shall be no shutoff valve in the fire department connection piping.

4-6.2.5 Drainage. The piping between the check valve and the outside hose coupling shall be equipped with an approved automatic drip.

Exception: An automatic drip is not required in areas not subject to freezing.

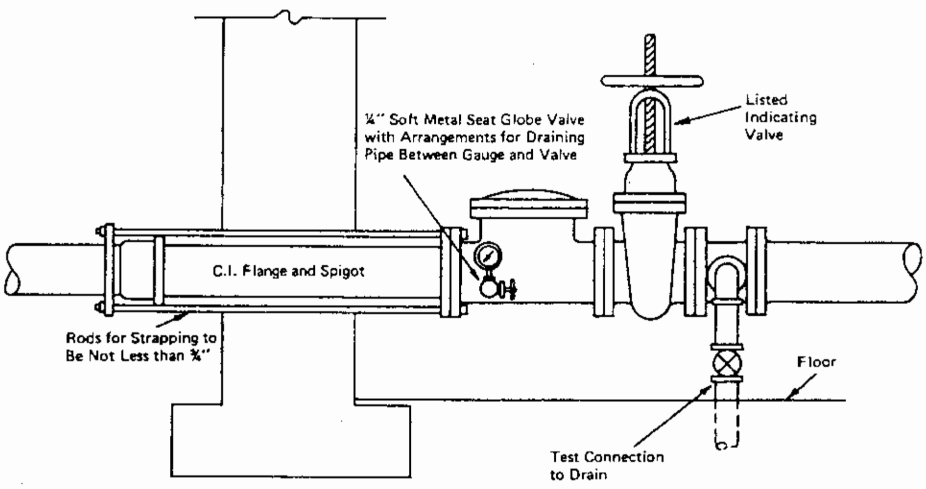
4-6.3 Gauges.

4-6.3.1 A pressure gauge with a connection not smaller than 1/4 in. (6.4 mm) shall be installed at the system main drain, at each main drain associated with a floor control valve, and on the inlet and outlet side of each pressure reducing valve. Each gauge connection shall be equipped with a shutoff valve and provisions for draining.

4-6.3.2 The required pressure gauges shall be listed and shall have a maximum limit not less than twice the normal working pressure at the point where installed. They shall be installed to permit removal and shall be located where they will not be subject to freezing.

4-6.4 System Test Connections.

4-6.4.1 Waterflow Test Connections. Waterflow test connections shall be provided at locations that will permit flow tests of water supplies and connections. They shall be so



For SI Units: 1 in. = 25.4 mm.

Figure 4-6.4.1 Water supply connection with test connection.

installed that the valve may be opened wide for a sufficient time to assure a proper test without causing water damage. (*See 4-5.3.4 and 4-5.3.6.*)

4-6.4.2* Wet Pipe Systems. A test connection not less than 1 in. (25 mm) in diameter, terminating in a smooth bore corrosion-resistant orifice, giving a flow equivalent to one sprinkler of a type having the smallest orifice installed on the particular system, shall be provided to test each waterflow alarm device for each system. The test connection valve shall be readily accessible. The discharge shall be to the outside, to a drain connection capable of accepting full flow under system pressure, or to another location where water damage will not result.

4-6.4.3* Dry Pipe Systems. A test connection not less than 1 in. (25 mm) in diameter, terminating in a smooth bore corrosion-resistant orifice, to provide a flow equivalent to one sprinkler of a type installed on the particular system, shall be installed on the end of the most distant sprinkler pipe in the upper story and be equipped with a readily accessible 1-in. (22-mm) shutoff valve and plug, at least one of which shall be brass. In lieu of a plug, a nipple and cap shall be acceptable.

4-6.4.4 Preaction Systems. A test connection shall be provided on a preaction system using supervisory air. The connection used to control the level of priming water is adequate to test the operation of the alarms monitoring the supervisory air pressure.

4-6.4.5 Deluge Systems. A test connection is not required on a deluge system.

Chapter 5 Design Approaches

5-1 General. Water demand requirements shall be determined from the occupancy hazard fire control approach of Section 5-2.

Exception: Special design approaches shall be permitted for specific hazards in Section 5-3.

5-2 Occupancy Hazard Fire Control Approach.

5-2.1 Occupancy Classifications.

5-2.1.1 Occupancy classifications for this standard relate to sprinkler installations and their water supplies only. They shall not be used as a general classification of occupancy hazards.

5-2.1.2 Occupancies or portions of occupancies shall be classified according to the quantity and combustibility of contents, the expected rates of heat release, the total potential for energy release, the heights of stockpiles, and the presence of flammable and combustible liquids, using the definitions contained in 1-4.7. Classifications are as follows:

Light Hazard

Ordinary Hazard (Groups 1 and 2)

Extra Hazard (Groups 1 and 2)

Special Occupancy Hazard

5-2.2 Water Demand Requirements—Pipe Schedule Method.

5-2.2.1 Table 5-2.2 shall be used in determining the minimum water supply requirements for Light and Ordinary Hazard Occupancies protected by systems with pipe sized according to the pipe schedules of Section 6-5. Pressure and flow requirements for Extra Hazard Occupancies shall be based on the hydraulic calculation methods of 5-2.3. The pipe schedule method shall be permitted only for new installations of 5000 sq ft (465 m^2) or less or for additions or modifications to existing pipe schedule systems.

Exception No. 1: The pipe schedule design method shall be permitted for use in systems exceeding 5000 sq ft (465 m^2) when the flows required in Table 5-2.2 are available at a minimum residual pressure of 50 psi (3.4 bar) at the elevation of the highest sprinkler.

Exception No. 2: The pipe schedule method shall be permitted for additions or modifications to existing extra hazard pipe schedule systems if the pressures and flows are determined to be acceptable to the authority having jurisdiction.

5-2.2.2 The lower duration value of Table 5-2.2 shall be acceptable only where remote station or central station waterflow alarm service is provided.

5-2.2.3* The residual pressure requirement of Table 5-2.2 shall be met at the elevation of the highest sprinkler. (*See the Exceptions to 5-2.2.1.*)

5-2.2.4 The lower flow figure of Table 5-2.2 shall be permitted only where the building is of noncombustible construction or the potential areas of fire are limited by building size or compartmentation such that no open areas exceed 3000 sq ft (279 m^2) for Light Hazard or 4000 sq ft (372 m^2) for Ordinary Hazard.

Table 5-2.2 Water Supply Requirements for Pipe Schedule Sprinkler Systems

Occupancy Classification	Minimum Residual Pressure Required	Acceptable Flow at Base of Riser	Duration in Minutes
Light Hazard	15 psi	500-750 gpm	30-60
Ordinary Hazard	20 psi	850-1500 gpm	60-90

For SI Units: 1 gpm = 3.785L/min; 1 psi = 0.0689 bar.

5-2.3 Water Demand Requirements—Hydraulic Calculation Methods.

5-2.3.1 General.

5-2.3.1.1* The minimum water supply requirements for a hydraulically designed occupancy hazard fire control sprinkler system shall be determined by adding the hose stream demand from Table 5-2.3 to the water supply for sprinklers determined in 5-2.3.1.2. This supply shall be available for the minimum duration specified in Table 5-2.3.

Exception No. 1: Where other NFPA standards have developed sprinkler system area/density or other design criteria and water supply requirements appropriate for fire control or suppression of Special Occupancy Hazards, they shall take precedence.

Exception No. 2: An allowance for inside and outside hose shall not be required when tanks supply sprinklers only.

Exception No. 3: When pumps taking suction from a private fire service main supply sprinklers only, the pump need not be sized to accommodate inside and outside hose. Such hose allowance shall be considered in evaluating the available water supplies.

5-2.3.1.2 The water supply for sprinklers only shall be determined either from the area/density curves of Figure 5-2.3 (*see following page*) in accordance with the method of 5-2.3.2 or be based upon the room design method in accordance with 5-2.3.3, at the discretion of the designer. For special areas under consideration, as described in 5-2.3.4, separate hydraulic calculations shall be required in addition to those required by 5-2.3.2 or 5-2.3.3.

Table 5-2.3 Hose Stream Demand and Water Supply Duration Requirements

Hazard Classification	Inside Hose (gpm)	Total Combined Inside and Outside Hose (gpm)	Duration in Minutes
Light	0, 50, or 100	100	30
Ordinary	0, 50, or 100	250	60-90
Extra Hazard	0, 50, or 100	500	90-120

For SI Units: 1 gpm = 3.785L/min.

5-2.3.1.3 Regardless of which of the two methods is used, the following restrictions apply:

(a) For areas of sprinkler operation less than 1500 sq ft (139 m^2) used for Light and Ordinary Hazard Occupancies, the density for 1500 sq ft (139 m^2) shall be used. For areas of sprinkler operation less than 2500 sq ft (232 m^2) for Extra Hazard Occupancies, the density for 2500 sq ft (232 m^2) shall be used.

(b)* For buildings having unsprinklered combustible concealed spaces (as described in 4-4.1.7.1.1) the minimum area of sprinkler operation shall be 3000 sq ft (279 m^2).

Exception No. 1: Combustible concealed spaces filled entirely with noncombustible insulation.

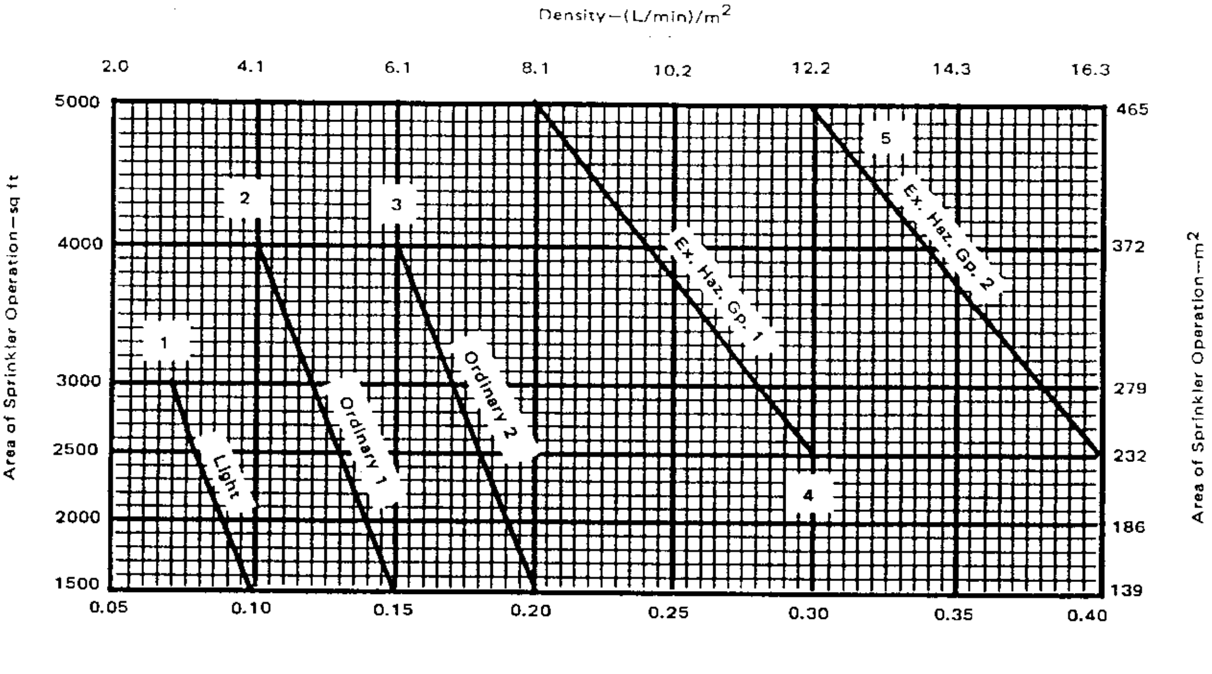
Exception No. 2: Light or Ordinary Hazard Occupancies where noncombustible or limited combustible ceilings are directly attached to the bottom of solid wood joists so as to create enclosed joist spaces 160 cu ft (4.8 m^3) or less in volume.

Exception No. 3: Concealed spaces where the exposed surfaces have a flame spread rating of 25 or less and the materials have been demonstrated to not propagate fire in the form in which they are installed in the space.*

(c) Water demand of sprinklers installed in racks or water curtains shall be added to the ceiling sprinkler water demand at the point of connection. Demands shall be balanced to the higher pressure. (*See Chapter 6.*)

Water demand of sprinklers installed in concealed spaces or under obstructions such as ducts and cutting tables need not be added to ceiling demand.

(d) When inside hose stations are planned or are required by other standards, a total water allowance of 50 gpm (189 L/min) for a single hose station installation or 100 gpm (378 L/min) for a multiple hose station installation shall be added to the sprinkler requirements. The water allowance shall be added in 50 gpm (189 L/min) increments beginning at the most remote hose station, with each increment added at the pressure required by the sprinkler system design at that point.



For SI Units: 1 sq ft = 0.0929 m²; 1 gpm/sq ft = 40.746 (L/min)/m².

Figure 5-2.3 Area/density curves.

(e) When hose valves for fire department use are attached to wet pipe sprinkler system risers in accordance with 4-4.1.7.24, the water supply need not be added to standpipe demand as determined from NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

Exception No. 1: When the combined sprinkler system demand and hose stream allowance of Table 5-2.3 exceeds the requirements of NFPA 14, Standard for the Installation of Standpipe and Hose Systems, this higher demand shall be used.

Exception No. 2: For partially sprinklered buildings, the sprinkler demand, not including hose stream allowance, as indicated in Table 5-2.3 shall be added to the requirements given in NFPA 14, Standard for the Installation of Standpipe and Hose Systems.

(f) Water allowance for outside hose shall be added to the sprinkler and inside hose requirement at the connection to the city water main, or a yard hydrant, whichever is closer to the system riser.

(g) The lower duration values in Table 5-2.3 shall be permitted where remote station or central station waterflow alarm service is provided.

(h) When pumps, gravity tanks, or pressure tanks supply sprinklers only, requirements for inside and outside hose need not be considered in determining the size of such pumps or tanks.

5-2.3.1.4 Total system water supply requirements shall be determined in accordance with the hydraulic calculation procedures of Section 6-4.

5-2.3.2 Area/Density Method.

5-2.3.2.1 The water supply requirement for sprinklers only shall be calculated from the area/density curves in Figure 5-2.3. The calculations shall satisfy any single point on the appropriate area/density curve as follows:

(a) Light Hazard	Area/Density Curve 1
(b) Ordinary Hazard (Group 1)	Area/Density Curve 2
(c) Ordinary Hazard (Group 2)	Area/Density Curve 3
(d) Extra Hazard (Group 1)	Area/Density Curve 4
(e) Extra Hazard (Group 2)	Area/Density Curve 5

It is not necessary to meet all points on the selected curve.

5-2.3.2.2 The densities and areas provided in Figure 5-2.3 are for use only with spray sprinklers. For use with other types of sprinklers see Section 5-3.

Exception No. 1: Quick-response sprinklers shall be permitted for use with Area/Density Curve 1 (Light Hazard) and Curves 2 and 3 (Ordinary Hazard) of Figure 5-2.3.

Exception No. 2: Sidewall spray sprinklers shall be permitted for use with Area/Density Curve 1 (Light Hazard) and, if specifically listed, with Area/Density Curves 2 or 3 (Ordinary Hazard).

5-2.3.2.3 For dry pipe systems, the area of sprinkler operation shall be increased by 30 percent without revising the density.

5-2.3.2.4 When high temperature sprinklers are used for Extra Hazard Occupancies, the area of sprinkler operation shall be permitted to be reduced by 25 percent without revising the density, but to not less than 2000 sq ft (186 m^2).

5-2.3.3 Room Design Method.

5-2.3.3.1* The water supply requirements for sprinklers only shall be based upon the room that creates the greatest demand. The density selected shall be that from Figure 5-2.3 corresponding to the room size. To utilize this method, all rooms shall be enclosed with walls having a fire-resistance rating equal to the water supply duration indicated in Table 5-2.3.

5-2.3.3.2 If the room is smaller than the smallest area shown in the applicable curve in Figure 5-2.3, the provisions of 5-2.3.1.3(a) shall apply.

5-2.3.3.3 Minimum protection of openings shall be as follows:

(a) Light Hazard — automatic or self-closing doors.

Exception: When openings are not protected, calculations shall include the sprinklers in the room plus two sprinklers in the communicating space nearest each such unprotected opening unless the communicating space has only one sprinkler, in which case calculations shall be extended to the operation of that sprinkler. The selection of the room and communicating space sprinklers to be calculated shall be that which produces the greatest hydraulic demand.

(b) Ordinary and Extra Hazard — automatic or self-closing doors with appropriate fire resistance ratings for the enclosure.

5-2.3.4 Special Design Methods.

5-2.3.4.1 When the design area consists of a building service chute supplied by a separate riser, the maximum number of sprinklers that needs to be calculated is 3.

5-2.3.4.2 When the room design method is used, and the area under consideration is a corridor protected by one row of sprinklers, the maximum number of sprinklers that needs to be calculated is 5. (*See 5-2.3.1.*)

Exception: Where the area under consideration is a corridor protected by a single row of sprinklers and the openings are not protected, the design area shall include all sprinklers in the corridor to a maximum of 7.

5-3 Special Design Approaches.

5-3.1 General. All special design approaches utilize the hydraulic calculation procedures of Section 6-4 except as specified.

5-3.2 Residential Sprinklers.

5-3.2.1 Sprinkler discharge rates shall be provided in accordance with minimum flow rates indicated in individual residential sprinkler listings, both for the single sprinkler discharge and the multiple sprinkler discharge of the design sprinklers.

5-3.2.2* The design area shall be that area that includes the 4 hydraulically most demanding sprinklers.

5-3.2.3 When areas such as attics, basements, or other types of occupancies are outside of dwelling units but within the same structure, these areas shall be protected in accordance with the provisions of this standard, including appropriate design criteria of 5-2.3.

5-3.2.4 Hose stream demand and water supply duration requirements shall be in accordance with those for Light Hazard Occupancies in Table 5-2.3.

5-3.3 Quick Response Early Suppression (QRES) Sprinklers. (Reserved) (*See 1-4.5.1 and A-1-4.5.1.*)

5-3.4* Large-Drop Sprinklers.

5-3.4.1 Protection shall be provided as specified in Table A-5-3.4 or appropriate NFPA standards in terms of minimum operating pressure and the number of sprinklers to be included in the design area.

5-3.4.2 Large-drop sprinkler systems shall be designed such that the minimum operating pressure is not less than 25 psi (170 kPa).

Exception: Lower pressures shall be permitted if proven successful by large-scale fire testing for a particular hazard.

5-3.4.3 For design purposes, 95 psi (650 kPa) shall be the maximum discharge pressure at the hydraulically most remote sprinkler.

5-3.4.4 The nominal diameter of branch line pipes (including riser nipples) shall be not less than $1^1/_4$ in. (33 mm) or greater than 2 in. (51 mm).

Exception No. 1: Starter pieces shall be permitted to be $2^1/_2$ in. (64 mm).

Exception No. 2: When branch lines are larger than 2 in. (51 mm), the sprinkler shall be supplied by a riser nipple to elevate the sprinkler 13 in. (330 mm) for $2^1/_2$-in. (64-mm) pipe and 15 in. (380 mm) for 3-in. (76-mm) pipe. These dimensions are measured from the centerline of the pipe to the deflector. In lieu of this, sprinklers may be offset horizontally a minimum of 12 in. (305 mm).

5-3.4.5 Hose stream demand and water supply duration requirements shall be in accordance with those for extra hazard occupancies in Table 5-2.3.

5-3.5* Early Suppression Fast Response (ESFR) Sprinklers.

5-3.5.1 ESFR sprinklers are suitable for use with the hazards listed in Table A-5-3.5 and may be used in other specific hazard classifications and configurations only when proven by large-scale or other suitable fire testing.

5-3.5.2 ESFR sprinkler systems shall be designed such that the minimum operating pressure is not less than 50 psi (340 kPa).

5-3.5.3 The design area shall consist of the most hydraulically demanding area of 12 sprinklers, consisting of 4 sprinklers on each of 3 branch lines. Design shall include a minimum of 960 sq ft (89 m^2).

5-3.5.4 Small hose stations shall be provided. Hose stream water demand is not required to be added to total water demand.

5-3.5.5 Water supply duration shall be at least 60 minutes.

5-3.6 Exposure Protection.

5-3.6.1* Piping shall be hydraulically calculated in accordance with Section 6-4 to furnish a minimum of 7 psi (48 kPa) at any sprinkler with all sprinklers facing the exposure operating.

5-3.6.2 When the water supply feeds other fire protection systems, it shall be capable of furnishing total demand for such systems as well as the exposure system demand.

5-3.7 Water Curtains. Sprinklers in a water curtain as described in 4-4.1.7.3.4 shall be hydraulically designed to provide a discharge of 3 gpm per lineal foot [37 (L/min)/m] of water curtain, with no sprinklers discharging less than 15 gpm (56.8 L/min). The number of sprinklers calculated in this water curtain shall be the number in the length corresponding to the length parallel to the branch lines in the area determined by 6-4.4.1(a). The water supply for these sprinklers shall be added to the water supply required for the area of operation in hydraulically designed systems or to the water supply required as determined in accordance with Table 5-2.2. Supplies shall be balanced to the higher pressure demand in either case.

Chapter 6 Plans and Calculations

6-1* Working Plans.

6-1.1* Working plans shall be submitted for approval to the authority having jurisdiction before any equipment is installed or remodeled. Deviation from approved plans will require permission of the authority having jurisdiction.

6-1.1.1 Working plans shall be drawn to an indicated scale, on sheets of uniform size, with a plan of each floor, and shall show those items from the following list that pertain to the design of the system.

(a) Name of owner and occupant.

(b) Location, including street address.

(c) Point of compass.

(d) Full height cross section, or schematic diagram, if required for clarity; including ceiling construction and method of protection for nonmetallic piping.

(e) Location of partitions.

(f) Location of fire walls.

(g) Occupancy class of each area or room.

(h) Location and size of concealed spaces, closets, attics, and bathrooms.

(i) Any small enclosures in which no sprinklers are to be installed.

(j) Size of city main in street and whether dead-end or circulating; and, if dead-end, direction and distance to nearest circulating main. City main test results and system elevation relative to test hydrant (*see A-7-2.1*).

(k) Other sources of water supply, with pressure or elevation.

(l) Make, type, and nominal orifice size of sprinklers.

(m) Temperature rating and location of high-temperature sprinklers.

(n) Total area protected by each system on each floor.

(o) Number of sprinklers on each riser per floor.

(p) Total number of sprinklers on each dry pipe system, preaction system, combined dry pipe-preaction system, or deluge system.

(q) Approximate capacity in gallons of each dry pipe system.

(r) Pipe type and schedule of wall thickness.

(s) Nominal pipe size and cutting lengths of pipe (or center to center dimensions).

NOTE: Where typical branch lines prevail, it will be necessary to size only one typical line.

(t) Location and size of riser nipples.

(u) Type of fittings and joints and location of all welds and bends. The contractor shall specify on drawing any sections to be shop welded and the type of fittings or formations to be used.

(v) Type and locations of hangers, sleeves, braces, and methods of securing sprinklers when applicable.

(w) All control valves, check valves, drain pipes, and test connections.

(x) Make, type, model, and size of alarm or dry pipe valve.

(y) Make, type, model, and size of preaction or deluge valve.

(z) Kind and location of alarm bells.

(aa) Size and location of hose outlets, hand hose, and related equipment.

(bb) Underground pipe size, length, location, weight, material, point of connection to city main; the type of valves, meters, and valve pits; and the depth that top of the pipe is laid below grade.

(cc) Piping provisions for flushing (*see 9-3.2*).

(dd) When the equipment is to be installed as an addition to an existing system, enough of the existing system indicated on the plans to make all conditions clear.

(ee) For hydraulically designed systems, the information on the hydraulic data nameplate.

(ff) A graphic representation of the scale used on all plans.

(gg) Name and address of contractor.

(hh) Hydraulic reference points shown on the plan shall correspond with comparable reference points on the hydraulic calculation sheets.

(ii) The minimum rate of water application (density), the design area of water application, in-rack sprinkler demand, and the water required for hose streams both inside and outside.

(jj) The total quantity of water and the pressure required noted at a common reference point for each system.

(kk) Relative elevations of sprinklers, junction points, and supply or reference points.

(ll) If room design method is used, all unprotected wall openings throughout the floor protected.

(mm) Calculation of loads for sizing, and details of, sway bracing.

(nn) The setting for pressure reducing valves.

(oo) Information about backflow preventers (manufacturer, size, type).

(pp) Information about antifreeze solution used (type and amount).

6-1.1.2* Working plans for automatic sprinkler systems with nonfire protection connections. Special symbols shall be used and explained for auxiliary piping, pumps, heat exchangers, valves, strainers, and the like, clearly distinguishing these devices and piping runs from those of the sprinkler system. Model number, type, and manufacturer's name shall be identified for each piece of auxiliary equipment.

6-2 Hydraulic Calculation Forms.

6-2.1 General. Hydraulic calculations shall be prepared on form sheets that include a summary sheet, detailed work sheets, and a graph sheet. (*See copies of typical forms, Figures A-6-2.2(a), A-6-2.3, and A-6-2.4.*)

6-2.2* Summary Sheet. The summary sheet shall contain the following information, where applicable:

(a) Date

(b) Location

(c) Name of owner and occupant

(d) Building number or other identification

(e) Description of hazard

(f) Name and address of contractor or designer

(g) Name of approving agency

(h) System design requirements

1. Design area of water application, sq ft

2. Minimum rate of water application (density), gpm per sq ft

3. Area per sprinkler, sq ft

(i) Total water requirements as calculated including allowance for inside hose, outside hydrants, and water curtain and exposure sprinklers

(j) Allowance for in-rack sprinklers, gpm

(k) Limitations (dimension, flow, and pressure) on extended coverage or other listed special sprinklers.

6-2.3* Detailed Work Sheets. Detailed work sheets or computer printout sheets shall contain the following information:

(a) Sheet number

(b) Sprinkler description and discharge constant (K)

(c) Hydraulic reference points

(d) Flow in gpm

(e) Pipe size

(f) Pipe lengths, center to center of fittings

(g) Equivalent pipe lengths for fittings and devices

(h) Friction loss in psi per ft of pipe

(i) Total friction loss between reference points

(j) In-rack sprinkler demand balanced to ceiling demand

(k) Elevation head in psi between reference points

(l) Required pressure in psi at each reference point

(m) Velocity pressure and normal pressure if included in calculations

(n) Notes to indicate starting points, reference to other sheets, or to clarify data shown

(o)* Diagram to accompany gridded system calculations to indicate flow quantities and directions for lines with sprinklers operating in the remote area

(p) Combined K-factor calculations for sprinklers on drops, armovers, or sprigs where calculations do not begin at sprinkler.

6-2.4* Graph Sheet. A graphic representation of the complete hydraulic calculation shall be plotted on semilogarithmic graph paper ($Q^{1.85}$) and shall include the following:

(a) Water supply curve

(b) Sprinkler system demand

(c) Hose demand (where applicable)

(d) In-rack sprinkler demand (where applicable).

6-3 Water Supply Information. The following information shall be included:

(a) Location and elevation of static and residual test gauge with relation to the riser reference point

(b) Flow location

(c) Static pressure, psi

(d) Residual pressure, psi

(e) Flow, gpm

(f) Date

(g) Time

(h) Test conducted by or information supplied by

(i) Other sources of water supply, with pressure or elevation.

6-4 Hydraulic Calculation Procedures.

6-4.1* General. A calculated system for a building, or a calculated addition to a system in an existing sprinklered building, supersedes the rules in the sprinkler standard governing pipe schedules, except that all systems continue to be limited by area, and pipe sizes shall be no less than 1 in. (25.4 mm) nominal for ferrous piping and ¾ in. (19 mm) nominal for copper tubing or nonmetallic piping listed for fire sprinkler service. The size of pipe, number of sprinklers per branch line, and number of branch lines per cross main are otherwise limited only by the available water supply. However, sprinkler spacing and all other rules covered in this and other applicable standards shall be observed.

6-4.2 Formulas.

6-4.2.1 Friction Loss Formula. Pipe friction losses shall be determined on the basis of the Hazen-Williams formula.

$$p = \frac{4.52\ Q^{1.85}}{C^{1.85}\ d^{4.87}}$$

where p is the frictional resistance in pounds pressure per square inch per foot of pipe, Q is the gallons per minute flowing, and d is the actual internal diameter of pipe in inches with C as the friction loss coefficient.

For SI Units: $P_m = 6.05 \times \frac{Q_m^{\ 1.85}}{C^{1.85}\ d_m^{\ 4.87}} \times 10^5$

Where P_m is the frictional resistance in bars per meter of pipe, Q_m is the flow in L/min, d_m is the actual internal diameter in mm and C is the friction loss coefficient.

6-4.2.2 Velocity Pressure Formula. Velocity pressure shall be determined on the basis of the formula

$P_v = 0.001\ 123\ Q^2 D^4$

P_v = velocity pressure in psi.

where:

Q = flow in gpm

D = the inside diameter in inches.

For SI units: 1 in. = 25.4 mm; 1 gal = 3.785 L; 1 psi = 0.0689 bar.

6-4.2.3 Normal Pressure Formula. Normal pressure (P_n) shall be determined on the basis of the formula

$P_n = P_t - P_v$

where:

P_t = total pressure in psi (bars)

P_v = velocity pressure in psi (bars)

6-4.2.4 Hydraulic Junction Points. Pressures at hydraulic junction points shall balance within 0.5 psi (0.03 bar). The highest pressure at the junction point, and the total flows as adjusted, shall be carried into the calculations.

6-4.3 Equivalent Pipe Lengths of Valves and Fittings.

6-4.3.1 Table 6-4.3.1 shall be used to determine the equivalent length of pipe for fittings and devices unless manufacturer's test data indicate that other factors are appropriate. For saddle-type fittings having friction loss greater than that shown in Table 6-4.3.1, the increased friction loss shall be included in hydraulic calculations.

6-4.3.2 Table 6-4.3.1 shall be used with Hazen-Williams C = 120 only. For other values of C, the values in Table 6-4.3.1 shall be multiplied by the factors indicated in Table 6-4.3.2.

Table 6-4.3.2

Value of C	100	130	140	150
Multiplying Factor	0.713	1.16	1.33	1.51

NOTE: This is based upon the friction loss through the fitting being independent of the C factor available to the piping.

Table 6-4.3.1 Equivalent Pipe Length Chart

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet of Pipe													
	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
45° Elbow	1	1	1	2	2	3	3	3	4	5	7	9	11	13
90° Standard Elbow	2	2	3	4	5	6	7	8	10	12	14	18	22	27
90° Long Turn Elbow	1	2	2	2	3	4	5	5	6	8	9	13	16	18
Tee or Cross (Flow Turned 90°)	3	5	6	8	10	12	15	17	20	25	30	35	50	60
Butterfly Valve	-	-	-	-	6	7	10	-	12	9	10	12	19	21
Gate Valve	-	-	-	-	1	1	1	1	2	2	3	4	5	6
Swing Check*	-	5	7	9	11	14	16	19	22	27	32	45	55	65

For SI Units: 1 ft = 0.3048 m.

*Due to the variations in design of swing check valves, the pipe equivalents indicated in the above chart are considered average.

NOTE: This table applies to all types of pipe listed in Table 6-4.4.5

6-4.3.3 Specific friction loss values or equivalent pipe lengths for alarm valves, dry pipe valves, deluge valves, strainers, and other devices shall be made available to the authority having jurisdiction.

6-4.4* Calculation Procedure.

6-4.4.1* For all systems the design area shall be the hydraulically most demanding based on the criteria of 5-2.3.

Exception: Special design approaches in accordance with 5-3.3.

(a) When the design is based on area/density method, the design area shall be a rectangular area having a dimension parallel to the branch lines at least 1.2 times the square root of the area of sprinkler operation (A) used. This may include sprinklers on both sides of the cross main. Any fractional sprinkler shall be carried to the next higher whole sprinkler.

Exception: In systems having branch lines with an insufficient number of sprinklers to fulfill the 1.2 $\sqrt{A}$ requirement, the design area shall be extended to include sprinklers on adjacent branch lines supplied by the same cross main.

(b) When the design is based on the room design method, see 5-2.3.3. The calculation shall be based on the room and communicating space, if any, that is the hydraulically most demanding.

6-4.4.2* For gridded systems, the designer shall verify that the hydraulically most demanding area is being used. A minimum of two additional sets of calculations shall be submitted to demonstrate peaking of demand area friction loss when compared to areas immediately adjacent on either side along the same branch lines.

Exception: Computer programs that show the peaking of the demand area friction loss shall be acceptable based on a single set of calculations.

6-4.4.3 System piping shall be hydraulically designed using design densities and areas of operation in accordance with Figure 5-2.3 as required for the occupancies involved.

(a)* The density shall be calculated on the basis of area of sprinkler operation. The area covered by any sprinkler for use in hydraulic design and calculations shall be determined in accordance with 4-2.2.1.

(b)* When sprinklers are installed above and below a ceiling or in a case where more than two areas are supplied from a common set of branch lines, the branch lines and supplies shall be calculated to supply the largest water demand.

6-4.4.4* Each sprinkler in the design area and the remainder of the hydraulically designed system shall discharge at a flow rate at least equal to the stipulated minimum water application rate (density) multiplied by the area of sprinkler operation. Begin calculations at the hydraulically most remote sprinkler. Discharge at each sprinkler shall be based on the calculated pressure at that sprinkler.

Exception No. 1: When area of application is equal to or greater than 1500 sq ft, sprinkler discharge in closets, washrooms, and similar small compartments requiring only one sprinkler shall be permitted to be omitted from hydraulic calculations within the area of application. Sprinklers in these small compartments shall, however, be capable of discharging minimum densities in accordance with Figure 5-2.3.

Exception No. 2: When sprinklers are provided above and below obstructions such as wide ducts or tables, the water supply for one of the levels of sprinklers shall be permitted to be omitted from the hydraulic ceiling design calculations within the area of application. In any case, the most hydraulically demanding arrangement shall be calculated.

6-4.4.5 Calculate pipe friction loss in accordance with the Hazen-Williams formula with C values from Table 6-4.4.5.

(a) Include pipe, fittings, and devices such as valves, meters, and strainers, and calculate elevation changes that affect the sprinkler discharge.

Exception: Tie-in drain piping shall not be included in the hydraulic calculations.

(b) Calculate the loss for a tee or a cross where flow direction change occurs based on the equivalent pipe length of the piping segment in which the fitting is included. The tee at the top of a riser nipple shall be included in the branch line; the tee at the base of a riser nipple shall be included in the riser nipple; and the tee or cross at a cross main-feed main junction shall be included in the cross main. Do not include fitting loss for straight-through flow in a tee or cross.

(c) Calculate the loss of reducing elbows based on the equivalent feet value of the smallest outlet. Use the equivalent feet value for the standard elbow on any abrupt 90-degree turn, such as the screw-type pattern. Use the equivalent feet value for the long-turn elbow on any sweeping 90-degree turn, such as a flanged, welded, or mechanical joint-elbow type. (*See Table 6-4.3.1.*)

(d) Friction loss shall be excluded for the fitting directly connected to a sprinkler.

(e) Losses through a pressure-reducing valve shall be included based on the normal inlet pressure condition. Pressure loss data from the manufacturer's literature shall be used.

Table 6-4.4.5 Hazen-Williams C Values

Pipe or Tube	C Value*
Unlined Cast or Ductile Iron	100
Black Steel (Dry Systems including Preaction)	100
Black Steel (Wet Systems including Deluge)	120
Galvanized (all)	120
Plastic (listed)—All	150
Cement Lined Cast or Ductile Iron	140
Copper Tube or Stainless Steel	150

*The authority having jurisdiction may recommend other C values.

6-4.4.6* Orifice plates or sprinklers of different orifice sizes shall not be used for balancing the system.

Exception No. 1: Sprinklers with different orifice sizes shall be acceptable for special use such as exposure protection, small rooms or enclosures, or directional discharge. (See 1-4.2 for definition of small rooms.)

Exception No. 2: Sprinklers with different orifice sizes shall be acceptable in light hazard occupancies that utilize extended coverage sprinklers for part of the protection area.

6-4.4.7* Velocity pressure (P_v) may or may not be included in the calculations at the discretion of the designer. If velocity pressures are used, they shall be used on both branch lines and cross mains where applicable.

6-4.4.8 Minimum operating pressure of any sprinkler shall be 7 psi (0.5 bar).

Exception: When different minimum operating pressure for the desired application is specified in the listing of the sprinkler.

6-5 Pipe Schedules. Pipe schedules shall not be used, except in existing systems and in new systems or extensions to existing systems described in Chapter 5. Water supplies shall conform to 5-2.2.

6-5.1* General. The pipe schedule sizing provisions shall not apply to hydraulically calculated systems. Sprinkler systems having sprinklers with orifices other than 1/2 in. (13 mm) nominal, listed piping material other than that covered in Table 2-3.1, Extra Hazard Groups 1 and 2 systems, and exposure protection systems shall be hydraulically calculated.

6-5.1.1 The number of automatic sprinklers on a given pipe size on one floor shall not exceed the number given in 6-5.2, 6-5.3, or 6-5.4 for a given occupancy.

6-5.1.2* Size of Risers. Each system riser shall be sized to supply all sprinklers on the riser on any one floor as determined by the standard schedules of pipe sizes in 6-5.2, 6-5.3, or 6-5.4.

6-5.1.3 Slatted Floors, Large Floor Openings, Mezzanines, and Large Platforms. Buildings having slatted floors, or large unprotected floor openings without approved stops, shall be treated as one area with reference to pipe sizes, and the feed mains or risers shall be of the size required for the total number of sprinklers.

6-5.1.4 Stair Towers. Stairs, towers, or other construction with incomplete floors, if piped on independent risers, shall be treated as one area with reference to pipe sizes.

6-5.2 Schedule for Light Hazard Occupancies.

6-5.2.1 Branch lines shall not exceed 8 sprinklers on either side of a cross main.

Exception: When more than 8 sprinklers on a branch line are necessary, lines may be increased to 9 sprinklers by making the two end lengths 1 in. (25.4 mm) and 1 1/4 in. (33 mm), respectively, and the sizes thereafter standard. Ten sprinklers may be placed on a branch line making the two end lengths 1 in. (25.4 mm) and 1 1/4 in. (33 mm), respectively, and feeding the tenth sprinkler by a 2 1/2-in. (64-mm) pipe.

6-5.2.2 Pipe sizes shall be in accordance with Table 6-5.2.2.

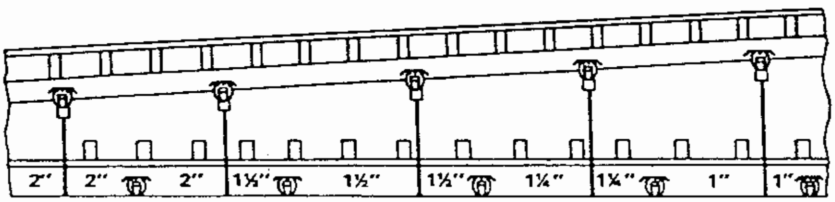
Exception: Each area requiring more sprinklers than the number specified for 3 1/2-in. (89-mm) pipe in Table 6-5.2.2 and without subdividing partitions (not necessarily fire walls) shall be supplied by mains or risers sized for Ordinary Hazard Occupancies.

Table 6-5.2.2 Light Hazard Pipe Schedules

Steel		Copper	
1 in.	2 sprinklers	1 in.	2 sprinklers
1 1/4 in.	3 sprinklers	1 1/4 in.	3 sprinklers
1 1/2 in.	5 sprinklers	1 1/2 in.	5 sprinklers
2 in.	10 sprinklers	2 in.	12 sprinklers
2 1/2 in.	30 sprinklers	2 1/2 in.	40 sprinklers
3 in.	60 sprinklers	3 in.	65 sprinklers
3 1/2 in.	100 sprinklers	3 1/2 in.	115 sprinklers
4 in.	See 4-2.1	4 in.	See 4-2.1

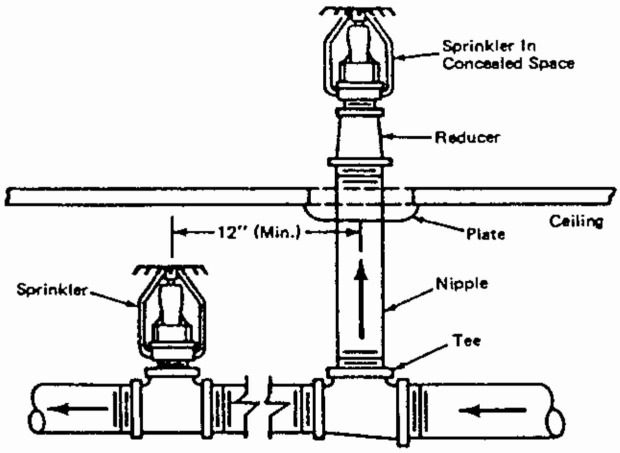
For SI Units: 1 in. = 25.4 mm.

6-5.2.3 When sprinklers are installed above and below ceilings [*see Figures 6-5.2.3(a), (b), and (c)*] and such sprinklers are supplied from a common set of branch lines or separate branch lines from a common cross main, such branch lines shall not exceed 8 sprinklers above and 8 sprinklers below any ceiling on either side of the cross main. Pipe sizing up to and including 2 1/2 in. (64 mm) shall be as shown in Table 6-5.2.3 utilizing the greatest number of sprinklers to be found on any two adjacent levels.



For SI Units: 1 in. = 25.4 mm.

Figure 6-5.2.3(a) Arrangement of branch lines supplying sprinklers above and below a ceiling.



For SI Units: 1 in. = 25.4 mm.

Figure 6-5.2.3(b) Sprinkler on riser nipple from branch line in lower fire area.

6-5.2.3.1* When the total number of sprinklers above and below a ceiling exceeds the number specified in Table 6-5.2.3 for 2½-in. (64-mm) pipe, the pipe supplying such sprinklers shall be increased to 3 in. (76 mm) and sized thereafter according to the schedule shown in Table 6-5.2.2 for the number of sprinklers above or below a ceiling, whichever is larger.

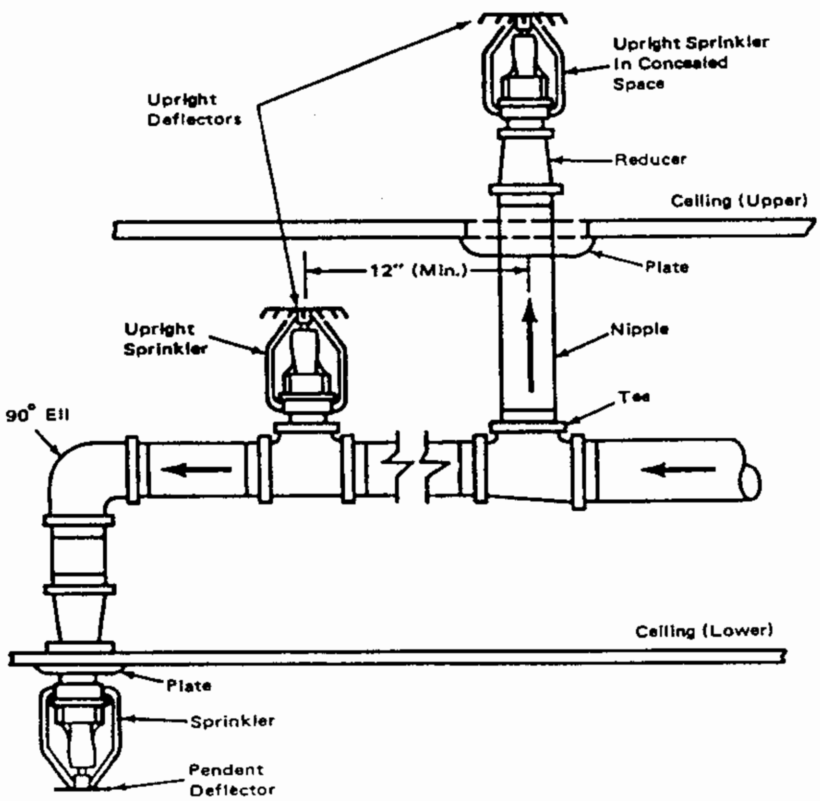
Table 6-5.2.3 Number of Sprinklers above and below a Ceiling

Steel		Copper	
1 in.	2 sprinklers	1 in.	2 sprinklers
1¼ in.	4 sprinklers	1¼ in.	4 sprinklers
1½ in.	7 sprinklers	1½ in.	7 sprinklers
2 in.	15 sprinklers	2 in.	18 sprinklers
2½ in.	50 sprinklers	2½ in.	65 sprinklers

6-5.3 Schedule for Ordinary Hazard Occupancies.

6-5.3.1 Branch lines shall not exceed 8 sprinklers on either side of a cross main.

Exception: When more than 8 sprinklers on a branch line are necessary, lines may be increased to 9 sprinklers by making the two end lengths 1 in. (25.4 mm) and 1¼ in. (33 mm), respectively, and the sizes thereafter standard. Ten sprinklers may be placed on



For SI Units: 1 in. = 25.4 mm.

Figure 6-5.2.3(c) Arrangement of branch lines supplying sprinklers above and below ceilings.

a branch line making the two end lengths 1 in. (25.4 mm) and 1 1/4 in. (33 mm), respectively, and feeding the tenth sprinkler by a 2 1/2-in. (64-mm) pipe.

6-5.3.2 Pipe sizes shall be in accordance with Table 6-5.3.2(a).

Table 6-5.3.2(a) Ordinary Hazard Pipe Schedule

Steel		Copper	
1 in.	2 sprinklers	1 in.	2 sprinklers
1 1/4 in.	3 sprinklers	1 1/4 in.	3 sprinklers
1 1/2 in.	5 sprinklers	1 1/2 in.	5 sprinklers
2 in.	10 sprinklers	2 in.	12 sprinklers
2 1/2 in.	20 sprinklers	2 1/2 in.	25 sprinklers
3 in.	40 sprinklers	3 in.	45 sprinklers
3 1/2 in.	65 sprinklers	3 1/2 in.	75 sprinklers
4 in.	100 sprinklers	4 in.	115 sprinklers
5 in.	160 sprinklers	5 in.	180 sprinklers
6 in.	275 sprinklers	6 in.	300 sprinklers
8 in.	See 4-2.1	8 in.	See 4-2.1

For SI Units: 1 in. = 25.4 mm.

Exception: When the distance between sprinklers on the branch line exceeds 12 ft (3.7 m), or the distance between the branch lines exceeds 12 ft (3.7 m), the number of sprinklers for a given pipe size shall be in accordance with Table 6-5.3.2(b).

Table 6-5.3.2(b) Number of Sprinklers—Greater than 12 ft Separations

Steel		Copper	
2 1/2 in.	15 sprinklers	2 1/2 in.	20 sprinklers
3 in.	30 sprinklers	3 in.	35 sprinklers
3 1/2 in.	60 sprinklers	3 1/2 in.	65 sprinklers
For other pipe and tube sizes, see Table 6-5.3.2(a)			

For SI Units: 1 in. = 25.4 mm.

6-5.3.3 When sprinklers are installed above and below ceilings and such sprinklers are supplied from a common set of branch lines or separate branch lines supplied by a common cross main, such branch lines shall not exceed 8 sprinklers above and 8 sprinklers below any ceiling on either side of the cross main. Pipe sizing up to and including 3 in. (76 mm) shall be as shown in Table 6-5.3.3 [*see Figures 6-5.2.3(a), (b), and (c)*] utilizing the greatest number of sprinklers to be found on any two adjacent levels.

Table 6-5.3.3 Number of Sprinklers above and below a Ceiling

Steel		Copper	
1 in.	2 sprinklers	1 in.	2 sprinklers
1 1/4 in.	4 sprinklers	1 1/4 in.	4 sprinklers
1 1/2 in.	7 sprinklers	1 1/2 in.	7 sprinklers
2 in.	15 sprinklers	2 in.	18 sprinklers
2 1/2 in.	30 sprinklers	2 1/2 in.	40 sprinklers
3 in.	60 sprinklers	3 in.	65 sprinklers

For SI Units: 1 in. = 25.4 mm.

6-5.3.3.1* When the total number of sprinklers above and below a ceiling exceeds the number specified in Table 6-5.3.3 for 3-in. (76-mm) pipe, the pipe supplying such sprinklers shall be increased to 3 1/2 in. (89 mm) and sized thereafter according to the schedule shown in Table 6-5.2.2 or Table 6-5.3.2(a) for the number of sprinklers above or below ceiling, whichever is larger.

Exception: When the distance between the sprinklers protecting the occupied area exceeds 12 ft (3.7 m) or the distance between the branch lines exceeds 12 ft (3.7 m), the branch lines shall be sized in accordance with either Table 6-5.3.2(b), taking into consideration the sprinklers protecting the occupied area only, or paragraph 6-5.3.3, whichever requires the greater size of pipe.

6-5.4* Extra Hazard Occupancies shall be hydraulically calculated.

Exception: For existing systems, see A-6-5.4.

6-5.5 Deluge Systems. Open sprinkler and deluge systems shall be hydraulically calculated according to applicable standards.

6-5.6* Exposure Systems. Exposure sprinklers shall be hydraulically calculated using Table 6-5.6 and a relative classification of exposures Guide Number.

Chapter 7 Water Supplies

7-1 General. Every automatic sprinkler system shall have at least one automatic water supply.

7-1.1 Capacity. Water supplies shall be reliable and be capable of providing the required flow and pressure for the recommended duration as specified in Chapter 5 (Design Approaches).

7-1.2 Arrangement.

7-1.2.1 Underground Supply Pipe. For pipe schedule systems, the underground supply pipe shall be at least as large as the system riser.

7-1.2.2 Connection between Underground and Aboveground Piping. The connection between the system piping and underground piping shall be made with a suitable transition piece and shall be properly strapped or fastened by approved devices. The transition piece shall be protected against possible damage from corrosive agents, solvent attack, or mechanical damage.

7-1.2.3* Connection Passing through or under Foundation Walls. When system piping pierces a foundation wall below grade or is located under the foundation wall, clearance shall be provided to prevent breakage of the piping due to building settlement.

7-1.3 Meters. Where meters are required by other authorities, they shall be listed.

Table 6-5.6 Exposure Protection

SECTION A—WINDOW SPRINKLERS					
Guide Number	Level of Window Sprinkler	Window Sprinkler Orifice Size	Discharge Coefficient (K Factor)	Flow Rate (Q)	Application Rate over 25 ft² of Window Area
1.50 or less	Top 2 levels	3/8 in.	2.8	7.4 gpm	0.30 gpm/ft²
	Next lower 2 levels	5/16 in.	1.9	5.0 gpm	0.20 gpm/ft²
	Next lower 2 levels	1/4 in.	1.4	3.7 gpm	0.15 gpm/ft²
1.51 to 2.20	Top 2 levels	1/2 in.	5.6	14.8 gpm	0.59 gpm/ft²
	Next lower 2 levels	7/16 in.	4.2	11.1 gpm	0.44 gpm/ft²
	Next lower 2 levels	3/8 in.	2.8	7.4 gpm	0.30 gpm/ft²
2.21 to 13.15	Top 2 levels	5/8 in.	11.2	29.6 gpm	1.18 gpm/ft²
	Next lower 2 levels	17/32 in.	8.0	21.2 gpm	0.85 gpm/ft²
	Next lower 2 levels	1/2 in.	5.6	14.8 gpm	0.59 gpm/ft²

SECTION B—CORNICE SPRINKLERS		
Guide Number	Cornice Sprinkler Orifice Size	Application Rate per Lineal Foot
1.50 or less	3/8 in.	0.75 gpm
1.51 to 2.20	1/2 in.	1.50 gpm
2.21 to 13.15	5/8 in.	3.00 gpm

7-2 Types.

7-2.1* Connections to Water Works Systems. A connection to a reliable water works system shall be an acceptable water supply source. The volume and pressure of a public water supply shall be determined from waterflow test data. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*) The authority having jurisdiction shall be permitted to require an adjustment to the waterflow test data to account for daily and seasonal fluctuations, possible interruption by flood or ice conditions, large simultaneous industrial use, future demand on the water supply system, or any other condition that could affect the water supply.

7-2.2 Pumps.

7-2.2.1* Acceptability. A single automatically controlled fire pump installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, shall be an acceptable water supply source.

7-2.2.2* Supervision. When a single fire pump constitutes the sole sprinkler supply, it shall be provided with supervisory service from an approved central station, proprietary, or remote station system or equivalent.

7-2.3 Pressure Tanks.

7-2.3.1 Acceptability.

7-2.3.1.1 A pressure tank installed in accordance with NFPA 22, *Standard for Water Tanks for Private Fire Protection*, shall be an acceptable water supply source.

7-2.3.1.2 Pressure tanks shall be provided with an approved means for automatically maintaining the required air pressure. When a pressure tank is the sole water supply, there shall also be provided an approved trouble alarm to indicate low air pressure and low water level with the alarm supplied from an electrical branch circuit independent of the air compressor.

7-2.3.1.3 Pressure tanks shall not be used to supply other than sprinklers and hand hose attached to sprinkler piping.

7-2.3.2 Capacity. In addition to the requirements of 7-1.1, the water capacity of a pressure tank shall include the extra capacity needed to fill dry pipe or preaction systems when installed. The total volume shall be based on the water capacity, plus the air capacity required by 7-2.3.3.

7-2.3.3* Water Level and Air Pressure. Pressure tanks shall be kept two-thirds full of water, and an air pressure of at least 75 psi (5.2 bars) by the gauge shall be maintained. When the bottom of the tank is located below the highest sprinklers served, the air pressure by the gauge shall be at least 75 psi (5.2 bars) plus three times the pressure caused by the column of water in the sprinkler system above the tank bottom.

7-2.4 Gravity Tanks. An elevated tank installed in accordance with NFPA 22, *Standard for Water Tanks for Private Fire Protection*, shall be an acceptable water supply source.

Chapter 8 System Acceptance

8-1 Approval of Sprinkler Systems. The installing contractor shall:

(a) Notify the authority having jurisdiction and owner's representative of the time and date testing will be performed.

(b) Perform all required acceptance tests. (*See Section 8-2.*)

(c) Complete and sign the appropriate Contractor's Material and Test Certificate(s) [*see Figures 8-1(a) and 8-1(b)*].

CONTRACTOR'S MATERIAL & TEST CERTIFICATE FOR ABOVEGROUND PIPING

PROCEDURE

Upon completion of work, inspection and tests shall be made by the contractor's representative and witnessed by an owner's representative. All defects shall be corrected and system left in service before contractor's personnel finally leave the job.

A certificate shall be filled out and signed by both representatives. Copies shall be prepared for approving authorities, owners, and contractor. It is understood the owner's representative's signature in no way prejudices any claim against contractor for faulty material, poor workmanship, or failure to comply with approving authority's requirements or local ordinances.

PROPERTY NAME	DATE
PROPERTY ADDRESS	

PLANS	ACCEPTED BY APPROVING AUTHORITIES (NAMES)	
	ADDRESS	
	INSTALLATION CONFORMS TO ACCEPTED PLANS	☐ YES ☐ NO
	EQUIPMENT USED IS APPROVED	☐ YES ☐ NO
	IF NO, EXPLAIN DEVIATIONS	
INSTRUCTIONS	HAS PERSON IN CHARGE OF FIRE EQUIPMENT BEEN INSTRUCTED AS TO LOCATION OF CONTROL VALVES AND CARE AND MAINTENANCE OF THIS NEW EQUIPMENT?	☐ YES ☐ NO
	IF NO, EXPLAIN	
	HAVE COPIES OF THE FOLLOWING BEEN LEFT ON THE PREMISES:	☐ YES ☐ NO
	1. SYSTEM COMPONENTS INSTRUCTIONS	☐ YES ☐ NO
	2. CARE AND MAINTENANCE INSTRUCTIONS	☐ YES ☐ NO
	3. NFPA 13A	☐ YES ☐ NO
LOCATION OF SYSTEM	SUPPLIES BUILDINGS	

SPRINKLERS

MAKE	MODEL	YEAR OF MANUFACTURE	ORIFICE SIZE	QUANTITY	TEMPERATURE RATING

PIPE AND FITTINGS

Type of Pipe __________

Type of Fittings __________

ALARM VALVE OR FLOW INDICATOR

ALARM DEVICE			MAXIMUM TIME TO OPERATE THROUGH TEST CONNECTION	
TYPE	MAKE	MODEL	MIN.	SEC.

DRY PIPE OPERATING TEST

DRY VALVE			Q.O.D.		
MAKE	MODEL	SERIAL NO.	MAKE	MODEL	SERIAL NO.

	TIME TO TRIP THRU TEST CONNECTION*		WATER PRESSURE	AIR PRESSURE	TRIP POINT AIR PRESSURE	TIME WATER REACHED TEST OUTLET*		ALARM OPERATED PROPERLY	
	MIN.	SEC.	PSI	PSI	PSI	MIN.	SEC.	YES	NO
Without Q.O.D.									
With Q.O.D.									

IF NO, EXPLAIN

* MEASURED FROM TIME INSPECTOR'S TEST CONNECTION IS OPENED.

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Figure 8-1(a).

DELUGE & PREACTION VALVES	OPERATION ☐ PNEUMATIC ☐ ELECTRIC ☐ HYDRAULIC							
	PIPING SUPERVISED ☐ YES ☐ NO				DETECTING MEDIA SUPERVISED ☐ YES ☐ NO			
	DOES VALVE OPERATE FROM THE MANUAL TRIP AND/OR REMOTE CONTROL STATIONS ☐ YES ☐ NO							
	IS THERE AN ACCESSIBLE FACILITY IN EACH CIRCUIT FOR TESTING ☐ YES ☐ NO				IF NO, EXPLAIN			
	MAKE	MODEL	DOES EACH CIRCUIT OPERATE SUPERVISION LOSS ALARM		DOES EACH CIRCUIT OPERATE VALVE RELEASE		MAXIMUM TIME TO OPERATE RELEASE	
			YES	NO	YES	NO	MIN.	SEC.

TEST DESCRIPTION	HYDROSTATIC: Hydrostatic tests shall be made at not less than 200 psi (13.6 bars) for two hours or 50 psi (3.4 bars) above static pressure in excess of 150 psi (10.2 bars) for two hours. Differential dry-pipe valve clappers shall be left open during test to prevent damage. All aboveground piping leakage shall be stopped. PNEUMATIC: Establish 40 psi (2.7 bars) air pressure and measure drop which shall not exceed 1-1/2 psi (0.1 bars) in 24 hours. Test pressure tanks at normal water level and air pressure and measure air pressure drop which shall not exceed 1-1/2 psi (0.1 bars) in 24 hours.
TESTS	ALL PIPING HYDROSTATICALLY TESTED AT ______ PSI FOR ______ HRS. — IF NO, STATE REASON DRY PIPING PNEUMATICALLY TESTED ☐ YES ☐ NO EQUIPMENT OPERATES PROPERLY ☐ YES ☐ NO
	DO YOU CERTIFY AS THE SPRINKLER CONTRACTOR THAT ADDITIVES AND CORROSIVE CHEMICALS, SODIUM SILICATE OR DERIVATIVES OF SODIUM SILICATE, BRINE, OR OTHER CORROSIVE CHEMICALS WERE NOT USED FOR TESTING SYSTEMS OR STOPPING LEAKS? ☐ YES ☐ NO
	DRAIN TEST — READING OF GAGE LOCATED NEAR WATER SUPPLY TEST CONNECTION: ______ PSI — RESIDUAL PRESSURE WITH VALVE IN TEST CONNECTION OPEN WIDE ______ PSI
	UNDERGROUND MAINS AND LEAD IN CONNECTIONS TO SYSTEM RISERS FLUSHED BEFORE CONNECTION MADE TO SPRINKLER PIPING. VERIFIED BY COPY OF THE U FORM NO. 85B ☐ YES ☐ NO — OTHER — EXPLAIN FLUSHED BY INSTALLER OF UNDERGROUND SPRINKLER PIPING ☐ YES ☐ NO
BLANK TESTING GASKETS	NUMBER USED — LOCATIONS — NUMBER REMOVED
WELDING	WELDED PIPING ☐ YES ☐ NO IF YES . . .
	DO YOU CERTIFY AS THE SPRINKLER CONTRACTOR THAT WELDING PROCEDURES COMPLY WITH THE REQUIREMENTS OF AT LEAST AWS D10.9, LEVEL AR-3 ☐ YES ☐ NO
	DO YOU CERTIFY THAT THE WELDING WAS PERFORMED BY WELDERS QUALIFIED IN COMPLIANCE WITH THE REQUIREMENTS OF AT LEAST AWS D10.9, LEVEL AR-3 ☐ YES ☐ NO
	DO YOU CERTIFY THAT WELDING WAS CARRIED OUT IN COMPLIANCE WITH A DOCUMENTED QUALITY CONTROL PROCEDURE TO INSURE THAT ALL DISCS ARE RETRIEVED, THAT OPENINGS IN PIPING ARE SMOOTH, THAT SLAG AND OTHER WELDING RESIDUE ARE REMOVED, AND THAT THE INTERNAL DIAMETERS OF PIPING ARE NOT PENETRATED ☐ YES ☐ NO
CUTOUTS (DISCS)	DO YOU CERTIFY THAT YOU HAVE A CONTROL FEATURE TO ENSURE THAT ALL CUTOUTS (DISCS) ARE RETRIEVED? ☐ YES ☐ NO
HYDRAULIC DATA NAMEPLATE	NAME PLATE PROVIDED ☐ YES ☐ NO — IF NO, EXPLAIN
REMARKS	DATE LEFT IN SERVICE WITH ALL CONTROL VALVES OPEN:
SIGNATURES	NAME OF SPRINKLER CONTRACTOR
	TESTS WITNESSED BY
	FOR PROPERTY OWNER (SIGNED) — TITLE — DATE
	FOR SPRINKLER CONTRACTOR (SIGNED) — TITLE — DATE

ADDITIONAL EXPLANATION AND NOTES

85A BACK

Figure 8-1(a) (cont.).

CONTRACTOR'S MATERIAL & TEST CERTIFICATE FOR UNDERGROUND PIPING

PROCEDURE

Upon completion of work, inspection and tests shall be made by the contractor's representative and witnessed by an owner's representative. All defects shall be corrected and system left in service before contractor's personnel finally leave the job.

A certificate shall be filled out and signed by both representatives. Copies shall be prepared for approving authorities, owners, and contractor. It is understood the owner's representative's signature in no way prejudices any claim against contractor for faulty material, poor workmanship, or failure to comply with approving authority's requirements or local ordinances.

PROPERTY NAME	DATE
PROPERTY ADDRESS	

PLANS	ACCEPTED BY APPROVING AUTHORITIES (NAMES) ADDRESS INSTALLATION CONFORMS TO ACCEPTED PLANS ☐ YES ☐ NO EQUIPMENT USED IS APPROVED ☐ YES ☐ NO IF NO, STATE DEVIATIONS
INSTRUCTIONS	HAS PERSON IN CHARGE OF FIRE EQUIPMENT BEEN INSTRUCTED AS TO LOCATION OF CONTROL VALVES AND CARE AND MAINTENANCE OF THIS NEW EQUIPMENT? ☐ YES ☐ NO IF NO, EXPLAIN HAVE COPIES OF APPROPRIATE INSTRUCTIONS AND CARE AND MAINTENANCE CHARTS BEEN LEFT ON PREMISES? ☐ YES ☐ NO IF NO, EXPLAIN
LOCATION	SUPPLIES BUILDINGS
UNDERGROUND PIPES AND JOINTS	PIPE TYPES AND CLASS / TYPE JOINT PIPE CONFORMS TO ______________ STANDARD ☐ YES ☐ NO FITTINGS CONFORM TO ______________ STANDARD ☐ YES ☐ NO IF NO, EXPLAIN JOINTS NEEDING ANCHORAGE CLAMPED, STRAPPED, OR BLOCKED IN ACCORDANCE WITH ______________ STANDARD ☐ YES ☐ NO IF NO, EXPLAIN
TEST DESCRIPTION	FLUSHING. Flow the required rate until water is clear as indicated by no collection of foreign material in burlap bags at outlets such as hydrants and blow-offs. Flush at flows not less than 390 GPM (1476 L/min) for 4-inch pipe, 880 GPM (3331 L/min) for 6-inch pipe, 1560 GPM (5905 L/min) for 8-inch pipe, 2440 GPM (9235 L/min) for 10-inch pipe, and 3520 GPM (13323 L/min) for 12-inch pipe. When supply cannot produce stipulated flow rates, obtain maximum available. HYDROSTATIC. Hydrostatic tests shall be made at not less than 200 psi (13.8 bars) for two hours or 50 psi (3.4 bars) above static pressure in excess of 150 psi (10.3 bars) for two hours. LEAKAGE. New pipe laid with rubber gasketed joints shall, if the workmanship is satisfactory, have little or no leakage at the joints. The amount of leakage at the joints shall not exceed 2 qts. per hr. (1.89 L/h) per 100 joints irrespective of pipe diameter. The leakage shall be distributed over all joints. If such leakage occurs at a few joints the installation shall be considered unsatisfactory and necessary repairs made. The amount of allowable leakage specified above may be increased by 1 fl oz per in. valve diameter per hr. (30 mL/25 mm/h) for each metal seated valve isolating the test section. If dry barrel hydrants are tested with the main valve open, so the hydrants are under pressure, an additional 5 oz per minute (150 mL/min) leakage is permitted for each hydrant.
FLUSHING TESTS	NEW UNDERGROUND PIPING FLUSHED ACCORDING TO ______________ STANDARD ☐ YES ☐ NO BY (COMPANY) IF NO, EXPLAIN HOW FLUSHING FLOW WAS OBTAINED ☐ PUBLIC WATER ☐ TANK OR RESERVOIR ☐ FIRE PUMP / THROUGH WHAT TYPE OPENING ☐ HYDRANT BUTT. ☐ OPEN PIPE LEAD-INS FLUSHED ACCORDING TO ______________ STANDARD ☐ YES ☐ NO BY (COMPANY) IF NO, EXPLAIN HOW FLUSHING FLOW WAS OBTAINED ☐ PUBLIC WATER ☐ TANK OR RESERVOIR ☐ FIRE PUMP / THROUGH WHAT TYPE OPENING ☐ Y CONN. TO FLANGE & SPIGOT ☐ OPEN PIPE

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Figure 8-1(b).

HYDROSTATIC TEST	ALL NEW UNDERGROUND PIPING HYDROSTATICALLY TESTED AT _______ PSI FOR _______ HOURS		JOINTS COVERED ☐ YES ☐ NO
LEAKAGE TEST	TOTAL AMOUNT OF LEAKAGE MEASURED _______ GALS. _______ HOURS		
	ALLOWABLE LEAKAGE _______ GALS. _______ HOURS		
HYDRANTS	NUMBER INSTALLED	TYPE AND MAKE	ALL OPERATE SATISFACTORILY ☐ YES ☐ NO
CONTROL VALVES	WATER CONTROL VALVES LEFT WIDE OPEN IF NO, STATE REASON		☐ YES ☐ NO
	HOSE THREADS OF FIRE DEPARTMENT CONNECTIONS AND HYDRANTS INTERCHANGEABLE WITH THOSE OF FIRE DEPARTMENT ANSWERING ALARM		☐ YES ☐ NO
REMARKS	DATE LEFT IN SERVICE		
SIGNATURES	NAME OF INSTALLING CONTRACTOR		
	TESTS WITNESSED BY		
	FOR PROPERTY OWNER (SIGNED)	TITLE	DATE
	FOR INSTALLING CONTRACTOR (SIGNED)	TITLE	DATE

ADDITIONAL EXPLANATION AND NOTES

Figure 8-1(b) (cont.).

8-2 Acceptance Requirements.

8-2.1* Flushing of Piping. Underground mains and lead-in connections to system risers shall be completely flushed before connection is made to sprinkler piping. The flushing operation shall be continued for a sufficient time to ensure thorough cleaning. The minimum rate of flow shall be not less than:

(a) The hydraulically calculated water demand rate of the system including any hose requirements, or

(b) That flow necessary to provide a velocity of 10 ft per second (3 m/s), or

(c) The maximum flow rate available to the system under fire conditions.

Table 8-2.1 Flow Required to Produce a Velocity of 10 ft per second (3 m/s) in Pipes

Pipe Size (in.)	Flow Rate (gpm)	Flow Rate (L/min)
4	390	1476
6	880	3331
8	1560	5905
10	2440	9235
12	3520	13323

8-2.2 Hydrostatic Tests.

8-2.2.1* All interior piping and attached appurtenances subjected to system working pressure shall be hydrostatically tested at 200 psi (13.8 bars) and shall maintain that pressure without loss for 2 hours. Loss shall be determined by a drop in gauge pressure or visual leakage.

Exception No. 1: Portions of systems normally subjected to working pressures in excess of 150 psi (10.4 bars) shall be tested as described above at a pressure of 50 psi (3.5 bars) in excess of normal working pressure.

Exception No. 2: When cold weather will not permit testing with water, an interim air test may be conducted as described in 8-2.3.

The test pressure shall be read from a gauge located at the low elevation point of the system or portion being tested.

8-2.2.2 Additives. Additives, corrosive chemicals such as sodium silicate or derivatives of sodium silicate, brine, or other chemicals shall not be used while hydrostatically testing systems or for stopping leaks.

8-2.2.3 Piping between the exterior fire department connection and the check valve in the fire department inlet pipe shall be hydrostatically tested in the same manner as the balance of the system.

8-2.2.4 When hydrostatically testing deluge systems, plugs shall be installed in fittings and replaced with open sprinklers after the test is completed, or the operating elements of automatic sprinklers shall be removed after the test is completed.

8-2.2.5 All underground piping shall be hydrostatically tested in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances.* The allowable leakage shall be within the limits prescribed by NFPA 24 and shall be recorded on the test certificate.

8-2.2.6 Provision shall be made for proper disposal of water used for flushing or testing.

8-2.2.7* Test blanks shall have painted lugs protruding in such a way as to clearly indicate their presence. The test blanks shall be numbered, and the installing contractor shall have a record-keeping method ensuring their removal after work is completed.

8-2.2.8 **Differential Type Valves.** The clapper of a differential type valve when subject to hydrostatic test pressures shall be held off its seat to prevent damaging the valve.

8-2.3 Dry System Air Test. In addition to the standard hydrostatic test, an air pressure leakage test at 40 psi (2.8 bars) shall be conducted for 24 hours. Any leakage that results in a loss of pressure in excess of $1^1/_2$ psi (0.1 bar) for the 24 hours shall be corrected.

8-2.4 System Operational Tests

8-2.4.1 Waterflow detecting devices including the associated alarm circuits shall be flow tested through the inspector's test connection to result in an alarm on the premises within 5 minutes after such flow begins.

8-2.4.2 A working test of the dry pipe valve alone, and with a quick-opening device, if installed, shall be made by opening the inspector's test connection. The test shall measure the time to trip the valve and the time for water to be discharged from the inspector's test connection. All times shall be measured from the time the inspector's test connection is completely opened. The results shall be recorded using the Contractor's Material and Test Certificate for Aboveground Piping.

8-2.4.3 The automatic operation of a deluge or preaction valve shall be tested in accordance with the manufacturer's instructions. The manual and remote control operation, when present, shall also be tested.

8-2.4.4 Main Drain Flow Test. The main drain valve shall be opened and remain open until the system pressure stabilizes. The static and residual pressures shall be recorded on the contractor's test certificate.

8-2.5 Each pressure reducing valve shall be tested upon completion of the installation to ensure proper pressure reduction at both maximum and normal inlet pressures.

8-2.6 Operating tests shall be made of exposure protection systems upon completion of the installation, when such tests do not risk water damage to the building on which it is installed or to adjacent buildings.

8-3 Circulating Closed Loop Systems. For sprinkler systems with nonfire protection connections, additional information shall be appended to the Contractor's Material and Test Certificate shown in Figure 8-1(a) as follows:

(a) Certification that all auxiliary devices, such as heat pumps, circulating pumps, heat exchangers, radiators, and luminaries, if a part of the system, have a pressure rating of at least 175 psi or 300 psi if exposed to pressures greater than 175 psi (12.1 or 20.7 bars).

(b) All components of sprinkler system and auxiliary system have been pressure tested as a composite system in accordance with 8-2.2.

(c) Waterflow tests have been conducted and waterflow alarms have operated while auxiliary equipment is in each of the possible modes of operation.

(d) With auxiliary equipment tested in each possible mode of operation and with no flow from sprinklers or test connection, waterflow alarm signals did not operate.

(e) Excess temperature controls for shutting down the auxiliary system have been properly field tested.

8-4 Instructions.

8-4.1 The installing contractor shall provide the owner with:

(a) All literature and instructions provided by the manufacturer describing proper operation and maintenance of any equipment and devices installed.

(b) Publication titled NFPA 13A, *Recommended Practice for the Inspection, Testing and Maintenance of Sprinkler Systems.*

8-5* Hydraulic Design Information Sign. The installing contractor shall identify a hydraulically designed sprinkler system with a permanently marked weatherproof metal or rigid plastic sign secured with corrosion resistant wire, chain, or other approved means. Such signs shall be placed at the alarm valve, dry pipe valve, preaction valve, or deluge valve supplying the corresponding hydraulically designed area. The sign shall include the following information:

(a) Location of the design area or areas.

(b) Discharge densities over the design area or areas.

(c) Required flow and residual pressure demand at the base of riser.

(d) Hose stream demand included in addition to the sprinkler demand.

8-6 Circulating Closed Loop Systems. Discharge tests of sprinkler systems with nonfire protection connections shall be conducted using system test connections described in 2-7.2. Pressure gauges shall be installed at critical points and readings taken under various modes of auxiliary equipment operation. Waterflow alarm signals shall be responsive to discharge of water through system test pipes while auxiliary equipment is in each of the possible modes of operation.

Chapter 9 System Maintenance

9-1 General.

9-1.1* A sprinkler system installed in accordance with this standard shall be properly maintained to provide at least the same level of performance and protection as designed. The owner shall be responsible for maintaining the system and keeping the system in good operating condition. (Guidance for maintaining the system is provided in NFPA 13A, *Recommended Practice for Inspection and Maintenance of Sprinkler Systems*.)

9-1.2 When the sprinkler system has been subjected to adverse conditions such as freezing conditions in wet sprinkler systems, structural damage, severe earthquakes, or fire exposure, the sprinkler system, including hangers, piping, alarms, and sprinklers, shall be inspected and repaired or replaced if damaged. Sprinklers in the fire area shall be replaced.

9-1.3* When the sprinkler piping is given any kind of coating, such as whitewash or paint, care shall be exercised to see that no automatic sprinklers are coated.

9-2 Replacement of Sprinklers.

9-2.1 When sprinklers are replaced, the replacement sprinkler shall be of the same type, orifice, and temperature rating unless conditions require a different type sprinkler be installed. The replacement sprinkler shall then be of a type, orifice, and temperature rating to suit the new conditions.

9-2.2 Old-style sprinklers may be replaced with old-style sprinklers or with the appropriate pendent or upright sprinkler.

9-2.3 Old-style sprinklers shall not be used to replace pendent or upright sprinklers.

9-2.4 Extreme care shall be exercised when replacing horizontal sidewall and extended coverage sprinklers to assure the correct replacement sprinkler is installed.

9-2.5 Sprinklers that have been painted or coated, except by the manufacturer, shall be replaced and shall not be cleaned by use of chemicals, abrasives, or other means. (*See 2-2.4.3.*)

9-2.6 Sprinkler or spray nozzles used in commercial cooking equipment shall be replaced as specified in 3-9.12.

9-3 Obstruction in Piping.

9-3.1 Screens located in the inlet piping directly connected to rivers, lakes, ponds, reservoirs, uncovered tanks, and similar sources shall be cleaned annually and after work has been performed on fire protection water supplies. (*See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*)

9-3.2 Visual or flushing investigation shall be conducted of all systems for presence of foreign material at intervals not exceeding 5 years.

9-3.3* The main drain shall be tested quarterly.

9-4 Testing of Antifreeze Systems. Before freezing weather each year, the solution in the entire system shall be emptied into convenient containers and brought to the proper specific gravity by adding concentrated liquid as needed. The resulting solution may be used to refill the system.

Chapter 10 Referenced Publications

10-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

10-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Mobile Homes*, 1991 edition

NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height*, 1991 edition

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1990 edition

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1990 edition

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1987 edition

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1987 edition

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1989 edition

NFPA 70, *National Electrical Code*, 1990 edition

NFPA 71, *Standard for the Installation, Maintenance, and Use of Signaling Systems for Central Station Service*, 1989 edition

NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*, 1990 edition

NFPA 96, *Standard for the Installation of Equipment for the Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment*, 1991 edition

NFPA 231, *Standard for General Storage*, 1990 edition

NFPA 231C, *Standard for Rack Storage of Materials*, 1991 edition

NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*, 1990 edition

10-1.2 The following NFPA codes and standards contain specific sprinkler design criteria.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1990 edition

NFPA 16, *Standard on Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, 1991 edition

NFPA 30, *Flammable and Combustible Liquids Code*, 1990 edition

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*, 1990 edition

NFPA 40, *Standard for the Storage and Handling of Cellulose Nitrate Motion Picture Film*, 1988 edition

NFPA 43A, *Code for the Storage of Liquid and Solid Oxidizers, 1990 edition*

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 1991 edition

NFPA 58, *Standard for the Storage and Handling of Liquefied Petroleum Gases*, 1989 edition

NFPA 81, *Standard for Fur Storage, Fumigation and Cleaning*, 1986 edition

NFPA *101,*® *Life Safety Code,*® 1991 edition

NFPA 214, *Standard on Water-Cooling Towers*, 1988 edition

NFPA 231, *Standard for General Storage*, 1990 edition

NFPA 231C, *Standard for Rack Storage of Materials*, 1991 edition

NFPA 231D, *Standard for Storage of Rubber Tires*, 1989 edition

NFPA 231E, *Recommended Practice for the Storage of Baled Cotton*, 1989 edition

NFPA 231F, *Standard for Storage of Roll Paper*, 1987 edition

NFPA 232, *Standard for the Protection of Records*, 1991 edition

NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, 1990 edition

NFPA 409, *Standard on Aircraft Hangars*, 1990 edition

NFPA 423, *Standard for Construction and Protection of Aircraft Engine Test Facilities*, 1989 edition

10-1.3 Other Publications.

10-1.3.1 ANSI Publications. American National Standards Institute, Inc., 1450 Broadway, New York, New York 10018.

ANSI B1.20.1-1983, *Pipe Threads, General Purpose*

ANSI B16.1-1989, *Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250 and 800*

ANSI B16.3-1985, *Malleable Iron Threaded Fittings, Class 150 and 300*

ANSI B16.4-1985, *Cast Iron Threaded Fittings, Classes 125 and 250*

ANSI B16.5-1988, *Pipe Flanges and Flanged Fittings*

ANSI B16.9-1986, *Factory-Made Wrought Steel Buttwelding Fittings*

ANSI B16.11-1980, *Forged Steel Fittings, Socket-Welding and Threaded*

ANSI B16.18-1984, *Cast Copper Alloy Solder Joint Pressure Fittings*

ANSI B16.22-1989, *Wrought Copper and Copper Alloy Solder Joint Pressure Fittings*

ANSI B16.25-1986, *Buttwelding Ends*

ANSI B36.10M-1985, *Welded and Seamless Wrought Steel Pipe*

10-1.3.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19105.

ASTM A53-1990, *Standard Specification for Welded Pipe, Steel, Black and Hot-Dipped, Zinc-Coated and Seamless Steel Pipe*

ASTM A135-1989, *Specifications for Electric-Resistance Welded Steel Pipe*

ASTM A234-1990, *Standard Specification for Piping Fittings of Wrought-Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures*

ASTM A795-1990, *Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use*

ASTM B32-1989, *Standard Specification for Solder Metal, 95-5 (Tin-Antimony-Grade 95TA)*

ASTM B75-1986, *Standard Specification for Seamless Copper Tube*

ASTM B88-1989, *Standard Specification for Seamless Copper Water Tube*

ASTM B251-1988, *Standard Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube*

ASTM E136-1982, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*

ASTM E380-1989, *Standard for Metric Practice*

10-1.3.3 AWS Publications. American Welding Society, 2501 N.W. 7th Street, Miami, FL 33125.

AWS A5.8-1989, *Specification for Brazing Filler Metal*

AWS D10.9-1980, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-4.2 Miscellaneous Storage. The sprinkler system design criteria for miscellaneous storage at heights below 12 ft (3.7 m) is covered by this standard in Chapters 4 and 5. Section 5-2.3.1.1 describes design criteria and 4-2.2 (Table 4-2.2) describes installation requirements (area limits). These apply to all storage of 12 feet or less in height.

A-1-4.2 Sprinkler System. A sprinkler system is considered to have a single system riser control valve.

A-1-4.4 See Figure A-1-4.4.

A-1-4.5.1 QRES Sprinkler. Research into the development of QRES sprinklers is continuing under the auspices of the National Fire Protection Research Foundation. It is expected that the proposed design criteria will be added to the standard when a thorough analysis of the test data is completed.

A-1-4.5.1 ESFR Sprinkler. It is important to realize that the effectiveness of these highly tested and engineered sprinklers depends on the combination of fast response and the quality and uniformity of the sprinkler discharge. It should also be realized that ESFR sprinklers cannot be relied upon to provide fire control, let alone suppression, if they are used outside the guidelines specified in 5-3.5.

A-1-4.5.3 Dry Sprinkler. Under certain ambient conditions wet pipe systems having dry-pendent (or upright) sprinklers may freeze due to heat loss by conduction. Therefore, due consideration should be given to the amount of heat maintained in the heated space, the length of the nipple in the heated space, and other relevant factors.

A-1-4.6(a) The following are examples of obstructed construction. The definitions are provided as guidance to assist the user in determining the type of construction feature:

(i) *Beam and Girder Construction.* The term *beam and girder construction* as used in this standard includes noncombustible and combustible roof or floor decks supported by wood beams of 4 in. (102 mm) or greater nominal thickness or concrete or steel beams spaced 3 to 7½ ft (0.9 to 2.3 m) on centers and either supported on or framed into girders. [When supporting a wood plank deck, this includes semi-mill and panel construction, and when supporting (with steel framing) gypsum plank, steel deck, concrete, tile, or similar material, this would include much of the so-called noncombustible construction.]

(ii) *Composite Wood Joist Construction.* The term *composite wood joist construction* refers to wood beams of I cross section constructed of wood flanges and solid wood web, supporting a floor or roof deck. Composite wood joists may vary in depth up to 48 in. (1.2 m), may be spaced up to 48 in. (1.2 m) on centers, and may span up to 60 ft (18 m) between supports. Joist channels should be fire-stopped to the full depth of the joists with material equivalent to the web construction so that individual channel areas do not exceed 300 sq ft (27.9 m²). See Figure A-1-4.6(a)(ii) for examples of composite wood joist construction.

(iii) *Panel Construction.* The term *panel construction* as used in this standard includes ceiling panels formed by members capable of trapping heat to aid the operation of sprinklers and limited to a maximum of 300 sq ft (27.9 m²) in area. Beams spaced more than 7½ ft (2.3 m) apart and framed into girders qualify for panel construction provided the 300 sq ft (27.9 m²) area limitation is met.

(iv) *Semi-Mill Construction.* The term *semi-mill construction* as used in this standard refers to a modified standard mill construction, where greater column spacing is used and beams rest on girders.

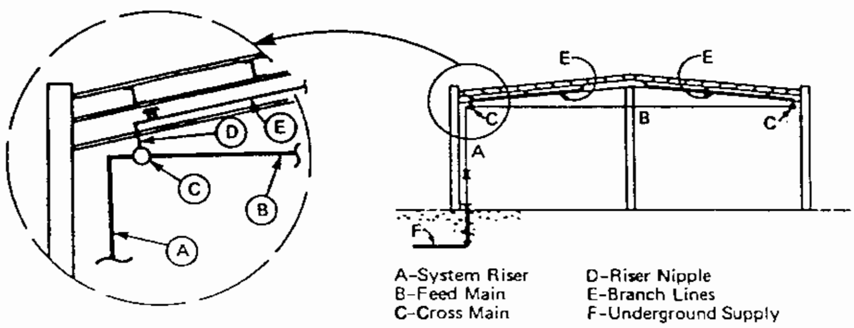


Figure A-1-4.4 Building elevation showing parts of sprinkler piping system.

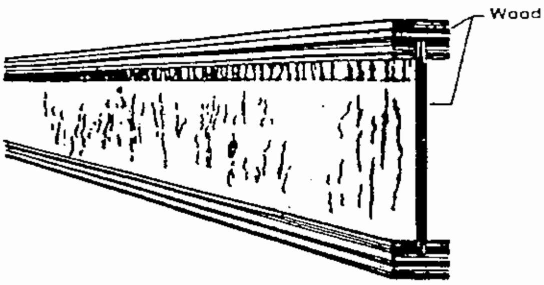


Figure A-1-4.6(a)(ii) Typical composite wood joist construction.

(v) *Wood Joist Construction.* The term *wood joist construction* refers to solid wood members of rectangular cross section, which may vary from 2 to 4 in. (51 to 102 mm) nominal width and up to 14 in. (356 mm) nominal depth spaced up to 3 ft (0.9 m) on centers, and spanning up to 40 ft (12 m) between supports, supporting a floor or roof deck. Solid wood members less than 4 in. (102 mm) nominal width and up to 14 in. (356 mm) nominal depth, spaced more than 3 ft (0.9 m) on centers are also considered as wood joist construction.

A-1-4.6(b) The following are examples of unobstructed construction. The definitions are provided as guidance to assist the user in determining the type of construction feature:

(i) *Bar Joist Construction.* The term *bar joist construction* refers to construction employing joists consisting of steel truss-shaped members. Wood truss-shaped members, which consist of wood top and bottom chord members not exceeding 4 in. (102 mm) in depth with steel tube or bar webs, are also defined as bar joists. Bar joist includes noncombustible or combustible roof or floor decks on bar joist construction. See Figures A-1-4.6(b)(i)1 and A-1-4.6(b)(i)2 for examples of bar joist construction.

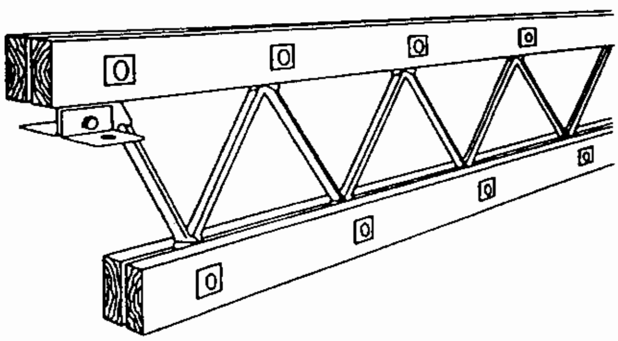


Figure A-1-4.6(b)(i)1 Wood bar joist construction.

(ii) *Open Grid Ceilings.* Open grid ceilings are ceilings in which the openings are ¼ in. (6.4 mm) or larger in the least dimension, the thickness of the ceiling material does not exceed the least dimension of the openings, and such openings constitute at least 70 percent of the ceiling area.

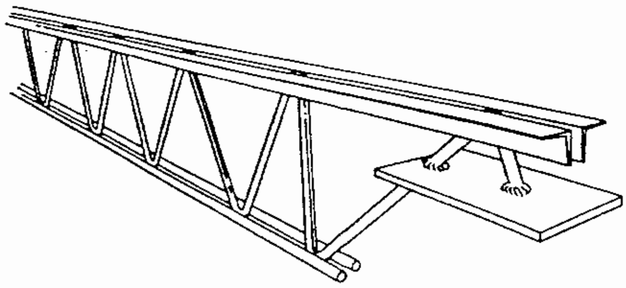


Figure A-1-4.6(b)(i)2 Open-web bar joist construction.

(iii) *Smooth Ceiling Construction.* The term *smooth ceiling construction* as used in this standard includes:

(a) Flat slab, pan-type reinforced concrete, concrete joist less than 3 ft (0.9 m) on centers.

(b) Continuous smooth bays formed by wood, concrete, or steel beams spaced more than 7½ ft (2.3 m) on centers — beams supported by columns, girders, or trusses.

(c) Smooth roof or floor decks supported directly on girders or trusses spaced more than 7½ ft (2.3 m) on centers.

(d) Smooth monolithic ceilings of at least ¾ in. (19 mm) of plaster on metal lath or a combination of materials of equivalent fire-resistive rating attached to the underside of wood joists, wood trusses, and bar joists.

(e) Open web-type steel beams, regardless of spacing.

(f) Smooth shell-type roofs, such as folded plates, hyperbolic paraboloids, saddles, domes, and long barrel shells.

NOTE: In (b) through (f) above, combustible or noncombustible floor decks are permitted. Item (b) would include standard mill construction.

(g) Suspended ceilings of combustible or noncombustible construction.

(h) Smooth monolithic ceilings with fire resistance less than that specified under item (d) attached to the underside of wood joists, wood trusses, and bar joists.

(iv) *Standard Mill Construction.* The term *standard mill construction* as used in this standard refers to heavy timber construction as defined in NFPA 220, *Standard on Types of Building Construction.*

(v) *Wood Truss Construction.* The term *wood truss construction* refers to parallel or pitched wood chord members connected by open wood members (webbing) supporting a roof or floor deck. Trusses with steel webbing, similar to bar joist construction, having top and bottom wood chords exceeding 4 in. (102 mm) in depth, should also be considered wood truss construction.

A-1-4.7 Occupancy examples in the listings as shown in the various hazard classifications are intended to represent the norm for those occupancy types. Unusual or abnormal fuel loadings or combustible characteristics and susceptibility for changes in these characteristics, for a particular occupancy, are considerations that should be weighed in the selection and classification.

The Light Hazard classification is intended to encompass residential occupancies; however, this is not intended to preclude the use of listed residential sprinklers in residential occupancies or residential portions of other occupancies.

A-1-4.7.1 Light Hazard Occupancies include occupancies having conditions similar to:

Churches
Clubs
Eaves and overhangs, if combustible construction with no combustibles beneath
Educational
Hospitals
Institutional
Libraries, except large stack rooms
Museums
Nursing or convalescent homes
Office, including data processing
Residential
Restaurant seating areas
Theaters and Auditoriums excluding stages and prosceniums
Unused attics.

A-1-4.7.2.1 Ordinary Hazard Occupancies (Group 1) include occupancies having conditions similar to:

Automobile parking and showrooms
Bakeries
Beverage manufacturing
Canneries
Dairy products manufacturing and processing
Electronic plants
Glass and glass products manufacturing
Laundries
Restaurant service areas.

A-1-4.7.2.2 Ordinary Hazard Occupancies (Group 2) include occupancies having conditions similar to:

Cereal mills
Chemical plants — ordinary
Confectionery products
Distilleries
Dry cleaners
Feed mills
Horse stables
Leather goods manufacturing
Libraries — large stack room areas
Machine shops
Metal working
Mercantile
Paper and pulp mills
Paper process plants
Piers and wharves
Post offices
Printing and publishing
Repair garages
Stages
Textile manufacturing
Tire manufacturing
Tobacco products manufacturing
Wood machining
Wood product assembly.

A-1-4.7.3.1 Extra Hazard Occupancies (Group 1) include occupancies having conditions similar to:

Aircraft hangars
Combustible hydraulic fluid use areas
Die casting
Metal extruding
Plywood and particle board manufacturing
Printing [using inks having flash points below 100°F (37.9°C)]
Rubber reclaiming, compounding, drying, milling, vulcanizing
Saw mills
Textile picking, opening, blending, garnetting, carding, combining of cotton, synthetics, wool shoddy, or burlap
Upholstering with plastic foams.

Extra Hazard Occupancies (Group 2) include occupancies having conditions similar to:

Asphalt saturating
Flammable liquids spraying
Flow coating
Mobile home or modular building assemblies (where finished enclosure is present and has combustible interiors)
Open oil quenching
Plastics processing
Solvent cleaning
Varnish and paint dipping.

A-1-4.7.4.1 Other NFPA standards contain design criteria for fire control or fire suppression (*see 1-4.7.4 and Chapter 10*). While these may form the basis of design criteria, this standard describes the methods of design, installation, fabrication, calculation, and evaluation of water supplies that should be used for the specific design of the system.

A-2-1.1 Included among items requiring listing are sprinklers, some pipe and some fittings, hangers, alarm devices, valves controlling flow of water to sprinklers, valve tamper switches, and gauges.

A-2-2.3 Information regarding the highest temperature that may be encountered in any location in a particular installation may be obtained by use of a thermometer that will register the highest temperature encountered; it should be hung for several days in the location in question, with the plant in operation.

A-2-2.4.1 Examples of such locations are paper mills, packing houses, tanneries, alkali plants, organic fertilizer plants, foundries, forge shops, fumigation, pickle and vinegar works, stables, storage battery rooms, electroplating rooms, galvanizing rooms, steam rooms of all descriptions including moist vapor dry kilns, salt storage rooms, locomotive sheds or houses, driveways, areas exposed to outside weather such as piers and wharves exposed to salt air, areas under sidewalks, around bleaching equipment in flour mills, all portions of cold storage buildings where a direct ammonia expansion system is used, and portions of any plant where corrosive vapors prevail.

A-2-2.4.2 Care should be taken in the handling and installation of wax-coated or similar sprinklers to avoid damaging the coating.

A-2-2.4.3 Painting of sprinklers may retard the thermal response of the heat-responsive element, may interfere with the free movement of parts, and may render the sprinkler inoperative. Moreover, painting may invite the application of subsequent coatings, thus increasing the possibility of a malfunction of the sprinkler.

A-2-2.5.2 The use of the wrong type of escutcheon with recessed or flush type sprinklers can result in severe disruption of the spray pattern, which can destroy the effectiveness of the sprinkler.

A-2-2.6 Sprinklers under open gratings should be provided with shields. Shields over automatic sprinklers should not be less, in least dimension, than four times the distance between the shield and fusible element, except special sprinklers incorporating a built-in shield need not comply with this recommendation if listed for the particular application.

A-2-3.2 See Table A-2-3.2.

A-2-3.4 See Table A-2-3.4.

A-2-3.5 Other types of pipe and tube that have been investigated and listed for sprinkler applications include lightweight steel pipe and thermoplastic pipe and fittings. While these products may offer advantages, such as ease of handling and installation, cost effectiveness, reduction of friction losses, and improved corrosion resistance, it is important to recognize that they also have limitations that are to be considered by those contemplating their use or acceptance.

With respect to lightweight steel pipe, corrosion studies have shown that, in comparison to Schedule 40 pipe, its effective life may be reduced, the level of reduction being related to its wall thickness. Further information with respect to corrosion resistance is contained in the individual listings of such products.

With respect to thermoplastic pipe and fittings, exposure of such piping to elevated temperatures in excess of that for which it has been listed may result in distortion or failure. Accordingly, care must be exercised when locating such systems to ensure that the ambient temperature, including seasonal variations, does not exceed the rated value.

Consideration must also be given to the possibility of exposure of the piping to elevated temperatures during a fire. The survival of thermoplastic piping under fire conditions derives primarily from the cooling effect of the discharge from the sprinklers it serves. As this discharge may not occur simultaneously with the rise in ambient temperature and, under some circumstances, may be delayed for periods beyond the tolerance of the piping, protection in the form of a fire resistant membrane is generally required. (Some listings do provide for the use of exposed piping in conjunction with residential or quick-response sprinklers, but only under specific, limited installation criteria.) When protection is required, it is described in the listing information for each individual product, and the requirements given must be followed. Equally important, such protection must be maintained. Removal of, for example, one or more panels in a lay-in ceiling can expose piping in the concealed space to the possibility of failure in the event of a fire. Similarly the relocation of openings through protective ceilings that expose the pipe to heat, inconsistent with the listing, would place the system in jeopardy. The potential for loss of the protective membrane under earthquake conditions should also be considered.

Table A-2-3.2 Steel Pipe Dimensions

Nominal Pipe Size	Outside Diameter		Schedule 10[1] Inside Diameter		Schedule 10[1] Wall Thickness		Schedule 30 Inside Diameter		Schedule 30 Wall Thickness		Schedule 40 Inside Diameter		Schedule 40 Wall Thickness	
in.	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
1	1.315	(33.4)	1.097	(27.9)	0.109	(2.8)	—	—	—	—	1.049	(26.6)	0.133	(3.4)
1 1/4	1.660	(42.2)	1.442	(36.6)	0.109	(2.8)	—	—	—	—	1.380	(35.1)	0.140	(3.6)
1 1/2	1.900	(48.3)	1.682	(42.7)	0.109	(2.8)	—	—	—	—	1.610	(40.9)	0.145	(3.7)
2	2.375	(60.3)	2.157	(54.8)	0.109	(2.8)	—	—	—	—	2.067	(52.5)	0.154	(3.9)
2 1/2	2.875	(73.0)	2.635	(66.9)	0.120	(3.0)	—	—	—	—	2.469	(62.7)	0.203	(5.2)
3	3.500	(88.9)	3.260	(82.8)	0.120	(3.0)	—	—	—	—	3.068	(77.9)	0.216	(5.5)
3 1/2	4.000	(101.6)	3.760	(95.5)	0.120	(3.0)	—	—	—	—	3.548	(90.1)	0.226	(5.7)
4	4.500	(114.3)	4.260	(108.2)	0.120	(3.0)	—	—	—	—	4.026	(102.3)	0.237	(6.0)
5	5.563	(141.3)	5.295	(134.5)	0.134	(3.4)	—	—	—	—	5.047	(128.2)	0.258	(6.6)
6	6.625	(168.3)	6.357	(161.5)	0.134[2]	(3.4)	—	—	—	—	6.065	(154.1)	0.280	(7.1)
8	8.625	(219.1)	8.249	(209.5)	0.188[2]	(4.8)	8.071	(205.0)	0.277	(7.0)	—	—	—	—
10	10.75	(273.1)	10.37	(263.4)	0.188[2]	(4.8)	10.14	(257.6)	0.307	(7.8)	—	—	—	—

NOTE 1: Schedule 10 defined to 5 in. (127 mm) nominal pipe size by ASTM A135.
NOTE 2: Wall thickness specified in 2-3.2.

Table A-2-3.4 Copper Tube Dimensions

Nominal Tube Size in.	Outside Diameter in.	Outside Diameter (mm)	Type K Inside Diameter in.	Type K Inside Diameter (mm)	Type K Wall Thickness in.	Type K Wall Thickness (mm)	Type L Inside Diameter in.	Type L Inside Diameter (mm)	Type L Wall Thickness in.	Type L Wall Thickness (mm)	Type M Inside Diameter in.	Type M Inside Diameter (mm)	Type M Wall Thickness in.	Type M Wall Thickness (mm)
3/4	0.875	(22.2)	0.745	(18.9)	0.065	(1.7)	0.785	(19.9)	0.045	(1.1)	0.811	(20.6)	0.032	(0.8)
1	1.125	(28.6)	0.995	(25.3)	0.065	(1.7)	1.025	(26.0)	0.050	(1.3)	1.055	(26.8)	0.035	(0.9)
1 1/4	1.375	(34.9)	1.245	(31.6)	0.065	(1.7)	1.265	(32.1)	0.055	(1.4)	1.291	(32.8)	0.042	(1.1)
1 1/2	1.625	(41.3)	1.481	(37.6)	0.072	(1.8)	1.505	(38.2)	0.060	(1.5)	1.527	(38.8)	0.049	(1.2)
2	2.125	(54.0)	1.959	(49.8)	0.083	(2.1)	1.985	(50.4)	0.070	(1.8)	2.009	(51.0)	0.058	(1.5)
2 1/2	2.625	(66.7)	2.435	(61.8)	0.095	(2.4)	2.465	(62.6)	0.080	(2.0)	2.495	(63.4)	0.065	(1.7)
3	3.125	(79.4)	2.907	(73.8)	0.109	(2.8)	2.945	(74.8)	0.090	(2.3)	2.981	(75.7)	0.072	(1.8)
3 1/2	3.625	(92.1)	3.385	(86.0)	0.120	(3.0)	3.425	(87.0)	0.100	(2.5)	3.459	(87.9)	0.083	(2.1)
4	4.125	(104.8)	3.857	(98.0)	0.134	(3.4)	3.905	(99.2)	0.110	(2.8)	3.935	(99.9)	0.095	(2.4)
5	5.125	(130.2)	4.805	(122.0)	0.160	(4.1)	4.875	(123.8)	0.125	(3.2)	4.907	(124.6)	0.109	(2.8)
6	6.125	(155.6)	5.741	(145.8)	0.192	(4.9)	5.845	(148.5)	0.140	(3.6)	5.881	(149.4)	0.122	(3.1)
8	8.125	(206.4)	7.583	(192.6)	0.271	(6.9)	7.725	(196.2)	0.200	(5.1)	7.785	(197.7)	0.170	(4.3)
10	10.13	(257.3)	9.449	(240.0)	0.338	(8.6)	9.625	(244.5)	0.250	(6.4)	9.701	(246.4)	0.212	(5.4)

While the listings of thermoplastic piping do not prohibit its installation in combustible concealed spaces where the provision of sprinkler protection is not required, and while the statistical record of fire originating in such space is low, it should be recognized that the occurrence of a fire in such a space could result in failure of the piping system.

The investigation of pipe and tube other than described in Table 2-3.1 should involve consideration of many factors, including:

(a) Pressure rating.

(b) Beam strength (hangers).

(c) Unsupported vertical stability.

(d) Movement during sprinkler operation (affecting water distribution).

(e) Corrosion (internal and external), chemical and electrolytic.

(f) Resistance to failure when exposed to elevated temperatures.

(g) Methods of joining (strength, permanence, fire hazard).

(h) Physical characteristics related to integrity during earthquakes.

A-2-4.2 Rubber-gasketed pipe fittings and couplings should not be installed where ambient temperatures can be expected to exceed 150°F (66°C) unless listed for this service. If the manufacturer further limits a given gasket compound, those recommendations should be followed.

A-2-4.4 Listed flexible connections are permissible and encouraged for sprinkler installations in racks to reduce the possibility of physical damage. When flexible tubing is used it should be located so that it will be protected against mechanical injury.

A-2-5.1.2 Some steel piping material having lesser wall thickness than specified in 2-5.1.2 has been listed for use in sprinkler systems when joined with threaded connections. The service life of such products may be significantly less than that of Schedule 40 steel pipe, and it should be determined if this service life will be sufficient for the application intended.

All such threads should be checked by the installer using working ring gauges conforming to the Basic Dimensions of Ring Gauges for USA (American) Standard Taper Pipe Threads, NPT, as per ANSI/ASME B1.20.1, Table 8.

A-2-5.2 See Figure A-2-5.2(a) and Figure A-2-5.2(b) on the following page.

A-2-5.2.2 As used in this standard, shop in the term ***shop welded*** means either:

(a) At the sprinkler contractor's or fabricator's premise.

(b) An approved welding area at the building site.

A-2-5.2.5(a) Listed, shaped, contoured nipples meet the definition of fabricated fittings.

A-2-5.4 The fire hazard of the brazing and soldering processes should be suitably safeguarded.

A-2-5.4.1 Continued corrosive action from self-cleaning fluxes after the soldering or brazing process is completed has resulted in leaks from the seats of sprinklers.

A-2-6.1 See Figure A-2-6.1 on page 79.

A-2-6.1.5 Table 2-6.1.5(a) assumes that the load from 15 ft (5 m) of water-filled pipe, plus 250 lb (114 kg), is located at the midpoint of the span of the trapeze member, with a maximum allowable bending stress of 15 KSI (111 kg). If the load is applied at other than the midpoint, for the purpose of sizing the trapeze member, an equivalent length of trapeze may be used, derived from the formula

$$L = \frac{4\,ab}{a + b}$$

where "L" is the equivalent length, "a" is the distance from one support to the load, and "b" is the distance from the other support to the load.

When multiple mains are to be supported or multiple trapeze hangers are provided in parallel, the required or available section modulus may be added.

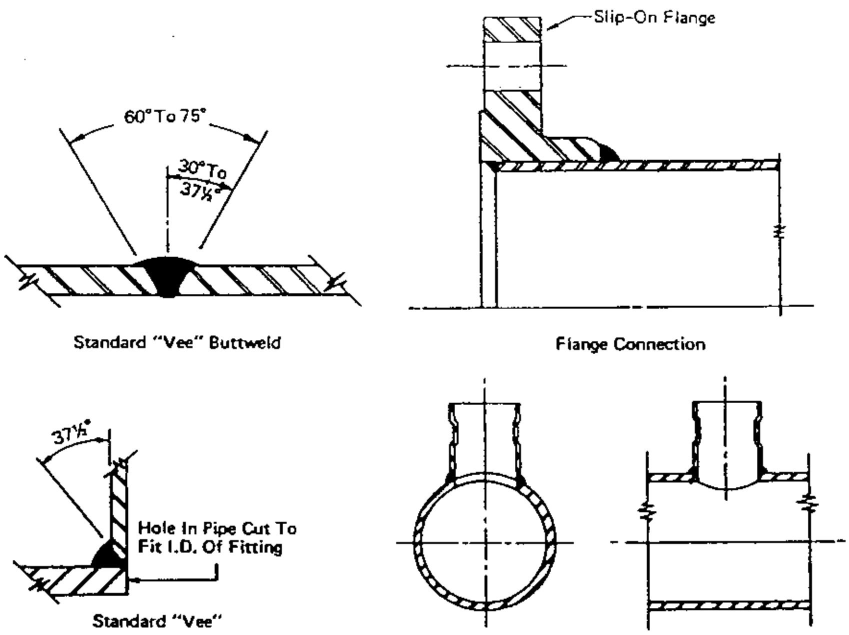


Figure A-2-5.2(a) Acceptable weld joints.

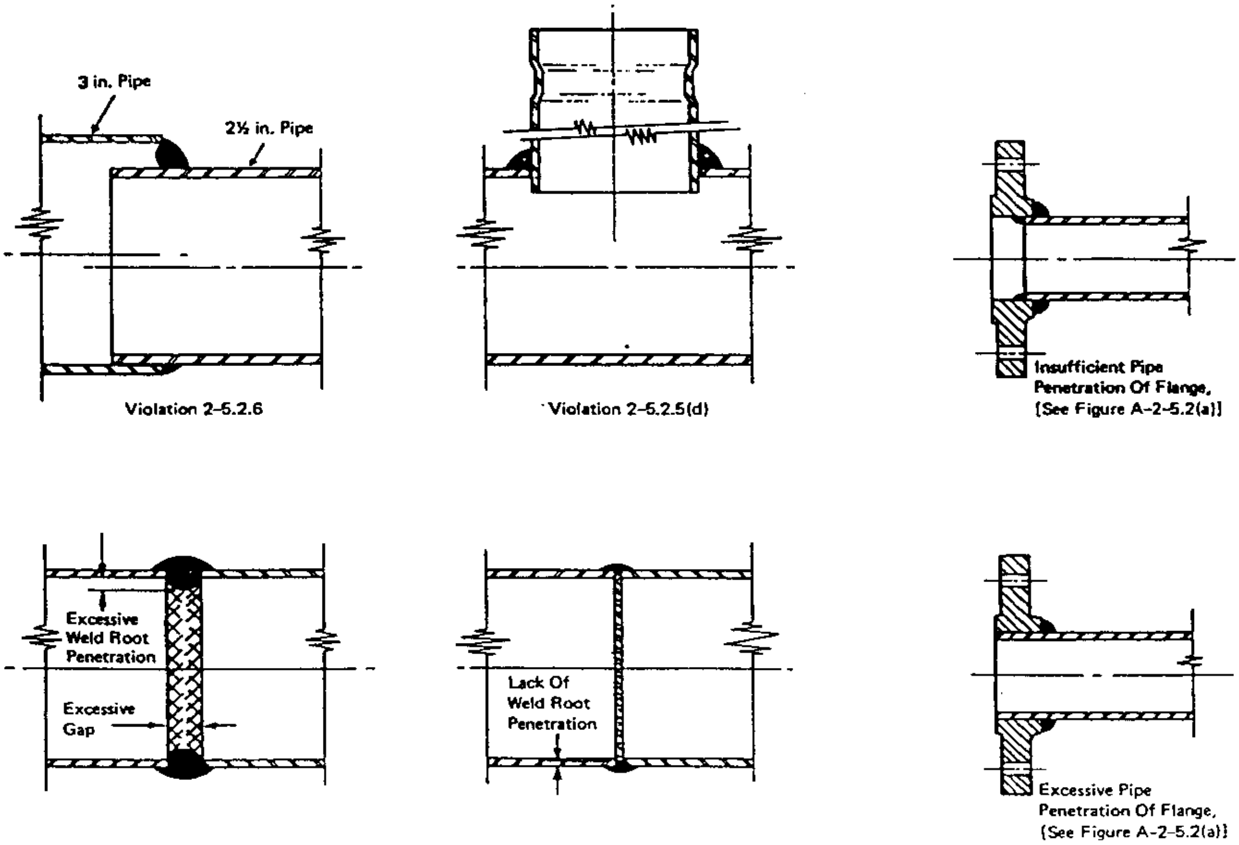


Figure A-2-5.2(b) Unacceptable weld joints.

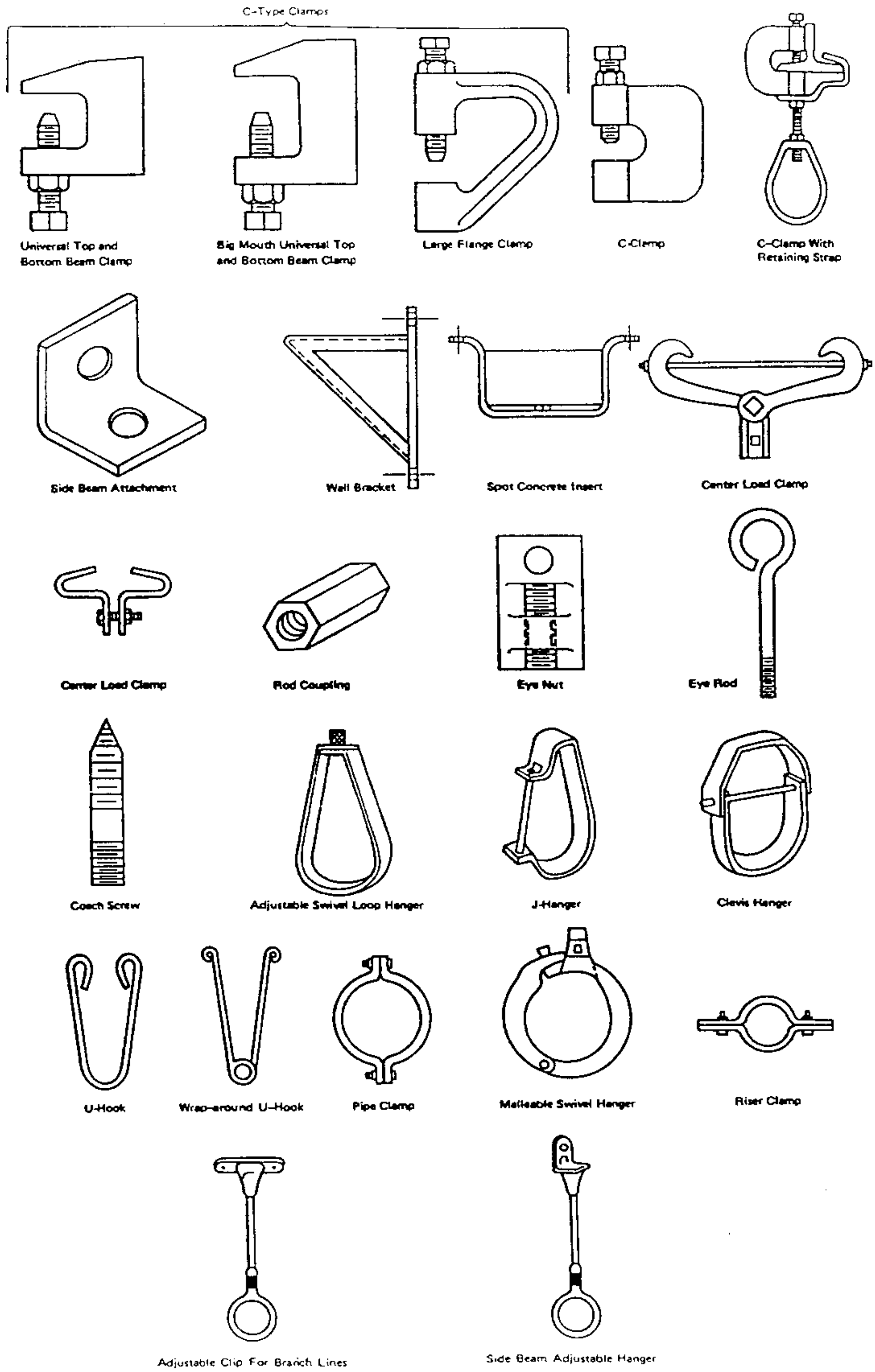


Figure A-2-6.1 Common types of acceptable hangers.

A-2-6.1.7 The rules covering the hanging of sprinkler piping take into consideration the weight of water-filled pipe plus a safety factor. No allowance has been made for the hanging of nonsystem components from sprinkler piping.

A-2-6.3.1 Powder-driven studs should not be used in steel of less than $^3/_{16}$ in. (4.8 mm) total thickness.

A-2-6.3.2 The ability of concrete to hold the studs varies widely according to type of aggregate, quality of concrete, and proper installation.

A-2-9.2.4 The surge of water when the valve trips may seriously damage the device.

A-2-9.3.1 Audible alarms are normally located on the outside of the building. Listed electric gongs, bells, horns, or sirens inside the building or a combination inside and outside are sometimes advisable.

A-2-9.3.2 All alarm apparatus should be so located and installed that all parts are accessible for inspection, removal, and repair and should be substantially supported.

A-2-9.5.1 Switches that will silence electric alarm sounding devices by interruption of electrical current are not desirable; however, if such means are provided, then the electrical alarm sounding device circuit should be arranged so that when the sounding device is electrically silenced, that fact should be indicated by means of a conspicuous light located in the vicinity of the riser or alarm control panel. This light should remain in operation during the entire period of the electrical circuit interruption.

A-3-2 A dry pipe system should be installed only where heat is not adequate to prevent freezing of water in all or sections of the system. Dry pipe systems should be converted to wet pipe systems when they become unnecessary because adequate heat is provided. Sprinklers should not be shut off in cold weather.

When two or more dry pipe valves are used, systems should preferably be divided horizontally to prevent simultaneous operation of more than one system and the resultant increased time delay in filling systems and discharging water, plus receipt of more than one waterflow alarm signal.

When adequate heat is present in sections of the dry pipe system, consideration should be given to dividing the system into a separate wet pipe system and dry pipe system. Minimized use of dry pipe systems is desirable where speed of operation is of particular concern.

A-3-2.3 The capacities of the various sizes of pipe given in Table A-3-2.3 are for convenience in calculating the capacity of a system.

A-3-2.5 The dry pipe valve should be located in an accessible place near the sprinkler system it controls. When exposed to cold, the dry pipe valve should be located in a valve room or enclosure of adequate size to properly service equipment.

Table A-3-2.3 Capacity of One Foot of Pipe (Based on actual internal pipe diameter)

Nominal Diameter	Gal Sch 40	Gal Sch 10	Nominal Diameter	Gal Sch 40	Gal Sch 10
$^3/_4$ in.	0.028	—	3 in.	0.383	0.433
1 in.	0.045	0.049	$3^1/_2$ in.	0.513	0.576
$1^1/_4$ in.	0.078	0.085	4 in.	0.660	0.740
$1^1/_2$ in.	0.106	0.115	5 in.	1.040	1.144
2 in.	0.174	0.190	6 in.	1.501	1.649[1]
$2^1/_2$ in.	0.248	0.283	8 in.	2.66[3]	2.776[2]

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m; 1 gal = 3.785 L.
[1]0.134 Wall Pipe
[2]0.188 Wall Pipe
[3]Schedule 30

A-3-2.6.2 The compressor should draw its air supply from a place where the air is dry and not too warm. Moisture from condensation may cause trouble in the system.

A-3-3.1 Conditions of occupancy or special hazards may require quick application of large quantities of water, and in such cases deluge systems may be needed.

Fire detection devices should be selected to assure operation, yet guard against premature operation of sprinklers, based on normal room temperatures and draft conditions.

In locations where ambient temperature at the ceiling is high from heat sources other than fire conditions, heat-responsive devices that operate at higher than ordinary temperature and are capable of withstanding the normal high temperature for long periods of time should be selected.

When corrosive conditions exist, materials or protective coatings that resist corrosion should be used.

To help avoid ice formation in piping due to accidental tripping of dry pipe valves in cold storage rooms, a deluge automatic water control valve may be used on the supply side of the dry pipe valve. When this combination is employed:

(a) Dry systems may be manifolded to a deluge valve, the protected area not exceeding 40,000 sq ft (3716 m^2). The distance between valves should be as short as possible to minimize water hammer.

(b) The dry pipe valves should be pressurized to 50 psi (3.4 bars) to reduce the possibility of dry pipe valve operation from water hammer.

A-3-3.2.1(c) This is sometimes referred to as a double interlock preaction system.

A-3-3.3 When 8-in. (203-mm) piping is employed to reduce friction losses in a system operated by fire detection devices, a 6-in. (152-mm) preaction or deluge valve and 6-in. (152-mm) gate valve between taper reducers should be permitted.

A-3-4.1 Combined dry pipe and preaction systems may be installed when wet pipe systems are impractical. They are intended for use in, but not limited to, structures where a number of dry pipe valves would be required if a dry pipe system were installed.

A-3-4.1.1 See Figure A-3-4.1.1.

A-3-4.3 See Figure A-3-4.3.

A-3-5.1 Antifreeze solutions may be used for maintaining automatic sprinkler protection in small unheated areas. Antifreeze solutions are recommended only for systems not exceeding 40 gal (151 L).

Because of the cost of refilling the system or replenishing small leaks, it is advisable to use small dry valves where more than 40 gal (151 L) are to be supplied.

A-3-5.2 Listed CPVC sprinkler pipe and fittings should be protected from freezing with glycerine only. The use of diethylene, ethylene, or propylene glycols are specifically prohibited. Laboratory testing shows that glycol-based antifreeze solutions present a chemical environment detrimental to CPVC.

A-3-5.2.3 Beyond certain limits, increased proportion of antifreeze does not lower the freezing point of solution. (*See Figure A-3-5.2.3 on the following page.*)

Glycerine, diethylene glycol, ethylene glycol, and propylene glycol should never be used without mixing with water in proper proportions, because these materials tend to thicken near 32°F (0°C).

A-3-5.3 All permitted antifreeze solutions are heavier than water. At the point of contact (interface) the heavier liquid will be below the lighter liquid, preventing diffusion of water into the unheated areas.

A-3-6.1.2 Outlets should be provided at critical points on sprinkler system piping to accommodate attachment of pressure gauges for test purposes.

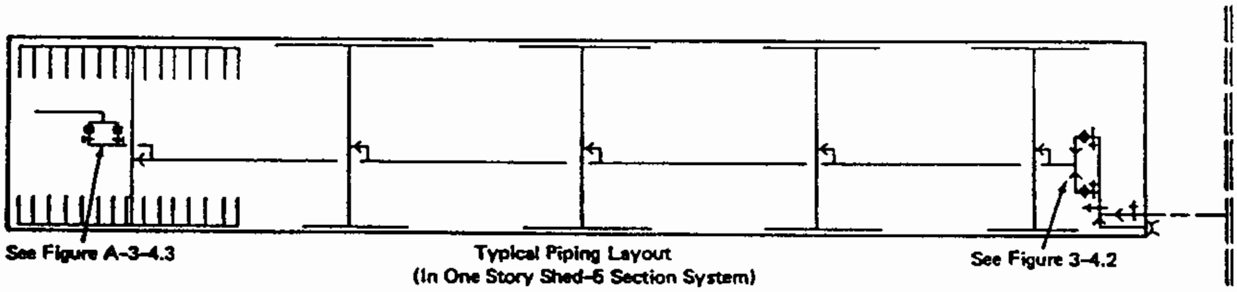


Figure A-3-4.1.1 Typical piping layout for combined dry pipe and preaction sprinkler system.

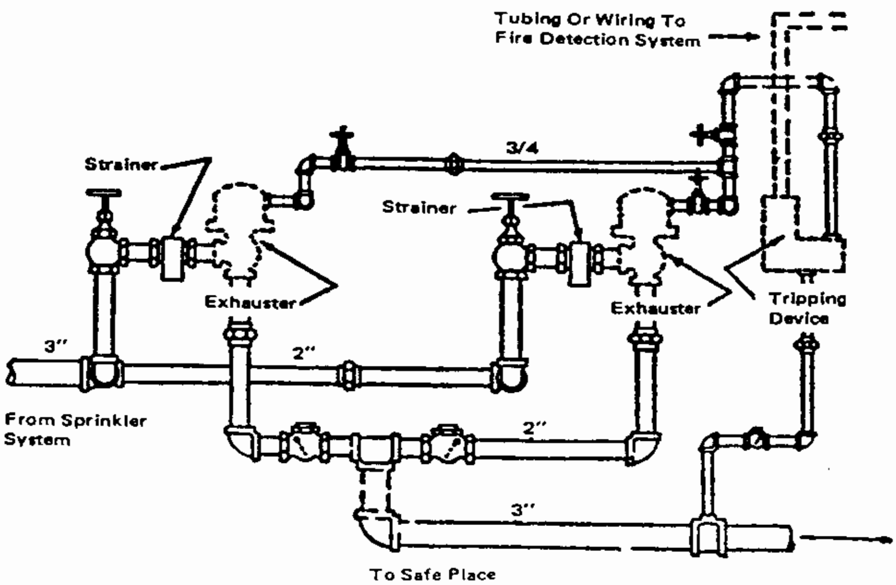


Figure A-3-4.3 Arrangement of air exhaust valves for combined dry pipe and preaction sprinkler system.

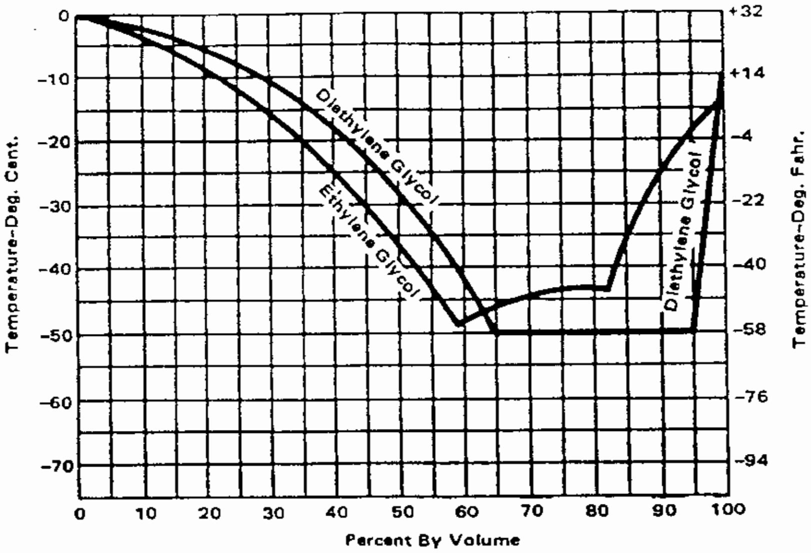


Figure A-3-5.2.3 Freezing points of water solutions of ethylene glycol and diethylene glycol.

A-3-7.2.1 The water supply should be capable of furnishing the total demand for all exposure sprinklers operating simultaneously for protection against the exposure fire under consideration for a duration of not less than 60 minutes.

A-3-8 Careful installation and maintenance, and some special arrangements of piping and devices as outlined in this section, are needed to avoid the formation of ice and frost inside piping in cold storage rooms that will be maintained at or below 32°F (0°C). Conditions are particularly favorable to condensation where pipes enter cold rooms from rooms having temperatures above freezing.

Whenever the opportunity offers, fittings such as those specified in 3-8.1 and illustrated in Figures A-3-8.1(a) and A-3-8.1(b), as well as flushing connections, should be provided in existing systems.

When possible, risers should be located in stair towers or other locations outside of refrigerated areas. This would reduce the probabilities of ice or frost formation within the riser (supply) pipe.

Cross mains should be connected to risers or feed mains with flanges. In general, flanged fittings should be installed at points that would allow easy dismantling of the system. Split ring or other easily removable types of hangers will facilitate the dismantling.

Because it is not practical to allow water to flow into sprinkler piping in spaces that may be constantly subject to freezing, or where temperatures must be maintained at or below 40°F (4.4°C), it is important that means be provided at the time of system installation to conduct trip tests on dry pipe valves that service such systems. NFPA 13A, *Recommended Practice for the Inspection, Testing and Maintenance of Sprinkler Systems*, contains guidance in this matter.

A-3-8.1 Joining of pipe and fittings using split housing couplings may allow separation of pipe for internal inspection.

A-3-8.1(a) This may be accomplished by a blind flange on a fitting (tee or cross) in the riser or cross main or a removable section 24 in. (610 mm) long in the feed main as shown in Figure A-3-8.1(a). Such fittings in conjunction with the flushing connections specified in 9-3.2 permit examination of the entire length of the cross mains. Branch lines may be examined by disconnecting them from cross mains.

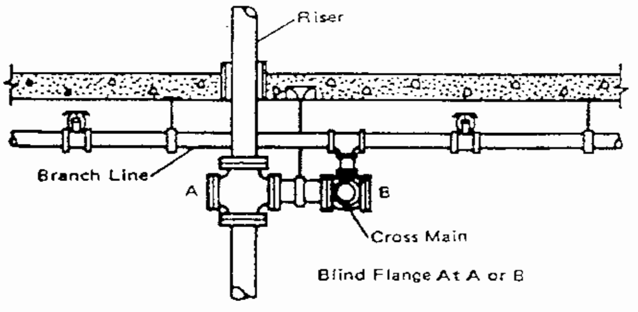
A-3-8.1(b) This may be accomplished by means of 2-in. (51-mm) capped nipples or blind flanges on fittings.

A-3-8.1(c) This can be accomplished at floor penetrations by a tee with a blind flange in the cold room and at wall penetrations by a 24-in. (610-mm) flanged removable section in the warm room as shown in Figure A-3-8.1(b).

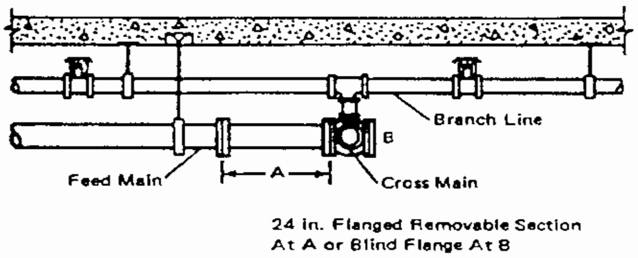
A-3-8.4 Propylene glycol or other suitable material may be used as a substitute for priming water, to prevent evaporation of the priming fluid and thus reduce ice formation within the system, subject to state and local health regulations.

A-3-9.2 See Figure A-3-9.2 on page 84.

A-4-1 The installation requirements are specific for the normal arrangement of structural members. There will be arrangements of structural members not specifically detailed by the requirements. By applying the basic principles, layouts for such construction can vary from specific illustrations, provided the maximum specified for the spacing and location of sprinklers (Section 4-4) are not exceeded.



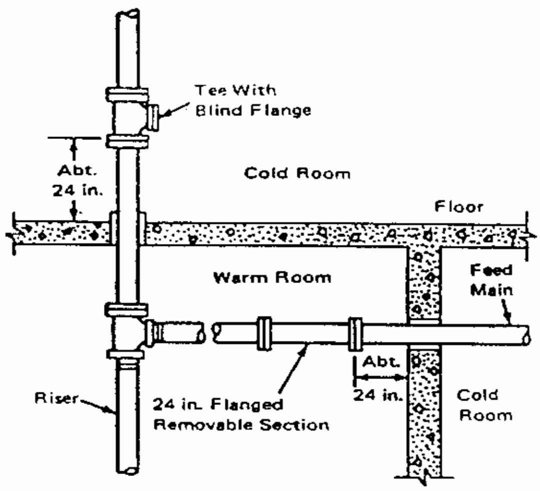
(a) Elevation At Riser And Cross Main



(b) Elevation At Feed Main And Cross Main

For SI Units: 1 in. = 25.4 mm.

Figure A-3-8.1(a) Fittings to facilitate examination of feed mains, risers, and cross mains in freezing areas.



For SI Units: 1 in. = 25.4 mm.

Figure A-3-8.1(b) Fittings in feed main or riser passing through wall or floor from warm room to cold room.

A-4-1.1 This standard contemplates full sprinkler protection for all areas. Other NFPA standards that mandate sprinkler installation may not require sprinklers in certain areas. The requirements of this standard should be used insofar as they are applicable. The authority having jurisdiction should be consulted in each case.

When buildings or portions of buildings are of combustible construction or contain combustible material, standard fire barriers should be provided to separate the areas that are sprinkler protected from adjoining unsprinklered areas. All openings should be protected in accordance with applicable standards, and no sprinkler piping should be placed in an unsprinklered area unless the area is permitted to be unsprinklered by this standard.

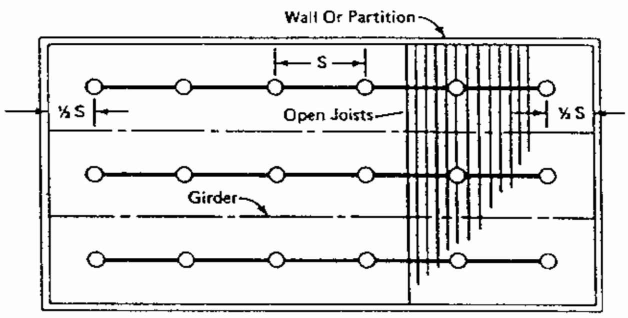
Water supplies for partial systems should be designed with consideration to the fact that in a partial system more sprinklers may be opened in a fire that originates in an unprotected area and spreads to the sprinklered area than would be the case in a completely protected building. Fire originating in a non-sprinklered area may overpower the partial sprinkler system.

When sprinklers are installed in corridors only, sprinklers should be spaced up to the maximum of 15 ft (4.5 m) along the corridor, with one sprinkler opposite the center of any door or pair of adjacent doors opening onto the corridor, and with an additional sprinkler installed inside each adjacent room above the door opening. When the sprinkler in the adjacent room provides full protection for that space, an additional sprinkler is not required in the corridor adjacent to the door.

A-4-2.2 Tests involving areas of coverage over 100 sq ft (9.3 m^2) for large-drop sprinklers are limited in number, and use of areas of coverage over 100 sq ft (9.3 m^2) should be carefully considered.

Joists above Girders or Framed into Girders;
Branch Lines Uniformly Spaced between Girders

Maximum Spacing: 130 sq ft per Sprinkler
L × S = 130 or less



Key

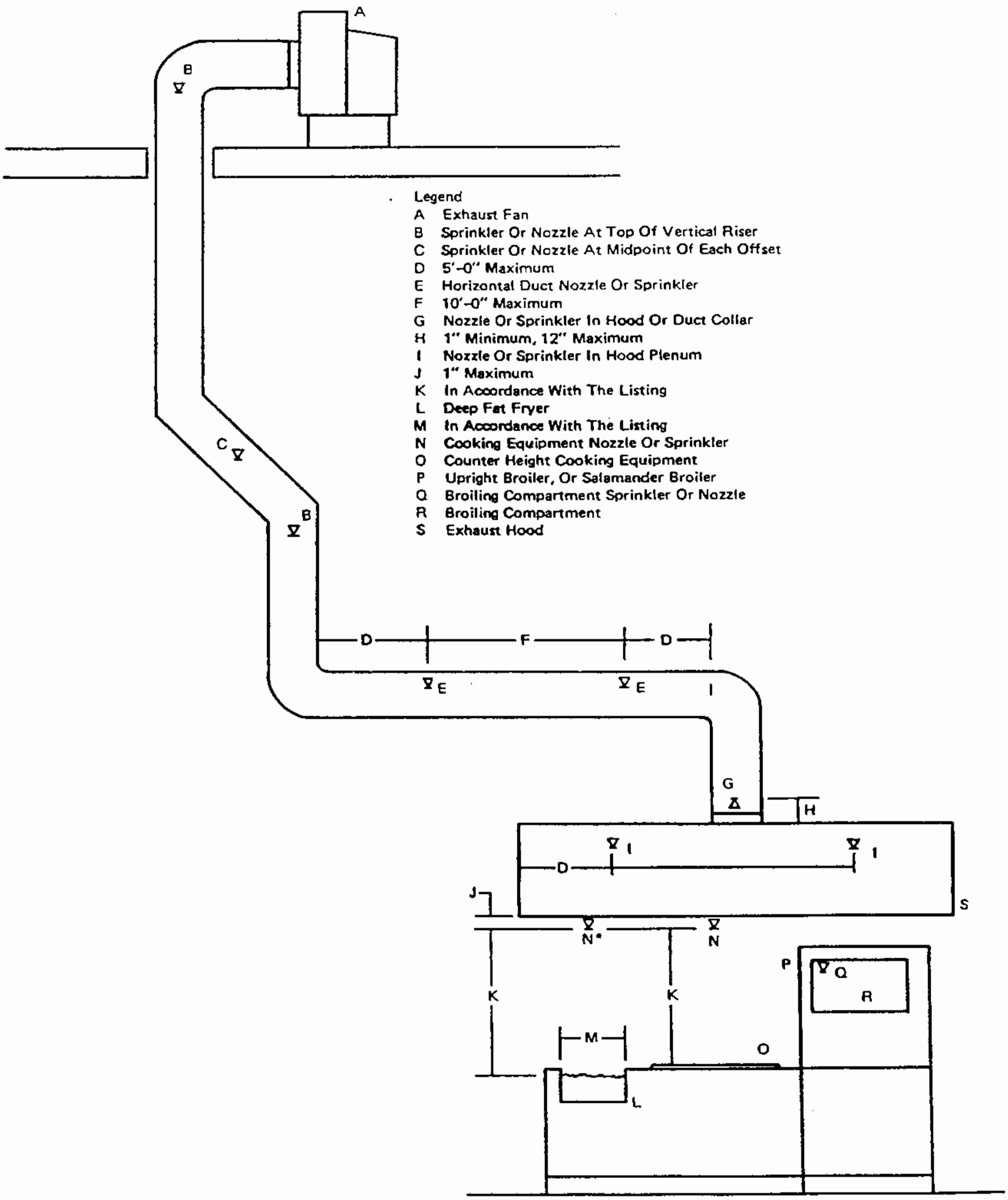
L = Distance between branch lines, limit 15 ft.
S = Distance bewteen sprinklers on branch lines, limit 15 ft.
Y = Maximum distance between girders.

Examples

Y	L	S (Max)	Y	L	S (Max)
10 ft 9 in.	10 ft 9 in.	12 ft 1 in.	10 ft 10 in. 12 ft 1 in.	10 ft 10 in. 12 ft 1 in.	12 ft 0 in. 10 ft 9 in.

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m; 1 ft^2 = 0.0929 m^2.

Figure A-4-2.2 Layout of sprinklers under open wood joist construction—Ordinary Hazard Occupancies.



*Listed For Deep Fat Fryer Protection

Figure A-3-9.2 Typical installation showing automatic sprinklers or automatic nozzles being used for the protection of commercial cooking equipment and ventilation systems.

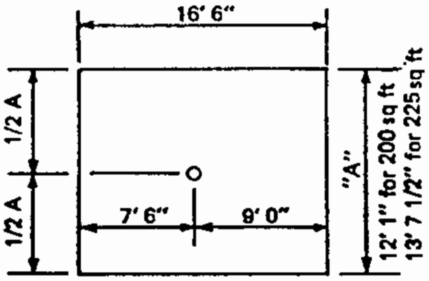
A-4-3.1.1 The evaluation for usage should be based upon a review of available technical data.

A-4-3.1.2 This requirement is to minimize the obstruction of the discharge pattern.

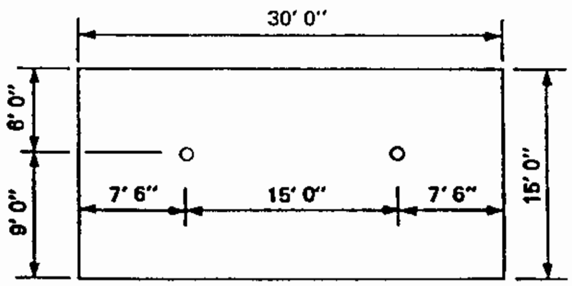
A-4-3.6.1 The response and water distribution pattern of listed residential sprinklers have been shown by extensive fire testing to provide better control than spray sprinklers in residential occupancies. These sprinklers are intended to prevent flashover in the room of fire origin, thus improving the chance for occupants to escape or be evacuated.

A-4-3.8.2 This requirement is to avoid scale accumulation.

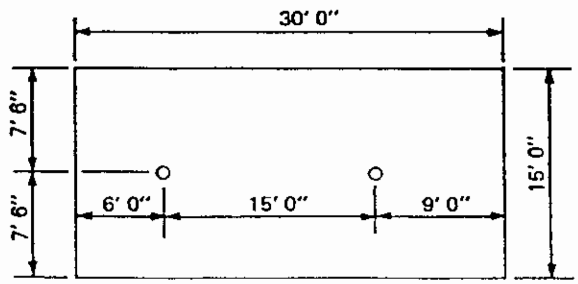
A-4-4.1.2.1 Exception An example of sprinklers in small rooms for hydraulically designed and pipe schedule systems is shown in Figure A-4-4.1.2.1(a), and examples for hydraulically designed systems only are shown in Figures A-4-4.1.2.1(b), (c), and (d).



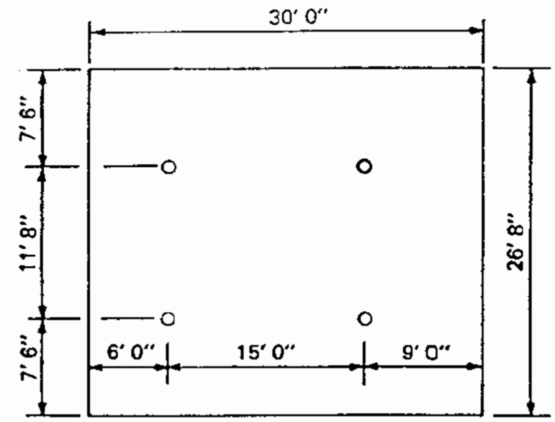
For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Figure A-4-4.1.2.1(a).



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Figure A-4-4.1.2.1(b).



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Figure A-4-4.1.2.1(c).



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.
Figure A-4-4.1.2.1(d).

A-4-4.1.3.1 When of a depth that will obstruct the spray discharge pattern, girders, beams or trusses forming narrow pockets of combustible construction along walls may require additional sprinklers.

A-4-4.1.3.2.1 Frequently, additional sprinkler equipment can be avoided by reducing the width of decks or galleries and providing proper clearances. Slatting of decks or walkways or the use of open grating as a substitute for automatic sprinklers thereunder is not acceptable. The use of cloth or paper dust tops for rooms forms obstruction to water distribution. If employed, the area below should be sprinklered.

A-4-4.1.3.3 The distances given in Table 4-4.1.3.3 were determined through tests in which privacy curtains with either a solid fabric or close mesh [1/4 in. (6.4 mm)] top panel were installed. For broader-mesh top panels, e.g., 1/2 in. (13 mm), the obstruction of the sprinkler spray is not likely to be severe and the authority having jurisdiction may not need to apply the requirements in 4-4.1.3.3.

A-4-4.1.5 On sprinkler lines larger than 2 in. (51 mm), consideration should be given to the distribution interference caused by the pipe, which can be minimized by installing sprinklers on riser nipples or installing sprinklers in the pendent position.

A-4-4.1.6 The 18 in. (457 mm) dimension is not intended to limit the height of shelving on a wall or shelving against a wall in accordance with 4-4.1.6. When shelving is installed on a wall and is not directly below sprinklers, the shelves, including storage thereon, may extend above the level of a plane located 18 in. (457 mm) below ceiling sprinkler deflectors. Shelving, and any storage thereon, directly below the sprinklers may not extend above a plane located 18 in. (457 mm) below the ceiling sprinkler deflectors.

A-4-4.1.7.1.1 Exceptions No. 1, 2, and 3 do not require sprinkler protection because it is not physically practical to install sprinklers in these spaces. To reduce the possibility of uncontrolled fire spread, consideration should be given in these unsprinklered concealed space situations to using Exceptions No. 5, 8, and 9.

A-4-4.1.7.2.2 When practicable, sprinklers should be staggered at the alternate floor levels, particularly when only one sprinkler is installed at each floor level.

A-4-4.1.7.3.3 See Figures A-4-4.1.7.3.3(a) and (b).

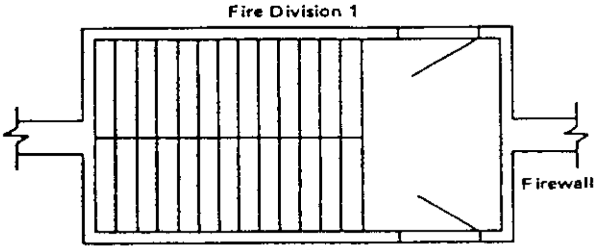


Figure A-4-4.1.7.3.3(a) Noncombustible stair shaft serving two fire sections.

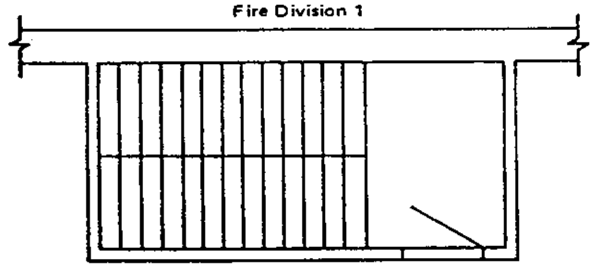


Figure A-4-4.1.7.3.3(b) Noncombustible stair shaft serving one fire section.

A-4-4.1.7.3.4 When sprinklers in the normal ceiling pattern are closer than 6 ft (1.8 m) from the water curtain, it may be preferable to locate the water curtain sprinklers in recessed baffle pockets. (*See Figure A-4-4.1.7.3.4.*)

A-4-4.1.7.4 The installation of sprinklers at floor levels should be arranged so as to protect the sprinklers from mechanical injury and from falling materials and not cause obstruction within the chute. This can usually be accomplished by recessing the sprinkler in the wall of the chute or by providing a protective deflector canopy over the sprinkler. Sprinklers should be placed so that there will be minimum interference of the discharge therefrom. (*See also 1-6.2.*) Sprinklers with special directional discharge characteristics may be advantageous. (*See Figure A-4-4.1.7.4.*)

A-4-4.1.7.6 Small loading docks, covered platforms, ducts, or similar small unheated areas may be protected by dry-pendent sprinklers extending through the wall from wet sprinkler piping in an adjacent heated area. When protecting covered platforms, loading docks, and similar areas, a dry-pendent sprinkler should extend down at a 45 degree angle. The width of the area to be protected should not exceed 7½ ft (2.3 m). Sprinklers should be spaced not over 12 ft (3.7 m) apart. (*See Figure A-4-4.1.7.6.*)

A-4-4.1.7.9.2 Saw-toothed roofs have regularly spaced monitors of saw tooth shape, with the nearly vertical side glazed and usually arranged for venting. Sprinkler placement is limited to a maximum of 3 ft down the slope from the peak because of the effect of venting on sprinkler sensitivity.

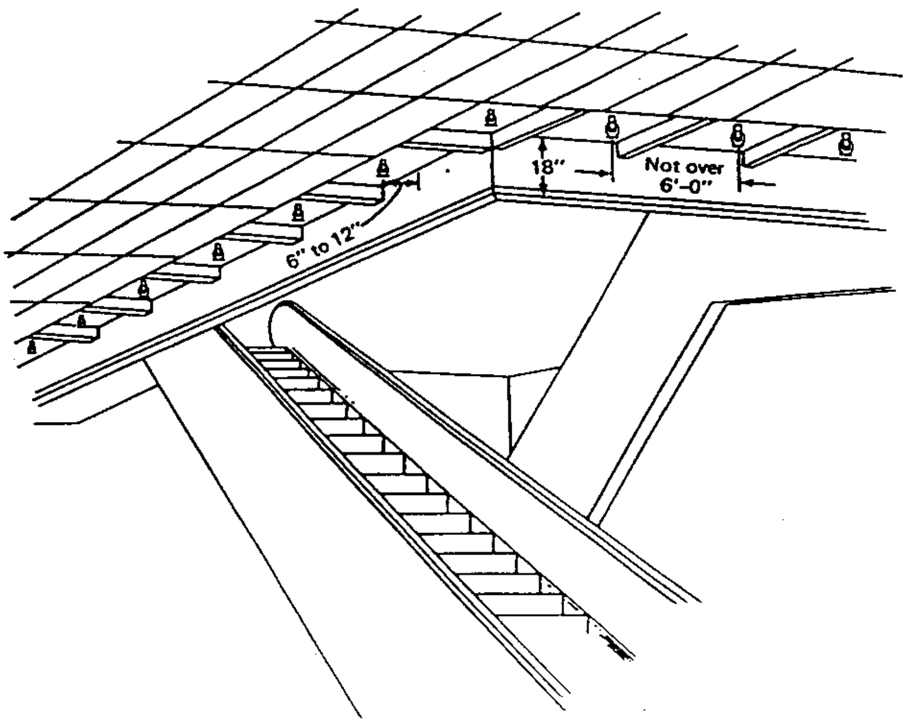


Figure A-4-4.1.7.3.4 Sprinklers around escalators.

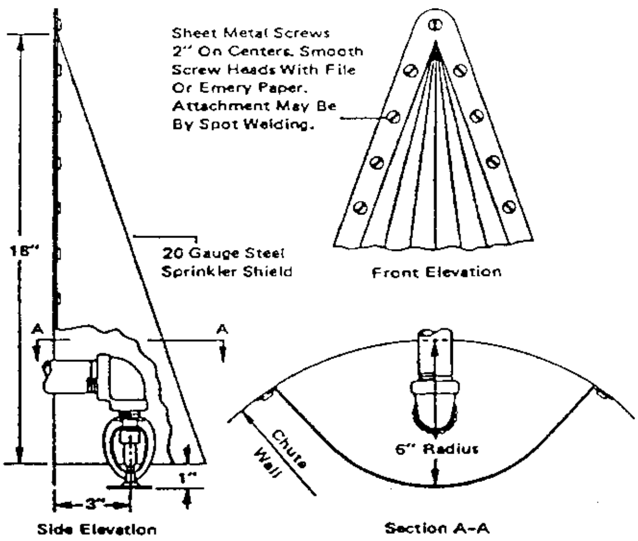


Figure A-4-4.1.7.4 Canopy for protecting sprinklers in building service chutes.

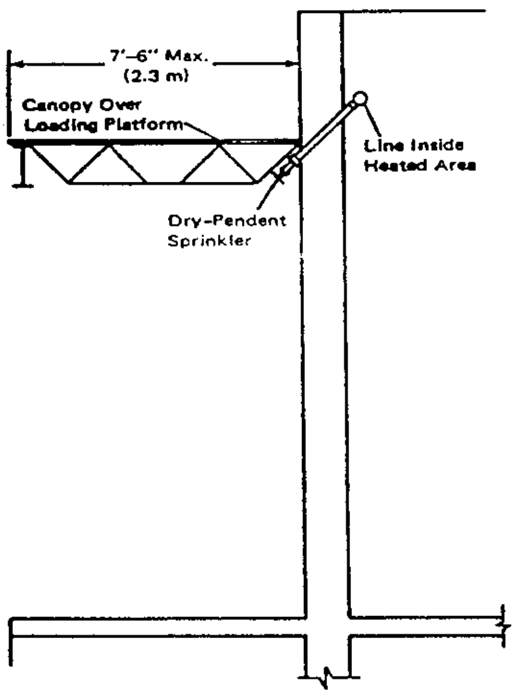


Figure A-4-4.1.7.6 Dry-pendent sprinklers for protection of covered platforms, loading docks, and similar areas.

A-4-4.1.7.13 The installation of open-grid egg crate, louver, or honeycomb ceilings beneath sprinklers restricts the sideways travel of the sprinkler discharge and may change the character of discharge.

A-4-4.1.7.14.3 Drop-out ceilings do not provide the required protection for soft-soldered copper joints or other piping that requires protection.

A-4-4.1.7.14.4 The ceiling tiles may drop before sprinkler operation. Delayed operation may occur because heat must then bank down from the deck above before sprinklers will operate.

A-4-4.1.7.15 See NFPA 81, *Standard on Fur Storage, Fumigation and Cleaning*. For tests of sprinkler performance in fur vaults see Fact Finding Report on Automatic Sprinkler Protection for Fur Storage Vaults of Underwriters Laboratories Inc., dated November 25, 1947.

A-4-4.1.7.23 One and one-half (1½) in. hose connections for use in storage occupancies and other locations where standpipe systems are not required are covered by this standard. When Class II standpipe systems are required, see the appropriate provisions of NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, with respect to hose stations and water supply for hose connections from sprinkler systems.

A-4-4.1.7.24 Combined automatic sprinkler and standpipe risers should not be interconnected by sprinkler system piping.

A-4-4.1.7.25 See Figure A-4-4.1.7.25.

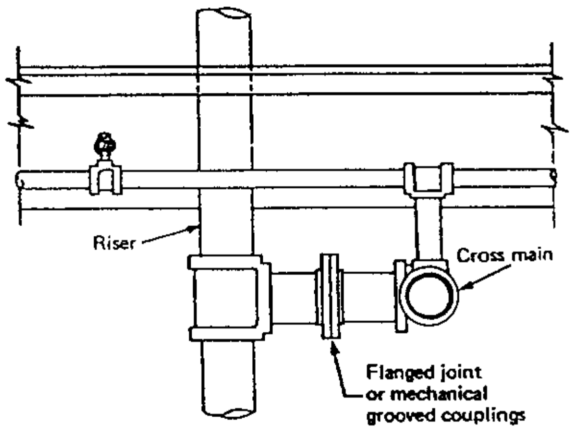


Figure A-4-4.1.7.25 One arrangement of flanged joint at sprinkler riser.

A-4-4.2.2.1 The protection area per sprinkler should be determined using the S x L = Protection Area rule as follows:

1. "S" — Determine distance to the next sprinkler (or to the wall, in case of an end sprinkler on a branch line) upstream and downstream. Choose the larger of either twice the distance to the wall or the distance to the next sprinkler.

2. "L" — The distance to the opposite side of the room will be "L." Where sprinklers are provided on both sides of the room, "L" should be half the distance between the walls.

A-4-4.3.1 It is important that sprinklers in the immediate vicinity of the fire center not skip, and this requirement imposes certain restrictions on the spacing.

A-4-4.3.3 If all other factors are held constant, the operating time of the first sprinkler will vary exponentially with the distance between the ceiling and deflector. At distances greater than 7 in. (178 mm), for other than open wood joist construction, the delayed operating time will permit the fire to gain headway, with the result that substantially more sprinklers operate. At distances less than 7 in. (178 mm), other effects come into play. Changes in distribution, penetration, and cooling nullify the advantage gained by faster operation. The net result is again increased fire damage accompanied by an increase in the number of sprinklers operated. The optimum clearance between deflectors and ceiling is, therefore, 7 in. (178 mm). For open wood joist construction the optimum clearance between deflectors and the bottom of joists is 3 1/2 in. (89 mm).

A-4-4.3.4 To a great extent, large-drop sprinklers rely on direct attack to gain rapid control of both the burning fuel and ceiling temperatures. Therefore, interference with the discharge pattern and obstructions to the distribution should be avoided.

A-4-5.1.1 See Figure A-4-5.1.1.

A-4-5.1.1.1 A water supply connection should not extend into a building or through a building wall unless such connection is under the control of an outside listed indicating valve or an inside listed indicating valve located near the outside wall of the building.

All valves controlling water supplies for sprinkler systems or portions thereof, including floor control valves, should be accessible to authorized persons during emergencies. Permanent ladders, clamped treads on risers, chain-operated hand wheels, or other accepted means should be provided when necessary.

Outside control valves are suggested in the following order of preference:

(a) Listed indicating valves at each connection into the building at least 40 ft (12.2 m) from buildings if space permits.

(b) Control valves installed in a cutoff stair tower or valve room accessible from outside.

(c) Valves located in risers with indicating posts arranged for outside operation.

(d) Key-operated valves in each connection into the building.

A-4-5.1.1.6 When a system having only one dry pipe valve is supplied with city water and fire department connection it will be satisfactory to install the main check valve in water supply connection immediately inside of the building. In instances where there is no outside control valve, the system indicating valve should be placed at the service flange, on the supply side of all fittings.

A-4-5.1.1.7 See Figure A-4-5.1.1.7.

A-4-5.1.2.3 When the relief valve operation would result in water being discharged onto interior walking or working surfaces, consideration should be given to piping the discharge from the valve to a drain connection or other safe location.

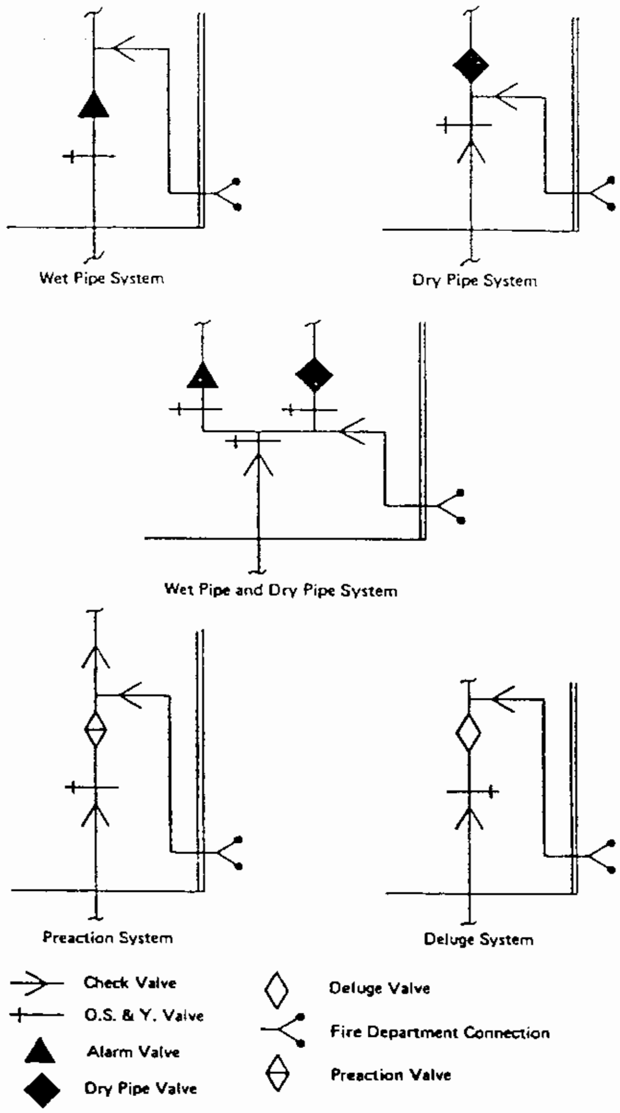


Figure A-4-5.1.1 Examples of acceptable valve arrangements.

A-4-5.2.2.1 When copper tube is to be installed in moist areas or other environments conducive to galvanic corrosion, copper hangers or ferrous hangers with an insulating material should be used.

A-4-5.2.3.1 Exception No. 1 See Figure A-4-5.2.3.1.

A-4-5.2.3.3 Sprinkler piping should be adequately secured to restrict the movement of piping upon sprinkler operation. The reaction forces caused by the flow of water through the sprinkler could result in displacement of the sprinkler, thereby adversely affecting sprinkler discharge. Listed CPVC pipe and listed polybutylene pipe have specific requirements for piping support to include additional pipe bracing of sprinklers. (*See Figure A-4-5.2.3.3.*)

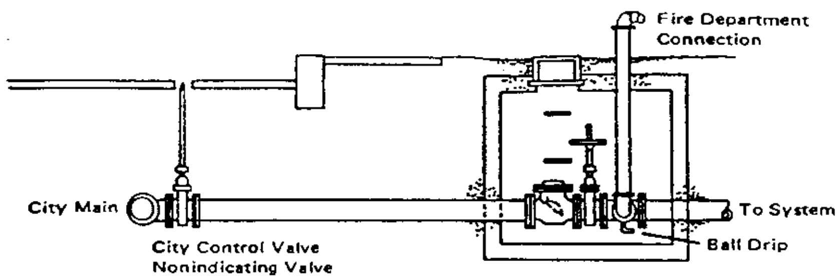
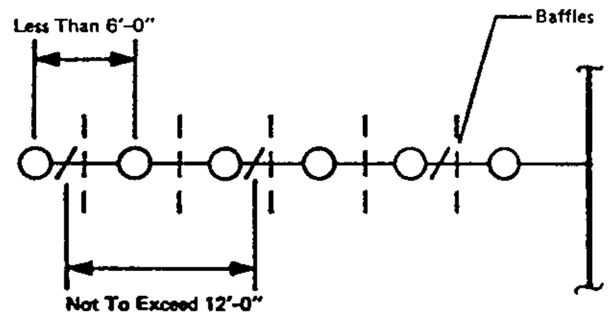


Figure A-4-5.1.1.7 Pit for gate valve, check valve, and fire department connection.



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure A-4-5.2.3.1 Distance between hangers.

A-4-5.2.3.3 Exception No. 1 See Figure A-4-5.2.3.3 Exception No. 1.

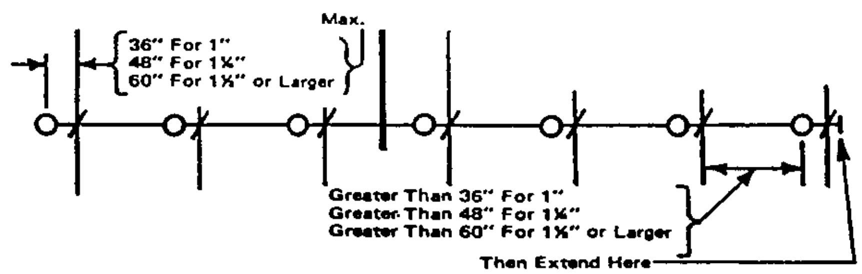
A-4-5.2.3.3 Exception No. 2 See Figure A-4-5.2.3.3 Exception No. 2 on the following page.

A-4-5.2.3.4 See Figure A-4-5.2.3.4 on the following page.

A-4-5.2.3.4 Exception See Figure A-4-5.2.3.4 Exception on the following page.

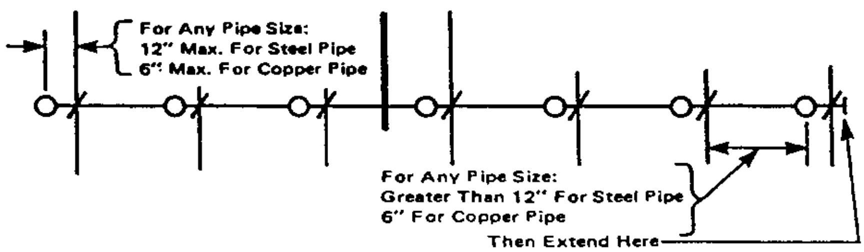
A-4-5.3.1 All piping should be arranged where practicable to drain to the main drain valve.

A-4-5.3.5.2.3 An example of an accessible location would be a valve located approximately 7 ft (2 m) above the floor level to which a hose could be connected to discharge the water in an acceptable manner.



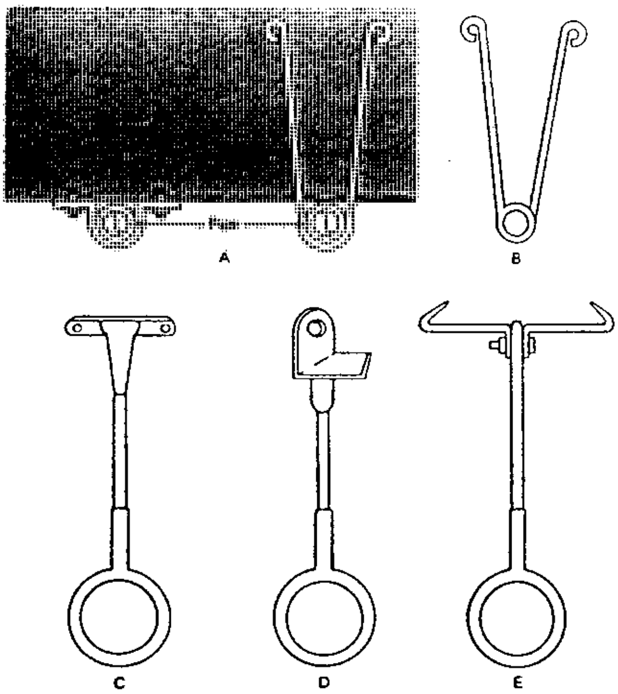
For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure A-4-5.2.3.3 Distance from sprinkler to hanger.



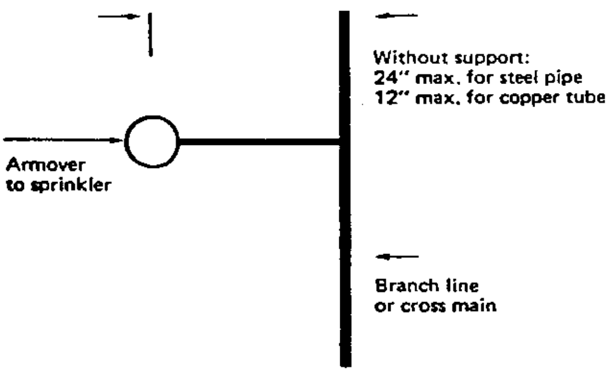
For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure A-4-5.2.3.3 Exception No. 1 Distance from sprinkler to hanger where maximum pressure exceeds 100 psi (6.9 bars) and a branch line above a ceiling supplies pendent sprinklers below the ceiling.



A U-type hangers for branch lines
B Wraparound U-hook
C Adjustable clip for branch lines
D Side beam adjustable hanger
E Adjustable coach screw clip for branch lines

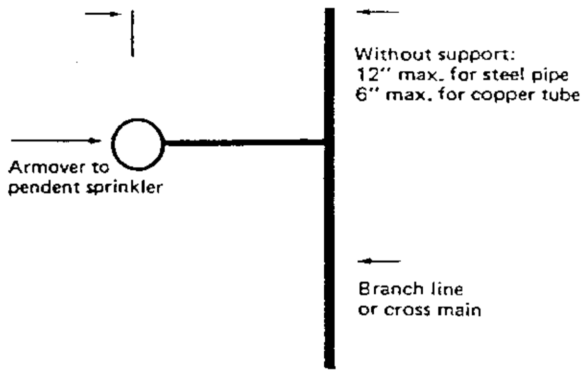
Figure A-4-5.2.3.3 Exception No. 2 Examples of acceptable hangers for end of line (or armover) pendent sprinklers.



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure A-4-5.2.3.4 Maximum length for unsupported armover.

A-4-5.3.6.1 When possible, the main sprinkler riser drain should discharge outside the building at a point free from the possibility of causing water damage. When it is not possible to discharge outside the building wall, the drain should be piped to a sump, which in turn should discharge by gravity or be pumped to a waste water drain or sewer. The main sprinkler riser drain connection should be of a size sufficient to carry off water from the fully open drain valve while it is discharging under normal water system pressures. When this is not possible, a supplementary drain of equal size should be provided for test purposes with free discharge, located at or above grade.



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

NOTE: The pendent sprinkler may be installed either directly in the fitting at the end of the armover or in a fitting at the bottom of a drop nipple.

Figure A-4-5.2.3.4 Exception Maximum length of unsupported armover when the maximum pressure exceeds 100 psi (6.9 bars) and a branch line above a ceiling supplies pendent sprinklers below the ceiling.

A-4-5.4.2.1 Types of locations where corrosive conditions may exist include bleacheries, dye houses, metal plating processes, animal pens, and certain chemical plants.

If corrosive conditions are not of great intensity and humidity is not abnormally high, good results can be obtained by a protective coating of red lead and varnish or by a good grade of commercial acid-resisting paint. The paint manufacturer's instructions should be followed in the preparation of the surface and in the method of application.

Where moisture conditions are severe but corrosive conditions are not of great intensity, copper tube or galvanized steel pipe, fittings, and hangers may be suitable. The exposed threads of steel pipe should be painted.

In instances where the piping is not readily accessible and where the exposure to corrosive fumes is severe, either a protective coating of high quality may be employed or some form of corrosion-resistant material used.

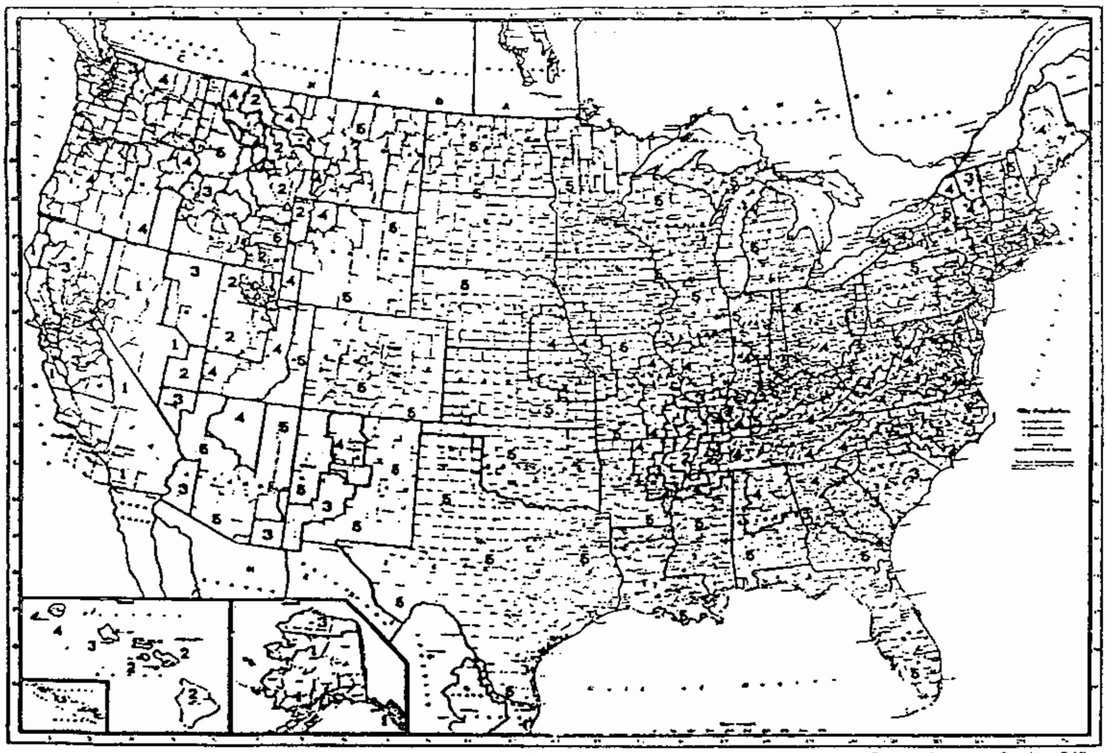
A-4-5.4.3.1 Sprinkler systems are protected against earthquake damage by means of the following:

(a) Stresses that would develop in the piping due to differential building movement are minimized through the use of flexible joints or clearances.

(b) Bracing is used to keep the piping fairly rigid when supported from a building component expected to move as a unit, such as a ceiling.

Areas known to have a potential for earthquakes have been identified in building code and insurance maps. An example of such a map is shown in Figure A-4-5.4.3.1.

A-4-5.4.3.2 Strains on sprinkler piping can be greatly lessened and, in many cases, damage prevented by increasing the flexibility between major parts of the sprinkler system. One part of the piping should never be held rigidly and another part allowed to move freely without provision for relieving the strain. Flexibility can be provided by using listed flexible couplings, by joining grooved end pipe at critical points, and by allowing clearances at walls and floors.



Source—Insurance Services Office

Earthquake Zones

1—Maximum potential for earthquake damage
2—Reasonable potential
3—Slight potential
4 and 5—Earthquake protection not required

Figure A-4-5.4.3.1 Example of seismic map.

Tank or pump risers should be treated the same as sprinkler risers for their portion within a building. The discharge pipe of tanks on buildings should have a control valve above the roof line so any pipe break within the building can be controlled.

Piping 3 in. (76 mm) or smaller in size is pliable enough so that flexible couplings are not usually necessary. A flexible coupling is a mechanical coupling or fitting that permits some angular displacement, axial displacement, and rotation of the piping without failure of the pipe or fitting. "Rigid-type" mechanical couplings that do not permit movement at the grooved connections are not considered flexible couplings [*See Figures A-4-5.4.3.2(a) and (b) on the following page.*]

A-4-5.4.3.2(d) A building expansion joint is usually a bituminous fiber strip used to separate blocks or units of concrete to prevent cracking due to expansion as a result of temperature changes. In this case, the flexible coupling required on one side by 4-5.4.3.2(d) will suffice.

For seismic separation joints, considerably more flexibility is needed, particularly for piping above the first floor. Figure A-4-5.4.3.3 on page 93 shows a method of providing additional flexibility through the use of swing joints.

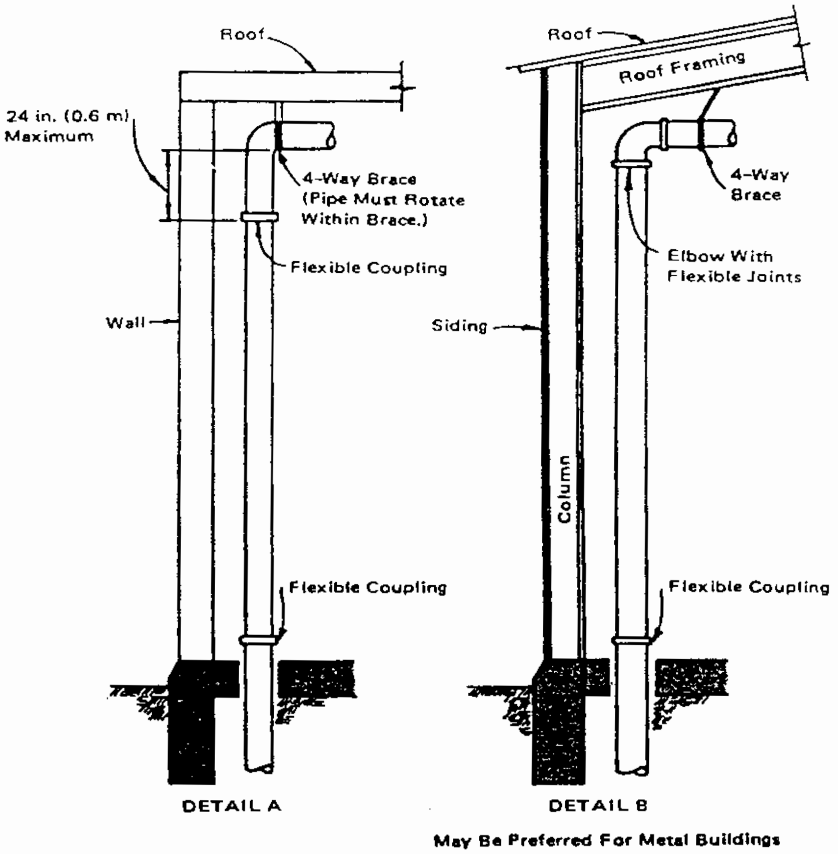
A-4-5.4.3.3 Plan and elevation views of a seismic separation assembly assembled with flexible elbows are shown in Figure A-4-5.4.3.3.

A seismic separation assembly is considered to be an assembly of fittings, pipe, and couplings or an assembly of pipe and couplings that permits movement in all directions. The extent of permitted movement should be sufficient to accommodate calculated differential motions during earthquakes. In lieu of calculations, permitted movement can be made at least twice the actual separations, at right angles to the separation as well as parallel to it.

A-4-5.4.3.4 While clearances are necessary around the sprinkler piping to prevent breakage due to building movement, suitable provision should also be made to prevent passage of water, smoke, or fire.

Drains, fire department connections, and other auxiliary piping connected to risers should not be cemented into walls or floors; similarly, pipes that pass horizontally through walls or foundations should not be cemented solidly or strains will accumulate at such points.

When risers or lengths of pipe extend through suspended ceilings, they should not be fastened to the ceiling framing members.



Note to Detail A: The four-way brace should be attached above the upper flexible coupling required for the riser and preferably to the roof structure if suitable. The brace should not be attached directly to a plywood or metal deck.

Figure A-4-5.4.3.2(a) Riser details.

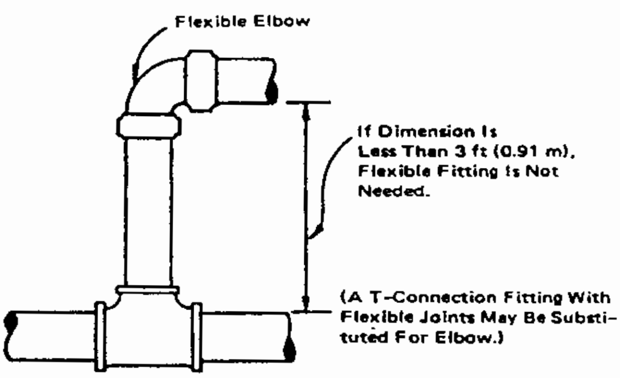


Figure A-4-5.4.3.2(b) Detail at short riser.

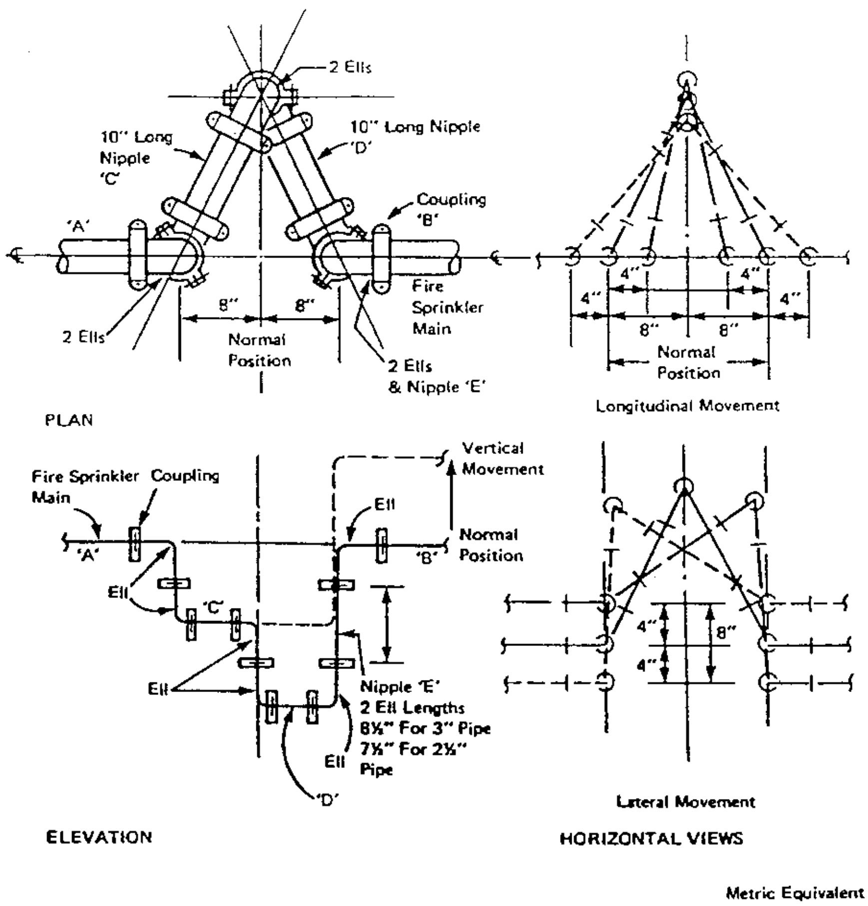
A-4-5.4.3.5.1 Location of Sway Bracing. Two-way braces are either longitudinal or lateral depending on their orientation with the axis of the piping. [*See Figures A-4-5.4.3.5.1(a), (b), (c), and (d) on the following pages.*] The simplest form of two-way brace is a piece of steel pipe or angle. Because the brace must act in both compression and tension, it is necessary to size the brace to prevent buckling.

An important aspect of sway bracing is its location. In Building 1 of Figure A-4-5.4.3.5.1(a), the relatively heavy main will pull on the branch lines when shaking occurs. If the branch lines are held rigidly to the roof or floor above, the fittings can fracture due to the induced stresses.

Bracing should be on the main as indicated at Location B. With shaking in the direction of the arrows, the light branch lines will be held at the fittings. Where necessary, a lateral brace or other restraint should be installed to prevent a branch line from striking against building components or equipment.

A four-way brace is indicated at Location A. This keeps the riser and main lined up and also prevents the main from shifting.

In Building 1, the branch lines are flexible in a direction parallel to the main, regardless of building movement. The heavy main cannot shift under the roof or floor, and it also steadies the branch lines. While the main is braced, the flexible couplings on the riser allow the sprinkler system to move with the floor or roof above, relative to the floor below.



NOTE: The figure illustrates an 8-in. separation crossed by pipes up to 4 in. in nominal diameter. For other separation distances and pipe sizes, lengths and distances should be modified proportionally.

Figure A-4-5.4.3.3 Seismic separation assembly.

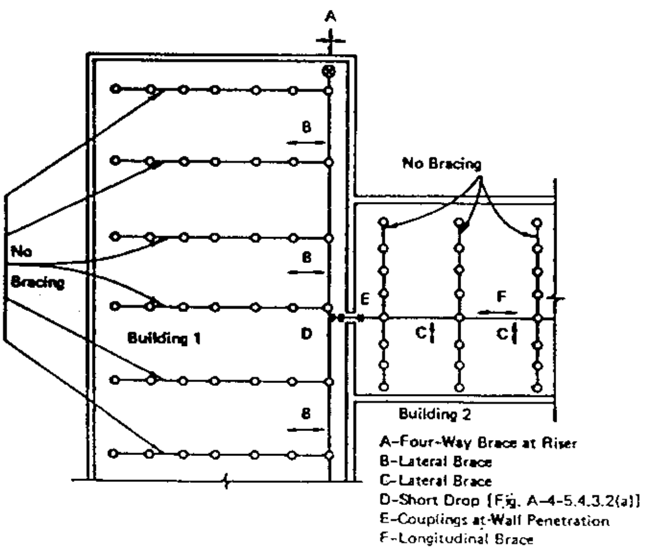


Figure A-4-5.4.3.5.1(a) Earthquake protection for sprinkler piping.

Figures A-4-5.4.3.5.1(b), (c), and (d) show typical locations of sway bracing.

Listed devices permitting connection of braces to both the pipe and the building structure are available and are recommended. However, alternate means of attachment capable of handling the expected loads are acceptable.

Connection of the brace to the pipe can be made with a pipe clamp or U-bolt. One bolt of the pipe clamp can pass through a flattened end of pipe or one leg of an angle. (The other leg and filet of the angle can be cut away.) Pipe rings should be avoided because they result in a loose fit. Once the pipe is able to vibrate within a loose fitting, the bolts in the ring assembly can be fractured.

The brace can be attached to the structural system directly through a leg of an angle or a flattened portion of pipe. Where dimensions are tight or some play must be allowed, a special fitting can be used. [*See Figure A-4-5.4.3.5.1(b).*] This threads on an end of pipe. Rotation of the flat around the bolt allows play in the angle of the brace without sacrificing snugness.

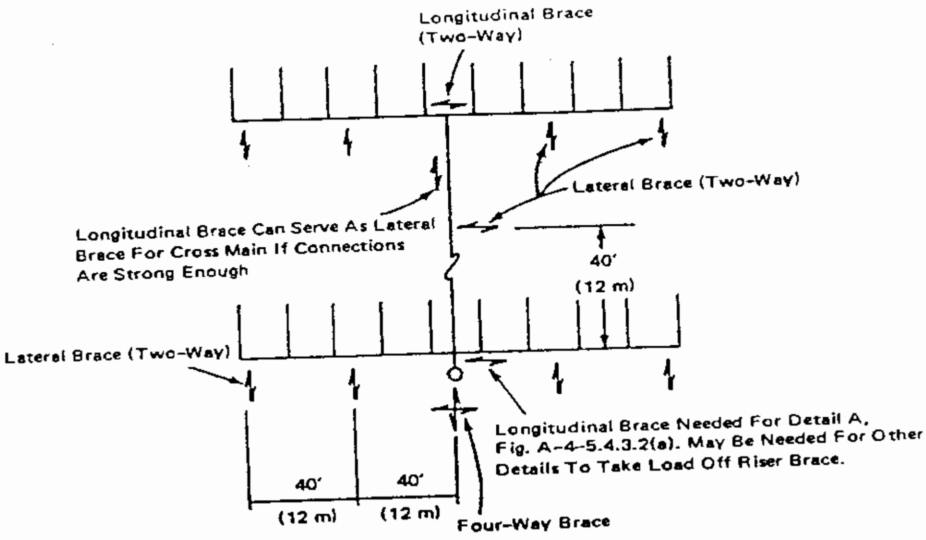


Figure A-4-5.4.3.5.1(b) Typical location of bracing on a tree system.

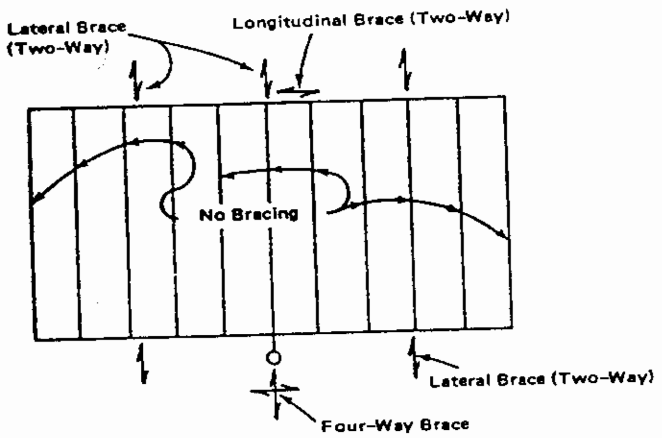


Figure A-4-5.4.3.5.1(c) Typical location of bracing on a gridded system.

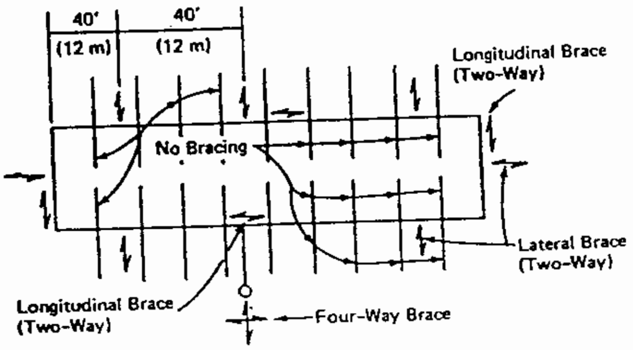


Figure A-4-5.4.3.5.1(d) Typical location of bracing on a looped system.

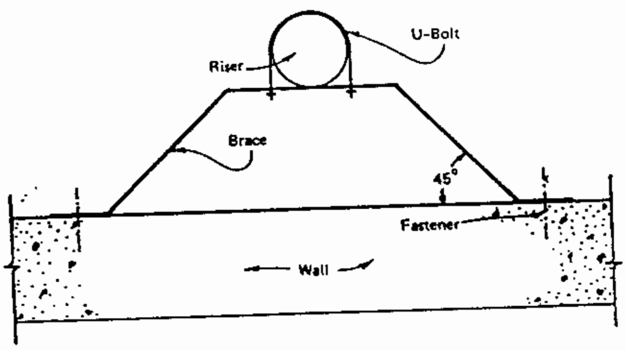


Figure A-4-5.4.3.5.1(e) Detail of four-way brace at riser.

Some adjustment can be provided in a pipe brace by use of a left-hand/right-hand coupling. For all threaded connections, sight holes or other means should be provided to permit indication that sufficient thread is engaged.

To properly size and space braces, it is necessary to employ the following steps:

(a) Based on the distance of mains from the structural members that will support the braces, choose brace shapes and sizes from Table 4-5.4.3.5.1(b) such that the maximum slenderness ratios l/r do not exceed 200. The angle of the braces from the vertical should be at least 30 degrees and preferably 45 degrees or more.

(b) Tentatively space lateral braces at 40 ft (12 m) maximum distances along mains and tentatively space longitudinal braces at 80 ft (24 m) maximum distances along mains. Lateral braces should meet the piping at right angles, and longitudinal braces should be aligned with the piping.

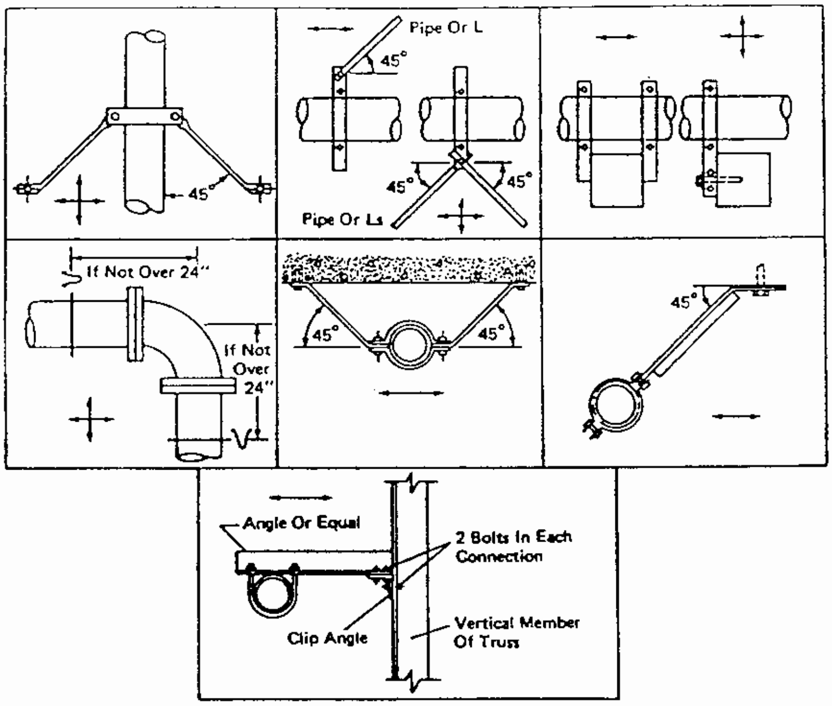


Figure A-4-5.4.3.5.1(f) Acceptable types of sway bracing.

(c) Determine the total load tentatively applied to each brace in accordance with the examples shown in Figure A-4-5.4.3.5.1(h) and the following:

1. For the loads on lateral braces on cross mains, add one-half the weight of branch to one-half the weight of the portion of the cross main within the zone of influence of the brace. [*See examples 1, 3, 6, and 7 in Figure A-4-5.4.3.5.1(h) on the following page.*]

2. For the loads on longitudinal braces on cross mains, consider only one-half the weight of the cross mains, feed mains, and the first 15 ft of branch line piping within the zone of influence. Branch lines need not be included if piping is provided with lateral sway bracing.

3. For the four-way brace at the riser, add the longitudinal and lateral loads within the zone of influence of the brace. [*See examples 2, 3, 4, 5, 7, and 8 in Figure A-4-5.4.3.5.1(h) on the following page.*]

Use the information on weights of water-filled piping contained within Table A-4-5.4.3.5.1.

(d) If the total expected loads are less than the maximums permitted in Table 4-5.4.3.5.1(b) for the particular brace and orientation, go on to step (e). If not, add additional braces to reduce the zones of influence of overloaded braces.

(e) Check that fasteners connecting the braces to structural supporting members are adequate to support the expected loads on the braces in accordance with Table 4-5.4.3.5.1(c). If not, again add additional braces or additional means of support.

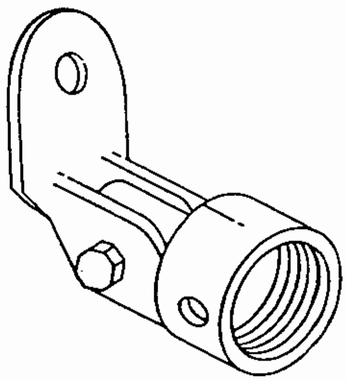


Figure A-4-5.4.3.5.1(g) Special fitting.

A-4-5.4.3.5.3 The four-way brace provided at the riser may also provide longitudinal and lateral bracing for adjacent mains.

A-4-5.4.3.5.8 Wires used for piping restraints should be attached to the branch line with two tight turns around the pipe, and fastened with four tight turns within $1^1/_2$ inches, and should be attached to the structure in accordance with the details shown in Figures A-4-5.4.3.5.8(a) through (d) on the following pages or other approved method.

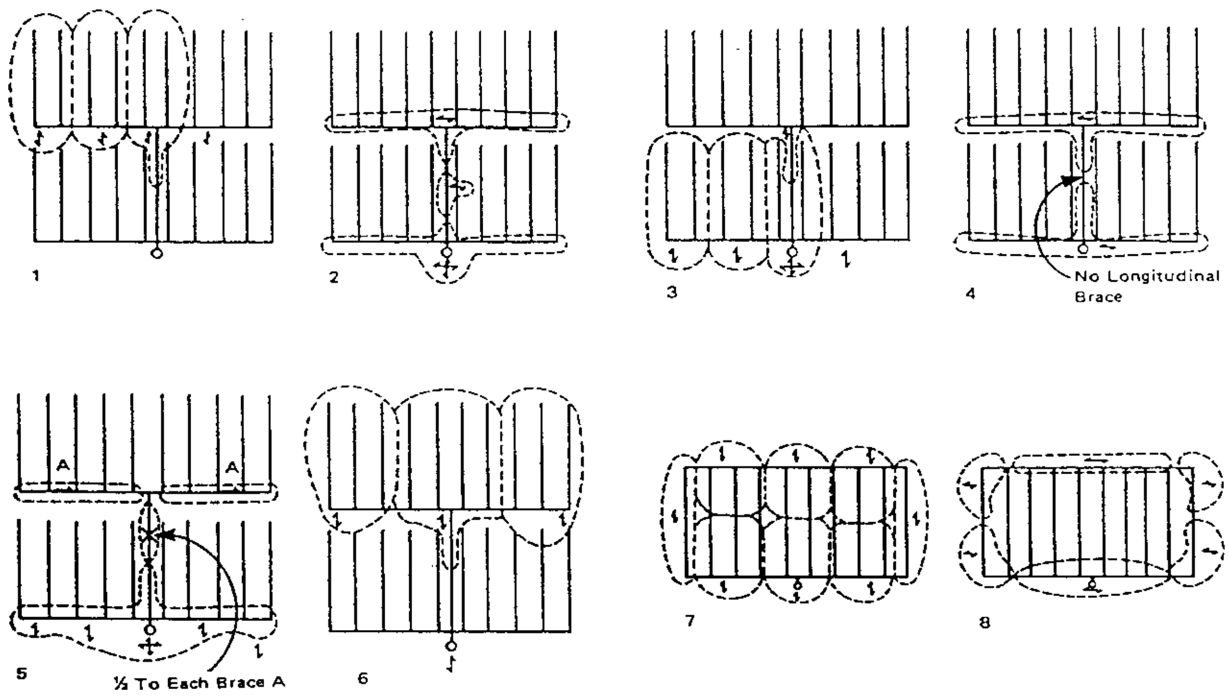
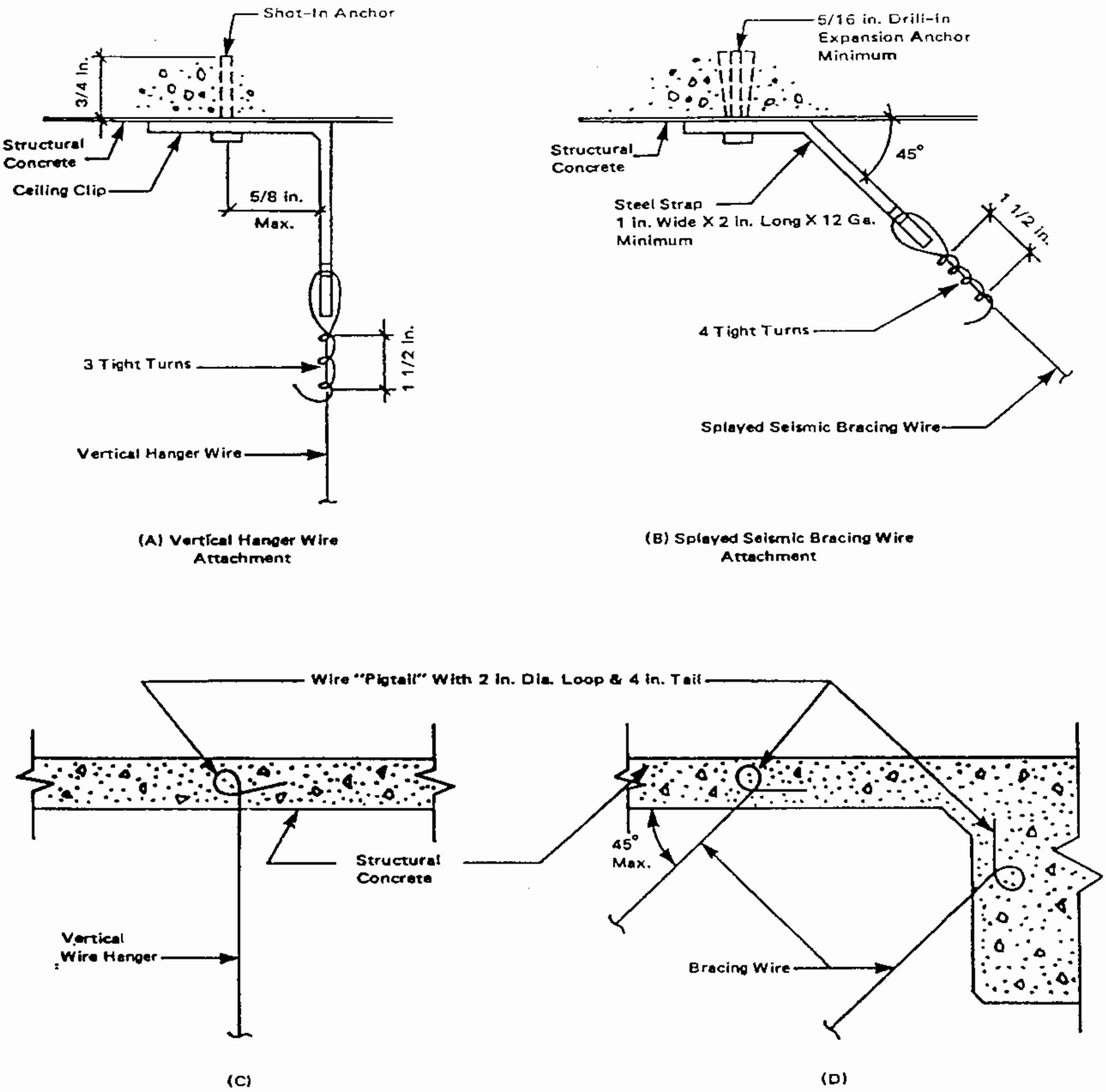


Figure A-4-5.4.3.5.1(h) Examples of load distribution to bracing.

Table A-4-5.4.3.5.1 Piping Weights for Determining Horizontal Load

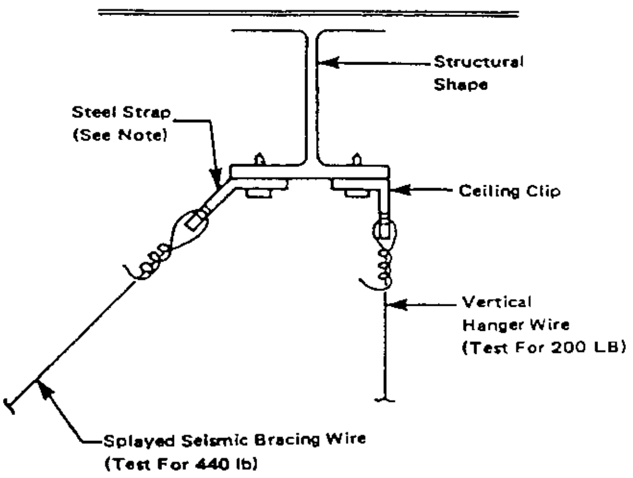
Schedule 40 Pipe	Weight of Water-Filled Pipe (lb per ft)	½ Weight of Water-Filled Pipe (lb per ft)
1	2.05	1.03
1¼	2.93	1.47
1½	3.61	1.81
2	5.13	2.57
2½	7.89	3.95
3	10.82	5.41
3½	13.48	6.74
4	16.40	8.20
5	23.47	11.74
6	31.69	15.85
8*	47.70	23.85
Schedule 10 Pipe		
1	1.81	0.91
1¼	2.52	1.26
1½	3.04	1.52
2	4.22	2.11
2½	5.89	2.95
3	7.94	3.97
3½	9.78	4.89
4	11.78	5.89
5	17.30	8.65
6	23.03	11.52
8	40.08	20.04

* Schedule 30



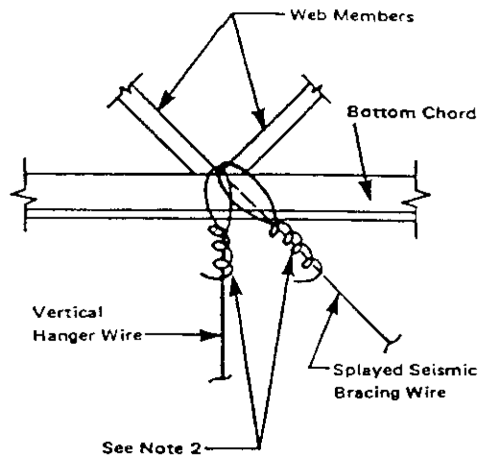
Wire Attachment To Cast-In-Place Concrete

Figure A-4-5.4.3.5.8(a).



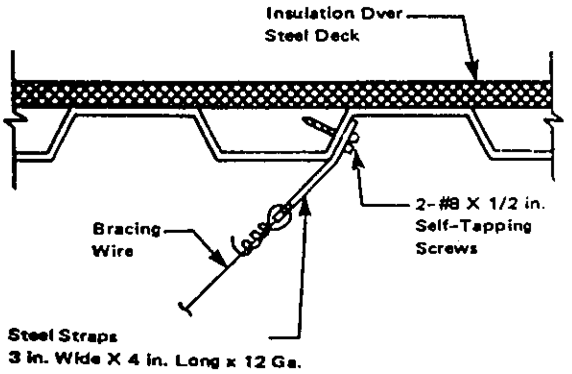
(A) At Steel Beams

Note: See Figure A-4-5.4.3.5.8(a), Detail B.

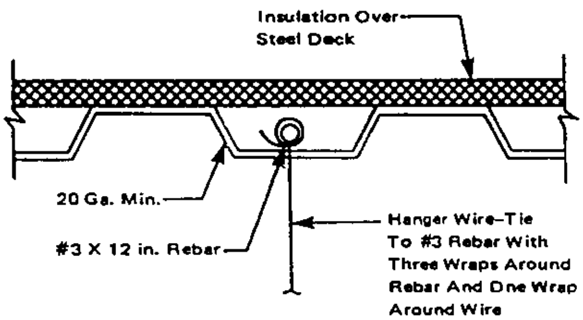


(B) At Open-Web Steel Joist

Note 1: Splay wires parallel to joist. Splay wires cannot be perpendicular to joist.
Note 2: See Figure A-4-5.4.3.5.8(a), Details (A) and (B).



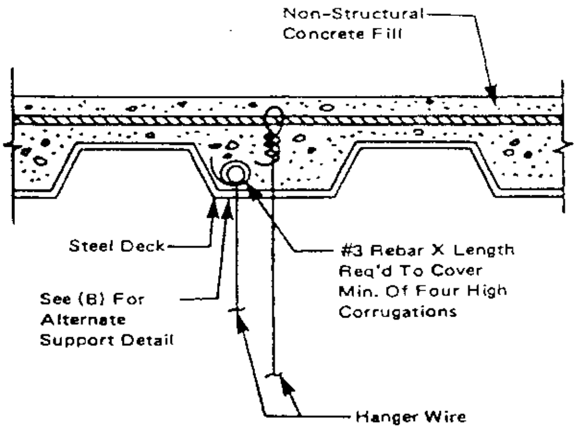
(C) At Steel Roof Deck



(D) At Steel Roof Deck

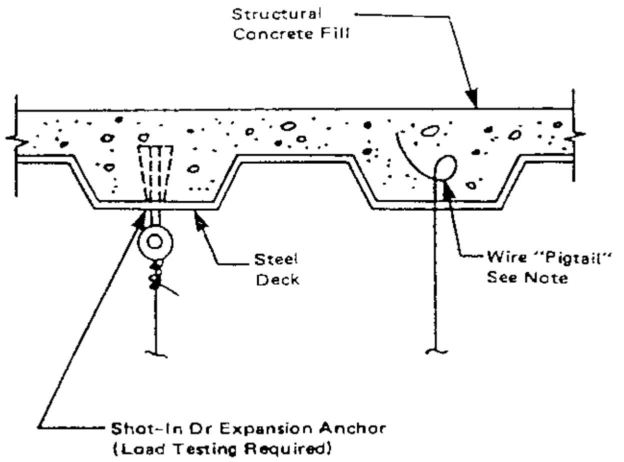
Note: If self-tapping screws are used with concrete fill, set screws before placing concrete.

Acceptable Details-Wire Connections To Steel Framing
Figure A-4-5.4.3.5.8(b).



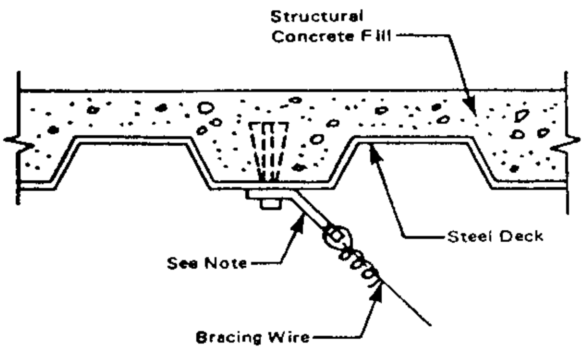
(A) At Steel Deck With
Insulating Fill

Note: Bracing wire detail similar.



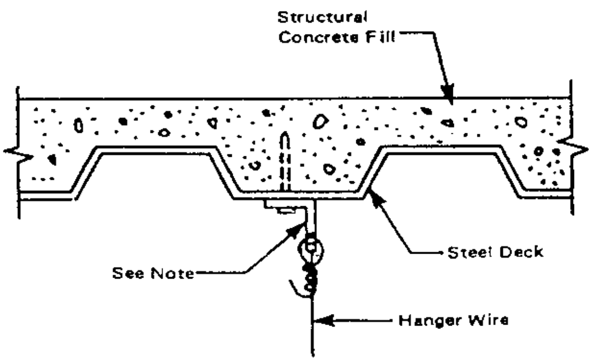
(B) At Steel Deck With
Concrete Fill

Note: See Figure A-4-5.4.3.5.8(a),
Detail (C).



(C) At Steel Deck With
Concrete Fill

Note: See Figure A-4-5.4.3.5.8(a),
Detail (B).



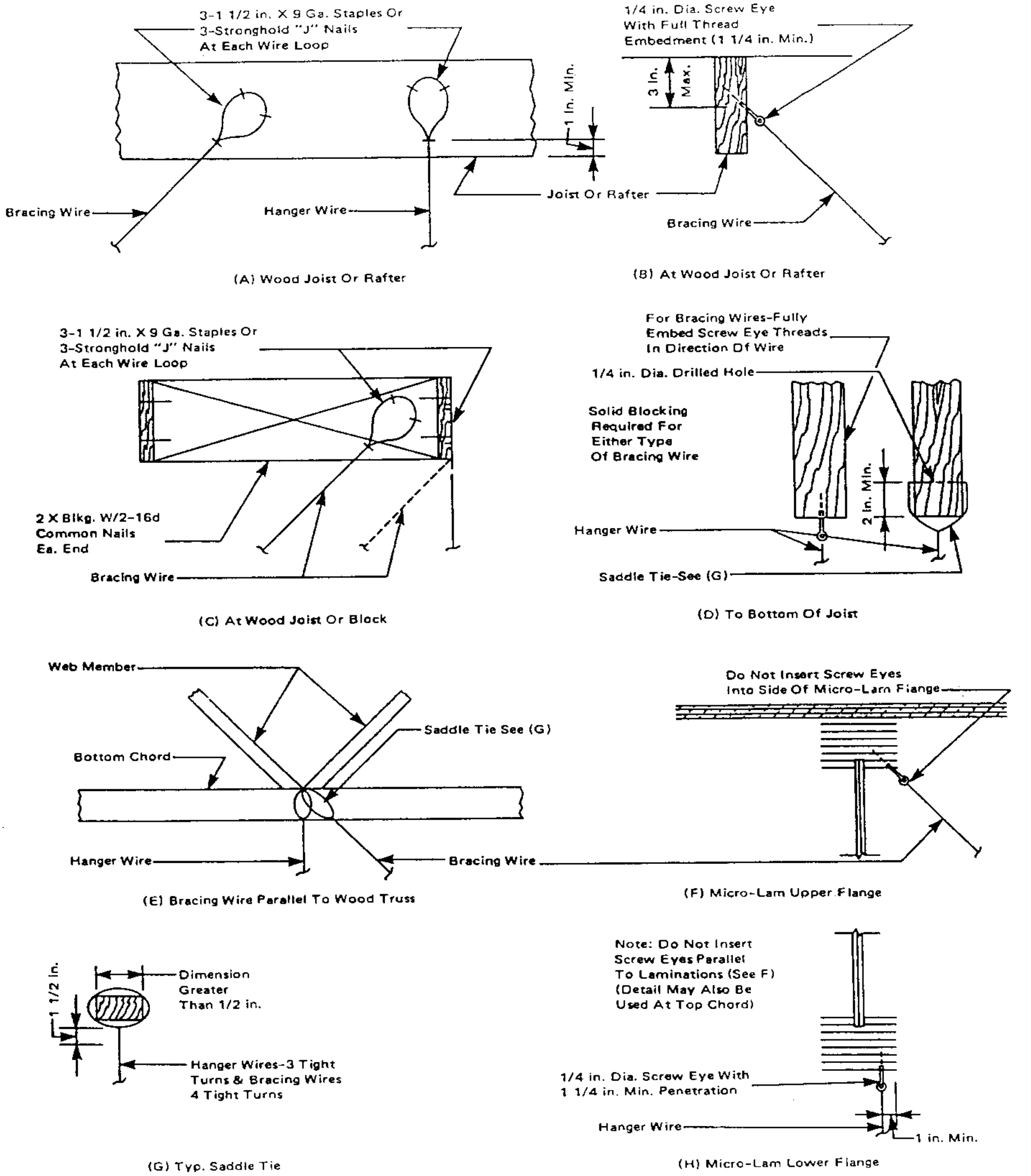
(D) At Steel Deck With
Concrete Fill

Note: See Figure A-4-5.4.3.5.8(a),
Detail (A).

Note: If self-tapping screws are used with concrete fill,
set screws before placing concrete.

Acceptable Details-Wire Connections To Steel Framing

Figure A-4-5.4.3.5.8(c).



Acceptable Details-Wire Connections To Wood Framing
Figure A-4-5.4.3.5.8(d).

A-4-6.1.1 Central station, auxiliary, remote station, or proprietary protective signaling systems are a highly desirable supplement to local alarms, especially from a safety to life standpoint. (*See 4-6.1.1.6.*)

Identification Signs. Approved identification signs should be provided for outside alarm devices. The sign should be located near the device in a conspicuous position and should be worded as follows:

"SPRINKLER FIRE ALARM — WHEN BELL RINGS CALL FIRE DEPARTMENT OR POLICE."

Figure A-4-6.1.1 Identification sign.

A-4-6.1.1.5 Water-motor-operated devices should be located as near as practicable to the alarm valve, dry pipe valve, or other waterflow detecting device. The total length of the pipe to these devices should not exceed 75 ft (22.9 m) nor should the water-motor-operated device be located over 20 ft (6.1 m) above the alarm device or dry pipe valve.

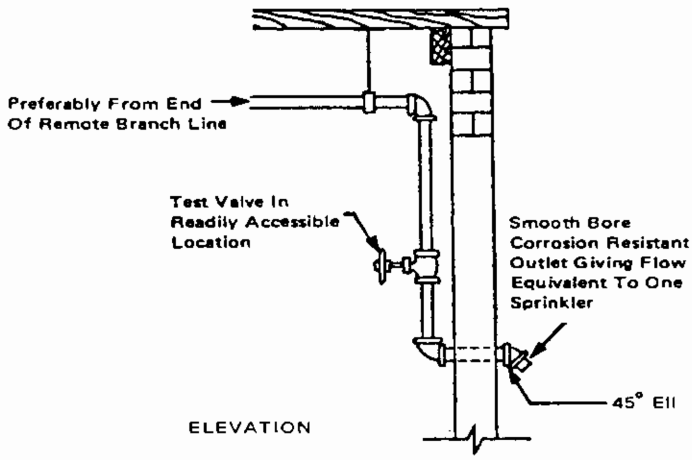
A-4-6.1.1.6 Monitoring should include but not be limited to control valves, building temperatures, fire pump power supplies and running conditions, and water tank levels and temperatures. Pressure supervision shall also be provided on pressure tanks.

A-4-6.2 The fire department connection should be located not less than 18 in. (457 mm) and not more than 4 ft (1.22 m) above the level of the adjacent grade or access level.

A-4-6.2.1 Fire department connections should be located and arranged so that hose lines can be readily and conveniently attached without interference from nearby objects including buildings, fences, posts, or other fire department connections. When a hydrant is not available, other water supply sources such as a natural body of water, a tank, or reservoir should be utilized. The water authority should be consulted when a nonpotable water supply is proposed as a suction source for the fire department.

A-4-6.2.3 The check valve should be located to maximize accessibility and minimize freezing potential.

A-4-6.4.2 This test connection should be in the upper story, and the connection should preferably be piped from the end of the most remote branch line. The discharge should be at a point where it can be readily observed. In locations where it is not practical to terminate the test connection outside the building, the test connection may terminate into a drain capable of accepting full flow under system pressure. In this event, the test connection should be made using an approved sight test connection containing a smooth bore corrosion-resistant orifice giving a flow equivalent to one sprinkler simulating the least flow from an individual sprinkler in the system. [*See Figures A-4-6.4.2(a) and A-4-6.4.2(b).*] The test valve should be located at an accessible point and preferably not over 7 ft (2.1 m) above the floor. The control valve on the test connection should be located at a point not exposed to freezing.



For SI Units: 1 ft = 0.3048 m.
NOTE: Not less than 4 ft (1.2 m) of exposed test pipe in warm room beyond valve when pipe extends through wall to outside.

Figure A-4-6.4.2(a) System test connection on wet pipe system.

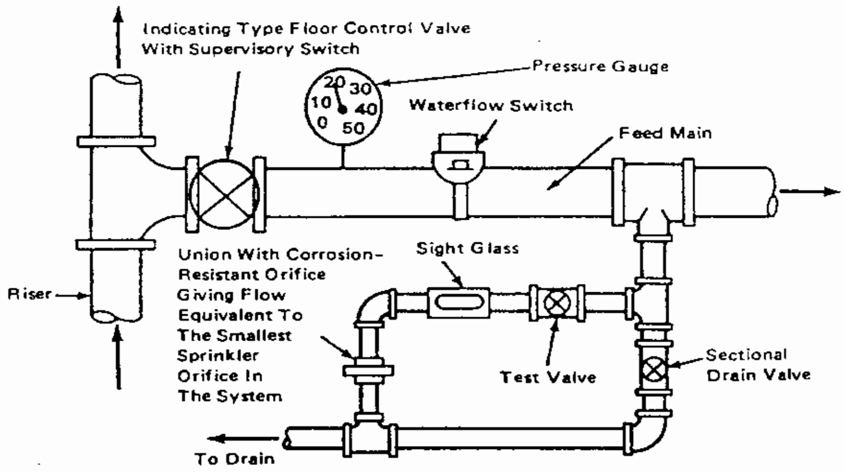
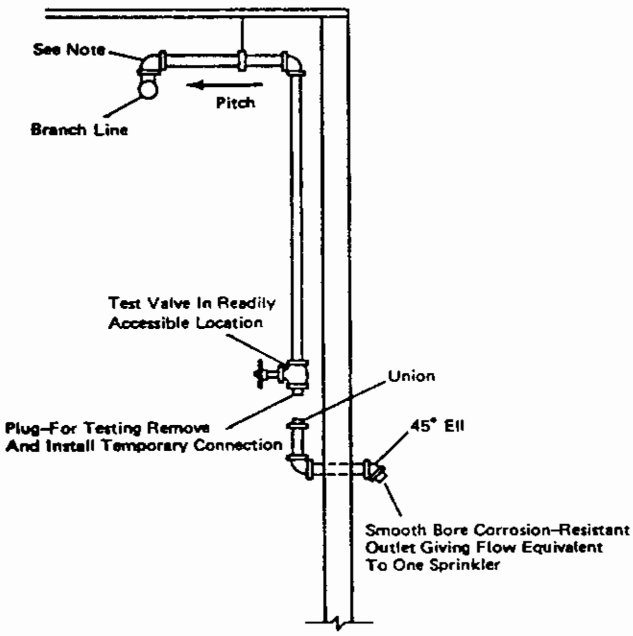


Figure A-4-6.4.2(b) Floor control valve.

A-4-6.4.3 See Figure A-4-6.4.3.



NOTE: To minimize condensation of water in the drop to the test connection, provide a nipple-up off of the branch line.

Figure A-4-6.4.3 System test connection on dry pipe system.

A-5-2.2.3 The additional pressure that is needed at the level of the water supply to account for sprinkler elevation is 0.433 psi per ft (9.8 kPa/m) of elevation above the water supply.

A-5-2.3.1.1 Appropriate area/density, other design criteria, and water supply requirements should be based on scientifically based engineering analyses that may include submitted fire testing, calculations, or results from appropriate computational models.

A-5-2.3.1.3(b) This section is included to compensate for possible delay in operation of sprinklers from fires in combustible concealed spaces found in wood frame, brick veneer, and ordinary construction.

A-5-2.3.1.3(b) Exception No. 3 This exception is intended to apply only when the exposed materials in the space are limited combustible materials or fire retardant treated wood as defined in NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials*.

A-5-2.3.3.1 This section allows for calculation of the sprinklers in the largest room, so long as the calculation produces the greatest hydraulic demand among selection of rooms and communicating spaces. For example, in a case where the largest room has four sprinklers and a smaller room has two sprinklers but communicates through unprotected openings with three other rooms, each having two sprinklers, the smaller room and group of communicating spaces should also be calculated.

Corridors are rooms and should be considered as such.

Walls may terminate at a substantial suspended ceiling and need not be extended to a rated floor slab above for this section to be applied.

A-5-3.2.2 See Figure A-5-3.2.2.

A-5-3.4 See Table A-5-3.4 on pages 104-105.

A-5-3.5 See Table A-5-3.5 on page 106.

A-5-3.6.1 If the system is a deluge type, then all the sprinklers need to be calculated even if they are located on different building faces.

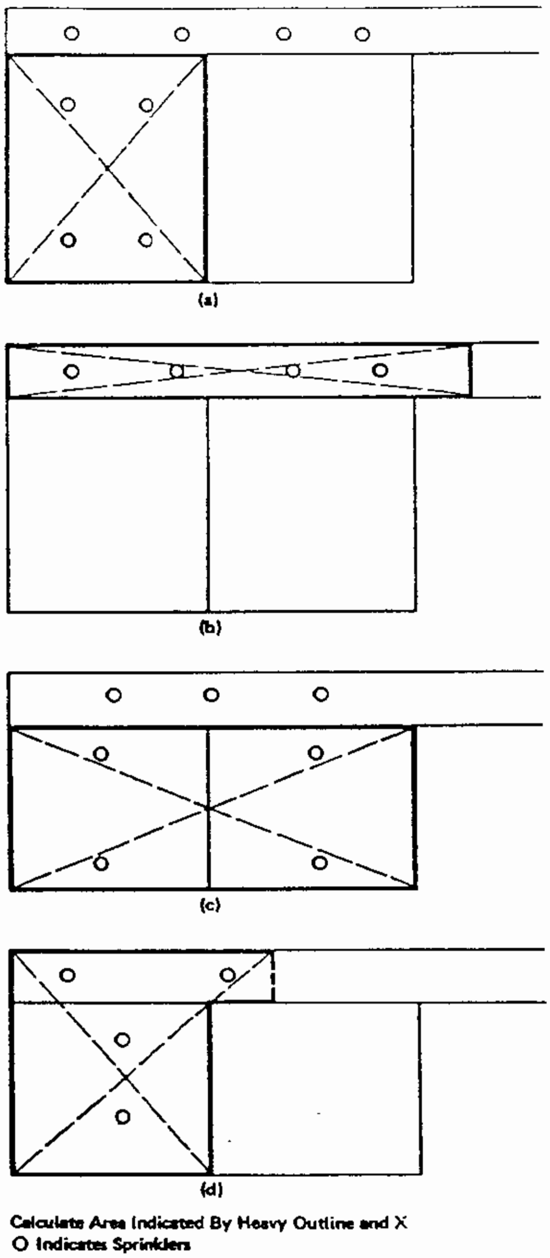


Figure A-5-3.2.2 Examples of design area for dwelling units.

A-6-1 Preliminary layouts should be submitted for review to the authority having jurisdiction before any equipment is installed or remodeled in order to avoid error or subsequent misunderstanding. (*See Figure A-6-1 on page 106.*) Any material deviation from approved plans will require permission of the authority having jurisdiction.

Preliminary layouts should show as much of the following information as is required to provide a clear representation of the system, hazard, and occupancy.

(a) Name of owner and occupant

(b) Location, including street address

(c) Point of compass

(d) Construction and occupancy of each building

NOTE: Data on special hazards should be submitted as they may require special rulings.

(e) Building height in feet

(f) If it is proposed to use a city main as a supply, whether the main is dead-end or circulating, size of main and pressure in psi, and, if dead-end, direction and distance to nearest circulating main

(g) Distance from nearest pumping station or reservoir

(h) In cases where reliable, up-to-date information is not available, a waterflow test of the city main should be conducted in accordance with A-7-2.1. The preliminary plans should specify who conducted the test, date and time, the location of the hydrants where flow was taken, and where static and residual pressure readings were recorded; the size of main supplying these hydrants, and the results of the test, giving size and number of open hydrant butts flowed; also data covering minimum pressure in the connection with the city main should be included.

(i) Data covering waterworks systems in small towns in order to expedite the review of plans

(j) Fire walls, fire doors, unprotected window openings, large unprotected floor openings, and blind spaces

(k) Distance to and construction and occupancy of exposing buildings—e.g., lumber yards, brick mercantiles, fire-resistive office buildings, etc.

(l) Spacing of sprinklers, number of sprinklers in each story or fire area and total number of sprinklers, number of sprinklers on each riser and on each system by floors, total area protected by each system on each floor, total number of sprinklers on each dry pipe system or preaction or deluge system and if extension to present equipment, sprinklers already installed

(m) Capacities of dry pipe systems with bulk pipe included, see Table A-3-2.3; and, if an extension is made to an existing dry pipe system, the total capacity of the existing and also the extended portion of the system

(n) Weight or class, size, and material of any proposed underground pipe

(o) Whether property is located in a flood or earthquake area requiring consideration in the design of sprinkler system

(p) Name and address of party submitting the layout.

A-6-1.1 See Figure A-6-1.1 on page 107.

A-6-1.1.2 See Figures A-6-1.1.2(a) and (b) on page 108.

A-6-2.2 See Figures A-6-2.2(a) through (d) on pages 109 through 112.

A-6-2.3 See Figure A-6-2.3 on page 113.

A-6-2.3(o) See Figure A-6-2.3(o) on page 114.

A-6-2.4 See Figure A-6-2.4 on page 115.

Table A-5-3.4 Large-Drop Sprinkler Data
Pressure and Number of Design Sprinklers Required for Various Hazards for Large Drop Sprinklers

Hazard	Type of System	Minimum Operating Pressure,[1] psi (bar) 25 (1.7)	50 (3.4)	75 (5.2)	Hose Stream Demand gal/min (dm³/min)	Water Supply Duration, Hr
		Number Design Sprinklers				
Palletized[2] Storage						
Class I, II, and III commodities up to 25 ft (7.6 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	15	Note 4	Note 4	500 (1900)	2
	Dry	25	Note 4	Note 4		
Class IV commodities up to 20 ft (6.1 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	20	15	Note 4		
	Dry	Does not apply	Does not apply	Does not apply	500 (1900)	2
Unexpanded plastics up to 20 ft (6.1 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	25	15	Note 4		
	Dry	Does not apply	Does not apply	Does not apply	500 (1900)	2
Expanded plastics commodities up to 18 ft (5.5 m) with maximum 8 ft (2.4 m) clearance to ceiling	Wet	Does not apply	15	Note 4	500 (1900)	2
	Dry	Does not apply	Does not apply	Does not apply		
Idle wood pallets up to 20 ft (6.1 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	15	Note 4	Note 4		
	Dry	25	Note 4	Note 4	500 (1900)	1½
Solid Piled[2] Storage						
Class I, II, and III commodities up to 20 ft (6.1 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	15	Note 4	Note 4		
	Dry	25	Note 4	Note 4	500 (1900)	1½
Class IV commodities and unexpanded plastics up to 20 ft (6.1 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	Does not apply	15	Note 4		
	Dry	Does not apply	Does not apply	Does not apply	500 (1900)	1½
Double-Row Rack Storage[3] with Minimum 5.5 ft (1.7 m) Aisle Width						
Class I and II commodities up to 25 ft (7.6 m) with maximum 5 ft (1.5 m) clearance to ceiling	Wet	20	Note 4	Note 4		
	Dry	30	Note 4	Note 4	500 (1900)	1½
Class I and II commodities up to 30 ft (9.2 m) with maximum 5 ft (1.5 m) clearance to ceiling	Wet	20 plus one level of in-rack sprinklers[6]	Note 4	Note 4		
	Dry	30 plus one level of in-rack sprinklers[6]	Note 4	Note 4	500 (1900)	1½
Class I, II, and III commodities up to 20 ft (6.1 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	15	Note 4	Note 4		
	Dry	25	Note 4	Note 4	500 (1900)	1½
Class I, II, and III commodities up to 25 ft (7.6 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	15 plus one level of in-rack sprinklers[6]	Note 4	Note 4	500 (1900)	1½
	Dry	25 plus one level of in-rack sprinklers[6]	Note 4	Note 4		
Class IV commodities up to 20 ft (6.1 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	Does not apply	20	15		
	Dry	Does not apply	Does not apply	Does not apply	500 (1900)	2
Class IV commodities up to 25 ft (7.6 m) with maximum 10 ft clearance to ceiling	Wet	Does not apply	20 plus one level of in-rack sprinklers[6]	15 plus one level of in-rack sprinklers[6]	500 (1900)	2
	Dry	Does not apply	Does not apply	Does not apply		

Table A-5-3.4 (cont.)

Unexpanded plastics up to 20 ft (6.1 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	Does not apply	30	20	500 (1900)	2
	Dry	Does not apply	Does not apply	Does not apply		
Unexpanded plastics up to 25 ft (7.6 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	Does not apply	30 plus one level of in-rack sprinklers[4]	20 plus one level of in-rack sprinklers[4]	500 (1900)	2
	Dry	Does not apply	Does not apply	Does not apply		
Class IV commodities and unexpanded plastics up to 20 ft (6.1 m) with maximum 5 ft (1.5 m) clearance to ceiling	Wet	Does not apply	15	Note 4	500 (1900)	2
	Dry	Does not apply	Does not apply	Does not apply		
Class IV commodities and unexpanded plastics up to 25 ft (7.6 m) with maximum 5 ft (1.5 m) clearance to ceiling	Wet	Does not apply	15 plus one level of in-rack sprinklers[4]	Note 4	500 (1900)	2
	Dry	Does not apply	Does not apply	Does not apply		
On-end Storage of Roll Paper[2]						
Heavyweight paper in closed array, banded in open array, or banded or unbanded in a standard array, up to 26 ft (7.9 m) with maximum 34 ft (10.4 m) clearance to ceiling	Wet	Does not apply	15	Note 4		
	Dry	Does not apply	Does not apply	Does not apply	0 (Note 7)	4 (Note 7)
Any grade of paper, except lightweight paper with stacks in closed array, or banded or unbanded in a standard array, up to 20 ft (6.1 m) with maximum 10 ft (3.0 m) clearance to ceiling	Wet	Does not apply	15	Note 4		
	Dry	Does not apply	25	Note 4	0 (Note 7)	4 (Note 7)
Medium weight paper completely wrapped (sides and ends) in one or more layers of heavyweight paper, or lightweight paper in two or more layers of heavyweight paper, with closed array, banded in open array, or unbanded in a standard array, up to 26 ft (7.9 m) with maximum 34 ft (10.4 m) clearance to ceiling	Wet	Does not apply	15	Note 4		
	Dry	Does not apply	Does not apply	Does not apply	0 (Note 7)	4 (Note 7)
Record Storage						
Paper records and/or computer tapes in multitier steel shelving up to 5 ft (1.5 m) in width and with aisles 30 in. (76 cm) or wider, without catwalks in the aisles, up to 15 ft (4.6 m) with maximum 5 ft (1.5 m) clearance to ceiling	Wet	15	Note 4	Note 4	500 (1900)	1½
	Dry	25	Note 4	Note 4		
Same as above, but with catwalks of expanded metal or metal grid with minimum 50% open area in the aisles	Wet	Does not apply	15	Note 4	500 (1900)	1½
	Dry	Does not apply	15	Note 4		

NOTES:
1. Open wood joist construction. Fully firestop each joist channel to its full depth at intervals not exceeding 20 ft (6.2 m). In unfirestopped open wood joist construction, or if firestops are installed at intervals not exceeding 20 ft (6.1 m), increase the minimum operating pressures of Table A-5-3.4 by 40 percent.
2. See NFPA 231, *Standard for General Storage*.
3. With rack storage, use conventional wood pallets only, no slave pallets.
4. The high pressure may be used, but the required number of design sprinklers may not be reduced from that required for the lower pressure.
5. See NFPA 231F, *Standard for the Storage of Roll Paper*.
6. Install in-rack sprinklers in accordance with NFPA 231C, *Standard for Rack Storage*.
7. Hose stream demands and water supply durations may vary for roll paper storage depending on local conditions. See NFPA 231F, *Standard for the Storage of Roll Paper*.

Table A-5-3.5 ESFR Sprinkler Data

Type of Storage	Commodity	Maximum Height of Storage (ft)	Maximum Height See Note (ft)
Single-, double-, and multiple-row and portable rack storage (no open-top containers or solid-piled or palletized storage)	Cartoned plastics (unexpanded or expanded) and Class I through IV commodities, all either encapsulated or unencapsulated	25	30
Roll paper on end, open/standard closed array, banded or unbanded	Heavyweight paper	20	30
Roll paper on end, open/standard closed array, banded or unbanded	Mediumweight paper	20	30
Aerosol storage	See NFPA 30B		

NOTE: The maximum height is to be measured to the underside of the roof deck or ceiling.

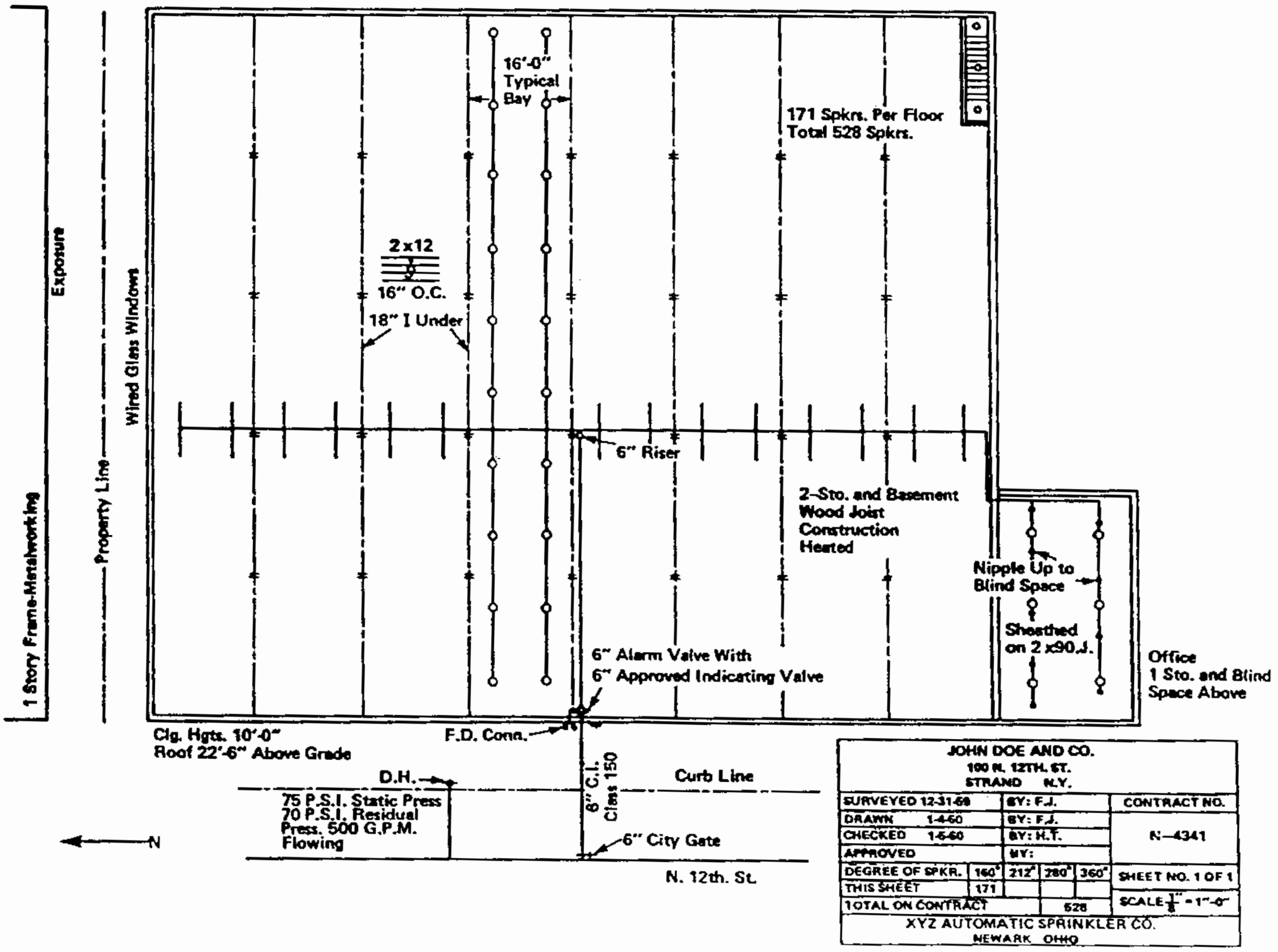


Figure A-6-1 Typical preliminary plan.

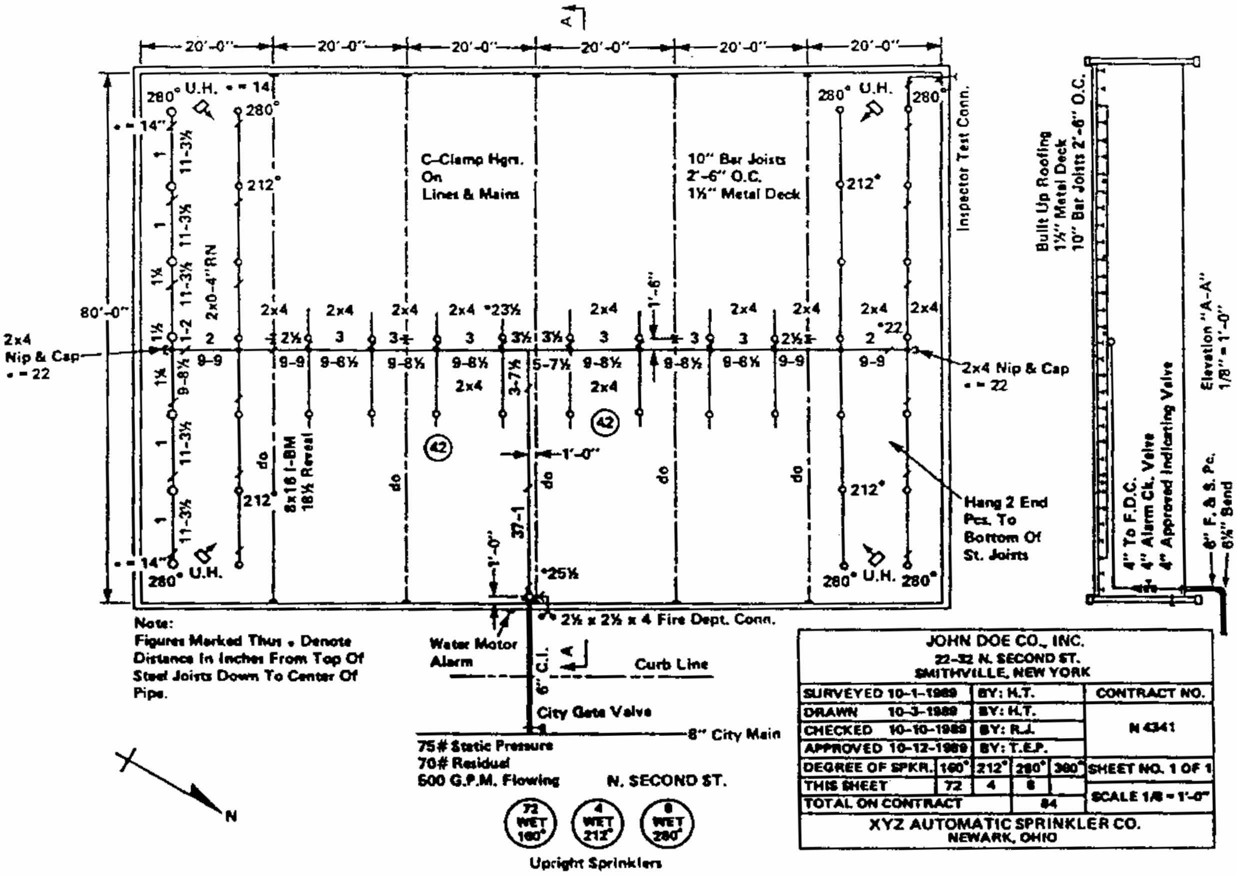
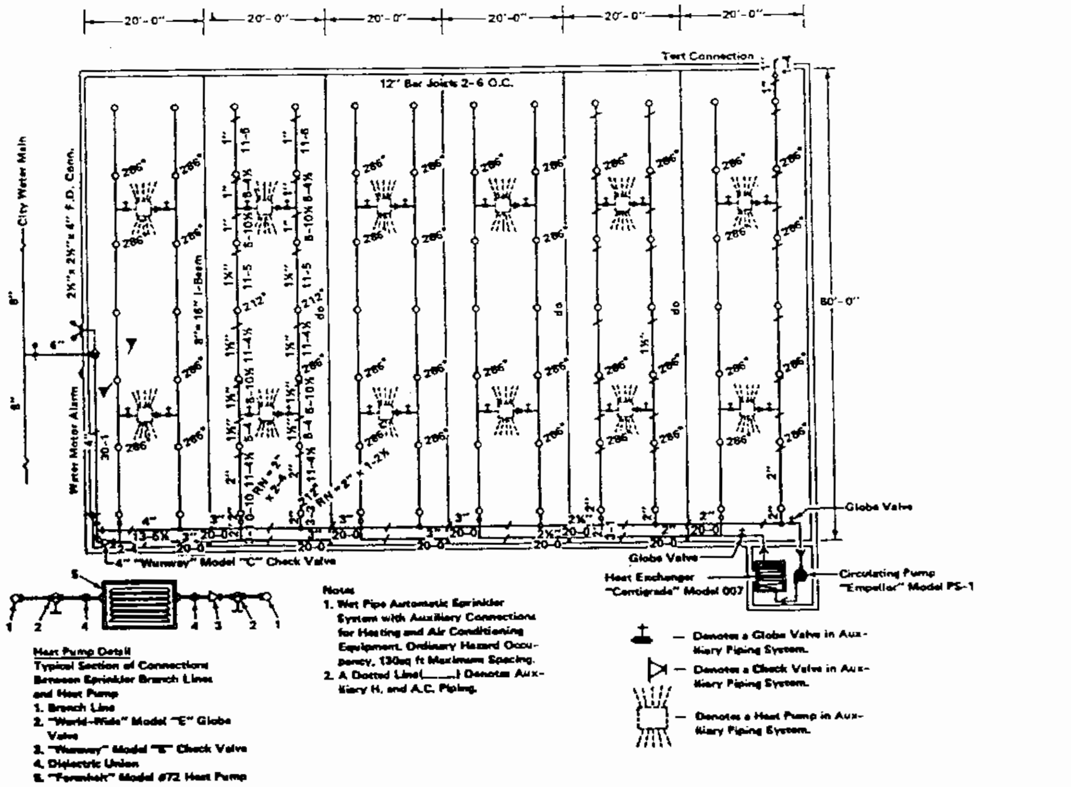


Figure A-6-1.1 Typical working plans.



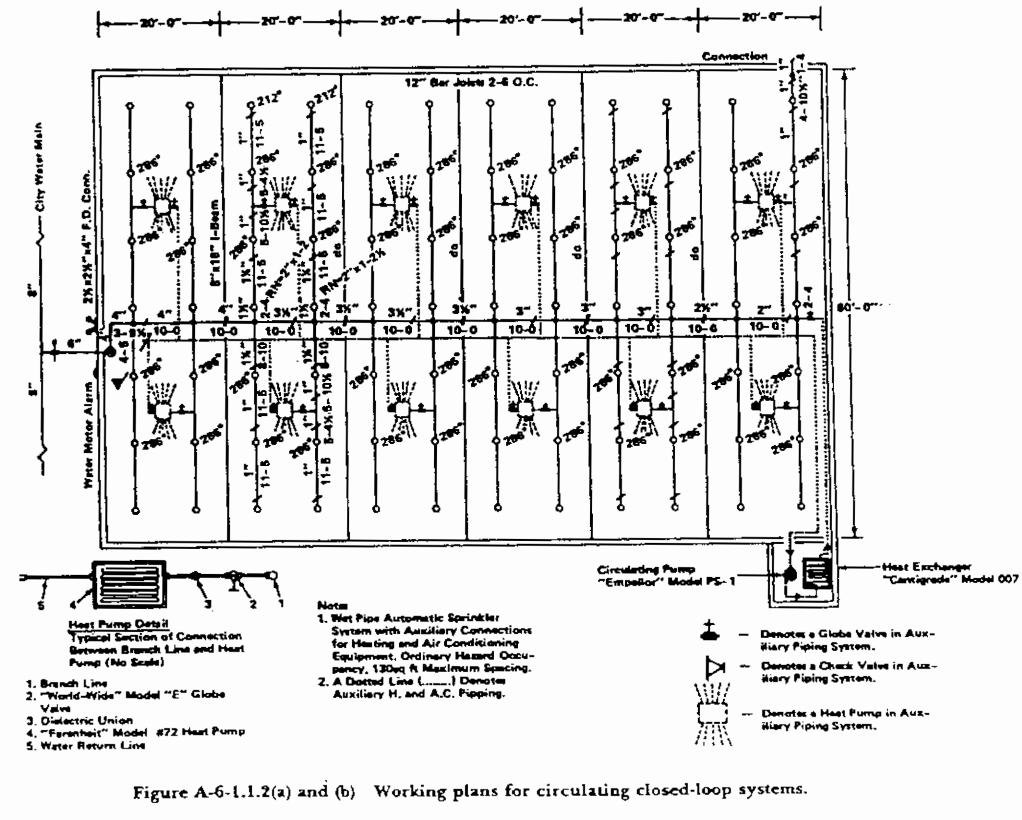


Figure A-6-1.1.2(a) and (b) Working plans for circulating closed-loop systems.

HYDRAULIC CALCULATIONS

for

ABC Company, Employee Garage

7499 Franklin Road

Charleston, SC

CONTRACT NO. 4001

DATE 1-7-91

DESIGN DATA:

OCCUPANCY CLASSIFICATION ORD. GR. I

DENSITY .15 GPM/SQ. FT.

AREA OF APPLICATION 1500 SQ. FT.

COVERAGE PER SPRINKLER 130 SQ. FT.

SPECIAL SPRINKLERS —

NO. OF SPRINKLERS CALCULATED 12

IN-RACK DEMAND —

HOSE STREAMS 250 GPM.

TOTAL WATER REQUIRED 510.4 GPM
INCLUDING HOSE STREAMS

NAME OF CONTRACTOR ______

NAME OF DESIGNER ______

ADDRESS ______

AUTHORITY HAVING JURISDICTION ______

Figure A-6-2.2(a) Summary sheet.

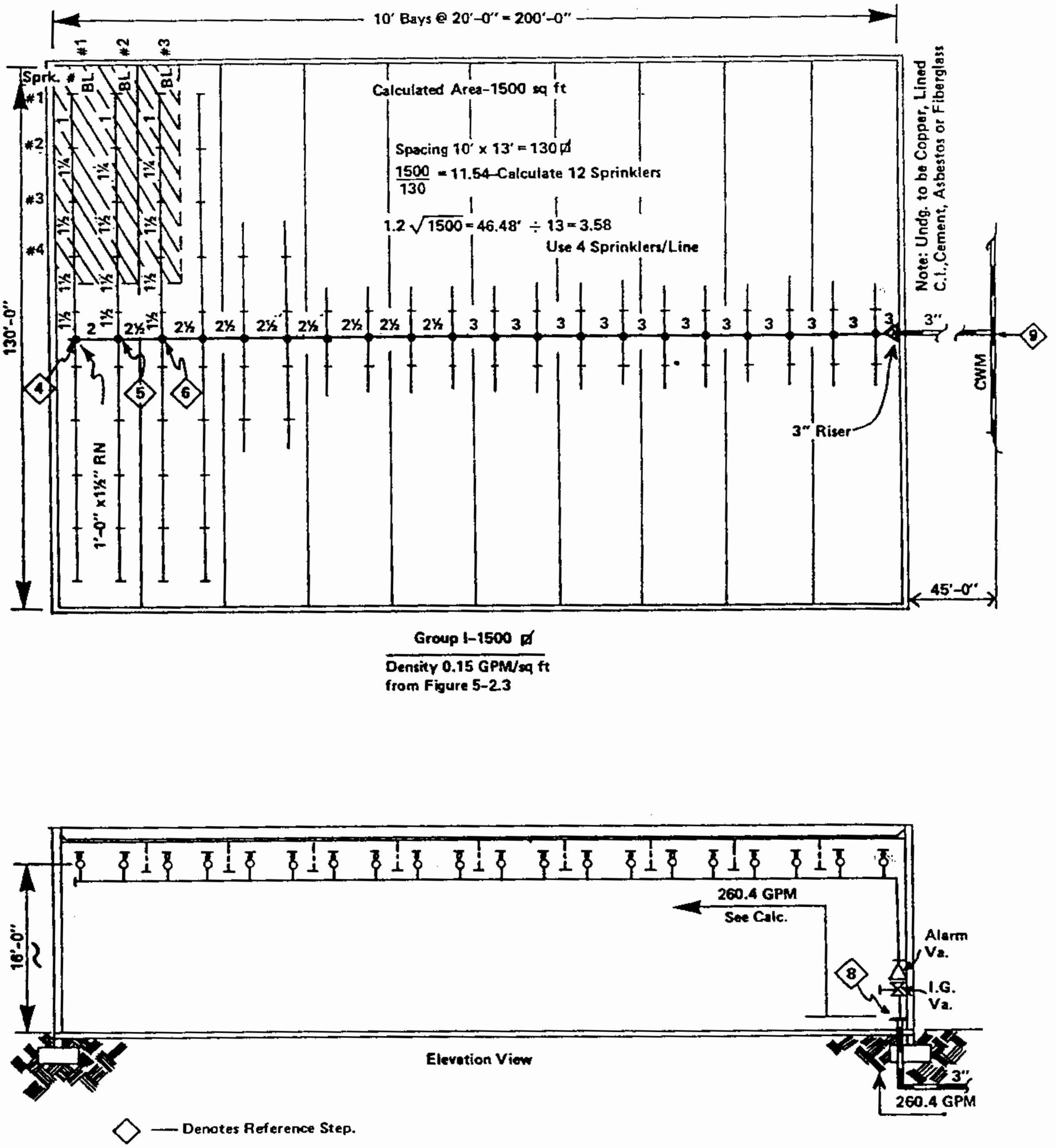


Figure A-6-2.2(b) Hydraulic calculation example (plan view and elevation view).

CONTRACT NAME GROUP I 1500 Φ SHEET 2 OF 3

STEP NO.	NOZZLE IDENT. AND LOCATION	FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV. PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NORMAL PRESSURE	D=0.15 GPM/Φ NOTES K=5.65	REF. STEP
1	1 BL-1	q	1		L 13.0	C=120	Pt 11.9	Pt	q=130X.15=19.5	
					F		Pe	Pv		
		Q 19.5			T 13.0	.124	Pf 1.6	Pn		
2	2	q 20.7	1 1/4		L 13.0		Pt 13.5	Pt	q=5.65√13.5	
					F		Pe	Pv		
		Q 40.2			T 13.0	.125	Pf 1.6	Pn		
3	3	q 22	1 1/2		L 13.0		Pt 15.1	Pt	q=5.65√15.1	
					F		Pe	Pv		
		Q 62.2			T 13.0	.132	Pf 1.7	Pn		
4	4 DN RN	q 23.2	1 1/2	2T-16	L 20.5		Pt 16.8	Pt	q=5.65√16.8	4
					F 16.0		Pe	Pv		
		Q 85.4			T 36.5	.237	Pf 8.6	Pn		
5	CM TO BL-2	q	2		L 10.0		Pt 25.4	Pt	K= 85.4/√25.4	5
					F		Pe	Pv		
		Q 85.4			T 10.0	.07	Pf .7	Pn	K= 16.95	
6	BL-2 CM TO BL-3	q 86.6	2 1/2		L 10.0		Pt 26.1	Pt	q=16.95√26.1	6
					F		Pe	Pv		
		Q 172.0			T 10.0	.109	Pf 1.1	Pn		
7	BL-3 CM	q 88.4	2 1/2		L 70.0		Pt 27.2	Pt	q=16.95√27.2	
					F		Pe	Pv		
		Q 260.4			T 70.0	.233	Pf 16.3	Pn		
8	CM TO F/S	q	3	E5	L 119.0		Pt 43.5	Pt	Pe=15 x .433	8
				AV15	F		Pe 6.5	Pv		
		Q 260.4		GV1	T 140.0	.081	Pf 11.3	Pn		
9	THRU UNDER-GROUND TO CITY MAIN	q	3	E5	L 50.0	C=150	Pt 61.3	Pt	COPPER	9
				GV1	F 32.0	TYPE "M"	Pe	Pv	21 X 1.51=32	
		Q 260.4		T15	T 82.2	.061	Pf 5.0	Pn		
		q			L		Pt 66.3	Pt		
					F		Pe	Pv		
		Q			T		Pf	Pn		
		q			L		Pt	Pt		
					F		Pe	Pv		
		Q			T		Pf	Pn		
							Pt			

Figure A-6-2.2(c) Hydraulic calculations.

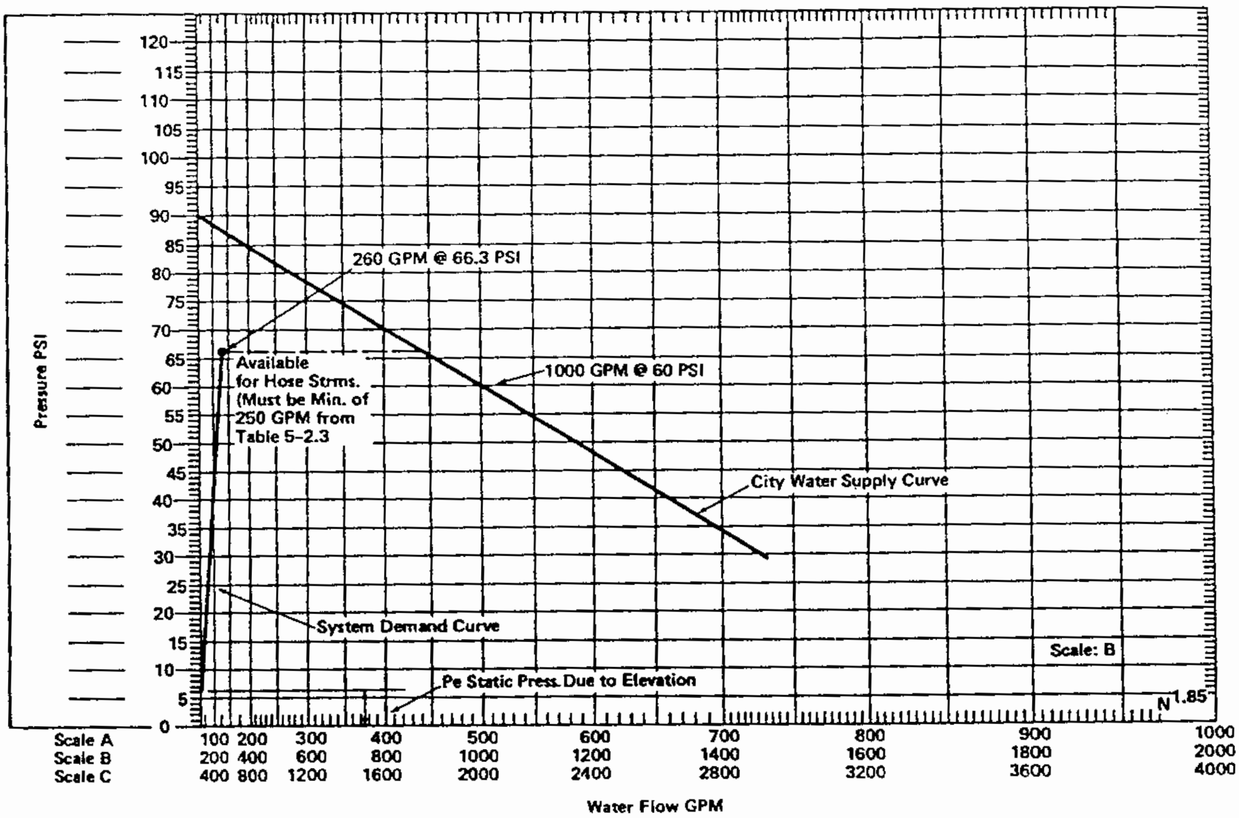


Figure A-6-2.2(d) Hydraulic graph.

Contract No. ____________________ Sheet No. __________ of __________

Name & Location ____

Reference	Nozzle Type & Location	Flow in GPM (L/min)	Pipe Size in.	Fitting & Devices	Pipe Eqiv. Length	Friction Loss psi/ft. (bars/m)	Req. Psi. (bars)	Normal Pressure	Notes
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	
		q			lgth.		Pt	Pt	
					ftg.		Pf	Pv	
		Q			tot.		Pe	Pn	

Figure A-6-2.3 Sample work sheet.

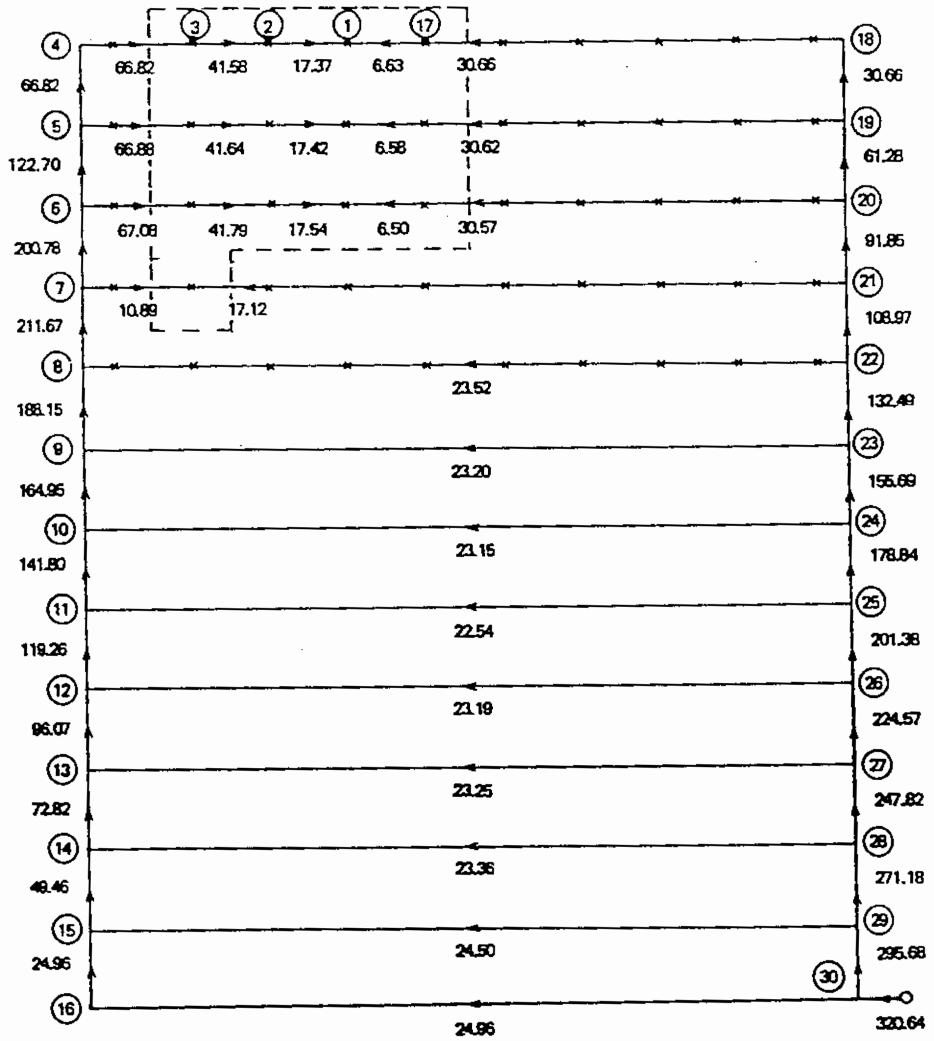


Figure A-6-2.3(o).

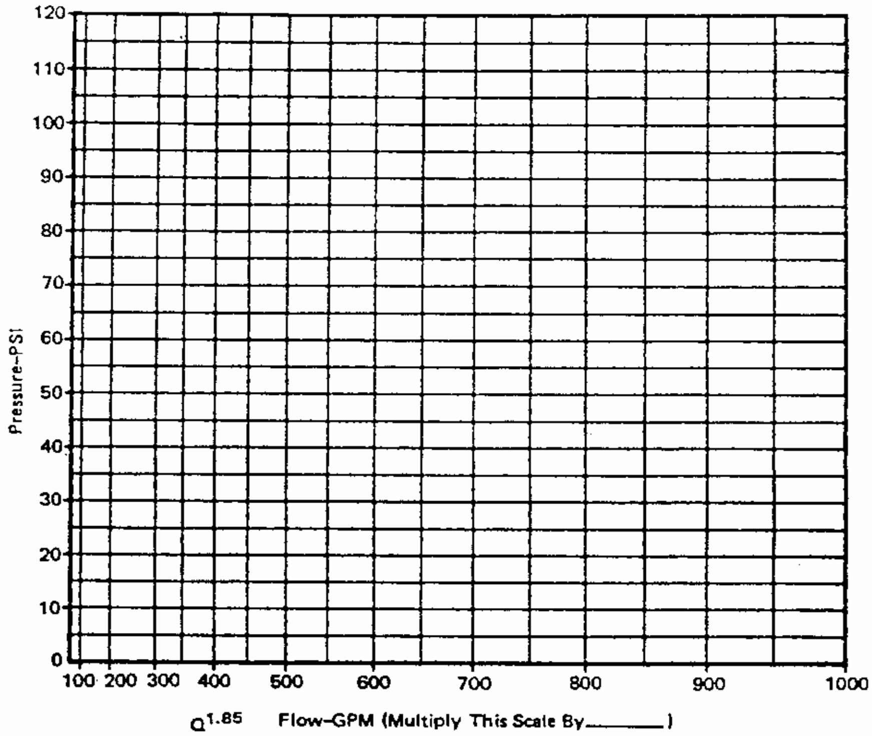
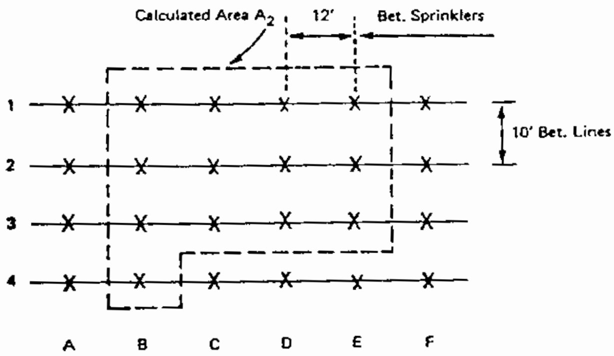


Figure A-6-2.4 Sample graph sheet.

A-6-4.1 When additional sprinkler piping is added to an existing system, the existing piping does not have to be increased in size to compensate for the additional sprinklers, provided the new work is calculated and the calculations include that portion of the existing system as may be required to carry water to the new work.

A-6-4.4 See Figure A-6-4.4.



NOTE 1: For gridded systems, the extra sprinkler (or sprinklers) on branch line 4 may be placed in any adjacent location from B to E at the designer's option.

NOTE 2: For tree and looped systems, the extra sprinkler on line 4 should be placed closest to the cross main.

Assume a remote area of 1,500 sq ft with sprinkler coverage of 120 sq ft

$$\text{Total sprinklers to calculate} = \frac{\text{Design Area}}{\text{Area per Sprinkler}}$$

$$= \frac{1500}{120} = 12.5\text{, calculate } 13$$

$$\text{Number of sprinklers on branch line} = \frac{1.2\sqrt{A}}{S}$$

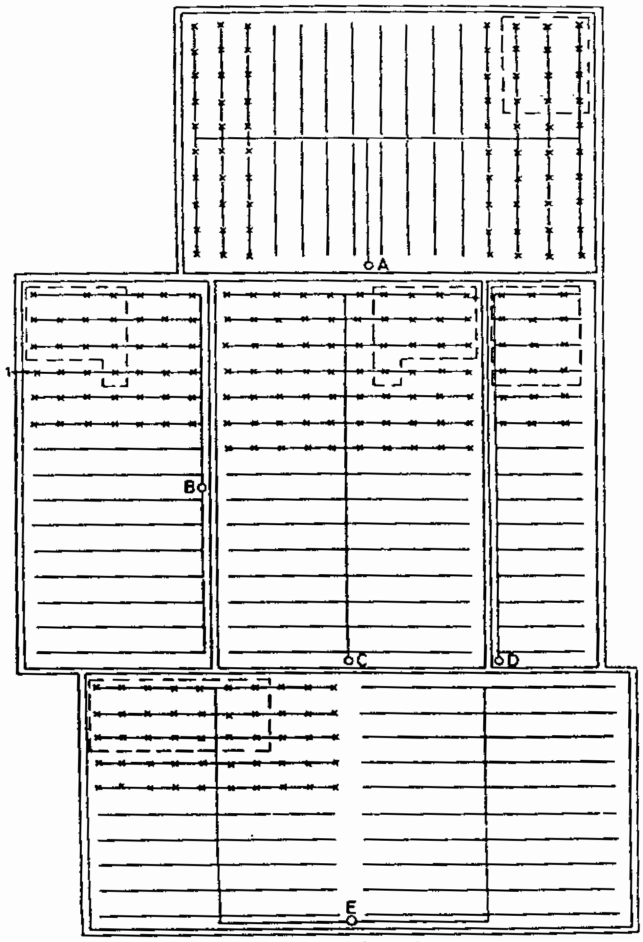
Where A = Design Area
S = Distance between Sprinklers on Branch Line

$$\text{Number of sprinklers on branch line} = \frac{1.2\sqrt{1500}}{12} = 3.87.$$

For SI Units: 1 ft = 0.3048 m; 1 sq ft = 0.0929 m^2.

Figure A-6-4.4 Example of determining the number of sprinklers to be calculated.

A-6-4.4.1 See Figures A-6-4.4.1(a) and (b).



[1] This sprinkler is not in the selected area of operation.

Figure A-6-4.4.1(a) Example of hydraulically most demanding area.

A-6-4.4.2 See Figure A-6-4.4.2.

A-6-4.4.3(a) See Figure A-6-4.4.3(a) on page 118.

A-6-4.4.3(b) This subsection assumes a ceiling constructed so as to reasonably assure that a fire on one side of the ceiling will operate sprinklers on one side only. When a ceiling is sufficiently open, or of such construction that operation of sprinklers above and below the ceiling may be anticipated, the operation of such additional sprinklers should be considered in the calculations.

A-6-4.4.4 When it is not obvious by comparison that the design selected is the hydraulically most remote, additional calculations should be submitted. The most distant area is not necessarily the hydraulically most remote.

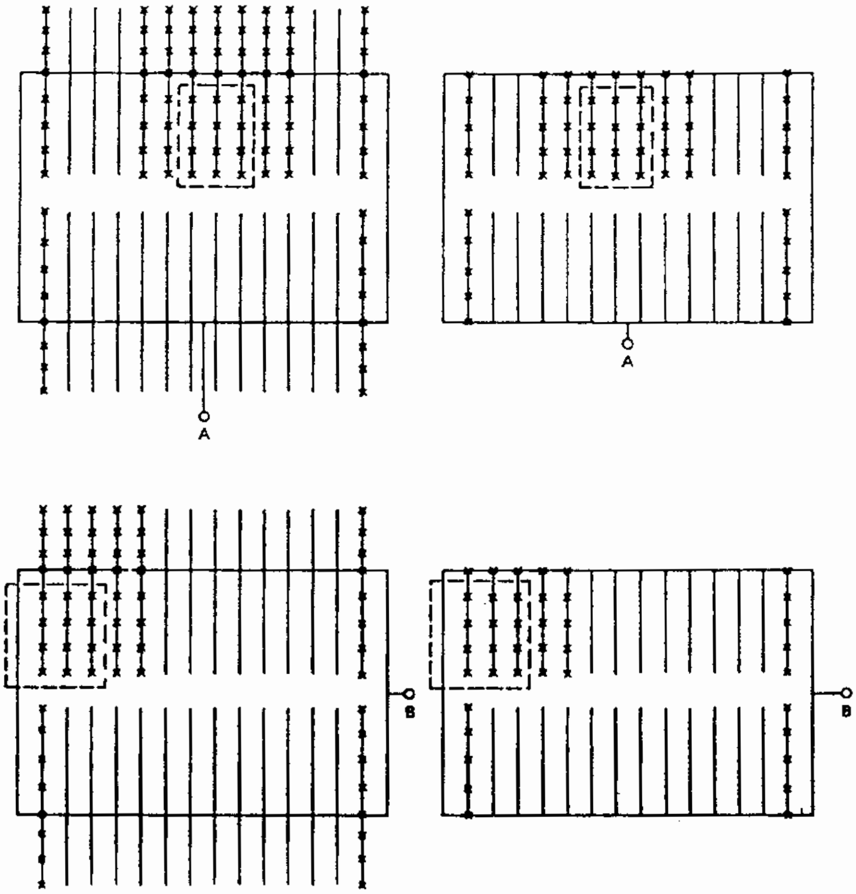


Figure A-6-4.4.1(b) Example of hydraulically most demanding area.

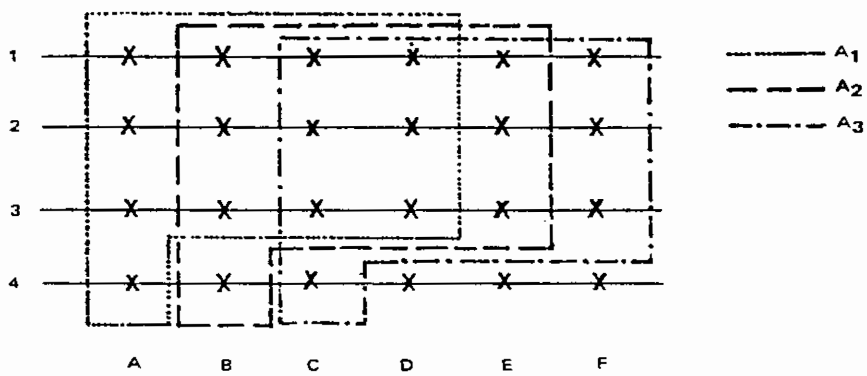
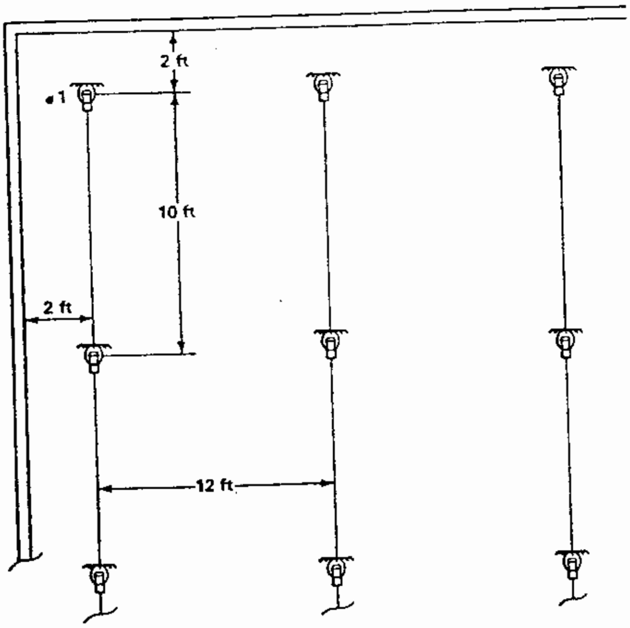


Figure A-6-4.4.2 Example of determining the most remote area for a gridded system.



For SI Units: 1 ft = 0.3048 m.

Figure A-6-4.4.3(a) Sprinkler design area.

A-6-4.4.6 The use of sprinklers with differing orifice sizes in situations where different protection areas are needed is not considered balancing. An example would be a room that could be protected with sprinklers having different orifice size in closet, foyer, and room areas. However, this procedure introduces difficulties when restoring a system to service after operation since it is not always clear which sprinklers go where.

A-6-4.4.7 When velocity pressure is included in the calculations, the following assumptions should be used:

(a) At any flowing outlet along a pipe, except the end outlet, only the normal pressure (P_n) can act on the outlet. At the end outlet the total pressure (P_t) can act. The following should be considered end outlets:

1. The last flowing sprinkler on a dead-end branch line

2. The last flowing branch line on a dead-end cross main

3. Any sprinkler where a flow split occurs on a gridded branch line

4. Any branch line where a flow split occurs on a looped system.

(b) At any flowing outlet along a pipe, except the end outlet, the pressure acting to cause flow from the outlet is equal to the total pressure (P_t) minus the velocity pressure (P_v) on the upstream (supply) side.

(c) To find the normal pressure (P_n) at any flowing outlet, except the end outlet, assume a flow from the outlet in question and determine the velocity pressure (P_v) for the total flow on the upstream side. Because normal pressure (P_n) equals total pressure (P_t) minus velocity pressure (P_v), the value of the normal pressure (P_n) so found should result in an outlet flow approximately equal to the assumed flow; if not, a new value should be assumed, and the calculations repeated.

A-6-5.1 The demonstrated effectiveness of pipe schedule systems is limited to their use with 1/2 in. (13 mm) orifice sprinklers. The use of other size orifices may require hydraulic calculations to prove their ability to deliver the required amount of water within the available water supply.

A-6-5.1.2 Long Runs of Pipe. When the construction or conditions introduce unusually long runs of pipe or many angles in risers or feed or cross mains, an increase in pipe size over that called for in the schedules may be required to compensate for increased friction losses.

A-6-5.2.3.1 For example, a 2 1/2 in. (64 mm) steel pipe, which is permitted to supply 30 sprinklers, may supply a total of 50 sprinklers when not more than 30 sprinklers are above, or below, a ceiling.

A-6-5.3.3.1 For example, a 3 in. (76 mm) steel pipe, which is permitted to supply 40 sprinklers in an Ordinary Hazard area, may supply a total of 60 sprinklers when not more than 40 sprinklers protect the occupied space below the ceiling.

A-6-5.4 Schedule for Extra Hazard Occupancies. This piping schedule is reprinted only as a guide for existing systems. New systems for Extra Hazard Occupancies should be hydraulically calculated as required in 6-5.4.

Table A-6-5.4 Extra Hazard Pipe Schedule

Steel		Copper	
1 in.	1 sprinkler	1 in.	1 sprinkler
1 1/4 in.	2 sprinklers	1 1/4 in.	2 sprinklers
1 1/2 in.	5 sprinklers	1 1/2 in.	5 sprinklers
2 in.	8 sprinklers	2 in.	8 sprinklers
2 1/2 in.	15 sprinklers	2 1/2 in.	20 sprinklers
3 in.	27 sprinklers	3 in.	30 sprinklers
3 1/2 in.	40 sprinklers	3 1/2 in.	45 sprinklers
4 in.	55 sprinklers	4 in.	65 sprinklers
5 in.	90 sprinklers	5 in.	100 sprinklers
6 in.	150 sprinklers	6 in.	170 sprinklers

A-6-5.6 In designing an exposure protection system, the flow rate from window and cornice sprinklers is shown in Table 6-5.6. The flow rates are based on the guide numbers selected from Table 2-3 of NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1987 edition.

Section A of the Table is for window sprinklers. The orifice size is selected according to the level on which the sprinkler is located.

Section B of the Table is for cornice sprinklers.

A-7-1.2.3 When the system riser is close to an outside wall, underground fittings of proper length should be used in order to avoid pipe joints located in or under the wall. When the connection passes through the foundation wall below grade, a 1- to 3-in. (25- to 76-mm) clearance should be provided around the pipe and the clear space filled with asphalt mastic or similar flexible waterproofing material.

A-7-2.1 Water Supplies. Care should be taken in making water tests to be used in designing or evaluating the capability of sprinkler systems. The water supply tested should be representative of the supply that may be available at the time of a fire. For example, testing of public water supplies should be done at times of normal demand on the system. Public water supplies are likely to fluctuate widely from season to season and even within a 24-hour period. Allowance should be made for seasonal or daily fluctuations, for drought conditions, for possibility of interruption by flood, or for ice conditions in winter. Testing of water supplies also normally used for industrial use should be done while water is being drawn for industrial use. The range of industrial-use demand should be taken into account.

Future changes in water supplies should be considered. For example a large, established, urban supply is not likely to change greatly within a few years. However, the supply in a growing suburban industrial park may deteriorate quite rapidly as greater numbers of plants draw more water.

Testing of Water Supply. To determine the value of public water as a supply for automatic sprinkler systems, it is generally necessary to make a flow test to determine how much water can be discharged at a residual pressure at a rate sufficient to give the required residual pressure under the roof (with the volume flow hydraulically translated to the base of the riser), i.e., a pressure head represented by the height of the building plus the required residual pressure.

The proper method of conducting this test is to use two hydrants in the vicinity of the property. The static pressure should be measured on the hydrant in front of or nearest to the property and the water allowed to flow from the hydrant next nearest the property, preferably the one farthest from the source of supply if the main is fed only one way. The residual pressure will be that indicated at the hydrant where water is not flowing.

Referring to Figure A-7-2.1, the method of conducting the flow tests is as follows:

1. Attach gauge to hydrant (A) and obtain static pressure.

2. Either attach second gauge to hydrant (B) or use pitot tube at outlet. Have hydrant (B) opened wide and read pressure at both hydrants.

3. Use the pressure at (B) to compute the gallons flowing and read the gauge on (A) to determine the residual pressure or that which will be available on the top line of sprinklers in the property.

Water pressure in psi for a given height in feet equals height multiplied by 0.434.

In making flow tests, whether from hydrants or from nozzles attached to hose, always measure the size of the orifice. While hydrant outlets are usually $2^1/_2$ in. (64 mm) they are sometimes smaller and occasionally larger. The UL play pipe is $1^1/_8$ in. (29 mm) and $1^3/_4$ in. (44 mm) with tip removed, but occasionally nozzles will be 1 in. (25 mm) or $1^1/_4$ in. (33 mm), and with the tip removed the opening may be only $1^1/_2$ in. (38 mm).

The Pitot tube should be held approximately one-half the diameter of the hydrant or nozzle opening away from the opening. It should be held in the center of the stream, except that in using hydrant outlets the stream should be explored to get the average pressure.

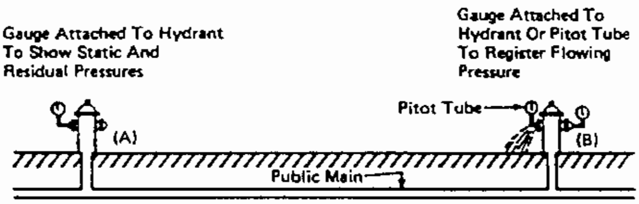


Figure A-7-2.1 Method of conducting flow tests.

A-7-2.2.1 An automatically controlled vertical turbine pump taking suction from a reservoir, pond, lake, river, or well complies with 7-2.2.1.

A-7-2.2.2 See sections dealing with sprinkler equipment supervisory and waterflow alarm services in NFPA 71, *Standard for the Installation, Maintenance, and Use of Signaling Systems for Central Station Service*, or NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*.

A-7-2.3.3 The air pressure to be carried and the proper proportion of air in the tank may be determined from the following formulas, in which,

P = Air pressure carried in pressure tank
A = Proportion of air in tank
H = Height of highest sprinkler above tank bottom

When tank is placed above highest sprinkler

$$P = \frac{30}{A} - 15.$$

If A = $^1/_3$ then P = 90 − 15 = 75 lb psi.
If A = $^1/_2$ then P = 60 − 15 = 45 lb psi.
If A = $^2/_3$ then P = 45 − 15 = 30 lb psi.

When tank is below level of the highest sprinkler

$$P = \frac{30}{A} - 15 + \frac{0.434H}{A}$$

If A = 1/3 then P = 75 + 1.30H.
If A = 1/2 then P = 45 + 0.87H.
If A = 2/3 then P = 30 + 0.65H.

The respective air pressures above are calculated to ensure that the last water will leave the tank at a pressure of 15 psi (1.03 bars) when the base of the tank is on a level with the highest sprinkler, or at such additional pressure as is equivalent to a head corresponding to the distance between the base of the tank and the highest sprinkler when the latter is above the tank.

The final pressure required at the pressure tank for systems designed from Table 5-2.3 will normally be higher than the 15 psi (1.03 bars) anticipated in the previous paragraph. The following formula should be used to determine the tank pressure and ratio of air to water in hydraulically designed systems.

$$P_i = \frac{P_f + 15}{A} - 15$$

where

P_i = Tank pressure
P_f = Pressure required from hydraulic calculations
A = Proportion of air

Example: Hydraulic calculations indicate 75 psi is required to supply the system. What tank pressure will be required?

$$P_i = \frac{75 + 15}{.5} - 15$$

$$P_i = 180 - 15 = 165 \text{ psi}$$

For SI Units: 1ft = 0.3048 m; 1 psi = 0.0689 bar.

In this case the tank would be filled with 50 percent air and 50 percent water and the tank pressure would be 165 psi (11.4 bars). If the pressure is too high, the amount of air carried in the tank will have to be increased.

Location of Pressure Tanks. Pressure tanks should be located above the top level of sprinklers but may be located in the basement or elsewhere.

A-8-2.1 Underground mains and lead-in connections to system risers should be flushed through hydrants at dead ends of the system or through accessible aboveground flushing outlets allowing the water to run until clear. If water is supplied from more than one source or from a looped system, divisional valves should be closed to produce a high-velocity flow through each single line. The flows specified in Table 8-2.1 will produce a velocity of at least 10 ft/sec (3 m/s), which is necessary for cleaning the pipe and for lifting foreign material to an aboveground flushing outlet.

A-8-2.2.1 A sprinkler system has for its water supply a connection to a public water service main. A 100 psi (6.9 bar) rated pump is installed in the connection. With a maximum normal public water supply of 70 psi (4.8 bars) at the low elevation point of the individual system or portion of the system being tested and a 120 psi (8.3 bars) pump (churn) pressure, the hydrostatic test pressure is 70 + 120 + 50 or 240 psi (16.5 bars).

Systems that have been modified or repaired to any appreciable extent should be hydrostatically tested at not less than 50 psi (3.4 bars) in excess of normal static pressure for 2 hours.

To reduce the possibility of serious water damage in case of a break, pressure may be maintained by a small pump, the main controlling gate meanwhile being kept shut during the test.

Polybutylene pipe will undergo expansion during initial pressurization. In this case a reduction in gauge pressure may not necessarily indicate a leak. The pressure reduction should not exceed the manufacturer's specifications and listing criteria.

When pressure testing systems having rigid thermoplastic piping such as CPVC, the sprinkler system should be filled with water. The air should be bled from the highest and farthest sprinklers. Compressed air or compressed gas should never be used to test systems with rigid thermoplastic pipe.

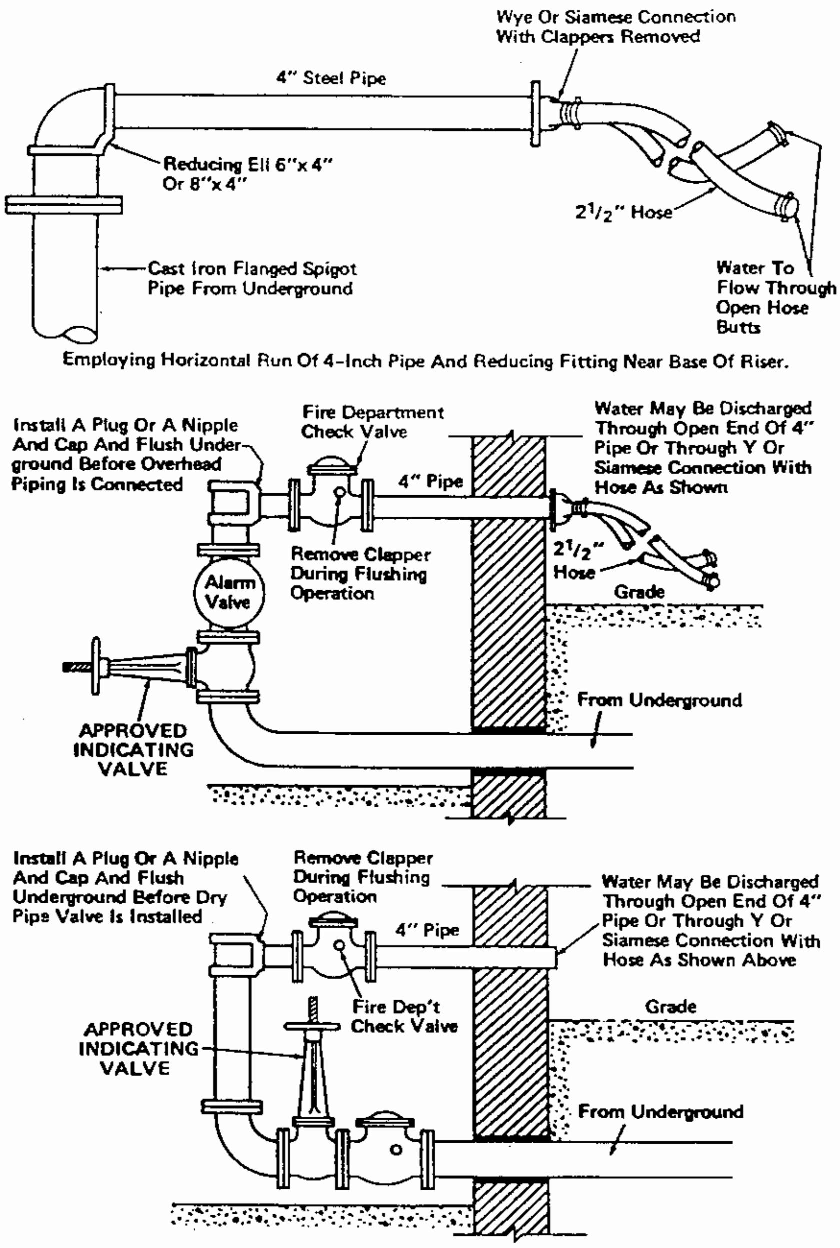
A-8-2.2.7 Valves isolating the section to be tested may not be "drop tight." When such leakage is suspected, test blanks of the type recommended in 8-2.2.7 should be used in a manner that includes the valve in the section being tested.

A-8-5 See Figure A-8-5.

This system as shown on ....company
print no. ....dated............
for..
at .... contract no..........
is designed to discharge at a rate of ....gpm
(L/min) per sq ft of floor area over a maximum
area of .... sq ft (m²) when supplied
with water at a rate of .... gpm (L/min)
at .... psi (bars) at the base of the riser.
Hose stream allowance of........................
gpm (L/min) is included in the above.

Figure A-8-5 Sample nameplate.

A-9-1.1 Impairments. Before shutting off a section of the fire service system to make sprinkler system connections, notify the authority having jurisdiction, plan the work carefully, and assemble all materials to enable completion in the shortest possible time. Work started on con-



Employing Horizontal Run Of 4-Inch Pipe And Reducing Fitting Near Base Of Riser.

Employing Fire Department Connections.

Figure A-8-2.1 Methods of flushing water supply connections.

nections should be completed without interruption and protection restored as promptly as possible. During the impairment, provide emergency hose lines and extinguishers and maintain extra watch service in the areas affected.

When changes involve shutting off water from any considerable number of sprinklers for more than a few hours, temporary water supply connections should be made to sprinkler systems so that reasonable protection can be maintained. In adding to old systems or revamping them, protection should be restored each night so far as possible. The members of the private fire brigade as well as public fire departments should be notified as to conditions.

Maintenance Schedule. The items shown in Table A-9-1.1 should be checked on a routine basis.

A-9-1.3 When painting sprinkler piping or painting in areas near sprinklers, the sprinklers may be protected by covering them with a biodegradable paper bag that should be removed immediately after the painting has been finished.

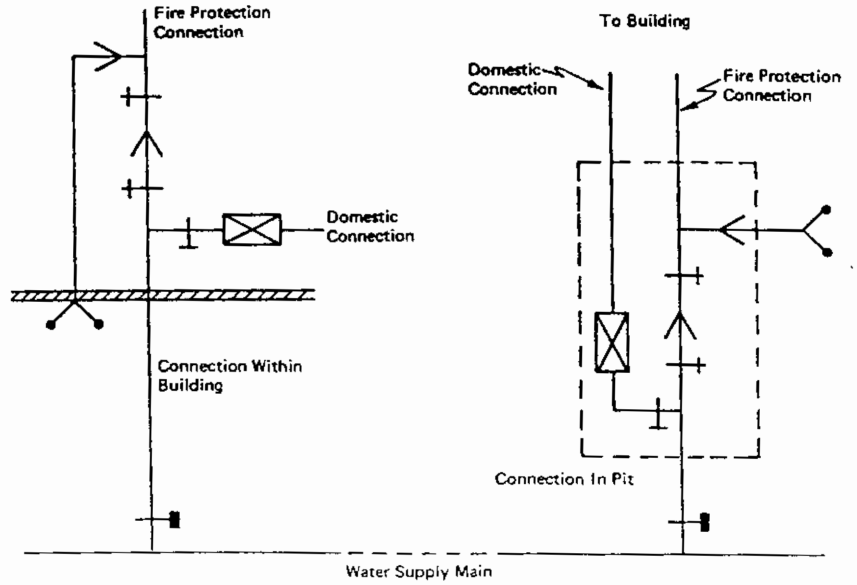
A-9-3.3 In the quarterly test, record the static pressure. Then fully open the main drain and record the residual pressure. A significant drop in the recorded residual pressure from the prior test may indicate an obstruction or a partially closed valve. A gradual decrease in pressure over several test intervals may indicate a buildup of corrosion in the supply piping or a decaying water supply.

Table A-9-1.1 Maintenance Schedule

Parts	Activity	Frequency
Flushing Piping	Test	5 years
Fire Department Connections	Inspection	Monthly
Control Valves	Inspection	Weekly—Sealed
	Inspection	Monthly—Locked
	Inspection	Monthly—Tamper Switch
	Maintenance	Yearly
Main Drain	Flow Test	Quarterly
Open Sprinklers	Test	Annual
Pressure Gauge	Calibration Test	
Sprinklers	Test	50 years
Sprinklers—High Temp	Test	5 years
Sprinklers—Residential	Test	20 years
Waterflow Alarms	Test	Quarterly
Preaction/Deluge Detection System	Test	Semiannually
Preaction/Deluge Systems	Test	Annually
Antifreeze Solution	Test	Annually
Cold Weather Valves	Open and Close Valves	Fall, Close; Spring, Open
Dry/Preaction/Deluge Systems		
Air Pressure and Water Pressure	Inspection	Weekly
Enclosure	Inspection	Daily—Cold Weather
Priming Water Level	Inspection	Quarterly
Low—Point Drains	Test	Fall
Dry Pipe Valves	Trip Test	Annual—Spring
Dry Pipe Valves	Full Flow Trip	3 years—Spring
Quick Opening Devices	Test	Semi-annually

Appendix B

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.



Permitted arrangements between the fire protection water supply and the domestic water supply.

Appendix C Referenced Publications

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

C-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

C-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13A, *Recommended Practice for the Inspection, Testing and Maintenance of Sprinkler Systems*, 1987 edition

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1990 edition

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*, 1990 edition

NFPA 71, *Standard for the Installation, Maintenance, and Use of Signaling Systems for Central Station Service*, 1989 edition

NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*, 1990 edition

NFPA 80A, *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*, 1987 edition

NFPA 81, *Standard for Fur Storage, Fumigation and Cleaning*, 1986 edition

NFPA 220, *Standard on Types of Building Construction*, 1985 edition

NFPA 231, *Standard for General Storage*, 1990 edition

NFPA 231C, *Standard for Rack Storage of Materials*, 1991 edition

NFPA 231F, *Standard for the Storage of Roll Paper*, 1987 edition.

NFPA 703, *Standard for Fire Retardant Impregnated Wood and Fire Retardant Coatings for Building Materials*, 1985 edition

C-2 The following NFPA Recommended Practices contain specific sprinkler design criteria on various subjects.

NFPA 16A, *Recommended Practice for the Installation of Closed-Head Foam-Water Sprinkler Systems*, 1988 edition

NFPA 231E, *Recommended Practice for the Storage of Baled Cotton*, 1989 edition

ERRATA

NFPA 13

Installation of Sprinkler Systems

1991 Edition

Reference: 6-4.2.2, Table A-5-3.4, and Table A-5-3.5

The Committee on Automatic Sprinklers notes the following errors in the 1991 edition of NFPA 13, *Standard for the Installation of Sprinkler Systems.*

1. In 6-4.2.2 revise the formula to read:

$$Pv = \frac{0.001123\ Q^2}{D^4}$$

2. In Table A-5-3.4, Large-Drop Sprinkler Criteria, revise the rack storage heading to read as follows:

Double-Row Rack Storage[3] with Minimum 5.5 ft (1.7 m) Aisle Width and Multiple-Row Rack Storage with Minimum 8.0 ft (2.5 m) Aisle Width.

3. In Table A-5-3.5, ESFR Sprinkler Data, revise the first entry under the "Type of Storage" heading as follows:

Single-, double-, and multiple-row and portable rack storage (no open-top containers or solid shelves), and solid-piled or palletized storage.

Issue Date: June 26, 1992
Correction Issued: January, 1993

UNIFORM BUILDING CODE STANDARD 9-2
STANDPIPE SYSTEMS

See Sections 902, 904.1.2 and 904.5.1, *Uniform Building Code*

This standard, with certain exceptions, is based on the National Fire Protection Association Standard for the Installation of Standpipe and Hose Systems, NFPA 14-1993.

Part I of this standard contains exceptions to NFPA 14-1993[1]. Part II of this standard contains NFPA 14-1993[1] reproduced in its entirety with permission of the publisher.

vertically in the margin of Part II indicates there is a revision to the provisions within Part I.

Unless specifically adopted elsewhere, supplemental standards referenced in this primary standard shall only be considered to be guidance material subject to the approval of the building official.

[1]The current edition is NFPA 14-1996.

Part I

SECTION 9.201 — AMENDMENTS

The Standard for Installation of Standpipe and Hose Systems, NFPA 14-1993, applies to the installation of standpipe systems except as follows:

1. Sec. 1-4 is revised by changing the definition of "authority having jurisdiction" as follows:

AUTHORITY HAVING JURISDICTION is the building official.

The definitions of "approved" and "listed" shall be as set forth in Volume I of this code.

The definition of "shall" is deleted.

2. Sec. 2-4.2.5 is revised by substituting "(See NFPA 13)" with "(See UBC Standard 9-1)" in the exception.

3. Sec. 2-7.2 is revised in the third line by deleting the words "not more than."

4. Sec. 4-1.2.5 is revised by substituting "NFPA 13, Standard for the Installation of Sprinkler Systems" with "UBC Standard 9-1."

5. Sec. 5-9.1.3.1 is revised by substituting "NFPA 13, Standard for the Installation of Sprinkler Systems" with "UBC Standard 9-1" in the exception.

6. Sec. 8-7 is revised by substituting "NFPA 72, Standard for the Installation, Maintenance and Use of Protective Signaling Systems" with "UFC Standard 14-1."

7. Sec. 8-8 is revised by deleting Subsection (b).

8. Chapter 10 is deleted.

Part II

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[1]The current edition is NFPA 14-1996.

Contents

NFPA 14

Standard for the

Installation of Standpipe and Hose Systems

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 10 and Appendix B.

Chapter 1 General Information

1-1 Scope. This standard covers the minimum requirements for the installation of standpipe and hose systems for buildings and structures.

1-2 Purpose. The purpose of this standard is to provide a reasonable degree of protection for life and property from fire through installation requirements for standpipe systems based on sound engineering principles, test data, and field experience. Nothing in this standard is intended to restrict new technologies or alternate arrangements providing the level of safety prescribed by the standard is not lowered.

-3 Retroactivity. The provisions of this document are considered necessary to provide a reasonable level of protection from loss of life and property from fire. They reflect situations and the state of the art at the time the standard was issued.

Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document.

Exception: In those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or property, this standard shall apply.

1-4 Definitions.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Automatic Standpipe System. A standpipe system that is attached to a water supply capable of supplying the system demand at all times and that requires no action other than opening a hose valve to provide water at hose connections. *(See Chapter 3.)*

Branch Line. A piping system, generally in a horizontal plane, connecting one or more hose connections with a standpipe.

Combined System. A standpipe system having piping that supplies both hose connections and automatic sprinklers.

Control Valve. A valve used to control the water supply system of a standpipe system.

Dry Standpipe. A standpipe system designed to have piping contain water only when the system is being utilized. *(See Chapter 3.)*

Feed Main. That portion of a standpipe system that supplies water to one or more standpipes.

Fire Department Connection. A connection through which the fire department can pump water into the standpipe system.

High-Rise Building. A building more than 75 ft (23 m) in height. Building height shall be measured from the lowest level of fire department vehicle access to the floor of the highest occupiable story.

Hose Connection. A combination of equipment provided for connection of a hose to the standpipe system that includes a hose valve with a threaded outlet.

Hose Station. A combination of a hose rack, hose nozzle, hose, and hose connection.

Hose Valve. The valve to an individual hose connection.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Manual Standpipe System. A standpipe system that relies exclusively on the fire department connection to supply the system demand. (*See Chapter 3.*)

Pressure, Nozzle. Pressure required at the inlet of a nozzle to produce the desired water discharge characteristics.

Pressure, Residual. Pressure acting on a point in the system with a flow being delivered by the system.

Pressure, Static. Pressure acting on a point in the system with no flow from the system.

Pressure Control Valve. A pilot-operated valve designed for the purpose of reducing the downstream water pressure to a specific value under both flowing (residual) and nonflowing (static) conditions.

Pressure Reducing Valve. A valve designed for the purpose of reducing the downstream water pressure under both flowing (residual) and nonflowing (static) conditions.

Pressure Regulating Device. A device designed for the purpose of reducing, regulating, controlling, or restricting water pressure. Examples include pressure reducing valves, pressure control valves, and pressure restricting devices.

Pressure Restricting Device. A valve or device designed for the purpose of reducing the downstream water pressure under flowing (residual) conditions only.

Semiautomatic Standpipe System. A standpipe system that is attached to a water supply capable of supplying the system demand at all times and that requires activation of a control device to provide water at hose connections. See Chapter 3.

Shall.* Indicates a mandatory requirement.

Standpipe. The riser portion of the system piping that delivers the water supply for hose connections, and sprinklers on combined systems, vertically from floor to floor.

Standpipe System. An arrangement of piping, valves, hose connections, and allied equipment installed in a building or structure with the hose connections located in such a manner that water can be discharged in streams or spray patterns through attached hose and nozzles, for the purpose of extinguishing a fire and so protecting a building or structure and its contents in addition to protecting the occupants. This is accomplished by connections to water supply systems or by pumps, tanks, and other equipment necessary to provide an adequate supply of water to the hose connections.

System Demand. The flow rate and residual pressure required from a water supply, measured at the point of connection of a water supply to a standpipe system, to deliver:

(a) The total water flow rate required for a standpipe system established in Section 5-9, and

(b) The minimum residual pressures established by Section 5-7 at the hydraulically most remote hose connection, and

(c) The minimum water flow rate for sprinkler connections, on combined systems.

Type (of System). (*See Chapter 3.*)

Wet Standpipe. A standpipe system having piping containing water at all times. (*See Chapter 3.*)

1-5 Units.

1-5.1 Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection. These units are listed in Table 1-5 with conversion factors.

Table 1-5

Name of Unit	Unit Symbol	Conversion Factor
meter	m	1 ft = 0.3048 m
millimeter	mm	1 in. = 25.4 mm
liter	L	1 gal = 3.785 L
cubic decimeter	dm^3	1 gal = 3.785 dm^3
Pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 10^5 Pa

For additional conversion and information, see ASTM E380.

1-5.2 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value could be approximate.

Chapter 2 System Components and Hardware

2-1* General. Standpipe system components and hardware shall be in accordance with this chapter. All devices and materials used in standpipe systems shall be of an approved type. System components shall be rated for working pressures not less than the maximum pressure to be developed at that point in the system under any condition including the pressure when a permanently installed fire pump is operating at shutoff pressure.

2-2 Pipe and Tube.

2-2.1 Pipe or tube used in standpipe systems shall meet or exceed one of the standards in Table 2-2.1 or be in accordance with 2-2.2 through 2-2.5.

Table 2-2.1 Pipe or Tube Materials and Dimensions

Material and Dimensions (Specifications)	Standard
Ferrous Piping	
Ductile-Iron Pipe, Centrifugally Cast, in Metal Molds or Sand-Lined Molds for Water or Other Liquids	AWWA C151
Electric-Resistance Welded Steel Pipe	
Spec. for Black and Hot-Dipped Zinc-Coated (Galvanized)	ASTM A135
Welded and Seamless Steel Pipe for Fire Protection Use	ASTM A795
Welded and Seamless Steel Pipe	ASTM A53
Wrought-Steel and Wrought-Iron Pipe	ANSI B36.10
Copper Tube (Drawn, Seamless)	
Seamless Copper Tube	ASTM B75
Seamless Copper Water Tube	ASTM B88
General Requirements for Wrought Seamless Copper and Copper-Alloy Tube	ASTM B251
Brazing Filler Metal (Classifications BCuP-3 or BCuP-4)	AWS A5.8

2-2.2 Where steel pipe listed in Table 2-2.1 is used and joined by welding as referenced in 2-4.2 or by roll-grooved pipe and fittings as referenced in 2-4.3, the minimum nominal wall thickness for pressures up to 300 psi (20.7 bars) shall be in accordance with Schedule 10 for sizes up to 5 in. (127 mm); 0.134 in. (3.40 mm) for 6 in. (152 mm); and 0.188 in. (4.78 mm) for 8- and 10-in. (203- and 254-mm) pipe.

Exception: Pressure limitations and wall thickness for steel pipe listed in accordance with 2-2.5 shall be in accordance with the listing requirements.

2-2.3 Where steel pipe listed in Table 2-2.1 is joined by threaded fittings referenced in 2-4.1 or by fittings used with pipe having cut grooves, the minimum wall thickness shall be in accordance with Schedule 30 [in sizes 8 in. (203 mm) and larger] or Schedule 40 [in sizes less than 8 in. (203 mm)] pipe for pressures up to 300 psi (20.7 bars).

Exception: Pressure limitations and wall thickness for steel pipe specially listed in accordance with 2-2.5 shall be in accordance with the listing requirements.

2-2.4 Copper tube as specified in the standards listed in Table 2-2.1 shall have a wall thickness of Type K, L, or M where used in standpipe systems.

2-2.5 Other types of pipe or tube investigated for suitability in standpipe installations and listed for this service, including but not limited to steel differing from that provided in Table 2-2.1, shall be permitted where installed in accordance with their listing limitations, including installation instructions. Pipe or tube shall not be listed for portions of an occupancy classification.

2-2.6 Pipe Bending. Bending of Schedule 40 steel pipe and Types K and L copper tube shall be permitted where bends are made with no kinks, ripples, distortions, reductions in diameter, or any noticeable deviations from round. The minimum radius of a bend shall be 6 pipe diameters for pipe sizes 2 in. (51 mm) and smaller, and 5 pipe diameters for pipe sizes $2^1/_2$ in. (64 mm) and larger.

2-3 Fittings.

2-3.1 Fittings used in sprinkler systems shall meet or exceed the standards in Table 2-3.1 or be in accordance with 2-3.2.

Table 2-3.1 Fittings Materials and Dimensions

Material and Dimensions	Standard
Cast Iron	
Cast-Iron Threaded Fittings, Class 125 and 250	ANSI B16.4
Cast-Iron Pipe Flanges and Flanged Fittings, Class 125 and 250	ANSI B16.1
Malleable Iron	
Malleable Iron Threaded Fittings, Class 150 and 300	ANSI B16.3
Ductile Iron	
Gray-Iron and Ductile-Iron Fittings, 3 in. through 48 in. for Water and Other Liquids	AWWA C110
Steel	
Factory-Made Wrought Steel Buttweld Fittings	ANSI B16.9
Buttwelding Endings for Pipe, Valves, Flanges, and Fittings	ANSI B16.25
Spec. for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures	ASTM A234
Steel Pipe Flanges and Flanged Fittings	ANSI B16.5
Forged Steel Fittings, Socketed, Welded and Threaded	ANSI B16.11
Copper	
Wrought Copper and Bronze Solder-Joint Pressure Fittings	ANSI B16.22
Cast Bronze Solder Joint Pressure Fittings	ANSI B16.18

2-3.2 Other types of fittings investigated for suitability in standpipe installations and listed for this service, including but not limited to steel differing from that provided in Table 2-3.1, shall be permitted where installed in accordance with their listing limitations, including installation instructions.

2-3.3 Fittings shall be extra-heavy pattern where pressures exceed 175 psi (12.1 bars).

Exception No. 1: Standard weight pattern cast-iron fittings 2 in. (51 mm) in size and smaller shall be permitted where pressures do not exceed 300 psi (20.7 bars).

Exception No. 2: Standard weight pattern malleable iron fittings 6 in. (152 mm) in size and smaller shall be permitted where pressures do not exceed 300 psi (20.7 bars).

Exception No. 3: Fittings shall be permitted for system pressures up to the limits specified in their listings.

2-3.4 Couplings and Unions. Screwed unions shall not be used on pipe larger than 2 in. (51 mm). Couplings and unions of other than screwed-type shall be of types listed specifically for use in sprinkler systems.

2-3.5 Reducers and Bushings. A one-piece reducing fitting shall be used wherever a change is made in the size of the pipe.

Exception: Hexagonal or face bushings shall be permitted in reducing the size of openings of fittings where standard fittings of the required size are not available.

2-4 Joining of Pipe and Fittings.

2-4.1 Threaded Pipe and Fittings.

2-4.1.1 All threaded pipe and fittings shall have threads cut to ANSI/ASME B1.20.1.

2-4.1.2 Steel pipe with wall thicknesses less than Schedule 30 [in sizes 8 in. (203 mm) and larger] or Schedule 40 [in sizes less than 8 in. (203 mm)] shall not be joined by threaded fittings.

Exception: A threaded assembly investigated for suitability in standpipe installations and listed for this service shall be permitted.

2-4.1.3 Joint compound or tape shall be applied only to male threads.

2-4.2 Welded Pipe and Fittings.

2-4.2.1 Welding methods that comply with all of the requirements of AWS D10.9, *Standard Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*, Level AR-3, are acceptable means of joining fire protection piping.

2-4.2.2 Standpipe piping shall be shop welded.

Exception: Welding of standpipe piping in place inside new buildings under construction shall be permitted only where the construction is noncombustible and no combustible contents are present, and when the welding process is performed in accordance with NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes.

2-4.2.3 Fittings used to join pipe shall be listed fabricated fittings or manufactured in accordance with Table 2-3.1. Such fittings joined in conformance with a qualified welding procedure as set forth in this section are an acceptable product under this standard, provided that materials and wall thickness are compatible with other sections of this standard.

Exception: Fittings are not required where pipe ends are buttwelded.

2-4.2.4 No welding shall be performed if there is impingement of rain, snow, sleet, or high wind on the weld area of the pipe product.

2-4.2.5 When welding is performed:

(a) Holes in piping for outlets shall be cut to the full inside diameter of fittings prior to welding in place of the fittings.

(b) Discs shall be retrieved.

(c) Openings cut into piping shall be smooth bore, and all internal slag and welding residue shall be removed.

(d) Fittings shall not penetrate the internal diameter of the piping.

(e) Steel plates shall not be welded to the ends of piping or fittings.

(f) Fittings shall not be modified.

(g) Nuts, clips, eye rods, angle brackets, or other fasteners shall not be welded to pipe or fittings.

Exception: Only tabs welded to pipe for longitudinal earthquake braces shall be permitted. (See NFPA 13.)

2-4.2.6 When reducing the pipe size in a run of piping, a reducing fitting designed for that purpose shall be used.

2-4.2.7 Torch cutting and welding shall not be permitted as a means of modifying or repairing standpipe systems.

2-4.2.8 Qualifications.

2-4.2.8.1 A welding procedure shall be prepared and qualified by the contractor or fabricator before any welding is done. Qualification of the welding procedure to be used and the performance of all welders and welding operators is required and shall meet or exceed the requirements of American Welding Society Standard AWS D10.9, Level AR-3.

2-4.2.8.2 Contractors or fabricators shall be responsible for all welding they produce. Each contractor or fabricator shall have an established written quality assurance procedure ensuring compliance with the requirements of 2-4.2.5 available to the authority having jurisdiction.

2-4.2.9 Records.

2-4.2.9.1 Welders or welding machine operators shall, upon completion of each weld, stamp an imprint of their identification into the side of the pipe adjacent to the weld.

2-4.2.9.2 Contractors or fabricators shall maintain certified records, which are available to the authority having jurisdiction, of the procedures used and the welders or welding machine operators employed by them along with their welding identification imprints. Records shall show the date and the results of procedure and performance qualifications.

2-4.3 Groove Joining Methods.

2-4.3.1 Pipe joined with grooved fittings shall be joined by a listed combination of fittings, gaskets, and grooves. Grooves cut or rolled on pipe shall be dimensionally compatible with the fittings.

2-4.3.2 Grooved fittings including gaskets used on dry pipe systems shall be listed for dry pipe service.

2-4.4 Brazed and Soldered Joints.

2-4.4.1 Joints for the connection of copper tube shall be brazed.

Exception No. 1: Solder joints shall be permitted for exposed wet standpipe systems in Light Hazard Occupancies.

Exception No. 2: Solder joints shall be permitted for wet standpipe systems in Light Hazard and Ordinary Hazard (Group 1) Occupancies where the piping is concealed.

2-4.4.2 Highly corrosive fluxes shall not be used.

2-4.5 Other Types. Other joining methods investigated for suitability in standpipe systems and listed for this service shall be permitted where installed in accordance with their listing limitations, including installation instructions.

2-4.6 End Treatment. After cutting, pipe ends shall have burrs and fins removed.

2-4.6.1 Pipe used with listed fittings and its end treatment shall be in accordance with the fitting manufacturer's installation instructions and the fitting's listing.

2-5 Hangers.

2-5.1* General. Types of hangers shall be in accordance with the requirements of this section.

Exception: Hangers certified by a registered professional engineer to include all of the following shall be acceptable:

(a) Hangers are designed to support 5 times the weight of the water-filled pipe plus 250 lb (114 kg) at each point of piping support.

(b) These points of support are adequate to support the standpipe system.

(c) Hanger components shall be ferrous.

Detailed calculations shall be submitted, where required by the reviewing authority, showing stresses developed both in hangers and piping and safety factors allowed.

2-5.1.1 The components of hanger assemblies that directly attach to the pipe or to the building structure shall be listed.

Exception: Mild steel hangers formed from rods need not be listed.

2-5.1.2 Hangers and their components shall be ferrous.

Exception: Nonferrous components that have been proven by fire tests to be adequate for the hazard application, that are listed for this purpose, and that are in compliance with the other requirements of this section shall be acceptable.

2-5.1.3 Standpipe piping shall be substantially supported from the building structure, which must support the added load of the water-filled pipe plus a minimum of 250 lb (114 kg) applied at the point of hanging.

2-5.1.4 Where standpipe piping is installed below ductwork, piping shall be supported from the building structure or from the ductwork supports, provided such supports are capable of handling both the load of the ductwork and the load specified in 2-5.1.3.

2-5.1.5 For trapeze hangers, the minimum size of steel angle or pipe span between purlins or joists shall be such that the available section modulus of the trapeze member from Table 2-5.1.5(b) equals or exceeds the section modulus required in Table 2-5.1.5(a).

Table 2-5.1.5(a) Section Modulus Required for Trapeze Member (in^3)

Span of Trapeze	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.	8 in.	10 in.
1 ft 6 in.	.08	.09	.09	.09	.10	.11	.12	.13	.15	.18	.24	.32
	.08	.09	.09	.10	.11	.12	.13	.15	.18	.22	.30	.41
2 ft 0 in.	.11	.12	.12	.13	.13	.15	.16	.17	.20	.24	.32	.43
	.11	.12	.12	.13	.15	.16	.18	.20	.24	.29	.40	.55
2 ft 6 in.	.14	.14	.15	.16	.17	.18	.20	.21	.25	.30	.40	.54
	.14	.15	.15	.16	.18	.21	.22	.25	.30	.36	.50	.68
3 ft 0 in.	.17	.17	.18	.19	.20	.22	.24	.26	.31	.36	.48	.65
	.17	.18	.18	.20	.22	.25	.27	.30	.36	.43	.60	.82
4 ft 0 in.	.22	.23	.24	.25	.27	.29	.32	.34	.41	.48	.64	.87
	.22	.24	.24	.26	.29	.33	.36	.40	.48	.58	.80	1.09
5 ft 0 in.	.28	.29	.30	.31	.34	.37	.40	.43	.51	.59	.80	1.08
	.28	.29	.30	.33	.37	.41	.45	.49	.60	.72	1.00	1.37
6 ft 0 in.	.33	.35	.36	.38	.41	.44	.48	.51	.61	.71	.97	1.30
	.34	.35	.36	.39	.44	.49	.54	.59	.72	.87	1.20	1.64
7 ft 0 in.	.39	.40	.41	.44	.47	.52	.55	.60	.71	.83	1.13	1.52
	.39	.41	.43	.46	.51	.58	.63	.69	.84	1.01	1.41	1.92
8 ft 0 in.	.44	.46	.47	.50	.54	.59	.63	.68	.81	.95	1.29	1.73
	.45	.47	.49	.52	.59	.66	.72	.79	.96	1.16	1.61	2.19
9 ft 0 in.	.50	.52	.53	.56	.61	.66	.71	.77	.92	1.07	1.45	1.95
	.50	.53	.55	.59	.66	.74	.81	.89	1.08	1.30	1.81	2.46
10 ft 0 in.	.56	.58	.59	.63	.68	.74	.79	.85	1.02	1.19	1.61	2.17
	.56	.59	.61	.65	.74	.82	.90	.99	1.20	1.44	2.01	2.74

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Top values are for Schedule 10 pipe; bottom values are for Schedule 40 pipe.

NOTE: The table is based on a maximum allowable bending stress of 15 KSI and a midspan concentrated luad from 15 ft of water-filled pipe, plus 250 lb.

Any other sizes or shapes giving equal or greater section modulus shall be acceptable. All angles shall be used with the longer leg vertical. The trapeze member shall be secured to prevent slippage. Where a pipe is suspended from a pipe trapeze of a diameter less than the diameter of the pipe being supported, ring, strap, or clevis hangers of the size corresponding to the suspended pipe shall be used on both ends.

Table 2-5.1.5(b) Available Section Moduli of Common Trapeze Hangers

Pipe	Modulus	Angles	Modulus
Schedule 10			
1 in.	.12	1½ × 1½ × 3/16	.10
1¼ in.	.19	2 × 2 × 1/8	.13
1½ in.	.26	2 × 1½ × 3/16	.18
2 in.	.42	2 × 2 × 3/16	.19
2½ in.	.69	2 × 2 × 1/4	.25
3 in.	1.04	2½ × 1½ × 3/16	.28
3½ in.	1.38	2½ × 2 × 3/16	.29
4 in.	1.76	2 × 2 × 5/16	.30
5 in.	3.03	2½ × 2½ × 3/16	.30
6 in.	4.35	2 × 2 × 3/8	.35
		2½ × 2½ × 1/4	.39
		3 × 2 × 3/16	.41
Schedule 40		3 × 2½ × 3/16	.43
1 in.	.13	3 × 3 × 3/16	.44
1¼ in.	.23	2½ × 2½ × 5/16	.48
1½ in.	.33	3 × 2 × 1/4	.54
2 in.	.56	2½ × 2 × 3/8	.55
2½ in.	1.06	2½ × 2½ × 3/8	.57
3 in.	1.72	3 × 3 × 1/4	.58
3½ in.	2.39	3 × 3 × 5/16	.71
4 in.	3.21	2½ × 2½ × 1/2	.72
5 in.	5.45	3½ × 2½ × 1/4	.75
6 in.	8.50	3 × 2½ × 3/8	.81
		3 × 3 × 3/8	.83
		3½ × 2½ × 5/16	.93
		3 × 3 × 7/16	.95
		4 × 4 × 1/4	1.05
		3 × 3 × 1/2	1.07
		4 × 3 × 5/16	1.23
		4 × 4 × 5/16	1.29
		4 × 3 × 3/8	1.46
		4 × 4 × 3/8	1.52
		5 × 3½ × 5/16	1.94
		4 × 4 × 1/2	1.97
		4 × 4 × 5/8	2.40
		4 × 4 × 3/4	2.81
		6 × 4 × 3/8	3.32
		6 × 4 × 1/2	4.33
		6 × 4 × 3/4	6.25
		6 × 6 × 1	8.57

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.30458 m.

2-5.1.6 The size of hanger rods and fasteners required to support the steel angle iron or pipe indicated in Table 2-5.1.5(a) shall comply with 2-5.4.

2-5.1.7 Standpipe piping or hangers shall not be used to support nonsystem components.

2-5.2 Hangers in Concrete.

2-5.2.1 The use of listed inserts set in concrete to support hangers shall be permitted.

2-5.2.2 Listed expansion shields for supporting pipes under concrete construction shall be permitted to be used in a horizontal position in the sides of beams. In concrete having gravel or crushed stone aggregate, expansion shields shall be permitted to be used in the vertical position to support pipes 4 in. (102 mm) or less in diameter.

2-5.2.3 For the support of pipes 5 in. (127 mm) and larger, expansion shields, if used in the vertical position, shall alternate with hangers connected directly to the structural members, such as trusses and girders, or to the sides of concrete beams. In the absence of convenient structural members, pipes 5 in. (127 mm) and larger shall be permitted to be supported entirely by expansion shields in the vertical position, but spaced not more than 10 ft (3 m) apart.

2-5.2.4 Expansion shields shall not be used in ceilings of gypsum or similar soft material. In cinder concrete, expansion shields shall not be used except on branch lines where they shall alternate with through bolts or hangers attached to beams.

2-5.2.5 Where expansion shields are used in the vertical position, the holes shall be drilled to provide uniform contact with the shield over its entire circumference. Depth of the hole shall not be less than specified for the type of shield used.

2-5.2.6 Holes for expansion shields in the side of concrete beams shall be above the center line of the beam or above the bottom reinforcement steel rods.

2-5.3 Powder-Driven Studs and Welding Studs.

2-5.3.1 Powder-driven studs, welding studs, and the tools used for installing these devices shall be listed. Pipe size, installation position, and construction material into which they are installed shall be in accordance with individual listings.

2-5.3.2 Representative samples of concrete into which studs are to be driven shall be tested to determine that the studs will hold a minimum load of 750 lb (341 kg) for 2-in. (51-mm) or smaller pipe, 1000 lb (454 kg) for 2½-, 3-, or 3½-in. (64-, 76-, or 89-mm) pipe, and 1200 lb (545 kg) for 4- or 5-in. (102- or 127-mm) pipe.

2-5.3.3 Increaser couplings shall be attached directly to the powder-driven studs or welding studs.

2-5.3.4 Welding studs or other hanger parts shall not be attached by welding to steel less than U.S. Standard, 12 gauge.

2-5.4 Rods and U-Hooks.

2-5.4.1 Hanger rod size shall be the same as that approved for use with the hanger assembly, and the size of rods shall not be less than that given in Table 2-5.4.1.

Exception: Rods of smaller diameter shall be permitted where the hanger assembly has been tested and listed by a testing laboratory and installed within the limits of pipe sizes expressed in individual listings. For rolled threads, the rod size shall be not less than the root diameter of the thread.

Table 2-5.4.1 Hanger Rod Sizes

Pipe Size	Dia. of Rod in.	Dia. of Rod mm
Up to and including 4 in.	3/8	9.5
5, 6, and 8 in.	1/2	12.7
10 and 12 in.	5/8	15.9

For SI Units: 1 in. = 25.4 mm.

2-5.4.2 U-Hooks. The size of the rod material of U-hooks shall not be less than that given in Table 2-5.4.2. Drive screws shall be used only in a horizontal position as in the side of a beam in conjunction with U-hangers only.

Table 2-5.4.2 U-Hook Rod Sizes

Pipe Size	Hook Material Diameter in.	Hook Material Diameter mm
Up to 2 in.	5/16	7.9
2 1/2 in. to 6 in.	3/8	9.5
8 in.	1/2	12.7

For SI Units: 1 in. = 25.4 mm.

2-5.4.3 Eye Rods.' The size of the rod material for eye rods shall not be less than that specified in Table 2-5.4.3. Where eye rods are fastened to wood structural members, the eye rod shall be backed with a large flat washer bearing directly against the structural member, in addition to the lock washer.

Table 2-5.4.3 Eye Rod Sizes

	Diameter of Rod			
	With Bent Eye		With Welded Eye	
Pipe Size	in.	mm	in.	mm
Up to 4 in.	3/8	9.5	3/8	9.5
5 to 6 in.	1/2	12.7	1/2	12.7
8 in.	3/4	19.1	1/2	12.7

For SI Units: 1 in. = 25.4 mm.

2-5.4.3.1 Eye rods shall be secured with lock washers to prevent lateral motion.

2-5.4.4 Threaded sections of rods shall not be formed or bent.

2-5.4.5 Screws. For ceiling flanges and U-hooks, screw dimensions shall not be less than those given in Table 2-5.4.5.

Exception: Where the thickness of planking and thickness of flange do not permit the use of screws 2 in. (51 mm) long, screws 1 3/4 in. (44 mm) long shall be permitted with hangers spaced not more than 10 ft (3 m) apart. Where the thickness of beams or joists does not permit the use of screws 2 1/2 in. (64 mm) long, screws 2 in. (51 mm) long shall be permitted with hangers spaced not more than 10 ft (3 m) apart.

Table 2-5.4.5 Screw Dimensions for Ceiling Flanges and U-Hooks

Pipe Size	2 Screw Flanges
Up to 2 in.	Wood Screw No. 18 x 1 1/2 in.
Pipe Size	**3 Screw Flanges**
Up to 2 in.	Wood Screw No. 18 x 1 1/2 in.
2 1/2 in., 3 in., 3 1/2 in.	Lag Screw 3/8 in. x 2 in.
4 in., 5 in., 6 in.	Lag Screw 1/2 in. x 2 in.
8 in.	Lag Screw 5/8 in. x 2 in.
Pipe Size	**4 Screw Flanges**
Up to 2 in.	Wood Screw No. 18 x 1 1/2 in.
2 1/2 in., 3 in., 3 1/2 in.	Lag Screw 3/8 in. x 1 1/2 in.
4 in., 5 in., 6 in.	Lag Screw 1/2 in. x 2 in.
8 in.	Lag Screw 5/8 in. x 2 in.
Pipe Size	**U-Hooks**
Up to 2 in.	Drive Screw No. 16 x 2 in.
2 1/2 in., 3 in., 3 1/2 in.	Lag Screw 3/8 in. x 2 1/2 in.
4 in., 5 in., 6 in.	Lag Screw 1/2 in. x 3 in.
8 in.	Lag Screw 5/8 in. x 3 in.

For SI Units: 1 in. = 25.4 mm.

2-5.4.6 The size bolt or lag (coach) screw used with an eye rod or flange on the side of the beam shall not be less than specified in Table 2-5.4.6.

Table 2-5.4.6 Minimum Bolt or Lag Screw Sizes

	Size of Bolt or Lag Screw		Length of Lag Screw Used with Wood Beams	
Size of Pipe	in.	mm	in.	mm
Up to and including 2 in.	3/8	9.5	2 1/2	64
2 1/2 to 6 in. (inclusive)	1/2	12.7	3	76
8 in.	5/8	15.9	3	76

For SI Units: 1 in. = 25.4 mm.

Exception: Where the thickness of beams or joists does not permit the use of screws 2 1/2 in. (64 mm) long, screws 2 in. (51 mm) long shall be permitted with hangers spaced not more than 10 ft (3 m) apart.

2-5.4.7 Wood screws shall be installed with a screwdriver. Nails are not acceptable for fastening hangers.

2-5.4.8 Screws in the side of a timber or joist shall be not less than 2 1/2 in. (64 mm) from the lower edge where supporting branch lines and not less than 3 in. (76 mm) where supporting main lines.

Exception: This requirement shall not apply to 2-in. (51-mm) or thicker nailing strips resting on top of steel beams.

2-5.4.9 The minimum plank thickness and the minimum width of the lower face of beams or joists in which lag screw rods are used shall be as given in Table 2-5.4.9.

Table 2-5.4.9 Minimum Plank Thicknesses and Beam or Joist Widths

Pipe Size	Nominal Plank Thickness in.	Nominal Plank Thickness mm	Nominal Width of Beam or Joist Face in.	Nominal Width of Beam or Joist Face mm
Up to 2 in.	3	76	2	51
$2^1/_2$ in. to $3^1/_2$ in.	4	102	2	51
4 in. and 5 in.	4	102	3	76
6 in.	4	102	4	102

For SI Units: 1 in. = 25.4 mm.

2-5.4.10 Lag screw rods shall not be used for support of pipes larger than 6 in. (152 mm). All holes for lag screw rods shall be predrilled $^1/_8$ in. (3.2 mm) less in diameter than the maximum root diameter of the lag screw thread.

2-6 Valves. All valves controlling connections to water supplies and standpipes shall be listed indicating valves.

Such valves shall not close in less than 5 sec when operated at maximum possible speed from the fully open position.

Exception No. 1: A listed underground gate valve equipped with a listed indicator post shall be permitted.

Exception No. 2: A listed water control valve assembly with a reliable position indication connected to a remote supervisory station shall be permitted.

Exception No. 3: A nonindicating valve, such as an underground gate valve with approved roadway box complete with T-wrench, accepted by the authority having jurisdiction, shall be permitted.

2-7 Hose Stations.

2-7.1 Closets and Cabinets.

2-7.1.1 Closets and cabinets used to contain fire hose shall be of sufficient size to permit the installation of the necessary equipment at hose stations and so designed as not to interfere with the prompt use of the hose connection, the hose, and other equipment at the time of fire. Within the cabinet, the hose connections shall be located so that there is at least 1 in. (25 mm) between any part of the cabinet and the handle of the valve when the valve is in any position from fully open to fully closed. The cabinet shall be used for fire equipment only, and each cabinet shall be conspicuously identified.

2-7.1.2 Where a "break glass" type protective cover for a latching device is provided, the device provided to break the glass panel shall be securely attached in the immediate area of the "break glass" panel and shall be so arranged that the device cannot be used to break other glass panels in the cabinet door.

2-7.1.3 Where a fire resistive assembly is penetrated by a cabinet, the fire resistance of the assembly shall be maintained as required by the local building code.

2-7.2* Hose. Each hose connection provided for use by building occupants (Class II and Class III systems) shall be equipped with not more than 100 ft (30.5 m) of listed $1^1/_2$-in. (38.1-mm) lined, collapsible or noncollapsible fire hose attached and ready for use.

Exception: Where hose less than $1^1/_2$ in. (38.1 mm) is used for $1^1/_2$-in. (38.1-mm) hose stations in accordance with 3-3.2 and 3-3.3, listed noncollapsible hose shall be used.

2-7.3 Hose Racks. Each $1^1/_2$-in. (38.1-mm) hose station provided with $1^1/_2$-in. (38.1-mm) hose shall be equipped with a listed rack or other approved storage facility.

Each $1^1/_2$ in. (38.1-mm) hose station provided with hose less than $1^1/_2$ in. (38.1 mm) in accordance with 3-3.2 and 3-3.3 shall be equipped with a listed continuous flow reel.

2-7.4 Nozzles. Nozzles provided for Class II service shall be listed.

2-7.5 Label. Each rack or storage facility for $1^1/_2$-in. (38.1-mm) or smaller hose shall be provided with a label that includes "Fire Hose for Use by Occupants" and operating instructions.

2-8 Hose Connections. Hose connections shall have external NH standard threads, for the valve size specified, as specified in NFPA 1963, *Standard for Screw Threads and Gaskets for Fire Hose Connections.* Hose connections shall be equipped with caps to protect hose threads.

Exception: Where local fire department hose threads do not conform to NFPA 1963, the authority having jurisdiction shall designate the hose threads to be used.

2-9* Fire Department Connections.

2-9.1 Fire department connections shall be listed for a working pressure equal to or greater than the pressure requirement of the system demand.

2-9.2* Each fire department connection shall have at least two $2^1/_2$-in. (63.5-mm) internal threaded swivel fittings having NH standard threads, as specified in NFPA 1963, *Standard for Screw Threads and Gaskets for Fire Hose Connections.* Fire department connections shall be equipped with caps to protect against entry of debris into the system.

Exception: Where the local fire department uses fittings different than those specified, fittings compatible with local fire department equipment shall be used and the minimum size shall be $2^1/_2$ in. (62 mm).

2-10 Signs. Signs shall be permanently marked and shall be constructed of weather-resistant metal or rigid plastic materials.

Chapter 3 System Requirements

3-1 General.

3-1.1 The number and arrangement of standpipe equipment necessary for proper protection is governed by the local conditions such as occupancy, character, and construction of building and accessibility. The authority having jurisdiction shall be consulted as to the required type of system, class of system, and special requirements.

3-1.2 Spacing and location of standpipes and hose connections shall be in accordance with Chapter 5.

3-1.3 Standpipe and hose systems not required by the authority having jurisdiction and not meeting the requirements of this standard shall be marked with a sign stating "FOR FIRE BRIGADE USE ONLY."

3-2 Types of Standpipe Systems.

3-2.1 Automatic-Dry. An automatic-dry standpipe system shall be a dry standpipe system, normally filled with pressurized air, that is arranged through the use of devices, such as a dry pipe valve, to automatically admit water into system piping upon opening of a hose valve. The water supply for an automatic-dry standpipe system shall be capable of supplying the system demand.

3-2.2 Automatic-Wet. An automatic-wet standpipe system shall be a wet standpipe system that has a water supply that is capable of supplying the system demand automatically.

3-2.3 Semiautomatic-Dry. A semiautomatic-dry standpipe system shall be a dry standpipe system that is arranged through the use of devices, such as a deluge valve, to admit water into system piping upon activation of a remote control device located at a hose connection. A remote control activation device shall be provided at each hose connection. The water supply for a semiautomatic-dry standpipe system shall be capable of supplying the system demand.

3-2.4 Manual-Dry. A manual-dry standpipe system shall be a dry standpipe system that does not have a permanent water supply attached to the system. Manual-dry standpipe systems require water from a fire department pumper (or the like) to be pumped into the system through the fire department connection to supply the system demand.

3-2.5 Manual-Wet. A manual-wet standpipe system shall be a wet standpipe system connected to a small water supply for the purpose of maintaining water within the system, but that does not have a water supply capable of delivering the system demand attached to the system. Manual-wet standpipe systems require water from a fire department pumper (or the like) to be pumped into the system to supply the system demand.

3-3 Classes of Standpipe Systems.

3-3.1 Class I Systems. A Class I standpipe system shall provide $2^1/_2$-in. (63.5-mm) hose connections to supply water for use by fire departments and those trained in handling heavy fire streams.

3-3.2 Class II Systems. A Class II standpipe system shall provide $1^1/_2$-in. (38.1-mm) hose stations to supply water for use primarily by the building occupants or by the fire department during initial response.

Exception: A minimum 1-in. (25.4-mm) hose shall be permitted to be used for hose stations in Light Hazard Occupancies where investigated and listed for this service and where approved by the authority having jurisdiction.

3-3.3 Class III Systems. A Class III standpipe system shall provide $1^1/_2$-in. (38.1-mm) hose stations to supply water for use by building occupants and $2^1/_2$-in. (63.5-mm) hose connections to supply a larger volume of water for use by fire departments and those trained in handling heavy fire streams.

Exception No. 1: A minimum 1-in. (25.4-mm) hose shall be permitted to be used for hose stations in Light Hazard Occupancies where investigated and listed for this service and where approved by the authority having jurisdiction.

Exception No. 2: Where the building is protected throughout by an approved automatic sprinkler system, hose stations for use by the building occupants are not required, subject to the approval of the authority having jurisdiction, provided that each hose connection is $2^1/_2$ in. (63.5 mm) and is equipped with a $2^1/_2$-in. by $1^1/_2$-in. (63.5-mm by 38.2-mm) reducer and a cap attached with a chain.

3-4 Requirements for Manual Standpipe Systems.

3-4.1 Manual standpipe systems shall not be used in high-rise buildings.

3-4.2 Each hose connection for manual standpipes shall be provided with a conspicuous sign stating "MANUAL STANDPIPE FOR FIRE DEPARTMENT USE ONLY."

3-4.3 Manual standpipes shall not be used for Class II or Class III systems.

3-5 Requirements for Dry Standpipe Systems.

3-5.1 Dry standpipes shall only be used where piping is subject to freezing.

3-5.2 Dry standpipes shall not be used for Class II or Class III systems.

3-6* Gauges.

3-6.1 A listed $3^1/_2$-in. (87-mm) dial spring pressure gauge shall be connected to each discharge pipe from the fire pump and public water works, at the pressure tank, at the air pump supplying the pressure tank, and at the top of each standpipe. Gauges shall be located in a suitable place so water will not freeze. Each gauge shall be controlled by a valve having an arrangement for draining.

Exception: Where several standpipes are interconnected at the top, a single gauge, properly located, shall be permitted to be substituted for a gauge at the top of each standpipe.

3-6.2 A valved outlet for a pressure gauge shall be installed on the upstream side of every pressure regulating device.

3-7* Water Flow Alarms.

3-7.1 Where required by the authority having jurisdiction for automatic or semiautomatic systems, listed water flow alarms shall be provided.

3-7.2 Water flow alarms shall utilize a sensing mechanism appropriate to the type of standpipe.

Chapter 4 Installation Requirements

4-1* Location and Protection of Piping.

4-1.1 Location of Dry Standpipes. Dry standpipes shall not be concealed in building walls or built into pilasters.

4-1.2 Protection of Piping.

4-1.2.1* Standpipe system piping shall not pass through hazardous areas and shall be located so that they are protected from mechanical and fire damage.

4-1.2.2 Standpipes and lateral piping supplied by standpipes shall be located in enclosed exit stairways or shall be protected by a degree of fire resistance equal to that required for enclosed exit stairways in the building in which they are located.

Exception No. 1: In buildings equipped with an approved automatic sprinkler system, lateral piping to $2^1/_2$-in. (63.5-mm) hose connections shall not be required to be protected.

Exception No. 2: Piping connecting standpipes to $1^1/_2$-in. (38.1-mm) hose connections.

4-1.2.3 Where a standpipe or lateral pipe that is normally filled with water passes through an area subject to freezing temperatures, it shall be protected by a reliable means to maintain the temperature of the water in the piping between 40°F (4.4°C) and 120°F (48.9°C).

Antifreeze solutions shall not be used to protect standpipe system piping from freezing.

4-1.2.4 Where corrosive conditions exist, or piping is exposed to the weather, corrosion-resistant types of pipe, tube, fittings, and hangers or protective corrosion-resistive coatings shall be used. If steel pipe is to be buried underground, it shall be protected against corrosion before being buried.

4-1.2.5 To minimize or prevent pipe breakage where subject to earthquakes, standpipe systems shall be protected in accordance with the rules contained in NFPA 13, *Standard for the Installation of Sprinkler Systems.*

4-2 Gate Valves and Check Valves.

4-2.1 Connections to each water supply, except the fire department connections, shall be provided with an approved indicating-type valve and check valve located close to the supply, such as at tanks, pumps, and connections from waterworks systems.

Where a backflow prevention device of the reduced pressure type is required by the authority having jurisdiction, the check valve and shutoff shall not be omitted and shall be installed on the discharge side of the reduced pressure backflow device.

4-2.2 Valves shall be provided to permit isolating a standpipe without interrupting the supply to other standpipes from the same source of supply.

4-2.3 Listed indicating type valves shall be provided at the standpipe for controlling branch lines for remote hose stations.

4-2.4 Where wafer-type valve discs are used, they shall be installed in such a manner that they do not interfere with the operation of other system components.

4-2.5 Valves on Combined Systems.

4-2.5.1 Each connection from a standpipe that is part of a combined system to a sprinkler system shall have an individual control valve of the same size as the connection.

4-2.5.2* Each connection from a standpipe that is part of a combined system to a sprinkler system and interconnected with other standpipes shall have an individual control valve and check valve of the same size at the connection.

4-2.6 Connections to public water systems shall be controlled by indicator post valves of an approved type located at least 40 ft (12.2 m) from the building protected. All valves shall be plainly marked to indicate the service that they control.

Exception No. 1: Where the valve cannot be located at least 40 ft (12.2 m) from the building, it shall be placed in an approved location and where it will be readily accessible in case of fire and not subject to damage.

Exception No. 2: Where post indicator valves cannot be used, underground valves shall be permitted. The valve locations, directions to open, and services that they control shall be plainly marked on the buildings served.

4-2.7* Where the standpipes are supplied from a yard main or header in another building, the connection shall be provided with a listed indicating-type valve located outside at a safe distance from the building or at the header.

4-2.8 System water supply valves, isolation control valves, and other valves in feed mains shall be supervised in an approved manner in the open position by one of the following methods:

(a) Central station, proprietary, or remote station signaling service

(b) Local signaling service that will cause the sounding of an audible signal at a constantly attended point

(c) Locking valves open

(d) Sealing of valves and an approved weekly recorded inspection where valves are located within fenced enclosures under the control of the owner.

Exception: Underground gate valves with roadway boxes need not be supervised.

4-2.9 Signs and Room Identification for Valves.

4-2.9.1 All main and sectional system control valves, including water supply control valves, shall have a sign indicating the portion of the system controlled by the valve.

4-2.9.2 All control, drain, and test connection valves shall be provided with signs indicating their purpose.

4-2.9.3 Where sprinkler system piping supplied by a combined system is supplied by more than one standpipe ("loop" or "dual feed" type design), a sign shall be located at each dual or multiple feed connection to the combination system standpipe to identify that to isolate the sprinkler system served by the control valve, an additional control valve or valves at other standpipes must be shut off. The sign shall also identify the location of the additional control valves.

4-2.9.4 Where a main or sectional system control valve is located in a closed room or concealed space, the location of the valve shall be indicated by a sign in an approved location on the outside of the door or near the opening to the concealed space.

4-3* Fire Department Connections.

4-3.1 There shall be no shutoff valve between the fire department connection and the system.

4-3.2 A listed check valve shall be installed in each fire department connection, located as near as practicable to the point where it joins the system.

4-3.3 The fire department connection shall be installed as follows:

(a) Automatic-wet and manual-wet standpipe systems: On the system side of the system control and check valve.

(b) Automatic-dry standpipe systems: On the system side of the control valve and check valve and the supply side of the dry pipe valve.

(c) Semiautomatic-dry standpipe systems: On the system side of the deluge valve.

(d) Manual-dry standpipe systems: Directly connected to system piping.

4-3.4 In areas subject to freezing, a listed automatic drip valve shall be installed in the piping between the check valve and the fire department connection that is arranged to allow drainage without causing water damage.

4-3.5 Location and Identification.

4-3.5.1 Fire department connections shall be on the street side of buildings and shall be located and arranged so that hose lines can be attached to the inlets without interference from nearby objects including buildings, fences, posts, or other fire department connections.

4-3.5.2 Each fire department connection shall be designated by a sign having raised letters, at least 1 in. (25 mm) in size cast on the plate or fitting, reading "STANDPIPE." If automatic sprinklers are also supplied by the fire department connection, the sign or combination of signs shall indicate both designated services, e.g., "STANDPIPE AND AUTOSPKR," or "AUTOSPKR AND STANDPIPE."

A sign shall also indicate the pressure required at the inlets to deliver the system demand.

4-3.5.3 Where a fire department connection services only a portion of a building, a sign shall be attached indicating the portions of the building served.

4-3.5.4* A fire department connection for each standpipe system shall be located not more than 100 ft (30.5 m) from the nearest fire hydrant connected to an approved water supply.

4-3.6 Fire department connections shall be located not less than 18 in. (45.7 cm) nor more than 48 in. (121.9 cm) above the level of the adjoining ground, sidewalk, or grade surface.

4-3.7 Fire department connection piping shall be supported in accordance with Section 4-4.

4-4 Support of Piping.

4-4.1 Support of Standpipes.

4-4.1.1 Standpipes shall be supported by attachments connected directly to the standpipe.

4-4.1.2 Standpipe supports shall be provided at the lowest level, at each alternate level above, and at the top of the standpipe. Supports above the lowest level shall restrain the pipe to prevent movement by an upward thrust where flexible fittings are used.

4-4.1.3 Clamps supporting pipe by means of set screws shall not be used.

4-4.2 Support of Horizontal Piping.

4-4.2.1 Horizontal piping from the standpipe to hose connections that are more than 18 in. (457 mm) in length shall be provided with hangers.

4-4.2.2 Horizontal piping hangers shall be spaced at a maximum separation distance of 15 ft (4.6 m). The piping shall be restrained to prevent movement by horizontal thrust where flexible fittings are used.

4-5 Installation of Signs. Signs shall be secured to a device or the building wall with substantial and corrosion-resistant chains or fasteners.

4-6 Signs for Water Supply Pumps. Where a fire pump is provided, a sign shall be located in the vicinity of the pump indicating the minimum pressure and flow required at the pump discharge flange to meet the system demand.

4-7* Hydraulic Design Information Sign. The installing contractor shall provide a sign identifying the design basis of a system as hydraulic calculations or pipe schedule. The sign shall be located at the water supply control valve for automatic or semiautomatic standpipe systems and at an approved location for manual systems.

The sign shall indicate the following:

(a) The location of the 2 hydraulically most remote hose connections

(b) The design flow rate for the connections identified in (a)

(c) The design residual inlet and outlet pressures for the connections identified in (a)

(d) The design static pressure and the design system demand (flow and residual pressure) at the system control valve, or at the pump discharge flange where a pump is installed, and at each fire department connection.

Chapter 5 Design

5-1* General. Design of the standpipe system is governed by building height, area per floor occupancy classification, egress system design, required flow rate and residual pressure, and the distance of the hose connection from the source(s) of water supply. See Chapter 3 for general system requirements.

5-2* Pressure Limitation. The maximum pressure at any point in the system at any time shall not exceed 350 psi.

5-3 Locations of Hose Connections.

5-3.1* General. Hose connections and hose stations shall be unobstructed and shall be located not less than 3 ft (0.9 m) or more than 5 ft (1.5 m) above the floor.

5-3.2* Class I Systems. Class I systems shall be provided with $2^1/_2$-in. (63.5-mm) hose connections in the following locations:

(a) At each intermediate landing between floor levels in every required exit stairway

Exception: Hose connections shall be permitted to be located at main floor landings in exit stairways when approved by the authority having jurisdiction.

(b) On each side of the wall adjacent to exit openings of horizontal exits

(c) In each exit passageway at the entrance from building areas into the passageway

(d) In covered mall buildings, at the entrance to each exit passageway or exit corridor, and at exterior public entrances to the mall

(e) At the highest landing of stairways with stairway access to a roof, and on the roof where stairways do not access the roof

(f)* Where the most remote portion of a nonsprinklered floor or story exceeds 150 ft (45.7 m) of travel distance from a required exit or the most remote portion of a sprinklered floor or story exceeds 200 ft (61 m) of travel distance from a required exit, additional hose connections shall be provided, in approved locations, where required by the local fire department.

5-3.3* Class II Systems. Class II systems shall be provided with $1^1/_2$-in. (38.1-mm) hose stations so that all portions of each floor level of the building are within 130 ft (39.7 m) of a hose connection provided with $1^1/_2$-in. (38.1-mm) hose or within 120 ft (36.6 m) of a hose connection provided with less than $1^1/_2$-in. (38.1-mm) hose. Distances shall be measured along a path of travel originating at the hose connection.

5-3.4 Class III Systems. Class III systems shall be provided with hose connections as required for both Class I and Class II systems.

5-4 Number of Standpipes. Separate standpipes shall be provided in each required exit stairway.

5-5 Interconnection of Standpipes. Where 2 or more standpipes are installed in the same building or section of building, they shall be interconnected at the bottom. Where standpipes are supplied by tanks located at the top of the building or zone, they shall also be interconnected at the top; in such cases, check valves shall be installed at the base of each standpipe to prevent circulation.

5-6 Minimum Sizes for Standpipes.

5-6.1 Class I and Class III standpipes shall be at least 4 in. (102 mm) in size.

5-6.2 Standpipes that are part of a combined system shall be at least 6 in. (152 mm) in size.

Exception: In fully sprinklered buildings having a combined standpipe system that is hydraulically calculated, the minimum standpipe size is 4 in (102 mm).

5-7* Minimum Pressure for System Design and Sizing of Pipe. Standpipe systems shall be designed so that the system demand can be supplied by both the attached water supply, where required, and fire department connections. For the water supply available from a fire department pumper, the authority having jurisdiction shall be consulted. Also see NFPA 1901, *Standard for Pumper Fire Apparatus*. Standpipe systems shall be either:

(a) Hydraulically designed to provide the required water flow rate at a minimum residual pressure of 100 psi (10.3 bars) at the outlet of the hydraulically most remote $2^1/_2$-in. (63.5-mm) hose connection and 65 psi (4.5 bars) at the outlet of the hydraulically most remote $1^1/_2$-in. (38.1-mm) hose station.

Exception: Where the authority having jurisdiction permits pressures lower than 100 psi for $2^1/_2$-in. (63.5-mm) hose connections, based on suppression tactics, the pressure shall be permitted to be reduced but not to less than 65 psi (4.5 bars).

(b) Sized in accordance with the pipe schedule of Table 5-7 to provide the required water flow rate at a minimum residual pressure of 100 psi (10.3 bars) at the topmost $2^1/_2$-in. (63.5-mm) hose connection and 65 psi (4.5 bars) at the topmost $1^1/_2$-in. (38.1-mm) hose station. Pipe schedule designs shall be limited to wet standpipes and for buildings that are not defined as high-rise.

Table 5-7 Pipe Schedule - Standpipes and Supply Piping Minimum Nominal Pipe Sizes in Inches

Total Accumulated Flow (gpm)	Total Distance of Piping from Furthest Outlet		
	< 50 ft	50–100 ft	> 100 ft
100	2	$2^1/_2$	3
101–500	4	4	6
501–750	5	5	6
751–1250	6	6	6
1251 and over	8	8	8

For SI Units: 1 gal = 3.785 L/min; 1 ft = 0.3048 m.

5-8* Maximum Pressure for Hose Connections.

5-8.1 Where the residual pressure at a $1^1/_2$-in. (38.1-mm) outlet on a hose connection available for occupant use exceeds 100 psi (6.9 bars), an approved pressure regulating device shall be provided to limit the residual pressure at the flow required by Section 5-9 to 100 psi (69 bars).

5-8.2 Where the static pressure at a hose connection exceeds 175 psi (12.1 bars), an approved pressure regulating device shall be provided to limit static and residual pressures at the outlet of the hose connection to 100 psi (6.9 bars) for $1^1/_2$-in. (38.1-mm) hose connections available for occupant use and 175 psi (12.1 bars) for other hose connections. The pressure on the inlet side of the pressure regulating device shall not exceed the device's rated working pressure.

5-9 Minimum Flow Rates for Hydraulically Designed Systems.

5.9.1 Class I and Class III Systems.

5-9.1.1* Minimum Flow Rate. For Class I and Class III systems, the minimum flow rate for the hydraulically most remote standpipe shall be 500 gpm (1893 L/min). The minimum flow rate for additional standpipes shall be 250 gpm (946 L/min) per standpipe, the total not to exceed 1250 gpm (4731 L/min).

For combined systems, see 5-9.1.3.

Exception: When the floor area exceeds 80,000 sq ft (7432 m²), the second most remote standpipe shall be designed to accommodate 500 gpm (1893 L/min).

5-9.1.2* Hydraulic Calculation Procedure. Hydraulic calculations and pipe sizes for each standpipe shall be based on providing 250 gpm (946 L/min) at the hydraulically most remote two hose connections on the standpipe and at the top most outlet of each of the other standpipes at the minimum residual pressure required by Section 5-7. Common supply piping shall be calculated and sized to provide the required flow rate for all standpipes connected to such supply piping, the total not to exceed 1250 gpm (4731 L/min).

5-9.1.3 Combined Systems.

5-9.1.3.1* For a building protected throughout by an approved automatic sprinkler system, the system demand established by Section 5-7 and 5-9.1 is also permitted to serve the sprinkler system. Sprinkler demand need not be added.

Exception: Where the sprinkler system water supply requirement, including hose stream allowance as determined in NFPA 13, Standard for the Installation of Sprinkler Systems, exceeds the system demand established by Section 5-7 and 5-9.1, the larger of the two values shall be provided. The flow rate required for the standpipe demand of a combined system in a building protected throughout by an automatic sprinkler system need not exceed 1000 gpm (3785 L/min) unless more supply is required by the authority having jurisdiction.

5-9.1.3.2 For a combined system in a building equipped with partial automatic sprinkler protection, the flow rate required by 5-9.1 shall be increased by an amount equal to the lesser of the hydraulically calculated sprinkler demand or 150 gpm (568 L/min) for Light Hazard Occupancies, or by 500 gpm (1893 L/min) for Ordinary Hazard Occupancies.

5-9.1.3.3 Where an existing standpipe system having standpipes with a minimum diameter of 4 in. (102 mm) is to be utilized to supply a new retrofit sprinkler system, the water supply required by 5-9.1 need not be provided by automatic or semiautomatic means if approved by the authority having jurisdiction, so long as the water supply is adequate to supply the hydraulic demand of the sprinkler system.

5-9.2 Class II Systems.

5-9.2.1 Minimum Flow Rate. For Class II systems, the minimum flow rate for the hydraulically most remote standpipe shall be 100 gpm (379 L/min). Additional flow need not be added when more than 1 standpipe is provided.

5-9.2.2 Hydraulic Calculation Procedure. Hydraulic calculations and pipe sizes for each standpipe shall be based on providing 100 gpm (379 L/min) at the hydraulically most remote hose connection on the standpipe at the minimum residual pressure required by Section 5-7. Common supply piping serving multiple standpipes shall be calculated and sized to provide 100 gpm (379 L/min).

5-10 Equivalent Pipe Lengths of Valves and Fittings for Hydraulically Designed Systems.

5-10.1 General. Table 5-10.1 shall be used to determine the equivalent length of pipe for fittings and devices unless manufacturer's test data indicate that other factors are appropriate. For saddle-type fittings having friction loss greater than that shown in Table 5-10.1, the increased friction loss shall be included in hydraulic calculations.

Table 5-10.1 Equivalent Pipe Length Chart

Fittings and Valves	Fittings and Valves Expressed in Equivalent Feet of Pipe													
	$^3/_4$ in.	1 in.	$1^1/_4$ in.	$1^1/_2$ in.	2 in.	$2^1/_2$ in.	3 in.	$3^1/_2$ in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.
45° Elbow	1	1	1	2	2	3	3	3	4	5	7	9	11	13
90° Standard Elbow	2	2	3	4	5	6	7	8	10	12	14	18	22	27
90° Long Turn Elbow	1	2	2	2	3	4	5	5	6	8	9	13	16	18
Tee or Cross (Flow Turned 90°)	3	5	6	8	10	12	15	17	20	25	30	35	50	60
Butterfly Valve	-	-	-	-	6	7	10	-	12	9	10	12	19	21
Gate Valve	-	-	-	-	1	1	1	1	2	2	3	4	5	6
Swing Check*	-	5	7	9	11	14	16	19	22	27	32	45	55	65
Globe Valve	-	-	-	46	-	70	-	-	-	-	-	-	-	-
Angle Valve	-	-	-	20	-	31	-	-	-	-	-	-	-	-

For SI Units: 1 ft = 0.3048 m.
*Due to the variations in design of swing check valves, the pipe equivalents indicated in the above chart are considered average.

5-10.2 Adjustments. Table 5-10.1 shall be used with Hazen-Williams C = 120 only. For other values of C, the values in Table 5-10.1 shall be multiplied by the factors indicated in Table 5-10.2.

Table 5-10.2 Adjustments Chart

Value of C	100	130	140	150
Multiplying Factor	0.713	1.16	1.33	1.51

5-11* Drains and Test Riser.

5-11.1 A permanently installed 3-in. (75-mm) drain riser shall be provided adjacent to each standpipe equipped with pressure regulating devices to facilitate tests of each device. The riser shall be equipped with a 3-in. (76.2-mm) × $2^1/_2$-in. (63.5-mm) tee with internal threaded swivel fitting having NH standard threads, as specified in NFPA 1963, *Standard for Screw Threads and Gaskets for Fire Hose Connections*, with plug, located on at least every other floor.

Exception: Where local fire department hose threads do not conform to NFPA 1963, the authority having jurisdiction shall designate the hose threads to be used.

5-11.2 Each standpipe shall be provided with a means of draining. A drain valve and piping, located at the lowest point of the standpipe piping downstream of the isolation valve, shall be arranged to discharge water at an approved location. Sizing shall be as follows:

Standpipe Size	Size of Drain Connection
Up to 2 in.	$^3/_4$ in. or larger
$2^1/_2$ in., 3 in., or $3^1/_2$ in.	$1^1/_4$ in. or larger
4 in. or larger	2 in. only

5-12* Fire Department Connections.

5-12.1 One or more fire department connections shall be provided for each Class I or Class III standpipe system.

5-12.2 High-rise buildings shall have at least 2 remotely located fire department connections.

Exception: A single connection shall be permitted where acceptable to the fire department.

Chapter 6 Plans and Calculations

6-1* Plans and Specifications. Plans accurately showing the details and arrangement of the standpipe system shall be furnished to the authority having jurisdiction prior to the installation of the system. Such plans shall be clear, readable, and drawn to scale. The drawings shall show the location, arrangement, water supply, equipment, and all other details necessary to show compliance with this standard.

The plans shall include specifications covering the character of materials used and shall describe all system components. Plans shall include an elevation diagram.

6-2 Hydraulic Calculations. Where standpipe system piping is sized by hydraulic calculations, a complete set of calculations shall be submitted with the plans.

Chapter 7 Water Supplies

7-1* Required Water Supply. Automatic and semiautomatic standpipe systems shall be attached to an approved water supply capable of supplying the system demand. Manual standpipe systems shall have an approved water supply accessible to a fire department pumper.

A single automatic or semiautomatic water supply shall be acceptable where it is capable of supplying the system demand for the required duration.

Exception: Where a secondary water supply is required by 7-4.3.

7-1.1* Acceptable water supplies shall be from:

(a) Public waterworks system where pressure and flow rate are adequate

(b) Automatic fire pumps connected to an approved water source

(c) Manually controlled fire pumps in combination with pressure tanks

(d) Pressure tanks installed in accordance with NFPA 22, *Standard for Water Tanks for Private Fire Protection*

(e) Manually controlled fire pumps operated by remote control devices at each hose station

(f) Gravity tanks installed in accordance with NFPA 22, *Standard for Water Tanks for Private Fire Protection.*

7-2 Minimum Supply for Class I and Class III Systems. The water supply shall be sufficient to provide the system demand established by Section 5-7 and 5-9.1 for a period of at least 30 min.

7-3 Minimum Supply for Class II Systems. The minimum supply for Class II systems shall be sufficient to provide the system demand established by Section 5-7 and 5-9.2 for a period of at least 30 min.

7-4 Standpipe System Zones. Each zone requiring pumps shall be provided with a separate pump. This shall not preclude the use of pumps arranged in series.

7-4.1 Where pumps supplying 2 or more zones are located at the same level, each zone shall have separate and direct supply piping of a size not smaller than the standpipe that it serves. Zones with 2 or more standpipes shall have at least 2 direct supply pipes of a size not smaller than the largest standpipe that they serve.

7-4.2 Where supply for each zone is pumped from the next lower zone, and the standpipe or standpipes in the lower zone are used to supply the higher zone, such standpipes shall comply with the provisions for supply lines in 7-4.1. At least 2 lines shall be provided between zones; 1 of these lines shall be arranged so that supply can be automatically delivered from the lower to the higher zone.

CONTRACTOR'S MATERIAL & TEST CERTIFICATE FOR ABOVEGROUND PIPING
Standpipe System NFPA 14

PROCEDURE

Upon completion of work, inspection and tests shall be made by the contractor's representative and witnessed by an owner's representative. All defects shall be corrected and system left in service before contractor's personnel finally leave the job.

A certificate shall be filled out and signed by both representatives. Copies shall be prepared for approving authorities, owners, and contractor. It is understood the owner's representative's signature in no way prejudices any claim against contractor for faulty material, poor workmanship, or failure to comply with approving authority's requirements or local ordinances.

PROPERTY NAME ____________ DATE ____________
PROPERTY ADDRESS ____________

PLANS

ACCEPTED BY APPROVING AUTHORITIES (NAMES) ____________
ADDRESS ____________

INSTALLATION CONFORMS TO ACCEPTED PLANS ☐ YES ☐ NO IF NO, EXPLAIN DEVIATIONS ____________

EQUIPMENT USED IS APPROVED OR LISTED ☐ YES ☐ NO IF NO, EXPLAIN DEVIATIONS ____________

TYPE OF SYSTEM

AUTOMATIC-DRY ☐ YES
AUTOMATIC-WET ☐ YES
SEMIAUTOMATIC-DRY ☐ YES
MANUAL-DRY ☐ YES
MANUAL-WET ☐ YES
COMBINATION STANDPIPE/SPRINKLER ☐ YES
OTHER ☐ YES EXPLAIN ____________

WATER SUPPLY DATA USED FOR DESIGN AND AS SHOWN ON PLANS

FIRE PUMP DATA
MANUFACTURER ____________ MODEL ____________
TYPE: ☐ ELECTRIC ☐ DIESEL ☐ OTHER EXPLAIN ____________
RATED GPM ____________ RATED PSI ____________ SHUT-OFF PSI ____________

WATER SUPPLY SOURCE CAPACITY, GALLONS

PUBLIC WATER-WORKS SYSTEM ☐ STORAGE TANK ☐ GRAVITY TANK ☐ OPEN RESERVOIR ☐ OTHER ☐ EXPLAIN ____________

IF PUBLIC WATER-WORKS SYSTEM:
STATIC PSI ☐ RESIDUAL PSI ☐ FLOW IN GPM ☐

HAVE COPIES OF THE FOLLOWING BEEN LEFT ON THE PREMISES?

☐ SYSTEM COMPONENTS INSTRUCTIONS ☐ CARE AND MAINTENANCE OF SYSTEM ☐ NFPA 25
☐ COPY OF ACCEPTED PLANS ☐ HYDRAULIC DATA/CALCULATIONS

SUPPLIES BUILDING(S)

MAIN WATER FLOW SHUT-OFF LOCATION ____________
NUMBER OF STANDPIPE RISERS ____________ DO ALL STANDPIPE RISERS HAVE BASE OF RISER SHUT-OFF VALVES? ☐ YES ☐ NO

VALVE SUPERVISION

LOCKED OPEN ☐ SEALED AND TAG ☐ TAMPER PROOF SWITCH ☐ OTHER ☐ IF OTHER, EXPLAIN ____________

TYPE OF PIPE ____________

TYPE OF FITTING ____________

BACKFLOW PREVENTER

A) DOUBLE CHECK ASSEMBLY ☐ SIZE ____________ MAKE AND MODEL ____________
B) REDUCED PRESSURE DEVICE ☐

Figure 8-1(a).

7-4.3 For systems with 2 or more zones in which portions of the second and higher zones cannot be supplied with the residual pressure required by Section 5-7 by fire department pumpers through a fire department connection, another auxiliary means of supply shall be provided. This shall be in the form of high-level water storage with additional pumping equipment or other means acceptable to the authority having jurisdiction.

Chapter 8 System Acceptance

8-1* General.

8-1.1 All new systems shall be tested prior to building occupancy. Existing standpipe systems that are to be utilized as standpipes for a combination system in the retrofit of a new sprinkler system shall be tested in accordance with Section 8-4.

8-1.2 The installing contractor shall complete and sign the appropriate Contractors Material and Test Certificate(s). [*See Figures 8-1(a) and 8-1(b).*]

8-2 Flushing of Piping.

8-2.1 Underground piping supplying the system shall be flushed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*

8-2.2 Piping between the fire department connection and the check valve in the inlet pipe shall be flushed with a sufficient volume of water so as to remove any construction debris and trash accumulated in this pipe prior to the completion of the system and prior to the installation of the fire department connection.

8-3 Hose Threads. All hose connection and fire department connection threads shall be tested to verify compatibility with threads used by the local fire department. The test shall consist of threading coupling samples, caps, or plugs onto the installed devices.

8-4 Hydrostatic Tests.

8-4.1* General. All new systems, including yard piping and fire department connections, shall be tested hydrostatically at not less than 200 psi (13.8 bars) pressure for 2 hr, or at 50 psi (3.5 bars) in excess of the maximum pressure where the maximum pressure is in excess of 150 psi (10.3 bars). The hydrostatic test pressure shall be measured at the low elevation point of the individual system or zone being tested. The inside standpipe system piping shall show no leakage. Underground pipe shall be tested in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*

Exception: Where cold weather will not permit testing with water, an interim air test can be conducted prior to the standard hydrostatic test. An air pressure leakage test at 40 psi (2.8 bars) shall be conducted for 24 hr. Any leakage that results in a loss of pressure in excess of $1^1/_2$ psi (0.1 bars) during a continuous 24-hr period shall be corrected.

8-4.2 Fire Department Connection. Piping between the fire department connection and the check valve in the inlet pipe shall be tested hydrostatically in the same manner as the balance of the system.

8-4.3 Existing Systems. Where an existing standpipe system, including yard piping and fire department connection, is modified, the new piping shall be tested in accordance with 8-4.1.

8-4.4 Protection from Freezing. During testing, care shall be taken to ensure no portion of the piping is subject to freezing during cold weather.

8-4.5 Gauges. During the hydrostatic test, the pressure gauge at the top of each standpipe shall be observed and the pressure recorded.

8-4.6 Water Additives. Additives, corrosive chemicals such as sodium silicate, or derivatives of sodium silicate, brine, or other chemicals shall not be used while hydrostatically testing systems or for stopping leaks.

CONTROL VALVE DEVICE

TYPE	SIZE	MAKE	MODEL

TIME TO TRIP THROUGH REMOTE HOSE VALVE ______ MIN ____ SEC WATER PRESSURE _______ AIR PRESSURE ____________
TIME WATER REACHED REMOTE HOSE VALVE OUTLET ________ MIN ________ SEC TRIP POINT AIR PRESSURE ________ PSI
ALARM OPERATED PROPERLY ☐ YES ☐ NO IF NO, EXPLAIN ____

TIME WATER REACHED REMOTE HOSE VALVE OUTLET ____________ MIN ____________ SEC

HYDRAULIC ACTIVATION ☐ YES
ELECTRIC ACTIVATION ☐ YES
PNEUMATIC ACTIVATION ☐ YES
MAKE AND MODEL OF ACTIVATION DEVICE ____
EACH ACTIVATION DEVICE TESTED ☐ YES ☐ NO IF NO, EXPLAIN ____

EACH ACTIVATION DEVICE OPERATED PROPERLY ☐ YES ☐ NO IF NO, EXPLAIN ____

PRESSURE REGULATING DEVICE

LOCATION & FLOOR	MODEL	NON-FLOWING (PSI)		FLOWING (PSI)		GPM
		INLET	OUTLET	INLET	OUTLET	

ALL HOSE VALVES ON SYSTEM OPERATED PROPERLY ☐ YES ☐ NO IF NO, EXPLAIN ______________________________

Figure 8-1(a) (cont.).

<table>
<tr><td>TEST DESCRIPTION</td><td colspan="4">HYDROSTATIC: HYDROSTATIC TESTS SHALL BE MADE AT NOT LESS THAN 200 PSI (13.6 BARS) FOR TWO HOURS OR 50 PSI (3.4 BARS) ABOVE STATIC PRESSURE IN EXCESS OF 150 PSI (10.2 BARS) FOR TWO HOURS. DIFFERENTIAL DRY-PIPE VALVE CLAPPERS SHALL BE LEFT OPEN DURING TEST TO PREVENT DAMAGE. ALL ABOVEGROUND PIPING LEAKAGE SHALL BE STOPPED.
PNEUMATIC: ESTABLISH 40 PSI (2.7 BARS) AIR PRESSURE AND MEASURE DROP WHICH SHALL NOT EXCEED 1-1/2 PSI (0.1 BARS) IN 24 HOURS. TEST PRESSURE TANKS AT NORMAL WATER LEVEL AND AIR PRESSURE AND MEASURE AIR PRESSURE DROP WHICH SHALL NOT EXCEED 1-1/2 PSI (0.1 BARS) IN 24 HOURS.</td></tr>
<tr><td rowspan="4">TESTS</td><td colspan="3">ALL PIPING HYDROSTATICALLY TESTED AT ______ PSI FOR _____ HRS.
DRY PIPING PNEUMATICALLY TESTED ☐ YES ☐ NO
EQUIPMENT OPERATES PROPERLY ☐ YES ☐ NO</td><td>IF NO, STATE REASON</td></tr>
<tr><td colspan="4">DO YOU CERTIFY AS THE STANDPIPE CONTRACTOR THAT ADDITIVES AND CORROSIVE CHEMICALS, SODIUM SILICATE OR DERIVATIVES OF SODIUM SILICATE, BRINE, OR OTHER CORROSIVE CHEMICALS WERE NOT USED FOR TESTING SYSTEMS OR STOPPING LEAKS? ☐ YES ☐ NO</td></tr>
<tr><td>DRAIN TEST</td><td colspan="2">READING OF GAUGE LOCATED NEAR WATER SUPPLY TEST CONNECTION: ____________ PSI</td><td>RESIDUAL PRESSURE WITH VALVE IN TEST CONNECTION OPEN WIDE ________ PSI</td></tr>
<tr><td colspan="4">UNDERGROUND MAINS AND LEAD IN CONNECTIONS TO SYSTEM RISERS FLUSHED BEFORE CONNECTION MADE TO STANDPIPE PIPING.
VERIFIED BY COPY OF THE U FORM NO. 85B ☐ YES ☐ NO OTHER EXPLAIN
FLUSHED BY INSTALLER OF UNDER-GROUND STANDPIPE PIPING ☐ YES ☐ NO</td></tr>
<tr><td>BLANK TESTING</td><td>NUMBER USED</td><td colspan="2">LOCATIONS</td><td>NUMBER REMOVED</td></tr>
<tr><td rowspan="3">WELDING</td><td colspan="4">WELDED PIPING ☐ YES ☐ NO</td></tr>
<tr><td colspan="4">IF YES. . .</td></tr>
<tr><td colspan="4">DO YOU CERTIFY AS THE STANDPIPE CONTRACTOR THAT WELDING PROCEDURES COMPLY WITH THE REQUIREMENTS OF AT LEAST AWS D10.9, LEVEL AR-3 ☐ YES ☐ NO
DO YOU CERTIFY THAT THE WELDING WAS PERFORMED BY WELDERS QUALIFIED IN COMPLIANCE WITH THE REQUIREMENTS OF AT LEAST AWS D10.9, LEVEL AR-3 ☐ YES ☐ NO
DO YOU CERTIFY THAT WELDING WAS CARRIED OUT IN COMPLIANCE WITH A DOCUMENTED QUALITY CONTROL PROCEDURE TO INSURE THAT ALL DISCS ARE RETRIEVED, THAT OPENINGS IN PIPING ARE SMOOTH, THAT SLAG AND OTHER WELDING RESIDUE ARE REMOVED, AND THE THE INTERNAL DIAMETERS OF PIPING ARE NOT PENETRATED ☐ YES ☐ NO</td></tr>
<tr><td>CUTOUTS (DISCS)</td><td colspan="4">DO YOU CERTIFY THAT YOU HAVE A CONTROL FEATURE TO INSURE THAT ALL CUTOUTS (DISCS) ARE RETRIEVED? ☐ YES ☐ NO</td></tr>
<tr><td>HYDRAULIC DATA NAMEPLATE</td><td colspan="2">NAME PLATE PROVIDED
☐ YES ☐ NO</td><td colspan="2">IF NO, EXPLAIN</td></tr>
<tr><td rowspan="2">REMARKS</td><td colspan="4">DATE LEFT IN SERVICE WITH ALL CONTROL VALVES OPEN:</td></tr>
<tr><td colspan="4"></td></tr>
</table>

NAME OF SPRINKLER/STANDPIPE CONTRACTOR

NAME OF CONTRACTOR ____
ADDRESS ____
STATE LICENSE NUMBER (IF APPLICABLE) ______________________________

SYSTEM OPERATING TEST WITNESSED BY

FOR PROPERTY OWNER ______________________ TITLE ________________ DATE ______________
FOR SPRINKLER/STANDPIPE CONTRACTOR__________ TITLE ________________ DATE ______________
FOR APPROVING AUTHORITIES ________________ TITLE ________________ DATE ______________

ADDITIONAL EXPLANATION AND NOTES

Figure 8-1(a) (cont.).

CONTRACTOR'S MATERIAL & TEST CERTIFICATE FOR UNDERGROUND PIPING

PROCEDURE

Upon completion of work, inspection and tests shall be made by the contractor's representative and witnessed by an owner's representative. All defects shall be corrected and system left in service before contractor's personnel finally leave the job.

A certificate shall be filled out and signed by both representatives. Copies shall be prepared for approving authorities, owners, and contractor. It is understood the owner's representative's signature in no way prejudices any claim against contractor for faulty material, poor workmanship, or failure to comply with approving authority's requirements or local ordinances.

PROPERTY NAME	DATE
PROPERTY ADDRESS	

PLANS	ACCEPTED BY APPROVING AUTHORITIES (NAMES)
	ADDRESS
	INSTALLATION CONFORMS TO ACCEPTED PLANS ☐ YES ☐ NO EQUIPMENT USED IS APPROVED ☐ YES ☐ NO IF NO, STATE DEVIATIONS
INSTRUCTIONS	HAS PERSON IN CHARGE OF FIRE EQUIPMENT BEEN INSTRUCTED AS TO LOCATION OF CONTROL VALVES AND CARE AND MAINTENANCE OF THIS NEW EQUIPMENT? ☐ YES ☐ NO IF NO, EXPLAIN
	HAVE COPIES OF APPROPRIATE INSTRUCTIONS AND CARE AND MAINTENANCE CHARTS BEEN LEFT ON PREMISES? ☐ YES ☐ NO IF NO, EXPLAIN
LOCATION	SUPPLIES BUILDINGS
UNDERGROUND PIPES AND JOINTS	PIPE TYPES AND CLASS — TYPE JOINT
	PIPE CONFORMS TO ______ STANDARD ☐ YES ☐ NO FITTINGS CONFORM TO ______ STANDARD ☐ YES ☐ NO IF NO, EXPLAIN
	JOINTS NEEDING ANCHORAGE CLAMPED, STRAPPED, OR BLOCKED IN ACCORDANCE WITH ______ STANDARD ☐ YES ☐ NO IF NO, EXPLAIN
TEST DESCRIPTION	FLUSHING. Flow the required rate until water is clear as indicated by no collection of foreign material in burlap bags at outlets such as hydrants and blow-offs. Flush at flows not less than 390 GPM (1476 L/min) for 4-inch pipe, 880 GPM (3331 L/min) for 6-inch pipe, 1560 GPM (5905 L/min) for 8-inch pipe, 2440 GPM (9235 L/min) for 10-inch pipe, and 3520 GPM (13323 L/min) for 12-inch pipe. When supply cannot produce stipulated flow rates, obtain maximum available. HYDROSTATIC. Hydrostatic tests shall be made at not less than 200 psi (13.8 bars) for two hours or 50 psi (3.4 bars) above static pressure in excess of 150 psi (10.3 bars) for two hours. LEAKAGE. New pipe laid with rubber gasketed joints shall, if the workmanship is satisfactory, have little or no leakage at the joints. The amount of leakage at the joints shall not exceed 2 qts. per hr. (1.89 L/h) per 100 joints irrespective of pipe diameter. The leakage shall be distributed over all joints. If such leakage occurs at a few joints the installation shall be considered unsatisfactory and necessary repairs made. The amount of allowable leakage specified above may be increased by 1 fl oz per in. valve diameter per hr. (30 mL/25 mm/h) for each metal seated valve isolating the test section. If dry barrel hydrants are tested with the main valve open, so the hydrants are under pressure, an additional 5 oz per minute (150 mL/min) leakage is permitted for each hydrant.
FLUSHING TESTS	NEW UNDERGROUND PIPING FLUSHED ACCORDING TO ______ STANDARD ☐ YES ☐ NO BY (COMPANY) IF NO, EXPLAIN
	HOW FLUSHING FLOW WAS OBTAINED ☐ PUBLIC WATER ☐ TANK OR RESERVOIR ☐ FIRE PUMP — THROUGH WHAT TYPE OPENING ☐ HYDRANT BUTT. ☐ OPEN PIPE
	LEAD-INS FLUSHED ACCORDING TO ______ STANDARD ☐ YES ☐ NO BY (COMPANY) IF NO, EXPLAIN
	HOW FLUSHING FLOW WAS OBTAINED ☐ PUBLIC WATER ☐ TANK OR RESERVOIR ☐ FIRE PUMP — THROUGH WHAT TYPE OPENING ☐ Y CONN. TO FLANGE & SPIGOT ☐ OPEN PIPE

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Figure 8-1(b).

HYDROSTATIC TEST	ALL NEW UNDERGROUND PIPING HYDROSTATICALLY TESTED AT ________ PSI FOR ________ HOURS		JOINTS COVERED ☐ YES ☐ NO
LEAKAGE TEST	TOTAL AMOUNT OF LEAKAGE MEASURED ________ GALS. ________ HOURS		
	ALLOWABLE LEAKAGE ________ GALS. ________ HOURS		
HYDRANTS	NUMBER INSTALLED	TYPE AND MAKE	ALL OPERATE SATISFACTORILY ☐ YES ☐ NO
CONTROL VALVES	WATER CONTROL VALVES LEFT WIDE OPEN IF NO, STATE REASON		☐ YES ☐ NO
	HOSE THREADS OF FIRE DEPARTMENT CONNECTIONS AND HYDRANTS INTERCHANGEABLE WITH THOSE OF FIRE DEPARTMENT ANSWERING ALARM		☐ YES ☐ NO
REMARKS	DATE LEFT IN SERVICE		
SIGNATURES	NAME OF INSTALLING CONTRACTOR		
	TESTS WITNESSED BY		
	FOR PROPERTY OWNER (SIGNED)	TITLE	DATE
	FOR INSTALLING CONTRACTOR (SIGNED)	TITLE	DATE

ADDITIONAL EXPLANATION AND NOTES

Figure 8-1(b) (cont.).

8-5 Flow Tests.

8-5.1• The water supply shall be tested to verify compliance with the design. This test shall be conducted by flowing water from the hydraulically most remote hose connections.

8-5.2 For a manual standpipe, a fire department pumper or portable pump of adequate capacity (required flow and pressure) shall be used, to verify the system design, by pumping into the fire department connection.

8-5.3 A flow test shall be conducted at each roof outlet to verify that the required pressure is available at the required flow.

8-5.4 The filling arrangement for suction tanks shall be verified by shutting down all supplies to the tank, draining the tank to below designated low water level, then opening the supply valve to ensure operation of its automatic features.

8-5.5 Pressure Regulating Devices. Each pressure regulating device shall be tested to verify that the installation is correct, that the device is operating properly, and that the inlet and outlet pressures at the device are in accordance with the design. Static and residual inlet pressure and static and residual outlet pressure and flow shall be recorded on the contractor's test certificate.

8-5.6 Main Drain Flow Test. The main drain valve shall be opened and remain open until the system pressure stabilizes. The static and residual pressure shall be recorded on the contractor's test certificate.

8-5.7 Testing of Automatic and Semiautomatic Dry Systems. Automatic and semiautomatic dry systems shall be tested by initiating a flow of water from the hydraulically most remote hose connection. The system shall deliver a minimum of 250 gpm (946 L/min) at the hose connection within 3 min of opening the hose valve. Each remote control device for operating a semiautomatic system shall be tested in accordance with the manufacturer's instructions.

8-5.8 Systems Having Pumps. Where pumps are part of the water supply for a standpipe system, testing shall be conducted with pumps operating.

8-6 Manual Valve Test. Each valve intended to be manually opened or closed shall be operated by turning the handwheel crank or wrench throughout its range and returned to its normal position. Hose valve caps shall be tightened sufficiently to avoid leaking during the test, then removed after the test to drain water and relieve pressure.

8-7 Alarm and Supervision Tests. Each alarm and supervisory device provided shall be tested in accordance with NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems*.

8-8 Instructions. The installing contractor shall provide the owner with the following:

(a) All literature and instructions provided by the manufacturer describing proper operation and maintenance of equipment and devices installed

(b) A copy of NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.*

8-9 Signs. The installation of signs required by this standard shall be verified.

Chapter 9 Buildings under Construction

9-1 General. Where required by the authority having jurisdiction, in buildings under construction a standpipe system, either temporary or permanent in nature, shall be provided in accordance with this chapter.

9-2 Fire Department Connections. The standpipes shall be provided with conspicuously marked and readily accessible fire department connections on the outside of the building at the street level.

9-3 Other System Features. Pipe sizes, hose connections, hose, water supply, and other details for new construction shall be in accordance with this standard.

9-4 Support of Piping. Standpipes shall be securely supported and restrained at each alternate floor.

9-5* Hose Connections. At each floor level, there shall be provided at least 1 hose connection. Hose valves shall be kept closed at all times and guarded against mechanical injury.

9-6* Extension of System Piping. Standpipes shall be extended up with each floor and securely capped at the top.

9-7 Temporary Installations. Temporary standpipes shall remain in service until the permanent standpipe is complete. Where temporary standpipes normally contain water, the piping shall be protected against freezing.

9-8 Timing of Water Supply Installation. Where construction reaches a height at which public waterworks system pressure is no longer adequate, temporary or permanent fire pumps shall be installed to provide protection to the uppermost level or to the height as required by the authority having jurisdiction.

Exception: Unless local fire department pumping apparatus is acceptable to the authority having jurisdiction as adequate for the standpipe pressure required.

9-9 Protection of Hose Connections and Fire Department Connections. Threaded caps and plugs shall be installed on fire department connections and hose connections. Fire department connections and hose connections shall be protected against physical damage.

Chapter 10 Referenced Publications

10-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

10-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 1991 edition

NFPA 22, *Standard for Water Tanks for Private Fire Protection,* 1993 edition

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 1992 edition

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 1992 edition

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes,* 1989 edition

NFPA 72, *Standard for the Installation, Maintenance, and Use of Protective Signaling Systems,* 1990 edition

NFPA 1901, *Standard for Pumper Fire Apparatus,* 1991 edition

NFPA 1963, *Standard for Screw Threads and Gaskets for Fire Hose Connections,* 1985 edition

10-1.2 ANSI Publications. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B16.1-1989, *Cast-Iron Pipe Flanges and Flanged Fittings*

ANSI B16.3-1985, *Malleable Iron Threaded Fittings,* Classes 150 and 300

ANSI B16.4-1985, *Cast-Iron Threaded Fittings,* Classes 125 and 250

ANSI B16.5-1988, *Pipe Flanges and Flanged Fittings*

ANSI B16.9-1986, *Factory-Made Wrought Steel Buttwelding Fittings*

ANSI B16.11-1991, *Forged Fittings, Socket Welding and Threaded*

ANSI B16.18-1984, *Cast Copper Alloy Solder-Joint Pressure Fittings*

ANSI B16.22-1989, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*

ANSI B16.25-1986, *Buttwelding Ends*

ANSI B36.10M-1985, *Welded and Seamless Wrought Steel Pipe*

ANSI B1.20.1-1983, *Pipe Threads, General Purpose (Inch)*

10-1.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A53-1990, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless Pipe*

ASTM A135-1989, *Standard Specification for Electric-Resistance-Welded Steel Pipe*

ASTM A234-1991, *Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures*

ASTM A795-1990, *Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use*

ASTM B75-1991, *Standard Specification for Seamless Copper Tube (Metric)*

ASTM B88-1989, *Standard Specification for Seamless Copper Water Tube (Metric)*

ASTM B251-1988, *Standard Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube*

ASTM E380-1991, *Standard Practice for Use of the International System of Units (SI)*

10-1.4 AWS Publications. American Welding Society, 550 N. LeJeune Road, P.O. Box 351040, Miami, FL 33135.

AWS A5.8-1989, *Specification for Filler Metals for Brazing*

AWS D10.9-1980, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*

10-1.5 AWWA Publications. American Water Works Association, 6666 W. Quincy Avenue, Denver, CO 80235.

AWWA C110-87, *Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in. for Water and Other Liquids*

AWWA C151-80, *Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids*

Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-4 Should. Indicates a recommendation or that which is advised but not required.

A-2-1 The use of standard-weight valves and fittings should ordinarily be confined to the upper stories of very high buildings and to equipments where the highest available pressures are less than 175 psi (12.1 bars).

A-2-5.1 Many fire departments will lay a hose line from the pumper into the building and connect to an accessible valve outlet using a double female swivel when the building fire department connections are inaccessible or inoperable. To pressurize the standpipe, the hose valve is opened and the engine pumps into the system.

If the standpipe is equipped with pressure reducing hose valves, the valve will act as a check valve prohibiting pumping into the system when the valve is opened.

A supplementary single inlet fire department connection or hose valve with female threads at an accessible location on the standpipe will permit pumping into that system.

A-2-7.2 See NFPA 1961, *Standard for Fire Hose.*

The factors to be considered in selecting a rack or reel for storage of 1½-in. hose are the number of persons likely to be available to place the equipment into operation and the extent to which potential users are trained. With hose racks of the "semiautomatic" or "one-person" type, the hose valve should first be opened wide. The nozzle should then be grasped firmly and the hose lines drawn toward the fire. The water is automatically released as the last few feet of hose are pulled from the rack.

A-2-9 See Figure A-4-3.

A-2-9.2 See Sections 5-7 and 5-12 for design requirements.

A-3-6 Additional pressure gauges at the base of the standpipes may be desirable in some equipment, particularly in large plants and high buildings.

A-3-7 Audible alarms are normally located on the outside of the building. Approved electric gong bells, horns, or sirens inside the building or a combination inside and outside are sometimes advisable.

A-4-1 Connections from fire pumps and sources outside the building should be made at the base of the standpipes.

A-4-1.2.1 Standpipes should not be placed in unsprinklered areas of combustible construction.

A-4-2.5.2 Combined automatic sprinkler and standpipe risers should not be interconnected by sprinkler system piping.

A-4-2.7 See NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*

A-4-3 See Figure A-4-3.

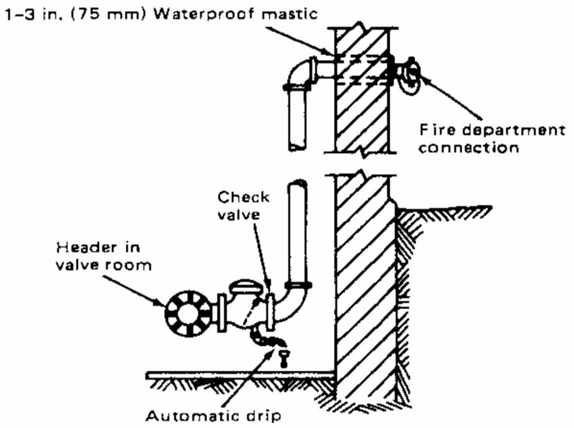


Figure A-4-3 Typical fire department connection for wet standpipes.

A-4-3.5.4 The system designer should contact the authority having jurisdiction prior to establishing the location of the fire department connection. The location should be based on the requirements of the fire department.

A-4-7 See Figure A-4-7.

Location of the 2 hydraulically most remote hose connections:______
Design flow rate for the connections identified above: ______
Design residual inlet and outlet pressures for the connections identified above: ______
Design static pressure and the design system demand (flow and residual pressure) at the system control valve, or at the pump discharge flange when a pump is installed, and at each fire department connection: ____

Figure A-4-7 System hydraulic information.

A-5-1 The building height determines the number of vertical zones. The area of a floor or fire area and exit locations, as well as the occupancy, will determine the number and locations of hose connections. Local building codes influence types of systems, classes of systems, and locations of hose connections. Pipe sizing is dependent on the number of hose connections flowing, quantity of water flowed, the required residual pressure, and vertical and horizontal distance of those hose connections from the water supplies.

For typical elevation drawings, see Figures A-5-1(a), A-5-1(b), and A-5-1(c).

A-5-2 The system pressure units have been implemented to replace the prior height units. Since the issue addressed by the heights units has always been maximum pressure, pressure limitations are a more direct method of regulation and allow flexibility in height units when pumps are used because a pump curve with less excess pressure at churn yields lower maximum system pressures while achieving the required system demand.

The maximum system pressure will normally be at pump churn. The measurement should include both the pump boost and city static pressures. The 350 psi limit was selected because it is the maximum pressure at which most system components are available, and it recognizes the need for a reasonable pressure unit.

A-5-3.1 Hose may be located at one side of the standpipe and supplied by short lateral connections to the standpipe where necessary to avoid obstructions.

Hose connections for Class I systems should be located in a stairway enclosure, and for Class II systems in the corridor or space adjacent to the stairway enclosure and connected through the wall to the standpipe. For Class III systems, the connections for $2^1/_2$-in. (63.5-mm) hose should be located in a stairway enclosure, and for Class II system hose, located in the corridor or space adjacent to the stairway enclosure. These arrangements make it possible to use Class II system hose streams promptly in case the stairway is filled with people escaping at the time of fire. In buildings having large areas, connections for Class I and Class III systems may be located at interior columns.

A-5-3.2 Hose connections are now specified to be located at intermediate landings between floors to prevent congestion at doorways. Where there are multiple intermediate floor landings between floors, hose connections should be located at the landing approximately midway between floors. It is recognized that fire departments often use the hose connection on the floor below the fire floor, and the location of hose connections at intermediate landings also reduces the hose lay distance in such cases as well.

The approach to locating hose connections with respect to exits is shown in Figure A-5-3.2.

For purposes of this standard, the following definitions will assist the user in locating the hose connections.

Exit Passageways. Hallways, corridors, passages, or tunnels used as exit components and separated from other parts of the building in accordance with the NFPA *101*,® *Life Safety Code*.®

Horizontal Exit. A way of passage from an area in one building to an area in another building on approximately the same level, or a way of passage through or around a fire barrier from one area to another on approximately the same level in the same building that affords safety from fire and smoke originating from the area of incidence and areas communicating therewith.

A-5-3.2(f) This paragraph is intended to provide authority to local fire departments to require additional hose connections outside of or away from a 2-hr fire-resistive separation. These additional hose connections may be needed to allow fire fighters to attack a fire in a reasonable time frame based on the lengths of hose available on fire department standpipe packs or in carry bags. While it is recognized that outlet spacing limitations provide controls to limit the maximum hose length needed to fight a fire, thereby minimizing the physical demands on fire fighters, it is also recognized that in some cases based on architectural layout, additional outlets may be indicated in open floor areas just to meet spacing requirements. In such cases, it is unlikely that such outlets could be utilized, since there would not be a staging area for fire fighters to use when accessing the hose connection. Therefore, additional hose connections, when provided to meet distance limitations, should be located in 1-hr fire-resistive exit corridors whenever possible to provide a degree of protection for fire fighters accessing the connection. It is also desirable to locate such connections as uniformly as possible from floor to floor for ease of locating connections during a fire.

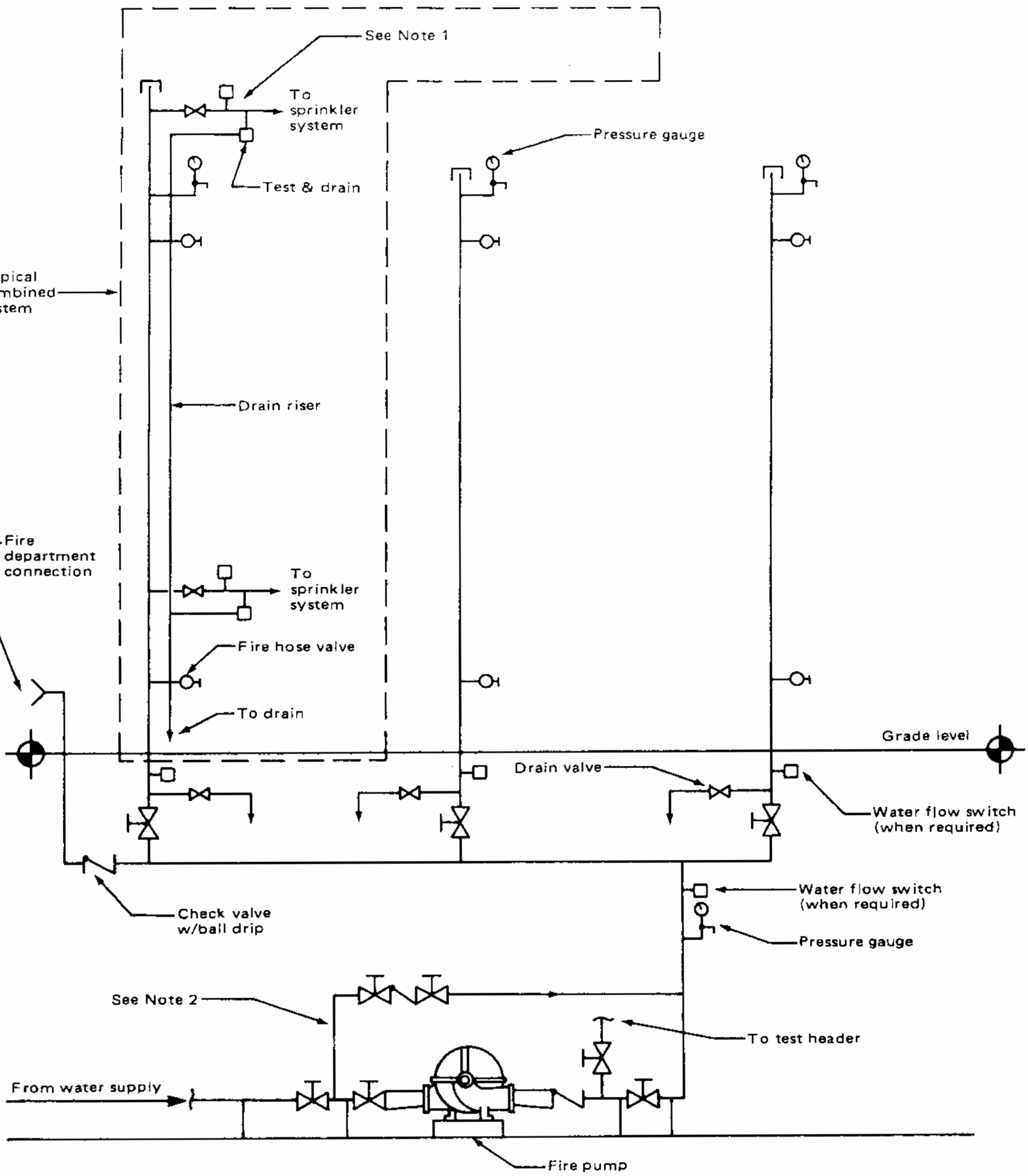
It is recognized that the 200-ft (61-m) distance allowed for sprinklered buildings may require additional hose lengths to be added to reach the most remote portion of a floor; however, automatic sprinklers should provide adequate control to allow time for fire fighters to extend hoses in those cases where a fire may be located in the most remote area.

A-5-3.3 Hose stations should be so arranged as to permit directing the discharge from the nozzle into all portions of important enclosures such as closets and like enclosures.

A-5-7 When determining the pressure at the outlet of the remote hose connection, the pressure loss in the hose valve should be considered.

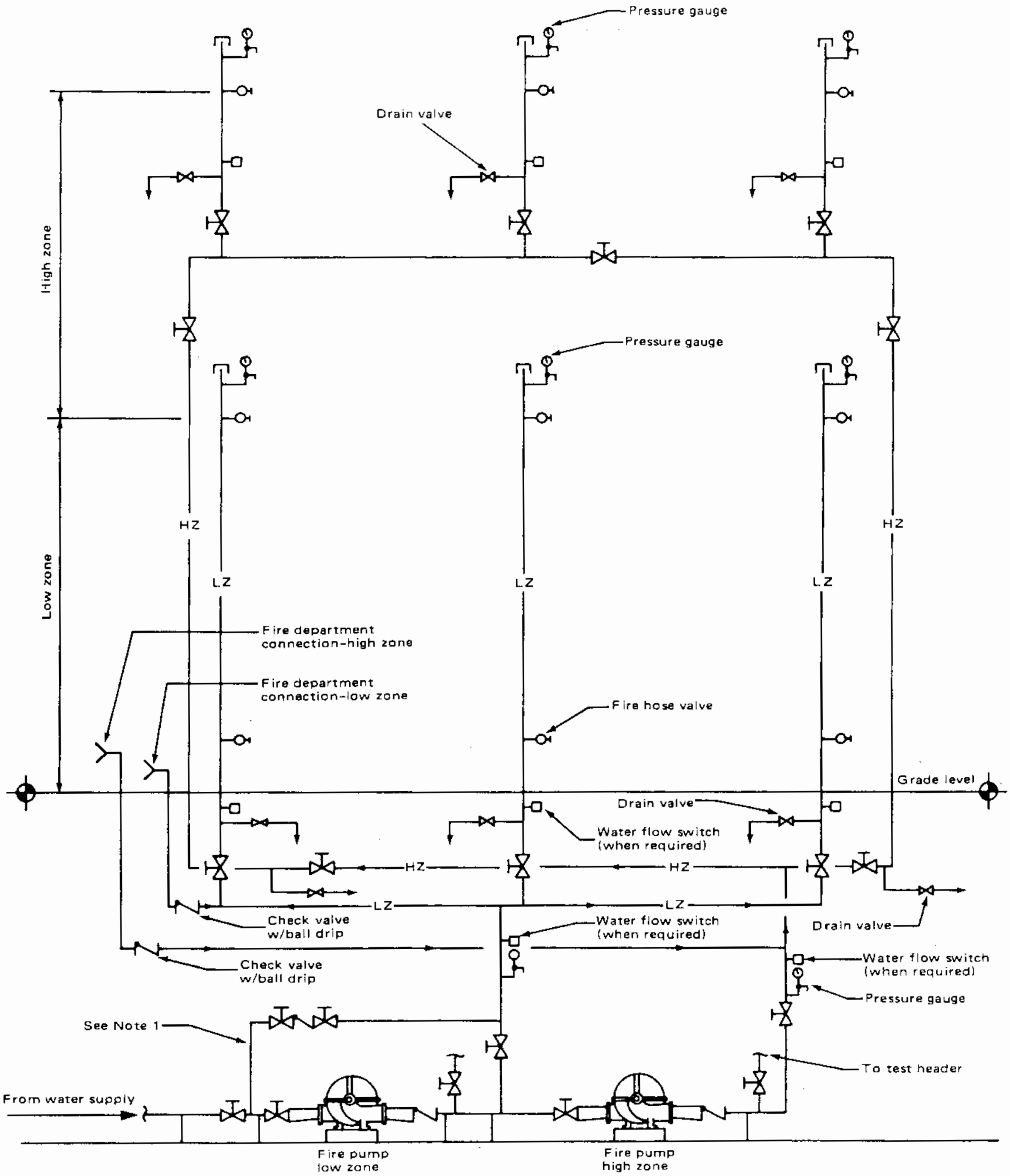
It is very important that fire departments choose an appropriate nozzle type for their standpipe fire fighting operations. Constant pressure (automatic) type spray nozzles (*See NFPA 1964*) should not be used for standpipe operations because many of this type require a minimum of 100 psi at the nozzle inlet to produce a reasonably effective fire stream. In standpipe operations, hose friction loss may prevent the delivery of 100 psi to the nozzle.

In high-rise standpipe systems with pressure reducing hose valves, the fire department has little or no control over hose valve outlet pressure.



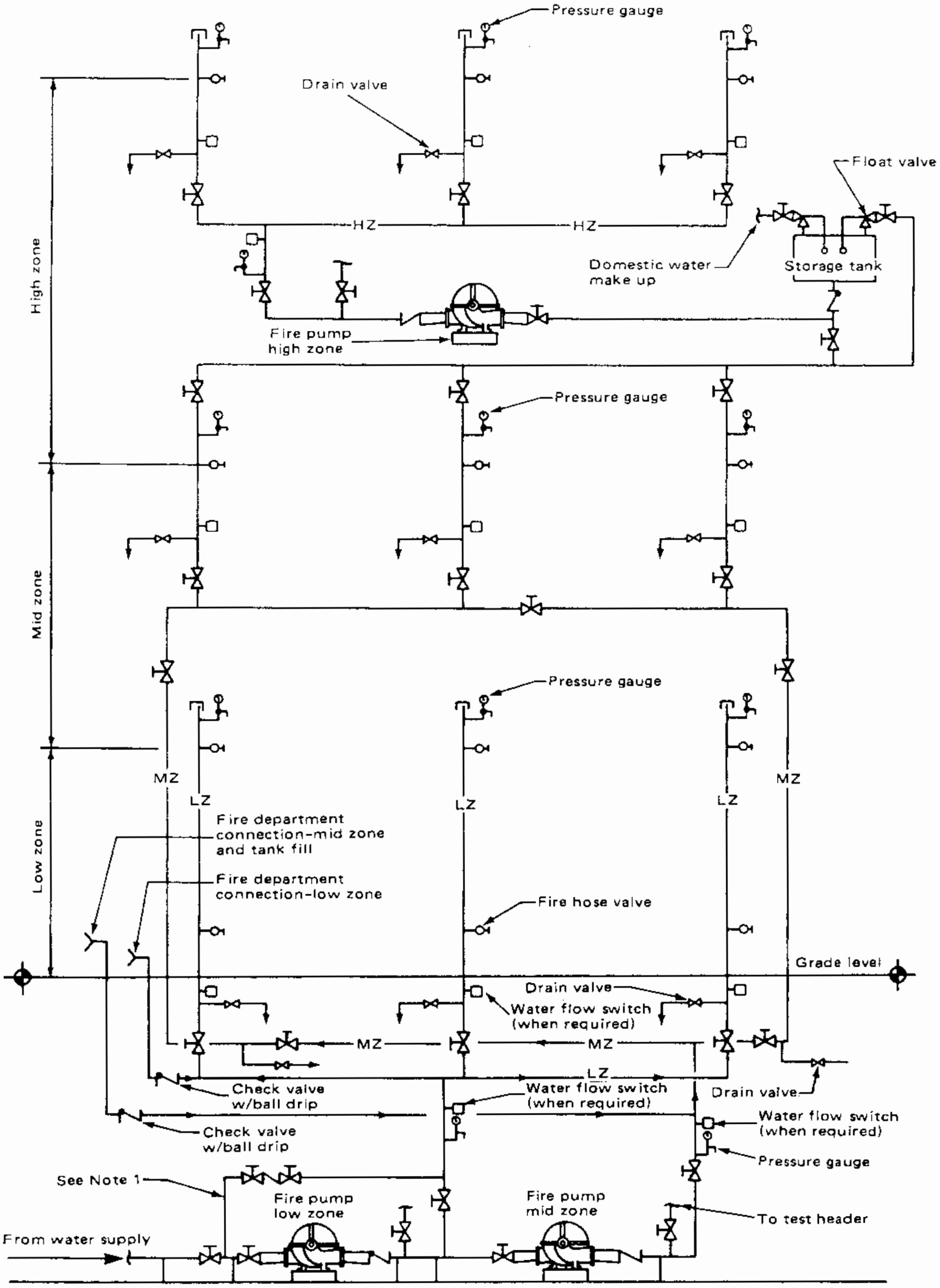
NOTE 1: Sprinkler floor assembly. NFPA 13.
NOTE 2: Bypass subject to NFPA 20.

Figure A-5-1(a) Typical single-zone system.



NOTE 1: Bypass subject to NFPA 20.
NOTE 2: High zone pump may be arranged to take suction directly from source of supply.

Figure A-5-1(b) Typical two-zone system.



NOTE 1: Bypass subject to NFPA 20.

Figure A-5-1(c) Typical multi-zone system.

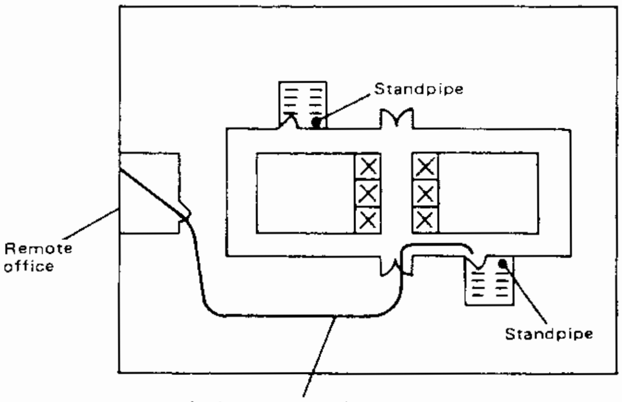


Figure A-5-3.2.

Many fire departments use combination (fog and straight stream) nozzles requiring 100 psi (6.9 bar) residual pressure at the nozzle inlet with 1½-in., 1¾-in., or 2-in. hose in lengths of up to 150 ft. Some use 2½-in. hose with a smooth bore nozzle or a combination nozzle.

The 2½-in. smooth bore with a 1⅛-in. tip will produce a usable stream (250 gpm) at 50 psi inlet pressure requiring 65 psi at the valve outlet with 100 ft of 2½-in. hose or 73 psi at the outlet with 150 ft of hose.

Some departments may use 50 ft of 2½-in. hose to a gated wye, supplying two 100-ft lengths of 1½-in. to 2-in. hose with combination nozzles, requiring 120 psi to 149 psi at the valve outlet. (*See Table A-5-7.*)

Table A-5-7 Hose Stream Friction Losses Summary

Calc #	Nozzle/Hose	Flow (gpm)	psi @ Valve Outlet
1	2½-in. combination nozzle, with 150 ft 2½-in. hose	250	123
2	2½-in. smooth bore with 1⅛-in. tip 150 ft 2½-in. hose	250	73
3	2½-in. combination nozzle with 50 ft 2½-in. hose, 2½-in. gated wye, and 100 ft 1½-in. hose	250	149
4	Same with two 100-ft lengths of 1¾-in. hose	250	139
5	Same with two 100-ft lengths of 2-in. hose	250	120
6	1½-in. combination nozzles with 150 ft 2-in. hose	200	136
7	Same with 1¾-in hose	200	168

A-5-8 Due to the different pressure limitations established in Section 5-8, it may be necessary to arrange piping so that separate pressure regulating devices can be provided on the Class I and Class II hose connections.

A-5-9.1.1 If a water supply system supplies more than one building or more than one fire area, the total supply may be calculated based on the single building or fire area requiring the greatest number of standpipes.

For a discussion of use by the fire department of fire department connections, see NFPA 13E, *Recommendations for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems.*

A-5-9.1.2 See Chapter 7 of NFPA 13, *Standard for the Installation of Sprinkler Systems.*

A-5-9.1.3.1 Occupancy examples in the listings as shown in the various hazard classifications are intended to represent the norm for those occupancy types. Unusual or abnormal fuel loadings or combustible characteristics and susceptibility for changes in these characteristics, for a particular occupancy, are considerations that should be weighed in the selection and classification.

The Light Hazard classification is intended to encompass residential occupancies; however, this is not intended to preclude the use of listed residential sprinklers in residenrial occupancies or residential portions of other occupancies.

Light Hazard Occupancies include occupancies having conditions similar to:

Churches
Clubs
Eaves and overhangs, if combustible construction with no combustibles beneath
Educational
Hospitals
Institutional
Libraries, except large stack rooms
Museums
Nursing or convalescent homes
Office, including data processing
Residential
Restaurant seating areas
Theaters and auditoriums excluding stages and prosceniums
Unused attics.

Ordinary Hazard Occupancies (Group 1) include occupancies having conditions similar to:

Automobile parking and showrooms
Bakeries
Beverage manufacturing
Canneries
Dairy products manufacturing and processing
Electronic plants
Glass and glass products manufacturing
Laundries
Restaurant service areas.

Ordinary Hazard Occupancies (Group 2) include occupancies having conditions similar to:

Cereal mills
Chemical plants — ordinary
Confectionery products
Distilleries
Dry cleaners
Feed mills
Horse stables
Leather goods manufacturing
Libraries — large stack room areas

Machine shops
Metal working
Mercantile
Paper and pulp mills
Paper process plants
Piers and wharves
Post offices
Printing and publishing
Repair garages
Stages
Textile manufacturing
Tire manufacturing
Tobacco products manufacturing
Wood machining
Wood product assembly.

Extra Hazard Occupancies (Group 1) include occupancies having conditions similar to:

Aircraft hangars
Combustible hydraulic fluid use areas
Die casting
Metal extruding
Plywood and particle board manufacturing
Printing [using inks having flash points below 100°F (37.9°C)]
Rubber reclaiming, compounding, drying, milling, vulcanizing
Sawmills
Textile picking, opening, blending, garnetting, carding, combining of cotton, synthetics, wool shoddy, or burlap
Upholstering with plastic foams.

Extra Hazard Occupancies (Group 2) include occupancies having conditions similar to:

Asphalt saturating
Flammable liquids spraying
Flow coating
Mobile home or modular building assemblies (where finished enclosure is present and has combustible interiors)
Open oil quenching
Plastics processing
Solvent cleaning
Varnish and paint dipping.

A-5-11 During flow testing of PRVs, care should be taken in making connections to drain risers. An air gap should be maintained in order to prevent cross connection to nonpotable water sources.

A-5-12 See NFPA 13E, *Recommendations for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems*.

The number of 2½-in. (63.5-mm) inlets to supply the required water volume and pressure at the fire department connection is dependent on several variables such as the performance of the water supply at the source, the distance from the source to the location of the inlets, the diameter of the hose used, the size of the fire department pumper, and the required water volume and pressure at the base of the standpipe riser(s).

A-6-1 Plans should indicate the type of fire department equipment that the system is designed to serve, including the hose size, hose length, and hose nozzle. Such equipment would be the basis for the pressure selected in accordance with Section 5-7.

A-7-1 The selection of water supplies for each installation should be determined in cooperation with the authority having jurisdiction.

A-7-1.1 See NFPA 22, *Standard for Water Tanks for Private Fire Protection*, and NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

A-8-1 Where standpipe connections are built in the walls or partitions, the hydrostatic tests should be made before they are covered in or permanently sealed.

Example of Required Hydrostatic Test Pressure: A standpipe system has for its water supply the connection to a public water service main. A 100 psi (6.9 bars) rated pump is installed in the connection. With a maximum normal public water supply pressure of 70 psi (4.9 bars) at the low elevation point of the system or zone being tested and a 120 psi (8.3 bars) pump (churn) pressure the hydrostatic test pressure, is 70 + 120 + 50, or 240 psi (16.6 bars). Refer to NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, for permissible leakage in underground piping.

A-8-4.1 The testing and flushing of the underground pipe should be in accordance with NFPA 24.

A-8-5.1 The hydraulically most remote hose connections in a building are generally at a roof manifold, if provided, or at the top of a stair leading to the roof. In a multizone system, the testing means is generally at a test header at grade or at a suction tank on higher floors.

Where a flow test at the most hydraulically remote hose connection is not practical, the authority having jurisdiction should be consulted for the appropriate location of the test.

A-9-5 At the highest hose connection there should be maintained a substantial box, preferably of metal, in which should be kept a sufficient amount of hose to reach all parts of the floor, a 1⅛-in. (29-mm) nozzle, spanner wrenches, and hose straps.

A-9-6 Top hose connections should at all times be not more than 1 floor below the highest forms, staging, and like combustibles.

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus should not be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition

NFPA 13E, *Recommendations for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems*, 1989 edition

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1990 edition

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 1993 edition

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 1992 edition

NFPA *101*, *Life Safety Code*, 1991 edition

NFPA 1961, *Standard for Fire Hose*, 1992 edition

NFPA 1964, *Standard for Spray Nozzles (Shutoff and Tip)*, 1993 edition.

Fire Protection Handbook, Section 5, Chapter 14

UNIFORM BUILDING CODE STANDARD 9-3
INSTALLATION OF SPRINKLER SYSTEMS IN GROUP R OCCUPANCIES FOUR STORIES OR LESS

See Sections 804.1, 805, 902, 904.1.2, 2603.7.1 and 2603.8.1, *Uniform Building Code*

Part I

SECTION 9.301 — ADOPTION OF NFPA STANDARD

Except for the limitations, deletions, modifications and amendments set forth in Section 9.302 of this standard, the installation of sprinkler systems in Group R Occupancies required by this code shall be in accordance with the Standard for the Installation of Sprinkler Systems in Residential Occupancies, NFPA 13R-1989[1], published by the National Fire Protection Association, copyright © 1989, Batterymarch Park, Quincy, Massachusetts 02269, as if set out at length herein, or UBC Standard 9-1.

[1]The current edition is NFPA 13R-1996.

SECTION 9.302 — AMENDMENTS

The National Fire Protection Association standard adopted by Section 9.301 applies to the selection, installation, acceptance inspection and acceptance testing of sprinkler systems in residential occupancies four stories or less, except as follows:

1. Sec. 1-3 is amended as follows:

The definition of "authority having jurisdiction" is revised as follows:

The **"authority having jurisdiction"** is the building official.

The definitions of "approved" and "listed" shall be as set forth in Volume 1 of this code.

The definitions of "should" and "standard" are deleted.

The definition of "residential occupancies" is revised as follows:

RESIDENTIAL OCCUPANCIES are Group R Occupancies.

The definitions of "acceptance" and "building official" are added as follows:

ACCEPTANCE is acceptance by the building official.

BUILDING OFFICIAL is the officer or other designated authority charged with the administration and enforcement of this standard, or the officer's or other designated authority's duly authorized representative.

2. Sec. 1-6.2.1 is revised by changing the reference to "NFPA 13" to "UBC Standard 9-1."

3. Sec. 2-1.3.2 is revised by changing the reference to "NFPA 13" to "UBC Standard 9-1."

4. Sec. 2-3.2 is revised by changing the reference to "NFPA 20 and 22" to "nationally recognized standards" and changing the reference to "NFPA 13" to "UBC Standard 9-1."

5. Sec. 2-3.3.2 is revised by changing the reference to "NFPA 13" to "UBC Standard 9-1."

6. Sec. 2-4.4 is revised by changing the reference to "NFPA 13" to "UBC Standard 9-1."

7. Sec. 2-5.2 is revised by changing the references to "NFPA 13" to "UBC Standard 9-1."

8. Sec. 2-5.3 is revised by changing the reference to "NFPA 13" to "UBC Standard 9-1."

9. Sec. 2-6 is revised by changing the reference to "NFPA 220" to "the Building Code."

10. Secs. 2-7.1 and 2-7.2 are added as follows:

2-7.1. A sprinkler system installed under this standard shall be maintained in accordance with the Fire Code.

2-7.2. The installer of the system shall provide the owner with written instructions and information relating to the care and maintenance of the sprinkler system, with special attention given to the sprinkler system devices.

11. Chapter 3 is deleted in its entirety.

Part II

[1]The current edition is NFPA 13R-1996.

Contents

NFPA 13R

Standard for the Installation of Sprinkler Systems in Residential Occupancies up to Four Stories in Height

1989 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 3 and Appendix B.

Preface

It is intended that this standard provide a method for those individuals wishing to install a sprinkler system for life safety and property protection. It is not the purpose of this standard to require the installation of an automatic sprinkler system. This standard assumes that one or more smoke detectors will be installed in accordance with NFPA 74, *Standard for the Installation, Maintenance, and Use of Household Fire Warning Equipment.*

Chapter 1 General Information

1-1* Scope. This standard deals with the design and installation of automatic sprinkler systems for protection against fire hazards in residential occupancies up to four stories in height.

1-2* Purpose. The purpose of this standard is to provide design and installation requirements for a sprinkler system to aid in the detection and control of fires in residential occupancies and thus provide improved protection against injury, life loss, and property damage. A sprinkler system designed and installed in accordance with this standard is expected to prevent flashover (total involvement) in the room of fire origin, when sprinklered, and to improve the chance for occupants to escape or be evacuated.

Nothing in this standard is intended to restrict new technologies or alternate arrangements, providing that the level of safety prescribed by the standard is not lowered.

1-3 Definitions.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Check Valve. A valve that allows flow in one direction only.

Control Valve. An indicating valve employed to control (shut) a supply of water to a sprinkler system.

Design Discharge. Rate of water discharged by an automatic sprinkler, expressed in gallons per minute.

Dry System. A system employing automatic sprinklers that are attached to a piping system containing air under atmospheric or higher pressures. Loss of pressure from the opening of a sprinkler or detection of a fire condition causes the release of water into the piping system and out the opened sprinkler.

Dwelling Unit. One or more rooms arranged for the use of one or more individuals living together as in a single housekeeping unit, normally having cooking, living, sanitary, and sleeping facilities.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the "autbority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either tbat the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Multipurpose Piping Systems. Piping systems within residential occupancies intended to serve both domestic and fire protection needs.

Residential Occupancies. Residential occupancies as included in the scope of this standard include the following, as defined in NFPA *101®*, *Life Safety Code®*:

(1) Apartment buildings.

(2) Lodging and rooming houses.

(3) Board and care facilities (slow evacuation type with 16 or less occupants and prompt evacuation type).

(4) Hotels, motels, and dormitories.

Residential Sprinkler. An automatic sprinkler that has been specifically listed for use in residential occupancies.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Sprinkler—Automatic. A fire suppression device that operates automatically when its heat-actuated element is heated to or above its thermal rating, allowing water to discharge over a specific area.

Sprinkler System. An integrated system of piping connected to a water supply, with listed sprinklers that will automatically initiate water discharge over a fire area. When required, the sprinkler system also includes a control valve and a device for actuating an alarm when the system operates.

Standard. A document containing only mandatory provisions using the word "shall" to indicate requirements. Explanatory material may be included only in the form of "fine print" notes, in footnotes, or in an appendix.

Waterflow Alarm. A sounding device activated by a waterflow detector or alarm check valve.

Waterflow Detector. An electric signaling indicator or alarm check valve actuated by water flow in one direction only.

Wet System. A system employing automatic sprinklers that are attached to a piping system containing water and connected to a water supply, so that water discharges immediately from sprinklers opened by a fire.

1-4 Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection. These units are listed, with conversion factors, in Table 1-4.

1-4.1 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value may be approximate.

Table 1-4

Name of Unit	Unit Symbol	Conversion Factor
liter	L	1 gal = 3.785 L
pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 105 Pa

For additional conversions and information see ASTM E380, *Standard for Metric Practice*.

1-4.2 The conversion procedure for the SI units has been to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

1-5 Piping.

1-5.1 Pipe or tube used in sprinkler systems shall be of the materials in Table 1-5.1 or in accordance with 1-5.2 through 1-5.5. The chemical properties, physical properties, and dimensions of the materials listed in Table 1-5.1 shall be at least equivalent to the standards cited in the table and designed to withstand a working pressure of not less than 175 psi (12.1 bars).

Table 1-5.1

Materials and Dimensions	Standard
Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use	ASTM A795
Specification for Welded and Seamless Steel Pipe	ASTM A53
Wrought-Steel Pipe	ANSI B36.10M
Specification for Electric-Resistance Welded Steel Pipe	ASTM A135
Copper Tube (Drawn, Seamless) Specification for Seamless Copper Tube	ASTM B88
Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube	ASTM B251
Brazing Filler Metal (Classification BCuP-3 or BCuP-4)	AWS A5.8
Specification for Solder Metal, 95-5 (Tin-Antimony-Grade 95TA)	ASTM B32

1-5.2 Other types of pipe or tube may be used, but only those listed for this service.

1-5.3 Whenever the word pipe is used in this standard, it shall be understood to also mean tube.

1-5.4 Pipe joined with mechanical grooved fittings shall be joined by a listed combination of fittings, gaskets, and grooves. When grooves are cut or rolled on the pipe they shall be dimensionally compatible with the fittings.

Exception: Steel pipe with wall thicknesses less than Schedule 30 [in sizes 8 in. (203 mm) and larger] or Schedule 40 [in *sizes less than 8 in. (203 mm)] shall not be joined by fittings used with pipe having cut grooves.*

1-5.5 Fittings used in sprinkler systems shall be of the materials listed in Table 1-5.5 or in accordance with 1-5.7. The chemical properties, physical properties, and dimensions of the materials listed in Table 1-5.5 shall be at least equivalent to the standards cited in the table. Fittings used in sprinkler systems shall be designed to withstand the working pressures involved, but not less than 175 psi (12.1 bars) cold water pressure.

Table 1-5.5

Materials and Dimensions	Standard
Cast Iron	
Cast Iron Threaded Fittings, Class 125 and 250	ANSI B16.4
Cast Iron Pipe Flanges and Flanged Fittings	ANSI B16.1
Malleable Iron	
Malleable Iron Threaded Fittings, Class 150 and 300	ANSI B16.3
Steel	
Factory-made Threaded Fittings Class 150 and 300	ANSI B16.9
Buttwelding Ends for Pipe, Valves, Flanges, and Fittings	ANSI B16.25
Spec. for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures	ASTM A234
Pipe Flanges and Flanged Fittings, Steel Nickel Alloy and Other Special Alloys	ANSI B16.5
Forged Steel Fittings, Socket Welded and Threaded	ANSI B16.11
Copper	
Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings	ANSI B16.22
Cast Copper Alloy Solder-Joint Pressure Fittings	ANSI B16.18

1-5.6 Joints for the connection of copper tube shall be brazed.

Exception: Soldered joints (95-5 solder metal) may be used for wet-pipe copper tube systems.

1-5.7 Other types of fittings may be used, but only those listed for this service.

1-6 System Types.

1-6.1 Wet-Pipe Systems. A wet-pipe system shall be used when all piping is installed in areas not subject to freezing.

1-6.2 Provision shall be made to protect piping from freezing in unheated areas by use of one of the following acceptable methods:

(a) Antifreeze system.

(b) Dry-pipe system.

Exception: Listed standard dry-pendent, dry upright, or dry sidewall sprinklers may be extended into unheated areas not intended for living purposes.

1-6.2.1 Antifreeze solutions shall be installed in accordance with 5-5.3 of NFPA 13, *Standard for the Installation of Sprinkler Systems.*

Chapter 2 Working Plans, Design, Installation, Acceptance Tests, and Maintenance

2-1 Working Plans and Acceptance Tests.

2-1.1 Working Plans.

2-1.1.1 Working plans shall be submitted for approval to the authority having jurisdiction before any equipment is installed or remodeled. Deviations from approved plans will require permission of the authority having jurisdiction.

2-1.1.2 Working plans shall be drawn to an indicated scale, on sheets of uniform size, with a plan of each floor, made so that they can be easily duplicated, and shall show the following data:

(a) Name of owner and occupant.

(b) Location, including street address.

(c) Point of compass.

(d) Ceiling construction.

(e) Full height cross section.

(f) Location of fire walls.

(g) Location of partitions.

(h) Occupancy of each area or room.

(i) Location and size of concealed spaces, attics, closets, and bathrooms.

(j) Any small enclosures in which no sprinklers are to be installed.

(k) Size of city main in street, pressure and whether dead-end or circulating and, if dead-end, direction and distance to nearest circulating main, city main test results including elevation of test hydrant.

(l) Make, manufacturer, type, heat-response element, temperature rating, and nominal orifice size of sprinkler.

(m) Temperature rating and location of high-temperature sprinklers.

(n) Number of sprinklers on each riser, per floor.

(o) Kind and location of alarm bells.

(p) Type of pipe and fittings.

(q) Type of protection for nonmetallic pipe.

(r) Nominal pipe size with lengths shown to scale.

NOTE: Where typical branch lines prevail, it will be necessary to size only one line.

(s) Location and size of riser nipples.

(t) Type of fittings and joints and location of all welds and bends.

(u) Types and locations of hangers, sleeves, braces, and methods of securing sprinklers, where applicable.

(v) All control valves, check valves, drain pipes, and test connections.

(w) Underground pipe size, length, location, weight, material, point of connection to city main; the type of valves, meters, and valve pits; and the depth at which the top of the pipe is laid below grade.

(x) For hydraulically designed systems, the material to be included on the hydraulic data nameplate.

(y) Name and address of contractor.

2-1.2 Approval of Sprinkler Systems.

2-1.2.1 The installer shall perform all required acceptance tests (*see 2-1.3*), complete the Contractor's Material and Test Certificate(s) (*see Figure 2-1.2.1*), and forward the certificate(s) to the authority having jurisdiction, prior to asking for approval of the installation.

2-1.2.2 When the authority having jurisdiction desires to be present during the conducting of acceptance tests, the installer shall give advance notification of the time and date the testing will be performed.

2-1.3 Acceptance Tests.

2-1.3.1 Flushing of Underground Connections.

2-1.3.1.1 Underground mains and lead-in connections to system risers shall be flushed before connection is made to sprinkler piping, in order to remove foreign materials that may have entered the underground piping during the course of the installation. For all systems, the flushing operation shall be continued until water is clear.

2-1.3.1.2 Underground mains and lead-in connections shall be flushed at the hydraulically calculated water demand rate of the system.

CONTRACTOR'S MATERIAL & TEST CERTIFICATE FOR ABOVEGROUND PIPING

PROCEDURE

Upon completion of work, inspection and tests shall be made by the contractor's representative and witnessed by an owner's representative. All defects shall be corrected and system left in service before contractor's personnel finally leave the job.

A certificate shall be filled out and signed by both representatives. Copies shall be prepared for approving authorities, owners, and contractor. It is understood the owner's representative's signature in no way prejudices any claim against contractor for faulty material, poor workmanship, or failure to comply with approving authority's requirements or local ordinances.

PROPERTY NAME	DATE
PROPERTY ADDRESS	

PLANS	ACCEPTED BY APPROVING AUTHORITIES (NAMES)	
	ADDRESS	
	INSTALLATION CONFORMS TO ACCEPTED PLANS	☐ YES ☐ NO
	EQUIPMENT USED IS APPROVED	☐ YES ☐ NO
	IF NO, EXPLAIN DEVIATIONS	
INSTRUCTIONS	HAS PERSON IN CHARGE OF FIRE EQUIPMENT BEEN INSTRUCTED AS TO LOCATION OF CONTROL VALVES AND CARE AND MAINTENANCE OF THIS NEW EQUIPMENT?	☐ YES ☐ NO
	IF NO, EXPLAIN	
	HAVE COPIES OF THE FOLLOWING BEEN LEFT ON THE PREMISES:	☐ YES ☐ NO
	1. SYSTEM COMPONENTS INSTRUCTIONS	☐ YES ☐ NO
	2. CARE AND MAINTENANCE INSTRUCTIONS	☐ YES ☐ NO
	3. NFPA 13A	☐ YES ☐ NO
LOCATION OF SYSTEM	SUPPLIES BUILDINGS	

	MAKE	MODEL	YEAR OF MANUFACTURE	ORIFICE SIZE	QUANTITY	TEMPERATURE RATING
SPRINKLERS						

PIPE AND FITTINGS

Type of Pipe ________

Type of Fittings ________

ALARM VALVE OR FLOW INDICATOR	ALARM DEVICE			MAXIMUM TIME TO OPERATE THROUGH TEST CONNECTION	
	TYPE	MAKE	MODEL	MIN.	SEC.

DRY PIPE OPERATING TEST	DRY VALVE			Q.O.D.		
	MAKE	MODEL	SERIAL NO.	MAKE	MODEL	SERIAL NO.

	TIME TO TRIP THRU TEST CONNECTION*		WATER PRESSURE	AIR PRESSURE	TRIP POINT AIR PRESSURE	TIME WATER REACHED TEST OUTLET*		ALARM OPERATED PROPERLY	
	MIN.	SEC.	PSI	PSI	PSI	MIN.	SEC.	YES	NO
Without Q.O.D.									
With Q.O.D.									

IF NO, EXPLAIN

* MEASURED FROM TIME INSPECTOR'S TEST CONNECTION IS OPENED.

85A (10-88) PRINTED IN U.S.A. (OVER)

Figure 2-1.2.1 Contractor's Material and Test Certificate for Aboveground Piping.

2-1.3.1.3 To avoid property damage, provision shall be made for the disposal of water issuing from test outlets.

2-1.3.2* All systems shall be tested for leakage at 50 psi (3.4 bars) above maximum system design pressure.

Exception: When a fire department connection is provided, hydrostatic pressure tests shall be provided in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems.

2-2 Design and Installation.

2-2.1 Devices and Materials.

2-2.1.1* Only new sprinklers shall be employed in the installation of sprinkler systems.

2-2.1.2 Only listed or approved devices and materials as indicated in this standard shall be used in sprinkler systems.

2-2.1.3 Sprinkler systems shall be designed for a maximum working pressure of 175 psi (12.1 bars).

Exception: Higher design pressures may be used when all system components are rated for pressures higher than 175 psi (12.1 bars).

2-3 Water Supply.

2-3.1 General Provisions. Every automatic sprinkler system shall have at least one automatic water supply. When stored water is used as the sole source of supply, the minimum quantity shall equal the water demand rate times 30 minutes. (*See 2-5.1.3.*)

DELUGE & PREACTION VALVES	OPERATION ☐ PNEUMATIC ☐ ELECTRIC ☐ HYDRAULIC PIPING SUPERVISED ☐ YES ☐ NO | DETECTING MEDIA SUPERVISED ☐ YES ☐ NO DOES VALVE OPERATE FROM THE MANUAL TRIP AND/OR REMOTE CONTROL STATIONS ☐ YES ☐ NO IS THERE AN ACCESSIBLE FACILITY IN EACH CIRCUIT FOR TESTING ☐ YES ☐ NO | IF NO, EXPLAIN
	MAKE | MODEL | DOES EACH CIRCUIT OPERATE SUPERVISION LOSS ALARM (YES | NO) | DOES EACH CIRCUIT OPERATE VALVE RELEASE (YES | NO) | MAXIMUM TIME TO OPERATE RELEASE (MIN. | SEC.)
TEST DESCRIPTION	HYDROSTATIC: Hydrostatic tests shall be made at not less than 50 psi (3.4 bars) above design pressure for two hours. Differential dry-pipe valve clappers shall be left open during test to prevent damage. All aboveground piping leakage shall be stopped. Systems with fire department connections shall be hydrostatically tested in accordance with NFPA 13, paragraph 1-11.2. PNEUMATIC: Establish 40 psi (2.7 bars) air pressure and measure drop which shall not exceed 1-1/2 psi (0.1 bars) in 24 hours. Test pressure tanks at normal water level and air pressure and measure air pressure drop which shall not exceed 1-1/2 psi (0.1 bars) in 24 hours.
TESTS	ALL PIPING HYDROSTATICALLY TESTED AT ______ PSI FOR ______ HRS. | IF NO, STATE REASON DRY PIPING PNEUMATICALLY TESTED ☐ YES ☐ NO EQUIPMENT OPERATES PROPERLY ☐ YES ☐ NO DO YOU CERTIFY AS THE SPRINKLER CONTRACTOR THAT ADDITIVES AND CORROSIVE CHEMICALS, SODIUM SILICATE OR DERIVATIVES OF SODIUM SILICATE, BRINE, OR OTHER CORROSIVE CHEMICALS WERE NOT USED FOR TESTING SYSTEMS OR STOPPING LEAKS? ☐ YES ☐ NO DRAIN TEST | READING OF GAGE LOCATED NEAR WATER SUPPLY TEST CONNECTION: ______ PSI | RESIDUAL PRESSURE WITH VALVE IN TEST CONNECTION OPEN WIDE ______ PSI UNDERGROUND MAINS AND LEAD IN CONNECTIONS TO SYSTEM RISERS FLUSHED BEFORE CONNECTION MADE TO SPRINKLER PIPING. VERIFIED BY COPY OF THE U FORM NO. 85B ☐ YES ☐ NO | OTHER EXPLAIN FLUSHED BY INSTALLER OF UNDERGROUND SPRINKLER PIPING ☐ YES ☐ NO
BLANK TESTING GASKETS	NUMBER USED | LOCATIONS | NUMBER REMOVED
WELDING	WELDED PIPING ☐ YES ☐ NO IF YES . . . DO YOU CERTIFY AS THE SPRINKLER CONTRACTOR THAT WELDING PROCEDURES COMPLY WITH THE REQUIREMENTS OF AT LEAST AWS D10.9, LEVEL AR-3 ☐ YES ☐ NO DO YOU CERTIFY THAT THE WELDING WAS PERFORMED BY WELDERS QUALIFIED IN COMPLIANCE WITH THE REQUIREMENTS OF AT LEAST AWS D10.9, LEVEL AR-3 ☐ YES ☐ NO DO YOU CERTIFY THAT WELDING WAS CARRIED OUT IN COMPLIANCE WITH A DOCUMENTED QUALITY CONTROL PROCEDURE TO INSURE THAT ALL DISCS ARE RETRIEVED, THAT OPENINGS IN PIPING ARE SMOOTH, THAT SLAG AND OTHER WELDING RESIDUE ARE REMOVED, AND THAT THE INTERNAL DIAMETERS OF PIPING ARE NOT PENETRATED ☐ YES ☐ NO
CUTOUTS (DISCS)	DO YOU CERTIFY THAT YOU HAVE A CONTROL FEATURE TO ENSURE THAT ALL CUTOUTS (DISCS) ARE RETRIEVED? ☐ YES ☐ NO
HYDRAULIC DATA NAMEPLATE	NAME PLATE PROVIDED ☐ YES ☐ NO | IF NO, EXPLAIN
REMARKS	DATE LEFT IN SERVICE WITH ALL CONTROL VALVES OPEN:
SIGNATURES	NAME OF SPRINKLER CONTRACTOR TESTS WITNESSED BY FOR PROPERTY OWNER (SIGNED) | TITLE | DATE FOR SPRINKLER CONTRACTOR (SIGNED) | TITLE | DATE

ADDITIONAL EXPLANATION AND NOTES

85A BACK

Figure 2-1.2.1 (Continued) Contractor's Material and Test Certificate for Aboveground Piping.

2-3.2* Water Supply Sources. The following water supply sources are acceptable:

(a) A connection to a reliable water works system with or without a booster pump, as required.

(b) An elevated tank.

(c) A pressure tank installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems,* and NFPA 22, *Standard for Water Tanks for Private Fire Protection.*

(d) A stored water source with an automatically operated pump, installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps.*

2-3.3 Multipurpose Piping System.

2-3.3.1* A common supply main to the building, serving both sprinklers and domestic uses, shall be acceptable when the domestic design demand is added to the sprinkler system demand.

Exception: Domestic design demand need not be added if provision is made to prevent flow on the domestic water system upon operation of sprinklers.

2-3.3.2 Sprinkler systems with nonfire protection connections shall comply with Section 5-6 of NFPA 13, *Standard for the Installation of Sprinkler Systems.*

2-4 System Components.

2-4.1 Valve and Drains.

2-4.1.1 When a common supply main is used to supply both domestic and sprinkler systems, a single listed control valve shall be provided to shut off both the domestic and sprinkler systems, and a separate shutoff valve shall be provided for the domestic system only. [*See Figure A-2-3.2(a).*]

Exception: The sprinkler system piping may have a separate control valve when supervised by one of the following methods:

(a) Central station, proprietary, or remote station alarm service,

(b) Local alarm service that will cause the sounding of an audible signal at a constantly attended point, or

(c) Locking the valves open.

2-4.1.2 Each sprinkler system shall have a 1-in. (25.4-mm) or larger drain and test connection with valve on the system side of the control valve.

2-4.1.3 Additional ½-in. (13-mm) drains shall be installed for each trapped portion of a dry system that is subject to freezing temperatures.

2-4.2 At least one 1½ in. (38 mm) or 2½ in. (64 mm) fire department connection shall be provided when the sprinkler system has 20 sprinklers or more.

2-4.3 Pressure Gages. Pressure gages shall be provided to indicate pressures on the supply and system sides of main check valves and dry-pipe valves, and to indicate pressure on water supply pressure tanks.

2-4.4 Piping Support. Piping hanging and bracing methods shall comply with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

2-4.5 Sprinklers.

2-4.5.1 Listed residential sprinklers shall be used inside dwelling units. The basis of such a listing shall consist of tests to establish the ability of the sprinklers to control residential fires under standardized fire test conditions. The standardized room fires shall be based on a residential array of furnishings and finishes.

Exception No. 1: Residential sprinklers shall not be used in dry systems unless specifically listed for that purpose.

Exception No. 2: Other types of listed sprinklers may be installed in accordance with their listing in dwelling units meeting the definition of a compartment (as defined in 2-5.1.2.2) provided no more than four sprinklers are located in the dwelling unit and at least one smoke detector is provided in each sleeping room.

2-4.5.2 Ordinary temperature rated sprinklers [135 to 170°F (57 to 77°C)] shall be installed where maximum ambient ceiling temperatures do not exceed 100°F (38°C).

2-4.5.3 Intermediate temperature rated residential sprinklers [175 to 225°F (79 to 107°C)] shall be installed where maximum ambient ceiling temperatures are between 101 and 150°F (38 and 66°C).

2-4.5.4 The following practices shall be observed when installing residential sprinklers, unless maximum expected ambient temperatures are otherwise determined.

(a) Sprinklers under glass or plastic skylights exposed to direct rays of the sun shall be of intermediate temperature classification.

(b) Sprinklers in an unventilated concealed space under an uninsulated roof, or in an unventilated attic, shall be of intermediate temperature classification.

2-4.5.5 When residential sprinklers are installed within a compartment, as defined in 2-5.1.2.2, all sprinklers shall be from the same manufacturer and have the same heat-response element, including temperature rating.

Exception: Different temperature ratings are permitted when required by 2-4.5.4.

2-4.5.6 Standard sprinklers shall be used in areas outside the dwelling unit.

Exception No. 1: Residential sprinklers may be used in adjoining corridors or lobbies with flat, smooth ceilings and a height not exceeding 10 ft (3.0 m).

Exception No. 2: Quick-response sprinklers may be used in accordance with 2-5.2, Exception No. 1.

2-4.5.7 Operated or damaged sprinklers shall be replaced with sprinklers having the same performance characteristics as original equipment.

2-4.5.8 When nonmetallic ceiling plates (escutcheons) are used, they shall be listed. Escutcheon plates used to create a recessed or flush-type sprinkler shall be part of a listed sprinkler assembly.

2-4.5.9 Painting and Ornamental Finishes.

2-4.5.9.1 Sprinkler frames may be factory painted or enameled as ornamental finish in accordance with 2-4.5.9.2; otherwise, sprinklers shall not be painted and any sprinklers that have been painted, except those with factory applied coatings, shall be replaced with new listed sprinklers.

2-4.5.9.2* Ornamental finishes shall not be applied to sprinklers by anyone other than the sprinkler manufacturer, and only sprinklers listed with such finishes shall be used.

2-4.6 Alarms. Local waterflow alarms shall be provided on all sprinkler systems and shall be connected to the building fire alarm system, when provided.

2-5 System Design.

2-5.1 Design Criteria—Inside Dwelling Unit.

2-5.1.1 Design Discharge. The system shall provide a discharge of not less than 18 gpm (68 L/min) to any single operating sprinkler and not less than 13 gpm (49 L/min) per sprinkler to the number of design sprinklers, but not less than the listing of the sprinkler(s).

Exception: Design discharge for sprinklers installed in accordance with Exception No. 2 of 2-4.5.1 shall be in accordance with sprinkler listing criteria.

2-5.1.2* Number of Design Sprinklers.

2-5.1.2.1 The number of design sprinklers shall include all sprinklers within a compartment to a maximum of four sprinklers.

2-5.1.2.2 The definition of compartment for use in 2-5.1.2.1 to determine the number of design sprinklers is a space that is completely enclosed by walls and a ceiling. The compartment enclosure may have openings to an adjoining space if the openings have a minimum lintel depth of 8 in. (203 mm) from the ceiling.

2-5.1.3 Water Demand. The water demand for the system shall be determined by multiplying the design discharge of 2-5.1.1 by the number of design sprinklers of 2-5.1.2.

2-5.1.4 Sprinkler Coverage.

2-5.1.4.1 Residential sprinklers shall be spaced so that the maximum area protected by a single sprinkler does not exceed 144 sq ft (13.4 m^2).

2-5.1.4.2 The maximum distance between sprinklers shall not exceed 12 ft (3.7 m) and the maximum distance to a wall or partition shall not exceed 6 ft (1.8 m).

2-5.1.4.3 The minimum distance between sprinklers within a compartment shall be 8 ft (2.4 m).

2-5.1.5 The minimum operating pressure of any sprinkler shall be in accordance with the listing information of the sprinkler and shall provide the minimum flow rates specified in 2-5.1.1.

2-5.1.6 Application rates, design areas, areas of coverage, and minimum design pressures other than those specified in 2-5.1.1, 2-5.1.2, 2-5.1.4, and 2-5.1.5 may be used with special sprinklers that have been listed for such specific residential installation conditions.

2-5.1.7 Position of Residential Sprinklers.

2-5.1.7.1 Pendent and upright sprinklers shall be positioned so that the deflectors are within 1 to 4 in. (25.4 to 102 mm) from the ceiling.

Exception: Special residential sprinklers shall be installed in accordance with the listing limitations.

2-5.1.7.2 Sidewall sprinklers shall be positioned so that the deflectors are within 4 to 6 in. (102 to 152 mm) from the ceiling.

Exception: Special residential sprinklers shall be installed in accordance with the listing limitations.

2-5.1.7.3* Sprinklers shall be positioned so that the response time and discharge are not unduly affected by obstructions such as ceiling slope, beams, or light fixtures.

2-5.2 Design Criteria—Outside Dwelling Unit. The design discharge, number of design sprinklers, water demand of the system, sprinkler coverage, and position of sprinklers for areas to be sprinklered outside the dwelling unit shall comply with specifications in NFPA 13, *Standard for the Installation of Sprinkler Systems.*

Exception No. 1: When compartmented into areas of 500 sq ft (46 m^2) or less by 30-minute fire-rated construction, and the area is protected by standard or quick-response sprinklers not exceeding 130 sq ft (12 m^2) per sprinkler, the system demand may be limited to the number of sprinklers in the compartment area, but not less than a total of four sprinklers. Openings from the compartments need not be protected provided such openings are provided with a lintel at least 8 in. (203 mm) in depth and the total area of such openings does not exceed 50 sq ft (4.6 m^2) for each compartment. Discharge density shall be appropriate for the hazard classification as determined by NFPA 13.

Exception No. 2: Lobbies, in other than hotels and motels, foyers, corridors, and halls outside the dwelling unit, with flat, smooth ceilings and not exceeding 10 ft (3.0 m) in height, may be protected with residential sprinklers, with a maximum system demand of four sprinklers.

2-5.3 Pipe Sizing. Piping shall be sized in accordance with hydraulic calculation procedures to comply with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

2-6 Location of Sprinklers. Sprinklers shall be installed in all areas.

Exception No. 1: Sprinklers may be omitted from bathrooms not exceeding 55 sq ft (5.1 m^2) with noncombustible plumbing fixtures.

Exception No. 2: Sprinklers may be omitted from small clothes closets where the least dimension does not exceed 3 ft (0.9 m) and the area does not exceed 24 sq ft (2.2 m^2) and the walls and ceiling are surfaced with noncombustible or limited combustible materials as defined by NFPA 220, Standard on Types of Building Construction.

Exception No. 3: Sprinklers may be omitted from open attached: porches, balconies, corridors, and stairs.

Exception No. 4: Sprinklers may be omitted from attics, penthouse equipment rooms, crawl spaces, floor/ceiling spaces, elevator shafts, and other concealed spaces that are not used or intended for living purposes or storage.

2-7* Maintenance. The owner is responsible for the condition of a sprinkler system and shall keep the system in normal operating condition.

Chapter 3 Referenced Publications

3-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

3-1.1 NFPA Publications. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 13-1989, *Standard for the Installation of Sprinkler Systems*

NFPA 20-1987, *Standard for the Installation of Centrifugal Fire Pumps*

NFPA 22-1987, *Standard for Water Tanks for Private Fire Protection*

NFPA 74-1989, *Standard for the Installation, Maintenance, and Use of Household Fire Warning Equipment*

NFPA *101*®-1988, *Life Safety Code*®

NFPA 220-1985, *Standard on Types of Building Construction.*

3-1.2 Other Publications.

3-1.2.1 ANSI Publications. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B16.1-1975, *Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250 and 800*

ANSI B16.3-1985, *Malleable Iron Threaded Fittings, Class 150 and 300*

ANSI B16.4-1985, *Cast Iron Threaded Fittings, Classes 125 and 250*

ANSI B16.5-1981, *Pipe Flanges and Flanged Fittings*

ANSI B16.9-1986, *Factory-Made Wrought Steel Buttwelding Fittings*

ANSI B16.11-1980, *Forged Steel Fittings, Socket-Welding and Threaded*

ANSI B16.18-1984, *Cast Copper Alloy Solder Joint Pressure Fittings*

ANSI B16.22-1980, *Wrought Copper and Copper Alloy Solder Joint Pressure Fittings*

ANSI B16.25-1986, *Buttwelding Ends*

ANSI B36.10M-1985, *Welded and Seamless Wrought Steel Pipe.*

3-1.2.2 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A53-1987, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless Steel Pipe*

ASTM A135-1986, *Standard Specification for Electric-Resistance-Welded Steel Pipe*

ASTM A234-1987, *Standard Specification for Piping Fittings of Wrought-Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures*

ASTM A795-1985, *Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use*

ASTM B32-1987, *Standard Specification for Solder Metal, 95-5 (Tin-Antimony-Grade 95TA)*

ASTM B88-1986, *Standard Specification for Seamless Copper Water Tube*

ASTM B251-1987, *Standard Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube*

ASTM E380-1986, *Standard for Metric Practice.*

3-1.2.3 AWS Publication. American Welding Society, 2501 N.W. 7th Street, Miami, FL 33125.

AWS A5.8-1981, *Specification for Brazing Filler Metal.*

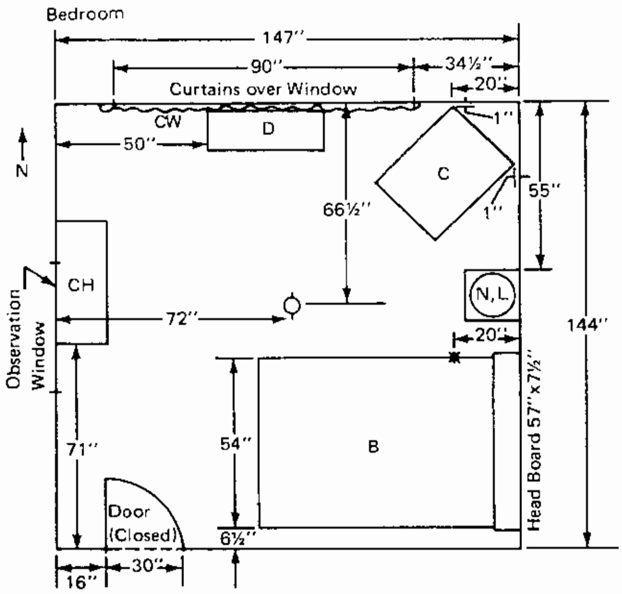
Appendix A

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1-1 NFPA 13R is appropriate for use only in residential occupancies, as an option to NFPA 13, *Standard for the Installation of Sprinkler Systems,* as defined in this standard, up to four stories in height. Residential portions of any other building may be protected with residential sprinklers in accordance with 3-11.2.9 of NFPA 13, *Standard for the Installation of Sprinkler Systems.* Other portions of such sections should be protected in accordance with NFPA 13.

The criteria in this standard are based on full-scale fire tests of rooms containing typical furnishings found in residential living rooms, kitchens, and bedrooms. The furnishings were arranged as typically found in dwelling units in a manner similar to that shown in Figures A-1-1(a), (b), and (c). Sixty full-scale fire tests were conducted in a two-story dwelling in Los Angeles, California, and 16 tests were conducted in a 14-ft (4.3-m) wide mobile home in Charlotte, North Carolina. Sprinkler systems designed and installed according to this standard are expected to prevent flashover within the compartment of origin if sprinklers are installed in the compartment. A sprinkler system designed and installed according to this standard may not, however, be expected to control a fire involving unusually higher average fuel loads than typical for dwelling units [10 psi (0.7 bar)], configurations of fuels other than those with typical residential occupancies, or conditions where the interior finish has an unusually high flame spread rating (greater than 225).

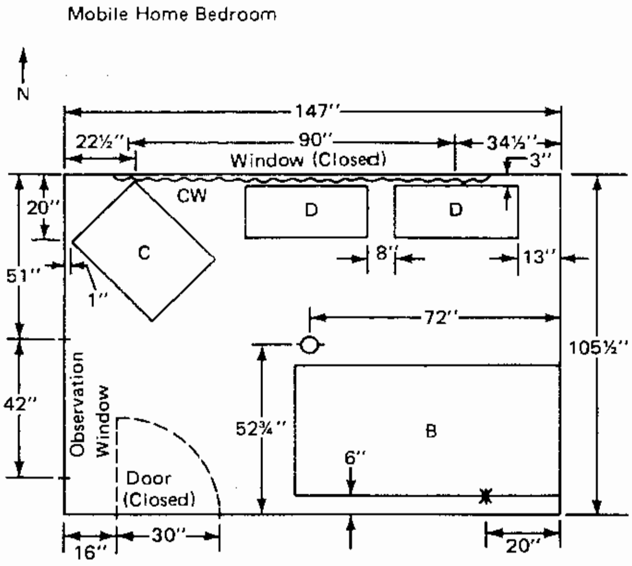
To be effective, sprinkler systems installed in accordance with this standard must have the sprinklers closest to the fire open before the fire exceeds the ability of the sprinkler discharge to extinguish or control that fire. Conditions that allow the fire to grow beyond that point before sprinkler activation or that interfere with the quality of water distribution can produce conditions beyond the capabilities of the sprinkler system described in this standard. Unusually high ceilings or ceiling configurations that tend to divert the rising hot gases from sprinkler locations or change the sprinkler discharge pattern from its standard pattern can produce fire conditions that cannot be extinguished or controlled by the systems described in this standard.



✱ Ignition
Sprinkler
CW Curtains
D Dresser
CH Chest
C Chair
B Bed
HB Head Board
N Night Stand
L Lamp

For SI Units: 1 in. = 25.4 mm.

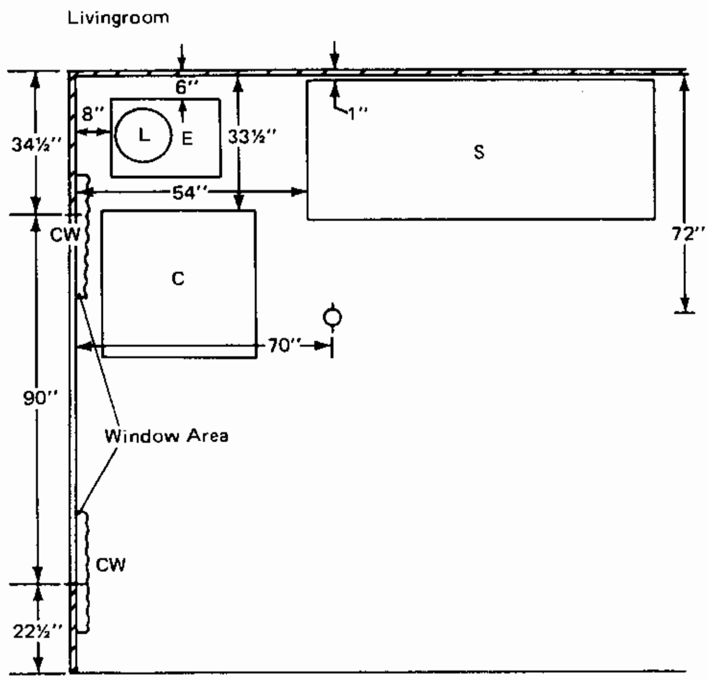
Figure A-1-1(a) Bedroom.



✱ Ignition
Sprinkler
CW Curtains
D Dresser
C Chair
B Bed

For SI Units: 1 in. = 25.4 mm.

Figure A-1-1(b) Mobile Home Bedroom.



S - Sofa
E - End Table
L - Lamp
C - Chair
CW - Curtains
Sprinkler

For SI Units: 1 in. = 25.4 mm.

Figure A-1-1(c) Living Room.

Table A-1-2
Annual Averages of Deaths and Injuries in Apartments
1980-1984

Fires–123,000	Civilian Deaths–930		Civilian Injuries–5,470
	Percentages by Area of Origin		
Area of Origin (901 Code)	Civilian Deaths (Used for Ranking)	Fires	Civilian Injuries
Living room, den, lounge (14)	38.5	11.3	23.2
Bedroom (21-22)	28.7	17.4	27.1
Kitchen (24)	9.8	35.3	27.2
Hallway corridor (101)	4.3	3.2	3.4
Interior stairway (03)	3.2	1.0	1.1
Structural Area (70-79)	3.1	8.1	3.5
[Balcony, porch (72)]	(1.2)	(1.3)	(0.7)
[Unspecified (79)]	(1.0)	(0.5)	(0.2)
[Ceiling/Roof assembly (74)]	(0.3)	(0.7)	(0.3)
Lobby (05)	1.3	0.6	0.7
Dining room (23)	1.2	0.8	1.0
Closet (42)	1.2	1.9	1.9
Balcony, porch (72)	1.2	1.3	0.7
Other known single area	4.1	17.8	8.8
[Bathroom (25)]	(0.6)	(2.1)	(1.3)
Multiple areas (97)	1.6	0.7	0.9
Unclassified, not applicable (98-99)	1.8	0.6	0.5
Total:	100.0	100.0	100.0

A-1-2 Levels of Protection. Various levels of sprinkler protection are available to provide life safety and property protection. The standard is designed to provide a high, but not absolute, level of life safety and a lesser level of property protection. Greater protection to both life and property could be achieved by sprinklering all areas in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, which permits the use of residential sprinklers in residential areas.

This standard recommends, but does not require, sprinklering of all areas in the building; it permits sprinklers to be omitted in certain areas. These areas are the ones shown by NFPA statistics to be ones where the incidence of life loss from fires in residential occupancies is low. Such an approach provides a reasonable degree of fire safety to life. (*See Table A-1-2 for Deaths and Injuries in Multifamily Residential Buildings.*)

It should be recognized that the omission of sprinklers from certain areas could result in the development of untenable conditions in adjacent spaces. Where evacuation times may be delayed, additional sprinkler protection and other fire protection features, such as detection and compartmentation, may be necessary.

A-2-1.3.2 Testing of a system can be accomplished by filling the system with water and checking visually for leakage at each joint or coupling.

Fire department connections are not required for all systems covered by this standard, but may be installed at the discretion of the owner. In these cases, hydrostatic tests in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, are required.

Dry systems should also be tested by placing the system under air pressure. Any leak that results in a drop in system pressure greater than 2 psi (0.14 bar) in 24 hours should be corrected. Check for leaks using soapy water brushed on each joint or coupling. Leaks will be shown by the presence of bubbles. This test should be made prior to concealing of piping.

A-2-2.1.1 At least three spare sprinklers of each type, temperature rating, and orifice size used in the system should be kept on the premises. When fused sprinklers are replaced by the owner, fire department, or others, care should be taken to assure that the replacement sprinkler has the same operating characteristics.

A-2-3.2 Connection for fire protection to city mains is often subject to local regulation concerning metering and backflow prevention requirements. Preferred and acceptable water supply arrangements are shown in Figures A-2-3.2(a), (b), and (c). When a meter must be used between the city water main and the sprinkler system supply, an acceptable arrangement is shown in Figure A-2-3.2(c). Under these circumstances, the flow characteristics of the meter must be included in the hydraulic calculation of the system. When a tank is used for both domestic and fire protection purposes, a low water alarm acuated when the water level falls below 110 percent of the minimum quantity specified in 2-3.1 should be provided.

A-2-3.3.1 The tables on the following page can be used to determine a domestic design demand. Using Table A-2-3.3.1(a), determine the total number of water supply fixture units downstream of any point in the piping serving both sprinkler and domestic needs. Using Table A-2-3.3.1(b), determine the appropriate total flow allowance, and add this flow to the sprinkler demand at the total pressure required for the sprinkler system at that point.

A-2-4.5.9.2 Decorative painting of a residential sprinkler is not to be confused with the temperature identification

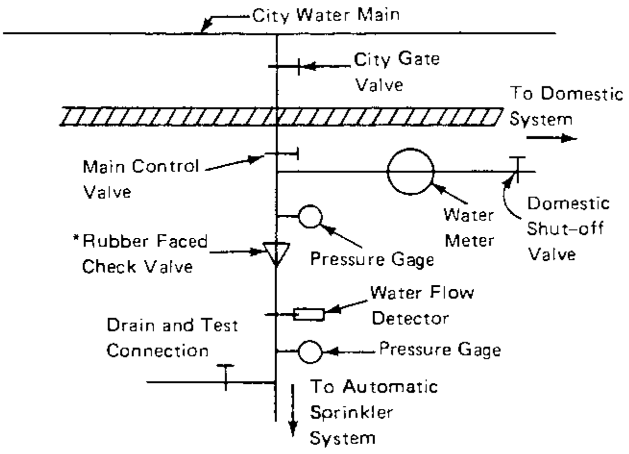


Figure A-2-3.2(a) Preferable Arrangement.

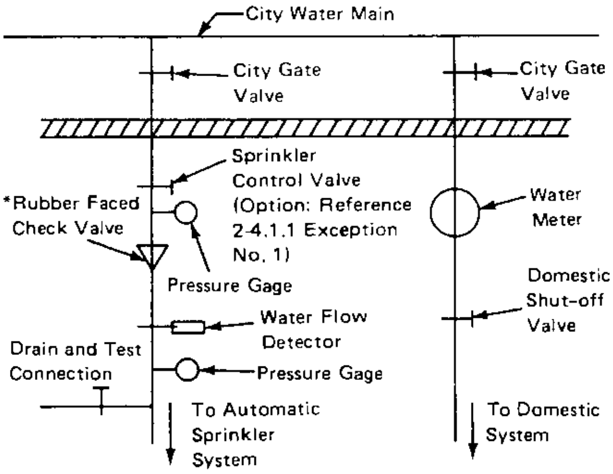
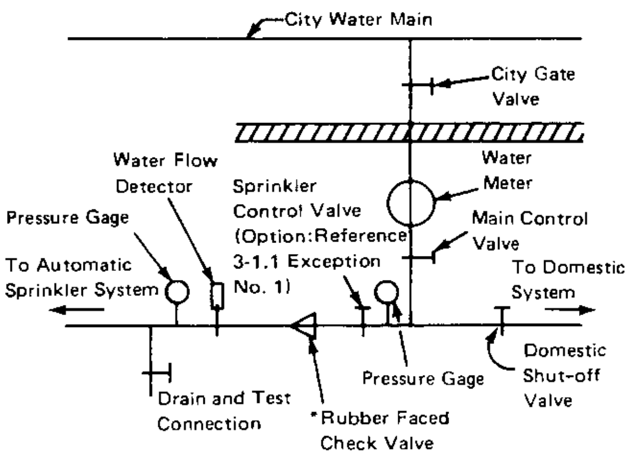


Figure A-2-3.2(b) Acceptable Arrangement with Valve Supervision. (*See 2-4.1.1 Exception.*)



*Rubber Faced Check Valves Optional.

Figure A-2-3.2(c) Acceptable Arrangement with Valve Supervision. (*See 2-4.1.1 Exception.*)

Table A-2-3.3.1(a) Fixture Load Values

Private facilities (within individual dwelling units)	**Unit**
Bathroom group with flush tank (including lavatory, water closet, and bathtub with shower)	6
Bathroom group with flush valve	8
Bathtub	2
Dishwasher	1
Kitchen sink	2
Laundry trays	3
Lavatory	1
Shower stall	2
Washing machine	2
Water closet with flush valve	6
Water closet with flush tank	3
Public Facilities	
Bathtub	4
Drinking fountain	0
Kitchen sink	4
Lavatory	2
Service sink	3
Shower head	4
Urinal with 1 in. flush valve	10
Urinal with ¾ in. flush valve	5
Urinal with flush tank	3
Washing machine (8 lb)	3
Washing machine (16 lb)	4
Water closet with flush valve	10
Water closet with flush tank	5

Table A-2-3.3.1(b) Total Estimated Domestic Demand

Total Fixture Load Units [from Table A-2-3.3.1(a)]	**Total Demand in Gallons Per Minute**	
	For Systems with Predominantly Flush Tanks	**For Systems with Predominantly Flush Valves**
1	3 gpm	
2	5	
5	10	15 gpm
10	15	25
20	20	35
35	25	45
50	30	50
70	35	60
100	45	70
150	55	80
200	65	90
250	75	100
350	100	125
500	125	150
750	175	175
1000	200	200
1500	275	275
2000	325	325
3500	500	500

colors as referenced in 3-11.6 of NFPA 13, *Standard for the Installation of Sprinkler Systems.*

A-2-5.1.2 It is intended that the design area is to include up to four adjacent sprinklers producing the greatest water demand within the compartment.

A-2-5.1.7.3 Fire testing has indicated the need to wet walls in the area protected by residential sprinklers at a level

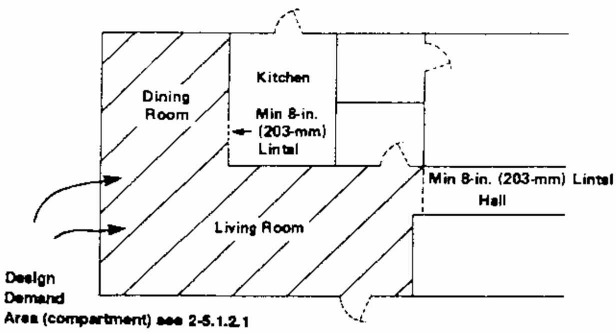


Figure A-2-5.1.2(a) Sprinkler Design Areas for Typical Residential Occupancy.

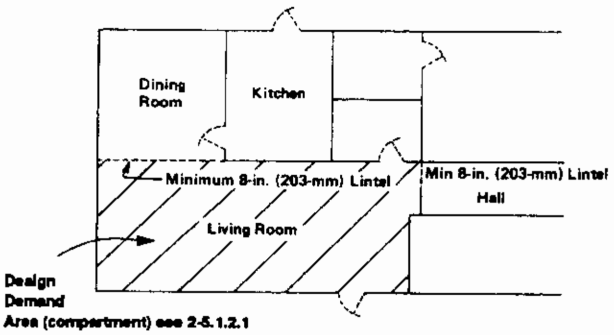


Figure A-2-5.1.2(b) Sprinkler Design Areas for Typical Residential Occupancy.

closer to the ceiling than that accomplished by standard sprinkler distribution. Where beams, light fixtures, sloped ceilings, and other obstructions occur, additional residential sprinklers may be necessary to achieve proper response and distribution, and a greater water supply may be necessary.

Table A-2-5.1.7.3 and Figure A-2-5.1.7.3 provide guidance for location of sprinklers near ceiling obstructions.

Table A-2-5.1.7.3 Maximum Distance from Sprinkler Deflector to Bottom of Ceiling Obstruction

Distance from Sprinkler to Side of Ceiling Obstruction	Maximum Distance from Sprinkler Deflector to Bottom of Ceiling Obstruction
Less than 6 in.	Not permitted
6 in. to less than 1 ft	0 in.
1 ft to less than 2 ft	1 in.
2 ft to less than 2 ft 6 in.	2 in.
2 ft 6 in. to less than 3 ft	3 in.
3 ft to less than 3 ft 6 in.	4 in.
3 ft 6 in. to less than 4 ft	6 in.
4 ft to less than 4 ft 6 in.	7 in.
4 ft 6 in. to less than 5 ft	9 in.
5 ft to less than 5 ft 6 in.	11 in.
5 ft 6 in. to less than 6 ft	14 in.

For SI Units: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

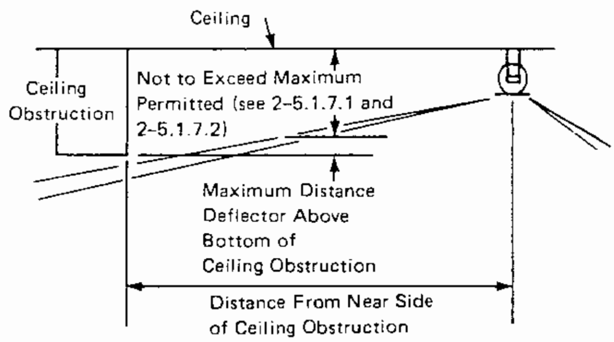


Figure A-2-5.1.7.3 Position of Deflector, Upright or Pendent, When Located Above Bottom of Ceiling Obstruction.

A-2-7 The responsibility for properly maintaining a sprinkler system is the obligation of the owner or manager, who should understand the sprinkler system operation. A minimum monthly maintenance program should include the following:

(a) Visual inspection of all sprinklers to ensure against obstruction of spray.

(b) Inspection of all valves to assure that they are open.

(c) Testing of all waterflow devices.

(d) Testing of the alarm system, if installed.

NOTE: When it appears likely that the test will result in a response of the fire department, notification to the fire department should be made prior to the test.

(e) Operation of pumps, where employed, should be operated. See NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps.*

(f) Checking of the pressure of air used with dry systems.

(g) Checking of water level in tanks.

Table A-2-7 Inspection, Testing, and Maintenance Requirements

Component	Activity	Frequency	Reference
Control Valve	Inspection	Monthly	
	Maintenance	Annually	NFPA 13A, 2-7.1.4
Main Drain Valve	Flow Test	Annually	NFPA 13A, 2-6.1
Inspectors' Test Valve	Flow Test	Annually	
Waterflow Alarm	Flow Test	Annually	NFPA 13A, 4-5.3, 4-7.1
Sprinklers	Test	50 Yrs.	NFPA 13A, 3-3.3
Sprinklers, Res/QR	Test	20 Yrs.	NFPA 13A, 3-3.4
Pump	Flow Test	Annually	NFPA 13A, 2-4.2.5
Antifreeze Solutions	Test	Annually	NFPA 13A, 4-7.3

(h) Care should be taken to see that sprinklers are not painted either at the time of installation or during subsequent redecoration. When painting sprinkler piping or painting in areas next to sprinklers, the sprinklers may be protected by covering with a bag, which should be removed immediately after painting is finished.

For further information see NFPA 13A, *Recommended Practice for the Inspection, Testing and Maintenance of Sprinkler Systems.*

Appendix B Referenced Publications

B-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

B-1.1 NFPA Publications. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 13-1989, *Standard for the Installation of Sprinkler Systems*

NFPA 13A-1987, *Recommended Practice for the Inspection, Testing and Maintenance of Sprinkler Systems*

NFPA 20-1987, *Standard for the Installation of Centrifugal Fire Pumps.*

UNIFORM BUILDING CODE STANDARD 10-1
POWER-OPERATED EGRESS DOORS

Test Standard of the International Conference of Building Officials

See Sections 1001.2 and 1003.3.1.2, *Uniform Building Code*

SECTION 10.101 — SCOPE

10.101.1 General. These requirements and methods of test apply to power-operated swinging doors and combination sliding and swinging doors intended for installation in locations where conforming exits are required by Chapter 10.

10.101.2 Operators and Activators. Power-operated doors may be provided with air, hydraulic or electric operators actuated from a floor, activating carpet, photoelectric device or other approved signaling device.

10.101.3 Fire Door Assemblies. Power-operated doors intended for installation in openings where fire door assemblies are required shall, in addition to the requirements of this standard, be tested in accordance with Fire Tests of Door Assemblies, UBC Standard 7-2.

SECTION 10.102 — GENERAL

10.102.1 Panic Hardware. Power-operated doors intended for installation in openings where panic hardware is required shall be tested with panic hardware on the doors.

10.102.2 Opening Degree. When manually operated in the direction of egress, leaves of swinging doors or swing-out sections of sliding doors shall swing open to not less than 90 degrees from the closed position.

10.102.3 Locking Mechanisms. Locking mechanisms on doors intended for locations which do not require panic hardware shall be of a type readily identified as locked, and the doors shall be posted with durable, permanent signs reading THESE DOORS MUST REMAIN UNLOCKED DURING BUSINESS HOURS. Signs shall be 1-inch-high (25.4 mm) block letters on a contrasting background. Signs shall be located on the header framing.

10.102.4 Swinging and Sliding Doors. Each swing-out leaf of swinging or sliding doors with swinging sections shall be provided with durable signs in not less than 1-inch (25.4 mm) block letters on a contrasting background reading, IN EMERGENCY PUSH TO OPEN, or other approved wording. The sign shall be located at the closing edge of the door not less than 36 inches (914 mm) nor more than 60 inches (1524 mm) above the floor. The sign shall read horizontally and may be in two lines.

10.102.5 Electrical Wiring and Devices. Electrical wiring, electrical devices and controls shall be of a type tested and approved by the building official.

10.102.6 Testing. Doors with power operators shall be examined and tested by an approved testing agency.

10.102.7 Test Report. The test report shall contain engineering data and drawings, size and weight of door tested, wiring diagrams of electrical control systems, schematic drawings of mechanical controls and operating manuals. The report shall describe the mechanical operation of the power operator in sequence as the door opens and closes under normal and emergency conditions. The report shall set forth the tests performed in accordance with the provisions of this standard and the results thereof. Additionally, the report shall contain an analysis comparing each feature of the design against the performance test procedures contained herein.

10.102.8 Simulated Installation and Test Equipment. Doors with power operators shall be installed in a simulated wall and door framing assembly in accordance with the manufacturer's instructions. The test specimen shall not be less than 3 feet wide (914 mm) by 7 feet high (2134 mm). A motor-driven or suitable mechanism shall be used to actuate the activating carpet. The rate of operation or number of cycles shall be three to five per minute. On sliding doors with a swing-out section, additional operating endurance tests shall be conducted. A motor-driven mechanism or other approved means shall be used to push the swinging door section open and pull the swinging section closed at a rate of three to five cycles per minute, so that the latching mechanism and disconnect switches operate as in service. During the test the door specimen shall have only the lubrication which is provided by the manufacturer at the factory, or as may be recommended in the manufacturer's installation instructions.

10.102.9 Endurance Tests. The power operator shall function as intended to open and close the door for 100,000 cycles of operation without failure or excessive wear of parts. The release mechanisms and disconnect switches of the swinging section in sliding doors shall function as intended for 250 cycles of operation without failure or excessive wear of parts. The opening and closing forces, and the speed of opening and closing, shall be recorded at the start of the endurance tests and shall again be recorded at the end of the endurance tests. Opening and closing forces at the beginning and at the end of the endurance test shall not exceed the maximum forces prescribed in these test procedures.

SECTION 10.103 — SWINGING DOORS

10.103.1 Opening Size. Each door opening, when the door is in the 90-degree open position, shall provide a clear opening width of not less than 32 inches (813 mm), with no single leaf less than 24 inches (610 mm) in width.

10.103.2 Doors in Pairs. Doors in pairs shall be equipped with a separate operator for each leaf unless tests with a tandem operator with one leaf jammed in a closed and in a partially open position indicates that the second leaf continues to operate or is free to swing into the open position without exceeding the maximum permitted manual opening pressures. On doors with mechanical controls, one mechanism shall be subjected to fault conditions; during the fault condition, the second leaf shall be openable manually without exceeding the maximum permitted opening pressure.

10.103.3 Closing Mechanism. Normal closing of doors shall be by spring action, pressure-operated mechanism or electrically driven mechanism. The closing force measured at the closing stile shall not exceed 40 pounds (178 N) at any point in the closing arc. The time of final 10 degrees of closing shall not be less than one and one-half seconds.

10.103.4 Operation. Each possible fault condition that affects the power supply shall be introduced into the door and power operator assembly. Under each fault condition, single doors and each leaf of doors in pairs shall open to the 90-degree position with an applied pressure at the normal location of the push plate not exceeding 40 pounds (178 N).

10.103.5 In-swinging Doors. Power-operated in-swinging doors are not recognized for determining exit width opening required to swing in the direction of egress.

10.103.6 Activating Carpets and Safety Mats. Activating carpets and safety mats shall comply with the following provisions:

1. When carpets are used as the activating device, they shall have a width not less than 10 inches (254 mm) less than the clear width of the door opening with the center line of the carpet in the center line of the door opening. The width shall be measured between the exposed edges of the carpet tread surface excluding molded edge bevels or edge trim.

2. The length of activating carpets shall not be less than 42 inches (1067 mm). The length of activating carpets for doors exceeding 42 inches (1067 mm) in width shall not be less than 56 inches (1422 mm). The length shall be measured from the center line of the door pivot to the exposed edge of the carpet tread surface excluding molded edge bevels or edge trim.

3. Doors serving one-way traffic only shall be provided with a safety mat having a length not less than the width of the widest leaf. A safety mat is one that will prevent the door from opening if there is pressure on the safety mat before pressure is applied to the activating mat, and one that will prevent the door from closing following normal door actuation until pressure on the safety mat is removed.

4. Doors serving both egress and ingress shall have a series of joined carpets on the swing side of the door arranged as follows:

4.1 One safety carpet or mat nearest to the door at least as long as the width of the door leaf;

4.2 One or more activating carpets to provide a total carpet length on the swing side of not less than two and one-half times the width of the widest door leaf.

SECTION 10.104 — SLIDING DOORS

10.104.1 General. Sliding doors shall comply with the following provisions:

1. Sliding leaves of sliding doors shall be provided with swinging sections arranged to swing in the direction of egress when pressure is applied at the location of normal push plates or on the crossbar of panic hardware on doors where panic hardware is required.

2. Operation of the swinging section shall disconnect the sliding door power operator.

3. Permanent stops shall be provided to prevent double swing.

4. Location of the breakaway tension adjustment, opening and closing speed adjustment, opening and closing snub speed adjustments, opening and closing power pressure adjustments, and similar controls shall be concealed and not readily accessible where they may be subject to tampering.

5. Doors shall be suspended from an overhead track. Operators and control levers or mechanisms shall be guarded.

10.104.2 Closing Mechanism. The closing force of sliding doors at 24 inches (610 mm) of opening shall not exceed 30 pounds (133 N) with a closing speed not in excess of 1.5 feet (457 mm) per second.

10.104.3 Opening Width. The minimum clear width of the door opening with the swinging section or sections in the 90-degree open position shall not be less than 32 inches (813 mm) with no single leaf less than 24 inches (610 mm) in width.

10.104.4 Opening Forces. The swinging section in sliding doors shall swing open into the full open position when an opening force not exceeding 40 pounds (178 N) is applied at the normal push plate location or on the crossbar of panic hardware.

10.104.5 Fault Condition Introduced. Under each possible fault condition that affects the power supply and with the sliding leaf or leaves retracted one half the leaf width into its or their pocket, each swinging section shall open to the 90-degree position with an applied pressure at the normal location of the push plate not exceeding 40 pounds (178 N).

10.104.6 Sliding Doors without Swing-out Section. Power-operated sliding doors which are not provided with a swing-out section may be evaluated for conformance to the mechanical requirements and endurance tests provided in this standard. Power-operated sliding doors which are not provided with a swing-out section shall not be listed for use in locations where required exits are specified by this code.

10.104.7 Activating Carpets and Safety Mats. Activating carpets and safety mats shall conform to Section 10.103.5.

SECTION 10.105 — MARKING

The name of the manufacturer, or trademark by which the manufacturer can be readily identified, shall be legibly marked on the operating equipment where it can be seen after installation. The type, model number or letter designation identifying the product as a listed device shall be provided on a label attached in a location as indicated in its listing.

UNIFORM BUILDING CODE STANDARD 10-2
STAIRWAY IDENTIFICATION

Specification Standard of the International Conference of Building Officials

See Sections 1001.2 and 1003.3.3.13, *Uniform Building Code*

SECTION 10.201 — SCOPE

Signs to provide information to the occupants and fire department personnel to ensure that they do not become confused during emergencies shall be installed in accordance with this standard.

SECTION 10.202 — GENERAL

Standardized signs shall be installed in stairways when the building is four or more stories in height. The signs shall identify each stair landing and indicate the upper and lower termination of the stairway.

SECTION 10.203 — SIGN DETAILS

10.203.1 Size. Signs shall be a minimum 12 inches (305 mm) by 12 inches (305 mm).

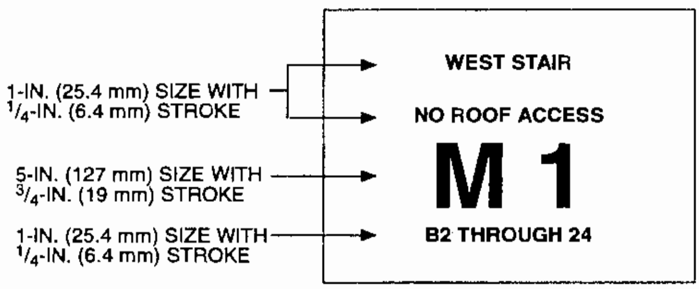
10.203.2 Stairway Location. The stairway location, such as STAIR NO. 1 or WEST STAIR, shall be placed at the top of the sign in 1-inch-high (25.4 mm) block lettering with $^{1}/_{4}$-inch (6.4 mm) strokes.

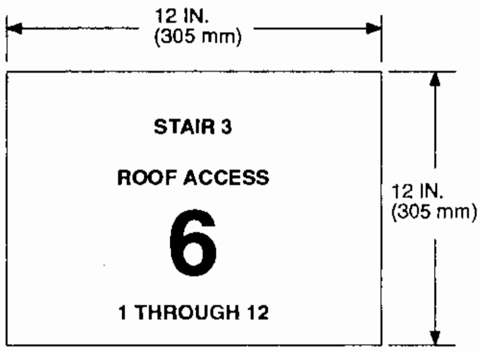
10.203.3 Upper Terminus. The stairway's upper terminus, such as ROOF ACCESS or NO ROOF ACCESS, shall be placed under the stairway identification in 1-inch-high (25.4 mm) block lettering with $^{1}/_{4}$-inch (6.4 mm) strokes.

10.203.4 Floor Level Number. The floor level number shall be placed in the middle of the sign in 5-inch-high (127 mm) lettering with $^{3}/_{4}$-inch (19 mm) strokes. The mezzanine levels shall have the letter "M" preceding the floor number. Basement levels shall have the letter "B" preceding the floor number.

10.203.5 Lower Terminus. The lower and upper terminus of the stairway shall be placed at the bottom of the sign in 1-inch-high (25.4 mm) block lettering with $^{1}/_{4}$-inch (6.4 mm) strokes.

Examples:





UNIFORM BUILDING CODE STANDARD 10-3
EXIT LADDER DEVICE

Test Standard of the International Conference of Building Officials

See Appendix Section 3407.1, *Uniform Building Code*

SECTION 10.301 — SCOPE

This standard for exit ladder devices is applicable where such devices are permitted by the building official for installation on existing apartment houses and hotels in conformance with Appendix Section 3412.1 of this code.

SECTION 10.302 — INSTRUCTIONS

Installation shall be in accordance with the manufacturer's instructions. Instructions shall be illustrated and shall include directions and information adequate for attaining proper and safe installation of the product. Where exit ladder devices are intended for mounting on different support surfaces, specific installation instructions shall be provided for each surface.

SECTION 10.303 — GENERAL DESIGN

All load-bearing surfaces and supporting hardware shall be of noncombustible materials. Exit ladder devices shall have a minimum width of 12 inches (305 mm) when in the position intended for use. The design load shall not be less than 400 pounds (1780 N) for 16-foot (4877 mm) length and 600 pounds (2669 N) for 25-foot (7620 mm) length.

SECTION 10.304 — PERFORMANCE

10.304.1 Exit ladder devices shall be capable of withstanding an applied load of four times the design load when installed in the manner intended for use. Test loads shall be applied for a period of one hour.

10.304.2 Exit ladder devices of the retractable type shall, in addition to the static load requirements of Section 10.304.1, be capable of withstanding the following tests:

1. Rung strength.
2. Rung-to-side-rail shear strength.
3. Release mechanism.
4. Low temperature.

SECTION 10.305 — RUNG-STRENGTH TEST

Rungs of retractable exit ladder devices shall be capable of withstanding a load of 1,000 pounds (4448 N) when applied to a $3^1/_2$-inch-wide (89 mm) block resting at the center of the rung. The test load shall be applied for a period of one hour. The ladder shall remain operational following this test.

SECTION 10.306 — RUNG-TO-SIDE-RAIL SHEAR TEST

Rungs of retractable exit ladder devices shall be capable of withstanding a load of 1,000 pounds (4448 N) when applied to a $3^1/_2$-inch-wide (89 mm) block resting on the center rung as near the side rail as possible. The test load shall be applied for a period of one hour. Upon removal of the test load the fasteners attaching the rung to the side rail shall show no evidence of failure. The ladder shall remain operational following this test.

SECTION 10.307 — RELEASE MECHANISM TEST

The release mechanism of retractable exit ladder devices shall operate with an average applied force of not more than 5 pounds (22.2 N) for hand-operated releasing mechanisms and an average applied force of not more than 25 pounds (111 N) for foot-pedal types of releasing mechanisms. For these tests, a force gauge shall be applied to the release mechanism, and the average of three consecutive readings shall be computed.

SECTION 10.308 — LOW TEMPERATURE OPERATION TEST

Representative samples of the exit ladder device shall be subjected to a temperature of –40°C in an environmental chamber for a period of 24 hours. The release mechanism shall be operated immediately upon removal from the chamber. The ladder device shall function as intended without any restriction of operation.

UNIFORM BUILDING CODE STANDARD 10-4
PANIC HARDWARE

Based on Standard 305, July 30, 1979, of the Underwriters Laboratories Inc.

See Sections 1001.2 and 1003.3.1.9, *Uniform Building Code*

SECTION 10.401 — SCOPE

10.401.1 General. These requirements cover releasing devices actuated by a crossbar for outward-opening doors designed to facilitate the safe egress of persons from buildings in the event of panic or other emergency.

10.401.2 Installation. A copy of the operating and installation instructions or equivalent information is to be furnished with the samples submitted for investigation for use as a guide in the examination and test of the mechanism. For this purpose a printed edition is not required.

SECTION 10.402 — CONSTRUCTION

10.402.1 Assembly. The mechanism shall be of a type which can be readily maintained in proper operating condition.

The mechanism shall be designed so as to release the door latch or latches when pressure is applied to the release bar in the direction of exit travel.

The ends of the release bar shall be curved, guarded or otherwise designed to prevent them from catching on the clothing of persons during exit.

The release mechanism shall not depend on springs to open the door latch or latches.

A locking or dogging device provided as part of the mechanism shall not prevent release of the door latch or latches when pressure is applied to the release bar in the direction of exit travel.

A dead-locking bolt shall not be employed unless it is released by the action of the release bar.

The projection of the release bar when in the depressed position shall not unduly restrict the exit opening.

10.402.2 Materials. The materials employed shall have adequate mechanical strength to perform their intended function. A metal or alloy shall have a solidus point not less than 1,000°F (538°C).

The materials employed shall minimize the likelihood of the release mechanism becoming inoperative due to corrosion.

SECTION 10.403 — PERFORMANCE

10.403.1 Endurance Test. The release mechanism and latches shall function as intended for 100,000 cycles of operation without failure or excessive wear of the parts.

The assembly is to be installed on a simulated door and frame assembly in accordance with the manufacturer's instructions. A motor-driven mechanism is to actuate the release bar so as to release the latches and push the door open, as in service. The rate of operation is to be approximately 30 cycles of operation per minute. For this test, the assembly is to have the lubrication which is provided at the factory or recommended by the manufacturer.

10.403.2 Emergency Operation Test. The release mechanism shall be so designed that a horizontal force of 15 pounds (67 N) or less will actuate the release bar and latches. When the latched door is subjected to outward pressure as described below, a force of 50 pounds (222 N) or less shall actuate the release bar.

The sample is to be subjected to the 15-pound (67 N) test before and after the endurance test and subjected to the 50-pound (222 N) test after the endurance test.

A horizontal force of 250 pounds (1112 N) is to be applied against the latching edge adjacent to the latch in the direction in which the door opens. A spring scale or similar means is to be used to measure the horizontal force which is applied against the center of the release bar.

For double doors, a horizontal force of 250 pounds (1112 N) is to be applied against the midpoint of the outer stile of each door.

The release bar is not to be deformed by the test, and a spacing of at least 1 inch (25.4 mm) is to be provided between the release bar and the door face when the horizontal force is applied against the center of the release bar.

SECTION 10.404 — MARKING

The manufacturer's or vendor's name and a distinctive type of model designation shall be plainly marked on the release-bar assembly.

If a manufacturer produces panic hardware assemblies at more than one factory, each such assembly shall have a distinctive marking or identifying symbol to identify it as the product of a particular factory.

UNIFORM BUILDING CODE STANDARD 14-1
KRAFT WATERPROOF BUILDING PAPER

Based on Federal Specification UU-B-790a (February 5, 1968)

See Sections 601.3, 711.1, 1401.2 and 1402.1, *Uniform Building Code*

SECTION 14.101 — SCOPE

This standard covers building papers composed predominantly of sulfate pulp fibers intended for use as a weather-resistive barrier.

SECTION 14.102 — CLASSIFICATION

The building papers shall be of Type I and not less than the following grades:

Grade A—High water-vapor resistance.

Grade B—Moderate water-vapor resistance.

Grade C—Water resistant.

Grade D—Water-vapor permeable.

Style 1a—Uncreped, not reinforced.

Style 1b—Uncreped, not reinforced, red rosin sized.

Style 2—Uncreped, not reinforced, saturated.

Style 3—Creped one direction, not reinforced.

Style 4—Uncreped, reinforced.

SECTION 14.103 — GENERAL REQUIREMENTS

14.103.1 Description. The paper shall be either a single-ply or a multi-ply lamination.

14.103.2 Paper. The paper shall consist of 100 percent sulfate pulp fibers, free of ground wood pulp, except as permitted in Section 14.104.8.

14.103.3 Construction. Lapped papers shall be securely cemented together throughout the seam area and shall have a minimum lap of 4 inches (102 mm). Laminated paper shall contain no area of more than $^1/_2$ inch (13 mm), measured from the longitudinal edge of the combined sheet, which is devoid of the laminating agent. The paper shall not stick together to such an extent as to cause tearing when unrolled.

14.103.4 Treatment. The paper shall be treated by the addition of asphalt, asphalt waxes, wax blends, wet-strength resins, rosins, fire-retarding salts or any combining agent, to impart the necessary characteristics to the paper.

14.103.5 Reinforcing. When reinforcing is provided, the paper shall be reinforced by imbedding cords or strands of vegetable or inorganic fibers in the combining agent of the lamination.

SECTION 14.104 — SPECIFIC REQUIREMENTS

14.104.1 General. Except for Style 2, the paper shall not crack when bent over a $^1/_{16}$-inch (1.6 mm) mandrel at the temperature of 32°F (0°C). If reinforced, the cords or strands shall average not less than 10 per foot (305 mm) in each direction.

14.104.2 Grade A, High Water-Vapor Resistant. Grade A paper shall have the dry tensile strength, water-resistance and water-vapor transmission properties shown in Table 14-1-A.

14.104.3 Grade B, Moderate Water-Vapor Resistant. Grade B paper shall have the dry tensile strength, water-resistance and water-vapor transmission properties shown in Table 14-1-A.

14.104.4 Grade C, Water Resistant. Grade C paper shall have the dry tensile strength and water-resistance properties shown in Table 14-1-A.

14.104.5 Grade D, Water-Vapor Permeable. Grade D paper shall have the dry tensile strength, water-resistance and water-vapor transmission properties shown in Table 14-1-A.

14.104.6 Style 1a, Uncreped, Unreinforced. Style 1a paper shall be uncreped and shall not be reinforced.

14.104.7 Style 1b, Uncreped, Unreinforced, Red Rosin Sized. Style 1b paper shall be uncreped, not reinforced, and shall be coated with red rosin sizing.

14.104.8 Style 2, Uncreped, Unreinforced, Saturated. Style 2 paper shall be uncreped, not reinforced, and shall be saturated or infused with asphalt on both sides. Ground wood pulp may be included in the paper.

14.104.9 Style 3, Creped One Direction, Unreinforced. Style 3 paper shall be creped in one direction, not reinforced, and shall have a minimum elongation (stretch) of 15 percent.

14.104.10 Style 4, Uncreped, Reinforced. Style 4 paper shall be uncreped and reinforced.

SECTION 14.105 — TEST SPECIMENS

14.105.1 General. Test specimens shall be of the size designated by the applicable test or as otherwise provided herein.

The specimens shall be cut from the interior of the sample roll so that no specimen edge is nearer than 3 inches (76 mm) to the original sample edge. A minimum of 10 specimens, five in each direction of the paper, shall be cut from each sample for fire-resistance tests. Five specimens, each 5 inches square (127 mm by 127 mm), shall be cut from each sample for water-repellency tests. One specimen, 6 inches by 1 inch (153 mm by 25 mm) in the machine direction of the paper, shall be cut from each sample for the pliability test.

14.105.2 Grade Requirement. Grade requirement tests shall be made. Nonconformance to grade requirements of Table 14-1-A shall constitute failure of this test.

TABLE 14-1-A—GRADE REQUIREMENTS[1]

PHYSICAL PROPERTY REQUIREMENT	GRADE A	GRADE B	GRADE C	GRADE D
Dry tensile strength: minimum, pounds per inch width, both directions	20 (3500 N/m)	20 (3500 N/m)	20 (3500 N/m)	20 (3500 N/m)
Water resistance: permeation of water through papers, hours minimum	24	16	8	$^1/_6$
Water-vapor transmission: grams per sq. meter per 24 hours				
Maximum	4	6	—	—
Minimum	—	—	—	35

[1]Approved test methods shall be used.

UNIFORM BUILDING CODE STANDARD 14-2
VINYL SIDING

Based on Standard Specification D 3679-91 for Rigid Polyvinyl Chloride (PVC) of the American Society for Testing and Materials

See Sections 1401.2 and 1404, *Uniform Building Code*

SECTION 14.201 — SCOPE

This standard establishes requirements and test methods for the materials, dimensions, warp, impact strength, weatherability, expansion and appearance of extruded single-wall siding manufactured from rigid PVC compound.

Unless specifically adopted elsewhere, supplemental standards referenced in this primary standard shall only be considered as guidance subject to the approval of the building official.

SECTION 14.202 — CONDITIONING

Specimens shall be preconditioned and tested in accordance with Procedure A of the ASTM D 618-61 (Reapproved 1990) for Method of Conditioning Plastics and Electrical Insulating Materials for Testing.

SECTION 14.203 — PHYSICAL REQUIREMENTS

The siding shall be made principally of polyvinyl chloride compound prepared from polyvinyl chloride homopolymer resin. The compound shall conform to the requirements of Table 14-2-A. The siding made from the resin shall conform to the requirements of Table 14-2-B.

14.203.1 Warp. A full length of siding shall not have a warp greater than $^1/_8$ inch (3.2 mm).

14.203.2 Surface Distortion. The siding shall be free of bulges, waves and ripples.

SECTION 14.204 — WEATHERABILITY

14.204.1 General. The purpose of this test is to determine whether the siding will successfully retain its appearance after exposure to weather conditions for an extended period of time.

14.204.2 Procedure. Extruded specimens 6 inches (153 mm) long shall be exposed to the following climates:

1. Hot, dry climate (example: Phoenix, Arizona).

2. Hot, humid climate (example: Miami, Florida).

3. Temperature, northern, industrial climate (example: Cincinnati, Ohio).

Specimen exposures shall be in accordance with ASTM D 1435-85. Samples shall face south either at a 45-degree angle of elevation for a minimum of one year or at an angle of elevation representative of the manufacturer's normal installation requirements for the siding for at least two years.

14.204.3 Conditions of Acceptance. Following exposure, the siding shall maintain a uniform color and be free of any visual surface or structural changes such as peeling, chipping, cracking, flaking and pitting.

SECTION 14.205 — MARKING

Each carton shall be labeled "Conforms to UBC Standard 14-2."

TABLE 14-2-A—MINIMUM PROPERTIES FOR PVC COMPOUNDS USED FOR SIDING

Impact strength: (ft. lb./in. of notch)	1.5 (0.08 N•m/mm of notch)
Tensile strength (psi)	5,510 (37.99 MPa)
Modulus of elasticity (psi)	290,000 (1999 MPa)
Deflection temperature under load, (°F, at 264 psi)	158 (70°C, at 1.82 MPa)

TABLE 14-2-B—MINIMUM PROPERTIES FOR PVC SIDING

Thickness (in.)	0.035 (0.89 mm)
Impact Resist. (in./lb./mil)	
Embossed Siding	1.74 (391 mm/N/mm)
Unembossed	2.0 (450 mm/N/mm)
Coefficient of Lineal Expansion (max.) (in./in./°F)	4.5×10^{-5} (2.5×10^{-5} m/m/°C)

UNIFORM BUILDING CODE STANDARD 15-1
ROOFING AGGREGATES

Material Standard of the International Conference of Building Officials

See Section 1501.1 and Table 15-E, *Uniform Building Code*

SECTION 15.101 — SCOPE

This standard covers the quality, grading and amounts to be applied of mineral roofing aggregate.

SECTION 15.102 — CHARACTERISTICS

The mineral aggregate at the time of application shall be hard, durable, opaque, chemically inert, free of clay, loam, sand or foreign substances, and surface dry to 0.5 percent by weight moisture content.

SECTION 15.103 — GRADING

The mineral aggregate shall conform to the sieve analysis requirements prescribed in Table 15-1-A.

SECTION 15.104 — WATER ABSORPTION

Aggregate shall not absorb more than 5 percent of the dry weight of the aggregate when tested using any nationally recognized standard.

SECTION 15.105 — TRANSLUCENCY

Aggregate shall have a translucency intensity of not more than "slight" when visually inspected.

SECTION 15.106 — HARDNESS

Aggregate shall have a hardness factor of not more than 20 percent.

SECTION 15.107 — APPLICATION

If the unit weight (loose) of the aggregate is 60 pounds per cubic foot (960 kg/m^3), or more, the amount applied per roofing square shall be as specified in this code.

If the unit weight (loose) is less than 60 pounds per cubic foot (960 kg/m^3), the amount applied shall be as follows:

1. For an embedment coat of 60 pounds of asphalt per roofing square (3.0 kg/m^2), not less than 5 cubic feet of aggregate per roofing square (0.015 m^3/m^2) shall be applied.

2. For an embedment coat of 50 pounds of asphalt per roofing square (2.5 kg/m^2), not less than 4 cubic feet of aggregate per roofing square (0.012 m^3/m^2) shall be applied.

TABLE 15-1-A—MINERAL AGGREGATE SIEVE ANALYSIS REQUIREMENTS

SIEVE SIZE	FOR USE WITH EMBEDMENT COAT OF 60 POUNDS PER ROOFING SQUARE (3.0 kg/m^2) (percentage)	FOR USE WITH EMBEDMENT COAT OF 50 POUNDS PER ROOFING SQUARE (2.5 kg/m^2) (percentage)
$^5/_8$" (16 mm)	100	100
$^1/_2$" (12.5 mm)	90-100	100
$^3/_8$" (9.5 mm)	25-60	90-100
$^1/_4$" (6.3 mm)	0-10	30-70
No. 4 (4.75 mm)	0-2	0-10
No. 8 (2.36 mm)		0-4
No. 10 (2 mm)		0-1
No. 20 (850 mm)	0-0.5	0-0.5

UNIFORM BUILDING CODE STANDARD 15-2
TEST STANDARD FOR DETERMINING THE FIRE RETARDANCY OF ROOF ASSEMBLIES

Based on Standard Specification 790 October 5, 1983, of the Underwriters Laboratories Inc.

See Sections 601.3; 1501.1; 1502; 2602.5.2; 2603.1.6; 2603.7.1, Item 2; Table 15-A, *Uniform Building Code*

SECTION 15.201 — GENERAL

15.201.1 Scope. These requirements cover the performance of roof-covering materials exposed to fire conditions, and are intended to indicate the characteristics of roof coverings when exposed to fire originating from sources outside a building on which the coverings may be installed. They are applicable to roof coverings intended for installation on either combustible or noncombustible decks when the roof coverings are applied as intended.

Class A roofing assemblies are effective against severe fire test exposures. Under such exposures, roofing assemblies of this class are not readily flammable, afford a fairly high degree of fire protection to the roof deck, do not slip from position, and are not expected to produce flying brands.

Class B roofing assemblies are effective against moderate fire test exposures. Under such exposures, roofing assemblies of this class are not readily flammable, afford a moderate degree of fire protection to the roof deck, do not slip from position, and are not expected to produce flying brands.

Class C roofing assemblies are effective against light fire test exposures. Under such exposures, roofing assemblies of this class are not readily flammable, afford a measurable degree of fire protection to the roof deck, do not slip from position and are not expected to produce flying brands.

Tests conducted in accordance with these requirements are intended to demonstrate the performance of roof coverings during the types and periods of exposure involved, but are not intended to determine the acceptability of roof coverings for use after exposure to fire.

Roof-covering materials are also required to comply with the requirements for construction, material specifications and performance as applicable to specific types, designs, sizes and arrangements. All such applicable additional requirements are not considered to be within the scope of these requirements for fire tests.

The terms "combustible" and "noncombustible" as used in the standard apply to decks as follows:

1. Combustible is a deck formed of wood (sheathing boards or plywood).

2. Noncombustible is a deck formed of metal, concrete or poured gypsum.

15.201.2 Test Apparatus. As illustrated in Figure 15-2-1, the apparatus used for the tests described in Section 15.202 is to consist of the following:

1. A test deck to which the roof-covering materials to be tested are applied, mounted on a framework. The pitch of the framework is to be adjustable.

2. A construction of noncombustible boards, mounted on the front of the framework to simulate eaves and cornices.

3. A gas burner (for intermittent-flame, spread-of-flame and flying-brand tests) consisting of a 44-inch (1120 mm) length of nominal 2-inch (51 mm) [2.38-inch (60.3 mm) outside diameter] pipe having a $^1/_2$-inch-wide (12.7 mm), 36-inch-long (910 mm) slot in the side toward the test deck. The burner is to be supplied with gas at both ends through nominal 1-inch (25 mm) [1.32-inch (33.4 mm) outside diameter] pipe to provide uniform gas pressure at the burner assembly.

4. A blower and air duct for providing the required wind conditions. The air introduced by the blower is to be taken from outside the test room.

5. Adjustable fins mounted inside the air duct to straighten the airstream and reduce turbulence.

6. A baffle mounted on the back edge of the test deck to prevent backfiring under the deck.

7. Noncombustible boards extending from the sides and bottom of the air duct to the simulated-eaves-and-cornice construction mentioned in Item 2 (not used during burning-brand test).

The tests are to be conducted in a room vented to the outer air to relieve the air pressure created by the blower. During these tests, all doors and windows in the room are to be closed, and the room otherwise controlled as necessary to prevent outside wind and weather conditions from affecting the test results. Tests are not to be conducted if the room temperature is less than 50°F (10°C) or more than 90°F (32°C).

Figure 15-2-2 illustrates the essential elements of the rain test apparatus.

15.201.3 Preparation of Samples.

15.201.3.1 Deck construction. Except for treated wood shingles or shakes for the intermittent-flame and the burning-brand tests, the test deck is to be $3^1/_3$ feet (1016 mm) wide by $4^1/_3$ feet (1320 mm) long and is to be made of kiln-dried No. 1 white pine or ponderosa pine lumber with not less than 8 percent or more than 12 percent moisture content. The lumber is to be free from large or loose knots, sapwood, rot or pitch pockets, and is to contain no edge knots. Individual deck boards are to be of nominal 1-inch-by-8-inch (25 mm by 203 mm) lumber (dressed on four sides). If used for the Class C burning-brand test, the width of the deck board is to be such that the brands will be located directly over the spaces between the boards. The deck boards are to be laid across the shorter dimension of the test deck, spaced $^1/_4$ inch (6.4 mm) apart, and securely nailed to two nominal 2-inch-by-4-inch (51 mm by 102 mm) wood battens located under and flush with the outer edges of the deck. Decks so constructed are to be even and uniform.

For the intermittent-flame, burning-brand and flying-brand tests on treated wood shingles and shakes, the test decks are to be constructed of nominal 1-inch-by-4-inch (25 mm by 102 mm) lumber (dressed on four sides), spaced $^1/_2$ inch (13 mm) apart and securely nailed to two nominal 2-inch-by-4-inch (51 mm by 102 mm) wood battens. The lumber is to be of the quality specified in the above paragraph.

At the manufacturer's option, the roof covering may be investigated when applied to plywood decks of the minimum thickness recommended by the manufacturer. The plywood (A-C grade, Group 1, exterior) is to have face and back veneers of Douglas fir. A plywood deck is to have $^1/_8$-inch (3.2 mm) vertical and horizontal joints, and all vertical joints are to be centered on nominal 2-inch-by-4-inch (51 mm by 102 mm) wood battens. If the manufacturer specifies that the battens are also to be used for horizontal joints, the classification shall be so restricted.

A plywood deck to be used for the intermittent-flame test is to have a horizontal joint 8 inches (229 mm) from and parallel to the $3^1/_3$-foot-long (1020 mm) leading edge. In addition, a vertical joint that is centered on the deck and extends from the leading edge of the deck to the horizontal joint is to be provided. As the lower $1^1/_2$ inches (38 mm) of this joint is not protected by the nominal 2-inch-by-4-inch (51 mm by 102 mm) batten, due to the mounting arrangement of the carriage, the underside of this joint from the end of the 2 by 4 (51 mm by 102 mm) to the leading edge of the deck is to be covered by a piece of sheet steel 2 inches (51 mm) wide.

A plywood deck to be used for a Class A or Class B burning-brand test is to be provided with a horizontal joint that is $22^1/_2$ inches (572 mm) from and parallel to the leading edge of the deck. A deck to be used for a Class A test is to have a vertical joint centered on the deck and extending above the horizontal joint. A deck to be used for a Class B test is to be provided with two vertical joints, extending above the horizontal joint, and each located 10 inches (254 mm) from and parallel to the side edges of the deck. A plywood deck to be used for a Class C burning-brand test is to have five horizontal joints with at least $^1/_8$-inch (3.2 mm) spacing between joints in the plywood.

Unless the material to be tested is intended for use on noncombustible decks only, the test deck for the spread-of-flame test, on material other than wood shingles and shakes, is to be constructed in accordance with either the intermittent-flame test or the manufacturer's option above, except that (1) the vertical and horizontal joints need not be provided and (2) the length of the deck is to be 13 feet (3962 mm) for Class C tests; 9 feet (2743 mm) for Class B tests; and 8 feet (2438 mm) for Class A tests. For tests on materials intended for use on noncombustible decks only, a noncombustible deck of the applicable length may be used. The test deck for wood shingles and shakes is to be constructed of nominal 1-inch-by-4-inch (25 mm by 102 mm) lumber (dressed on four sides) spaced $1^1/_2$ inches (38 mm) apart, and securely nailed to two nominal 2-inch-by-4-inch (51 mm by 102 mm) wood battens, except that the length of the deck is to be as specified above.

15.201.3.2 Roofing assembly application. Representative samples of roofing assemblies or roof-covering material are to be applied to test decks constructed in accordance with the applicable requirements described. The assemblies are to be conditioned in accordance with Section 15.201.3.3. The material to be tested is to be applied, in accordance with the manufacturer's instructions, to the applicable number of test decks as specified in Table 15-2-A. The material is to extend to, and be flush with, the edges of the deck, except for a 1-inch (25 mm) overhang at the leading edge.

15.201.3.3 Conditioning. The completed test assemblies are to be stored indoors at temperatures not lower than 60°F (16°C) or higher than 90°F (32°C) for the period of time necessary to cure the material, but not more than 60 days. Should storage conditions vary from those specified, the decks are to be stored until moisture determinations indicate that the deck lumber has no less than 8 percent or more than 12 percent moisture content. Test decks are to be stored so that each will be surrounded by freely circulating air.

SECTION 15.202 — PERFORMANCE

15.202.1 General. The intermittent-flame test, the spread-of-flame test and the burning-brand test are applicable to all roof coverings. The flying-brand test, the rain test and the weathering test are conducted only on treated wood shingles and shakes.

> **EXCEPTION:** When the roof covering is limited to installation on noncombustible decks, the penetration tests, that is, the intermittent-flame test and the burning-brand test, need not be conducted.

For these tests, mortar (cementitious mixture, lime and water) is to be troweled into the joint formed by the leading edge of the roof-covering material and the framework of the carriage, to prevent air or the test flame from traveling under the material being tested.

During the tests, the test decks are to be subjected to an air current that flows uniformly over the top surface of the roof-covering material, as determined by a pretest calibration of the equipment using a bare $3^1/_3$-foot-by-$3^1/_4$-foot (1016 mm by 991 mm) plywood deck. At points midway up the slope of the bare deck, with the deck positioned at an incline of 5 inches to the horizontal foot (127 mm per 0.3 m), the velocity of the air current is to be 12 ± $^1/_2$ miles per hour (19 ± 0.8 km/h), as measured at the center and edges of the deck, with each measurement being $3^{11}/_{16}$ inches (94 mm) above the surface of the deck.

For these tests, the test decks are to be at an incline of 5 inches per horizontal foot (127 mm per 0.3 m); except that built-up roof coverings are to be tested at the maximum incline recommended by the manufacturer, but not more than 5 inches per horizontal foot (127 mm per 0.3 m).

15.202.2 Intermittent-flame Test. A test deck is to be mounted on the framework at the required incline, and subjected to the specified air current. The test deck is then to be subjected to a luminous gas flame approximately triangular in shape, approximately 3 feet (914 mm) wide at the leading edge of the deck, and gradually narrowing to a width of approximately 6 inches (151 mm) at the top of the deck. Licks of flame may extend approximately an additional 1 to 2 feet (300 mm to 600 mm). The gas supply is to be regulated so that the flame, if not augmented by combustion of the roof covering, develops a temperature of 1,400°F ± 50°F (760°C ± 28°C) for a Class A or Class B test, and 1,300°F ± 50°F (704°C ± 28°C) for a Class C test. The temperature is to be determined by a No. 14 B.&S. gage (0.064 inches) (1.63 mm) chromel-alumel wire thermocouple located 1 inch (25.4 mm) toward the source of flame from the lower edge of the first board of a bare deck formed of noncombustible material.

The flame is to be intermittently applied at intervals as specified in Table 15-2-B.

Following the last application of flame, air current is to be maintained until all evidence of flame, glow and smoke has disappeared from the exposed surface of the material being tested or until unacceptable results occur, but in no case is the air current to be maintained for more than one hour for a Class A or Class B test or one-half hour for a Class C test.

During the intermittent-flame test, including the on and off periods of flame application and the subsequent period of maintained airflow, the test deck is to be observed for the appearance of sustained flaming on the underside, production of flaming or glowing brands, displacement of portions of the test sample, and exposure or falling away of portions of the roof deck.

15.202.3 Spread-of-flame Test. A test deck is to be mounted and luminous gas flame applied, as described in Section 15.202.2, second paragraph, for the intermittent-flame tests.

For a Class A or Class B test, the gas flame is to be applied continuously for 10 minutes or until the spread of flame (flaming of the material being tested) permanently recedes from a point of maximum spread, whichever is the shorter duration. For a Class C test, the gas flame is to be applied for four minutes and then removed.

During and after the application of the test flame, the test sample is to be observed for the distance to which flaming of the material has spread, production of flaming or glowing brands, and displacement of portions of the test sample. The observation is to continue until the flame has permanently receded from a point of maximum spread.

15.202.4 Burning-brand Test.

15.202.4.1 General. A test deck is to be mounted as described in Section 15.202.2, second paragraph, for the intermittent-flame test, except that the framework is to be 60 inches (1524 mm) from the air duct outlet (see Figure 15-2-1), and the gas piping and burner are to be removed so as not to obstruct the airflow.

15.202.4.2 Size and construction of brands. The brands to be used in these tests are to be as shown in Figure 15-2-3 and are to be constructed as follows. Prior to the test, the brands are to be conditioned in an oven at 105°F to 120°F (40°C to 49°C) for at least 24 hours.

The Class A brand is to consist of a grid, 12 inches (305 mm) square and approximately $2^1/_4$ inches (57 mm) thick, made of kiln-dried Douglas fir lumber that is free from knots and pitch pockets. The brand is to be made of 36 strips of lumber each $^3/_4$ inch by $^3/_4$ inch (19.1 mm by 19.1 mm) square by 12 inches (305 mm) long, placed in three layers of 12 strips each, with strips placed $^1/_4$ inch (6.4 mm) apart. These strips are to be placed at right angles to those in adjoining layers and are to be nailed, using $1^1/_2$-inch (38.1 mm) long No. 16 gage nails, or stapled using No. 16 gage steel wire staples having a $^7/_{32}$-inch (5.6 mm) crown and $1^1/_4$-inch (31.8 mm) legs, at each end of each strip on one face, and in a diagonal pattern as shown in Figure 15-2-3 on the other face. The dry weight of the finished brand is to be 2,000 grams ± 150 grams at the time of the test.

The Class B brand is to consist of a grid, 6 inches (153 mm) square and approximately $2^1/_4$ inches (57 mm) thick, made of kiln-dried Douglas fir lumber that is free from knots and pitch pockets. The brand is to be made of 18 strips of lumber $^3/_4$ inch by $^3/_4$ inch (19.1 mm by 19.1 mm) square and 6 inches (153 mm) long, placed in three layers of six strips each, with strips spaced $^1/_4$ inch (6.4 mm) apart. The strips are to be placed at right angles to those in adjoining layers and are to be nailed, using $1^1/_2$-inch-long (38.1 mm) No. 16 gage nails, or stapled using No. 16 gage steel wire staples having a $^7/_{32}$-inch (5.6 mm) crown and $1^1/_4$-inch (31.8 mm) legs, at each end of each strip on one face, and in a diagonal pattern as shown in Figure 15-2-3 on the other face. The dry weight of the finished brand is to be 500 grams ± 50 grams at the time of the test.

The Class C brand is to consist of a piece of kiln-dried nonresinous white pine lumber that is free from knots and pitch pockets. The brand is to measure $1^1/_2$ inches by $1^1/_2$ inches by $^{25}/_{32}$ inch (38.1 mm by 38.1 mm by 19.8 mm) and a saw kerf $^1/_8$ inch (3.2 mm) wide is to be cut across the center of both the top and bottom faces to a depth of one half the thickness of the brand, and at right angles to each other. The dry weight of the finished brand is to be $9^1/_4$ grams ± $1^1/_4$ grams at the time of the test.

15.202.4.3 Ignition of brands. Before application to the test deck, the brands are to be ignited so as to burn freely in still air as described below. The flame of the gas burner used to ignite the brands is to essentially envelop the brands during the process of ignition. The temperature of the igniting flame is to be 1,630°F ± 50°F (888°C ± 10°C) measured $2^5/_{16}$ inches (58.7 mm) above the top of the burner. The burner is to be shielded from drafts.

Class A brands are to be exposed to the flame for five minutes, during which time they are to be rotated to present each surface to the flame as follows:

Each 12-inch-by-12-inch (305 mm by 305 mm) face for 30 seconds.

Each $2^1/_4$-inch-by-12-inch (57.2 mm by 305 mm) face for 45 seconds.

Each 12-inch-by-12-inch (305 mm by 305 mm) face again for 30 seconds.

Class B brands are to be exposed to the flame for four minutes, during which time they are to be rotated to present each surface to the flame as follows:

Each 6-inch-by-6-inch (152 mm by 152 mm) face for 30 seconds.

Each $2^1/_4$-inch-by-6-inch (57.2 mm by 152 mm) face for 30 seconds.

Each 6-inch-by-6-inch (152 mm by 152 mm) face again for 30 seconds.

Class C brands are to be exposed to the flame for two minutes, during which time they are to be rotated to present each of the $1^1/_2$-inch-by-$1^1/_2$-inch (38.1 mm by 38.1 mm) faces to the flame for one minute.

15.202.4.4 Test conditions.

15.202.4.4.1 Class A. A brand is to be placed on the surface of each test deck at the location considered most vulnerable (point of minimum coverage over deck joint) with respect to ignition of the deck, but in no case closer than 4 inches (102 mm) from either side or 12 inches (305 mm) from the top or bottom edge of the deck. The brand is to be placed so that the strips in both the upper and lower layers are parallel to the direction of airflow. The brand is to be secured to the deck by a No. 18 B.&S. gage (0.040 inches) (1.02 mm) soft iron wire.

If the roofing assembly is applied to a pine board deck, the brand ordinarily will be in the most vulnerable location when the upper edge of the brand is located 3 inches (76 mm) above a horizontal joint in the test deck. If the roofing assembly is applied to a plywood deck, the brand ordinarily will be in the most vulnerable location when the brand is placed so that it is centered laterally with respect to the vertical joint in the test deck, and the upper edge of the brand is located 3 inches (76 mm) above the horizontal joint.

15.202.4.4.2 Class B. A brand is to be placed on the surface of the test deck at each of the two locations considered most vulnerable (point of minimum coverage over deck joint) with respect to ignition of the deck. Each brand is to be positioned with its upper edge $1^1/_2$ inches (38.1 mm) above the selected joint in the deck boards, but in no case closer than 6 inches (152 mm) from each side or 12 inches (305 mm) from the top or bottom edge of the deck. The brands are to be placed so that the strips in both the upper and lower layers are parallel to the direction of airflow. They are to be secured to the deck by a No. 18 B.&S. gage (0.040 inch) (1.02 mm) soft iron wire. The second brand is not to be applied until all burning resulting from the first brand has ceased.

If the roofing assembly is applied to a pine board deck, the brands ordinarily will be in the most vulnerable location when the upper edge of each brand is located 3 inches (76 mm) above a horizontal joint in the test deck. If the roofing assembly is applied to a plywood deck, the brands ordinarily will be in the most vulnerable location when they are placed so that they are centered laterally with respect to a vertical joint in the test deck, and the upper edge of each brand is located $1^1/_2$ inches (38.1 mm) above the horizontal joint.

15.202.4.4.3 Class C asphalt shingles. Loose or unfastened portions of the shingles that can be bent up to 90 degrees without injury to the fastenings are to be cut away. Twenty ignited brands are then to be placed at one- or two-minute intervals in the areas of minimum coverage $^1/_2$ inch (12.7 mm) away from any cut edge of shingles in the course above that course on which the brand is placed. No brand is to be placed closer than 4 inches (102 mm) to the point where the previous brand was located.

Brands are to be located not closer than 2 inches (50.8 mm) to the joints between adjacent shingles on the same course. All brands are to be placed so that the center of each brand is directly over the space between the deck boards. Brands are to be held in position throughout the test by a No. 18 B.&S. gage (0.040 inches) (1.02 mm) soft iron wire stretched across the width of the deck. The saw kerf on the deck side of the brand is to be parallel to the direction of the airflow. The wire is to be placed in the other saw kerf.

If the roofing assembly is applied to plywood decks, the brands are to be placed centrally over the joints in the plywood deck.

15.202.4.4.4 Class C sheet roofing or built-up covering assemblies. Twenty ignited brands are to be placed at one- or two-minute intervals in the areas of minimum coverage. No brand is to be placed closer than 4 inches (102 mm) to the joint where a previous brand was located. All brands are to be placed so that the center of each brand is directly over the space between the deck boards. See "asphalt shingles" for securing of brands in place and relative positioning of brand saw kerfs.

15.202.4.4.5 Class C treated wood shingles and shakes. Twenty ignited brands are to be placed on each treated wood shingle deck at one- or two-minute intervals. For treated wood shakes, 20 ignited brands are to be distributed at one- or two-minute intervals on each pair of decks. Each brand is to be centered over the $^1/_4$-inch (6.4 mm) joint between shakes or shingles so that the top edge of the brand is approximately $^1/_2$ inch (12.7 mm) below the butt of the shake or shingle in the course above. No brand is to be placed closer than 4 inches (102 mm) to the point where a previous brand was located. See "asphalt shingles" for securing of brands in place and relative positioning of brand saw kerfs.

15.202.4.4.6 Duration of tests. Each individual test, whether Class A, Class B or Class C, is to be continued until the brand is consumed and until all evidence of flame, glow and smoke has disappeared from both the exposed surface of the material being tested and the underside of the test deck, or until unacceptable results occur, but not for more than $1^1/_2$ hours for a Class A or Class B test. The results of tests in which the brands do not show progressive and substantially complete consumption after application to the test deck are to be disregarded.

15.202.4.4.7 Observations. During the tests, observations are to be made for the appearance of sustained flaming on the underside of the test deck, production of flaming or glowing brands of roof-covering material, displacement of the test sample and the exposure or falling away of portions of the roof deck.

15.202.5 Flying-brand Test. This test applies to Class B and Class C treated wood shingles and shakes. If a Class A rating is desired, appropriate tests of increased severity are to be conducted.

A test deck is to be mounted and a luminous gas flame applied as described in Section 15.202.2, second paragraph, for the intermittent-flame test.

The gas flame is to be applied continuously for (1) 10 minutes for a Class B test and (2) four minutes for a Class C test. The air current is to be maintained until all evidence of flame, glow and smoke has disappeared from the exposed surface of the material being tested to determine if flying brands will be developed. For treated wood shakes, the velocity of the air current is to be increased to 18 miles per hour (29 km/h) after the gas flame is extinguished.

15.202.6 Rain Test. The test decks are to be mounted in a framework at 4 units vertical in 12 units horizontal (33.3% slope). Spray nozzles that deliver an average of 0.7 inch (18 mm) of water per hour at a temperature of 35°F to 60°F (2°C to 15°C) are to be mounted approximately 7 feet (2134 mm) above the test decks. The test decks are to be exposed to 12 one-week conditioning cycles. Each cycle is to consist of 96 hours of water exposure followed by 72 hours of drying time at 140°F (60°C). The final drying cycle is to be controlled so that the moisture content of the deck lumber is between 8 and 12 percent. The conditioned decks are then to be tested in accordance with Table 15-2-A.

An alternative test cycle may be utilized at the manufacturer's option whereby two sets of six decks are to be alternately exposed to seven days (168 hours) of water exposures, followed by two days' (48 hours) draining and five days' (120 hours) curing at 140°F (60°C). This cycle is to be repeated seven times, except that the seventh water exposure is to be reduced to six days (144 hours).

15.202.7 Weathering Test. The test decks are to be mounted outdoors at an incline of 5 units vertical in 12 units horizontal (41.7% slope), facing south. After each of one, two, three, five and 10 years of exposure, three test decks are to be brought indoors and conditioned until the deck lumber attains a moisture content between 8 and 12 percent. From each set of decks, one deck is to be subjected to the intermittent-flame test, one to the burning-brand test and one to the flying-brand test.

SECTION 15.203 — CONDITIONS OF ACCEPTANCE FOR CLASSIFICATION

At no time during the intermittent-flame, spread-of-flame or burning-brand tests shall:

1. Any portion of the roof-covering material be blown or fall off the test deck in the form of flaming or glowing brands, or

2. The roof deck be exposed by breaking, sliding, cracking or warping of the roof covering, or

3. Portions of the roof deck fall away in the form of glowing particles.

For the purpose of the requirements, any piece of roof covering that continues to glow or flame upon landing on the test room floor is considered to be a glowing or flaming brand, respectively.

At no time during the Class A, Class B or Class C intermittent-flame or burning-brand tests shall there be sustained flaming of the underside of the deck.

EXCEPTION: If flaming does occur, another series of tests may be conducted and the results accepted provided no additional sustained flaming occurs.

For the spread-of-flame test, the flaming of the material shall not have spread beyond 6 feet (1829 mm) for Class A, 8 feet (2438 mm) for Class B and 13 feet (3962 mm) (the top of the deck) for Class C. There shall have been no significant lateral spread of flame from the path directly exposed to the test flame.

For the flying-brand test on treated wood shingles and shakes, flying, flaming or glowing brands shall not be produced.

TABLE 15-2-A—REQUIRED TESTS AND TEST ASSEMBLIES

MATERIAL TO BE TESTED	REQUIRED NUMBER OF TEST ASSEMBLIES					
	Intermittent-flame Test	Spread-of-flame Test	Burning-brand Test	Flying-brand Test	Rain Test	Weathering Test
Other than wood shakes or shingles, for installation on:						
A. Combustible decks:						
1. Class A	2	2	4	NA	NA	NA
2. Class B or C	2	2	2	NA	NA	NA
B. Noncombustible decks only	NA	2	NA	NA	NA	NA
Wood shakes and shingles:						
A. Class A	3 (2) [5]	3	6 (2) [5]	3 (2) [5]	6	15
B. Class B or C	3 (2) [5]	3	3 (2) [5]	3 (2) [5]	6	15

NOTES:

NA—Test is not required.
The number in parentheses is the number of samples from the rain test.
The number in brackets is the number of samples from the weathering test.

TABLE 15-2-B—FLAME APPLICATION

CLASS	FLAME ON (minutes)	FLAME OFF (minutes)	NUMBER OF TEST CYCLES
A	2	2	15
B	2	2	8
C	1	2	3

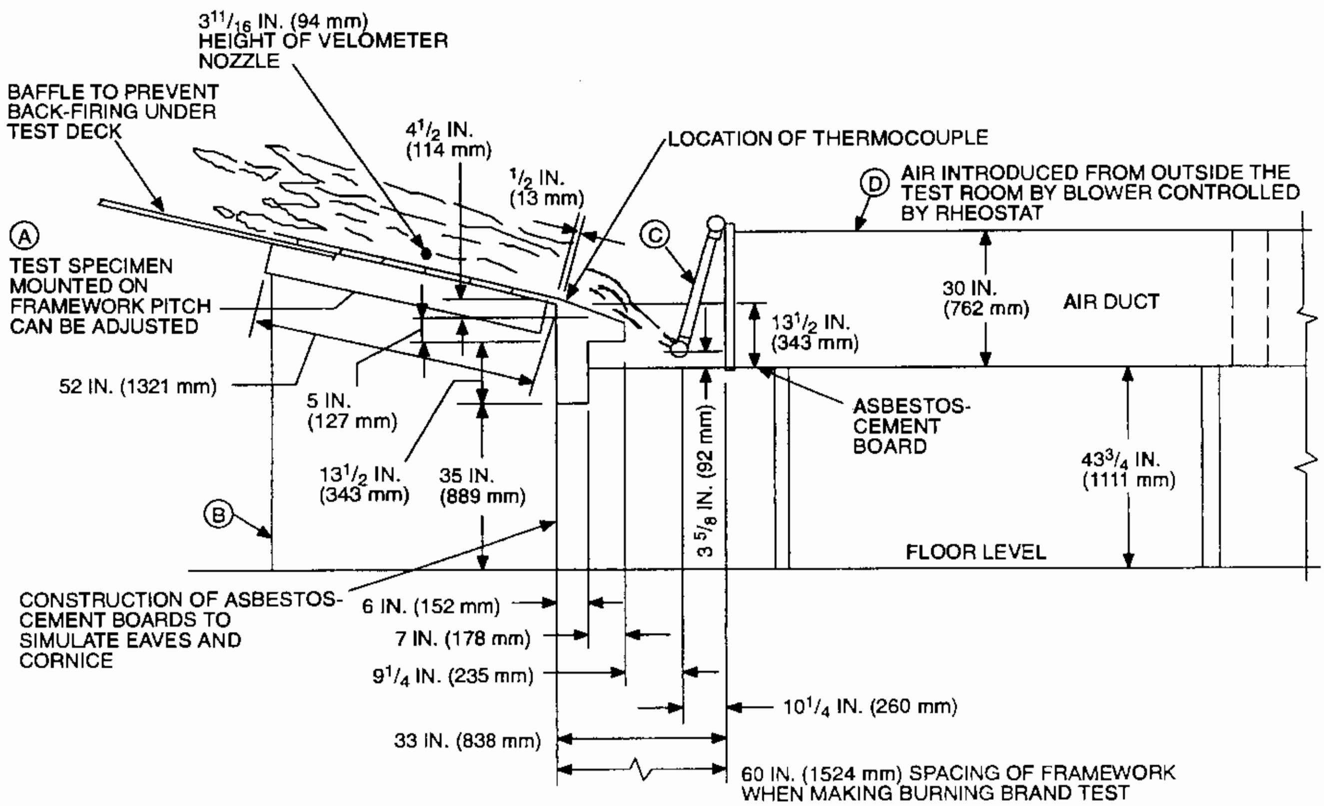
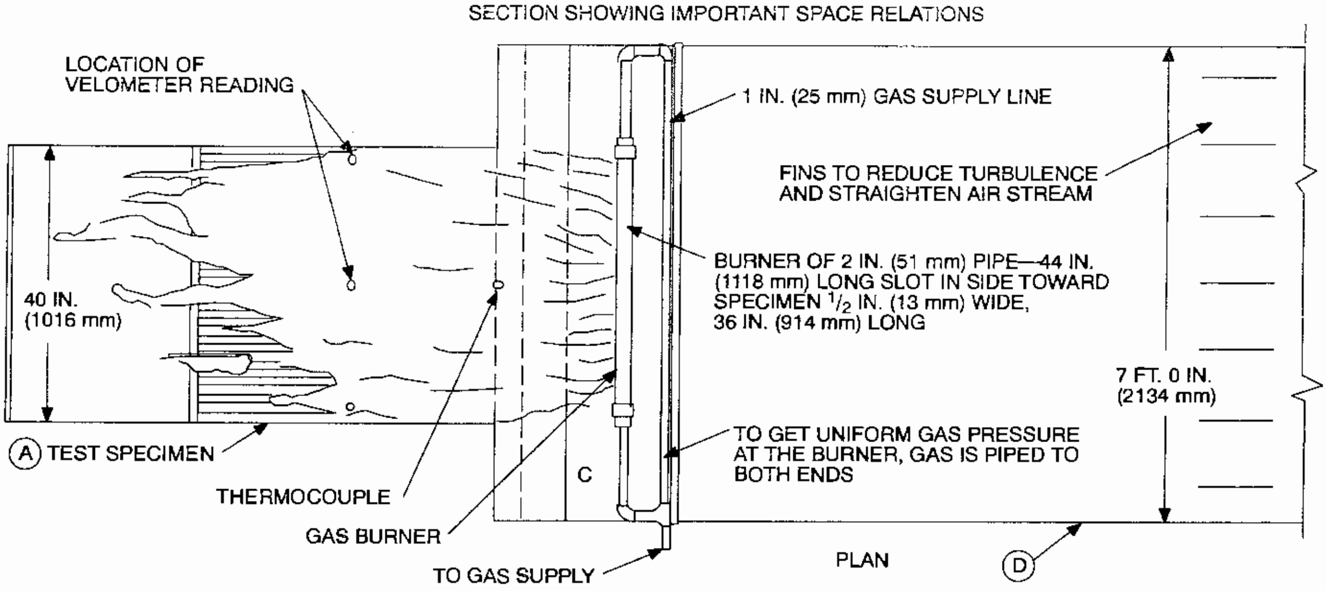


FIGURE 15-2-1—FIRE TEST APPARATUS



Free outlet to be provided to relieve air pressure created by blower. Doors and windows in the room that houses the apparatus to be kept closed at all times during tests to prevent turbulence which would otherwise distort flame and prevent adequate control thereof.

FIGURE 15-2-1—FIRE TEST APPARATUS—(Continued)

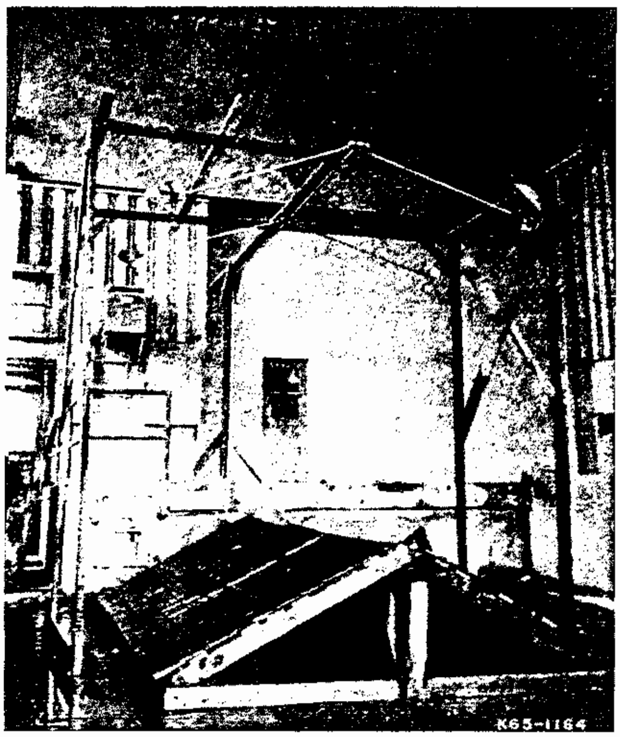


FIGURE 15-2-2—RAIN-TEST APPARATUS

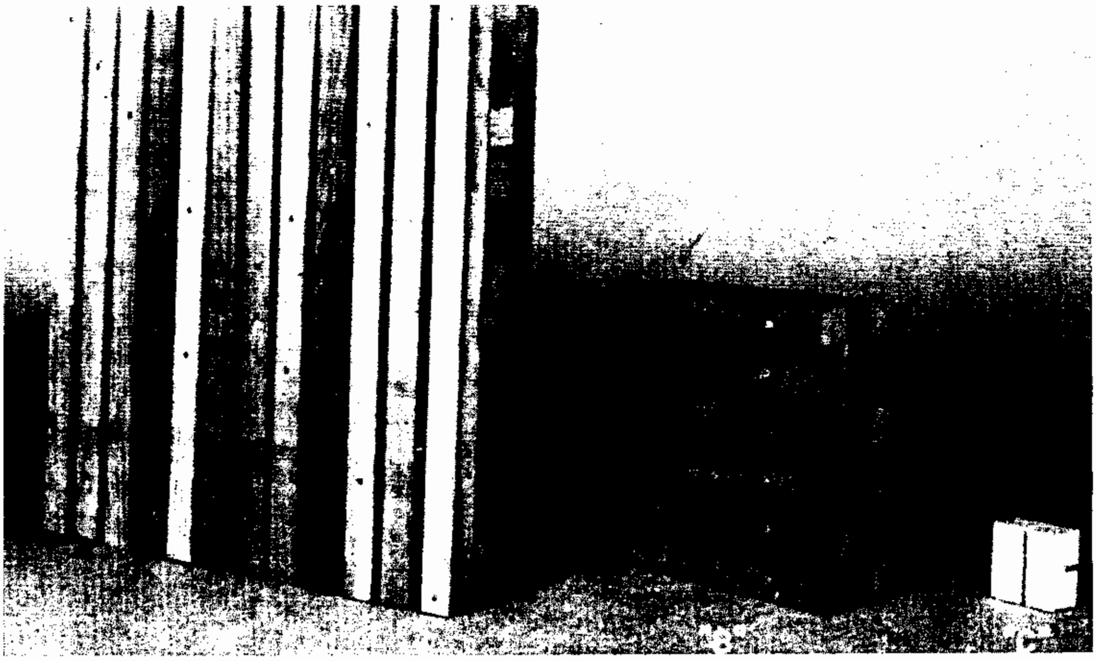


FIGURE 15-2-3—A, B AND C BRANDS

UNIFORM BUILDING CODE STANDARD 15-3
WOOD SHAKES

Based on Grading and Packing Rules for Red Cedar Shakes of the Cedar Shake and Shingle Bureau, 1975

See Sections 1501.1, 1502, 1507.2 and 1507.12, *Uniform Building Code*

Part I—Wood Shakes (Nonpreservative Treated)

SECTION 15.301 — SCOPE

Wood shakes regulated under this part shall be of an approved durable wood and shall be manufactured and graded No. 1 shakes or No. 1 or 2 taper-sawn shakes in accordance with this standard, and their use shall be governed by the provisions of Chapter 15 of this code.

SECTION 15.302 — DEFINITIONS

15.302.1 General. For the purposes of this part, certain words and phrases are defined as follows:

BEST FACE is the side of a shake or shingle which is graded and contains the least amount of defects as described within this standard.

BREAKAGE is damage caused after manufacture and subsequent to packing.

BUNDLE is a unit or package comprising sufficient material of the same grade and length to cover a specified area at recommended exposures.

BUTT is the thicker end of the shake.

BUTT CHECK (SUN CHECK) is a condition caused by heat or excessively dry temperature and usually occurs while the raw material is in block form. It is considered a defect when it extends more than $^3/_8$ inch (9 mm) upward from the butt of the shake.

CHECK is any separation of the wood. A check that causes an obvious, readily identifiable section that is easily separated during the grading process shall not be considered defective unless the separated sections are less than the minimum required width.

CLEAR LINE is an imaginary line across the width of a shake which marks the "clear zone."

CLEAR ZONE is that portion of the shake between the butt and the "clear line" involving both the face and the reverse.

COURSE is a horizontal layer forming one of a series of layers on a roof or wall or in the packed bundle.

CRIMPS is a breaking down or collapse of wood cells during drying, characterized by a caved-in or corrugated appearance.

DECAY (ROT) is the decomposition of wood substance caused by action of wood-destroying fungi, resulting in softening, loss of strength and weight, and change of texture and color.

EDGE is the long side of a shake.

EXPOSURE is the portion which, when applied, is exposed to the weather.

EXPOSURE LINE is an imaginary line drawn across the shake at the same distance above the butt that is equal to the weather exposure.

FEATHER TIP or shim is a condition of manufacture found on the thin ends (tips) of some shakes where the saw came out of the piece prematurely, producing a thin, flimsy, feather-like tip that is uneven or has corners sawn off.

GRAIN is the direction, size, arrangement, appearance or quality of the fibers in wood. To have a specific meaning, the term must be qualified:

Cross Grain is a condition that should not be confused with the terms "flat grain" or "edge grain," and that might better be termed "cross fiber," since it is a deviation of the wood fibers from the true parallel of the face of the taper-sawn shake. It is a defect when it runs from one face of the taper-sawn shake to the other within a longitudinal distance of 3 inches (75 mm) or less in that portion measured $5^1/_2$ inches (140 mm), $7^1/_2$ inches (190 mm) and 10 inches (255 mm) from the butt on 15-inch (380 mm), 18-inch (455 mm) and 24-inch (610 mm) shakes. There is to be no excessive cross grain in the remainder of the shake.

Diagonal Grain is a condition where the grain of the wood does not run parallel to the edges of the shake. It is considered a defect when the grain diverges or slants 2 inches (50 mm) or more in width in 12 inches (305 mm) of length measured from the butt.

Edge Grain or Vertical Grain is wood cut in a plane approximately at right angles to the annual rings. A condition in which the rings form an angle of 45 degrees or more with the face of the piece.

Flat Grain is wood cut in a plane approximately tangential to the annual rings and means a condition in which the rings form an angle of less than 45 degrees with the face of the piece.

Mixed Grain is the condition in which edge and flat grain are present in the same piece of wood.

Torn Grain (Torn Fiber) is a fuzzy or whiskered appearance in the face of the shake. Usually caused by a dull saw or grain deviations.

HEARTWOOD (HEART) is the inner layer of a woody stem wholly composed of nonliving cells and usually differentiated from the outer enveloping layer (sapwood) by its darker color.

KNOT is that portion of a branch or limb which has been surrounded by subsequent growth of wood of the tree.

KNOT, DIAMETER, shall be measured by average facial dimensions.

LINEAL INCHES are the total width of any given number of shakes when laid edge to edge.

PLY is the minimum number of thicknesses, when applied, of shakes or at any point on the covered surface. This term is relative to exposure.

REVERSE FACE refers to the entire reverse side of a shake or shingle, which would be expected to be installed down.

SAPWOOD is wood containing some living cells and forming the initial wood layer beneath the bark of the log. Sapwood may be lighter in color than heartwood.

SHIM. See "feather tip."

SQUARE PACK is a unit providing sufficient shakes for the coverage of a given area when the shakes are laid at the required exposure to the weather. (See Tables 15-3-A and 15-3-B.)

TIP is the thinner end of the shake.

TIP ZONE refers to that area 22 inches (560 mm) or more from the butt in 24-inch (610 mm) shakes, 17 inches (430 mm) or more from the butt in 18-inch (455 mm) shakes and 14 inches (355 mm) or more from the butt in 15-inch (380 mm) shakes.

WARPAGE refers to facial curvature (bow), or twist, or both. Warpage is measured from a level plane, with the shake convex to the highest point at the butt. The shake is held firmly 4 inches (102 mm) down from the tip.

WAVES are the washboard-like irregularities on the face of a shake.

WORMHOLE is a hole or passage burrowed by a worm or insect.

15.302.2 Shake Types. Shake types shall be one of the following types:

1. **Handsplit-and-resawn** have split faces and sawn backs, and are produced by running split wood blanks or boards of proper thickness diagonally through a bandsaw to produce two tapered shakes from each blank.

2. **Straight-split** are manufactured by splitting from only one end of a block of wood, producing shakes which are the same thickness throughout.

3. **Taper-sawn** are tapered pieces sawn both sides.

4. **Taper-split** are split both sides. A natural taper, from butt to tip, is achieved by reversing the block, end for end, with each split.

SECTION 15.303 — QUALITY STANDARDS

15.303.1 No. 1 Grade Shake. Shakes shall be 100 percent clear, graded from the split face in the case of handsplit-and-resawn shakes and from the best face in the case of taper-split, taper-sawn and straight-split shakes.

Shakes shall be 100 percent heartwood, free of bark and sapwood, except that up to $^1/_8$ inch (3 mm) of sapwood is permitted on one edge from the butt to the maximum recommended exposure line on the graded face. Additional sapwood shall be permitted above the exposure line provided the sapwood is contained within a diagonally drawn line from the outside edge at the butt to a point 1 inch (25 mm) inward from the tip edge on handsplit and resawn shakes and $^5/_8$ inch (16 mm) on tapersawn shakes.

Taper-split shakes and straight-split shakes shall be 100 percent edge-grain. Handsplit-and-resawn shakes and taper-sawn shakes may average up to 20 percent of flat-grain in the lineal inches (mm) of any bundle.

Curvature in the sawed face of handsplit-and-resawn shakes shall not exceed 1 inch (25 mm) from a level plane in the length of the shake. Excessive grain sweep on the face shall not be permitted. Knots, wormholes, decay, checks, crimps, waves and torn fiber are not permitted.

15.303.2 No. 2 Grade Taper-sawn Shakes. No. 2 grade taper-sawn shakes shall be of sound and serviceable material, graded from the best face. Flat grain is allowed in the No. 2; sapwood is restricted to 1 inch (25 mm) in width in the first 10 inches (255 mm) above the butt. Defects such as knots, wormholes, decay, crimps, cross grain, waves or torn fiber are not allowed in the first $7^1/_2$ inches, 9 inches and 12 inches (190 mm, 230 mm and 305 mm) from the butt in the 15-inch, 18-inch and 24-inch (380 mm, 455 mm and 610 mm) lengths, respectively, of the No. 2 grade taper-sawn shakes. In the same product, grain characteristics, other than excessive cross grain, are not considered defects; defects may be up to $1^1/_2$ (38 mm) inches in diameter, but aggregate defects must not exceed one half the width of the shakes.

15.303.3 Standard Grade Shakes. Shakes shall be handsplit-and-resawn taper-sawn. Shakes shall be edge grain or flat grain or any combination of edge and flat grain. Shakes shall be graded from the split or best face. Grain characteristics other than excessive cross grain are not considered defects. Curvature shall not exceed 1 inch (25 mm) from a level plane in the length of the shake.

SECTION 15.304 — SIZE

15.304.1 Length.

15.304.1.1 No. 1 grade shakes. Nominal shake lengths shall be 15 inches, 18 inches or 24 inches (380 mm, 455 mm or 610 mm), with a minus tolerance of 1 inch (25 mm) and a plus tolerance of 2 inches (50 mm) for 18-inch (455 mm) shakes. A variation, including shims or feather tips, of 1 inch (25 mm) from these nominal lengths of 18-inch (455 mm) shakes shall be permitted in any bundle. A variation of 2 inches (50 mm) below the nominal length shall be permitted in 24-inch (610 mm) shakes and may contain, but is not limited to, shims or feather tips within the specified variation and shall have a plus tolerance of 3 inches (75 mm). See Table 15-3-A. The 15-inch (380 mm) starter-finish course grade shall permit a tolerance of 1 inch (25 mm) over and under the nominal 15-inch (380 mm) length.

15.304.1.2 No. 2 taper-sawn grade shakes. For No. 2 grade taper-sawn shakes, minimum lengths of 15-inch, 18-inch and 24-inch (380 mm, 455 mm and 610 mm) shakes shall be 14, 16 and 22 inches (355, 405 and 560 mm), respectively.

15.304.1.3 Standard grade shakes. For standard grade shakes, the minimum length of 18-inch (455 mm) and 24-inch (610 mm) shakes shall be 17 inches (430 mm) and 22 inches (560 mm), respectively.

15.304.2 Thickness.

15.304.2.1 No. 1 grade shakes. Shake thickness shall be determined by measurement of the butt within $^1/_2$ inch (13 mm) from each edge. If corrugations or valleys exceed $^1/_2$ inch (13 mm) in depth, a minus tolerance of $^1/_8$ inch (3 mm) is permitted in the minimum specified thickness. [Providing the required minimum shake thickness is maintained within $^1/_2$ inch (13 mm) of each edge at the butt, a minus tolerance of $^1/_{16}$ inch (1.5 mm) less than the nominal thickness shall be permitted on the remaining width of the shake.] No minus tolerance shall be permitted for 24-inch-by-$^3/_8$-inch (610 mm by 9 mm) shakes. The thickness at the exposure line shall be a minimum of one half the butt thickness, except that $^3/_8$-inch (9 mm) shakes shall have a minimum thickness of $^1/_4$ inch (6 mm) at the exposure line.

15.304.2.2 No. 1 and No. 2 grade taper-sawn shakes. No. 1 and No. 2 grade taper-sawn shakes shall have one of two thicknesses at the butt, $^5/_8$ inch (16 mm) or $^3/_4$ inch (19 mm) with a minus tolerance of $^1/_{16}$ inch (1.5 mm) in 10 percent of a bundle.

15.304.2.3 Standard grade shakes. Standard grade shakes shall have one thickness. Eighteen-inch (455 mm) and 24-inch (610 mm) shakes shall have a minimum butt thickness of $^3/_4$-inch (19 mm). Thickness at the exposure line shall be a minimum of one half the minimum specified butt thickness.

15.304.3 Width.

15.304.3.1 No. 1 grade shake. Shakes shall be of random widths, none narrower than 4 inches (100 mm). Minimum width for taper-sawn shakes shall be $3^1/_2$ inches (90 mm). Taper-sawn shakes less than 4 inches (100 mm) in width shall not constitute more than 5 percent of the running inches (mm) of each bundle.

15.304.3.2 No. 2 grade taper-sawn shake. No. 2 grade taper-sawn shakes shall have a minimum width of 3 inches (75 mm).

Taper-sawn shakes less than 4 inches (100 mm) in width shall not constitute more than 10 percent of the running inches of each bundle. Edges shall be parallel within $^1/_2$ inch (13 mm).

15.304.3.3 Standard grade shakes. Standard grade shakes shall be of random widths no narrower than 4 inches (100 mm) and none wider than 8 inches (200 mm).

15.304.4 Edges. Edges of shakes shall be parallel within 1 inch (25 mm). Edges of taper-sawn shakes shall be parallel within $^5/_8$ inch (16 mm).

SECTION 15.305 — PACKING

15.305.1 General. Shakes shall be packed in straight courses in regular frames 18 to 20 inches (457 to 508 mm) wide. See Tables 15-3-A and 15-3-B.

15.305.2 Identification. Each bundle of wood shakes graded under this standard shall bear the label of an approved inspection bureau or agency. The label shall be white base stock printed with predominately blue ink and shall clearly indicate No. 1 grade. For No. 2 grade taper-sawn shakes, the label shall be white base stock printed with predominately red ink and shall clearly indicate the No. 2 grade. For standard grade shakes, the label shall be white base stock printed with predominately brown ink and shall clearly indicate standard grade.

SECTION 15.306 — INSPECTION

Shakes packed in a five-bundle square shall be judged off grade if the total lineal inches of on-grade shakes is less than 268 inches (6807 mm) per bundle.

SECTION 15.307 — REINSPECTION

In case of reinspection, 10 or more bundles selected at random shall constitute a fair sampling of the shipment. The criteria for inspection of shakes specified in Section 15.306 shall also apply for reinspection.

Part II—Grading Rules for Shake Hip and Ridge Based on the Standards of the Cedar Shake and Shingle Bureau

SECTION 15.308 — DEFINITION

Shake hip and ridge are two shakes that have one edge, each sawn on a bevel and fastened together to produce the cap for the hip or ridge of the roof.

SECTION 15.309 — QUALITY STANDARDS

No. 1 hip and ridge units shall be produced from material that meets the standard for No. 1 shakes; No. 2 units shall be produced from material that meets the standard for No. 2 taper-sawn shakes. Lower grade material is not permitted.

SECTION 15.310 — SIZE

At the time of manufacture, the shake hip and ridge assembly width shall be 9 inches (230 mm), measured on the underneath side of the assembly at the butt end. A minus tolerance of $^1/_8$ inch (3 mm) is allowed. Butt misalignment of assemblies in excess of $^1/_4$ inch (6 mm) is not permitted. The narrow component shall have a minimum width of $4^1/_2$ inches (115 mm) at the butt end. For taper-sawn ridge, top corners at the outer edge of the units shall not be more than a 90-degree angle.

SECTION 15.311 — PACKING

Individual shake hip and ridge units are made up of one wide and one narrow component. They shall be packed 20 units per bundle with an equal number of right-hand and left-hand units (for alternating laps). Units shall be manufactured to a 4 units vertical in 12 units horizontal (33.3% slope) pitch or steeper. Units shall be joined with not less than two fasteners applied between 1 inch and 8 inches (25 mm and 200 mm) from the butt. Either staples or nails are acceptable. Fasteners shall be corrosion resistant, spaced approximately 4 inches (100 mm) apart.

SECTION 15.312 — INSPECTION

Each off-grade unit counts as 5 percent of the grade; more than two off-grade units per bundle shall preclude a passing grade.

Part III—Wood Shakes Preservatively Treated

SECTION 15.313 — SCOPE

Wood shakes regulated by this part shall be manufactured, preservative treated and graded in accordance with this standard, and their use shall be governed by the provisions of Chapter 15 of this code.

SECTION 15.314 — DEFINITIONS

For the purpose of this section, certain words and phrases are defined as follows:

COVERED AREA refers specifically to that portion of the face which will be covered in place.

EXPOSED FACE refers specifically to that 10-inch (250 mm) or $7^1/_2$-inch (190 mm) section which will be exposed to the elements.

FACE refers to the entire best side of the shake, which would be expected to be installed facing up.

REVERSE refers to the entire reverse side which would be expected to be installed facing down.

TAPER-SAWN SHAKES are sawn both sides with edges sawn and are 18 inches or 24 inches (455 mm or 610 mm) in length.

TIP ZONE refers to the final 4 inches (100 mm) or 3 inches (75 mm) [of a 24-inch (610 mm) or 18-inch (455 mm) shake, respectively] adjacent to the tip.

SECTION 15.315 — QUALITY STANDARDS

15.315.1 Manufacture.

15.315.1.1 Length. The length of shakes shall be 24 inches (610 mm) and 18 inches (455 mm), allowing for a minus tolerance of $^1/_2$ inch (13 mm) and a plus tolerance of 2 inches (50 mm).

A variation of a minus 1 inch (25 mm), including shims and feathertips, would be permitted in 5 percent of lineal inches (mm) of shakes per bundle, provided that the shake thickness on both edges at the 22-inch (560 mm) and 16-inch (405 mm) lengths is at least $^1/_8$ inch (3 mm).

Angled end trim at butt shall not exceed approximately $^1/_2$ inch (13 mm) per 4 inches (100 mm) of width.

15.315.1.2 Thickness. The green butt thickness of shakes shall be $^{13}/_{16}$ inch (21 mm), with a minus tolerance of $^{1}/_{8}$ inch (3 mm) allowed in 10 percent of lineal inches (mm) of shakes per bundle. The maximum thickness shall not exceed $1^{1}/_{16}$ inches (25 mm).

Tip thickness shall be $^{1}/_{8}$ inch to $^{1}/_{4}$ inch (3 mm to 6 mm).

Thickness variation across the width limited by the above-stated maximums and minimums.

"Dish out" of thickness along length is allowed if it does not reduce the thickness more than $^{1}/_{4}$ inch (6 mm) on the exposed face and is not less than one half the standard thickness in the covered area.

15.315.1.3 Width. Minimum green width shall be 4 inches (100 mm); maximum shall be 8 inches (200 mm). When checking dry material, a maximum shrinkage allowance of $^{1}/_{4}$ inch (6 mm) under the 4-inch (100 mm) minimum will be considered.

Shakes shall be parallel within $^{1}/_{2}$ inch (13 mm).

15.315.1.4 Treatment. Southern pine and red pine taper-sawn shakes shall be preservative treated in accordance with approved nationally recognized standards.

15.315.2 Grade Defects Limited throughout Each Shake.

15.315.2.1 Compression wood. Compression wood is prohibited if in readily identifiable and damaging form. Damaging form includes, but is not limited to, bands of compression wood exceeding $^{1}/_{2}$ inch (13 mm) in width, or bands running along an edge, or solid blocks of compression wood.

15.315.2.2 Density. Medium to dense grain is required measured across the entire butt. Not less than four complete annual rings per inch are permitted at any location.

15.315.2.3 Heart or ring shakes. Heart or ring shakes are prohibited.

15.315.2.4 Slope of grain. Diagonal or spiral grain shall not exceed 1 inch (25 mm) in 10 inches (255 mm). Abnormal grain distortions on face are not permitted.

15.315.2.5 Stain. Medium blue stain is permitted.

15.315.2.6 Unsound wood. Unsound wood is prohibited on either face.

15.315.2.7 Warp. Facial curvature (bow), twist, or both, shall not exceed $^{1}/_{4}$ inch (6.4 mm) from a level plane.

15.315.3 Grade Defects Limited by Location.

15.315.3.1 General. The shake shall be graded from the best face.

15.315.3.2 Holes. Well-scattered ambrosia beetle pin holes up to $^{1}/_{16}$ inch (1 mm) in diameter are allowed if not through the thickness and if limited to six per 10 inches (255 mm) of length on the face. All other types of knot, insect or mechanical holes are prohibited, except an occasional $^{1}/_{2}$-inch (13 mm) hole or encased pith knot is allowed along an edge of the covered area if not extending more than $^{1}/_{2}$ inch (13 mm) into the shake width.

15.315.3.3 Knots. Knots shall be measured by average facial dimensions.

Pith knots are prohibited on the face. They are allowed on reverse side only if the pith hole is not through the thickness.

Generally, no knots are permitted on the exposed face. However, 5 percent of the lineal inches (mm) of shakes per bundle may have up to a $1^{1}/_{2}$-inch (38 mm) cumulative area of sound or firm and tight knots.

Sound or firm and tight knots are limited to a 2-inch (50 mm) cumulative size located in the top one half of the shake at the tapered end.

Individual knots of any quality are limited to a maximum size of $1^{1}/_{2}$ inches (38 mm) on the reverse face. A No. 2 shake may contain up to a $1^{1}/_{2}$-inch (38 mm) cumulative area of sound or firm and tight knots in the exposed $7^{1}/_{2}$- or $5^{1}/_{2}$-inch (190 mm or 140 mm) face.

15.315.3.4 Grain. Generally, vertical grain is required. On the exposed face, flat grain is allowed only along an edge of the face. Center of flat grain not permitted within $1^{1}/_{2}$ inches (38 mm) of center of shake. For No. 2 grade shakes, there are no restrictions on amount or location of flat grain in shake.

15.315.3.5 Pitch pockets. Pitch pockets are prohibited on the exposed face. They are allowed if not through in the covered area and on the reverse side, with the exception that through pitch pockets are allowed in the tip zone.

15.315.3.6 Pith. Pith is not allowed if contained within the thickness of a shake, or if along the surface of the exposed face. A superficial (split) pith is allowed in the covered area or on the reverse side.

15.315.3.7 Wane. Pencil wane is only allowed on the face. Wane on the reverse side is allowed, not to exceed one half the thickness by one sixth the width if located within one half the shake length from the butt; otherwise, wane in occasional pieces may be through the thickness if not reducing the face width by more than $^{1}/_{2}$ inch (13 mm).

15.315.3.8 Reverse Face. Other than the limitations described, the reverse face shall be free of defects which might prevent normal use.

SECTION 15.316 — INSPECTION

Shakes shall be adjudged off grade if the total lineal inches (mm) of defective shakes exceeds 5 percent of the total lineal inches (mm) per bundle. See Table 15-3-A.

SECTION 15.317 — REINSPECTION

In case of reinspection, 10 or more bundles selected at random shall constitute a fair sampling of the shipment. The 5 percent tolerance for defective materials per bundle specified in Section 15.316 shall also apply for reinspection.

Part IV—Southern Yellow Pine, Red Pine, Black Gum/Sweetgum Taper-sawn Shake Hip and Ridge Units

SECTION 15.318 — SCOPE

Southern yellow pine, red pine, black gum/sweetgum taper-sawn shake hip and ridge units regulated by this part shall be manufactured, treated and graded in accordance with this standard and their use shall be governed by the provisions of Chapter 15 of this code.

SECTION 15.319 — QUALITY STANDARDS

Shake hip and ridge units shall be manufactured from only No. 1 grade taper-sawn shakes.

Units shall be fabricated at point of attachment with alternating laps, and shall be correspondingly packed 12/12 inches (12/30 mm) per bundle.

Inner surface of units at the butt shall measure not less than 9 inches (230 mm), with the width of the narrower pieces not less than $4^1/_2$ inches (115 mm).

Units shall be joined with not less than two fasteners applied within 8 inches (203 mm) of the butt. Fasteners shall be a minimum of approximately 3 inches (75 mm) apart and shall be corrosion resistant. Either staples or nails are acceptable. Fasteners shall hold the assembly together until applied properly on the roof.

TABLE 15-3-A—HANDSPLIT SHAKES SUMMARY OF SIZES, PACKING REGULATIONS AND COVERAGE

LENGTH AND THICKNESS	20-INCH (508 mm) PACK		18-INCH (457 mm) PACK		APPROXIMATE COVERAGE (in square feet) OF ONE SQUARE BASED ON FOLLOWING WEATHER EXPOSURES[1]											
					× 0.0929 for m²											
	No. of Courses per Bdl.	No. of Bdls. per Sq. (9.29 m²)	No. of Courses per Bdl.	No. of Bdls. per Sq. (9.29 m²)	$5^1/_2$″ (140 mm)	$6^1/_2$″ (165 mm)	7″ (178 mm)	$7^1/_2$″ (191 mm)	8″ (203 mm)	$8^1/_2$″ (216 mm)	10″ (254 mm)	$11^1/_2$″ (292 mm)	13″ (330 mm)	14″ (356 mm)	15″ (381 mm)	16″ (406 mm)
× 25.4 for mm			× 25.4 for mm													
18″ × $^1/_2$″ handsplit and resawn	10/10	4	9/9	5	55	65	70	75	80	85						
18″ × $^3/_4$″ handsplit and resawn	8/8	5	9/9	5	55	65	70	75	80	85						
24″ × $^3/_8$″ handsplit	10/10	4	9/9	5	—	65	70	75	80	85	100	115				
24″ × $^1/_2$″ handsplit and resawn	10/10	4	9/9	5	—	65	70	75	80	85	100	115				
24″ × $^3/_4$″ handsplit and resawn	8/8	5	9/9	5	—	65	70	75	80	85	100	115				
24″ × $^1/_2$″ taper split	10/10	4	9/9	5	—	65	70	75	80	85	100	115				
18″ × $^3/_8$″ true edge straight split	14 Straight	4	—	—	—	—	—	—	—	—	—	—	—	100	106	112
18″ × $^3/_8$″ straight split	19 Straight	5	—	—	65	75	80	90	95	100						
24″ × $^3/_8$″ straight split	16 Straight	5	—	—	—	65	70	75	80	85	100	115				
15″ starter finish course	8/8	5	9/9	5	Use supplementary with shakes applied not over 10″ (254 mm) weather exposure											
	10/10	4														
18″ × $^5/_8$″ taper sawn	—	—	9/9	5	55	65	70	75	—	85	100					
24″ × $^5/_8$″ taper sawn	—	—	9/9	5	—	65	70	75	—	85	100	115				

[1]For maximum weather exposure on wall construction, see Table 23-L; on roof construction, see Table 15-3-B of the *Uniform Building Code.*

TABLE 15-3-B—MAXIMUM WEATHER EXPOSURE

GRADE LENGTH	3 INCHES TO LESS THAN 4 INCHES IN 12 INCHES (25% to less than 33%)	4 INCHES IN 12 INCHES AND STEEPER (33% and steeper)
	× 25.4 for mm	
	Wood Shakes[1]	
No. 1 18-inch	$7^1/_2$	$7^1/_2$
No. 1 24-inch	10	10
No. 2 18-inch taper-sawn shakes	—	$5^1/_2$
No. 2 24-inch taper-sawn shakes	—	$7^1/_2$

[1]Exposure of 24-inch by $^3/_8$-inch (610 by 10 mm) handsplit resawn shakes shall not exceed 5 inches (127 mm) regardless of the roof slope.

UNIFORM BUILDING CODE STANDARD 15-4
WOOD SHINGLES

See Sections 1501.1, 1502, 1507.2 and 1507.13, *Uniform Building Code*

Part I—Based on the Standards of the Red Cedar Shingle and Handsplit Shake Bureau and Material Product Standards of the International Conference of Building Officials

SECTION 15.401 — SCOPE

This standard provides a minimum specification for sawn wood shingles of No. 1 grade, No. 2 grade and No. 3 grade. It covers length, width, thickness, and grain characteristics for these requirements, plus definitions and specifications.

SECTION 15.402 — DEFINITIONS

For the purposes of this standard, the following terms shall be construed as herein specified.

BEST FACE is the side of a shingle which is graded and contains the least amount of defects.

BREAKAGE is damage caused after manufacture and subsequent to packing.

BUNDLE is a unit or package comprising sufficient material of the same grade and length to cover a specified area at recommended exposures.

BUTT is the thicker end of the shingle.

BUTT CHECK (SUN CHECK) is a condition caused by heat or excessively dry temperature and usually occurs while the raw material is in block form. It is considered a defect when it extends more than $^3/_8$ inch (9 mm) upward from the butt of the shake.

CHECK is any separation of the wood.

CLEAR LINE is an imaginary line across the width of a shingle which marks the "clear zone."

CLEAR ZONE is that portion of the shingle between the butt and the "clear line," involving both the face and the reverse.

COURSE is a horizontal layer forming one of a series of layers on a roof or wall or in the packed bundle.

CRIMPS are a breaking down or collapse of wood cells during drying, characterized by a caved-in or corrugated appearance.

DECAY (ROT) is the decomposition of wood substance caused by action of wood-destroying fungi, resulting in softening, loss of strength and weight, and change of texture and color.

EDGE is the long side of a shingle.

EXPOSURE is the portion which, when applied, is exposed to the weather.

EXPOSURE LINE is an imaginary line drawn across the shake or shingle at the same distance above the butt that is equal to the weather exposure.

GRAIN is the direction, size, arrangement, appearance or quality of the fibers in wood. To have a specific meaning, the term must be qualified:

Cross Grain is a condition that should not be confused with the terms "flat" or "edge" grain, and that might better be termed "cross fiber," since it is a deviation of the wood fibers from the true parallel of the face of the shingle. It is a defect when it runs from one face of the shingle to the other within a longitudinal distance of 3 inches (75 mm) or less in that portion measured 6 inches (150 mm) from the butt. Excessive cross grain must not be present in the remainder of the shingle.

Diagonal Grain is a condition where the grain of the wood does not run parallel to the edges of the shingle. It is considered a defect when the grain diverges or slants 2 inches (50 mm) or more in width in 12 inches (305 mm) of length.

Edge Grain or Vertical Grain is wood cut in a plane approximately at right angles to the annual rings. A condition in which the rings form an angle of 45 degrees or more with the face of the piece.

Flat Grain is a condition in shingles or lumber where the growth rings are flat or horizontal, as opposed to edge-grained or quartered material where the growth rings are on edge, or vertical to the surface. Wood cut in a plane approximately tangential to the annual rings and means a condition in which the rings form an angle of less than 45 degrees with the face of the piece.

FEATHER TIPS (or shims) is a condition of manufacture found on the thin ends (tips) of some shingles where the saw came out of the piece prematurely, producing a thin, flimsy, feather-like tip that is uneven or has corners sawn off.

HEARTWOOD (HEART) is the inner layer of a woody stem wholly composed of nonliving cells and usually differentiated from the outer enveloping layer (sapwood) by its darker color.

KNOT is that portion of a branch or limb which has been surrounded by subsequent growth of wood of the tree.

KNOT DIAMETER shall be measured by average facial dimensions.

LINEAL INCHES are the total width of any given number of shingles when laid edge to edge.

PLY is the minimum number of thicknesses, when applied, of shingles at any point on the covered surface. This term is related to exposure.

REVERSE FACE refers to the entire reverse side of a shake or shingle, which would be expected to be installed down.

SAPWOOD is wood containing some living cells and forming the initial wood layer beneath the bark of the log. Sapwood may be lighter in color than heartwood.

SHIM. See "feather tips."

SQUARE PACK is a unit providing sufficient shingles for the coverage of a given area when the shingles are laid at the specified exposure to the weather in Tables 15-C and 23-II-K of this code.

TIP is the thinner end of the shingle.

TIP ZONE refers to that area 23 inches (585 mm) or more from the butt in 24-inch (610 mm) shingles, 17 inches (430 mm) or more from the butt in 18-inch (455 mm) shingles, and 15 inches (380 mm) or more from the butt in 16-inch (405 mm) shingles.

TORN FIBER (TORN GRAIN) is a fuzzy or whiskered appearance on the face of the shingle usually caused by a dull saw or grain deviations.

WAVES are the washboard-like irregularities on the face of a shingle.

WORMHOLE is a hole or passage burrowed by a worm or insect.

SECTION 15.403 — GRADING AND LABELING

15.403.1 General. Each bundle of No. 1 grade, No. 2 grade and No. 3 grade wood shingles graded under this standard shall bear the label of an approved inspection bureau or agency. For No. 1 grade, the label shall be of white base stock printed with predominantly blue ink and shall clearly indicate the No. 1 grade. For No. 2 grade, the label shall be of white base stock printed with predominantly red ink and shall clearly indicate the No. 2 grade. For No. 3 grade, the label shall be of white base stock printed with predominantly black ink and shall clearly indicate the No. 3 grade. All grades shall be well manufactured and neatly packed; they shall comply with or exceed the specifications herein established for quality. All shingles shall be graded from their best face. Wormholes, decay and crimps are not allowed on either face of No. 1 shingles and below the clear line to the butts on either face of No. 2 and No. 3 grade shingles.

15.403.2 Characteristics.

15.403.2.1 General. Shingles characteristics shall be in accordance with the provisions of this section:

15.403.2.2 No. 1 grade. No. 1 grade shall be vertical grain or edge grain, be clear of defects on the graded face and be 100 percent heartwood. Knots, knotholes, wormholes, decay and crimps are not allowed on either face. Flat grain, cross grain and sapwood constitute natural characteristics that are not admissible. Defects in manufacturing, including shims, excessive feather tips, diagonal grain, and cross grain are likewise not admissible. Manufacturing defects such as checks, waves or torn fiber are permitted on the ungraded face.

15.403.2.3 No. 2 grade. In No. 2 grade, sapwood is restricted to 1 inch (25 mm) in width in the first 10 inches (255 mm) above the butt. Grain characteristics, other than cross grain, are not considered defects. Defects such as knots, knotholes, wormholes, decay and crimps are not allowed on either face in the first 10 inches, 11 inches and 16 inches (255 mm, 280 mm and 405 mm) from the butt in the 16-inch, 18-inch and 24-inch (405 mm, 455 mm and 610 mm) lengths, respectively. Manufacturing defects such as checks, waves or torn fiber are permitted on the ungraded face. Defects may be up to 3 inches (75 mm) in diameter, but aggregate defects shall not exceed one half the width of the shingle.

15.403.2.4 No. 3 Grade. In No. 3 grade, sapwood is permitted. Other grain deviations are not considered defects. Other defects, as listed above for No. 2 grade, are not allowed in the first 6 inches (150 mm) from the butt for 16-inch (405 mm) and 18-inch (455 mm) lengths and 10 inches (255 mm) for 24-inch (610 mm) lengths. Defects may be up to 3 inches (75 mm) in diameter, but aggregate defects shall not exceed two-thirds the width of the shingle.

SECTION 15.404 — LENGTH, WIDTH, THICKNESS

15.404.1 Length.

15.404.1.1 No. 1 Grade. Shingles are usually manufactured in 16-inch, 18-inch and 24-inch (405 mm, 455 mm and 610 mm) lengths. A minus tolerance of 1 inch (25 mm) below the nominal length is allowed.

15.404.1.2 No. 2 Grade. For No. 2 grade the minimum lengths, including shims or feather tips for 16-inch, 18-inch and 24-inch (405 mm, 455 mm and 610 mm) shingles, shall be 15 inches (381 mm), 16 inches (406 mm) and 20 inches (510 mm), respectively.

15.404.1.3 No. 3 Grade. For No. 3 grade the minimum lengths, including shims or feather tips for 16-inch, 18-inch and 24-inch (405 mm, 455 mm and 610 mm) shingles, shall be 14 inches (355 mm), 16 inches (406 mm) and 18 inches (455 mm), respectively.

15.404.2 Width.

15.404.2.1 No. 1 Grade. Minimum width up to but not including 24-inch lengths (610 mm), shall be 3 inches (75 mm). Minimum width for shingles 24 inches (610 mm) and longer shall be 4 inches (100 mm). In 16-inch and 18-inch (405 mm and 455 mm) shingles those less than 4 inches (100 mm) in width shall not constitute more than 10 percent of the running inches per bundle. Shingles shall be uniform in width; that is, with parallel sides. Edges shall be parallel within a tolerance of $^1/_4$ inch (6 mm) on 16-inch (405 mm) and 18-inch (455 mm) shingles and $^3/_8$ inch (9 mm) on 24-inch (610 mm) shingles.

15.404.2.2 No. 2 Grade. Minimum width shall be 3 inches (75 mm). Not more than 20 percent of the running inches (mm) in each bundle shall be less than 4 inches (100 mm) wide. Edges shall be parallel within a tolerance of $^1/_4$ inch (6 mm) in the 16-inch (405 mm) and $^3/_8$ inch (9 mm), 18-inch and 24-inch (455 mm and 610 mm) lengths.

15.404.2.3 No. 3 Grade. Minimum width shall be 3 inches (75 mm) except it may be $2^1/_2$ inches (65 mm) for the 16-inch (405 mm) length. Not more than 30 percent of the running inches in each bundle shall be less than 4 inches (100 mm) wide. Edges shall be parallel within a tolerance of $^3/_8$ inch (9 mm).

15.404.3 Thickness. Shingles are measured for thickness at the butt ends and designated according to the number of pieces necessary to constitute a specific unit of thickness. At the time of manufacture, 16-inch (405 mm) shingles shall be nominally 5/2 [the thickness of five butts will be 2 inches (50 mm)], 18 inches (455 mm) shall be nominally $5/2^1/_4$ [five butts measure $2^1/_4$ inches (55 mm)] and 24 inches (610 mm) shall be nominally 4/2 [four butts measure 2 inches (50 mm)]. Shingles shall be uniform in thickness, with a plus or minus tolerance of 3 percent permitted to compensate for variations in saw movement. A further plus or minus tolerance of 3 percent is allowable to compensate for the difference in shrinkage due to seasoning or kiln drying. This tolerance is based on the total thickness of the bundle.

SECTION 15.405 — INSPECTION

Shingles packed as a four-bundle square shall be judged off grade if the total lineal inches (mm) of on-grade shingles is less than 695 inches (17 653 mm), 635 inches (16 129 mm) and 465 inches (11 811 mm) per bundle for 16-inch (405 mm), 18-inch (455 mm) and 24-inch (610 mm) shingles, respectively.

SECTION 15.406 — REINSPECTION

In case of reinspection, 10 or more bundles selected at random shall constitute a fair sampling of the shipment. The 4 percent tolerance for defective shingles specified in Section 15.405 shall also apply for reinspection.

Part II—Grading Rules for Shingle Hip and Ridge Units Based on the Standards of the Cedar Shake and Shingle Bureau

SECTION 15.407 — DEFINITION

Hip and ridge shingles are two shingles that have one edge of each sawn on a bevel and fastened together to produce the cap for the hip or ridge of the roof. Hip and ridge units are manufactured from No. 1 or No. 2 grade shingles.

SECTION 15.408 — QUALITY STANDARDS

No. 1 hip and ridge units shall be produced from material that meets the standard for No. 1 shingles; No. 2 hip and ridge units shall be produced from material that meets the standard for No. 2 shingles. Lower-grade material is not permitted.

SECTION 15.409 — SIZE

At the time of manufacture, the shingle hip and ridge assembly width shall be 7 inches (180 mm), measured over the top of the assembly at the butt end. A minus tolerance of $^1/_8$ inch (3 mm) is allowed. Butt misalignment of assemblies in excess of $^1/_8$ inch (3 mm) is not permitted. On the outer edge of the units, top corners shall not be more than a 90-degree angle. The narrow component shall have a minimum width of $3^5/_{16}$ (85 mm) inches at the butt end.

SECTION 15.410 — PACKING

Individual shingle and ridge units are made up of one wide and one narrow component. Sixteen-inch (405 mm) shingles shall be packed 40 units per bundle; 18-inch (455 mm) shingles shall be packed 36 units per bundle, with an equal number of right-hand and left-hand units (for alternating laps). Units shall be manufactured to a 4 units vertical to 12 units horizontal (33.3%) pitch or steeper. Units shall be joined with not less than two fasteners applied between $^1/_2$ inch and $5^1/_2$ inches (13 mm and 140 mm) from the butt. Either staples or nails are acceptable. Fasteners shall be corrosion resistant, spaced approximately 3 inches (75 mm) apart.

SECTION 15.411 — INSPECTION

Each off-grade unit shall count for $2^1/_2$ percent of the grade; more than four off-grade units per bundle shall preclude a passing grade.

UNIFORM BUILDING CODE STANDARD 15-5
ROOF TILE

Recommended Standard of the International Conference of Building Officials

See Sections 1501.1, 1502 and 1507.7, *Uniform Building Code*

SECTION 15.501 — SCOPE

This standard applies to all clay, concrete and other cement-based tiles. Supplementary tests justifying adequacy under loads prescribed in Chapter 16 shall be provided.

SECTION 15.502 — BASIC INFORMATION

The following basic information shall be submitted:

1. Manufacturing data as applicable such as mix design, density, protective coatings, mixing, forming, extruding, firing, curing, coloring and glazing.

2. Dimensioned scale drawings and details noting thicknesses, lugs, lips, contours, water diverters, size and location of all fasteners.

3. Method of packaging and identification of components.

SECTION 15.503 — REPORT OF TESTS

A qualified representative of the independent testing agency shall witness the production, fabrication and installation of test specimens.

The test report must be in sufficient detail to identify specimen properties that could affect performance as a roof covering. The testing agency must verify and report dimensions, weight, density, moisture content and other relevant physical properties of the major components.

SECTION 15.504 — REQUIRED TESTS

Tiles shall be tested for strength and water absorption as set forth in this standard.

SECTION 15.505 — SAMPLES

A total of 10 representative samples shall be selected by the independent laboratory from the production line. The laboratory shall document production procedures as specified in Section 15.503. Cement-based products shall be conditioned at a temperature of 73°F ± 5°F (23°C ± 2.8°C) and 50 percent relative humidity for a period of 28 days. At the end of the conditioning period, the size and weight for each specimen shall be recorded.

SECTION 15.506 — TEST PROCEDURES

15.506.1 Strength Test.

15.506.1.1 Sample. Five samples conditioned as specified in Section 15.505 shall be subjected to the strength test.

15.506.1.2 Procedure.

15.506.1.2.1 Barrel-shaped ("Spanish") tile. The supports for the sample shall be two knife edges of the rocker type with edges at least as long as the width of the sample. The loading knife edge may be either the fixed or the rocker type and shall be at least as long as the width of the sample.

Place the sample on the knife edges with the open side or turned-down edges down, so that the sample is supported by the knife edges at a span of 12 inches (305 mm) centered on the length of the sample. Apply the load at center of the span and sample width through the loading knife edge. Apply loads at rates not to exceed 10 pounds (4.45 N) per second until failure and record the breaking load to the nearest 5 pounds (22 N).

15.506.1.2.2 Other tile. The test span shall be the maximum unsupported span specified for field installation. The sample shall be tested as shown in Figure 15-5-1 with the load applied at a uniform rate not exceeding 10 pounds (4.45 N) per second until failure, which shall be recorded to the nearest pound (5 N). The test shall be repeated on the other specimens and the average breaking load determined.

15.506.1.3 Conditions of acceptance.

15.506.1.3.1 Barrel-shaped tile. Barrel-shaped tiles are tiles having a minimum rise-to-width ratio of 1:4. The average breaking load shall not be less than 400 pounds (1780 N) with no single load less than 350 pounds (1560 N).

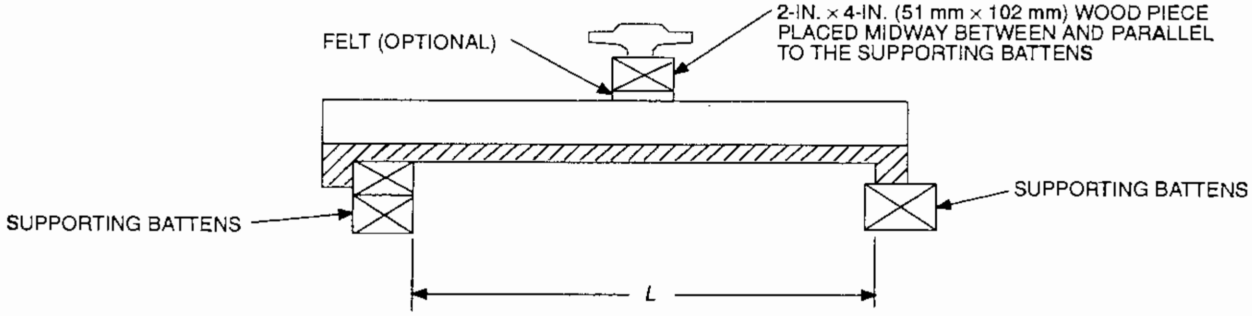
15.506.1.3.2 Other tiles. The average breaking load shall not be less than 300 pounds (1335 N) for five consecutively tested samples or 250 pounds (1110 N) for any individual sample.

15.506.2 Water Absorption Test.

15.506.2.1 Sample. A minimum of five samples from the tile fractured in the strength test shall be tested for water absorption. The sum of the dry weight for five samples at room temperature shall not be less than 12 pounds (5.4 kg). A total of five or more samples of the ridge and other accessory tile not subjected to the strength test shall also be tested. The aggregate dry weight at room temperature of these samples shall not be less than 5 pounds (2.2 N).

15.506.2.2 Procedure. Loose particles shall be removed by scrubbing with a fiber brush and clean water. Samples shall be dried in a well-ventilated oven for 24 hours at a temperature of 221°F (105°C) varying not more than 3.6°F (2.0°C). After drying, the samples may be cooled at room temperature for 15 minutes after identifying and weighing to the nearest 0.01 gram. The samples shall then be immersed in filtered or distilled water for 48 hours at a temperature of 68°F (20°C), varying not more than 9°F (5°C). One sample shall be removed, surfaces wiped dry and weighed immediately. The process shall be repeated for each sample.

15.506.2.3 Condition of acceptance. No sample shall absorb more than 15 percent water of its dry weight.



L = maximum unsupported span specified for field installation.

NOTE: The load shall be applied with a 2-in. × 4-in. (51 mm by 102 mm) (nominal size) wood piece laid flat and continuous from edge to edge of the tile. Where the effective width of tile exceeds 16 inches (406 mm), the loads specified in Section 15.506.1.2 shall be increased in proportion to the tile width.

FIGURE 15-5-1—TRANSVERSE BREAKING STRENGTH

UNIFORM BUILDING CODE STANDARD 15-6

MODIFIED BITUMEN, THERMOPLASTIC AND THERMOSET MEMBRANES USED FOR ROOF COVERINGS

Based on Standard Specifications D 412-87, D 471-79, D 570-81, D 624-86, D 638-84, D 751-79, D 816-82, D 1004-66 (1981), D 1204-84, D 2136-84 and D 2137-83 of the American Society for Testing and Materials

See Sections 1501.1 and 1502, *Uniform Building Code*

SECTION 15.601 — SCOPE

15.601.1 General. This standard covers the following membranes used for roof coverings.

15.601.2 Modified Bitumen Membranes. Composite sheets consisting of bitumen modifiers and reinforcements. The material shall be of the following types of classes:

Type I—APP modified bitumen reinforced membrane composed primarily of asphalt blended with atactic polypropylene.

Type II—SBS modified bitumen reinforced membrane composed primarily of asphalt blended with styrene-butadiene-styrene.

Type III—Self-adhesive modified bitumen membrane composed primarily of asphalt blended with styrene-butadiene-styrene.

15.601.3 Thermoplastic Membranes. Sheets composed of polymers and other proprietary ingredients whose chemical composition allows the sheet to be welded together by either heat or solvent throughout its service life.

15.601.4 Thermoset Membranes. Sheets composed of polymers and other proprietary ingredients whose chemical composition vulcanizes or cross-links during its service life.

SECTION 15.602 — PHYSICAL PROPERTIES

The materials shall conform to the physical properties prescribed in Tables 15-6-A, 15-6-B, 15-6-C, 15-6-D and 15-6-E.

TABLE 15-6-A—PROPERTIES OF THERMOSET REINFORCED MEMBRANES USED FOR ROOF COVERINGS

MATERIALS' PROPERTIES	TEST METHODS[1]	UNITS	PHYSICAL PROPERTIES
Thickness	ASTM D 751-79	inches (× 25.4 for mm)	≥ 0.030
Breaking strength[2]	ASTM D 751-79	lb./inch (× 0.175 for N/mm)	≥ 90
Elongation at fabric break[3]	ASTM D 751-79	Percentage	≥ 15
Tear resistance	ASTM D 751-79	lb. (× 4.45 for N)	≥ 25
Water absorption	ASTM D 471-79 166 hours at 73°F	Weight change percentage	≤ 10
Dimensional stability	ASTM D 1204-84 24 hours at 130°F	Percentage	≤ 2
Low temperature flexibility	ASTM D 2137-83	°F (–32 ÷ 1.8 for °C)	≤ –30
Factory seam strength	ASTM D 751-79	lb./inch (× 0.175 for N/mm)	≥ 50[4]

[1]The test to be used shall be a method approved by the building official.

[2]Results of tensile strength after heat aging at 212°F (100°C) for 166 hours will remain at ≥ 90 pounds (400 N). Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 176°F (80°C) will not reduce the breaking strength to less than 90 pounds (400 N).

[3]Elongation at break shall not be reduced by heat aging or accelerated weathering by more than 20 percent.

[4]Or membrane rupture.

TABLE 15-6-B—PROPERTIES OF THERMOSET NONREINFORCED MEMBRANES USED FOR ROOF COVERINGS

MATERIALS' PROPERTIES	TEST METHODS[1]	UNITS	PHYSICAL PROPERTIES
Thickness	ASTM D 412-87	inches (× 25.4 for mm)	≥ 0.040
Tensile strength[2]	ASTM D 412-87	psi (× 6.89 for kPa)	≥ 1,000
Elongation[3]	ASTM D 412-87	Percentage	≥ 300
Tear resistance	ASTM D 624-86	lb./inch (× 0.175 for N/mm)	≥ 120
Water absorption	ASTM D 471-79 166 hours at 158°F	Weight change percentage	≤ 10
Dimensional stability	ASTM D 1204-84 70 hours at 212°F	Percentage	≤ 2.0
Low temperature flexibility	ASTM D 2137-83	°F (–32 ÷ 1.8 for °C)	≤ –30
Factory seam strength	ASTM D 816-82	lb./inch (× 0.175 for N/mm)	≥ 30[4]

[1]The test to be used shall be a method approved by the building official.

[2]Results of tensile strength after heat aging at 212°F (100°C) for 166 hours will remain at ≥ 1,000 psi (6890 kPa). Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 176°F (80°C) will not reduce the tensile strength to less than 1,000 pounds (6890 kPa).

[3]Elongation shall not be reduced by heat aging or accelerated weathering to less than 200 percent.

[4]Or membrane rupture.

TABLE 15-6-C—PROPERTIES OF THERMOPLASTIC REINFORCED MEMBRANES USED FOR ROOF COVERINGS

MATERIALS' PROPERTIES	TEST METHODS[1]	UNITS	PHYSICAL PROPERTIES
Thickness	ASTM D 751-79	inches (× 25.4 for mm)	≥ 0.030
Breaking strength[2]	ASTM D 751-79	lb. (× 4.45 for N)	≥ 90
Elongation at fabric break[3]	ASTM D 751-79	Percentage	≥ 15
Tear resistance	ASTM D 751-79	lb. (× 4.45 for N)	≥ 20
Water absorption	ASTM D 570-81 166 hours at 158°F	Weight change percentage	≤ 5.0
Dimensional stability	ASTM D 1204-84 6 hours at 176°F	Percentage	≤ 1.0
Low temperature flexibility	ASTM D 2136-84	°F (–32 ÷ 1.8 for °C)	≤ –30
Factory seam strength	ASTM D 751-79	lb./inch (× 0.175 for N/mm)	≥ 50[4]

[1]The test to be used shall be a method approved by the building official.

[2]Results of tensile strength after heat aging at 158°F (70°C) for 30 days will remain at ≥ 90 pounds (400 N). Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 145°F (63°C) will not reduce the breaking strength to less than 90 pounds (400 N).

[3]Elongation at break shall not be reduced by heat aging or accelerated weathering by more than 20 percent.

[4]Or membrane rupture.

TABLE 15-6-D—PROPERTIES OF THERMOPLASTIC NONREINFORCED MEMBRANES USED FOR ROOF COVERINGS

MATERIALS' PROPERTIES	TEST METHODS[1]	UNITS	PHYSICAL PROPERTIES
Thickness	ASTM D 638-84	inches (× 25.4 for mm)	≥ 0.045
Tensile strength[2]	ASTM D 638-84	psi (× 6.89 for kPa)	≥ 1,500
Elongation[3]	ASTM D 638-84	Percentage	≥ 250
Tear resistance	ASTM D 1004-66 (1981)	lb. (× 4.45 for N)	≥ 10
Water absorption	ASTM D 570-81 166 hours at 158°F	Weight change percentage	≤ 3.0
Dimensional stability	ASTM D 1204-84 6 hours at 176°F	Percentage	≤ 2.0
Low temperature flexibility	ASTM D 2136-84	°F (–32 ÷ 1.8 for °C)	≤ –30
Factory seam strength	ASTM D 638-84	psi (× 6.89 for kPa)	≥ 1,300[4]

[1]The test to be used shall be a method approved by the building official.

[2]Results of tensile strength after heat aging at 194°F (90°C) for 168 hours will remain at ≥ 1,000 psi (6890 kPa). Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 145°F (63°C) will not reduce the tensile strength to less than 1,000 psi (6890 kPa).

[3]Elongation at break shall not be reduced by heat aging or accelerated weathering to less than 200 percent.

[4]Or membrane rupture.

TABLE 15-6-E—PROPERTIES OF MODIFIED BITUMEN MEMBRANES USED FOR ROOF COVERINGS

MATERIALS' PROPERTIES	UNITS	PHYSICAL PROPERTIES[1]		
		Type I Membrane	Type II Membrane	Type III Membrane
Thickness	mils (× 0.0254 for mm)	≥ 120	≥ 120	≥ 40
Weight	lb./100 ft.^{2} (× 0.05 for kg/m^2)	≥ 60	≥ 60	≥ 30
Tensile strength at 0°F[2,3] machine or cross-machine direction	lb./in. (× 0.175 for N/mm)	≥ 100	≥ 100	≥ 50
Elongation at 0°F[2,3] machine or cross-machine direction	Percentage	≥ 4	≥ 4	≥ 50
Strain energy at 0°F[3]	lb. in./in. (× 4.45 for N mm/mm)	≥ 2	≥ 2	N/A
Water absorption	Percentage	≤ 5	≤ 5	≤ 5
Low temperature flexibility[2]	°F (–32 ÷ 1.8°C)	≤ 32	≤ 5	≤ 5
Dimensional stability	Percentage	≤ 1	≤ 1	≤ 1
Compound stability	°F (–32 ÷ 1.8°C)	≥ 250	≥ 220	N/A

[1]Tests shall be approved methods of evaluating the properties of roofing materials.

[2]Stated property is before and after heat conditioninng at 158°F (70°C) for 2,000 hours. Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 145°F (63°C) will not reduce the tensile strength by more than 5 percent or the elongation by more than 10 percent.

[3]Strain energy is the area under the load elongation curve obtained from the machine chart or computer system converted to units of pounds per inch per inch (N per mm per mm). This is required if one of the minimum values for tensile strength or elongation is not met. Ultimate elongation for this calculation shall be the elongation to the point the load is 5 percent of the tensile strength of the membrane after the maximum load has been reached.

UNIFORM BUILDING CODE STANDARD 15-7
AUTOMATIC SMOKE AND HEAT VENTS

Standard of the International Conference of Building Officials

See Sections 906.1, 906.4 and 1501.1, *Uniform Building Code*

SECTION 15.701 — SCOPE

15.701.1 General. This standard applies to thermally activated, automatic smoke and heat vents designed for installation on the roof of buildings as required by Section 906 of the Building Code.

15.701.2 Instructions. A copy of the installation and operating instructions shall be supplied with each unit. The instructions shall prescribe construction representative of that used in the examination and testing of the product.

SECTION 15.702 — CONSTRUCTION AND MATERIALS

The critical operating components of vents, such as heat sensors, hinges, latches, linkages and other mechanical parts, shall be constructed of corrosion-resistant materials.

Plastics shall be approved plastics as defined in the Building Code.

Vent design for minimum roof live load shall be of adequate strength and durability to withstand the design loads as prescribed in the Building Code.

SECTION 15.703 — METHOD OF ACTIVATION

Releasing devices for vents shall be activated by heat. The heat-activated device shall be one of the following:

1. A fixed-temperature device having a melting temperature rating at least 30°F (17°C) above the maximum expected ambient temperatures at the intended location.

2. A rate-of-rise device.

3. Approved, heat-sensitive glazing designed to shrink and drop out of the vent opening.

SECTION 15.704 — TEST PROCEDURES

15.704.1 General. Recognized and accepted testing procedures and testing equipment shall be used.

15.704.2 Samples. Samples submitted for acceptance tests shall be production units whose materials, design and specifications are representative of the models for which acceptance is sought. Written specifications shall be submitted for each model. Tests for multiple-sized models shall utilize the largest size unit for evaluations.

15.704.3 Heat Sensors. Heat-sensing devices shall be capable of activation in accordance with the requirements of the simulated fire test.

15.704.4 Load Performance. Vents shall be tested to open freely and fully against a live load of 10 pounds per square foot (495 N/m^2). Vents intended for installation in areas subject to snow loads shall be tested to open freely and fully against snow loads as determined by the building official.

15.704.5 Simulated Fire Test.

15.704.5.1 Requirements. Vents shall be tested to open fully to operational position in five minutes when subjected to a precalibrated time-temperature gradient that heats the air within the vent cavity to 500°F (260°C) within the five-minute period. Where vents are operated by fixed-temperature fusible devices, the device shall be located in the expected flow pattern of hot gases and not shielded from fire temperatures. The actual load on the device shall not exceed its greatest load capacity.

15.704.5.2 Calibration. Correction of the test calibration may be accomplished by varying the height of the vent being tested or the height of the test-fuel pan.

15.704.5.3 Test method. Test units shall be end-supported 35 inches (890 mm) above the fire test floor. Two Type K, chrome lus. alumel 18-gage thermocouples shall be attached to the inside of the vent, 1 inch (25.4 mm) below the highest point of the cavity. The leads shall be connected to a recording potentiometer, 0°F to 2,000°F (–18°C to 1093°C) range multipoint.

A one-square-foot (305 mm by 305 mm) steel test-fuel pan shall be centered under the test unit on the floor. Isopropyl alcohol shall be poured into the pan to a depth of $^1/_2$ inch (13 mm). The alcohol shall be ignited and a determination made as to the ability of the test unit to meet the test requirements.

During the test there shall not be any flame impingment on the test unit lid or dropout glazing.

15.704.5.4 Repetitions. Each unit tested shall successfully pass five simulated fire tests per mode of operation without mechanical or structural failure. Modes of operation tested shall include (i) activation of the manual release mechanism on units so equipped, and (ii) activation of the heat-sensing device.

> **EXCEPTION:** Drop-out glazing vents need be tested only once per unit. Release of the glazing is a normal test response.

Necessary resetting or replacement of the heat-sensing device shall not be considered a mechanical or structural failure.

SECTION 15.705 — MARKING

Each unit shall bear a durable, visible label stating the name and location of the manufacturer, the model designation and the year of manufacture.

UNIFORM BUILDING CODE STANDARD 18-1
SOILS CLASSIFICATION

Based on Standard Method D 2487-69 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 1801.2 and 1803.1, *Uniform Building Code*

SECTION 18.101 — SCOPE

This standard describes a system for classifying mineral and organomineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit and plasticity index.

SECTION 18.102 — APPARATUS

Apparatus of an approved type shall be used to perform the following tests and procedures: Preparation of soil samples, liquid limit test, plastic limit test and particle-size analysis.

SECTION 18.103 — SAMPLING

Sampling shall be conducted in accordance with approved methods for soil investigation and sampling by auger borings, for Penetration Test and Split-barrel Sampling of Soils, and for Thin-walled Tube Sampling of Soils.

The sample shall be carefully identified as to origin by a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated center line.

The sample should also be described in accordance with an approved visual-manual procedure. (A soil which is composed primarily of undecayed or partially decayed organic matter and has a fibrous texture, dark brown to black color, and organic odor should be designated as a highly organic soil, PT, and not subjected to the classification procedures described hereafter.)

SECTION 18.104 — TEST SAMPLE

Test samples shall represent that portion of the field sample finer than the 3-inch (76 mm) sieve and shall be obtained as follows:

Air dry the field sample; weigh the field sample; and separate the field sample into two fractions on a 3-inch (76 mm) sieve. Weigh the fraction retained on the 3-inch (76 mm) sieve. Compute the percentage of plus 3-inch (76 mm) material in the field sample and note this percentage as auxiliary information. Thoroughly mix the fraction passing the 3-inch (76 mm) sieve and select test samples.

SECTION 18.105 — PRELIMINARY CLASSIFICATION PROCEDURE

Procedure for the determination of percentage finer than the No. 200 (75 μm) sieve is as follows:

1. From the material passing the 3-inch (76 mm) sieve, select a test sample and determine the percentage of the test sample finer than the No. 200 (75 μm) sieve. (This step may be omitted if the soil can obviously be classified as fine-grained by visual inspection.)

2. Classify the soil as coarse-grained if more than 50 percent of the test sample is retained on the No. 200 (75 μm) sieve.

3. Classify the soil as fine-grained if 50 percent or more of the test sample passes the No. 200 (75 μm) sieve.

SECTION 18.106 — PROCEDURE FOR CLASSIFICATION OF COARSE-GRAINED SOILS (MORE THAN 50 PERCENT RETAINED)

Select test samples from the material passing the 3-inch (76 mm) sieve for the determination of particle-size characteristics, liquid limit and plasticity index. Determine the cumulative particle-size distribution of the fraction coarser than the No. 200 (75 μm) sieve.

Classify the sample as *gravel,* G, if 50 percent or more of the coarse fraction [plus No. 200 (75 μm) sieve] is retained on the No. 4 (4.75 mm) sieve. Classify the sample as *sand,* S, if more than 50 percent of the coarse fraction [plus No. 200 (75 μm) sieve] passes the No. 4 (75 mm) sieve.

If less than 5 percent of the test sample passed the No. 200 (75 μm) sieve, compute the coefficient of uniformity, C_u, and coefficient of curvature, C_z, as given in Formulas 18-1-1 and 18-1-2:

$$C_u = \frac{D_{60}}{D_{10}} \qquad (18\text{-}1\text{-}1)$$

$$C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}} \qquad (18\text{-}1\text{-}2)$$

in which D_{10}, D_{30} and D_{60} are the particle size diameters corresponding respectively to 10, 30 and 60 percent passing on the cumulative particle size distribution curve.

Classify the sample as well-graded gravel, GW, or well-graded sand, SW, if C_u is greater than 4 for gravel and 6 for sand, and C_z is between 1 and 3. Classify the sample as poorly graded gravel, GP, or poorly graded sand, SP, if either the C_u or the C_z criteria for well-graded soils are not satisfied.

If more than 12 percent of the test sample passed the No. 200 (75 μm) sieve, determine the liquid limit and the plasticity index of a portion of the test sample passing the No. 40 (425 μm) sieve in accordance with approved methods.

Classify the sample as silty gravel, GM, or silty sand, SM, if the results of the limits tests show that the fines are silty, that is, the plot of the liquid limit versus plasticity index falls below the "A" line (see Plasticity Table 18-1-A) or the plasticity index is less than 4.

Classify the sample as clayey gravel, GC, or clayey sand, SC, if the fines are clayey, that is, the plot of liquid limit versus plasticity index falls above the "A" line and the plasticity index is greater than 7.

If the fines are intermediate between silt and clay, that is, the plot of liquid limit versus plasticity index falls on or practically on the "A" line or falls above the "A" line but the plasticity index is in the range of 4 to 7, the soil should be given a borderline classification, such as GM-GC or SM-SC.

If 5 to 12 percent of the test sample passed the No. 200 (75 μm) sieve, the soil should be given a borderline classification based on both its gradation and limit test characteristics, such as GW-GC or SP-SM. (In doubtful cases the rule is to favor the less plastic classification. Example: A gravel with 10 percent fines, a C_u of 20, a C_z of 2.0, and a plasticity index of 6 would be classified as GW-GM rather than GW-GC.)

SECTION 18.107 — PROCEDURE FOR CLASSIFICATION OF FINE-GRAINED SOILS (50 PERCENT OR MORE PASSING)

From the material passing the 3-inch (76 mm) sieve, select a test sample for the determination of the liquid limit and plasticity index. The method for wet preparation shall be used for soils containing organic matter or irreversible mineral colloids.

Determine the liquid limit and the plasticity index of a portion of the test sample passing the No. 40 (425 μm) sieve.

Classify the soil as inorganic clay, C, if the plot of liquid limit versus plasticity index falls above the "A" line and the plasticity index is greater than 7.

Classify the soil as inorganic clay of low to medium plasticity, CL, if the liquid limit is less than 50 and the plot of liquid limit versus plasticity index falls above the "A" line and the plasticity index is greater than 7. See area identified as CL on the Plasticity Chart of Table 18-1-A.

Classify the soil as inorganic clay of high plasticity, CH, if the liquid limit is greater than 50 and the plot of liquid limit versus plasticity index falls above the "A" line. In cases where the liquid limit exceeds 100 or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scales on both axes and extending the "A" line at the indicated slope. See areas identified as CH on the Plasticity Chart, Table 18-1-A.

Classify the soil as inorganic silt, M, if the plot of liquid limit versus plasticity index falls below the "A" line or if the plasticity index is less than 4, unless it is suspected that organic matter is present in sufficient amounts to influence the soil properties, then tentatively classify the soil as organic silt or clay, O.

If the soil has a dark color and an organic odor when moist and warm, a second liquid limit test should be performed on a test sample which has been oven dried at 110°C ± 5°C for 24 hours.

Classify the soil as organic silt or clay, O, if the liquid limit after oven drying is less than three fourths of the liquid limit of the original sample determined before drying.

Classify the soil as inorganic silt of low plasticity, ML, or as organic silt of low plasticity, ML, or as organic silt or silt-clay of low plasticity, OL, if the liquid limit is less than 50 and the plot of liquid limit versus plasticity index falls below the "A" line or the plasticity index is less than 4. See area identified as ML and OL on the Plasticity Chart, Table 18-1-A.

Classify the soil as inorganic silt of medium to high plasticity, MH, or as organic clay or silt-clay of medium to high plasticity, OH, if the liquid limit is more than 50 and the plot of liquid limit versus plasticity index falls below the "A" line. See area identified as MH and OH on the Plasticity Chart of Table 18-1-A.

In order to indicate their borderline characteristics, some fine-grained soils should be classified by dual symbols.

If the plot of liquid limit versus plasticity index falls on or practically on the "A" line or above the "A" line where the plasticity index is in the range of 4 to 7, the soil should be given an appropriate borderline classification such as CL-ML or CH-OH.

If the plot of liquid limit versus plasticity index falls on or practically on the line liquid limit = 50, the soil should be given an appropriate borderline classification such as CL-CH or ML-MH. (In doubtful cases the rule for classification is to favor the more plastic classification. Example: a fine-grained soil with a liquid limit of 50 and a plasticity index of 22 would be classified as CH-MH rather than CL-ML.)

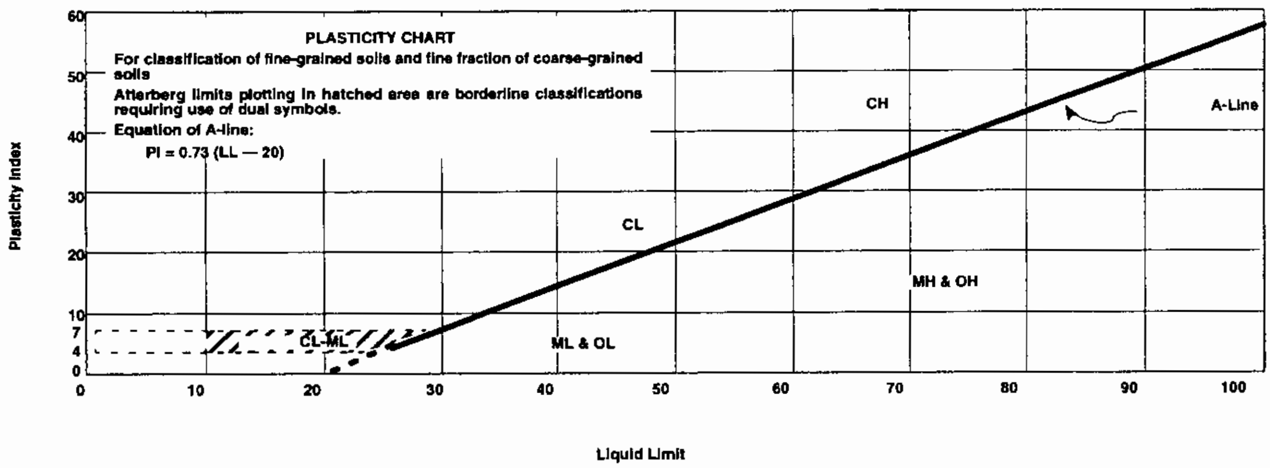
TABLE 18-1-A—SOIL CLASSIFICATION CHART

	MAJOR DIVISIONS		GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS More than 50% retained on No. 200 (75 μm) sieve[1]	GRAVELS 50% or more of coarse fraction retained on No. 4 (4.75 mm) sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 (4.75 mm) sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly and sands, little or no fines
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS 50% or more passes No. 200 (75 μm) sieve[1]	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
	Highly Organic Soils		PT	Peat, muck and other highly organic soils

[1]Based on the material passing the 3-inch (76 mm) sieve.

TABLE 18-1-A—SOIL CLASSIFICATION CHART—(Continued)

CLASSIFICATION CRITERIA		
CLASSIFICATION ON BASIS OF PERCENTAGE OF FINES **Less than 5%, Pass No. 200 (75 μm) sieve** — **GW, GP, SW, SP** **More than 12% Pass N. 200 (75 μm) sieve** — **GM, GC, SM, SC** **5% to 12% Pass No. 200 (75 μm) sieve** — **Borderline Classification requiring use of dual symbols**	$C_u = D_{60}/D_{10}$ Greater than 4 $C_z = \frac{(D_{30})^3}{D_{10} \times D_{60}}$ Between 1 and 3	
	Not meeting both criteria for GW	
	Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
	Atterberg limits plot below "A" line and plasticity index greater than 7	
	$C_u = D_{60}/D_{10}$ Greater than 6 $C_z = \frac{(D_{30})^3}{D_{10} \times D_{60}}$ Between 1 and 3	
	Not meeting both criteria for SW	
	Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
	Atterberg limits plot above "A" line and plasticity index greater than 7	



Visual-Manual Identification

UNIFORM BUILDING CODE STANDARD 18-2
EXPANSION INDEX TEST

Based on Recommendations of the Los Angeles Section ASCE Soil Committee

See Sections 1801.2 and 1803.1, *Uniform Building Code*

SECTION 18.201 — SCOPE

The expansion index test is designed to measure a basic index property of the soil and in this respect is comparable to other index tests such as the Atterberg limits. In formulating the test procedures no attempt has been made to duplicate any particular moisture or loading conditions which may occur in the field. Rather, an attempt has been made to control all variables which influence the expansive characteristics of a particular soil and still retain a practical test for general engineering usage.

SECTION 18.202 — APPARATUS

18.202.1 Mold. The mold shall be cylindrical in shape, made of metal and have the capacity and dimensions indicated in Figure 18-2-1. It shall have a detachable collar inscribed with a mark 2.00 inches (50.8 mm) above the base. The lower section of the mold is designed to retain a removable stainless steel ring 1.00 inch (25.4 mm) in height, 4.01-inch (101.85 mm) internal diameter and 0.120-inch (3.048 mm) wall thickness.

18.202.2 Tamper. A metal tamper having a 2-inch-diameter (50.8 mm) circular face and weighing 5.5 pounds (2.5 kg) shall be equipped with a suitable arrangement to control height of drop to a free fall of 12 inches (305 mm) above the top of the soil.

18.202.3 Balance. A balance or scale of at least 1,000-gram capacity sensitive to 0.1 gram.

18.202.4 Drying Oven. A thermostatically controlled drying oven capable of maintaining a temperature of 230°F ± 9°F (110°C ± 5°C), for drying moisture samples.

18.202.5 Straight Edge. Steel straight edge 12 inches (305 mm) in length and having one bevelled edge.

18.202.6 Sieves. A No. 4 (4.75 mm) sieve conforming to the requirements of the specifications for sieves for testing purposes.

18.202.7 Mixing Tools. Miscellaneous tools such as mixing pans, spoons, trowels, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

SECTION 18.203 — SAMPLE PREPARATION

18.203.1 Preparation for Sieving. If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of the individual particles. If particles larger than 1/4 inch (6.4 mm) are possibly expansive, such as claystone, shale or weathered volcanic rock, they should be broken down so as to pass the No. 4 (4.75 mm) sieve.

18.203.2 Sieving. Sieve an adequate quantity of the representative pulverized soil over the No. 4 (4.75 mm) sieve. Record the percentage of coarse material retained on the No. 4 (4.75 mm) sieve and discard.

18.203.3 Sample. Select a representative sample, weighing approximately 2 pounds (0.91 kg) or more, of the soil prepared as described in Sections 18.203.1 and 18.203.2 above.

SECTION 18.204 — SPECIMEN PREPARATION

18.204.1 Moisture Determination. Thoroughly mix the selected representative sample with sufficient distilled water to bring the soil to approximately optimum moisture content. After mixing, take a representative sample of the material for moisture determination and seal the remainder of the soil in a close-fitting airtight container for a period of at least six hours.

Weigh the moisture sample immediately and dry in an oven at 230° ± 9°F (110°C ± 5°C), for at least 12 hours or to a constant weight to determine the moisture content. Moisture sample shall not weigh less than 300 grams.

18.204.2 Specimen Molding. Form a specimen by compacting the cured soil in the 4-inch-diameter (102 mm) mold in two equal layers to give a total compacted depth of approximately 2 inches (51 mm). Compact each layer by 15 uniformly distributed blows of the tamper dropping free from a height of 12 inches (305 mm) above the top of the soil, when a sleeve-type rammer is used, or from 12 inches (305 mm) above the approximate elevation of each finally compacted layer when a stationary mounted type of tamper is used. During the compaction the mold shall rest on a uniform, rigid foundation, such as provided by a cube of concrete weighing at least 200 pounds (90.72 kg).

18.204.3 Trim Specimen. Following compaction, remove the upper and lower portions of the mold from the inner ring and carefully trim the top and bottom of the ring by means of the straight edge.

18.204.4 Saturation. Weigh the compacted sample and determine the percent saturation. Adjust the moisture content to achieve 50 percent saturation by the addition of water or air drying the sample. Repeat Sections 18.204.2 and 18.204.3 above.

18.204.5 Specific Gravity. Repeat Section 18.204.4 until the saturation of the compacted sample is between 49 percent and 51 percent for a specific gravity of 2.7.

SECTION 18.205 — EXPANSION MEASUREMENT

18.205.1 Consolidometer. Place the soil specimen in a consolidometer or equivalent loading device with porous stones at the top and bottom. Place on the specimen a total load of 12.63 pounds (56.2 N), including the weight of the upper porous stone and any unbalanced weight of the loading machine. Allow the specimen to consolidate under this load for a period of 10 minutes, after which time make the initial reading on the consolidometer dial indicator to an accuracy of 0.0005 inch (0.010 mm).

18.205.2 Sample Submersion. Submerge the sample in distilled water, making periodic readings on the dial indicator for a period of 24 hours or until the rate of expansion becomes less than 0.0002 inch (0.0051 mm) per hour but not less than three hours submerged time.

18.205.3 Weighing. Remove the sample from the loading machine after the final reading and weigh the specimen to the nearest 0.1 gram.

SECTION 18.206 — CALCULATIONS AND REPORT

18.206.1 Expansion Index. Calculate the expansion index as follows:

$$E.I. = \frac{(\text{final thickness} - \text{initial thickness})}{\text{initial thickness}} \times 1{,}000$$

Report the expansion index to the nearest whole number. If the initial sample thickness is greater than the final sample thickness, report the expansion index as 0. The molding moisture content and initial dry density of the specimen should accompany the expansion index in the complete presentation of results.

18.206.2 Weighted Expansion Index. The weighted expansion index for a particular soil profile shall be determined as the summation of the products obtained by multiplying the expansion index by the factor appropriate to its elevation.

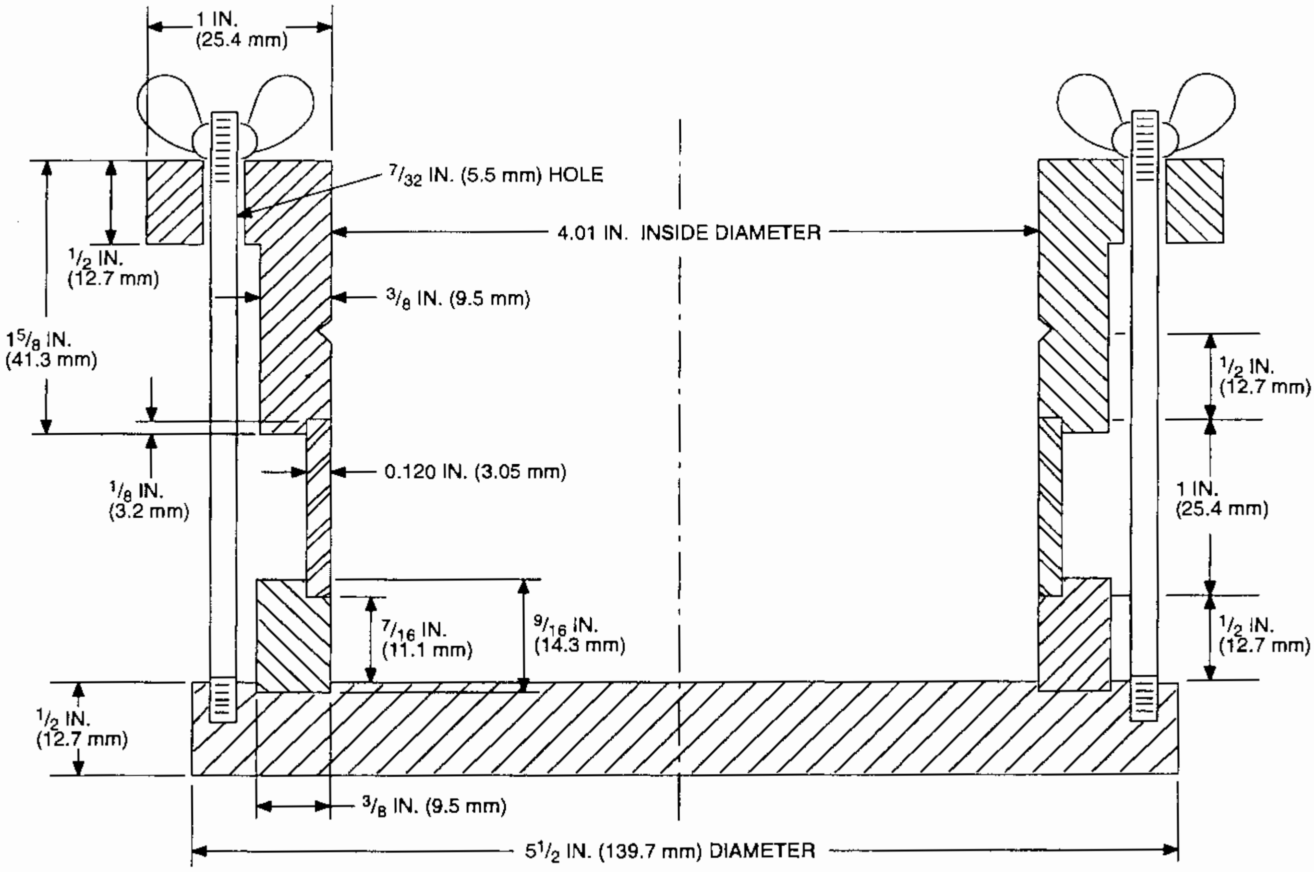


FIGURE 18-2-1—EXPANSION TEST MOLD

UNIFORM BUILDING CODE STANDARD 19-1

WELDING REINFORCING STEEL, METAL INSERTS AND CONNECTIONS IN REINFORCED CONCRETE CONSTRUCTION

See Sections 1903.5.2, 1903.10, and 1912.14, *Uniform Building Code*

SECTION 19.101 — ADOPTION OF AWS CODE

19.101.1 Except for the limitations, deletions, modifications or amendments set forth in Section 19.102 of this standard, the welding of concrete reinforcing steel for splices (prestressing steel excepted), steel connection devices, inserts, anchors and anchorage details, as well as any other welding required in reinforced concrete construction, shall be in accordance with the *Structural Welding Code—Reinforcing Steel,* ANSI/AWS D1.4-92, published by the American Welding Society, Inc., Copyright 1992, 550 North LeJeune Road, Miami, Florida 33135, as if set out at length herein.

SECTION 19.102 — DELETIONS AND AMENDMENTS

19.102.1 General. The American Welding Society, Inc., code adopted by Section 19.101 applies to all materials, processes, design, workmanship and testing of welding performed as a part of reinforced concrete construction, except as set forth in this section.

19.102.2 Deletions. The following sections and chapters are deleted:

Section 1.6

Section 1.7

Section 3.7

Section 5.6.3

Chapter 7

19.102.3 Amendments

1. **Sec. 1.2.1** is amended by changing the last sentence to read as follows:

When reinforcing steel is welded to primary structural steel members, welding procedures, welder qualification requirements and welding electrodes shall be in accordance with Chapter 22, Divisions II; III and VI or VII, of this code and approved national standards.

2. **Sec. 1.2.3** is amended to read as follows:

1.2.3. All references to the need for approval shall be interpreted to mean approval by the building official.

3. **Sec. 1.2.4** is amended to read as follows:

1.2.4 When structural steel base metals make up the entire weld joint, the engineer may select the use of welding procedures and welder qualifications in accordance with Chapter 22, Divisions II, III and VI or VII, of this code and approved national standards to perform that weld, provided other relevant provisions of UBC Standard 19-1 are considered.

4. **Sec. 1.3.3** is amended to read as follows:

1.3.3 Base metal, other than those previously listed, shall be one of the structural steels listed in Chapter 22, Divisions II, III and VI or VII, of this code.

5. **Sec. 1.5** is amended to read as follows:

1.5 Definitions

The welding terms used in this code shall be interpreted in accordance with the definitions given in Chapter 22, Divisions V, VIII and IX or X, of this code and approved national standards.

6. **Sec. 2.1** is amended to read as follows:

2.1 Base Metal Stresses. The allowable base metal stresses shall be those specified in this code for reinforced concrete construction.

UNIFORM BUILDING CODE STANDARD 19-2

MILL-MIXED GYPSUM CONCRETE AND POURED GYPSUM ROOF DIAPHRAGMS

Based on Reports of Test Programs by S. B. Barnes and Associates dated February 1955, November 1956, January 1958, and February 1962, and Standard Specification C 317-70 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 1903.9 and 1925.3, *Uniform Building Code*

Part I—Mill-mixed Gypsum Concrete

SECTION 19.201 — SCOPE

This part covers mill-mixed gypsum concrete. Gypsum concrete supplied under this standard shall be mill-mixed gypsum concrete, consisting essentially of calcined gypsum and suitable aggregate, requiring the addition of water only at the job. Gypsum concrete is intended for use in construction of poured-in-place roof decks or slabs. Two classes, based on the compressive strength and density, are covered.

SECTION 19.202 — COMPOSITION

Gypsum concrete shall consist essentially of calcined gypsum and wood chips or wood shavings, proportioned to meet the applicable requirements of this standard. Calcined gypsum used in the mill mixed gypsum concrete shall conform to the requirements of ASTM C 28-76a. Wood chips or wood shavings shall be of dry wood, uniform and clean in appearance, shall pass a 1-inch (25 mm) sieve, and shall not be more than $^1/_{16}$ inch (1.6 mm) in thickness.

SECTION 19.203 — TIME OF SETTING

Gypsum concrete shall not set in less than 20 minutes nor more than 90 minutes.

SECTION 19.204 — COMPRESSIVE STRENGTH AND DENSITY

Gypsum concrete shall have the following compressive strength and density for the respective classes:

	COMPRESSIVE STRENGTH MINIMUM psi (MPa)	DENSITY POUNDS PER CUBIC FOOT (kg/m³)
Class A	500 (3.5)	60 (960)
Class B	1,000 (6.9)	—

SECTION 19.205 — METHODS OF TESTING

The physical properties of gypsum concrete shall be determined in accordance with approved methods.

Part II—Poured-in-place Reinforced Gypsum Concrete

SECTION 19.206 — SCOPE

This part covers the design of poured-in-place reinforced gypsum concrete roof decks when used as a horizontal diaphragm.

SECTION 19.207 — DESIGN

19.207.1 General. The gypsum roof diaphragm shall consist of sub-purlins welded transversely to primary purlins. Formboard is then placed on the flanges of the subpurlins. Wire mesh reinforcement is then placed over the subpurlins and formboard and lapped at least 4 inches (102 mm) or one mesh on ends and edges, whichever is greater. Gypsum concrete meeting the requirements of Part I of this standard is then placed to a minimum thickness of 2 inches (51 mm) over the formboard and $^5/_8$ inch (16 mm) over the subpurlins and doweling elements. The bulb section or top flange of the subpurlin shall be fully embedded in the gypsum concrete.

19.207.2 Diaphragm Shear. Shear in poured gypsum concrete diaphragms shall be determined by the formula:

$$Q = .16 f_g \, t \, C_l + 1{,}000\,(k_l \, d_l + k_2 \, d_2)$$

For SI: $$Q = 1.36 f_g \, t \, C_l + 17.86\,(k_l \, d_l + k_2 \, d_2)$$

WHERE:

C_l = 1.0 for Class A gypsum; 1.5 for Class B gypsum.

d_l = diameter of mesh wires passing over subpurlins, in inches (mm), except hexagonal mesh.

d_2 = diameter, in inches (mm), of mesh wires parallel to subpurlins or of hexagonal wires.

f_g = oven-dry compressive strength of gypsum in pounds per square inch (MPa) as determined by tests conforming to this standard.

k_l = number of mesh wires per foot (m) passing over subpurlins.

k_2 = number of mesh wires per foot (m) parallel to subpurlins or .7 times the number of hexagonal wires. Note: k_2 = 8.5 (27.9) for 2-inch (51 mm) hexagonal mesh woven of No. 19 gage galvanized wire with additional longitudinal No. 16 gage galvanized wires spaced every 3 inches (76 mm) across the width of the mesh.

Q = allowable shear on diaphragm in pounds per linear foot (kg/m), which includes a one-third increase for short-time loading.

t = thickness of gypsum concrete between subpurlins, in inches (mm). For the purpose of computing diaphragm shear values, t shall not exceed 4 inches (102 mm).

The solution of the above equation for commonly used thickness and mesh types for each class of gypsum would give the values set forth in Table 19-2-A.

19.207.3 Shear Transfer. Bolts, dowels or other approved elements may be used to transfer diaphragm shears to perimeter or other structural members. Allowable bolt and dowel stresses shall comply with Table 19-G and Section 1603 of this code.

TABLE 19-2-A—ALLOWABLE SHEAR VALUES IN POUNDS PER FOOT USING BULB TEE SUBPURLINS[1]

CLASS OF GYPSUM CONCRETE	CONCRETE THICKNESS (inches)	MESH TYPE[2]		
		4" × 8" (102 mm × 203 mm) No. 12-No. 14 (Galvanized)	6" × 6" (152 mm × 152 mm) No. 10-No. 10	Hexagonal[3] (Galvanized)
× 6.89 for kPa	× 25.4 for mm	× 14.59 for N/m		
A (500 psi)	2	600	700	760
	$2^1/_2$	640	740	800
B (1,000 psi)	2	920	1,020	1,080
	$2^1/_2$	1,040	1,140	1,200

[1]The tabulated shear values are for short-time loads due to wind or earthquake forces and are not permitted a one-third increase for duration of load.

[2]Mesh shall be lapped at least 4 inches (102 mm) or one mesh on ends and edges, whichever is greater.

[3]Two-inch (51 mm) hexagonal mesh woven of No. 19 gage galvanized wire with additional longitudinal No. 16 gage galvanized wires spaced every 3 inches (76 mm) across the width of the mesh.

UNIFORM BUILDING CODE STANDARD 21-1
BUILDING BRICK, FACING BRICK AND HOLLOW BRICK (MADE FROM CLAY OR SHALE)

Based on Standard Specifications C 62-94a, C 216-92c, and C 652-94 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 4, *Uniform Building Code*

SECTION 21.101 — SCOPE

21.101.1 General. This standard covers brick made from clay or shale and subjected to heat treatment at elevated temperatures (firing), and intended for use in brick masonry. In addition, this standard covers dimension and distortion tolerances for facing brick and hollow brick to be used in masonry construction.

21.101.2 Definition.

BRICK is a solid clay masonry unit whose net cross-sectional area in any plane parallel to the surface containing the cores or cells is at least 75 percent of the gross cross-sectional area measured in the same plane.

21.101.3 Grades. Three grades of brick are covered.

Grade SW. Brick intended for use where a high and uniform resistance to damage caused by cyclic freezing is desired and the exposure is such that the brick may be frozen when saturated with water.

Grade MW. Brick intended for use where moderate resistance to cyclic freezing damage is permissible or where brick may be damp but not saturated with water when freezing occurs.

Grade NW. Brick with little resistance to cyclic freezing damage but which may be acceptable for applications protected from water absorption and freezing.

21.101.4 Grade Requirements for Face Exposure. The selection of the grade of brick for face exposure of vertical or horizontal surfaces shall conform to Table 21-1-A and Figure 21-1-1.

SECTION 21.102 — PHYSICAL PROPERTIES

21.102.1 Durability. The brick shall conform to the physical requirements for the grade specified, as prescribed in Table 21-1-B.

21.102.2 Substitution of Grades. Grades SW and MW may be used in lieu of Grade NW, and Grade SW in lieu of Grade MW.

21.102.3 Waiver of Saturation Coefficient. The saturation coefficient shall be waived provided the average cold-water absorption of a random sample of five bricks does not exceed 8 percent, no more than one brick of the sample exceeds 8 percent and its cold-water absorption must be less than 10 percent.

21.102.4 Freezing and Thawing. The requirements specified in this standard for water absorption (five-hour boiling) and saturation coefficient shall be waived, provided a sample of five bricks, meeting all other requirements, complies with the following requirements when subjected to 50 cycles of the freezing-and-thawing test:

Grade SW	No breakage and not greater than 0.5 percent loss in dry weight of any individual brick.

Brick is not required to conform to the provisions of this section, and these do not apply unless the sample fails to conform to the requirements for absorption and saturation coefficient prescribed in Table 21-1-B or the absorption requirements in Section 21.102.3.

A particular lot or shipment shall be given the same grading as a previously tested lot, without repeating the freezing-and-thawing test, provided the brick is made by the same manufacturer from similar raw materials and by the same method of forming; and provided also that a sample of five bricks selected from the particular lot has an average and individual minimum strength not less than a previously graded sample, and has average and individual maximum water absorption and saturation coefficient not greater than those of the previously tested sample graded according to the freezing-and-thawing test.

21.102.5 Waiver of Durability Requirements. If brick is intended for use exposed to weather where the weathering index is less than 50 (see Figure 21-1-1), unless otherwise specified, the requirements given in Section 21.102.1 for water absorption (five-hour boiling) and for saturation coefficient shall be waived and a minimum average strength of 2,500 pounds per square inch (17 200 kPa) shall apply.

SECTION 21.103 — SIZE, CORING AND FROGGING

21.103.1 Tolerances on Dimensions. The maximum permissible variation in dimensions of individual units shall not exceed those given in Table 21-1-C.

21.103.2 Coring. The net cross-sectional area of cored brick in any plane parallel to the surface containing the cores or cells shall be at least 75 percent of the gross cross-sectional area measured in the same plane. No part of any hole shall be less than $^3/_4$ inch (19.1 mm) from any edge of the brick.

21.103.3 Frogging. One bearing face of each brick may have a recess or panel frog and deep frogs. The recess or panel frog shall not exceed $^3/_8$ inch (9.5 mm) in depth and no part of the recess or panel frog shall be less than $^3/_4$ inch (19.1 mm) from any edge of the brick. In brick containing deep frogs, frogs deeper than $^3/_8$ inch (9.5 mm), any cross section through the deep frogs parallel to the surface containing the deep frogs shall conform to the requirements of Section 21.103.2.

SECTION 21.104 — VISUAL INSPECTION

21.104.1 General. The brick shall be free of defects, deficiencies and surface treatments, including coatings, that would interfere with the proper setting of the brick or significantly impair the strength or performance of the construction.

Minor indentations or surface cracks incidental to the usual method of manufacture, or the chipping resulting from the customary methods of handling in shipment and delivery should not be deemed grounds for rejection.

SECTION 21.105 — SAMPLING AND TESTING

21.105.1 Sampling and Testing. Brick shall be sampled and tested in accordance with ASTM C 67.

SECTION 21.106 — FACING BRICK

21.106.1 General. Facing brick shall be of Grade SW or MW and shall comply with the degree of mechanical perfection and size variations specified in this section. Grade SW may be used in lieu of Grade MW.

21.106.2 Types. Three types of facing brick are covered:

Type FBS. Brick for general use in exposed exterior and interior masonry walls and partitions where greater variation in sizes are permitted than are specified for Type FBX.

Type FBX. Brick for general use in exposed exterior and interior masonry walls and partitions where a high degree of mechanical perfection and minimum permissible variation in size are required.

Type FBA. Brick manufactured and selected to produce characteristic architectural effects resulting from nonuniformity in size and texture of individual units.

When the type is not specified, the requirements for Type FBS shall govern.

21.106.3 Tolerances on Dimensions. The brick shall not depart from the specified size to be used by more than the individual tolerance for the type specified set forth in Table 21-1-D. Tolerances on dimensions for Type FBA shall be as specified by the purchaser, but not more restrictive than Type FBS.

21.106.4 Warpage. Tolerances for distortion or warpage of face or edges of indivi-dual brick from a plane surface and from a straight line, respectively, shall not exceed the maximum for the type specified as set forth in Table 21-1-E. Tolerances on distortion for Type FBA shall be as specified by the purchaser.

21.106.5 Coring. Brick may be cored. The net cross-sectional area of cored brick in any plane parallel to the surface containing the cores or cells shall be at least 75 percent of the gross cross-sectional area measured in the same plane. No part of any hole shall be less than $^3/_4$ inch (19.1 mm) from any edge of the brick.

21.106.6 Frogging. One bearing face of each brick may have a recess or panel frog and deep frogs. The recess or panel frog shall not exceed $^3/_8$ inch (9.5 mm) in depth and no part of the recess or panel frog shall be less than $^3/_4$ inch (19.1 mm) from any edge of the brick. In brick containing deep frogs, frogs deeper than $^3/_8$ inch (9.5 mm), any cross section through the deep frogs parallel to the surface containing the deep frogs shall conform to the requirements of Section 21.106.5.

21.106.7 Visual Inspection. In addition to the requirements of Section 21.104, brick used in exposed wall construction shall have faces which are free of cracks or other imperfections detracting from the appearance of the designated sample when viewed from a distance of 15 feet (4600 mm) for Type FBX and a distance of 20 feet (6100 mm) for Types FBS and FBA.

SECTION 21.107 — HOLLOW BRICK

21.107.1 General. Hollow brick shall be of Grade SW or MW and comply with the physical requirements in Table 21-1-B and other requirements of this section. Grade SW may be used in lieu of Grade MW.

21.107.2 Definitions.

HOLLOW BRICK is a clay masonry unit whose net cross-sectional area (solid area) in any plane parallel to the surface, containing the cores, cells or deep frogs is less than 75 percent of its gross cross-sectional area measured in the same plane.

CORES are void spaces having a gross cross-sectional area equal to or less than $1^1/_2$ square inches (968 mm^2).

CELLS are void spaces having a gross cross-sectional area greater than $1^1/_2$ square inches (968 mm^2).

21.107.3 Types. Four types of hollow brick are covered:

Type HBS. Hollow brick for general use in exposed exterior and interior masonry walls and partitions greater variation in size are permitted than is specified for Type HBX.

Type HBX. Hollow brick for general use in exposed exterior and interior masonry walls and partitions where a high degree of mechanical perfection and minimum permissible variation in size are required.

Type HBA. Hollow brick manufactured and selected to produce characteristic architectural effects resulting from nonuniformity in size and texture of the individual units.

Type HBB. Hollow brick for general use in masonry walls and partitions where a particular color, texture, finish, uniformity, or limits on cracks, warpage, or other imperfections detracting from the appearance are not a consideration.

When the type is not specified, the requirements for Type HBS shall govern.

21.107.4 Class. Two classes of hollow brick are covered:

Class H40V. Hollow brick intended for use where void areas or hollow spaces greater than 25 percent, but not greater than 40 percent, of the gross cross-sectional area of the unit measured in any plane parallel to the surface containing the cores, cells or deep frogs are desired. The void spaces, web thicknesses and shell thicknesses shall comply with the requirements of Sections 21.107.5, 21.107.6 and 21.107.7.

Class H60V. Hollow brick intended for use where larger void areas are desired. The sum of these void areas shall be greater than 40 percent, but not greater than 60 percent, of the gross cross-sectional area of the unit measured in any plane parallel to the surface containing the cores, cells or deep frogs. The void spaces, web thicknesses and shell thicknesses shall comply with the requirements of Sections 21.107.5, 21.107.6 and 21.107.7 and to the minimum requirements of Table 21-1-F.

When the class is not specified, the requirements for Class H40V shall govern.

21.107.5 Hollow Spaces. Core holes shall not be less than $^5/_8$ inch (15.9 mm) from any edge of the brick, except for cored-shell hollow brick. Cored-shell hollow brick shall have a minimum shell thickness of $1^1/_2$ inches (38 mm). Cores greater than 1 square inch (645 mm^2) in cored shells shall not be less than $^1/_2$ inch (13 mm) from any edge. Cores not greater than 1 inch square (645 mm^2) in shells cored not more than 35 percent shall not be less than $^3/_8$ inch (9.5 mm) from any edge.

Cells shall not be less than $^3/_4$ inch (19.1 mm) from any edge of the brick except for double-shell hollow brick.

Double-shell hollow brick with inner and outer shells not less than $^1/_2$ inch (13 mm) thick may not have cells greater than $^5/_8$ inch (15.9 mm) in width or 5 inches (127 mm) in length between the inner and outer shell.

21.107.6 Webs. The thickness for webs between cells shall not be less than $^1/_2$ inch (13 mm), $^3/_8$ inch (9.5 mm) between cells and cores or $^1/_4$ inch (6 mm) between cores. The distance of voids from unexposed edges, which are recessed not less than $^1/_2$ inch (13 mm), shall not be less than $^1/_2$ inch (13 mm).

21.107.7 Frogging. One bearing face of each brick may have a recess or panel frog and deep frogs. The recess or panel frog shall not exceed $^3/_8$ inch (9.5 mm) in depth and no part of the recess or panel frog shall be less than $^5/_8$ inch (15.9 mm) from any edge of the brick. In brick containing deep frogs, frogs deeper than $^3/_8$ inch (9.5 mm), any cross section through the deep frogs parallel to the bearing surface shall conform to other requirements of Sections 21.107.2 and 21.107.4 for void area and Section 21.107.5 for hollow spaces.

21.107.8 Tolerances on Dimensions. The hollow brick shall not depart from the specified size by more than the individual tolerance for specified size by more than individual tolerances for the type specified as set forth in Table 21-1-G. Tolerances and dimensions for Type HBA shall be as specified by the purchaser.

21.107.9 Warpage. Tolerances for distortion or warpage of face or edges of individual hollow brick from a plane surface and from a straight line, respectively, shall not exceed the maximum for the type specified in Table 21-1-H. Tolerances on distortion for Type HBA shall be as specified by the purchaser.

21.107.10 Visual Inspection. In addition to the requirements of Section 21.104, brick used in exposed wall construction shall have faces which are free of cracks or other imperfections detracting from the appearance of a sample wall when viewed from a distance of 15 feet (4600 mm) for Type HBX and a distance of 20 feet (6100 mm) for Types HBS and HBA.

TABLE 21-1-A—GRADE REQUIREMENTS FOR FACE EXPOSURE

EXPOSURE	WEATHERING INDEX: Less than 50	WEATHERING INDEX: 50 to 500	WEATHERING INDEX: 500 and greater
In vertical surfaces:			
In contact with earth	MW	SW	SW
Not in contact with earth	MW	SW	SW
In other than vertical surfaces:			
In contact with earth	SW	SW	SW
Not in contact with earth	MW	SW	SW

TABLE 21-1-B—PHYSICAL REQUIREMENTS FOR TYPES OF UNIT MASONRY[5]

TYPE OF MASONRY	GRADE	MINIMUM FACE SHELL THICKNESS (inches)	MINIMUM[1] COMPRESSIVE STRENGTH PSI AVERAGE GROSS AREA × 6.89 for kPa: Average of Five Tests	Individual	MAXIMUM WATER ABSORPTION By Five-hour Boiling (percent): Average of Five Tests	Individual	MAXIMUM SATURATION COEFFICIENT[2]: Average of Five Test	Individual	WATER ABSORPTION Maximum Pounds per Cubic Foot × 16 for kg/m³	MOISTURE CONTENT Maximum Percentage of Total Absorption	MINIMUM MODULUS OF RUPTURE: Average of Five Tests	Individual
			(brick flatwise)								(brick flatwise) psi Average Gross Area × 6.89 for kPa	
24-1. Building brick made from clay or shale[3]	SW		3,000	2,500	17	20	.78	.80				
	MW		2,500	2,200	22	25	.88	.90				
	NW		1,500	1,250	no limit							
			(net area)[4]									
Hollow Brick[3]	SW	See Table 21-1-F	3,000	2,500	17	20	.78	.80				
	MW		2,500	2,000	22	25	.88	.90				
24-2. Sand-lime building brick	SW		4,500	3,500							600	400
	MW		2,500	2,000							450	300
			Based on Net Area (psi)[4] × 6.89 for kPa						Based on % of Dry Wt.			
24-14. Unburned clay masonry units			300	250					2.5%	4.0%	50	35

[1]Gross area of a unit shall be determined by multiplying the horizontal face dimension of the unit as placed in the wall by its thickness.

[2]The saturation coefficient is the ratio of absorption by 24-hour submersion in cold water to that after five-hour submersion in boiling water.

[3]If the average cold-water absorption of a random sample of five bricks does not exceed 8.0 percent, when no more than one brick unit of the sample exceeds 8.0 percent and its cold-water absorption must be less than 10.0 percent, the saturation coefficient shall be waived.

[4]Based on net area of a unit which shall be taken as the area of solid material in shells and webs actually carrying stresses in a direction parallel to the direction of loading.

[5]For the compressive strength requirements, test the unit with the compressive force perpendicular to the bed surface of the unit, with the unit in the stretcher position.

TABLE 21-1-C—TOLERANCES ON DIMENSIONS

SPECIFIED DIMENSION (inches)	MAXIMUM PERMISSIBLE VARIATION FROM SPECIFIED DIMENSION, PLUS OR MINUS (inch)
× 25.4 for mm	
Up to 3, incl.	$^3/_{32}$
Over 3 to 4, incl.	$^1/_8$
Over 4 to 6, incl.	$^3/_{16}$
Over 6 to 8, incl.	$^1/_4$
Over 8 to 12, incl.	$^5/_{16}$
Over 12 to 16, incl.	$^3/_8$

TABLE 21-1-D—TOLERANCES ON DIMENSIONS

SPECIFIED DIMENSION (inches)	MAXIMUM PERMISSIBLE VARIATION FROM SPECIFIED DIMENSION, PLUS OR MINUS (inch)	
	Type FBX	Type FBS
× 25.4 for mm		
3 and under	$^1/_{16}$	$^3/_{32}$
Over 3 to 4, incl.	$^3/_{32}$	$^1/_8$
Over 4 to 6, incl.	$^1/_8$	$^3/_{16}$
Over 6 to 8, incl.	$^5/_{32}$	$^1/_4$
Over 8 to 12, incl.	$^7/_{32}$	$^5/_{16}$
Over 12 to 16, incl.	$^9/_{32}$	$^3/_8$

TABLE 21-1-E—TOLERANCES ON DISTORTION

MAXIMUM FACE DIMENSION (inches)	MAXIMUM PERMISSIBLE DISTORTION (inch)	
	Type FBX	Type FBS
× 25.4 for mm		
8 and under	$^1/_{16}$	$^3/_{32}$
Over 8 to 12, incl.	$^3/_{32}$	$^1/_8$
Over 12 to 16, incl.	$^1/_8$	$^5/_{32}$

TABLE 21-1-F—HOLLOW BRICK (Class H60V) MINIMUM THICKNESS OF FACE SHELLS AND WEBS

NOMINAL WIDTH OF UNIT (inches)	FACE SHELL THICKNESS (inches)		END SHELLS OR WEBS (inches)	WEB THICKNESS PER FOOT, TOTAL (inches per foot)[1]
	Solid	Cored or Double Shell		
× 25.4 for mm				× 83 for mm per m
3 and 4	$^3/_4$	—	$^3/_4$	$1^5/_8$
6	1	$1^1/_2$	1	$2^1/_4$
8	$1^1/_4$	$1^1/_2$	1	$2^1/_4$
10	$1^3/_8$	$1^5/_8$	$1^1/_8$	$2^1/_2$
12	$1^1/_2$	2	$1^1/_8$	$2^1/_2$

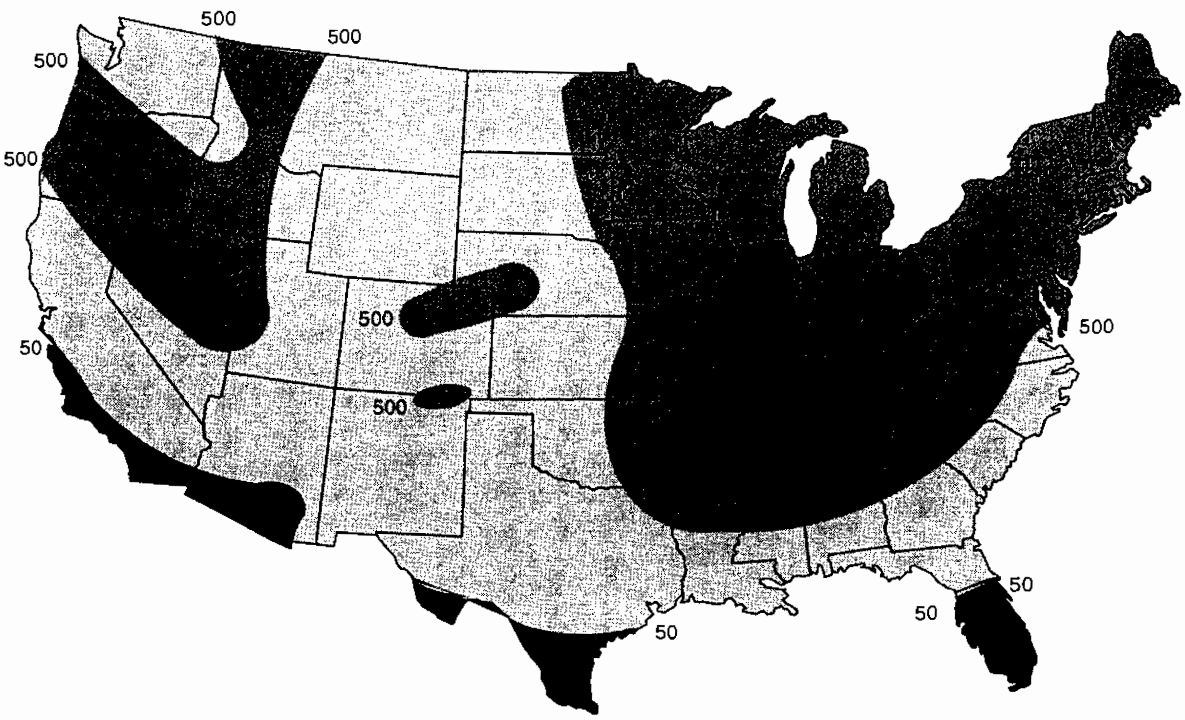
[1]The sum of the measured thickness of all webs in the unit, multiplied by 12 (305 when using metric), and divided by the length of the unit. In the case of open-ended units where the open-end portion is solid grouted, the length of that open-ended portion shall be deducted from the overall length of the unit.

TABLE 21-1-G—TOLERANCES ON DIMENSIONS

SPECIFIED DIMENSION (inches)	MAXIMUM PERMISSIBLE VARIATION FROM SPECIFIED DIMENSION, PLUS OR MINUS (inch)	
	Type HBX	Types HBS and HBB
	× 25.4 for mm	
3 and under	1/16	3/32
Over 3 to 4, incl.	3/32	1/8
Over 4 to 6, incl.	1/8	3/16
Over 6 to 8, incl.	5/32	1/4
Over 8 to 12, incl.	7/32	5/16
Over 12 to 16, incl.	9/32	3/8

TABLE 21-1-H—TOLERANCES ON DISTORTION

MAXIMUM FACE DIMENSION (inches)	MAXIMUM PERMISSIBLE DISTORTION (inch)	
	Type HBX	Types HBS and HBB
	× 25.4 for mm	
8 and under	1/16	3/32
Over 8 to 12, incl.	3/32	1/8
Over 12 to 16, incl.	1/8	5/32



WEATHERING REGIONS

SEVERE WEATHERING

MODERATE WEATHERING

NEGLIGIBLE WEATHERING

FIGURE 21-1-1—WEATHERING INDEXES IN THE UNITED STATES

UNIFORM BUILDING CODE STANDARD 21-2
CALCIUM SILICATE FACE BRICK (SAND-LIME BRICK)

See Section 2102.2, Item 6, *Uniform Building Code*

SECTION 21.201 — SCOPE

21.201.1 Grades. This standard covers brick made from sand and lime and intended for use in brick masonry. Two grades of brick are covered:

21.201.1.1 Grade SW. Brick intended for use where exposed to temperatures below freezing in the presence of moisture.

21.201.1.2 Grade MW. Brick intended for use where exposed to temperature below freezing but unlikely to be saturated with water.

21.201.2 Definition. The term "brick" used in this standard shall mean brick or a solid sand-lime masonry unit.

SECTION 21.202 — PHYSICAL PROPERTIES

21.202.1 Durability. The brick shall conform to the physical requirements for the grade specified as prescribed in Table 21-2-A.

21.202.2 Substitution of Grades. Unless otherwise specified, brick of Grade SW shall be accepted in lieu of Grade MW.

SECTION 21.203 — SIZE

The size of the brick shall be as specified by the purchaser, and the average size of brick furnished shall approximate the size specified in the invitation for bids.

No overall dimension (width, height and length) shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimension. Standard dimensions of units are the manufacturer's designated dimensions.

SECTION 21.204 — VISUAL INSPECTION

Brick shall pass a visual inspection for soundness, compact structure, reasonably uniform shape, and freedom from the following: cracks, warpage, large pebbles, balls of clay, or particles of lime that would affect the serviceability or strength of the brick.

SECTION 21.205 — METHODS OF SAMPLING AND TESTING

The purchaser or the purchaser's authorized representative shall be accorded proper facilities to inspect and sample the units at the place of manufacture from the lots ready for delivery. At least 10 days should be allowed for completion of the tests.

Sample and test units in accordance with ASTM C 140.

TABLE 21-2-A—PHYSICAL REQUIREMENTS FOR SAND-LIME BUILDING BRICK

TYPE OF MASONRY	GRADE	MINIMUM COMPRESSIVE STRENGTH PSI AVERAGE GROSS AREA		MINIMUM MODULUS OF RUPTURE (Brick Flatwise) psi Average Gross Area		WATER ABSORPTION MAX. lb./ft.^{3} (kg/m^3)
		Average of Five Tests	Individual	Average of Five Tests	Individual	
		× 6.89 for kPa				
Sand-lime	SW	4500	3500	600	400	10 (160)
Building brick	MW	2500	2000	450	300	13 (208)

Gross area of a unit shall be determined by multiplying the horizontal face dimension of the unit as placed in the wall by its thickness.

UNIFORM BUILDING CODE STANDARD 21-3
CONCRETE BUILDING BRICK

Based on Standard Specification C 55-95 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 5, *Uniform Building Code*

SECTION 21.301 — SCOPE

This standard covers concrete building brick and similar solid units made from portland cement, water and suitable mineral aggregates with or without the inclusion of other materials.

SECTION 21.302 — CLASSIFICATION

21.302.1 Types. Two types of concrete brick in each of two grades are covered, as follows:

21.302.1.1 Type I, moisture-controlled units. Concrete brick designated as Type I (Grades N-I and S-I) shall conform to all requirements of this standard, including the requirements of Table 21-3-A.

21.302.1.2 Type II, nonmoisture-controlled units. Concrete brick designated as Type II (Grades N-II and S-II) shall conform to all requirements of this standard except the requirements of Table 21-3-A.

21.302.2 Grades. Concrete brick manufactured in accordance with this standard shall conform to two grades as follows:

21.302.2.1 Grade N. For use as architectural veneer and facing units in exterior walls and for use where high strength and resistance to moisture penetration and severe frost action are desired.

21.302.2.2 Grade S. For general use where moderate strength and resistance to frost action and moisture penetration are required.

SECTION 21.303 — MATERIALS

21.303.1 Cementitious Materials. Materials shall conform to the following applicable standards:

1. Portland Cement—ASTM C 150 modified as follows:

   Limitation on insoluble residue—1.5 percent.
   Limitation on air content of mortar,
   Volume percent—22 percent maximum.
   Limitation on loss on ignition—7 percent maximum.
   Limestone with a minimum 85 percent calcium carbonate ($CaCO_3$) content may be added to the cement, provided the requirements of ASTM C 150 as modified above are met.
2. Blended Cements—ASTM C 595.
3. Hydrated Lime, Type S—UBC Standard 21-13.

21.303.2 Other Constituents. Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, etc., shall be previously established as suitable for use in concrete or shall be shown by test or experience not to be detrimental to the durability of the concrete.

SECTION 21.304 — PHYSICAL REQUIREMENTS

At the time of delivery to the work site, the concrete brick shall conform to the physical requirements prescribed in Table 21-3-B.

At the time of delivery to the purchaser, the total linear drying shrinkage of Type II units shall not exceed 0.065 percent when tested in accordance with ASTM C 426.

The moisture content of Type I concrete brick at the time of delivery shall conform to the requirements prescribed in Table 21-3-A.

SECTION 21.305 — DIMENSIONS AND PERMISSIBLE VARIATIONS

Overall dimensions (width, height, or length) shall not differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimensions.

NOTE: Standard dimensions of concrete brick are the manufacturer's designated dimensions. Nominal dimensions of modular-size concrete brick are equal to the standard dimensions plus $^3/_8$ inch (9.5 mm), the thickness of one standard mortar joint. Nominal dimensions of non-modular size concrete brick usually exceed the standard dimensions by $^1/_8$ inch to $^1/_4$ inch (3.2 mm to 6.4 mm).

Variations in thickness of architectural units such as split-faced or slumped units will usually vary from the specified tolerances.

SECTION 21.306 — VISUAL INSPECTION

21.306.1 General. All concrete brick shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or impair the strength or permanence of the construction. Minor cracks incidental to the usual method of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery, shall not be deemed grounds for rejection.

21.306.2 Brick in Exposed Walls. Where concrete brick is to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks or other imperfections when viewed from 20 feet (6100 mm), except that if not more than 5 percent of a shipment contains slight cracks or small chips not larger than $^1/_2$ inch (13 mm), this shall not be deemed grounds for rejection.

SECTION 21.307 — METHODS OF SAMPLING AND TESTING

The purchaser or authorized representative shall be accorded proper facilities to inspect and sample the concrete brick at the place of manufacture from the lots ready for delivery. At least 10 days shall be allowed for completion of the test.

Sample and test concrete brick in accordance with ASTM C 140 and C 426, when applicable.

Total linear drying shrinkage shall be based on tests of concrete brick made with the same materials, concrete mix design, manufacturing process and curing method, conducted in accordance with ASTM C 426 not more than 24 months prior to delivery.

SECTION 21.308 — REJECTION

If the shipment fails to conform to the specific requirements, the manufacturer may sort it, and new specimens shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. If the second set of specimens fails to conform to the test requirements, the entire lot shall be rejected.

TABLE 21-3-A—MOISTURE CONTENT REQUIREMENTS FOR TYPE I CONCRETE BRICK

	MOISTURE CONTENT, MAX. PERCENT OF TOTAL ABSORPTION (Average of 3 Concrete Brick)		
	Humidity[1] Conditions at Jobsite or Point of Use		
LINEAR SHRINKAGE, PERCENT	Humid	Intermediate	Arid
0.03 or less	45	40	35
From 0.03 to 0.045	40	35	30
0.045 to 0.065, max.	35	30	25

[1]Arid—Average annual relative humidity less than 50 percent.
Intermediate—Average annual relative humidity 50 to 75 percent.
Humid—Average annual relative humidity above 75 percent.

TABLE 21-3-B—STRENGTH AND ABSORPTION REQUIREMENTS

COMPRESSIVE STRENGTH, MIN., psi (Concrete Brick Tested Flatwise)			WATER ABSORPTION, MAX., (Avg. of 3 Brick) WITH OVEN-DRY WEIGHT OF CONCRETE Lb./Ft.^{3}		
× 6.89 for kPa			× 16 for kg/m^3		
Average Gross Area			Weight Classification		
Grade	Avg. of 3 Concrete Brick	Individual Concrete Brick	Lightweight Less Than 105	Medium Weight Less Than 125 to 105	Normal Weight 125 or More
N-I	3,500	3,000	15	13	10
N-II	3,500	3,000	15	13	10
S-I	2,500	2,000	18	15	13
S-II	2,500	2,000	18	15	13

UNIFORM BUILDING CODE STANDARD 21-4
HOLLOW AND SOLID LOAD-BEARING CONCRETE MASONRY UNITS

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SECTION 21.401 — SCOPE

This standard covers solid (units with 75 percent or more net area) and hollow load-bearing concrete masonry units made from portland cement, water and mineral aggregates with or without the inclusion of other materials.

SECTION 21.402 — CLASSIFICATION

21.402.1 Types. Two types of concrete masonry units in each of two grades are covered as follows:

21.402.1.1 Type 1, moisture-controlled units. Units designated as Type I shall conform to all requirements of this standard including the moisture content requirements of Table 21-4-A.

21.402.1.2 Type II, nonmoisture-controlled units. Units designated as Type II shall conform to all requirements of this standard except the moisture content requirements of Table 21-4-A.

21.402.2 Grades. Concrete masonry units manufactured in accordance with this standard shall conform to two grades as follows:

21.402.2.1 Grade N. Units having a weight classification of 85 pcf (1360 kg/m^3) or greater, for general use such as in exterior walls below and above grade that may or may not be exposed to moisture penetration or the weather and for interior walls and backup.

21.402.2.2 Grade S. Units having a weight classification of less than 85 pcf (1360 kg/m^3), for uses limited to above-grade installation in exterior walls with weather-protective coatings and in walls not exposed to the weather.

SECTION 21.403 — MATERIALS

21.403.1 Cementitious Materials. Materials shall conform to the following applicable standards:

1. Portland Cement—ASTM C 150 modified as follows:

   Limitation on insoluble residue—1.5 percent maximum.
   Limitation on air content of mortar,
   Volume percent—22 percent maximum.
   Limitation on loss on ignition—7 percent maximum.
   Limestone with a minimum 85 percent calcium carbonate (C_aCO_3) content may be added to the cement, provided the requirements of ASTM C 150 as modified above are met.

2. Blended Cements—ASTM C 595.

3. Hydrated Lime, Type S—UBC Standard 21-13.

21.403.2 Other Constituents and Aggregates. Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, aggregates, and other constituents, shall be previously established as suitable for use in concrete or shall be shown by test or experience to not be detrimental to the durability of the concrete.

SECTION 21.404 — PHYSICAL REQUIREMENTS

At the time of delivery to the work site, the units shall conform to the physical requirements prescribed in Table 21-4-B. The moisture content of Type I concrete masonry units at time of delivery shall conform to the requirements prescribed in Table 21-4-A.

At the time of delivery to the purchaser, the linear shrinkage of Type II units shall not exceed 0.065 percent.

SECTION 21.405 — MINIMUM FACE-SHELL AND WEB THICKNESSES

Face-shell (FST) and web (WT) thicknesses shall conform to the requirements listed in Table 21-4-C.

SECTION 21.406 — PERMISSIBLE VARIATIONS IN DIMENSIONS

21.406.1 Precision Units. For precision units, no overall dimension (width, height and length) shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimensions.

21.406.2 Particular Feature Units. For particular feature units, dimensions shall be in accordance with the following:

1. For molded face units, no overall dimension (width, height and length) shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimension. Dimensions of molded features (ribs, scores, hex-shapes, patterns, etc.) shall be within $^1/_{16}$ inch (1.6 mm) of the specified standard dimensions and shall be within $^1/_{16}$ inch (1.6 mm) of the specified placement of the unit.

2. For split-faced units, all non-split overall dimensions (width, height and length) shall differ by no more than $^1/_8$ inch (3.2 mm) from the specified standard dimensions. On faces that are split, overall dimensions will vary. Local suppliers should be consulted to determine dimensional tolerances achievable.

3. For slumped units, no overall height dimension shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimension. On faces that are slumped, overall dimensions will vary. Local suppliers should be consulted to determine dimension tolerances achievable.

NOTE: Standard dimensions of units are the manufacturer's designated dimensions. Nominal dimensions of modular size units, except slumped units, are equal to the standard dimensions plus $^3/_8$ inch (9.5 mm), the thickness of one standard mortar joint. Slumped units are equal to the standard dimensions plus $^1/_2$ inch (13 mm), the thickness of one standard mortar joint. Nominal dimensions of nonmodular size units usually exceed the standard dimensions by $^1/_8$ inch to $^1/_4$ inch (3.2 mm to 6.4 mm).

SECTION 21.407 — VISUAL INSPECTION

All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or impair the strength or perm-anence of the construction. Units may have minor cracks incidental to the usual method of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery.

Units that are intended to serve as a base for plaster or stucco shall have a sufficiently rough surface to afford a good bond.

Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks or other imperfections when viewed from 20 feet (6100 mm), except that not more than 5 percent of a shipment may have slight cracks or small chips not larger than 1 inch (25.4 mm).

SECTION 21.408 — METHODS OF SAMPLING AND TESTING

The purchaser or authorized representative shall be accorded proper facilities to inspect and sample the units at the place of manufacture from the lots ready for delivery.

Sample and test units in accordance with ASTM C 140.

Total linear drying shrinkage shall be based on tests of concrete masonry units made with the same materials, concrete mix design, manufacturing process and curing method, conducted in accordance with ASTM C 426 and not more than 24 months prior to delivery.

SECTION 21.409 — REJECTION

If the samples tested from a shipment fail to conform to the specified requirements, the manufacturer may sort it, and new specimens shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. If the second set of specimens fails to conform to the specified requirements, the entire lot shall be rejected.

TABLE 21-4-A—MOISTURE CONTENT REQUIREMENTS FOR TYPE I UNITS

LINEAR SHRINKAGE, PERCENT	MOISTURE CONTENT, MAX. PERCENT OF TOTAL ABSORPTION (Average of 3 Units)		
	Humidity Conditions at Jobsite or Point of Use		
	Humid[1]	Intermediate[2]	Arid[3]
0.03 or less	45	40	35
From 0.03 to 0.045	40	35	30
0.045 to 0.065, max.	35	30	25

[1]Average annual relative humidity above 75 percent.

[2]Average annual relative humidity 50 to 75 percent.

[3]Average annual relative humidity less than 50 percent.

TABLE 21-4-B—STRENGTH AND ABSORPTION REQUIREMENTS

COMPRESSIVE STRENGTH, MIN, psi (MPa)		WATER ABSORPTION, MAX, lb./ft. (kg/m) (Average of 3 Units)		
Average Net Area		Weight Classification—Oven-dry Weight of Concrete, lb./ft. (kg/m)		
Average of 3 Units	Individual Unit	Lightweight, Less than 105 (1680)	Medium Weight, 105 to less than 125 (1680-2000)	Normal Weight, 125 (2000) or more
1900 (13.1)	1700 (11.7)	18 (288)	15 (240)	13 (208)

TABLE 21-4-C—MINIMUM THICKNESS OF FACE-SHELLS AND WEBS

NOMINAL WIDTH (W) OF UNIT (inches)	FACE-SHELL THICKNESS (FST) MIN., (inches)[1, 4]	WEB THICKNESS (WT)	
		Webs[1] Min., (inches)	Equivalent Web Thickness, Min., in./Lin. Ft.[2]
× 25.4 for mm			× 83 for mm/lin. m
3 and 4	$^3/_4$	$^3/_4$	$1^5/_8$
6	1	1	$2^1/_4$
8	$1^1/_4$	1	$2^1/_4$
10	$1^3/_8$ $1^1/_4$[3]	$1^1/_8$	$2^1/_2$
12	$1^1/_2$ $1^1/_4$[3]	$1^1/_8$	$2^1/_2$

[1]Average of measurements on three units taken at the thinnest point.

[2]Sum of the measured thickness of all webs in the unit, multiplied by 12 (305 when using metric), and divided by the length of the unit. In the case of open-ended units where the open-ended portion is solid grouted, the length of that open-ended portion shall be deducted from the overall length of the unit.

[3]This face-shell thickness (FST) is applicable where allowable design load is reduced in proportion to the reduction in thicknesses shown, except that allowable design load on solid-grouted units shall not be reduced.

[4]For split-faced units, a maximum of 10 percent of a shipment may have face-shell thicknesses less than those shown, but in no case less than $^3/_4$ inch (19 mm).

UNIFORM BUILDING CODE STANDARD 21-5
NONLOAD-BEARING CONCRETE MASONRY UNITS

Based on Standard Specification C 129-95 (1980) of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 5, *Uniform Building Code*

SECTION 21.501 — SCOPE

This standard covers hollow and solid nonload-bearing concrete masonry units made from portland cement, water, and mineral aggregates with or without the inclusion of other materials. Such units are intended for use in nonload-bearing partitions but under certain conditions may be suitable for use in nonload-bearing exterior walls above grade, where effectively protected from the weather.

SECTION 21.502 — CLASSIFICATION

21.502.1 Weight Classifications. Nonload-bearing concrete masonry units manufactured in accordance with this standard shall conform to one of three weight classifications and two types as follows:

WEIGHT CLASSIFICATION	OVEN-DRY WEIGHT OF CONCRETE lb./cu.ft.
Lightweight	105 (1680 kg/m^3) max.
Medium weight	105 - 125 (1680 - 2000 kg/m^3)
Normal weight	125 (2000 kg/m^3) min.

21.502.2 Types. Nonload-bearing concrete masonry units shall be of two types as follows:

21.502.2.1 Type I, moisture-controlled units. Type I units shall conform to all requirements of this standard, including the requirements of Table 21-5-A.

21.502.2.2 Type II, nonmoisture-controlled units. Type II units shall conform to all requirements of this standard, except the requirements listed in Table 21-5-A.

SECTION 21.503 — MATERIALS

21.503.1 Cementitious Materials. Cementitious materials shall conform to the following applicable standards:

1. Portland Cement—ASTM C 150 modified as follows:

   Limitation on insoluble residue—1.5 percent.
   Limitation on air content of mortar,
   Volume percent—22 percent maximum.
   Limitation on loss on ignition—7 percent maximum.
   Limestone with a minimum 85 percent calcium carbonate ($CaCO_3$) content may be added to the cement, provided the requirements of ASTM C 150 as modified above are met.

2. Blended Cements—ASTM C 595.
3. Hydrated Lime, Type S—UBC Standard 21-13.

21.503.2 Other Constituents. Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, etc., shall be previously established as suitable for use in concrete or shall be shown by test or experience not to be detrimental to the durability of the concrete.

SECTION 21.504 — PHYSICAL REQUIREMENTS

At the time of delivery to the work site, the units shall conform to the strength requirements prescribed in Table 21-5-B.

The moisture content of Type I concrete masonry units at the time of delivery shall conform to the requirements prescribed in Table 21-5-A.

At the time of delivery to the purchaser, the total linear drying of Type II units shall not exceed 0.065 percent.

SECTION 21.505 — DIMENSIONS AND PERMISSIBLE VARIATIONS

Minimum face-shell thickness shall not be less than $^1/_2$ inch (13 mm).

No overall dimension (width, height or length) shall differ by more than $^1/_8$ inch (3.2 mm) from the specified standard dimensions.

NOTE: Standard dimensions of units are the manufacturer's designated dimensions. Nominal dimensions of modular-size units are equal to the standard dimensions plus $^3/_8$ inch (9.5 mm), the thickness of one standard mortar joint. Nominal dimensions of nonmodular size units usually exceed the standard dimensions by $^1/_8$ inch to $^1/_4$ inch (3.2 mm to 6.4 mm).

Variations in thickness of architectural units such as split-faced or slumped units will usually exceed the specified tolerances.

SECTION 21.506 — VISUAL INSPECTION

21.506.1 General. All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the units or impair the strength or permanence of the construction. Units may have minor cracks incidental to the usual method of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery.

21.506.2 Exposed Units. Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks or other imperfections when viewed from 20 feet (6100 mm), except that not more than 5 percent of a shipment may have slight cracks or small chips not larger than 1 inch (25 mm).

21.506.3 Identification. Nonloading concrete masonry units shall be clearly marked in a manner to preclude their use as load-bearing units.

SECTION 21.507 — METHODS OF SAMPLING AND TESTING

The purchaser or authorized representative shall be accorded proper facilities to inspect and sample the units at the place of manufacture from the lots ready for delivery. At least 10 days shall be allowed for the completion of the tests.

Sample and test units in accordance with ASTM C 140 and ASTM C 426 when applicable.

Total linear drying shrinkage shall be based on tests of concrete masonry units made with the same materials, concrete mix design, manufacturing process and curing method, conducted in accordance with ASTM C 426 and not more than 24 months prior to delivery.

SECTION 21.508 — REJECTION

If the shipment fails to conform to the specified requirements, the manufacturer may sort it, and new specimens shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. If the second set of specimens fails to conform to the specified requirements, the entire lot shall be rejected.

TABLE 21-5-A—MOISTURE CONTENT REQUIREMENTS FOR TYPE I UNITS

LINEAR SHRINKAGE, PERCENT	MOISTURE CONTENT, MAX. PERCENT OF TOTAL ABSORPTION (Average of 3 Units)		
	Humidity[1] Conditions at Jobsite or Point of Use		
	Humid	Intermediate	Arid
0.03 or less	45	40	35
From 0.03 to 0.045	40	35	30
0.045 to 0.065, max.	35	30	25

[1]Arid—Average annual relative humidity less than 50 percent.
Intermediate—Average annual relative humidity 50 to 75 percent.
Humid—Average annual relative humidity above 75 percent.

TABLE 21-5-B—STRENGTH REQUIREMENTS

	COMPRESSIVE STRENGTH (Average Net Area) Min., psi
	× 6.89 for kPa
Average of 3 units	600
Individual units	500

UNIFORM BUILDING CODE STANDARD 21-6
IN-PLACE MASONRY SHEAR TESTS

Test Standard of the International Conference of Building Officials

See Appendix Chapter 1, Sections A106.3.3 and A107.2,
Uniform Code for Building Conservation

SECTION 21.601 — SCOPE

This standard applies when the *Uniform Code for Building Conservation* requires in-place testing of the quality of masonry mortar.

SECTION 21.602 — PREPARATION OF SAMPLE

The bed joints of the outer wythe of the masonry shall be tested in shear by laterally displacing a single brick relative to the adjacent bricks in the same wythe. The head joint opposite the loaded end of the test brick shall be carefully excavated and cleared. The brick adjacent to the loaded end of the test brick shall be carefully removed by sawing or drilling and excavating to provide space for a hydraulic ram and steel loading blocks.

SECTION 21.603 — APPLICATION OF LOAD AND DETERMINATION OF RESULTS

Steel blocks, the size of the end of the brick, shall be used on each end of the ram to distribute the load to the brick. The blocks shall not contact the mortar joints. The load shall be applied horizontally, in the plane of the wythe, until either a crack can be seen or slip occurs. The strength of the mortar shall be calculated by dividing the load at the first cracking or movement of the test brick by the nominal gross area of the sum of the two bed joints.

UNIFORM BUILDING CODE STANDARD 21-7
TESTS OF ANCHORS IN UNREINFORCED MASONRY WALLS

Test Standard of the International Conference of Building Officials

See Appendix Chapter 1, Section A107.3 and A107.4, *Uniform Code for Building Conservation*

SECTION 21.701 — SCOPE

Shear and tension anchors in existing masonry construction shall be tested in accordance with this standard when required by the *Uniform Code for Building Conservation.*

SECTION 21.702 — DIRECT TENSION TESTING OF EXISTING ANCHORS AND NEW BOLTS

The test apparatus shall be supported by the masonry wall. The distance between the anchor and the test apparatus support shall not be less than one half the wall thickness for existing anchors and 75 percent of the embedment for new embedded bolts. Existing wall anchors shall be given a preload of 300 pounds (1335 N) prior to establishing a datum for recording elongation. The tension test load reported shall be recorded at $^1/_8$ inch (3.2 mm) relative movement of the existing anchor and the adjacent masonry surface. New embedded tension bolts shall be subject to a direct tension load of not less than 2.5 times the design load but not less than 1,500 pounds (6672 N) for five minutes (10 percent deviation).

SECTION 21.703 — TORQUE TESTING OF NEW BOLTS

Bolts embedded in unreinforced masonry walls shall be tested using a torque-calibrated wrench to the following minimum torques:

$^1/_2$-inch-diameter (13 mm) bolts—40 foot pounds (54.2 N·m)

$^5/_8$-inch-diameter (16 mm) bolts—50 foot pounds (67.8 N·m)

$^3/_4$-inch-diameter (19 mm) bolts—60 foot pounds (81.3 N·m)

SECTION 21.704 — PREQUALIFICATION TEST FOR BOLTS AND OTHER TYPES OF ANCHORS

This section is applicable when it is desired to use tension or shear values for anchors greater than those permitted by Table A-1-E of the *Uniform Code for Building Conservation.* The direct-tension test procedure set forth in Section 21.702 for existing anchors may be used to determine the allowable tension values for new embedded or through bolts, except that no preload is required. Bolts shall be installed in the same manner and using the same materials as will be used in the actual construction. A minimum of five tests for each bolt size and type shall be performed for each class of masonry in which they are proposed to be used. The allowable tension values for such anchors shall be the lesser of the average ultimate load divided by a factor of safety of 5.0 or the average load of which $^1/_8$ inch (3.2 mm) elongation occurs for each size and type of bolt and class of masonry.

Shear bolts may be similarly prequalified. The test procedure shall comply with ASTM E 488-90 or another approved procedure.

The allowable values determined in this manner may exceed those set forth in Table A-1-E of the *Uniform Code for Building Conservation.*

SECTION 21.705 — REPORTS

Results of all tests shall be reported. The report shall include the test results as related to anchor size and type, orientation of loading, details of the anchor installation and embedment, wall thickness, and joist orientation.

UNIFORM BUILDING CODE STANDARD 21-8
POINTING OF UNREINFORCED MASONRY WALLS

Construction Specification of the International Conference of Building Officials

See Appendix Chapter 1, Section A106.3.3.2,
Uniform Code for Building Conservation

SECTION 21.801 — SCOPE

Pointing of deteriorated mortar joints when required by the *Uniform Code for Building Conservation* shall be in accordance with this standard.

SECTION 21.802 — JOINT PREPARATION

The old or deteriorated mortar joint shall be cut out, by means of a toothing chisel or nonimpact power tool, to a uniform depth of $^3/_4$ inch (19 mm) until sound mortar is reached. Care shall be taken not to damage the brick edges. After cutting is complete, all loose material shall be removed with a brush, air or water stream.

SECTION 21.803 — MORTAR PREPARATION

The mortar mix shall be Type N or Type S proportioned as required by the construction specifications. The pointing mortar shall be prehydrated by first thoroughly mixing all ingredients dry and then mixing again, adding only enough water to produce a damp unworkable mix which will retain its form when pressed into a ball. The mortar shall be kept in a damp condition for one and one-half hours; then sufficient water shall be added to bring it to a consistency that is somewhat drier than conventional masonry mortar.

SECTION 21.804 — PACKING

The joint into which the mortar is to be packed shall be damp but without freestanding water. The mortar shall be tightly packed into the joint in layers not exceeding $^1/_4$ inch (6.4 mm) in depth until it is filled; then it shall be tooled to a smooth surface to match the original profile.

UNIFORM BUILDING CODE STANDARD 21-9

UNBURNED CLAY MASONRY UNITS AND STANDARD METHODS OF SAMPLING AND TESTING UNBURNED CLAY MASONRY UNITS

Test Standard of the International Conference of Building Officials

See Section 2102.2, Item 6, *Uniform Building Code*

Part I—Unburned Clay Masonry

SECTION 21.901 — SCOPE

This standard covers unburned clay masonry units made from a suitable mixture of soil, clay and stabilizing agent, and intended for use in brick masonry.

SECTION 21.902 — COMPOSITION OF UNITS

21.902.1 Soil. The soil used shall contain not less than 25 percent and not more than 45 percent of material passing a No. 200 mesh (75 µm) sieve. The soil shall contain sufficient clay to bind the particles together, but shall contain not more than 0.2 percent of water-soluble salts.

21.902.2 Stabilizer. The stabilizing agent shall be emulsified asphalt. The stabilizing agent shall be uniformly mixed with the soil in amounts sufficient to provide the required resistance to absorption.

SECTION 21.903 — PHYSICAL REQUIREMENTS

The units shall conform to the physical requirements prescribed in Table 21-1-B of UBC Standard 21-1.

SECTION 21.904 — SHRINKAGE CRACKS

No units shall contain more than three shrinkage cracks, and no shrinkage crack shall exceed 3 inches (76 mm) in length or $^1/_8$ inch (3.2 mm) in width.

Part II—Sampling and Testing of Unburned Clay Masonry Units

SECTION 21.905 — SCOPE

These methods cover procedures for the sampling and testing of unburned clay masonry units for compressive strength, modulus of rupture, absorption and moisture content.

Sampling

SECTION 21.906 — TEST SPECIMENS

For each of the tests prescribed in this standard, five sample units shall be selected at random from each lot of 5,000 units or fraction thereof.

SECTION 21.907 — IDENTIFICATION

Each specimen shall be marked so that it may be identified at any time. Markings shall not cover more than 5 percent of the superficial area of the specimen.

Compressive Strength

SECTION 21.908 — PROCEDURE

Five full-size specimens shall be tested for compressive strength according to the following procedure:

1. Dry the specimens at a temperature of 85°F ± 15°F (29°C ± 9°C) in an atmosphere having a relative humidity of not more than 50 percent. Weigh the specimens at one-day intervals until constant weight is attained.

2. Test the specimens in the position in which the unburned clay masonry unit is designed to be used, and bed on and cap with a felt pad not less than $^1/_8$ inch (3.2 mm) nor more than $^1/_4$ inch (6.4 mm) in thickness.

3. The specimens may be suitably capped with calcined gypsum mortar or the bearing surfaces of the tile may be planed or rubbed smooth and true. When calcined gypsum is used for capping, conduct the test after the capping has set and the specimen has been dried to constant weight in accordance with Item 1 of this section.

4. The loading head shall completely cover the bearing area of the specimen and the applied load shall be transmitted through a spherical bearing block of proper design. The speed of the moving head of the testing machine shall not be more than 0.05 inch (1.27 mm) per minute.

5. Calculate the average compressive strength of the specimens tested and report this as the compressive strength of the block.

Modulus of Rupture

SECTION 21.909 — PROCEDURE

Five full-size specimens shall be tested for modulus of rupture according to the following procedure:

1. Cured specimen shall be positioned on cylindrical supports 2 inches (51 mm) in diameter, located 2 inches (51 mm) from each end, and extending across the full width of the specimen.

2. A cylinder 2 inches (51 mm) in diameter shall be positioned on the specimen midway between and parallel to the cylindrical supports.

3. Load shall be applied to the cylinder at the rate of 500 pounds (2224 N) per minute until failure occurs.

4. Calculate modulus of rupture from the formula $S = \frac{3WL}{2Bd^2}$

WHERE:

B = width of specimen.
d = thickness of specimen.
L = distance between supports.
S = modulus of rupture, psi (kPa).
W = load at failure.

Absorption

SECTION 21.910 — PROCEDURE

A 4-inch (102 mm) cube cut from a sample unit shall be tested for absorption according to the following procedure:

1. Dry specimen to a constant weight in a ventilated oven at 212°F to 239°F (100°C to 115°C).

2. Place specimen on a constantly water-saturated porous surface for seven days. Weigh specimen.

3. Calculate absorption as a percentage of the initial dry weight.

Moisture Content

SECTION 21.911 — PROCEDURE

Five representative specimens shall be tested for moisture content according to the following procedure:

1. Obtain weight of each specimen immediately upon receiving.

2. Dry all specimens to constant weight in a ventilated oven at 212°F to 239°F (100°C to 115°C) and obtain dry weight.

3. Calculate moisture content as a percentage of the initial dry weight.

UNIFORM BUILDING CODE STANDARD 21-10
JOINT REINFORCEMENT FOR MASONRY

Specification Standard of the International Conference of Building Officials

See Sections 2102.2; 2104 and 2106.1.12.4, Item 2, *Uniform Building Code*

Part I—Joint Reinforcement for Masonry

SECTION 21.1001 — SCOPE

This standard covers joint reinforcement fabricated from cold-drawn steel wire for reinforcing masonry.

SECTION 21.1002 — DESCRIPTION

Joint reinforcement consists of deformed longitudinal wires welded to cross wires (Figure 21-10-1) in sizes suitable for placing in mortar joints between masonry courses.

SECTION 21.1003 — CONFIGURATION AND SIZE OF LONGITUDINAL AND CROSS WIRES

21.1003.1 General. The distance between longitudinal wires and the configuration of cross wires connecting the longitudinal wires shall conform to the design and the requirements of Figure 21-10-1.

21.1003.2 Longitudinal Wires. The diameter of longitudinal wires shall not be less than 0.148 inch (3.76 mm) or more than one half the mortar joint thickness.

21.1003.3 Cross Wires. The diameter of cross wires shall not be less than (No. 9 gage) 0.148-inch (3.76 mm) diameter nor more than the diameter of the longitudinal wires. Cross wires shall not project beyond the outside longitudinal wires by more than $^1/_8$ inch (3.2 mm).

21.1003.4 Width. The width of joint reinforcement shall be the out-to-out distance between outside longitudinal wires. Variation in the width shall not exceed $^1/_8$ inch (3.2 mm).

21.1003.5 Length. The length of pieces of joint reinforcement shall not vary more than $^1/_2$ inch (13 mm) or 1.0 percent of the specified length, whichever is less.

SECTION 21.1004 — MATERIAL REQUIREMENTS

21.1004.1 Tensile Properties. Wire of the finished product shall meet the following requirements:

Tensile strength, minimum	75,000 psi (517 MPa)
Yield strength, minimum	60,000 psi (414 MPa)
Reduction of area, minimum	30 percent

For wire testing over 100,000 psi (689 MPa), the reduction of area shall not be less than 25 percent.

21.1004.2 Bend Properties. Wire shall not break or crack along the outside diameter of the bend when tested in accordance with Section 21.1008.

21.1004.3 Weld Shear Properties. The least weld shear strength in pounds shall not be less than 25,000 (11.3 Mg) multiplied by the specified area of the smaller wire in square inches.

SECTION 21.1005 — FABRICATION

Wire shall be fabricated and finished in a workmanlike manner, shall be free from injurious imperfections and shall conform to this standard.

The wires shall be assembled by automatic machines or by other suitable mechanical means which will assure accurate spacing and alignment of all members of the finished product.

Longitudinal and cross wires shall be securely connected at every intersection by a process of electric-resistance welding.

Longitudinal wires shall be deformed. One set of four deformations shall occur around the perimeter of the wire at a maximum spacing of 0.7 times the diameter of the wire but not less than eight sets per inch (25.4 mm) of length. The overall length of each deformation within the set shall be such that the summation of gaps between the ends of the deformations shall not exceed 25 percent of the perimeter of the wire. The height or depth of the deformations shall be 0.012 inch (0.305 mm) for $^3/_{16}$ inch (4.76 mm) diameter or larger wire, 0.011 (0.28 mm) for 0.162-inch (4.11 mm) diameter wire and 0.009 inch (0.23 mm) for 0.148-inch (3.76 mm) diameter wire.

SECTION 21.1006 — TENSION TESTS

Tension tests shall be made on individual wires cut from the finished product across the welds.

Tension tests across a weld shall have the welded joint located approximately at the center of the wire being tested.

Tensile strength shall be the average of four test values determined by dividing the maximum test load by the specified cross-sectional area of the wire.

Reduction of area shall be determined by measuring the ruptured section of a specimen which has been tested.

SECTION 21.1007 — WELD SHEAR STRENGTH TESTS

Test specimens shall be obtained from the finished product by cutting a section of wire which includes one weld.

Weld shear strength tests shall be conducted using a fixture of such design as to prevent rotation of the cross wire. The cross wire shall be placed in the anvil of the testing device which is secured in the tensile machine and the load then applied to the longitudinal wire.

Weld shear strength shall be the average test load in pounds of four tests.

SECTION 21.1008 — BEND TESTS

Test specimens shall be obtained from the finished product by cutting a section of wire without welds.

The test specimens shall be bent cold through 180 degrees around a pin, the diameter of which is equal to the diameter of the specimen.

The specimen shall not break nor shall there be visual cracks on the outside diameter of the bend.

SECTION 21.1009 — FREQUENCY OF TESTS

One set of tension tests, weld strength shear tests and bend tests shall be performed for each 2,000,000 lineal feet (610 000 m) of joint reinforcement, but not less than monthly.

SECTION 21.1010 — CORROSION PROTECTION

When corrosion protection of joint reinforcement is provided, it shall be in accordance with one of the following:

21.1010.1 Brite Basic. No coating.

21.1010.2 Mill Galvanized. Zinc coated, by the hot-dipped method, with no minimum thickness of zinc coating. The coating may be applied before fabrication.

21.1010.3 Class I Mill Galvanized. Zinc coated, by the hot-dipped method, with a minimum of 0.40 ounce of zinc per square foot (0.12 kg/m^2) of surface area. The coating may be applied before fabrication.

21.1010.4 Class III Mill Galvanized. Zinc coated, by the hot-dipped method, with a minimum of 0.80 ounce of zinc per square foot (0.24 kg/m^2) of surface area. The coating may be applied before fabrication.

21.1010.5 Hot-dipped Galvanized. Zinc coated, by the hot-dipped method, with a minimum of 1.50 ounces of zinc per square foot (0.45 kg/m^2) of surface area. The coating shall be applied after fabrication.

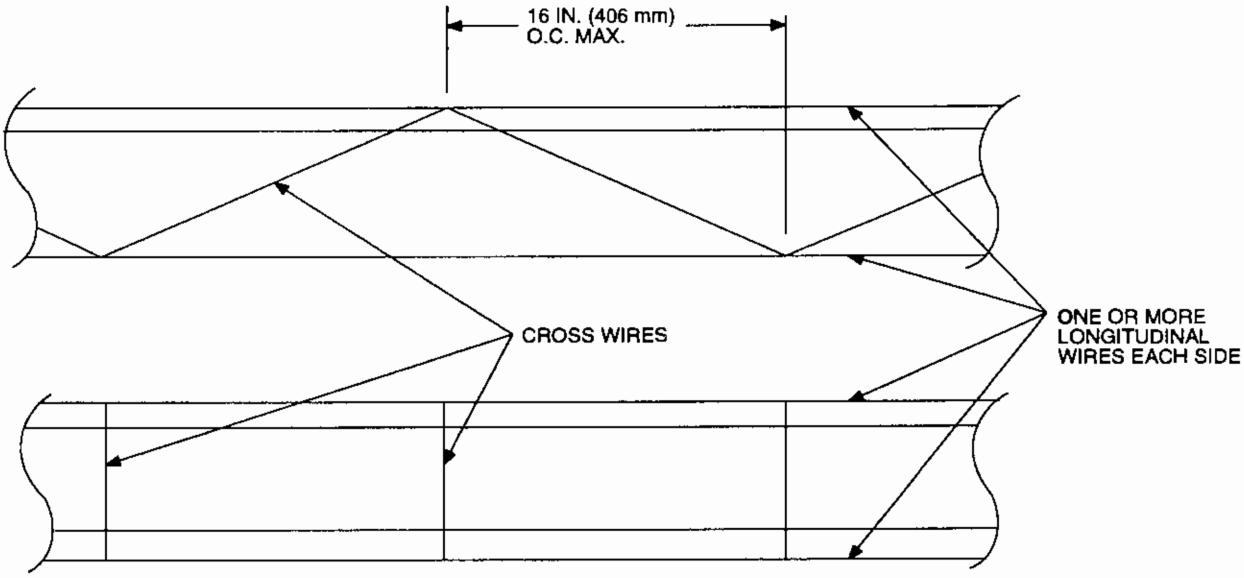

FIGURE 21-10-1—JOINT REINFORCEMENT

Part II—Cold-drawn Steel Wire for Concrete Reinforcement

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See Sections 2101.3; 2104 and 2106.1.12.4, Item 2, *Uniform Building Code*

SECTION 21.1011 — SCOPE

This standard covers cold-drawn steel wire to be used as such or in fabricated form, for the reinforcement as follows:

SIZE NUMBER	NOMINAL DIAMETER (inch) (× 25.4 for mm)	NOMINAL AREA (square inch) (× 645 for mm²)
W 31	0.628	0.310
W 30	0.618	0.300
W 28	0.597	0.280
W 26	0.575	0.260
W 24	0.553	0.240
W 22	0.529	0.220
W 20	0.505	0.200
W 18	0.479	0.180
W 16	0.451	0.160
W 14	0.422	0.140
W 12	0.391	0.120
W 10	0.357	0.100
W 8	0.319	0.080
W 6	0.276	0.060
W 5.5	0.265	0.055
W 5	0.252	0.050
W 4.5	0.239	0.045
W 4	0.226	0.040
W 3.5	0.211	0.035
W 2.9	0.192	0.029
W 2.5	0.178	0.025
W 2	0.160	0.020
W 1.4	0.134	0.014
W 1.2	0.124	0.012
W 0.5	0.080	0.005

SECTION 21.1012 — PROCESS

The steel shall be made by one or more of the following processes: open hearth, electric furnace or basic oxygen.

The wire shall be cold drawn from rods that have been hot rolled from billets.

Unless otherwise specified, the wire shall be "as cold drawn," except wire smaller than size number W 1.2 for welded fabric, which shall be galvanized at finish size.

SECTION 21.1013 — TENSILE PROPERTIES

The material, except as specified in this section, shall coufonn to the following tensile property requirements based on nominal area of wire:

Tensile strength, minimum, psi	80,000 (552 MPa)
Yield strength, minimum, psi	70,000 (483 MPa)
Reduction of area, minimum, percent	30

For material testing over 100,000 pounds per square inch (689 MPa) tensile strength, the reduction of area shall not be less than 25 percent.

For material to be used in the fabrication of welded fabric, the following tensile and yield strength properties based on nominal area of wire shall apply:

	SIZE W. 1.2 AND LARGER	SMALLER THAN SIZE W 1.2
Tensile strength, minimum, psi	75,000 (517 MPa)	70,000 (483 MPa)
Yield strength, minimum, psi	65,000 (448 MPa)	56,000 (386 MPa)

The yield strength shall be determined at an extension of 0.005 inch per inch (0.005 mm per mm) of gage length.

The material shall not exhibit a definite yield point as evidenced by a distinct drop of the beam or halt in the gage of the testing machine prior to reaching ultimate tensile load.

SECTION 21.1014 — BENDING PROPERTIES

The bend test specimen shall stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as follows:

SIZE NUMBER OF WIRE	BEND TEST
W 7 and smaller	Bend around a pin, the diameter of which is equal to the diameter of the specimen.
Larger than W 7	Bend around a pin, the diameter of which is equal to twice the diameter of the specimen.

SECTION 21.1015 — TEST SPECIMENS

Tension and bend test specimens shall be of the full section of the wire and shall be obtained from ends of wire coils.

SECTION 21.1016 — NUMBER OF TESTS

One tension test and one bend test shall be made from each 10 tons (89 kN) or less of each size of wire or fraction thereof in a lot, or a total of seven samples, whichever is less. A lot shall consist of all the coils of a single size offered for delivery at the same time.

If any test specimen shows imperfections or develops flaws, it may be discarded and another specimen substituted.

SECTION 21.1017 — PERMISSIBLE VARIATIONS IN WIRE DIAMETER

The permissible variation in the diameter of the wire shall conform to the following:

SIZE NUMBER	PERMISSIBLE VARIATION PLUS AND MINUS (inch) (× 25.4 for mm)
Smaller than W 5	0.003
W 5 to W 12, inclusive	0.004
Over W 12 to W 20, inclusive	0.006
Over W 20	0.008

The difference between the maximum and minimum diameter, as measured on any given cross section of the wire, shall be more than the tolerances shown above for the given wire size.

SECTION 21.1018 — FINISH

The wire shall be free from injurious imperfections and shall have a workmanlike finish with smooth surface.

Galvanized wire shall be completely covered in a workmanlike manner with a zinc coating.

UNIFORM BUILDING CODE STANDARD 21-11
CEMENT, MASONRY

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See Section 2102.2, Item 2 and Table 21-A, *Uniform Building Code*

SECTION 21.1101 — SCOPE

This standard covers three types of masonry cement for use in masonry mortars.

SECTION 21.1102 — CLASSIFICATIONS

21.1102.1 General. Masonry cement complying with this standard shall be classified as one of the types set forth in this section.

21.1102.2 Type N. Type N cement is for use as the cementitious material in the prep-aration of UBC Standard 21-15 Type N and Type O mortars. It is for use in combination with portland or blended hydraulic cements in the preparation of Type S or Type M mortars.

21.1102.3 Type S. Type S cement is for use as the cementitious material in the preparation of UBC Standard 21-15 Type S mortar.

21.1102.4 Type M. Type M cement is for use as the cementitious material in the preparation of UBC Standard 21-15 Type M mortar.

SECTION 21.1103 — PHYSICAL REQUIREMENTS

Masonry cement shall conform to the requirements set forth in Table 21-11-A for its classifications.

SECTION 21.1104 — PACKAGE LABELING

Masonry cement packages shall carry a statement indicating that the product conforms to requirements of this standard and shall include the brand, name of manufacturer, type of masonry cement and net weight of the package in pounds.

SECTION 21.1105 — CERTIFICATION

Certification shall be submitted upon request of the building official and shall certify compliance with the requirements of this standard.

SECTION 21.1106 — SAMPLING AND TESTING

Every 90 days, each masonry cement producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the masonry cement for compliance with the physical requirements of Table 21-11-A.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

SECTION 21.1107 — TEMPERATURE AND HUMIDITY

The temperature of the air in the vicinity of the mixing slab and dry materials, molds, base plates and mixing bowl shall be maintained between 68°F and 81.5°F (20°C and 27.5°C). The temperature of the mixing water, moist cabinet or moist room, and water in the storage tank shall not vary from 73.4°F (23°C) by more than 3°F (1.7°C).

The relative humidity of the laboratory air shall not be less than 50 percent. The moist cabinet or moist room atmosphere shall have a relative humidity of not less than 90 percent.

The moist cabinet or moist room shall conform to applicable standards.

SECTION 21.1108 — FINENESS

The fineness of the cement shall be determined from the residue on the No. 325 (45 μm) sieve.

SECTION 21.1109 — NORMAL CONSISTENCY

Determine normal consistency by the Vicat apparatus.

SECTION 21.1110 — AUTOCLAVE EXPANSION

The autoclave expansion shall be determined. After molding, store the bars in the moist cabinet or room for 48 hours ± 30 minutes before removal from the molds for measurement and test in the autoclave. Calculate the difference in the lengths of the test specimen before and after autoclaving to the nearest 0.01 percent of the effective gage length and report as the autoclave expansion of the masonry cement.

SECTION 21.1111 — TIME OF SETTING

The time of setting shall be determined by the Gillmore needle method.

SECTION 21.1112 — DENSITY

The density of the masonry cement shall be determined by using kerosene as the liquid. Use the density so determined in the calculation of the air content of the mortars.

SECTION 21.1113 — APPARATUS FOR MORTAR TESTS

The apparatus for mortar tests shall be in accordance with applicable standards.

SECTION 21.1114 — BLENDED SAND

The sand shall be a blend of equal parts by weight of graded standard sand and Standard 20-30 sand.

SECTION 21.1115 — PREPARATION OF MORTAR

21.1115.1 Proportions for Mortar. Mortar for air entrainment, compressive strength and water-retention tests shall be proportioned to contain the weight of cement, in grams, equal to six times the printed bag weight in pounds (13.228 times the printed bag weight in kilograms) and 1,440 grams of sand. The sand shall consist of 720 grams of graded Ottawa sand and 720 grams of Standard 20-30 sand. The quantity of water, measured in milliliters, shall be such as to produce a flow of 110 ± 5 as determined by the flow table.

21.1115.2 Mixing of Mortars. The mortar shall be mixed in accordance with the applicable standards.

21.1115.3 Determination of Flow. The flow shall be determined in accordance with applicable standards.

SECTION 21.1116 — AIR ENTRAINMENT

21.1116.1 Procedure. If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the mass of 400 ml of the mortar.

21.1116.2 Calculation. Calculate the air content of the mortar and report it to the nearest 0.1 percent as follows:

$$D = (W_1 + W_2 + V_w)\ [(W_1/S_1) + (W_2/S_2) + V_w]$$

$$A = 100 - (w_m/4D)$$

WHERE:

A = volume percent of entrained air.
D = density of air-free mortar, g/ml.
S_1 = density of cement, g/ml.
S_2 = density of standard sand, 2.65 g/ml.
V_w = milliliters-grams of water used.
W_m = mass of 400 ml.
W_1 = mass of cement, g.
W_2 = mass of sand, g.

SECTION 21.1117 — COMPRESSIVE STRENGTH

21.1117.1 Test Specimens.

21.1117.1.1 Molding. Immediately after determining the flow and the mass of 400 ml of mortar, return all the mortar to the mixing bowl and remix for 15 seconds at the medium speed. Then mold test specimens in accordance with applicable standards, except that elapsed time for mixing mortar, determining flow, determining air entrainment and starting the molding of cubes shall be within eight minutes.

21.1117.1.2 Storage. Store all test specimens immediately after molding in the molds on plane plates in a moist cabinet or moist room for 48 to 52 hours, in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds and place in the moist cabinet or moist room for five days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of seven days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrodible materials.

21.1117.2 Procedure. Test the cube specimens immediately after their removal from the moist cabinet or moist room for seven-day specimens, and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist cabinet or moist room for seven-day tests, cover these cubes with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, place these cubes in a pan of water at a temperature of 73.4°F ± 3°F (23°C ± 1.7°C), and of sufficient depth to completely immerse each cube until time of testing.

The remainder of the testing procedure shall conform to applicable standards.

SECTION 21.1118 — WATER RETENTION

21.1118.1 Apparatus. The water-retention test shall conform to applicable standards.

21.1118.2 Procedure. Adjust the mercury relief column to maintain a vacuum of 51 ± 3 mm as indicated by the manometer. Seat the perforated dish on the greased gasket or greased rim of the funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum to the funnel and check the apparatus for leaks and to determine that the required vacuum is obtained. Then turn the stopcock to shut off the vacuum from the funnel.

Mix the mortar to a flow of 110 ± 5 percent in accordance with applicable standards. Immediately after making the flow test, return the mortar on the flow table to the mixing bowl and remix the entire batch for 15 seconds at medium speed. Immediately after remixing the mortar, fill the perforated dish with the mortar to slightly above the rim. Tamp the mortar 15 times with the tamper. Apply 10 of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish and with the long axis of the tamping face held at right angles to the radius of the dish. Apply the remaining five tamping strokes at random points distributed over the central area of the dish. The tamping pressure shall be just sufficient to ensure filling of the dish. On completion of the tamping, the top of the mortar will extend slightly above the rim of the dish. Smooth off the mortar by drawing the flat side of the straightedge (with the leading edge slightly raised) across the top of the dish. Then cut off the mortar to a plane surface flush with the rim of the dish by drawing the straightedge with a sawing motion across the top of the dish in two cutting strokes, starting each cut from near the center of the dish. If the mortar is pulled away from the side of the dish during the process of drawing the straightedge across the dish, gently press the mortar back into contact with the side of the dish using the tamper.

Turn the stopcock to apply the vacuum to the funnel. The time elapsed from the start of mixing the cement and water to the time of applying the vacuum shall not exceed eight minutes. After suction for 60 seconds, quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off from the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then, using the bowl scraper, plow and mix the mortar in the dish for 15 seconds. Upon completion of mixing, place the mortar in the flow mold and determine the flow. The entire operation shall be carried out without interruption and as quickly as possible, and shall be completed within an elapsed time of 11 minutes after the start of mixing the cement and water for the first flow determination. Both flow determinations shall be made in accordance with applicable standards.

21.1118.3 Calculation. Calculate the water-retention value for the mortar as follows:

$$\text{Water-retention value} = (A/B) \times 100$$

WHERE:

A = flow after suction.
B = flow immediately after mixing.

TABLE 21-11-A—PHYSICAL REQUIREMENTS

MASONRY CEMENT TYPE	N	S	M
Fineness, residue on a No. 325 (45 μm) sieve, maximum percent	24	24	24
Soundness: Autoclave expansion, maximum, percent	1.0	1.0	1.0
Time of setting, Gilmore method: Initial set, minimum, hour Final set, maximum, hour	 2 24	 $1^1/_2$ 24	 $1^1/_2$ 24
Compressive strength (average of 3 cubes): Initial compressive strength of mortar cubes, composed of 1 part cement and 3 parts blended sand (half Graded Ottawa sand, and half Standard 20-30 Ottawa sand) by volume, prepared and tested in accordance with this specification shall be equal to or higher than the values specified for the ages indicated below: 7 days, psi 28 days, psi	 500 (3445 kPa) 900 (6201 kPa)	 1,300 (8957 kPa) 2,100 (14 469 kPa)	 1,800 (12 402 kPa) 2,900 (19 981 kPa)
Air content of mortar: Minimum percent by volume Maximum percent by volume	 8 21	 8 19	 8 19
Water retention, flow after suction, minimum, percent of original flow	70	70	70

UNIFORM BUILDING CODE STANDARD 21-12
QUICKLIME FOR STRUCTURAL PURPOSES

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See Section 2102.2, Item 3, *Uniform Building Code*

SECTION 21.1201 — SCOPE

This standard covers all classes of quicklime, such as crushed lime, granular lime, ground lime, lump lime, pebble lime and pulverized lime, used for structural purposes.

SECTION 21.1202 — GENERAL REQUIREMENTS

Quicklime shall be slaked and aged in accordance with the printed directions of the manufacturer. The resulting lime putty shall be stored until cool.

SECTION 21.1203 — CHEMICAL COMPOSITION

The quicklime shall conform to the following requirements as to chemical composition, calculated to the nonvolatile basis:

	CALCIUM LIME	MAGNESIUM LIME
Calcium oxide, minimum, percent	75	—
Magnesium oxide, minimum, percent	—	20
Calcium and magnesium oxides, minimum, percent	95	95
Silica, alumina, and oxide of iron, maximum, percent	5	5
Carbon dioxide, maximum, percent:		
If sample is taken at the place of manufacture	3	3
If sample is taken at any other place	10	10

SECTION 21.1204 — RESIDUE

The quicklime shall not contain more than 15 percent by weight of residue.

SECTION 21.1205 — QUALITY CONTROL

Every 90 days, each lime producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the lime for compliance with the physical requirements of Section 21.1204.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

UNIFORM BUILDING CODE STANDARD 21-13
HYDRATED LIME FOR MASONRY PURPOSES

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See Section 2102.2, Item 3, *Uniform Building Code*

SECTION 21.1301 — SCOPE

This standard covers four types of hydrated lime. Types N and S are suitable for use in mortar, in the scratch and brown coats of cement plaster, for stucco, and for addition to portland-cement concrete. Types NA and SA are air-entrained hydrated limes that are suitable for use in any of the above uses where the inherent properties of lime and air entrainment are desired. The four types of lime sold under this specification shall be designated as follows:

Type N—Normal hydrated lime for masonry purposes.

Type S—Special hydrated lime for masonry purposes.

Type NA—Normal air-entraining hydrated lime for masonry purposes.

Type SA—Special air-entraining hydrated lime for masonry purposes.

NOTE: Type S, special hydrated lime, and Type SA, special air-entraining hydrated lime, are differentiated from Type N, normal hydrated lime, and Type NA, normal air-entraining hydrated lime, principally by their ability to develop high, early plasticity and higher water retentivity and by a limitation on their unhydrated oxide content.

SECTION 21.1302 — DEFINITION

HYDRATED LIME. The hydrated lime covered by Type N or S in this standard shall contain no additives for the purpose of entraining air. The air content of cement-lime mortars made with Type N or S shall not exceed 7 percent. Types NA and SA shall contain an air-entraining additive as specified by Section 21.1305. The air content of cement-lime mortars made with Type NA or SA shall have a minimum of 7 percent and a maximum of 14 percent.

SECTION 21.1303 — ADDITIONS

Types NA and SA hydrated lime covered by this standard shall contain additives for the purpose of entraining air.

SECTION 21.1304 — MANUFACTURER'S STATEMENT

Where required, the nature, amount and identity of the air-entraining agent used and of any processing addition that may have been used shall be provided, as well as test data showing compliance of such air-entraining addition.

SECTION 21.1305 — CHEMICAL REQUIREMENTS COMPOSITION

Hydrated lime for masonry purposes shall conform to the requirements as to chemical composition set forth in Table 21-13-A.

SECTION 21.1306 — RESIDUE, POPPING AND PITTING

The four types of hydrated lime for masonry purposes shall conform to one of the following requirements:

1. The residue retained on a No. 30 (600 μm) sieve shall not be more than 0.5 percent, or

2. If the residue retained on a No. 30 (600 μm) sieve is over 0.5 percent, the lime shall show no pops and pits when tested.

SECTION 21.1307 — PLASTICITY

The putty made from Type S, special hydrate, or Type SA, special air-entraining hydrate, shall have a plasticity figure of not less than 200 within 30 minutes after mixing with water, when tested.

SECTION 21.1308 — WATER RETENTION

Hydrated lime mortar made with Type N, normal hydrated lime, or Type NA, normal air-entraining hydrated lime, after suction for 60 seconds, shall have a water-retention value of not less than 75 percent when tested in a standard mortar made from the dry hydrate or from putty made from the hydrate which has been soaked for a period of 16 to 24 hours.

Hydrated lime mortar made with Type S, special hydrated lime, or Type SA, special air-entraining hydrated lime, after suction for 60 seconds, shall have a water-retention value of not less than 85 percent when tested in a standard mortar made from the dry hydrate.

SECTION 21.1309 — SPECIAL MARKING

When Type NA or SA air-entraining hydrated lime is delivered in packages, the type under this standard and the words "air-entraining" shall be plainly indicated thereon or, in case of bulk shipments, so indicated on shipping notices.

SECTION 21.1310 — QUALITY CONTROL

Every 90 days, each lime producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the lime for compliance with the physical requirements of Sections 21.1306, 21.1307 and 21.1308.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

TABLE 21-13-A—CHEMICAL REQUIREMENTS

	HYDRATE TYPES			
	N	NA	S	SA
Calcium and magnesium oxides (nonvolatile basis), min. percent	95	95	95	95
Carbon dioxide (as-received basis), max. percent				
If sample is taken at place of manufacture	5	5	5	5
If sample is taken at any other place	7	7	7	7
Unhydrated oxides (as-received basis), max. percent	—	—	8	8

UNIFORM BUILDING CODE STANDARD 21-14
MORTAR CEMENT

Test Standard of the International Conference of Building Officials

See Section 2102.2, Item 2, *Uniform Building Code*

SECTION 21.1401 — SCOPE

This standard covers mortar cement for use in masonry mortars.

SECTION 21.1402 — CLASSIFICATIONS

There are three types of mortar cement:

1. **Type N.** For use as the cementitious material in the preparation of UBC Standard 21-15 Type N and Type O mortars. For use in combination with portland or blended hydraulic cements in the preparation of Type S or Type M mortars.

2. **Type S.** For use as the cementitious material in the preparation of UBC Standard 21-15 Type S mortar.

3. **Type M.** For use as the cementitious material in the preparation of UBC Standard 21-15 Type M mortar.

SECTION 21.1403 — PHYSICAL REQUIREMENTS

Mortar cement shall conform to the requirements set forth in Table 21-14-A for its classifications.

SECTION 21.1404 — CONSTITUENT MATERIALS

Upon request of the building official, the constituent materials shall be provided to the building official and engineer of record.

SECTION 21.1405 — RESTRICTED MATERIALS

Materials used in mortar cement shall conform to the requirements set forth in Table 21-14-B.

SECTION 21.1406 — DELETERIOUS MATERIAL

Materials listed in Table 21-14-C shall not be used in mortar cement.

SECTION 21.1407 — PACKAGE LABELING

Mortar cement packages shall carry a statement indicating that the product conforms to requirements of this standard and shall include the brand, name of manufacturer, type of mortar cement and net weight of the package in pounds.

SECTION 21.1408 — CERTIFICATION

Certification shall be submitted upon request of the building official and shall certify compliance with the requirements of this standard.

SECTION 21.1409 — SAMPLING AND TESTING

Every 90 days, each mortar cement producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the mortar cement for compliance with the physical requirements of Table 21-14-A.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

SECTION 21.1410 — TEMPERATURE AND HUMIDITY

The temperature of the air in the vicinity of the mixing slab and dry materials, molds, base plates and mixing bowl shall be maintained between 68°F and 81.5°F (20°C and 27.5°C). The temperature of the mixing water, moist cabinet or moist room, and water in the storage tank shall not vary from 73.4°F (23°C) by more than 3°F (1.7°C).

The relative humidity of the laboratory air shall not be less than 50 percent. The moist cabinet or moist room atmosphere shall have a relative humidity of not less than 90 percent.

The moist cabinet or moist room shall conform to applicable standards.

SECTION 21.1411 — FINENESS

Determine the residue on the No. 325 (45 μm) sieve.

SECTION 21.1412 — NORMAL CONSISTENCY

Determine normal consistency by the Vicat apparatus.

SECTION 21.1413 — AUTOCLAVE EXPANSION

Determine autoclave expansion. After molding, store bars in the moist cabinet or room for 48 hours, plus or minus 30 minutes, before removal from the molds for measurement and test in the autoclave. Calculate the difference in length of the test specimen before and after autoclaving to the nearest 0.01 percent of the effective gauge length and report as the autoclave expansion of the mortar cement.

SECTION 21.1414 — TIME OF SETTING

Determine the time of setting by the Gillmore needle method.

SECTION 21.1415 — DENSITY

Determine the density of the mortar cement using kerosene as the liquid. Use the density so determined in the calculation of the air content of the mortars.

SECTION 21.1416 — APPARATUS FOR MORTAR TESTS

Apparatus shall be in accordance with applicable standards.

SECTION 21.1417 — BLENDED SAND

The sand shall be a blend of equal parts by weight of graded Ottawa sand and Standard 20-30 Ottawa sand.

SECTION 21.1418 — PREPARATION OF MORTAR

21.1418.1 Proportions for Mortar. Mortar for air entrainment, compressive strength and water-retention tests shall be proportioned to contain the weight of cement, in grams, equal to six times the printed bag weight in pounds (13.228 times the printed bag weight in kilograms) and 1,440 grams of sand. The sand shall consist of 720 grams of graded Ottawa sand and 720 grams of Standard 20-30 sand. The quantity of water, measured in milliliters, shall be such as to produce a flow of 110 ± 5 as determined by the flow table.

21.1418.2 Mixing of Mortars. Mix the mortar in accordance with applicable standards.

21.1418.3 Determination of Flow. Determine the flow in accordance with applicable standards.

SECTION 21.1419 — AIR ENTRAINMENT

21.1419.1 Procedure. If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the weight of 400 cm^3 of mortar.

21.1419.2 Calculation. Calculate the air content of the mortar and report it to the nearest 0.1 percent as follows:

$$D = (W_1 + W_2 + V_w)/[(W_1/S_1) + (W_2/S_2) + V_w]$$

$$A = 100 - (W_m/4D)$$

WHERE:

A = volume percent of entrained air.
D = density of air-free mortar, g/cm^3.
S_1 = density of cement, g/cm^3.
S_2 = density of standard sand, 2.65 g/cm^3.
V_w = milliliters-grams of water used.
W_m = mass of 400 ml of mortar, g.
W_1 = weight of cement, g.
W_2 = weight of sand, g.

SECTION 21.1420 — COMPRESSIVE STRENGTH OF TEST SPECIMENS

21.1420.1 Molding. Immediately after determining the flow and the weight of 400 cm^3 or mortar, return all the mortar to the mixing bowl and remix for 15 seconds at the medium speed. Then mold test specimens in accordance with applicable standards, except that the elapsed time for mixing mortar, determining flow, determining air entrainment and starting the molding of cubes shall be within eight minutes.

21.1420.2 Storage. Store all test specimens immediately after molding in the molds on plane plates in a moist cabinet maintained at a relative humidity of 90 percent or more for 48 to 52 hours in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds and place in the moist cabinet for five days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of seven days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrodible materials.

SECTION 21.1421 — PROCEDURE

Test the cube specimens immediately after their removal from the moist cabinet for seven-day specimens, and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist closet for seven-day tests, cover these cubes with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, place these cubes in a pan of water at a temperature of 73.4°F ± 3°F (23°C ± 1.7°C), and of sufficient depth to completely immerse each cube until time of testing.

The remainder of the testing procedure shall conform to applicable standards.

SECTION 21.1422 — WATER RETENTION

21.1422.1 Water-retention Apparatus. For the water-retention test, and apparatus essentially the same as that shown in Figure 21-14-1 shall be used. This apparatus consists of a water aspirator or other source of vacuum controlled by a mercury-relief column and connected by way of a three-way stopcock to a funnel upon which rests a perforated dish. The perforated dish shall be made of metal not attacked by masonry mortar. The metal in the base of the dish shall have a thickness of 1.7 to 1.9 mm and shall conform to the requirements given in Figure 21-14-1. The bore of the stopcock shall have a 4 mm plus or minus 0.5 mm diameter, and the connecting glass tubing shall have a minimum inside diameter of 4 mm. A mercury manometer, connected as shown in Figure 21-14-1, indicates the vacuum. The contact surface of the funnel and perforated dish shall be plane and shall be lapped to ensure intimate contact. An airtight seal shall be maintained between the funnel and the dish during a test. This shall be accomplished by either of the following procedures: (1) a synthetic (grease-resistant) rubber gasket may be permanently sealed to the top of the funnel, using petrolatum or light grease to ensure a seal between the funnel and dish, or (2) the top of the funnel may be lightly coated with petrolatum or light grease to ensure a seal between the funnel and dish. Care should be taken to ensure that none of the holes in the perforated dish are clogged from the grease. Hardened, very smooth, not rapid filter paper shall be used. It shall be of such diameter that it will lie flat and completely cover the bottom of the dish.

A steel straightedge not less than 8 inches (203 mm) long and not less than $^1/_{16}$ inch (1.6 mm) nor more than $^1/_8$-inch (3.2 mm) thickness shall be used.

Other apparatus required for the water-retention tests shall conform to the applicable requirements of Section 21.1416.

21.1422.2 Procedure. Adjust the mercury-relief column to maintain a vacuum of 50.8 mm as measured on the manometer. Seat the perforated dish on the greased gasket of the funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum to the funnel and check the apparatus for leaks and to determine that the required vacuum is obtained. Then turn the stopcock to shut off the vacuum from the funnel.

Mix the mortar to a flow of 110 plus or minus 5 percent in accordance with applicable standards. Immediately after making the flow test, return the mortar on the flow table to the mixing bowl and remix the entire batch for 15 seconds at medium speed. Immediately after remixing the mortar, fill the perforated dish with the mortar to slightly above the rim. Tamp the mortar 15 times with the tamper. Apply 10 of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish and with the long axis of the tamping face held at right angles to the radius of the dish. Apply the remaining five tamping strokes at random points distributed over the central area of the dish. The tamping pressure shall be just sufficient to ensure filling of the dish. On completion of the tamping, the top of the mortar should extend slightly above the rim of the dish. Smooth off the mortar by drawing the flat side of the straightedge (with the leading edge slightly raised) across the top of the dish. Then cut off the mortar to a plane surface flush with the rim of the dish by drawing the straightedge with a sawing motion across the top of the dish in two cutting strokes, starting each cut from near the center of the dish. If the mortar is pulled away from the side of the dish during the process of drawing the straightedge across the dish, gently press the mortar back into contact with the side of the dish using the tamper.

Turn the stopcock to apply the vacuum to the funnel. The time elapsed from the start of mixing the cement and water to the time of applying the vacuum shall not exceed eight minutes. After suction for 60 seconds, quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off from the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then, using the bowl scraper, in accordance with applicable standards, plow and mix the mortar in the dish for 15 seconds. Upon completion of mixing, place the mortar in the flow mold and determine the flow. The entire operation shall be carried out without interruption and as quickly as possible, and shall be completed within an elapsed time of 11 minutes after the start of mixing the cement and water for the first flow determination. Both flow determinations shall be made in accordance with applicable standards.

21.1422.3 Calculation. Calculate the water-retention value for the mortar as follows:

$$\text{Water-retention value} = (a/b) \times 100$$

WHERE:

a = flow after suction.

b = flow immediately after mixing.

TABLE 21-14-A—PHYSICAL REQUIREMENTS

MORTAR CEMENT TYPE	N	S	M
Fineness, residue on a No. 325 (45 μm) sieve Maximum percent	24	24	24
Autoclave expansion Maximum, percent	1.0	1.0	1.0
Time of setting, Gillmore method: Initial set, minimum, hour Final set, maximum, hour	 2 24	 $1^1/_2$ 24	 $1^1/_2$ 24
Compressive strength[1] 7 days, minimum psi 28 days, minimum psi	 500 (3445 kPa) 900 (6201 kPa)	 1300 (8957 kPa) 2100 (14 469 kPa)	 1800 (12 402 kPa) 2900 (19 981 kPa)
Flexural bond strength[2] 28 days, minimum psi	71 (489 kPa)	104 (717 kPa)	116 (799 kPa)
Air content of mortar Minimum percent by volume Maximum percent by volume	 8 16	 8 14	 8 14
Water retention Minimum, percent	70	70	70

[1]Compressive strength shall be based on the average of three mortar cubes composed of one part mortar cement and three parts blended sand (one half graded Ottawa sand, and one half Standard 20-30 Ottawa sand) by volume and tested in accordance with this standard.

[2]Flexural bond strength shall be determined in accordance with UBC Standard 21-20.

TABLE 21-14-B—RESTRICTED MATERIALS

MATERIAL	MAXIMUM LIMIT (percentage)
Chloride salts	0.06
Carboxylic acids	0.25
Sugars	1.00
Glycols	1.00
Lignin and derivatives	0.50
Stearates	0.50
Fly ash	No limit
Clay (except fireclay)	5.00

TABLE 21-14-C—DELETERIOUS MATERIALS NOT PERMITTED IN MORTAR CEMENT

Epoxy resins and derivatives
Phenols
Asbestos fiber
Fireclays

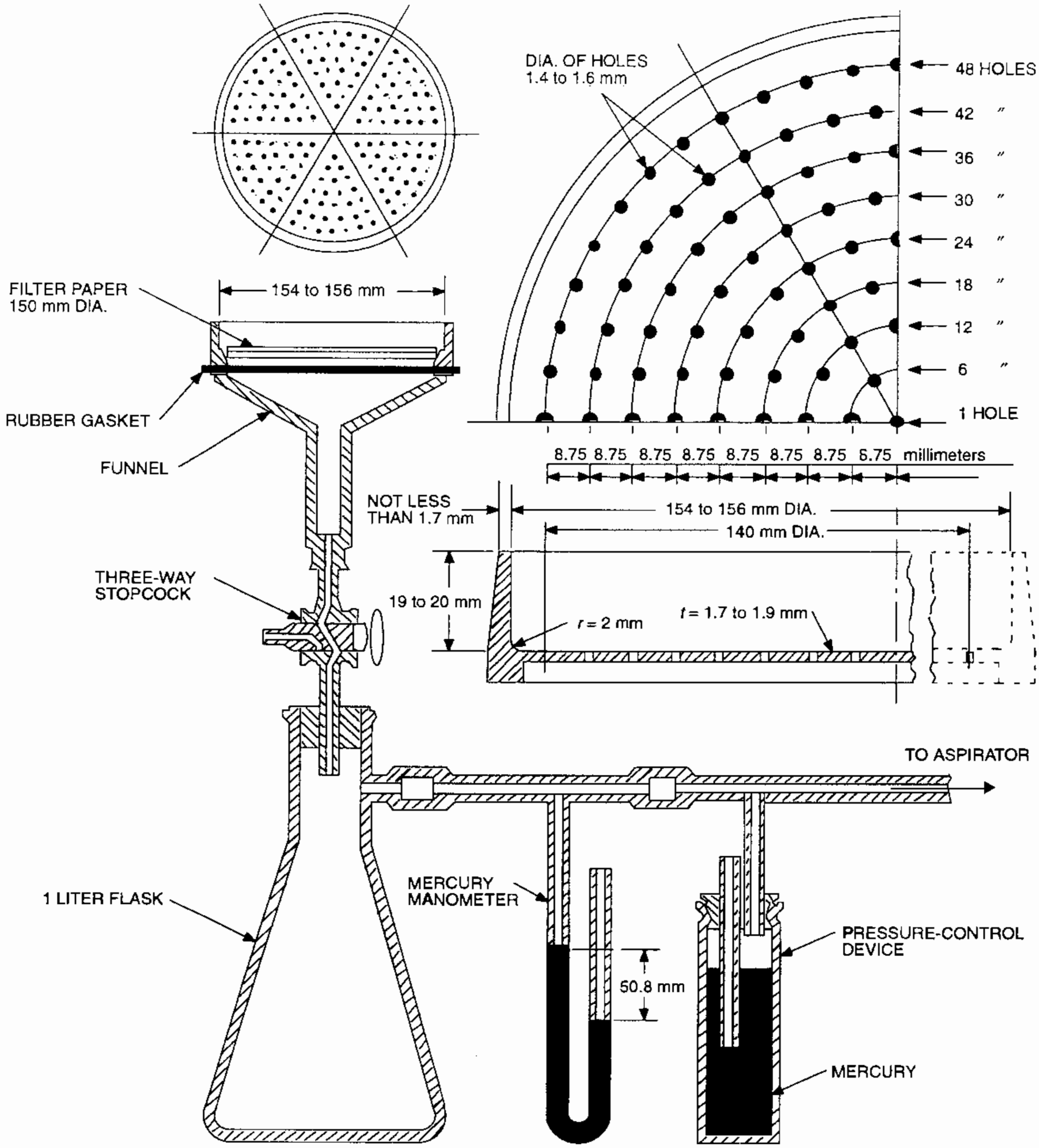

FIGURE 21-14-1—APPARATUS ASSEMBLY FOR THE WATER-RETENTION TEST

UNIFORM BUILDING CODE STANDARD 21-15
MORTAR FOR UNIT MASONRY AND REINFORCED MASONRY OTHER THAN GYPSUM

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See Section 2102.2, Item 8, *Uniform Building Code*

SECTION 21.1501 — SCOPE

These specifications cover the required properties of mortars determined by laboratory tests for use in the construction of reinforced brick masonry structures and unit masonry structures. Two alternative specifications are covered as follows:

21.1501.1 Property specifications. Property specifications are those in which the acceptability of the mortar is based on the properties of the ingredients (materials) and the properties (water retention and compressive strength) of samples of the mortar mixed and tested in the laboratory.

21.1501.2 Proportion specifications. Proportion specifications are those in which the acceptability of the mortar is based on the properties of the ingredients (materials) and a definite composition of the mortar consisting of fixed proportions of these ingredients.

Unless data are presented to show that the mortar meets the requirements of the physical property specifications, the proportion specifications shall govern. For field tests of grout and mortars see UBC Standard 21-16.

Property Specifications

SECTION 21.1502 — MATERIALS

21.1502.1 General. Materials used as ingredients in the mortar shall conform to the requirements specified in the pertinent UBC Standards.

21.1502.2 Cementitious Materials. Cementitious materials shall conform to the following specifications:

1. **Portland cement.** Type I, IA, II, IIA, III or IIIA of ASTM C 150.

2. **Blended hydraulic cement.** Type IS, IS-A, S, S-A, IP, IP-A, I(PM) or I(PM)-A of ASTM C 1157.

3. **Plastic cement.** Plastic cement conforming to the requirements of UBC Standard 25-1 and UBC Standard 21-11, when used in lieu of masonry cement.

4. **Mortar cement.** UBC Standard 21-14.

5. **Masonry cements.** UBC Standard 21-11.

6. **Quicklime.** UBC Standard 21-12.

7. **Hydrated lime.** UBC Standard 21-13.

21.1502.3 Water. Water shall be clean and free of deleterious amounts of acids, alkalies or organic materials.

21.1502.4 Admixtures or Mortar Colors. Admixtures or mortar colors shall not be added to the mortar at the time of mixing unless provided for in the contract specifications and, after the material is so added, the mortar shall conform to the requirements of the property specifications.

Only pure mineral mortar colors shall be used.

21.1502.5 Antifreeze Compounds. No antifreeze liquid, salts or other substances shall be used in the mortar to lower the freezing point.

21.1502.6 Storage of Materials. Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material. Any material that has become unsuitable for good construction shall not be used.

SECTION 21.1503 — MIXING MORTAR

Mortar blended on the jobsite shall be mixed for a minimum period of three minutes, with the amount of water required to produce the desired workability, in a drum-type batch mixer. Factory-dry blended mortar shall be mixed with water in a mechanical mixer until workable but not to exceed 10 minutes.

SECTION 21.1504 — MORTAR

21.1504.1 Mortar for Unit Masonry. Mortar conforming to the proportion specifications shall consist of a mixture of cementitious material and aggregate conforming to the requirements of Section 21.1502, and the measurement and mixing requirements of Section 21.1503, and shall be proportioned within the limits given in Table 21-15-B for each mortar type specified.

21.1504.2 Mortar for Reinforced Masonry. In mortar used for reinforced masonry the following special requirements shall be met: Sufficient water has been added to bring the mixture to a plastic state. The volume of aggregate in mortar shall be at least two and one-fourth times but not more than three times the volume of cementitious materials.

21.1504.3 Aggregate Ratio. The volume of damp, loose aggregate in mortar used in brick masonry shall be not less than two and one-fourth times or more than three times the total separate volumes of cementitious materials used.

21.1504.4 Water Retention. Mortar shall conform to the water retention requirements of Table 21-15-A.

21.1504.5 Air Content. Mortar shall conform to the air content requirements of Table 21-15-A.

SECTION 21.1505 — COMPRESSIVE STRENGTH

The average compressive strength of three 2-inch (51 mm) cubes of mortar (before thinning) shall not be less than the strength given in Table 21-15-A for the mortar type specified.

Proportion Specifications

SECTION 21.1506 — MATERIALS

21.1506.1 General. Materials used as ingredients in the mortar shall conform to the requirements of Section 21.1502 and to the requirements of this section.

21.1506.2 Portland Cement. Portland cement shall conform to the requirements of ASTM C 150.

21.1506.3 Blended Hydraulic Cements. Blended hydraulic cements of Type IS, IS-A, IP, IP-A, I(PM) or I(PM)-A shall conform to the requirements of ASTM C 595, when used in lieu of masonry cement.

21.1506.4 Plastic Cement. Plastic cement conforming to the requirements of UBC Standard 25-1 and UBC Standard 21-11.

21.1506.5 Mortar Cement. Mortar cement shall conform to the requirements of UBC Standard 21-14.

21.1506.6 Masonry Cement. Masonry cement shall conform to the requirements of UBC Standard 21-11.

21.1506.7 Hydrated Lime. Hydrated lime shall conform to either of the two following requirements:

1. The total free (unhydrated) calcium oxide (CaO) and magnesium oxide (MgO) shall not be more than 8 percent by weight (calculated on the as-received basis for hydrates).

2. When the hydrated lime is mixed with portland cement in the proportion set forth in Table 21-15-B, the mixture shall give an autoclave expansion of not more than 0.50 percent.

Hydrated lime intended for use when mixed dry with other mortar ingredients shall have a plasticity figure of not less than 200 when tested 15 minutes after adding water.

21.1506.8 Lime Putty. Lime putty made from either quicklime or hydrated lime shall be soaked for a period sufficient to produce a plasticity figure of not less than 200 and shall conform to either the requirements for limitation on total free oxides of calcium and magnesium or the autoclave test specified for hydrated lime in Section 21.1506.5.

SECTION 21.1507 — MORTAR

Mortar shall consist of a mixture of cementitious materials and aggregate conforming to the requirements specified in Section 21.1504, mixed in one of the proportions shown in Table 21-15-B, to which sufficient water has been added to reduce the mixture to a plastic state.

TABLE 21-15-A—PROPERTY SPECIFICATIONS FOR MORTAR[1]

MORTAR	TYPE	AVERAGE COMPRESSIVE STRENGTH OF 2-INCH (51 mm) CUBES AT 28 DAYS (Min., psi) × 6.89 for kPa	WATER RETENTION (Min., percent)	AIR CONTENT (Max., percent)[2]	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
Cement-lime or mortar cement	M	2,500	75	12	Not less than $2^1/_4$ and not more than $3^1/_2$ times the sum of the separate volumes of cementitious materials
	S	1,800	75	12	
	N	750	75	14[3]	
	O	350	75	14[3]	
Masonry cement	M	2,500	75	18	
	S	1,800	75	18	
	N	750	75	18	
	O	350	75	18	

[1]Laboratory-prepared mortar only.

[2]Determined in accordance with applicable standards.

[3]When structural reinforcement is incorporated in cement-lime mortar or mortar-cement mortar, the maximum air content shall be 12 percent.

TABLE 21-15-B—MORTAR PROPORTIONS FOR UNIT MASONRY

MORTAR	TYPE	PROPORTIONS BY VOLUME (CEMENTITIOUS MATERIALS)								AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
		Portland Cement or Blended Cement[1]	Masonry Cement[2]			Mortar Cement[3]			Hydrated Lime or Lime Putty[1]	
			M	S	N	M	S	N		
Cement-lime	M	1	—	—	—	—	—	—	$^1/_4$	Not less than $2^1/_4$ and not more than 3 times the sum of the separate volumes of cementitious materials
	S	1	—	—	—	—	—	—	over $^1/_4$ to $^1/_2$	
	N	1	—	—	—	—	—	—	over $^1/_2$ to $1^1/_4$	
	O	1	—	—	—	—	—	—	over $1^1/_4$ to $2^1/_2$	
Mortar cement	M	1	—	—	—	—	—	1	—	
	M	—	—	—	—	1	—	—	—	
	S	$^1/_2$	—	—	—	—	—	1	—	
	S	—	—	—	—	—	1	—	—	
	N	—	—	—	—	—	—	1	—	
Masonry cement	M	1	—	—	1	—	—	—	—	
	M	—	1	—	—	—	—	—	—	
	S	$^1/_2$	—	—	1	—	—	—	—	
	S	—	—	1	—	—	—	—	—	
	N	—	—	—	1	—	—	—	—	
	O	—	—	—	1	—	—	—	—	

[1]When plastic cement is used in lieu of portland cement, hydrated lime or putty may be added, but not in excess of one tenth of the volume of cement.

[2]Masonry cement conforming to the requirements of UBC Standard 21-11.

[3]Mortar cement conforming to the requirements of UBC Standard 21-14.

UNIFORM BUILDING CODE STANDARD 21-16
FIELD TESTS SPECIMENS FOR MORTAR

Test Standard of the International Conference of Building Officials

See Section 2102.2, Item 8, *Uniform Building Code*

SECTION 21.1601 — FIELD COMPRESSIVE TEST SPECIMEN FOR MORTAR

Spread mortar on the masonry units $^1/_2$ inch to $^5/_8$ inch (13 mm to 16 mm) thick, and allow to stand for one minute, then remove mortar and place in a 2-inch by 4-inch (51 mm by 102 mm) cylinder in two layers, compressing the mortar into the cylinder using a flat-end stick or fingers. Lightly tap mold on opposite sides, level off and immediately cover molds and keep them damp until taken to the laboratory. After 48 hours' set, have the laboratory remove molds and place them in the fog room until tested in damp condition.

SECTION 21.1602 — REQUIREMENTS

Each such mortar test specimen shall exhibit a minimum ultimate compressive strength of 1,500 pounds per square inch (10 304 kPa).

UNIFORM BUILDING CODE STANDARD 21-17
TEST METHOD FOR COMPRESSIVE STRENGTH OF MASONRY PRISMS

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See Sections 2102.2, Item 6.4; 2105.3.2; and 2105.3.3, *Uniform Building Code*

SECTION 21.1701 — SCOPE

This standard covers procedures for masonry prism construction, testing and procedures for determining the compressive strength of masonry.

SECTION 21.1702 — CONSTRUCTION OF PRISMS

Prisms shall be constructed on a flat, level base. Masonry units used in the prism shall be representative of the units used in the corresponding construction. Each prism shall be built in an opened moisture-tight bag which is large enough to enclose and seal the completed prism. The orientation of units, where top and bottom cross sections vary due to taper of the cells, or where the architectural surface of either side of the unit varies, shall be the same orientation as used in the corresponding construction. Prisms shall be a single wythe in thickness and laid up in stack bond (see Figure 21-17-1).

The length of masonry prisms may be reduced by saw cutting; however, prisms composed of regular shaped hollow units shall have at least one complete cell with one full-width cross web on either end. Prisms composed of irregular-shaped units shall be cut to obtain as symmetrical a cross section as possible. The minimum length of saw-cut prisms shall be 4 inches (102 mm).

Masonry prisms shall be laid in a full mortar bed (mortar bed both webs and face shells). Mortar shall be representative of that used in the corresponding construction. Mortar joint thickness, the tooling of joints and the method of positioning and aligning units shall be representative of the corresponding construction.

Prisms shall be a minimum of two units in height, but the total height shall not be less than 1.3 times the least actual thickness or more than 5.0 times the least actual thickness. Immediately following the construction of the prism, the moisture-tight bag shall be drawn around the prism and sealed.

Where the corresponding construction is to be solid grouted, prisms shall be solid grouted. Grout shall be representative of that used in the corresponding construction. Grout shall be placed not less than one day nor more than two days following the construction of the prism. Grout consolidation shall be representative of that used in the construction. Additional grout shall be placed in the prism after reconsolidation and settlement due to water loss, but prior to the grout setting. Excess grout shall be screeded off level with the top of the prism. Where open-end units are used, additional masonry units shall be used as forms to confine the grout during placement. Masonry unit forms shall be sufficiently braced to prevent displacement during grouting. Immediately following the grouting operation, the moisture-tight bag shall be drawn around the prism and resealed.

Where the corresponding construction is to be partially grouted, two sets of prisms shall be constructed; one set shall be grouted solid and the other set shall not be grouted.

Where the corresponding construction is of multiwythe composite masonry, masonry prisms representative of each wythe shall be built and tested separately.

Prisms shall be left undisturbed for at least two days after construction.

SECTION 21.1703 — TRANSPORTING MASONRY PRISMS

Prior to transporting each prism, strap or clamp the prism together to prevent damage during handling and transportation. Secure prism to prevent jarring, bouncing or falling over during transporting.

SECTION 21.1704 — CURING

Prisms shall remain sealed in the moisture-tight bag until two days prior to testing; the moisture-tight bag shall then be removed and curing continued in laboratory air maintained at a temperature of 75°F ± 15°F (24°C ± 8°C). Prisms shall be tested at 28 days after constructing the prism or at test age designated.

SECTION 21.1705 — PREPARATION FOR TESTING

21.1705.1 Capping the Prism. Cap top and bottom of the prism prior to testing with sulfur-filled capping or with high-strength gypsum plaster capping (such as "Hydrostone" or "Hyprocal White"). Sulfur-filled capping material shall be 40 to 60 percent by weight sulfur, the remainder being ground fireclay or other suitable inert material passing a No. 100 (150 μm) sieve, with or without a plasticizer. Spread the capping material over a level surface which is plane within 0.003 inch (0.076 mm) in 16 inches (406 mm). Bring the surface to be capped into contact with the capping paste; firmly press down the specimen, holding it so that its axis is at right angles to the capping surfaces. The average thickness of the cap shall not exceed $^1/_8$ inch (3.2 mm). Allow caps to age at least two hours before testing.

21.1705.2 Measurement of the Prism. Measure the length and thickness of the prism to the nearest 0.01 inch (0.25 mm) by averaging three measurements taken at the center and quarter points of the height of the specimen. Measure the height of the prism, including caps, to the nearest 0.1 inch (2.54 mm).

SECTION 21.1706 — TEST PROCEDURE

21.1706.1 Test Apparatus. The test machine shall have an accuracy of plus or minus 1.0 percent over the load range. The upper bearing shall be spherically seated, hardened metal block firmly attached at the center of the upper head of the machine. The center of the sphere shall lie at the center of the surface held in its spherical seat, but shall be free to turn in any direction, and its perimeter shall have at least $^1/_4$-inch (6.4 mm) clearance from the head to allow for specimens whose bearing surfaces are not exactly parallel. The diameter of the bearing surface shall be at least 5 inches (127 mm). A hardened metal bearing block may be used beneath the specimen to minimize wear of the lower platen of the machine. The bearing block surfaces intended for contact with the specimen shall have a hardness not less than 60 HRC (620 HB). These surfaces shall not depart from plane surfaces by more than

0.001 inch (0.0254 mm) in any 6-inch (153 mm) dimension. When the bearing area of the spherical bearing block is not sufficient to cover the area of the specimen, a steel plate with surfaces machined to true planes within plus or minus 0.001 inch (0.0254 mm) in any 6-inch (153 mm) dimension, and with a thickness equal to at least the distance from the edge of the spherical bearings to the most distant corner, shall be placed between the spherical bearing block and the capped specimen.

21.1706.2 Installing the Prism in the Test Machine. Wipe clean the bearing faces of the upper and lower platens or bearing blocks and of the test specimen and place the test specimen on the lower platen or bearing block. Align both centroidal axes of the specimen with the center of thrust of the test machine. As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

21.1706.3 Loading. Apply the load, up one half of the expected minimum load, at any convenient rate, after which adjust the controls of the machine so that the remaining load is applied at a uniform rate in not less than one or more than two minutes.

21.1706.4 Observations. Describe the mode of failure as fully as possible or illustrate crack patterns, spalling, etc., on a sketch, or both. Note whether failure occurred on one side or one end of the prism prior to failure of the opposing side or end of the prism.

SECTION 21.1707 — CALCULATIONS

Calculations of test results shall be as follows:

21.1707.1 Net cross-sectional area. Determine the net cross-sectional area [square inches (mm^2)] of solid grouted prisms by multiplying the average measured width dimension [inches (mm)] by the average measured length dimension [inches (mm)]. The net cross-sectional area of ungrouted prisms shall be taken as the net cross-sectional area of masonry units determined from a representative sample of units.

21.1707.2 Masonry prism strength. Determine the compressive strength of each prism [psi (kPa)] by dividing the maximum compressive load sustained [pounds (N)] by the net cross-sectional area of the prism [square inches (mm^2 × 1,000,000)].

21.1707.3 Compressive strength of masonry. The compressive strength of masonry [psi (kPa)] for each set of prisms shall be the lesser of the average strength of the prisms in the set, or 1.25 times the least prism strength multiplied by the prism height-to-thickness correction factor from Table 21-17-A. Where a set of grouted and nongrouted prisms are tested, the compressive strength of masonry shall be determined for the grouted set and for the nongrouted set separately. Where a set of prisms is tested for each wythe of a multiwythe wall, the compressive strength of masonry shall be determined for each wythe separately.

SECTION 21.1708 — MASONRY PRISM TEST REPORT

The test report shall include the following:

1. Name of testing laboratory and name of professional engineer responsible for the tests.

2. Designation of each prism tested and description of prism, including width, height and length dimensions, mortar type, grout and masonry unit used in the construction.

3. Age of prism at time of test.

4. Maximum compressive load sustained by each prism, net cross-sectional area of each prism and net area compressive strength of each prism.

5. Test observations for each prism in accordance with Section 21.1706.

6. Compressive strength of masonry for each set of prisms.

TABLE 21-17-A—PRISM HEIGHT-TO-THICKNESS CORRECTION FACTORS

Prisms h/t_p [1]	1.30	1.50	2.00	2.50	3.00	4.00	5.00
Correction factor	0.75	0.86	1.00	1.04	1.07	1.15	1.22

[1] h/t_p—ratio of prism height to least actual lateral dimension of prism.

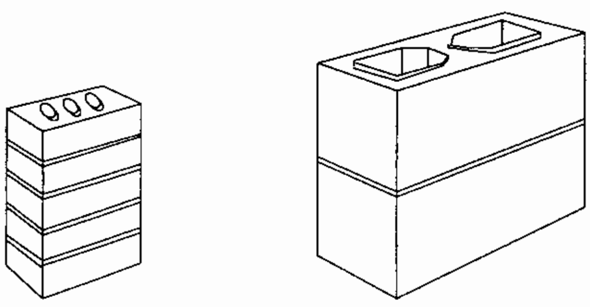

FIGURE 21-17-1—CONSTRUCTION OF PRISMS

UNIFORM BUILDING CODE STANDARD 21-18
METHOD OF SAMPLING AND TESTING GROUT

Based on Standard Method C 1019-89a (93) of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Section 2102.2, Item 9; and Table 21-B, *Uniform Building Code*

SECTION 21.1801 — SCOPE

This method covers procedures for both field and laboratory sampling and compression testing of grout used in masonry construction.

SECTION 21.1802 — APPARATUS

21.1802.1 Maximum-Minimum Thermometer.

21.1802.2 Straightedge. A steel straightedge not less than 6 inches (152.4 mm) long and not less than $^1/_{16}$ inch (1.6 mm) in thickness.

21.1802.3 Tamping Rod. A nonabsorbent smooth rod, either round or square in cross section nominally $^5/_8$ inch (15.9 mm) in dimension with ends rounded to hemispherical tips of the same diameter. The rod shall be a minimum length of 12 inches (304.8 mm).

21.1802.4 Wooden Blocks. Wooden squares with side dimensions equal to one-half the desired grout specimen height, within a tolerance of 5 percent, and of sufficient quantity or thickness to yield the desired grout specimen height, as shown in Figures 21-18-1 and 21-18-2.

Wooden blocks shall be soaked in limewater for 24 hours, sealed with varnish or wax, or covered with an impermeable material prior to use.

SECTION 21.1803 — SAMPLING

21.1803.1 Size of Sample. Grout samples to be used for slump and compressive strength tests shall be a minimum of $^1/_2$ ft.^{3} (0.014 m^3).

21.1803.2 Field Sample. Take grout samples as the grout is being placed into the wall. Field samples may be taken at any time except for the first and last 10 percent of the batch volume.

SECTION 21.1804 — TEST SPECIMEN AND SAMPLE

21.1804.1 Each grout specimen shall be a square prism, nominally 3 inches (76.2 mm) or larger on the sides and twice as high as its width. Dimensional tolerances shall be within 5 percent of the nominal width selected.

21.1804.2 Three specimens constitute one sample.

SECTION 21.1805 — PROCEDURE

21.1805.1 Select a level location where the molds can remain undisturbed for 48 hours.

21.1805.2 Mold Construction.

21.1805.2.1 The mold space should simulate the grout location in the wall. If the grout is placed between two different types of masonry units, both types should be used to construct the mold.

21.1805.2.2 Form a square prism space, nominally 3 inches (76.2 mm) or larger on each side and twice as high as its width, by stacking masonry units of the same type and moisture condition as those being used in the construction. Place wooden blocks, cut to proper size and of the proper thickness or quantity, at the bottom of the space to achieve the necessary height of specimen. Tolerance on space and specimen dimensions shall be within 5 percent of the specimen width. See Figures 21-18-1 and 21-18-2.

21.1805.2.3 Line the masonry surfaces that will be in contact with the grout specimen with a permeable material, such as paper towel, to prevent bond to the masonry units.

21.1805.3 Measure and record the slump of the grout.

21.1805.4 Fill the mold with grout in two layers. Rod each layer 15 times with the tamping rod penetrating $^1/_2$ inch (12.7 mm) into the lower layer. Distribute the strokes uniformly over the cross section of the mold.

21.1805.5 Level the top surface of the specimen with a straightedge and cover immediately with a damp absorbent material such as cloth or paper towel. Keep the top surface of the sample damp by wetting the absorbent material and do not disturb the specimen for 48 hours.

21.1805.6 Protect the sample from freezing and variations in temperature. Store an indicating maximum-minimum thermometer with the sample and record the maximum and minimum temperatures experienced prior to the time the specimens are placed in the moist room.

21.1805.7 Remove the masonry units after 48 hours. Transport field specimens to the laboratory, keeping the specimens damp and in a protective container.

21.1805.8 Store in a moist room conforming to nationally recognized standards.

21.1805.9 Cap the specimens in accordance with the applicable requirements of UBC Standard 21-17.

21.1805.10 Measure and record the width of each face at midheight. Measure and record the height of each face at midwidth. Measure and record the amount out of plumb at midwidth of each face.

21.1805.11 Test the specimens in a damp condition in accordance with applicable requirements of UBC Standard 21-17.

SECTION 21.1806 — CALCULATIONS

The report shall include the following:

1. Mix design.
2. Slump of the grout.
3. Type and number of units used to form mold for specimens.
4. Description of the specimens—dimensions, amount out of plumb—in percent.

5. Curing history, including maximum and minimum temperatures and age of specimen, when transported to laboratory and when tested.

6. Maximum load and compressive strength of the sample.

7. Description of failure.

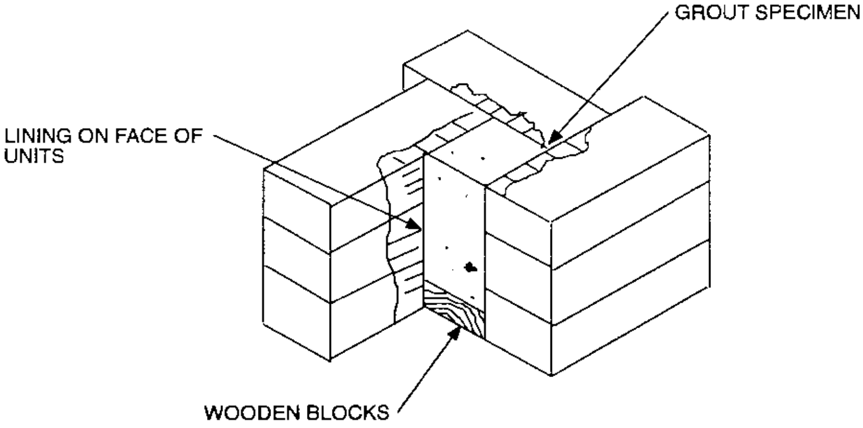

FIGURE 21-18-1—GROUT MOLD [UNITS 6 INCHES (152 mm) OR LESS IN HEIGHT, $2^1/_2$-INCH-HIGH (63.5 mm) BRICK SHOWN]

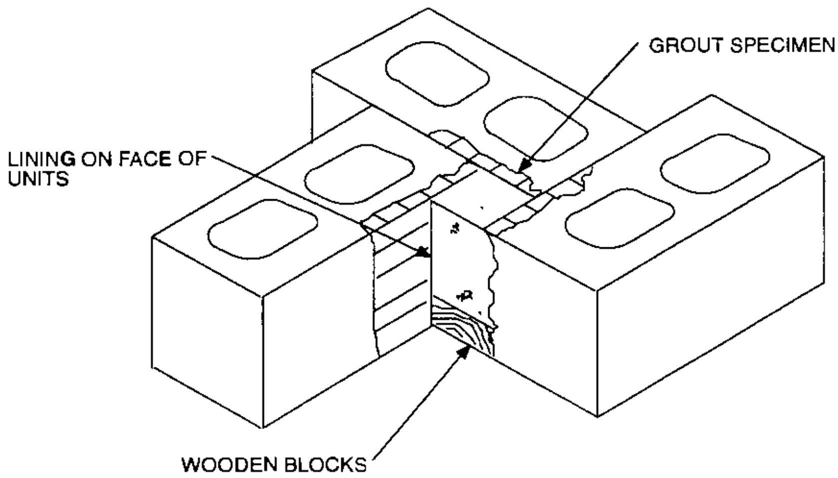

FIGURE 21-18-2—GROUT MOLD [UNITS GREATER THAN 6 INCHES (152 mm) IN HEIGHT, 8-INCH-HIGH (203 mm) CONCRETE MASONRY UNIT SHOWN]

UNIFORM BUILDING CODE STANDARD 21-19
GROUT FOR MASONRY

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See Section 2102.2, Item 9, *Uniform Building Code*

SECTION 21.1901 — SCOPE

This standard covers grout for use in the construction of reinforced and nonreinforced masonry structures.

SECTION 21.1902 — MATERIALS

Materials used as ingredients in grout shall conform to the following:

21.1902.1 Cementitious Materials. Cementitious materials shall conform to one of the following standards:

A. Portland Cement—Types I, II and III of ASTM C 150.

B. Blended Cement—Type IS, IS(MS) or IP of ASTM C 595.

C. Quicklime—UBC Standard 21-12.

D. Hydrated lime—Type S of UBC Standard 21-13.

21.1902.2 Water. Water shall be clean and potable.

21.1902.3 Admixtures. Additives and admixtures to grout shall not be used unless approved by the building official.

21.1902.4 Antifreeze Compounds. No antifreeze liquids, chloride salts or other substances shall be used in grout.

21.1902.5 Storage of Materials. Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material or moisture. Any material that has become unsuitable for good construction shall not be used.

SECTION 21.1903 — MEASUREMENT OF MATERIALS

The method of measuring materials for the grout used in construction shall be such that the specified proportions of the grout materials can be controlled and accurately maintained.

SECTION 21.1904 — GROUT

Grout shall consist of cementitious material and aggregate that have been mixed thoroughly for a minimum of five minutes in a mechanical mixer with sufficient water to bring the mixture to the desired consistency. The grout proportions and any additives shall be based on laboratory or field experience considering the grout ingredients and the masonry units to be used, or the grout shall be proportioned within the limits given in Table 21-B of this code, or the grout shall have a minimum compressive strength when tested in accordance with UBC Standard 21-18 equal to its specified strength, but not less than 2,000 psi (13 800 kPa).

EXCEPTION: Dry mixes for grout which are blended in the factory and mixed at the jobsite shall be mixed in mechanical mixers until workable, but not to exceed 10 minutes.

UNIFORM BUILDING CODE STANDARD 21-20
STANDARD TEST METHOD FOR FLEXURAL BOND STRENGTH OF MORTAR CEMENT

Test Standard of the International Conference of Building Officials

See Section 2102.2, Item 8, *Uniform Building Code*, and UBC Standard 21-14, Table 21-14-A

SECTION 21.2001 — SCOPE

This method covers the laboratory evaluation of the flexural bond strength of a standardized mortar and a standardized masonry unit.

SECTION 21.2002 — APPARATUS

The test apparatus consists of a metal frame designed to support a prism as shown in Figures 21-20-1 and 21-20-2. The prism support system shall be adjustable to support prisms ranging in height from two to seven masonry units. The upper clamping bracket that is clamped to the top masonry unit of the prism shall not come into contact with the lower clamping bracket during the test. An alignment jig, mortar template, and drop hammer as shown in Figures 21-20-3, 21-20-4 and 21-20-5 are used in the fabrication of prism specimens for testing.

SECTION 21.2003 — MATERIALS

21.2003.1 Masonry units used shall be standard masonry units selected for the purpose of determining the flexural bond strength properties of mortar cement mortars. The standard unit shall be in accordance with the following requirements:

1. Dimensions of units shall be $3^5/_8$ inches (92 mm) wide by $2^1/_4$ inches (57 mm) high by $7^5/_8$ inches (194 mm) long within a tolerance of plus or minus $^1/_8$ inch (3.2 mm) and shall be 100 percent solid.

2. The unit material shall be concrete masonry manufactured with the following material proportions by volume:

   One part portland cement to eight parts aggregate

3. Aggregate used in the manufacture of the unit shall be as follows:

Bulk Specific Gravity Gradation	2.6 to 2.7 Percent Retained by Weight
$^3/_8$-inch (9.5 mm) sieve	0
No. 4 (4.75 mm) sieve	0 to 5
No. 8 (2.36 mm) sieve	20 to 30
No. 16 (1.18 mm) sieve	20 to 30
No. 30 (600 μm) sieve	15 to 25
No. 50 (300 μm) sieve	5 to 15
No. 100 (150 μm) sieve	5 to 10
Pan	5 to 10

4. Density of the unit shall be 125 to 135 pounds per cubic foot (2000 to 2160 kg/m^3).

5. Unit shall be cured in a 100 percent relative humidity environment at 140°F ± 10°F (60°C ± 5.6°C) at atmospheric pressure for 10 to 20 hours. Additional curing, under covered atmospheric conditions, shall continue for at least 28 days. Unit shall be loose stacked in the cube (separated by a $^1/_4$-inch (6.4 mm) gap) to allow air to circulate during drying.

6. At the time of fabricating the prisms, units shall have a moisture content in the range of 25 percent to 35 percent.

7. Upon delivery units shall be stored in the laboratory at normal temperature and humidity. Units shall not be wetted or surface treated prior to or during prism fabrication.

21.2003.2 Mortar. Mortar shall be prepared in accordance with the following:

1. Mortar proportions shall be in accordance with Table 21-20-A. The aggregate shall consist of a blend of one-half graded Ottawa sand and one-half Standard 20-30 Ottawa sand.

2. Mortar materials shall be mixed in a drum-type batch mixer for five minutes.

3. Determine mortar flow in accordance with applicable standards and adjust water until a flow of 125 ± 5 is achieved.

4. Determine mortar density, air content and initial cone penetration immediately after mixing the mortar in accordance with applicable standards. Mortar shall not be used when cone penetration is less than 80 percent of the initial cone penetration value.

SECTION 21.2004 — TEST SPECIMENS

21.2004.1 Number. Test specimens shall consist of one set of six prisms constructed with the mortar cement mortar. Each prism shall be six units in height.

21.2004.2 Prism Construction. (1) Each prism shall be built in an opened moisture-tight bag which is large enough to enclose and seal the completed prism. Set the first unit on a $^1/_2$-inch (13 mm) plywood pallet in an alignment jig as shown in Figure 21-20-3. (2) Place the mortar template shown in Figure 21-20-4 on the unit such that the mortar bed depth prior to compaction is $^1/_2$ inch (13 mm). Place mortar in template and strike off excess mortar with straight edge. (3) Remove template and immediately place the next unit on the mortar bed in contact with the three alignment bolts for that course using a bulls-eye level to assure uniform initial contact of the unit surface and bed mortar. Carefully position drop hammer apparatus shown in Figure 21-20-5 on top of unit and drop its 4-pound (1.81 kg) weight, round end down, once from a height of 1.5 inches (38 mm). (4) Repeat (2) and (3) until the prisms are complete. (5) Joints shall be cut flush after the prism is completely built. Joints shall not be tooled. (6) One hour, ± 15 minutes after completion of construction, place two masonry units of the type used to construct the prism upon the top course. (7) Identify all prisms using a water-resistant marker. (8) Draw and seal the moisture-tight bag around the prism. (9) All prisms should be cured for 28 days. Two days prior to testing remove the moisture-tight bag and continue curing in the laboratory air, maintained at a temperature of 75°F ± 15°F (23.9°C ± 8.3°C), with a relative humidity between 30 to 70 percent.

SECTION 21.2005 — TEST PROCEDURE

Place the prism vertically in the support frame as shown in Figure 21-20-1 and clamp firmly into a locked position using the lower clamping bracket. Orient the prism so that the face of the joint intended to be subjected to flexural tension is on the same side of the specimen as the clamping screws. The prism shall be positioned at the required elevation that results in a single unit projecting above the lower clamping bracket. A soft bearing material (for example, polystyrene) at least $^1/_2$-inch (13 mm) thick shall be placed between the bottom of the prism and the adjustable prism base support.

Attach the upper clamping bracket to the top unit as shown in Figure 21-20-1. Tighten each clamping bolt using a torque not greater than 20 inch-pounds (2.26 N·m).

Apply the load at a uniform rate so that the total load is applied in not less than one minute or more than three minutes. Measure load to an accuracy of ± 2 percent with maximum error of five pounds (22.2 N).

SECTION 21.2006 — CALCULATIONS

Calculate the modulus of rupture of each mortar joint as follows:

$$f_r = \frac{6(PL + P_1 L_1)}{bd^2} - \frac{(P + P_1)}{bd}$$

For SI: $$f_r = \frac{6(PL + P_1 L_1)}{1000\, bd^2} - \frac{(P + P_1)}{1000\, bd}$$

WHERE:

b = average width of cross section of failure surface, inches (mm).

d = average thickness of cross section of failure surface, inches (mm).

f_r = modulus of rupture, psi (kPa).

L = distance from center of prism to loading point, inches (mm).

L_1 = distance from center of prism to centroid of loading arm, inches (mm).

P = maximum applied load, pounds (N).

P_1 = weight of loading arm, pounds (N).

The flexural bond strength of mortar shall be determined as the average modulus of rupture of 30 joints minus 1.28 times the standard deviation of the sample which yields a value that a mortar joint's modulus of rupture will equal or exceed nine out of 10 times.

SECTION 21.2007 — REPORT

The report shall include the manufacturer of the mortar cement being evaluated, the source of manufacture, type of mortar cement, date of testing, laboratory name and laboratory personnel.

Report mortar density, air content, flow and cone penetration test data. Report the following data for the mortar cement mortar being evaluated:

PRISM NO.	PRISM WEIGHT (lbs.) (kg)	JOINT NO.	TEST LOAD (lbs.) (N)	MOMENT (in.-lbs.) (N·m)	MODULUS OF RUPTURE			
					f_r psi (kPa)	Mean psi (kPa)	Std. Dev. psi[1] (kPa)	COV %
1	—	1	—	—	—	—	—	—
		2	—	—	—			
		3	—	—	—			
		4	—	—	—			
		5	—	—	—			

[1]Also, report the standard deviation for all six prisms (30 joints).

Report the flexural bond strength (determined in accordance with Section 21.2006) of the mortar cement mortar.

TABLE 21-20-A—MORTAR PROPORTIONS BY VOLUME FOR EVALUATING FLEXURAL BOND

MORTAR	MORTAR CEMENT TYPE	PROPORTIONS	
		Mortar Cement	Aggregate
Type N	N	1	3
Type S	S	1	3
Type M	M	1	3

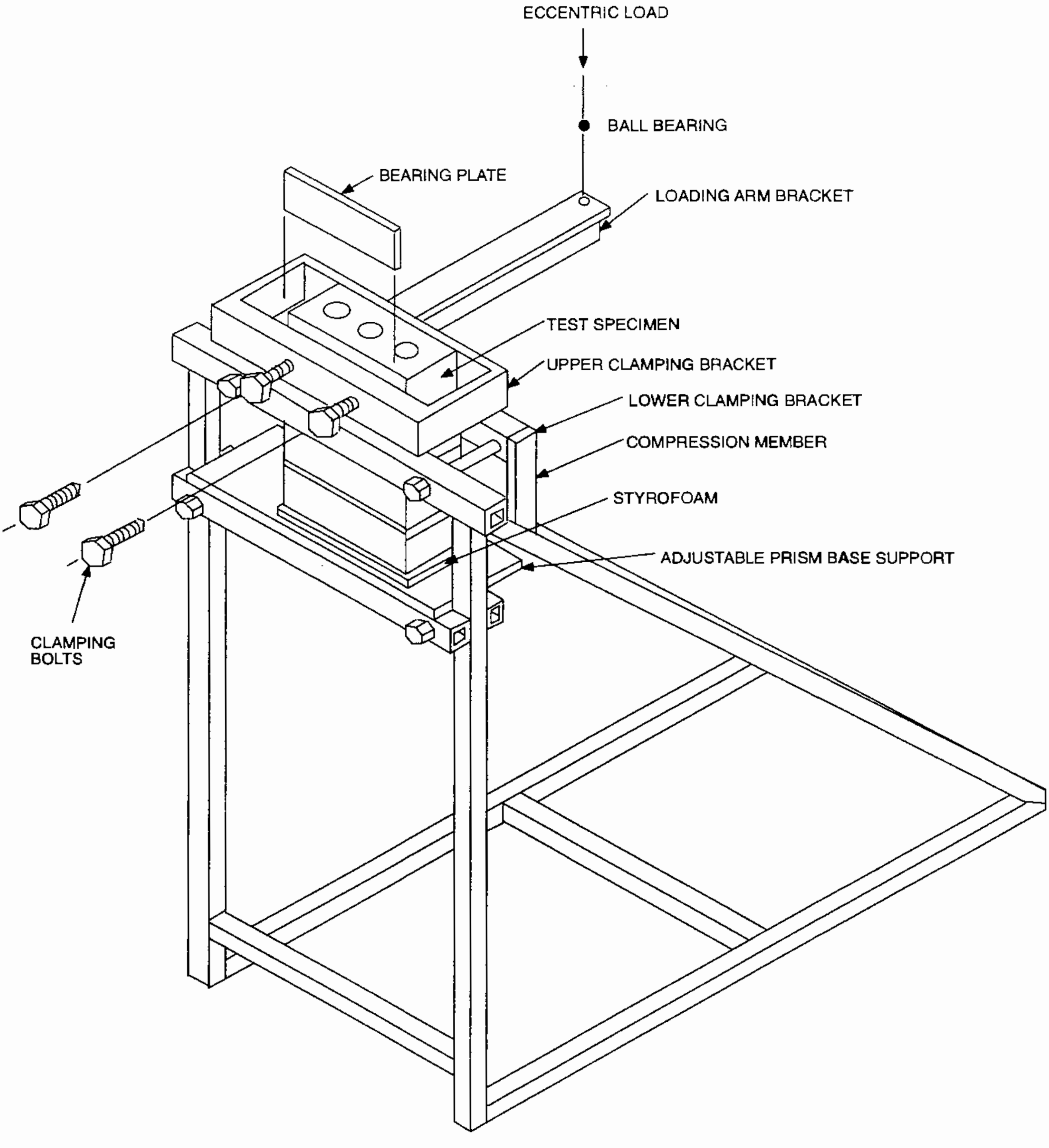
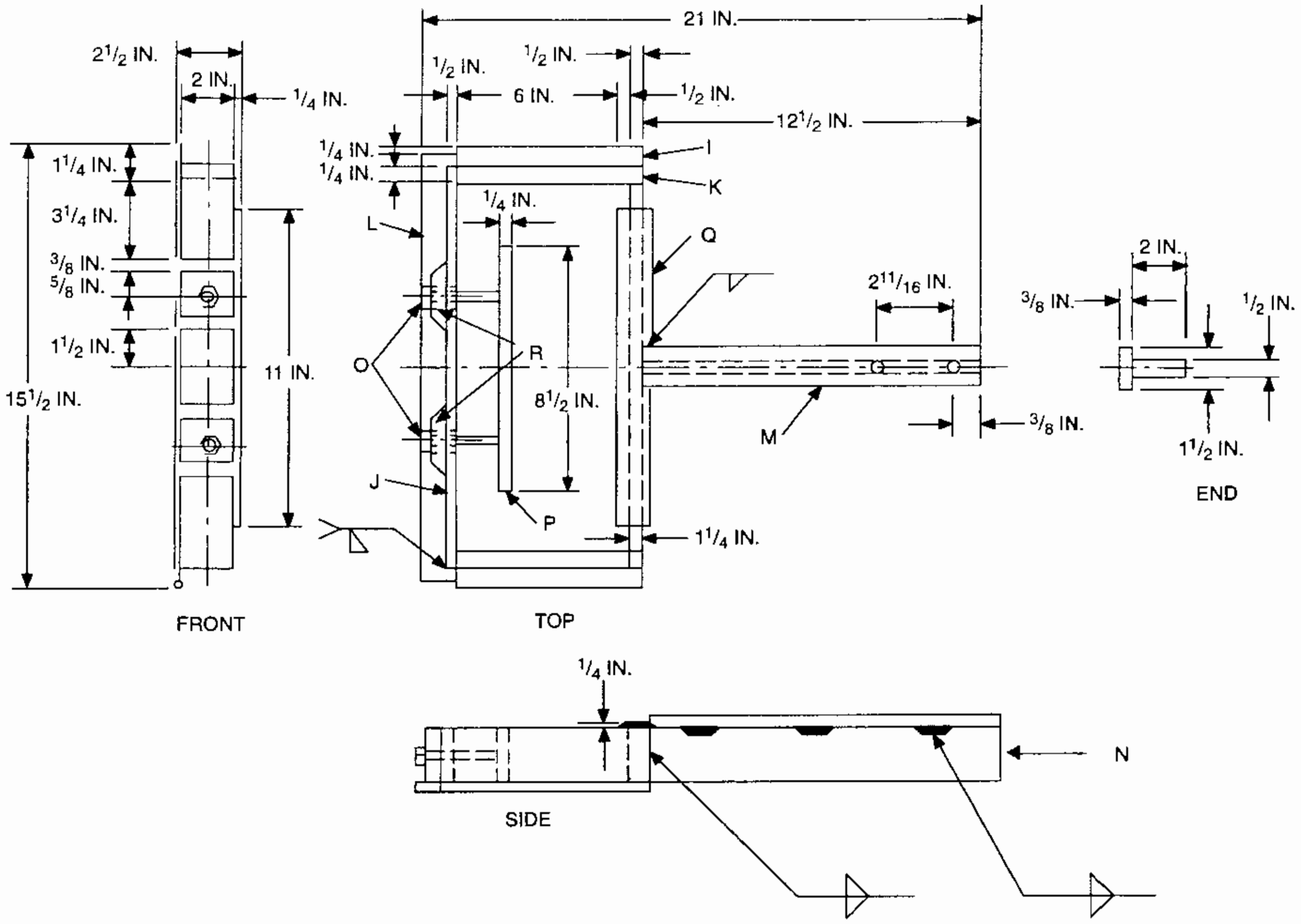
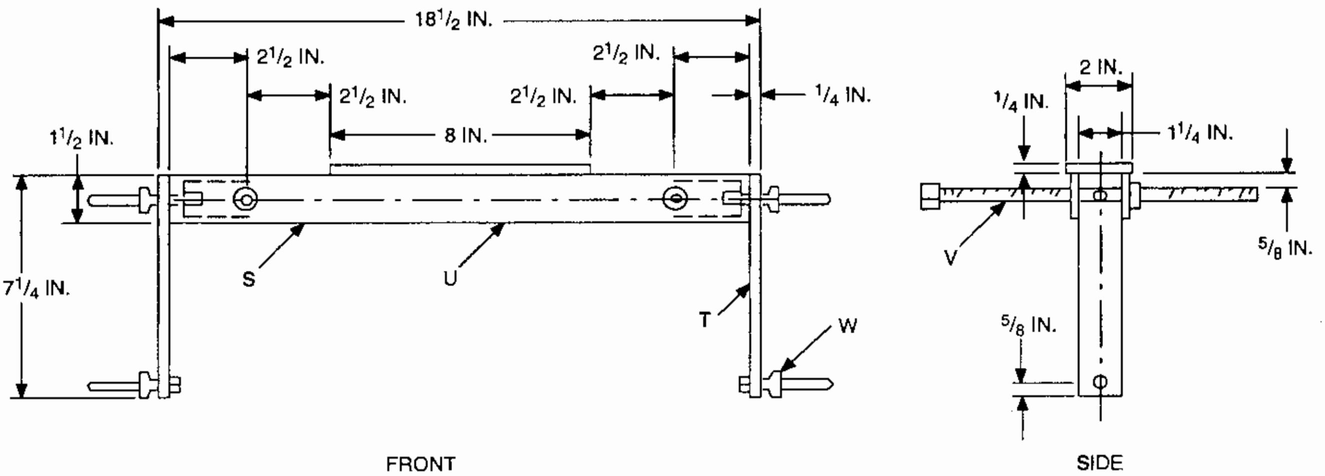


FIGURE 21-20-1—BOND WRENCH TEST APPARATUS



UPPER CLAMPING BRACKET

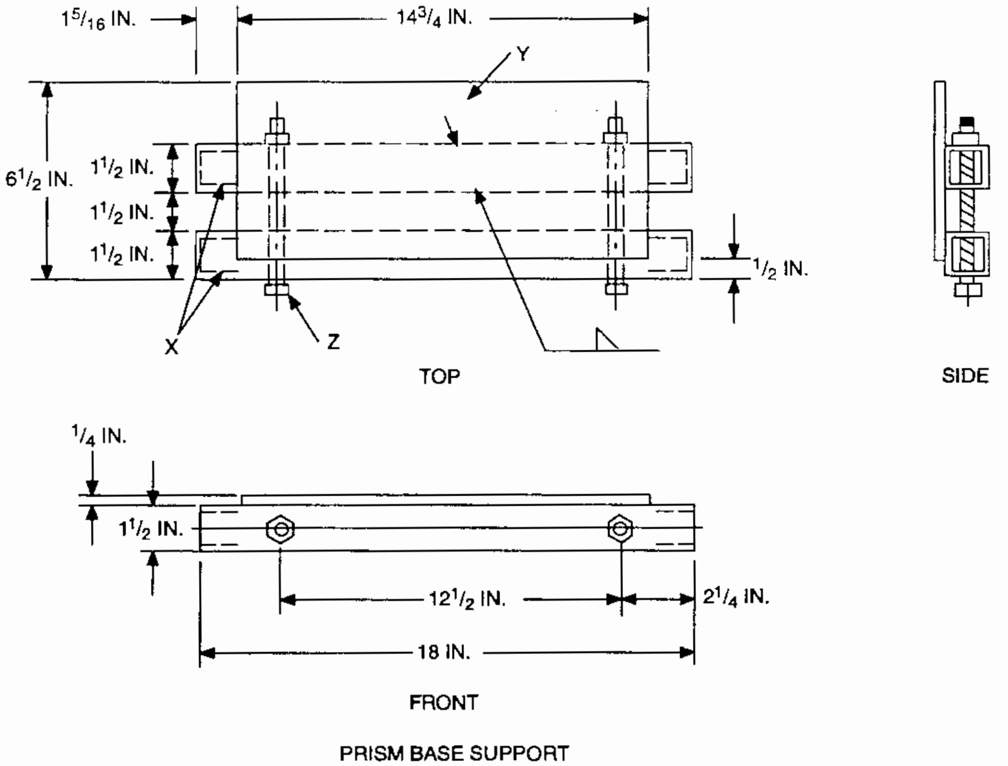


For SI: 1 inch = 25.4 mm.

LOWER CLAMPING BRACKET

FIGURE 21-20-2—DETAIL DRAWINGS OF BOND WRENCH

(Continued)



For SI: 1 inch = 25.4 mm.

FIGURE 21-20-2—DETAIL DRAWINGS OF BOND WRENCH—(Continued)

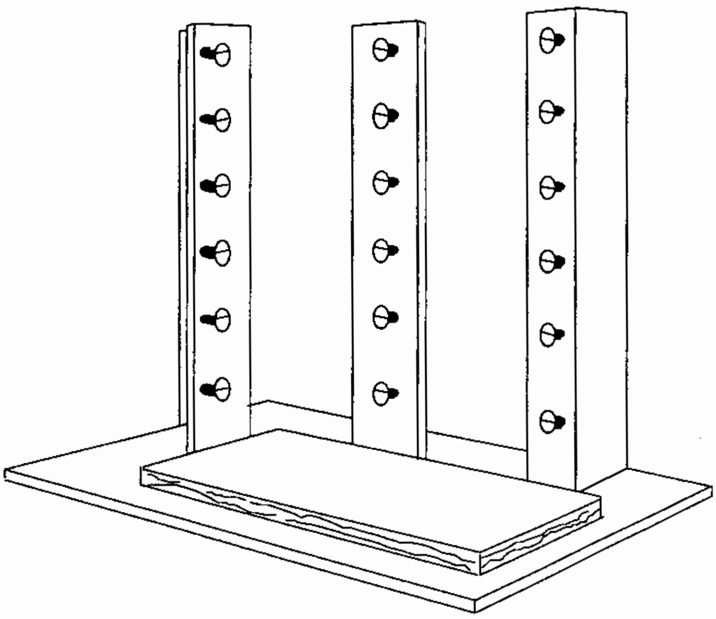


FIGURE 21-20-3—BOND WRENCH JIG WITH PALLET

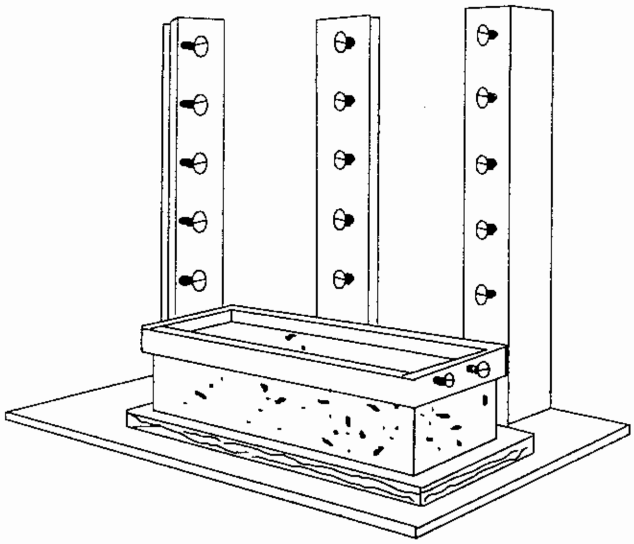


FIGURE 21-20-4—FIRST BRICK WITH MORTAR TEMPLATE

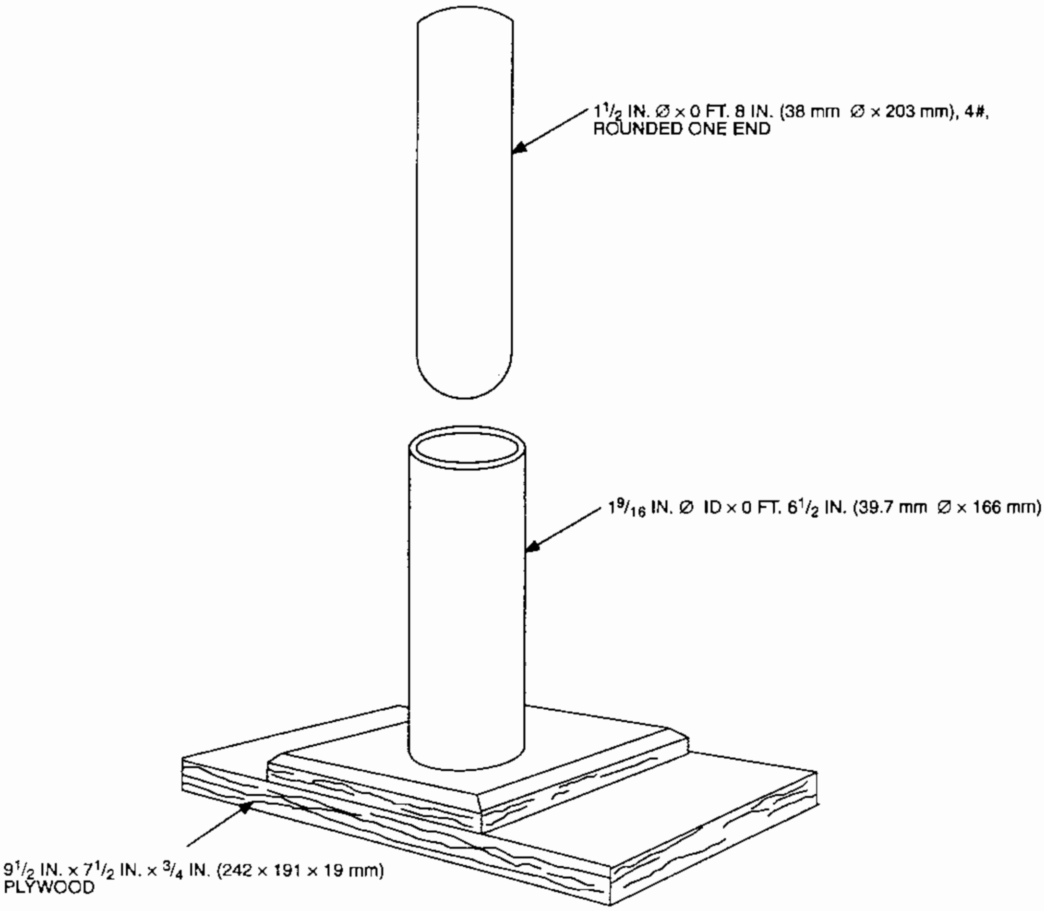


FIGURE 21-20-5—DROP HAMMER AND GUIDE

UNIFORM BUILDING CODE STANDARD 22-1
MATERIAL SPECIFICATIONS FOR STRUCTURAL STEEL

Based on Standard Specifications A 27, A 36, A 48, A 53, A 148, A 242, A 252, A 283, A 307, A 325, A 366, A 446, A 449, A 490, A 500, A 501, A 514, A 529, A 563, A 569, A 570, A 572, A 588, A 606, A 607, A 611, A 618, A 666, A 690 and A 715 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 1808.6.1, 1808.7 and 2202, *Uniform Building Code,* and Section 402.2, *Uniform Sign Code*

SECTION 22.101 — SCOPE

This standard covers steel and iron shapes, plates, sheet, strip, connectors and bars for use in the construction of buildings and for general structural purposes.

SECTION 22.102 — MATERIAL REQUIREMENTS

The material shall conform to the requirements as to the tensile properties set forth in Table 22-1-A.

TABLE 22-1-A—TENSILE REQUIREMENTS

MATERIAL	GRADE	SPECIFICATION TITLE	SIZE AND PRODUCT LIMITATIONS	TENSILE STRENGTH (ksi)	YIELD POINT (ksi)	REFERENCED ELSEWHERE
			× 25.4 for mm	× 6.89 for MPa		
A27-81a	60-30 65-35 70-36 70-40	Mild- to medium-strength carbon steel castings		60 65 70 70	30 35 36 40	
A36-81a		Structural steel		58-80	36	UBC Chapter 22, Divisions VII and IX
A48-76	Class No. 20 A, B, C and S 25 " 30 " 35 " 40 " 45 " 50 " 55 " 60 "	Gray iron castings		20 25 30 35 40 45 50 55 60	— — — — — — — — —	
A53-82	Type F A (Types E and S) B (Types E and S)	Steel pipe, black and hot-dipped, zinc-coated; welded and seamless	Furnace—butt welded Electric—resistance welded and seamless Electric—resistance welded and seamless	45 48 60	25 30 35	UMC Standard 11-1
A148-81	80-40 80-50 90-60 105-85 120-95 150-125 175-145	High-strength steel casting for structural purposes		80 80 90 105 120 150 175	40 50 60 85 95 125 145	
A242-81		High-strength Low-alloy Structural steel	$^3/_4''$ thick and under Over $^3/_4''$ to $1^1/_2''$, inclusive Over $1^1/_2''$ to $4''$ thick	70 67 63	50 46 42	UBC Chapter 22, Divisions VII and IX
A252-82	1 2 3	Welded and seamless steel pipe piles		50 60 66	30 35 45	
A283-81	A B C D	Low and intermediate strength carbon steel plates shapes and bars		45-55 50-60 55-65 60-72	24 27 30 33	
A307-82a	A and B B	Bolts Bolts with cast-iron flanges		60 (min) 100 (max)	—	
A325-83c		High-strength bolts for structural steel joints	$^1/_2''$ to $1''$ diameter, inclusive $1^1/_8''$ to $1^1/_2''$ diameter, inclusive	105 120	92 81	

(Continued)

TABLE 22-1-A—TENSILE REQUIREMENTS—(Continued)

MATERIAL	GRADE	SPECIFICATION TITLE	SIZE AND PRODUCT LIMITATIONS	TENSILE STRENGTH (ksi)	YIELD POINT (ksi)	REFERENCED ELSEWHERE
			× 25.4 for mm	× 6.89 for MPa		
A366-72 (79)		Carbon steel cold-rolled sheet, commercial quality		—	—	
A446-76 (81)	A B C D E F	Steel sheet zinc-coated (galvanized) by hot-dip process structural quality		45 52 55 65 82 70	33 37 40 50 80 50	UBC Chapter 22, Division VII
A449-83a		Quenched and tempered steel bolts and studs	1/4″ to 1″, inclusive Over 1″ to 1 1/2″, inclusive Over 1 1/2″ to 3″, inclusive	120 105 90	92 81 58	
A490-83a		Quenched and tempered alloy steel bolts for structural steel connections	1/2″ to 1 1/2″, inclusive	150 (min) 170 (max)	130	
A500-82a	A B C A B C	Cold-formed welded and seamless carbon steel structural tubing in rounds and shapes	Rounds Shapes	45 58 62 45 58 62	33 42 46 39 46 50	
A501-83		Hot-formed welded and seamless carbon steel structural tubing		58	36	
A514-82a		High-yield strength quenched and tempered alloy steel plate	2 1/2″ Over 2 1/2″ to 6″, inclusive	110-130 100-130	100 90	
A529-82		Structural steel with 42,000 psi minimum yield point	1/2″ maximum thickness	60-85	42	UBC Chapter 22, Division VII
A563-88a	O A B C D DH	Carbon and alloy steel nuts				UBC Chapter 22, Division III
A569-72 (79)		Steel, carbon hot-rolled sheet and strip, commercial quality		—	—	
A570-79	30 33 36 40 45 50	Hot-rolled carbon steel sheets and strip, structural quality	Maximum thickness of 0.2299″	49 52 53 55 60 65	30 33 36 40 45 50	UBC Chapter 22, Divisions VII and IX
A572-82	42 50 60 65	High-strength low-alloy columbium-vanadium steel, structural quality	Shapes, plates, piling and bars	60 65 75 80	42 50 60 65	UBC Chapter 22, Divisions VII and IX
A588-82		High-strength low-alloy structural steel with a 50 ksi minimum yield point to 4 inches thick	Plate and bars to 4″, inclusive Over 4″ to 5″, inclusive Over 5″ to 8″, inclusive Structural shapes—all grades	70 67 63 70	50 46 42 50	UBC Chapter 22, Divisions VII and IX
A606-75		Steel sheet and strip hot-rolled and cold-rolled high-strength low-alloy improved atmospheric corrosion resistance	Hot-rolled cut lengths Hot-rolled coils, Annealed or normalized cut lengths and coils	70 65 65	50 45 45	UBC Chapter 22, Divisions VII and IX
A607-75 (81)	45 50 55 60 65 70	Steel sheet and strip hot-rolled and cold-rolled high-strength low-alloy columbium and/or vanadium	Cut lengths or coils	60 65 70 75 80 85	45 50 55 60 65 70	UBC Chapter 22, Divisions VII and IX
A611-82	A B C D E	Types I and II cold-rolled sheet carbon steel, structural		42 45 48 52 82	25 30 33 40 80	UBC Chapter 22, Divisions VII and IX

(Continued)

TABLE 22-1-A—TENSILE REQUIREMENTS—(Continued)

MATERIAL	GRADE	SPECIFICATION TITLE	SIZE AND PRODUCT LIMITATIONS	TENSILE STRENGTH (ksi)	YIELD POINT (ksi)	REFERENCED ELSEWHERE
			× 25.4 for mm	× 6.89 for MPa		
A618-81	Ia, Ib, II Ia, Ib, II III	Hot-formed welded and seamless high-strength low-alloy structural tubing	Walls $^3/_4''$ and under Walls over $^3/_4''$ to $1^1/_2''$, inclusive Walls over $^3/_4''$ to $1^1/_2''$, inclusive	70 67 65	50 46 50	UBC Chapter 22, Division VII
A666-82	A B C D	Austenitic stainless steel, sheet strip, plate and flat bar for structural applications		75 75-95 115-125 125-150	30 40-4 75 100-110	
A668-85a	A B C D E F G H J K L M N	Steel forgings, carbon and alloy for general industrial use		47 60 66 75 85-83 90-82 80 90 95-105 105-100 125-110 145-135 170-160	— 30 33 37 44-43 55-48 50 60-58 65-80 80-75 105-85 120-110 140-130	UBC Chapter 22, Division III
A690-81a		Sheet piling for marine environment		70	50	
A715-81	50 60 70 80	Steel sheet and strip hot-rolled high-strength low-alloy		60 70 80 90	50 60 70 80	UBC Chapter 22, Division VII
A792-85	33 37 40 50B 50A	Steel sheet, aluminum-zinc alloy coated by the hot-dip process	Coils and lengths	45 52 55 65 —	33 37 40 50 50	
A852-88a		Quenched and tempered low-alloy structural steel plate with 70 ksi minimum yield strength	Maximum 4″ thick	90-110	70	UBC Chapter 22, Division III

UNIFORM BUILDING CODE STANDARD 23-1

CLASSIFICATION, DEFINITION, METHODS OF GRADING AND DEVELOPMENT OF DESIGN VALUES FOR ALL SPECIES OF LUMBER

See Sections 2302.1 and 2303, *Uniform Building Code*

SECTION 23.101 — ADOPTION OF ASTM D 1990, ASTM D 245 AND ASTM D 2555, THE WOOD HANDBOOK NO. 72, PS20-94 AND THE NATIONAL GRADING RULE FOR DIMENSION LUMBER

Classification, definition, methods of grading and development of design values for all species of lumber shall be in accordance with ASTM D 1990-91, ASTM D 245-88 and ASTM D 2555-95 published by the American Society for Testing and Materials, Wood Handbook No. 72 published by the U.S. Department of Agriculture, Voluntary Product Standard PS20-94 published by the U.S. Department of Commerce and the National Grading Rule for Dimension Lumber promulgated by the National Grading Rule Committee, Post Office Box 210, Germantown, Maryland 20875-0210, and published in the American Lumber Standard Committee certified grading rules, as if set out at length herein.

The grade mark on lumber or end-jointed lumber shall include an approved, easily distinguished mark, or insignia of the grading agency which has been accredited by an accreditation body which complies with the requirements of U.S. Department of Commerce PS20-94, or equivalent.

UNIFORM BUILDING CODE STANDARD 23-2
CONSTRUCTION AND INDUSTRIAL PLYWOOD

Based on Product Standard PS 1-95 (for Construction and Industrial Plywood) of the United States Department of Commerce, and National Institute of Science and Technology Calculation of Diaphragm Action, an Engineering Standard of the International Conference of Building Officials

See Sections 1404.1, 2302.1, 2303 and 2304, and Tables 23-III-A, 23-II-H, 23-II-I-1 and 23-II-E-2, *Uniform Building Code*

SECTION 23.201 — SCOPE

23.201.1 General. This standard covers construction and industrial plywood for both Exterior and Interior types. This standard also covers construction and industrial hardwood plywood of red and white lauan (Philippine mahogany), tanoak, red alder and western poplar.

23.201.2 Wood Species. Plywood produced under this standard considers four species classifications: Groups 1, 2, 3 and 4. The species used for the face and back plies are at the option of the manufacturer. When face and back veneers are of the same species group, the panels shall be identified as being of that species group. The species covered in each group are set forth in Table 23-2-A. In addition, other softwood or hardwood species having an average specific gravity of 0.41 or more, based on green volume and oven dry weight, may be used for inner plies except as required for premium grades in Section 23.205.

SECTION 23.202 — DEFINITIONS

General definitions not included in the following section are to be interpreted as defined in UBC Standard 23-1.

BACK is the side of a panel that is of lower veneer quality on any panel whose outer plies are of different veneer grades.

BORER HOLES are voids made by wood-boring insects, such as grubs or worms.

BROKEN GRAIN is a (leafing, shelling, grain separation) separation on veneer surface between annual rings.

CENTERS are inner plies whose grain direction runs parallel to that of the outer plies. May be of parallel laminated plies.

CHECK is a lengthwise separation of wood fibers, usually extending across the rings of annual growth caused chiefly by strains produced in seasoning.

CLASS I, CLASS II are terms used to identify different species group combinations of B-B concrete form panels. The standard provides for two classes, Class I and Class II, as described in Section 23.205.3.

CORE is sometimes referred to as a crossband.

CROSSBAND GAP and CENTER GAP are open joints extending through or partially through a panel, which results when crossband or center veneers are not tightly butted.

CROSSBANDS are inner layers whose grain direction runs perpendicular to that of the outer plies. They may be of parallel laminated plies and are sometimes referred to as core.

DEFECTS, OPEN, are irregularities such as splits, open joints, knotholes, or loose knots, that interrupt the smooth continuity of the veneer.

DELAMINATION is a visible separation between plies that would normally receive glue at their interface and be firmly contacted in the pressing operation. Wood characteristics, such as checking, leafing, splitting and broken grain, are not to be construed as delamination. See corresponding definition for those terms.

1. For purposes of reinspection, areas coinciding with open knotholes, pitch pockets, splits and gaps and other voids or characteristics permitted in the panel grade are not considered in evaluating ply separation of Interior-type panels bonded with interior or intermediate glue.

2. In evaluating Interior panels bonded with exterior glue, delamination in any glueline shall not exceed 3 square inches (1935 mm^2) except where directly attributable to defects permitted in the grade as follows:

Delamination associated with:

2.1 Knots and knotholes—shall not exceed the size of the defect plus a surrounding band not wider than $^3/_4$ inch (19 mm).

2.2 All other forms of permissible defects—shall not exceed the size of the defect.

3. In evaluating Exterior-type panels for ply separation, the area coinciding with the grade characteristics noted in Item 1 are considered, and a panel is considered delaminated if visible ply separation at a single glueline in such area exceeds 3 square inches (1935 mm^2).

EDGE SPLITS are wedge-shaped openings in the inner plies caused by splitting of the veneer before pressing.

FACE is the better side of any panel whose outer plies are of different veneer grades; also either side of a panel where the grading rules draw no distinction between faces.

GROUP is the term used to classify species covered by this standard in an order that provides a basis for simplified marketing and efficient utilization. Species covered by the standard are classified as Groups 1, 2, 3 and 4. See Table 23-2-A for listing of species in individual groups.

HEARTWOOD is the nonactive core of a log generally distinguishable from the outer portion (sapwood) by its darker color.

INNER PLIES are other than exposed face and back plies in a panel construction.

JOINTED INNER PLIES are crossband and center veneer that have had edges machine-squared to permit tightest possible layup.

KNOT is a natural characteristic of wood that occurs where a branch base is embedded in the trunk of a tree. Generally the size of a knot is distinguishable by (1) a difference in color of limbwood and surrounding trunkwood; (2) abrupt change in growth ring width between knot and bordering trunkwood; and (3) diameter of circular or oval shape described by points where checks on the face of a knot that extend radially from its center to its side experience abrupt change in direction.

KNOTHOLES are voids produced by the dropping of knots from the wood in which they are originally embedded.

LAP is a condition where the veneers are so placed that one piece overlaps the other.

LAYER is a single veneer ply or two or more plies laminated with grain direction parallel. Two or more plies laminated with grain direction parallel is a parallel laminated layer.

NOMINAL THICKNESS is full "designated" thickness. For example, $^{1}/_{10}$-inch (2.5 mm) nominal veneer is 0.10 inch (2.5 mm) thick. Nominal $^{1}/_{2}$-inch-thick (13 mm) panel is 0.50 inch (13 mm) thick. Also, commercial size designations are subject to acceptable tolerances.

PATCHES are insertions of sound wood or synthetic material in veneers or panels for replacing defects. "Boat" patches are oval shaped with sides tapering in each direction to a point or to a small rounded end. "Router" patches have parallel sides and rounded ends. "Sled" patches are rectangular with feathered ends.

PITCH POCKET is a well-defined opening between rings of annual growth, usually containing, or which has contained, pitch, either solid or liquid.

PITCH STREAK is a localized accumulation of resin in coniferous woods which permeates the cells forming resin soaks, patches or streaks.

PLUGS are sound wood of various shapes, including, among others, circular and dogbone, for replacing defective portions of veneer used to fill openings and provide a smooth, level, durable surface. Plugs usually are held in veneer by friction until veneers are bonded into plywood.

PLY is a single veneer lamina in a glued plywood panel. (See also "layer.")

PLYWOOD is a flat panel, built up of sheets of veneer called plies, united under pressure by a bonding agent to create a panel with an adhesive bond between plies as strong as or stronger than the wood. Plywood is constructed of an odd number of layers with grain of adjacent layers perpendicular. Layers may consist of a single ply or two or more plies laminated with grain direction parallel. Outer layers and all odd-numbered layers generally have the grain direction oriented parallel to the long dimension of the panel. The odd number of layers with alternating grain direction equalizes strains, prevents splitting and minimizes dimensional change and warping of the panel.

Exterior type—Plywood of this type is produced with a C grade veneer or better throughout and is bonded with completely waterproof adhesives. It is a plywood that will retain its glue bond when repeatedly wetted and dried or otherwise subjected to the weather, and is therefore intended for permanent exterior exposure. Table 23-2-E lists the grades within this type. Adhesive performance requirements are provided in Section 23.207.

Interior type—Plywood of this type is moisture resistant. It is intended for all interior applications as well as applications where it may be temporarily exposed to the elements. Table 23-2-D lists the grades within this type. Adhesive performance requirements are provided in Section 23.207.

Intermediate glue (IMG) type—Plywood of this type is bonded with adhesives that possess high-level bacteria, mold and moisture resistance. It is plywood suitable for protected construction and industrial uses where delays in providing protection may be expected. Adhesive performance requirements are provided in Section 23.207. (The grades of IMG-type plywood generally available are given in Table 23-2-D.)

Overlaid plywood is Exterior-type plywood to which has been added a resin-treated fiber surfacing material on one or both sides. It is made in two standard categories, "High Density" and "Medium Density," and a "Special" category, all of which refer to the surfacing materials. The overlay surfaces are permanently fused to the base panel under heat and pressure. Although designed for all types of moisture exposure and service, all overlaid plywood is made only in the Exterior type. This refers to the base panel and to the overlay itself.

REPAIR is any patch, plug or shim.

SAPWOOD is the living wood of lighter color occurring in the outer portion of a log. Sapwood is sometimes referred to as "sap."

SHIM is a long narrow repair of wood or suitable synthetic not more than $^{3}/_{16}$ inch (4.8 mm) wide.

SHOP CUTTING PANELS are panels which have been rejected as not conforming to grade requirements of standard grades in this standard. Identification of these panels shall be with a separate mark that makes no reference to this standard and contains the notation, "Shop Cutting Panel—All Other Marks Void." Blistered panels are not considered as coming within the category covered by this stamp.

SPAN RATING is a set of numbers used in marking sheathing and combination subfloor underlayment (single floor) grades of plywood as described in Section 23.209.

SPLIT is lengthwise separation of wood fibers completely through the veneer caused chiefly by manufacturing process or handling.

STREAKS are synonymous with "pitch streaks."

STRUCTURAL I is a name used to identify panels that provide for greatest refinement of engineering properties which may be important in the use of plywood for structural components and other sophisticated engineered applications. Manufacturing requirements include special provisions for species, panel construction and veneer grade characteristics as described in Section 23.205.4.

TORN GRAIN. See "broken grain."

TOUCH-SANDING is a sizing operation consisting of a light surface sanding in a sander. Sander skips to any degree are admissible.

VENEER consists of thin sheets of wood of which plywood is made. Veneer is also referred to as plies in the glued panel.

WATERPROOF ADHESIVE is glue capable of bonding plywood in a manner to satisfy the exterior performance requirements given herein.

WHITE POCKET is a form of decay (*Fomes pini*) that attacks most conifers but has never been known to develop in wood in service. In plywood manufacture, routine drying of veneer effectively removes any possibility of decay surviving.

Heavy white pockets may contain a great number of pockets, in dense concentrations, running together and at times appearing continuous. Holes may extend through the veneer but wood between pockets appears firm. At any cross section extending across the width of the affected area, sufficient wood fiber shall be present to develop not less than 40 percent of the strength of clear veneer. Brown cubical and similar forms of decay which have caused the wood to crumble are prohibited.

Light white pockets are advanced beyond incipient or stain stage to the point where the pockets are present and plainly visible, mostly small and filled with white cellulose and generally distributed with no heavy concentrations. Pockets for the most part are separate and distinct with few to no holes through the veneer.

WOOD FAILURE (PERCENT) is the area of wood fiber remaining at the glueline following completion of the specified shear test. Determination is by means of visual examination and expressed as a percent of the 1-square-inch (645 mm^2) test area. (See Section 23.214 for test.)

SECTION 23.203 — REQUIREMENTS

23.203.1 Workmanship. Unless otherwise specified, sanded plywood shall be surfaced on two sides. Faces and backs of panels shall be full width and full length except that C grade and D grade backs may be narrow on one edge or short on one end only, but by not more than $^1/_8$ inch (3.2 mm) for half the panel length or width, respectively. Inner plies shall be full width and length except that one edge or end void not exceeding $^1/_8$ inch (3.2 mm) in depth or 8 inches (203 mm) in length per panel will be acceptable. Crossband veneers not exceeding $^1/_8$ inch (3.2 mm) in thickness may be lapped but by not more than $^3/_{16}$ inch (4.8 mm) when adjacent to faces, or $^1/_2$ inch (13 mm) when adjacent to backs, and provided such laps create no adjacent visible opening. Sanding defects resulting from crossband laps shall not be permitted in panel faces.

C or D grade veneers may be lapped by not more than $^1/_2$ inch (13 mm), provided such laps create no adjacent visible opening. All plies of CD panels only shall be full length and full width except that no more than half the length of one edge nor half the width of one end may contain short or narrow plies. This is contingent on such plies not being short or narrow by more than $^3/_{16}$ inch (4.8 mm), the aggregate area in the plane of the plies of such edge characteristics not exceeding 6 square inches (3871 mm^2) in the entire panel, and such edge characteristics not occurring in more than one ply at any panel cross section.

In grades other than CD, backs may be narrow on one edge or short on one end only, but by not more than $^1/_8$ inch (3.2 mm) for half the panel length or width, respectively; inner plies shall be full width and length, except that one edge or end void not exceeding $^1/_8$ inch (3.2 mm) in depth or 8 inches (203 mm) in length per panel will be acceptable.

Crossband gaps or center gaps, except as noted for plugged crossband and jointed crossband shall not exceed 1 inch (25 mm) in width for a depth of 8 inches (203 mm) (measured from panel edge) and the average of all gaps occurring in a panel shall not exceed $^1/_2$ inch (13 mm). Every effort shall be made to produce closely butted core joints.

Where plugged inner plies are specified, inner plies shall be of C-Plugged veneer and gaps between adjacent pieces of inner plies shall not exceed $^1/_2$ inch (13 mm). Where jointed inner plies are specified, gaps between pieces of inner plies shall not exceed $^3/_8$ inch (9.5 mm), and the average of all gaps occurring in a panel shall not exceed $^3/_{16}$ inch (4.8 mm).

Unless otherwise specified, plugged core (also referred to as solid core) shall be core and center construction of C-Plugged veneer, and gaps between adjacent pieces of core shall not exceed $^1/_2$ inch (13 mm). When jointed core is specified, gaps between pieces of core shall not exceed $^3/_8$ inch (9.5 mm), and the average of all gaps occurring in a panel shall not exceed $^3/_{16}$ inch (4.8 mm).

Plywood shall be clean, well manufactured, and free from blisters, laps and other defects, except as expressly permitted herein. Panels shall have no continuous holes or through openings from face to back.

End butt joints may be used only under the following conditions:

1. Decorative grades as provided in Section 23.205.2.

2. Butt joints having a total aggregate width not exceeding the width of the panel may occur in the center ply of five-ply, five-layer panels. The butt joints must be perpendicular to the grain of the panel face and back plies. The use of butt-jointed centers is allowed in Interior sanded grades in thicknesses up to and including $^1/_2$ inch (13 mm), and in C-D and C-D Plugged thicknesses up to and including $^3/_4$ inch (19 mm). End butt joints shall not be used in Structural I panels. Panels with butt joints in center plies shall be marked "butt-jointed center."

Plywood panels shall be constructed in the grades and veneer combinations as set forth in Tables 23-2-D and 23-2-E. All terms used herein shall be interpreted as described in Section 23.202. Constructions for all panels shall conform to the minimum number of plies and layers as set forth in Table 23-2-C. The proportion of wood with grain perpendicular to panel face grain shall not be less than 33 percent or more than 70 percent of the total panel thickness. The combined thickness of inner layers in panels having four or more plies shall not be less than 45 percent of the total panel thickness. For application of the above requirements, the panel thickness shall be the actual finished panel thickness and veneer thickness shall be the dry veneer thickness before layup. The grain of all layers shall be at right angles to the grain of adjacent layers and to the ends or edges of the panels. The entire area of each contacting surface of the adjacent veneer plies including repairs shall be bonded with an adhesive in a manner to assure satisfactory compliance with the performance requirements for its type as set forth in the tests described in this standard. Where face or back plies consist of more than one piece of edge-joined veneer, gaps between adjacent pieces shall be graded as splits. Any adhesive or bonding system that causes degradation of the wood or latent failure of bond will not be permitted.

For the purpose of veneer repairing or edge joining, strings, ribbons or tapes up to $^3/_8$-inch (9.5 mm) maximum width can occur in a glueline and shall be considered as allowable localized defects in the evaluation of glueline test specimens. Wider strings, ribbons or tapes may be used for veneer repairing or joining if they are prequalified to show bonding equal to the required bonding for that panel. Glueline test specimens cut to include the strings, ribbons or tapes wider than $^3/_8$ inch (9.5 mm) shall not be discarded because of the presence of these materials.

Veneer strips may be joined by string stitching, provided the punch for making holes prior to stitching has a dimension across the grain of 0.095 inch (2.4 mm) or less and the holes are spaced $^1/_2$ inch (13 mm) center-to-center or greater. All veneer used for inner plies may be stitched. Stitched veneer used for outer plies is limited to panels with C or D grade faces or backs, except stitched C veneer may not be used for faces in decorative panels. Panels may have face or back plies stitched but not both.

Shims or strips of veneer shall not be used to repair panel edge voids. However, filling of permissible edge voids with approved synthetic fillers neatly applied will be admitted. Staples or pins of metal or synthetic material are prohibited. Face and back plies of exposed N, A and B veneer panels shall have the bark or tight surface out. Plies directly under surfaces of overlaid panels are not considered exposed veneers.

23.203.2 Tolerance. A tolerance of + 0.0 inch – $^1/_{16}$ inch (0.0625) (+ 0.0 mm – 1.6 mm) shall be allowed on the specified length and/or width. Sanded panels shall have a thickness tolerance of $^1/_{64}$ inch (0.0156) (0.4 mm) of the specified panel thickness of $^3/_4$ inch (19 mm) and less, and ± 3.0 percent of the specified thickness for panels thicker than $^3/_4$ inch (19 mm). Unsanded, touch-sanded, and overlaid panels shall fall within a plus or minus tolerance of $^1/_{32}$ inch (0.0312) (0.8 mm) of the specified panel thickness for all thicknesses through $^{13}/_{16}$ inch (21 mm), and such panels greater than $^{13}/_{16}$ inch (21 mm) shall have a thickness tolerance of 5 percent over or under the specified thickness. Panel thickness shall be based on a moisture content of 9 percent.

Panels shall be square within $^1/_{64}$ inch per lineal foot (1.3 mm per m) for panels of 4-foot by 4-foot (1219 mm by 1219 mm) size or larger. Panels less than 4 feet (1219 mm) in length or width shall be square within $^1/_{16}$ inch (1.6 mm) measured along the short dimension. All panels shall be sawn so that a straight line drawn from one corner to the adjacent corner shall fall within $^1/_{16}$ inch (1.6 mm) of panel edge.

23.203.3 Moisture Content. Moisture content of panels at time of shipment shall not exceed 18 percent of oven-dry weight as determined by the oven-dry test specified in Section 23.217.

SECTION 23.204 — VENEER

23.204.1 General. Except as noted, veneers shall be $^1/_{10}$ inch (2.5 mm) or thicker in panels $^3/_8$ inch (9.5 mm) rough (unsanded) thickness or over; $^1/_{12}$ inch (2.1 mm) or thicker in panels of lesser thickness. In no case shall veneers used in face or back layers be thicker than $^1/_4$ inch (6.4 mm), or veneers used in inner layers thicker than $^5/_{16}$ inch (7.9 mm).

One-twelfth-inch (2.1 mm) veneer may be used as crossbands in five-ply, five-layer, $^1/_2$-inch (13 mm) panels and in parallel laminated layers.

One-sixteenth-inch (1.6 mm) veneer may be used for any ply in five-ply Exterior-type panels less than $^1/_2$ inch (13 mm) in thickness, as the center only in other five-ply panels, and may be included in a parallel laminated layer.

Face and back veneers must be $^1/_8$-inch (3.2 mm) minimum thickness for $^{19}/_{32}$ inch and $^5/_8$ inch (15.1 mm and 15.9 mm), three-, four- and five-ply, three-layer panels of C-D, C-D Plugged, C-C, C-C Plugged and Underlayment grades.

For further limitations on panel layup, refer to Table 23-2-C panel constructions and workmanship.

The average veneer thickness shall conform to the limitations given in this standard within a tolerance of 5 percent of the specified nominal thickness measured dry before layup.

Parallel laminated outer layers may be used only in C-C, C-D, Structural I C-C and C-D grades. Such layers shall consist of veneers $^1/_{10}$ inch (2.5 mm) or thicker in any thickness combination not exceeding $^1/_4$-inch (6.4 mm) total layer thickness. The face and back plies or exposed plies of outer layers shall conform to the species group and grade requirements for faces and backs, respectively, of the panel grade. The unexposed plies of outer layers, or subface and subback plies, shall conform to the species group and grade requirements for inner plies of the panel grade as specified in Sections 23.204.3 and 23.204.4.

The maximum split or gap in subfaces and subbacks shall be $^1/_4$ inch (6.4 mm) under the faces of Structural I C-C and C-D panels, $^1/_2$ inch (13 mm) under the faces of C-C and C-D grades, and $^1/_2$ inch (13 mm) under D backs.

Parallel laminated inner layers in any grade shall consist of veneers $^1/_{16}$ inch (1.6 mm) or thicker in any thickness combination not exceeding $^7/_{16}$-inch (11 mm) total layer thickness. Individual plies in such layers shall conform to the species group and grade requirements for inner plies of the panel grade.

The veneers used in each ply of each panel and the completed panel shall conform with the applicable veneer grade and with the construction and workmanship requirements given herein. Additionally, the type and frequency of the characteristics shall be further limited as set forth for the grades listed in Table 23-2-B.

23.204.2 Number of Plies. For a given thickness, the number of plies used in the panel makeup shall not be less than as provided in Table 23-2-C.

23.204.3 Species for Faces and Backs. For purposes of this standard, veneer species are classified into the four groups given in Table 23-2-A. The species of face and back plies may be from any group; however, when a face or back is made of more than one piece, the entire ply shall be of the same species. Panels, other than unsanded and touch-sanded panels, with span ratings which are produced with face and back veneers of the same species group shall be classified as being of that species group. Touch-sanded panels without span ratings that are manufactured with face and back plies of different species groups shall be identified by the larger numbered species group (i.e., Group 4 is larger numbered than Group 1). Sanded panels $^3/_8$ inch (9.5 mm) or less in thickness and decorative panels of any thickness that are manufactured with face and back plies of different species groups shall be identified by the face species group number. Sanded panels greater than $^3/_8$ inch (9.5 mm) that are manufactured with face and back plies of different species groups shall be identified by the larger numbered species group, except that sanded panels with C or D grade backs may be identified by the face species group number if backs are no more than one species group larger in number than the face and are $^1/_8$ inch (3.2 mm) or thicker before sanding. The species classification group (except for unsanded and touch-sanded panels with span ratings) shall be set forth in the grade mark on each panel. See Section 23.209 for identification requirements for unsanded and touch-sanded panels with span ratings. Where intermixing between species groups occurs in the faces and backs of unsanded or touch-sanded panels with span ratings, provisions of Table 23-2-G shall be followed. (Douglas fir for the purpose . . . and loblolly *[Pinus taeda]* pines.) Because black, white and Engelmann spruce cannot be separated in veneer form by gross structure or minute anatomy, these species shall be classed as Engelmann spruce unless procedures are established for identification prior to peeling.

23.204.4 Species for Inner Plies. Inner plies may be of any species or of any softwood species or any hardwood species having a published average specific gravity value of 0.41 or more, based on green volume and oven-dry weight, except as required for premium panels in Section 23.205.

23.204.5 Scarfed Veneers. Scarfed veneer may be used for any face, back or inner ply except as provided in Section 23.211. Scarfed joints shall not have a slope steeper than 1 in 8, but may be specified at less than 1 in 8. Veneer in the scarf area shall not contain defects which reduce its effective cross section by more than 20 percent. Veneer scarfed joints shall be glued with a waterproof adhesive.

23.204.6 Classification. All veneers used in the construction of the plywood panels shall conform to one of the following grade requirements of which N grade is the highest classification:

23.204.6.1 Grade N veneer. Grade N veneer (intended for natural finish) shall be smoothly cut 100 percent heartwood or 100 percent sapwood, free from knots, knotholes, pitch pockets, open splits, other open defects, and stain; limited to not more than two pieces in a 48-inch (1219 mm) width; not more than three pieces in wider panels; and well matched for color and grain.

Suitable synthetic fillers may be used to fill small cracks or checks not more than $^1/_{32}$ inch (0.8 mm) wide; small splits or openings up to $^1/_{16}$ inch (1.6 mm) wide if not exceeding 2 inches (51 mm) in length; and small chipped areas or openings not more than $^1/_8$ inch (3.2 mm) wide by $^1/_4$ inch (6.4 mm) long. Pitch streaks averaging not more than $^3/_8$ inch (9.5 mm) in width and blending with color of wood are permitted.

Repairs shall be neatly made and parallel to grain and are limited to a total of six in number in any 4-foot by 8-foot (1219 mm by 2438 mm) face, with proportional limits for other sizes. They shall also be well matched for color and grain.

Patches are limited to three "router" patches not exceeding 1 inch (25 mm) in width and $3^1/_2$ inches (89 mm) in length.

No overlapping is permitted.

Wood shims not exceeding $^3/_{16}$ inch (4.8 mm) in width and 12 inches (305 mm) in length that occur only at the ends of the panel are permitted.

23.204.6.2 Grade A veneer. Grade A veneer (suitable for painting) shall be firm, smoothly cut and free from knots, pitch pockets, open splits and other open defects. It shall be well joined when of more than one piece.

Suitable synthetic fillers may be used to fill, in Exterior-type panels, small cracks or checks not more than $^1/_{32}$ inch (0.8 mm) wide; small splits or openings up to $^1/_{16}$ inch (1.6 mm) wide, if not exceeding 2 inches (51 mm) in length; and small chipped areas or openings not more than $^1/_8$ inch (3.2 mm) wide by $^1/_4$ inch (6.4 mm) long. In Interior-type panels: small cracks or checks not more than $^3/_{16}$ inch (4.8 mm) wide; openings or depressions up to $^1/_2$ inch (13 mm) wide by 2 inches (51 mm) long or equivalent area.

Pitch streaks averaging not more than $^3/_8$ inch (9.5 mm) in width, blending with color of wood, are permitted.

Sapwood and discolorations are also permitted.

Repairs shall be wood or of synthetic patching material neatly made and parallel to grain, limited to a total of 18 in number, excluding shims, in any 4-foot by 8-foot (1219 mm by 2438 mm) face and shall have proportional limits on other sizes.

Patches are limited to the boat, router and sled types. Radius of ends of boat patches shall not exceed $^1/_8$ inch (3.2 mm). Patches shall not exceed $2^1/_4$ inches (57 mm) in width singly. Multiple patches consisting of not more than two patches, neither of which may exceed 7 inches (178 mm) in length if either is wider than 1 inch (25 mm) are permitted, except that there may be one multiple repair consisting of three die-cut veneer patches. Synthetic repairs shall not exceed $2^1/_4$ inches (57 mm) in width. Shims are permitted except over or around patches or as multiple repairs.

23.204.6.3 Grade B veneer. Grade B veneer shall be solid and free from open defects and broken grain except as noted. Slightly rough grain and minor sanding and patching defects, including sander skips not exceeding 5 percent of panel area are permitted.

Suitable synthetic filler may be used to fill, in Exterior-type panels, small splits or openings up to $^1/_{16}$ inch (1.6 mm) wide if not exceeding 2 inches (51 mm) in length and small chipped areas or openings not more than $^1/_8$ inch (3.2 mm) wide by $^1/_4$ inch (6.4 mm) long. In Interior-type panels: small cracks or checks not more than $^3/_{16}$ inch (4.8 mm) wide; openings or depressions up to $^1/_2$ inch (13 mm) wide by 2 inches (51 mm) long or equivalent area.

Knots up to 1 inch (25 mm) measured across the grain if both sound and tight, pitch streaks averaging not more than 1 inch (25 mm) in width, and discolorations are permitted.

Splits not wider than $^1/_{32}$ inch (0.8 mm) and vertical holes not exceeding $^1/_{16}$ inch (1.6 mm) in diameter if not exceeding an average of one per square foot in number are permitted. Horizontal or surface tunnels limited to $^1/_{16}$ inch (1.6 mm) across, 1 inch (25 mm) in length, and 12 in number in a 4-foot by 8-foot (1219 mm by 2438 mm) panel or proportionately in panels of other dimensions are also permitted.

Repairs shall be neatly made of wood or synthetic patching material. Repairs permitted are patches ("boat," "router" and "sled") not exceeding 3 inches (76 mm) in width individually where occurring in multiple repairs, or 4 inches (102 mm) in width where occurring singly. Synthetic veneer repairs shall not exceed 4 inches (102 mm) in width. Synthetic panel repairs shall not exceed $2^1/_4$ inches (57 mm) in width. Shims are permitted. Synthetic shims shall completely fill kerfs or voids; shall present a smooth level surface; and shall not crack, shrink or lose their bond under Exterior-type plywood test exposures described in Sections 23.215.2 and 23.215.3. Performance of synthetic shims under normal conditions of service shall be comparable to that of wood shims.

Synthetic plugs not exceeding dimensions specified previously which present solid, level, hard surfaces and whose performances under normal conditions of service are comparable to that of wood plugs are permitted.

23.204.6.4 Grade C veneer. Grade C veneer permits sanding defects that will not impair the strength or serviceability of the panel, knots if tight and not more than $1^1/_2$ inches (38 mm) across the grain, and knotholes up to 1 inch (25 mm) measured across the grain. An occasional knothole more than 1 inch (25 mm) but not more than $1^1/_2$ inches (38 mm) measured across the grain, occurring in any section 12 inches (305 mm) along the grain in which the aggregate width of all knots and knotholes occurring wholly within the section does not exceed 6 inches (152 mm) in a 48-inch (1219 mm) width, and proportionately for other widths is also permitted.

Splits tapering to a point and limited to $^1/_2$ inch (13 mm) by one-half panel length, $^3/_8$ inch (9.5 mm) by any panel length are permitted, provided separation at one end does not exceed $^1/_{16}$ inch (1.6 mm) where split runs full panel length, or $^1/_4$ inch (6.4 mm) maximum width where located within 1 inch (25 mm) of parallel panel edge.

Voids due to missing wood on panel faces and backs not otherwise specified above shall not exceed the maximum width of knotholes permitted in the grade and the length of such voids shall not exceed 6 inches (152 mm).

Repairs shall be wood or synthetic material, neatly made. Wood veneer repairs shall be die cut, and wood panel repairs shall be router or sled type. Wood repairs shall not exceed 3 inches (76 mm) in width individually where occurring in multiple repairs, or 4 inches (102 mm) in width where occurring singly; plugs (circular or "dog bone") not exceeding 3 inches (76 mm) in width individually where occurring in multiple repairs or 4 inches (102 mm) in width where occurring singly; and shims including synthetic as provided for in B grade.

Synthetic veneer repairs shall not exceed 4 inches (102 mm) in width.

Synthetic panel repairs shall not exceed $2^1/_4$ inches (57 mm) in width.

Shims are permitted.

C-Plugged veneer (veneer used for faces of underlayment, C-D Plugged and C-C Plugged grades, and inner plies of overlaid panels and other products if specified) may contain knotholes, worm and borer holes, and other open defects not larger than $^1/_4$ inch by $^1/_2$ inch (6.4 mm by 13 mm), sound and tight knots up to $1^1/_2$ inches (38 mm) measured across the grain, splits up to $^1/_8$ inch (3.2 mm) wide, broken grain, pitch pockets, if solid and tight, plugs, patches and shims. Synthetic repairs in veneer shall not exceed 4 inches (102 mm) in width. Synthetic panel repairs shall not exceed $2^1/_4$ inches (57 mm) in width. Where grades having C-Plugged face veneer are specified as fully sanded, sanding defects shall be the same as admitted under B grade. Sander skips to any degree shall be admissible in C-Plugged veneer.

23.204.6.5 Grade D veneer. Grade D veneer permits any number of plugs, patches, shims, worm or borer holes, sanding defects and other characteristics, provided they do not seriously impair the strength or serviceability of the panels. See also Section 23.203.

Tight knots are permitted in inner plies; and in D grade backs where limited to $2^1/_2$ inches (64 mm) measured across the grain.

In D grade backs, an occasional tight knot larger than $2^1/_2$ inches (64 mm) but not larger than 3 inches (76 mm) measured across the grain, occurring in any section 12 inches (305 mm) along the grain in which the aggregate width of all knots and knotholes occurring wholly within the section does not exceed 10 inches (254 mm) in a 48-inch (1219 mm) width and proportionately for other widths is also permitted.

Knotholes up to $2^1/_2$ inches (64 mm) across the grain, an occasional knothole larger than $2^1/_2$ inches (64 mm) but not larger than 3-inch (76 mm) dimension occurring in any section 12 inches (305 mm) along the grain in which the aggregate width of all knots and knotholes occurring wholly within the section does not exceed 10 inches (254 mm) in a 48-inch (1219 mm) width, and proportionately for other widths; in sanded panels, knotholes not exceeding $2^1/_2$ inches (64 mm) across the grain in veneer thicker than $^1/_8$ inch (3.2 mm); and knotholes not exceeding $3^1/_2$ inches (89 mm) across the grain are permitted in veneers at least two plies removed from the face and back plies of C-D and C-D Plugged grades having five or more plies.

Splits measured at a point 8 inches (203 mm) from their end shall not exceed 1 inch (25 mm) in width, tapering to not more than $^1/_{16}$ inch (1.6 mm) where split runs full panel length; how-ever, the maximum width within 8 inches (203 mm) of the end of the split shall not exceed the maximum width of knotholes permitted within the grade.

Splits on panel faces and backs shall not exceed $^1/_4$ inch (6.4 mm) where located within 1 inch (25 mm) of parallel panel edge.

Voids due to missing wood on panel backs not otherwise specified above shall not exceed the maximum width of knotholes permitted in the grade and the length of such voids shall not exceed 6 inches (152 mm).

Any area 24 inches (610 mm) wide across the grain and 12 inches (305 mm) long, in which light or heavy white pocket occurs, shall not contain more than three of the following characteristics, in any combination: 6-inch (152 mm) width of heavy white pocket; 12-inch (305 mm) width of light white pocket. One knot or knothole, $1^1/_2$ inches to $2^1/_2$ inches (38 mm to 64 mm), or two knots or knotholes, 1 inch to $1^1/_2$ inches (25 mm to 38 mm); knots or knotholes less than 1 inch (25 mm) shall not be considered. Size of any knot or knothole shall be measured in greatest dimension. Any repair in white pocket area shall be treated for grading purposes as a knothole.

23.204.6.6 Synthetic repairs. Synthetic fillers shall be limited to the repair of minor defects as specified in this standard. Synthetic fillers shall be of an approved type.

23.204.6.7 Synthetic shims, patches and plugs. These repairs shall completely fill kerfs or voids; shall present a smooth, level surface; and shall not crack, shrink, or lose their bond. Performance of synthetic shims, patches and plugs under normal conditions of service shall be comparable to that of wood repairs. The equivalency shall be established by testing and evaluation in accordance with approved procedures.

SECTION 23.205 — PREMIUM GRADES

23.205.1 Marine Plywood. Marine grade shall be of Exterior-type meeting applicable requirements of this standard, and of one of the following grades: A-A, A-B, B-B, High Density Overlay, or Medium Density Overlay, all as modified below for "Marine" plywood.

Only Douglas fir 1 and western larch veneer shall be used.

"A" faces shall be limited to a total of nine single repairs in a 4-foot by 8-foot (1219 mm by 2438 mm) sheet, or to a proportionate number in any other size as manufactured. "B" faces or backs where specified, and all inner plies, shall conform to "B" quality veneer requirements and shall be full length and width.

All patches shall be glued with an adhesive meeting Exterior-type performance requirements of this standard and, in addition, shall be set in the panel using a technique involving both heat and pressure.

When the inner ply veneers consist of two or more pieces of veneer, the edges shall be straight and square without lapping.

Neither edge of a panel shall have any crossband gap or edge-split in excess of $^1/_8$ inch (3.2 mm) wide. Crossband gaps and edge-splits per 8 feet (2438 mm) of crossband ply shall not exceed four in number. End splits and gaps on either end of a panel shall not exceed $^1/_8$ inch (3.2 mm) in aggregate width. Filling of crossband gaps and edge-splits with crossband gaps and edge-split materials that serve to conceal the gaps or splits is prohibited.

23.205.2 Decorative Panels. Specialty panels with decorative face veneer treatments in the form of striations, grooving, embossing, brushing, etc., which, except for the special face treatment, meet all of the requirements of this standard, including veneer qualities, glue bond performance and workmanship, shall be considered as conforming to the standard.

An occasional butt joint up to 6 inches (152 mm) in width shall be permitted for decorative effect in veneer on one panel face only. Where butt joints occur, the aggregate width of all knots and knotholes and two thirds the aggregate width of all repairs, including butt joints, shall not exceed 6 inches (152 mm) in any area 12 inches (305 mm) along the grain by 48 inches (1219 mm) wide or proportionately for other widths.

23.205.3 Exterior B-B (Concrete Form) Panels. A panel especially made for general concrete form use. Face veneers shall not be less than B grade and shall always be from the same species group. Inner plies shall not be less than C grade. (See Table 23-2-E for veneer grade limitations of High Density overlaid concrete form panels.) This grade of plywood is produced in two classes and panels of each class shall be identified accordingly. Panels shall be sanded two sides, edge-sealed and, unless otherwise specified, mill-oiled. Species shall be limited as follows and are applicable also to High Density overlaid exterior concrete form panels.

Class I—Faces of any Group 1 species, crossband of any Group 1 or 2 species, and centers of any Group 1, 2, 3 or 4 species.

Class II—Faces of any Group 1 or 2 species, and crossband and centers of any Group 1, 2, 3 or 4 species, or faces of Group 3 species of $^1/_8$-inch (3.2 mm) minimum thickness before sanding, crossband of any Group 1, 2 or 3 species, and centers of any Group 1, 2, 3 or 4 species.

23.205.4 Structural Grade Panels. Panels especially designed for engineered applications such as structural components where design properties including tension, compression, shear, cross-panel flexural properties and nail bearing may be of significant importance. In addition to the special species, grade and glue bond requirements set forth in Table 23-2-F, all other provisions of this standard for the specific types and grades form a part of the specifications for Structural grade panels.

23.205.5 Special Exterior. A premium panel of Exterior type that may be produced of any specified species covered by this standard. It shall otherwise meet all of the requirements for Marine Exterior and be produced in one of the following grades: A-A, A-B, B-B, High Density Overlay, or Medium Density Overlay.

23.205.6 Underlayment, C-C Plugged. Face veneer shall be $^1/_{10}$ inch (2.5 mm) or thicker before sanding. The veneer immediately adjacent to the face ply of C-C Plugged and Underlayment shall be C grade or better with no knotholes over 1 inch (25 mm) across the grain, except that (1) veneer immediately adjacent to the face ply of Underlayment may be D grade with open defects up to $2^1/_2$ inches (64 mm) across the grain or (2) veneer immediately adjacent to the face ply of C-C Plugged may be C grade with open defects up to $1^1/_2$ inches (38 mm) across the grain, provided the face veneer is Group 1 or Group 2 species of $^1/_6$-inch (4.2 mm) minimum thickness before sanding. Also see requirements set forth in Table 23-2-B.

SECTION 23.206 — OVERLAYS

23.206.1 General. The standard grades of overlaid plywood are listed in Table 23-2-E.

23.206.2 High Density. The surfacing on the finished product shall be hard, smooth and of such character that further finishing by paint or varnish is not necessary. It shall consist of a cellulose-fiber sheet or sheets, containing not less than 45 percent resin solids based on a volatile-free weight of fiber and resin. The resin shall be a thermosetting phenol or melamine type. The total resin-impregnated materials for each face shall not be less than 0.012 inch (0.3 mm) thick before pressing and shall weigh not less than 60 pounds per 1,000 square feet (0.29 kg/m^2), including both resin and fiber. The resin impregnation shall be sufficient to make a continuous bond without voids or blisters between the surfacing material and the plywood. The overlay face is usually produced in natural translucent color, but certain other colors may be used by manufacturers for identification.

Other resin-cellulose fiber overlay systems having a weight of not less than 60 pounds per 1,000 square feet (0.29 kg/m^2) of single surface exclusive of glueline, and which possess performance capabilities of the above phenol system, may be identified as High Density Overlay. Determination of equivalent performance shall be based on approved tests.

23.206.3 Medium Density. The resin-treated facing on the finished product shall present a smooth, uniform surface intended for high-quality paint finishes. It shall consist of a cellulose-fiber sheet containing not less than 17 percent resin solids for a beater loaded sheet, or 22 percent for an impregnated sheet, both based on the volatile-free weight of resin and fiber exclusive of glueline. The resin shall be a thermosetting phenol or melamine type. The resin-treated material shall not weigh less than 58 pounds per 1,000 square feet (0.28 kg/m^2) of single face including both resin and fiber but exclusive of glueline. After application, the material shall not measure less than 0.012 inch (0.3 mm) thick. Some evidence of the underlying grain may appear. The overlay face is produced in a natural color and certain other colors.

Other resin-cellulose fiber overlay systems having a weight of 58 pounds per 1,000 square feet (0.28 kg/m^2) of single surface exclusive of glueline, and which possess performance capabilities of the above phenol system, may be identified as Medium Density Overlay. Determination of equivalent performance shall be based on approved test methods.

23.206.4 Special Overlays. Surfacing materials having special characteristics which do not fit the exact description of High Density or Medium Density types as outlined previously. These must meet the test requirements for overlaid plywood and have a durable surface material. Panels shall be identified as "Special Overlay."

SECTION 23.207 — ADHESIVE BOND REQUIREMENTS

23.207.1 General. Lots represented by test panels shall be considered as meeting the requirements of this standard if all of the following minimum requirements are met.

23.207.2 Interior-type Bonded with Interior Glue (Underlayment, C-D Plugged and C-D). A panel shall be considered as meeting the requirements of the standard if three or more of the five test specimens pass. The material represented by the sampling shall be considered as meeting the requirements of this standard if 90 percent or more of the panels pass the test described in Section 23.213.

23.207.3 Interior-type Bonded with Exterior Glue (Structural C-D). When tested in accordance with Section 23.213, the average wood failure of all test specimens, regardless of the number of panels tested, shall not be less than 80 percent.

When more than one panel is tested:

1. At least 90 percent of the panels represented by the test pieces shall have 60 percent wood failure or better.

2. At least 95 percent of the panels represented by the test pieces shall have 30 percent wood failure or better.

These requirements are applicable separately and independently to the results obtained from the vacuum-pressure test and the boiling test. Specimens cut through localized defects permitted in the grade shall be discarded. Test specimens showing delamination in excess of $^1/_8$ inch (3.2 mm) deep and 1 inch (25 mm) long shall be rated as 0 percent wood failure.

23.207.4 All Other Grades of Interior-type Plywood. A panel shall be classed as failing if more than two of the five test specimens fail. The material represented by the sampling shall be considered as meeting the requirements of this standard if 85 percent or more of the panels pass, when tested in accordance with Section 23.213.

23.207.5 Mold Resistance. Underlayment, C-D Plugged, and Standard shall be made with an adhesive possessing a mold resistance equivalent to that created by adding, to plain protein glue, 5 pounds (2.27 kg) of pentachlorophenol or its sodium salt per 100 pounds (45.36 kg) of dry glue base.

IMG-type plywood shall be made with an adhesive possessing a high degree of resistance to attack by bacteria and mold organisms. Adhesives, in order to qualify for use in the manufacture of IMG-type panels, must meet the "bacteria test" requirements published by the American Plywood Association. This procedure is specifically designed for adhesive qualification and is not applicable to inspection and testing, as covered in Section 23.212.

23.207.6 Resistance to Elevated Temperature. Underlayment, C-D Plugged shall be made with an adhesive possessing resistance to temperatures up to 160°F (71°C) at least equal to that of plain protein glue. Urea resin glue shall not be used in these grades unless evidence is submitted indicating performance equivalent to plain protein glues.

23.207.7 Interior-type Bonded with Intermediate Glue (IMG-type). When tested in accordance with Section 23.214, IMG-type plywood shall be considered as meeting the requirements of the standard if all of the following minimum conditions are met:

1. The average wood failure of all test specimens, regardless of the number of panels tested, shall not be less than 45 percent.

2. When more than one panel is tested, at least 90 percent of the panels represented by the test pieces shall have 30 percent wood failure or better.

Specimens cut through localized defects permitted in the grade shall be discarded. Test specimens showing delamination in excess of $^1/_8$ inch (3.2 mm) deep and 1 inch (25 mm) long shall be rated as 0 percent wood failure.

23.207.8 Exterior Type. When tested in accordance with Section 23.215, Exterior-type plywood shall be considered as meeting the requirements of this standard if all of the following minimum conditions are met:

1. The average wood failure of all test specimens, regardless of the number of panels tested, shall not be less than 85 percent.

2. When more than one panel is tested:

   2.1 At least 75 percent of the panels represented by the test pieces shall have 80 percent wood failure or better.

   2.2 At least 90 percent of the panels represented by the test pieces shall have 60 percent wood failure or better.

   2.3 At least 95 percent of the panels represented by the test pieces shall have 30 percent wood failure or better.

These requirements are applicable separately and independently to the results obtained from the vacuum-pressure test and the boiling test. Specimens cut through localized defects permitted in the grade shall be discarded. Test specimens showing delamination in excess of $^1/_8$ inch (3.2 mm) deep and 1 inch (25 mm) long shall be rated as 0 percent wood failure.

Plywood shall be tested for heat durability as described in Section 23.215. Any delamination due to combustion shall be considered as failure, except when occurring at a localized defect permitted in the grade. When testing overlaid plywood. blisters or bubbles in the surface caused by combustion shall not be considered delamination.

The bond between veneers of overlaid plywood as well as the bond between the overlay and the base panel shall meet the wood failure requirements described above for exterior. In evaluating specimens for separation of resin-treated face from the plywood, fiber failure shall be considered the same as wood failure.

SECTION 23.208 — GRADE MARKING

All plywood shall be grade marked in accordance with Section 2303 of this code. No reference shall be made to this standard in the certification or trademarking or grade marking of panels not conforming to all provisions of the standard. Each panel shall be identified with the mark of a qualified inspection and testing agency that shall designate the species group classification or span rating, glue bond type (Interior or Exterior), grade name or the grade of face and back veneers, and a symbol signifying conformance with the standard.

Panels not fully satisfying Exterior veneer requirements shall be identified as "Interior." However, the additional notation "Exterior Glue" or "Intermediate" (IMG) may be used where applicable to supplement the designation of Interior grades bonded with Exterior glue or Intermediate glue. Any further reference to adhesive bond, including those which imply premium performance or special warranty by the manufacturer, as well as manufacturer's proprietary designations, shall be separated from the grade marks or trademarks of the testing agency by not less than 6 inches (152 mm).

SECTION 23.209 — SPAN RATING FOR UNSANDED AND TOUCH-SANDED PANELS

Grade marking or trademarking of C-C, C-D, Structural C-C and Structural C-D, and of C-C Plugged and Underlayment to be used as combination subfloor underlayment (single floor) shall include a span rating for the thickness shown in Table 23-2-G. The numbers are presented as a fraction in the marking of sheathing grades of plywood, and as a single number for C-C Plugged and Underlayment. They describe the recommended maximum spans in inches (mm) under normal use conditions and correspond with commonly accepted criteria. For sheathing, the left-hand number refers to spacing of roof framing, and the right-hand number relates to spacing of the floor framing. The single number for Underlayment and C-C Plugged refers to spacing of the floor framing in single floor applications. The span rating number is related to species and thickness of the panel face and back veneers and panel thickness. It is established by either one of the following procedures:

1. By specification as detailed in Table 23-2-G.

2. By performance testing to satisfy the strength, stiffness and durability criteria as detailed in Section 23.210. Such performance testing is to be performed by a qualified testing agency.

Panels manufactured as C-C, C-D, Structural C-C and Structural C-D shall not be sanded, touch-sanded, surface textured or thickness sized by any mechanical means. However, sanded or touch-sanded panels which do not meet the grades for which they were intended may be reclassified and marked as C-C or C-D, provided the panels meet all applicable requirements for C-C or C-D and the finished face and back veneers after sanding each have a minimum net thickness equal to 90 percent of the applicable thickness in Table 23-2-G.

SECTION 23.210 — PERFORMANCE TESTING QUALIFICATION REQUIREMENTS

23.210.1 General. Acceptance of performance-tested plywood under this standard is based upon testing of panel strength, stiffness and durability. Panels selected for testing shall be of near-minimum grade and near-minimum thickness. All provisions of veneer grade and panel workmanship are applicable.

23.210.2 Performance Testing. Panels qualified for performance testing shall satisfy the criteria called for in this section when tested as required in Sections 23.210.3 and 23.210.4.

23.210.3 Structural Performance.

23.210.3.1 Concentrated loads. A minimum of 10 tests (specimens taken from at least five panels) shall be conducted for both concentrated static and impact loads according to Section 23.216. The tests shall be conducted for each exposure condition specified in Table 23-2-L or 23-2-N (wet, dry and/or wet/redry).

23.210.3.1.1 Deflection. At least 90 percent of tests shall deflect no more than the specified maximum.

23.210.3.1.2 Retest. If no more than two tests in a lot of 10 fail to meet the deflection requirements, another lot of 10 may be tested for that requirement. If no more than one test fails in this second round of testing, the requirements shall be considered satisfied.

23.210.3.1.3 Ultimate load. For each lot, 100 percent of tests shall support the specified minimum ultimate load.

23.210.3.1.4 Retest. If no more than one test in a lot of ten fails to meet the minimum ultimate load requirement, another lot of 10 may be tested for that requirement. If all pass the retest, the requirements shall be considered satisfied.

23.210.3.2 Uniform loads. A minimum of 10 tests (specimens taken from at least five panels) shall be conducted for uniform load capacity according to Section 23.217. The tests shall be conducted for each exposure condition specified in Table 23-2-M or 23-2-O.

23.210.3.2.1 Deflection. The average deflection shall not be greater than that specified.

23.210.3.2.2 Retest. If the average deflection is greater than specified, but does not exceed the requirement by 20 percent, another lot of 10 may be tested for that requirement. If the average of the first and second lot taken together does not exceed that specified, the requirement shall be considered satisfied.

23.210.3.2.3 Ultimate load. For each lot, 100 percent of tests shall support the specified minimum ultimate load.

23.210.3.2.4 Retest. If no more than one test in a lot of 10 fails to meet the ultimate load requirement, another lot of 10 may be tested for that requirement. If all specimens pass this retest, the requirements shall be completely satisfied.

23.210.4 Bond Durability. Panels shall be classed as Exposure 1 or Exterior.

23.210.4.1 Exposure Panels rated as Exposure 1 shall be so identified and shall satisfy the bond requirements for Interior panels bonded with exterior glue as specified in Section 23.207.3.

23.210.4.2 Exterior. Panels rated as Exterior shall be so identified and shall satisfy the bond requirements as specified in Section 23.207.8.

23.210.5 Product Evaluation. Upon satisfactory completion of the appropriate requirements of Sections 23.210.3 and 23.210.4, a manufacturing specification will be written based on product evaluation under this section. This specification is to be used for quality assurance purposes by the manufacturer and the manufacturer's qualified testing agency. Product evaluation will be made on the same lot supplied by the manufacturer for qualification testing. Control values established during product evaluation will be the basis for quality evaluation of future production. The mill specification shall contain the following information.

23.210.5.1 Panel construction. Panels shall be defined as to veneer species and construction.

23.210.5.2 Mechanical properties. Twenty tests (specimens taken from at least 10 panels) shall be evaluated for bending stiffness both along and across the major panel axis according to the procedures of Section 23.218. The control value for each panel direction will be the sample mean and the minimum will be the lower value of a 90 percent confidence interval established on the mean.

Ten tests (specimens taken from at least 10 different panels) shall be tested for maximum bending moment both along and across the major panel axis according to the procedures of Section 23.218. The control value for each panel direction will be the minimum observed value, or the sample mean less 1.8 times the sample standard deviation, whichever is the higher value.

23.210.6 Reexamination.

23.210.6.1 Quarterly reexamination. A product qualified by performance testing shall be subjected to quarterly reexamination by the manufacturer's qualified testing agency. Panels shall be tested according to the procedures of Section 23.210.5.2.

23.210.6.2 Resampling. Failure to meet established control values shall result in an immediate intensive resampling of current production which will be tested for the failing property. This resampling shall consist of 20 panels.

23.210.6.3 Requalification. When results of the resampling fail to meet the applicable test requirements, a requalification for structural properties under Section 23.210.3 shall be required.

SECTION 23.211 — SCARF- AND FINGER-JOINTED PANELS

23.211.1 General. Neither panels with N faces nor the faces of such panels, unless longer than 10 feet (3048 mm), shall be scarfed or finger jointed except when specifically so ordered. Panels of other grades may be scarfed or finger jointed. Panels longer than 12 feet (3658 mm) are necessarily scarfed. Scarf joints shall not have a slope greater than 1 to 8, but may be specified as less than 1 to 8. Joints shall be glued with a waterproof adhesive and meet the test requirements specified in this section as applicable. In addition, the adhesive shall not show creep or flow characteristics greater than unjointed wood when subject to load under any conditions of temperature and moisture.

23.211.2 Strength Requirements (Interior, IMG and Exterior) Scarfed and Finger-jointed Panels. Panels shall be tested in accordance with Section 23.216.1. If the average ultimate stress of the three test specimens of any one panel is less than 4,000 psi (27.58 N/mm^2) for panels of Group 1 species, or less than 2,800 psi (19.3 N/mm^2) for panels of Group 2 or Group 3 species, or 2,400 psi (16.55 N/mm^2) for panels of Group 4 species, then that panel fails. The jointed panels represented by the sampling are acceptable if not more than one of the panels fails.

23.211.3 Scarf- and Finger-joint Durability for Interior and IMG Panels. Panels shall be tested as outlined in Section 23.216.2. Test specimens showing continuous delamination in excess of $^1/_{16}$ inch (1.6 mm) deep and $^1/_2$ inch (13 mm) long at the joint glueline shall be considered as failing. More than one failing specimen in a panel shall constitute failure of that panel. The jointed panels represented by the sampling are acceptable if not more than one of the panels fails.

23.211.4 Scarf-joint Durability for Exterior and Interior Panel Bonded with Exterior and Intermediate Glue. Panels shall be tested in accordance with Section 23.219.3. The material represented by the sampling shall be evaluated in accordance with Sections 23.207.2 and 23.207.3.

23.211.5 Finger-joint Durability for Exterior-type Panels and Interior-type Panels Bonded with Exterior or Intermediate Glue. Panels shall be tested in accordance with Section 23.216. The joints shall meet the following minimum conditions:

23.211.5.1 The average wood failure rating of all specimens from each panel when tested in accordance with Section 23.216 shall not be less than 85 percent.

23.211.5.2 No single specimen from a panel (average of face and back gluelines) shall rate less than 60 percent wood failure.

23.211.5.3 No single face or back glueline in any specimen shall rate less than 30 percent wood failure.

SECTION 23.212 — INSPECTION AND TESTING

23.212.1 General. The tests specified in this section shall be used to determine the glue bond quality of plywood produced under this standard.

23.212.2 Inspections. All plywood designated as complying with this standard shall be subject to inspection prior to coating or finishing, except that concrete form material may have a priming coat of oil or other clear preparation before inspection. The above requirement does not apply to Interior-type plywood bonded with exterior glue or to Exterior-type plywood when tested for glue bond quality.

23.212.3 Plywood Panel Grade, Size and Thickness Reinspections. If reinspection establishes that an item is more than 5 percent below grade or out of dimensional tolerance according to the grade description, that item fails to pass the reinspection. The below-grade panels shall not be accepted. If reinspection establishes that a disputed item is 5 percent or less below grade or out of dimensional tolerance, it passes the reinspection. In addition to the above 5 percent grade and dimensional tolerance, a 5 percent tolerance shall apply separately to the inner-ply gap limitations, including the limitations applicable to the plugged crossband and jointed crossband, as specified in Section 23.203.

23.212.4 Plywood Glue Bond Quality Reinspections. Reinspection of the unused panels shall be carried out following the procedures specified in Sections 23.212, 23.213, 23.214 and 23.215. If the reinspection tests establish that the glue bond quality does not meet the requirements of Section 23.207, as applicable, the panels fail to pass the reinspection. If the glue bond quality requirements are met, panels pass the reinspection. Any delaminated Exterior-type or overlaid panels are not acceptable.

23.212.5 Sampling for Panel Grade, Size and Thickness Reinspections. Grade, size and thickness may include all panels of an item in dispute. However, when approved, a reduced basis for sampling consisting of at least 20 percent or 300 panels, whichever is smaller, shall be inspected for conformance to grade. For reduced sampling, the quantity of panels selected from each disputed item shall be prorated according to the number of panels. Panels found to be below grade or out of tolerance for size and thickness shall have improper grademarks obliterated and shall be remarked for appropriate classification with a special inspection mark registered by the qualified agency conducting the reinspection and applied by this agency's authorized representative.

23.212.6 Sampling for Glue Bond Reinspections. For test purposes, 20 panels, or 5 percent of the panels, whichever is less, shall be selected at random from the item which is in dispute. The number of panels required shall be calculated by applying the "percent panels" to the lot size and converting part panels to whole panels by using a rounding procedure where 0.01 to 0.49 parts are considered to be the smaller whole number, while 0.50 to 0.99 parts are considered to be the larger whole number. These panels shall be selected from locations distributed as widely as practicable throughout the material being sampled. When an item, lot, or shipment involves panels with different adhesive bond requirements as provided for in Section 23.207, testing and evaluation shall apply separately to each category.

Sampling shall include no less than 20 panels of Interior-type Underlayment, C-D Plugged, and C-D. Sampling of Interior-type (including the different adhesive qualities) or Exterior-type shall be prorated on the basis of ratio of their volume to total volume (i.e., for shipments containing 50 percent Exterior, 10 Exterior panels shall be selected), but in no case shall less than 10 panels of each type or adhesive quality be selected. Shipments of Interior-type plywood bonded with exterior glue shall be sampled in the same manner as Exterior plywood.

23.212.7 Specimen Preparation. One piece shall be cut from each Interior panel selected and from that piece five test specimens shall be cut. Each specimen shall be 2 inches wide by 5 inches (51 mm wide by 127 mm) along the grain. From each Exterior panel selected, one piece shall be cut from the panel and from that piece 10 test specimens shall be cut as described in Section 23.215.1. Of the 10 specimens cut from each test piece, five shall be for vacuum pressure test, and five shall be for the boil test. From each overlaid panel selected, 10 specimens shall be cut as described for Exterior plywood. These shall be for testing the bond between veneers. A second set of 10 specimens shall be cut to test the bond between the overlay and the base panel as described in Section 23.215.1.

From five of the Exterior test panels and five of the overlaid test panels, $5^1/_2$-inch by 8-inch (140 mm by 203 mm) specimens shall be cut and tested as described in Section 23.215.4.

SECTION 23.213 — TEST FOR INTERIOR-TYPE PLYWOOD

The test specimens prepared as described in Section 23.219.3 shall be placed in a pressure vessel and completely submerged in 110°F (43.3°C) water. A vacuum of 15 inches of mercury (50.7 kPa) shall be drawn, maintained for 30 minutes and released. Specimens shall then be allowed to soak in the same water at atmospheric pressure for four and one half hours with no additional heating. They shall be removed and dried for 15 hours at 150°F (65.6°C) in an oven with fan-forced air circulation of 45 to 50 air changes per minute. Specimens shall then be examined for delamination and evaluated in accordance with requirements given in the following paragraph.

Total continuous visible delamination of $^1/_4$ inch (6.4 mm) or more in depth and 2 inches (51 mm) in length along the edges of a 2-inch by 5-inch (51 mm by 127 mm) test specimen shall be considered as failure. Where required, this shall be determined by probing with a suitable feeler gage not greater than 0.013 inch (0.3 mm) in thickness. When delamination occurs by reason of a localized defect permitted in the grade, other than white pocket, that test specimen shall be discarded.

SECTION 23.214 — TESTS FOR IMG-TYPE PLYWOOD

23.214.1 Preparation of Test Specimens. Test specimens, taken as described in Section 23.219.3, shall be cut $3^1/_4$ inches (83 mm) long and 1 inch (25 mm) wide, and kerfed one third of the length of the specimen from each end, as illustrated in Figure 23-2-1, so that a 1-inch (25 mm) square test area in the center results. Specimens shall be oriented so that the grain direction of the ply under test runs at a 90-degree angle to the length of the specimen. Kerfing shall extend two thirds of the way through the ply under test, and shall not penetrate the next glueline.

If the number of plies exceeds three, the cuts shall be made so as to test any two of the joints, but the additional plies need not be stripped except as demanded by the limitations of the width of the retaining jaws on the testing device. When desired, special jaws may be constructed to accommodate the thicker plywood. If the number of plies exceeds three, the choice of joints to be tested shall be left to the discretion of the approved inspection and testing agency, but at least one half of the tests shall include the innermost joints.

23.214.2 Vacuum Soak Test. The test specimens shall be placed in a pressure vessel and submerged in water 120°F (48.9°C). A vacuum of 15 inches of mercury (50.7 kPa) shall be drawn and maintained for 30 minutes. Following release of vacuum, specimens shall continue soaking for 15 hours at atmospheric pressure. The temperature of the water shall not drop below 75°F (23.9°C) at any time during the 15-hour soaking period. Specimens shall then be removed from the vessel and tested while wet by tension loading to failure in a shear testing machine operated at a maximum head travel of 16 inches per minute (406 mm per minute). Jaws of the machine shall securely grip the specimen so there is no slippage. The percentage of wood failure of the specimens shall be determined with specimens in a dry condition and evaluated as described in Section 23.207.7.

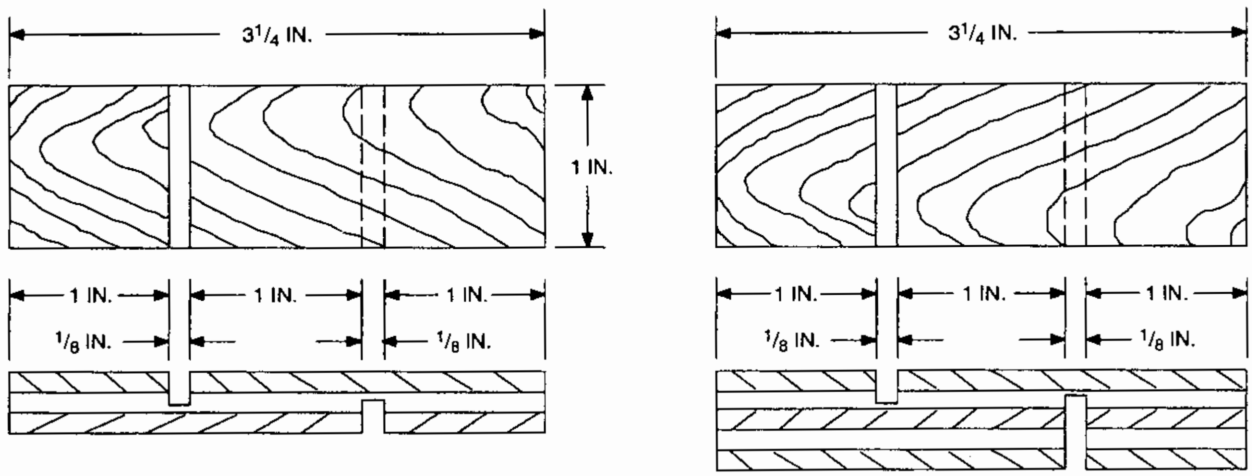
SECTION 23.215 — TESTS FOR EXTERIOR- AND INTERIOR-TYPE BONDED EXTERIOR GLUE (INCLUDES STRUCTURAL C-D AND C-D WITH EXTERIOR GLUE)

23.215.1 Preparation of Test Specimens. Test specimens, taken as described in Section 23.212.4 shall be cut $3^1/_4$ inches (83 mm) long and 1 inch (25 mm) wide, and kerfed one third of the length of the specimen from each end, as illustrated in Figure 23-2-1, so that a 1-inch (25 mm) square test area in the center results. Specimens shall be oriented so that the grain direction of the ply under test runs at a 90-degree angle to the length of the specimen. Kerfing shall extend two thirds of the way through the ply under test, and shall not penetrate the next glueline. Overlaid plywood specimens, taken as described in Section 23.212.3 for testing of bond between veneers, shall be cut as described above for Exterior specimens. Overlaid specimens for testing the bond between the overlay and the base panel, shall be cut 1 inch (25 mm) wide and long enough for handling (3 inches [76 mm] is a convenient length) and kerfed just through the overlay 1 inch (25 mm) from the end, on each overlay face.

If the number of plies exceeds three, the cuts shall be made so as to test any two of the joints, but the additional plies need not be stripped except as demanded by the limitations of the width of the retaining jaws on the testing device. When desired, special jaws may be constructed to accommodate the thicker plywood. If the number of plies exceeds three, the choice of joints to be tested shall be left to the discretion of the approved inspection and testing agency, but at least one half of the tests shall include the innermost joints.

23.215.2 Vacuum-pressure Test. The test specimen shall be placed in a pressure vessel and submerged in cold tap water. A vacuum of 25 inches of mercury (84.4. kPa) shall be drawn and maintained for 30 minutes, followed immediately with application of 65-70 psi (448-483 kPa) of pressure for 30 minutes duration. Specimens shall then be removed from the vessel and tested while wet by tension loading to failure in a shear testing machine operated at a maximum head travel of 16 inches per minute (406 mm per minute). Jaws of the machine shall securely grip the specimens so there is no slippage. The percentage of wood failure of the specimens shall be determined with specimens in a dry condition and evaluated as described in Section 23.207.8.

The bond between veneers in overlaid plywood shall be tested in an identical manner and evaluated as described in Section 23.207.8. Specimens for testing the bond between the overlay and the base panel shall be subjected to the same test cycle described above. The bond between the overlay and the base panel shall be tested by inserting a sharp, thin blade of adequate stiffness into the corner of the 1-inch (25 mm) test area at the overlay-veneer interface, taking care not to cut into the overlay, and attempting to peel off the overlay. It may be necessary to reinsert the blade several times in order to remove the overlay from the 1-square-inch (645 mm^2) area. The percentage of wood and/or fiber failure shall then be estimated with specimens in a dry condition and evaluated as described in Section 23.207.8. The value for each specimen shall be the average of the test areas on each face.



(a) THREE-PLY SPECIMEN (b) FIVE-PLY SPECIMEN

For **SI:** 1 inch = 25.4 mm.

NOTE: Orient grain direction across specimens to test inner two joints.

FIGURE 23-2-1—SHEAR TEST SPECIMENS

23.215.3 Boiling Test. Test specimens shall be boiled in water for four hours and then dried for 20 hours at a temperature of 145°F ± 5°F (62.8°C ± 2.8°C) with sufficient air circulation to lower moisture content of the specimens to a maximum of 8 percent, based on oven-dry weight. The specimens shall be boiled again for a period of four hours, cooled in water, and tested while wet by tension loading for failure in a shear testing machine operated at a maximum head travel of 16 inches per minute (406 mm per minute). Jaws of the machine shall securely grip the specimens so there is no slippage. The percentage of wood failure of the specimens shall be determined with specimens in a dry condition and evaluated as described in Section 23.207.8. The bond between veneers in overlaid plywood shall be tested and evaluated in an identical manner. Specimens to test the bond between the overlay and the base panels shall be subjected to the same test cycle described above. The bond between the overlay and the base panel shall be tested by inserting a sharp, thin blade of adequate stiffness into the corner of the 1-inch (25 mm) test area at the overlay-veneer interface, taking care not to cut into the overlay, and attempting to peel off the overlay. It may be necessary to reinsert the blade several times in order to remove the overlay from the 1-square-inch (645 mm^2) area. The percentage of wood and/or fiber failure shall then be estimated with specimens in a dry condition and evaluated as described in Section 23.207.8. The value for each specimen shall be the average of the test areas on each face.

23.215.4 Heat Durability Test. Specimens cut as described in Section 23.212.3 shall be placed on a stand as illustrated in Figure 23-2-1. It shall then be subjected to a 1,472°F to 1,652°F (800°C to 900°C) flame from a Bunsen-type burner for a period of 10 minutes or, in the case of a thin specimen, until a brown char area appears on the backside. The burner shall be equipped with a wing top to envelop the entire width of the specimen in flame. The top of the burner shall be 1 inch (25 mm) from the specimen face and the flame $1^1/_2$ inches (38 mm) high. The flame shall impinge on the face of the specimen 2 inches (51 mm) from the bottom end. After the test, the sample shall be removed from the stand and the gluelines examined for delamination by separating the charred plies with a sharp, chisel-like instrument. Specimens shall be evaluated in accordance with Section 23.207.8.

SECTION 23.216 — TESTS FOR PERFORMANCE UNDER CONCENTRATED STATIC AND IMPACT LOADS

23.216.1 Preparation of Test Specimens. Samples shall be selected representative of the plywood product being evaluated. Length, *L*, of panels shall conform to the maximum center-to-center support spacing, *S*, anticipated in service, continuous over the minimum number of spans recommended for its use. See Figures 23-2-7 and 23-2-8. Width, *W*, of individual pieces shall be 24 inches (610 mm) or greater for span ratings up to 24 inches (610 mm) on center and 48 inches (1219 mm) for greater span ratings.

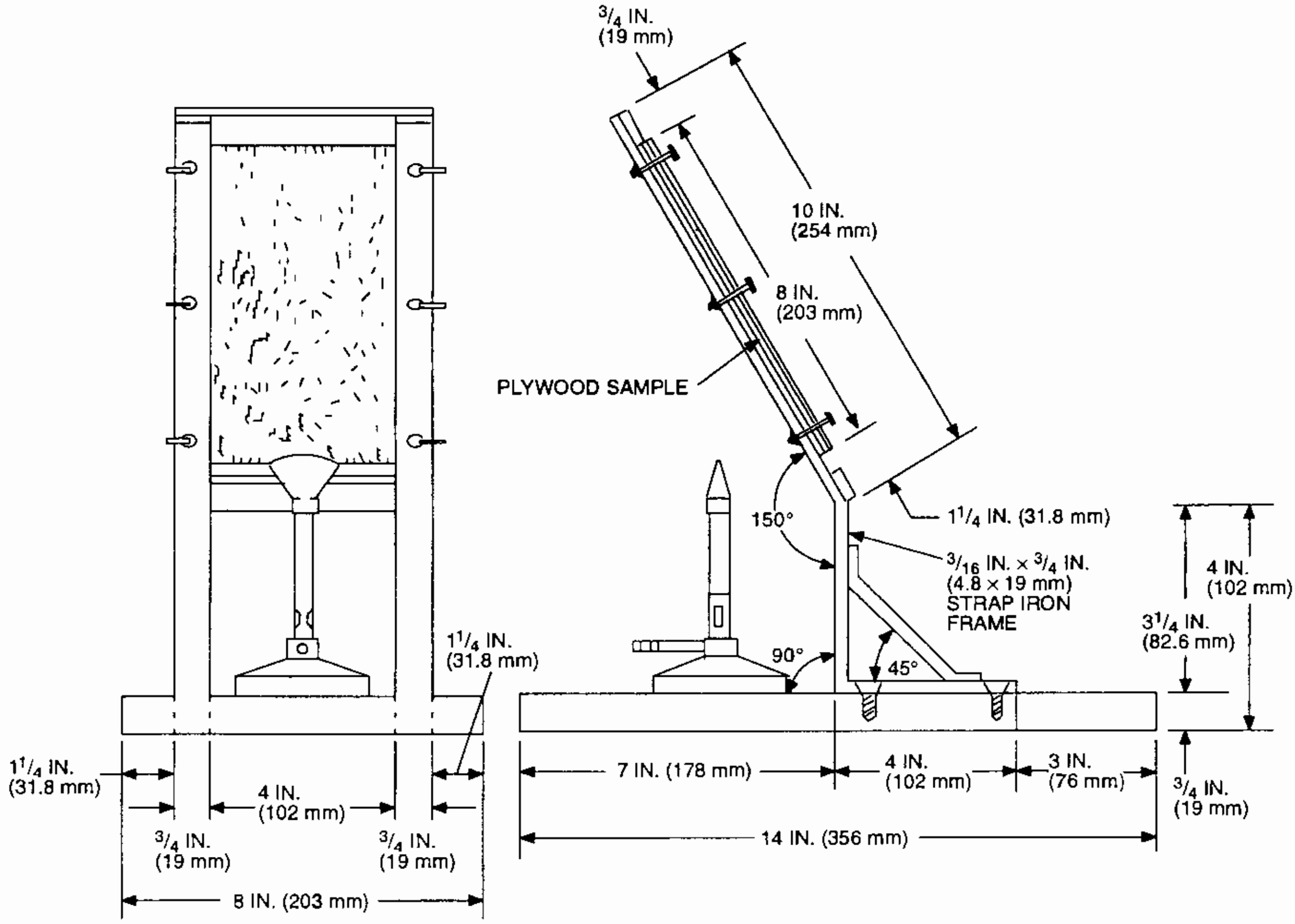


FIGURE 23-2-2—APPARATUS FOR HEAT DURABILITY TEST

23.216.2 Test Procedure.

23.216.2.1 Concentrated static. Specimens shall be loaded at locations shown in Figure 23-2-7 using a 3-inch-diameter (76 mm) loading disc, except a 1-inch-diameter (25 mm) loading disc shall be used to determine strength of single-layer floor panels in the dry or redried condition.

Stiffness shall be determined by measuring deflection in 50-pound (222 N) increments to 200 pounds (890 N). Strength shall be determined by loading to failure.

23.216.2.2 Concentrated impact. Specimens shall be loaded at locations shown in Figure 23-2-8 using an impact device 9 to $10^1/_2$ inches (229 to 267 mm) in diameter and weighing 30 pounds (13.6 kg), except that for span ratings greater than 24 inches (610 mm) on center, the impact device shall weigh 60 pounds (27.2 kg).

Strength shall be determined by impacting the specimen from the specified height at increments of 6 inches (152 mm). Deflection under a 200-pound (890 N) concentrated load, using a 3-inch-diameter (76 mm) disc, shall be measured before the test and after each impact. After the specified impact load has been reached, the concentrated load shall be applied to failure.

SECTION 23.217 — TEST FOR PERFORMANCE UNDER UNIFORM LOADS

23.217.1 Apparatus. A vacuum chamber is used consisting of a sealed box with the panel to be tested forming the top. See Figure 23-2-9. A 6-mil (0.15 mm) polyethylene sheet or equivalent is securely taped at the perimeter to seal the top surface. A vacuum pump reduces air pressure under the specimen such that load is measured.

23.217.2 Preparation of Test Specimens. Samples shall be selected representative of the plywood product being evaluated. The specimen length perpendicular to framing shall be equal to twice the maximum center-to-center support spacing, *S*, anticipated in service. See Figure 23-2-10. The specimen width is at least $23^1/_2$ inches (597 mm).

23.217.3 Test Procedure. The specimen is mounted in the vacuum box following anticipated joist spacing and recommended nail size and spacing and sealed. The panel is loaded to the specified level. Deflections are measured at locations shown in Figure 23-2-10 sufficient to develop the straight-line portion of the load-deflection curve, but in no case shall the number of data points be less than six.

SECTION 23.218 — TEST FOR PANEL BENDING

23.218.1 Apparatus. A testing machine shall be used capable of applying pure moments to opposite ends of the test panel through loading frames and measurement of moment and deformation.

23.218.2 Preparation of Test Specimens. Samples shall be selected representative of the plywood product being evaluated. Specimens shall measure 4 feet by 4 feet (1219 mm by 1219 mm).

23.218.3 Test Procedure. Separate specimens are subjected to pure moment along and across the major axis. Deformation or curvature is measured in a manner adequate to calculate bending stiffness. Test is carried on to failure to evaluate maximum moment.

SECTION 23.219 — SCARF- AND FINGER-JOINT TESTS

23.219.1 Strength. Three test specimens shall be cut at random along each joint from panels selected as directed in Section 23.219.3. Type, grade and species of the panels shall be recorded. The specimens shall be cut so as to include the joint and shall be prepared as illustrated in Figure 23-2-3.

Insofar as possible, the joint test area shall contain no localized natural defects permitted within the grade. At the joint, the maximum thickness and width of plies parallel with the load shall be recorded. Each specimen shall then be placed in the tension grips of a testing machine and loaded continuously at a rate of cross-head travel of 0.030 to 0.040 inch per minute (0.76 to 1.02 mm per minute) until failure, and the ultimate load recorded. The ultimate stress in pounds per square inch shall be computed using the ultimate load and area of those plies whose grain is parallel with direction of load. Moisture content of specimens at the time of testing shall not exceed 16 percent.

23.219.2 Scarf-joint Durability of Interior-type Panels Bonded with Interior Glue. Ten test specimens shall be cut at random along each scarf joint from panels selected as directed in Section 23.219.3, and shall be prepared following the general procedure in the same subsection, but shall be cut so that the scarf joint occurring on one surface of the panel runs across the middle of five specimens and the joint occurring on the opposite surface runs across the middle of the other five specimens. The specimens shall be subjected to the same test procedure as outlined in Section 23.212.

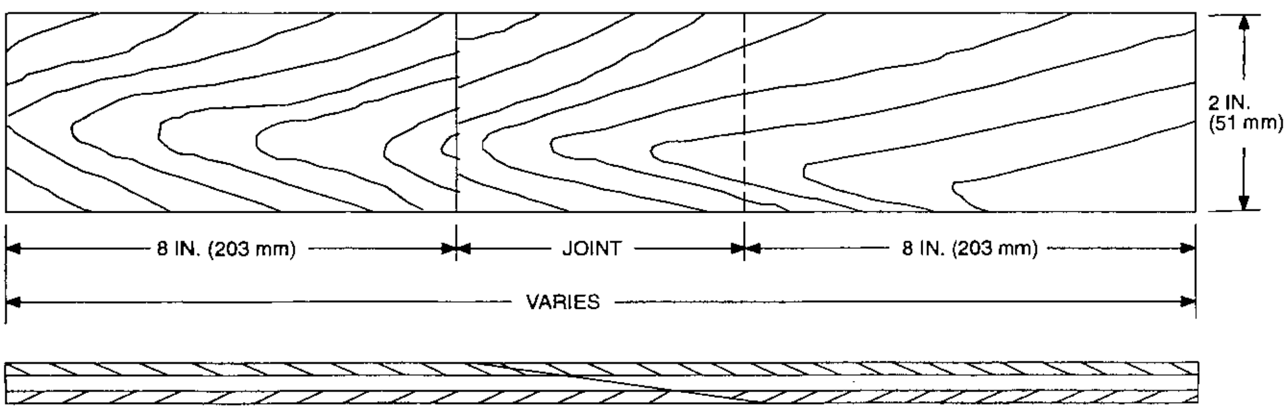


FIGURE 23-2-3—TENSION SPECIMEN FOR SCARF-JOINTED PANELS

23.219.3 Scarf-joint Durability of Exterior-type Panels and Interior-type Panels Bonded with Exterior or Intermediate Glue. Ten test specimens shall be cut at random along each joint from panels selected as directed in Section 23.219.3. The specimens shall be prepared following the general procedure described in Section 23.221.1, but, in addition, shall be cut so that the joints run through the test specimens as shown in Figure 23-2-4. For Exterior-type panels and Interior-type bonded with exterior glue, five specimens shall be subjected to the vacuum-pressure test described in Section 23.215.2, and five to the boiling test of Section 23.215.3. The panels shall be evaluated as described in Section 23.207.

For Interior-type panels bonded with intermediate glue (IMG), the 10 specimens shall be subjected to the vacuum soak test outlined in Section 23.214.2. The panels shall be evaluated as described in Section 23.207.

23.219.4 Finger-joint Durability of Interior-type Panels Bonded with Interior Glue. Five specimens shall be cut at random along the finger joint from each panel selected and shall be prepared following the general procedure in Section 23.211 so that the middle of the joint coincides with the middle of the five specimens. The specimens shall be subjected to the same test procedure as outlined in Section 23.219.

23.219.5 Finger-joint Durability of Exterior-type Panels and Interior-type Panels Bonded with Exterior or Intermediate-type Glue. Ten specimeus shall be cut at random along the finger joint from each panel selected according to Section 23.211. These specimens shall be cut so as to include the joint and shall be prepared as illustrated in Figure 23-2-5.

For Exterior-type panels and Interior-type panels bonded with exterior glue, five of the specimens shall be subjected to the vacuum pressure test of Section 23.215.2 and five to the boiling test of Section 23.215.1.

For Interior-type panels bonded with intermediate glue, the 10 specimens shall be subjected to the vacuum soak test of Section 23.214.

Upon completion of the vacuum pressure and boil tests, or vacuum soak tests, as applicable, a wedge or chisel (see Figure 23-2-6) shall be inserted in locations shown in Figure 23-2-5 in such a manner as to pry apart the scarfed portions of the joint without directly contacting the glued area. Test specimens shall be dried and percent wood failure in the test area estimated and applied separately for both the boil and vacuum pressure treatments. The panels shall be evaluated as described in Section 23.207.

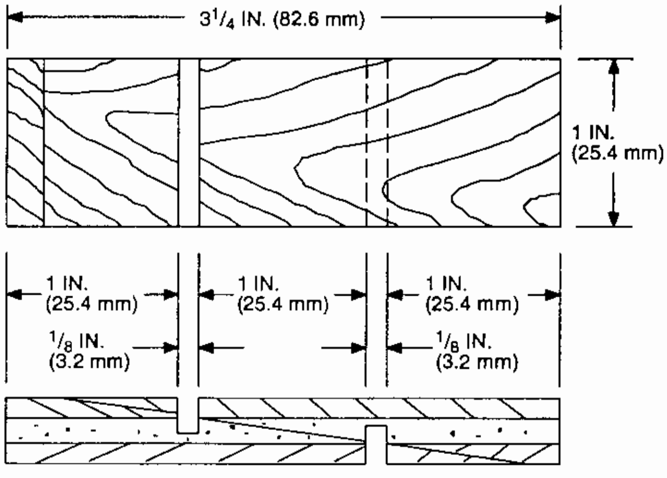
SECTION 23.220 — TEST FOR DETERMINATION OF MOISTURE CONTENT (OVEN-DRYING METHOD)

The moisture content of the plywood shall be determined as follows: a small test specimen shall be cut from each sample panel; the test specimen shall measure not less than 9 square inches (5806 mm^2) in area and shall weigh not less than 20 grams (approximately $^3/_4$ ounce). All loose splinters shall be removed from the specimen. The specimen shall be immediately weighed on a scale that is accurate to 0.5 percent, and the weight shall be recorded as original weight. The specimen shall then be dried in an oven at 212°F to 221°F (100°C to 105°C) until constant weight is attained. After drying, the specimen shall be reweighed immediately, and this weight shall be recorded as the oven-dry weight. The moisture content shall be calculated as follows:

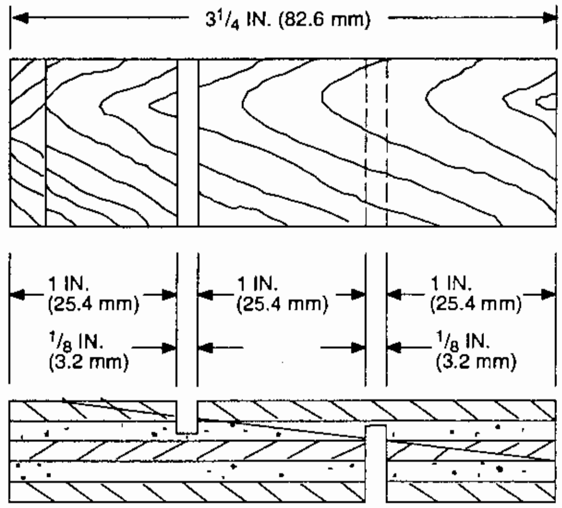
$$\frac{\text{Original weight} - \text{Oven-dry weight}}{\text{Oven-dry weight}} \times 100 = \text{Moisture content (percent)}$$

SECTION 23.221 — PLYWOOD SECTION PROPERTIES

23.221.1 General. Section properties set forth in Tables 23-2-H and 23-2-I shall be used with all species and grades of plywood in this standard. The section properties shall be used in determining compliance with allowable stresses set forth in Table 23-III-A of this code. The properties have been adjusted to reflect "effective" section properties in each of two directions, assuming a homogenous material. As a result of these adjusted values, moment of inertia "*I*" shall be used only in stiffness calculations, with section modulus "*S*" used in bending stress calculations.



(a) THREE-PLY SPECIMEN



(b) FIVE-PLY SPECIMEN

FIGURE 23-2-4—SCARF-JOINT SPECIMENS FOR VACUUM SOAK, VACUUM PRESSURE AND BOILING TESTS

23.221.2 Veneer Lay-up. Section properties listed are adjusted to allow for variations in panel veneer constructions. Properties parallel to the face grain of the plywood are based on a panel construction giving minimum values in that direction. Properties perpendicular to the face grain are based on a different panel construction, giving minimum values in that direction. Properties for the two directions, however, cannot be added to achieve properties of the full panel.

SECTION 23.222 — CALCULATION OF DIAPHRAGM DEFLECTION

Calculations for diaphragm deflection shall account for the usual bending and shear components as well as any other factors, such as nail deformation, which will contribute to the deflection.

The deflection (Δ) of a blocked plywood diaphragm uniformly nailed throughout may be calculated by use of the following formula. If not uniformly nailed, the constant 0.188 (0.614) in the third term must be modified accordingly.

$$\Delta = \frac{5vL^3}{8EAb} + \frac{vL}{4Gt} + 0.188\,Le_n + \frac{\Sigma(\Delta_c X)}{2b}$$

For SI: $$\Delta = \frac{52vL^3}{EAb} + \frac{vL}{4Gt} + 0.614\,Le_n + \frac{\Sigma(\Delta_c X)}{2b}$$

WHERE:

A = area of chord cross section, in square inches (mm^2).

b = diaphragm width, in feet (m).

E = elastic modulus of chords, in pounds per square inch (N/mm^2).

e_n = nail deformation, in inches (mm) (see Table 23-2-K).

G = modulus of rigidity of plywood, in pounds per square inch (N/mm^2) (see Table 23-2-J).

L = diaphragm length, in feet (m).

t = effective thickness of plywood for shear, in inches (mm) (see Tables 23-2-H and 23-2-I).

v = maximum shear due to design loads in the direction under consideration, in pounds per lineal foot (N/m).

Δ = the calculated deflection, in inches (mm).

$\Sigma(\Delta_c X)$ = sum of individual chord-splice slip values on both sides of the diaphragm, each multiplied by its distance to the nearest support.

SECTION 23.223 — CALCULATION OF SHEAR WALL DEFLECTION

The deflection (Δ) of a blocked shear wall uniformly nailed throughout may be calculated by use of the following formula:

$$\Delta = \frac{8vh^3}{EAb} + \frac{vh}{Gt} + 0.75he_n + \frac{h}{b}\,d_a$$

For SI: $$\Delta = \frac{2000\,vh^3}{3EAb} + \frac{vh}{Gt} + 2.46\,he_n + \frac{h}{b}\,d_a$$

WHERE:

A = area of boundary element cross section in square inches (mm^2) (vertical member at shear wall boundary).

b = wall width, in feet (m).

d_a = deflection due to anchorage details (rotation and slip at tie-down bolts).

E = elastic modulus of boundary element (vertical member at shear wall boundary), in pounds per square inch (N/mm^2).

e_n = nail deformation, in inches (mm) (see Table 23-2-K).

G = modulus of rigidity of plywood, in pounds per square inch (N/mm^2) (see Table 23-2-J).

h = wall height, in feet (m).

t = effective thickness of plywood for shear, in inches (mm) (see Tables 23-2-H and 23-2-I).

v = maximum shear due to design loads at the top of the wall, in pounds per lineal foot (N/m).

Δ = the calculated deflection, in inches (mm).

SECTION 23.224 — ALLOWABLE STRESSES FOR SHEAR THROUGH THE THICKNESS

Shear-through-the-thickness stresses in Table 23-III-A of this code are based on the most common structural applications, as where plywood is mechanically fastened to framing. If the plywood is rigidly glued to full-length, continuous (unjointed) framing around all panel edges, increase allowable shear-through-the-thickness stresses by 33 percent. If the continuous framing is glued to only two edges parallel to the face grain, increase stresses by 19 percent. When continuous framing is only at edges perpendicular to the face grain, no increase in stresses shall be taken.

In lieu of the increase in shear-through-the-thickness stresses given above for continuous glued framing, a 33 percent increase may be taken when panels are regraded to limit core gap width and placement. Contiguous core gaps in adjacent plies within a layer shall be measured as a single gap from the outermost edge of one to the opposite edge of the other. Noncontiguous core gaps in any parallel ply of the panel shall be offset by at least 1 inch (25 mm), measured from innermost edges of the gaps. Gap width limitations are as follows:

1. For all three-layer panels (including three-ply and four-ply), core gaps shall not be wider than $^1/_4$ inch (6.4 mm).

2. For panels with five or more layers, core gaps shall be limited to 1 inch (25 mm) in $^1/_2$-inch-thick (13 mm) panels and to $^1/_2$ inch (13 mm) in thicker panels.

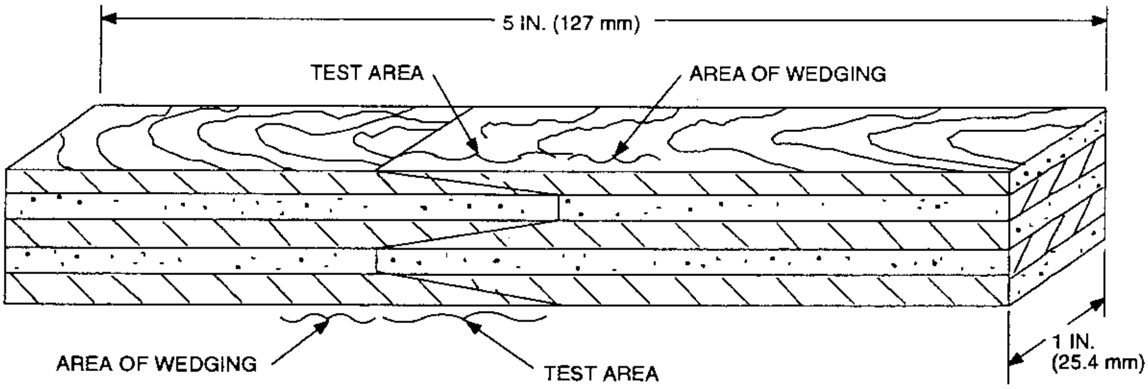


FIGURE 23-2-5—CLEAVAGE TEST, TYPICAL TEST SPECIMEN

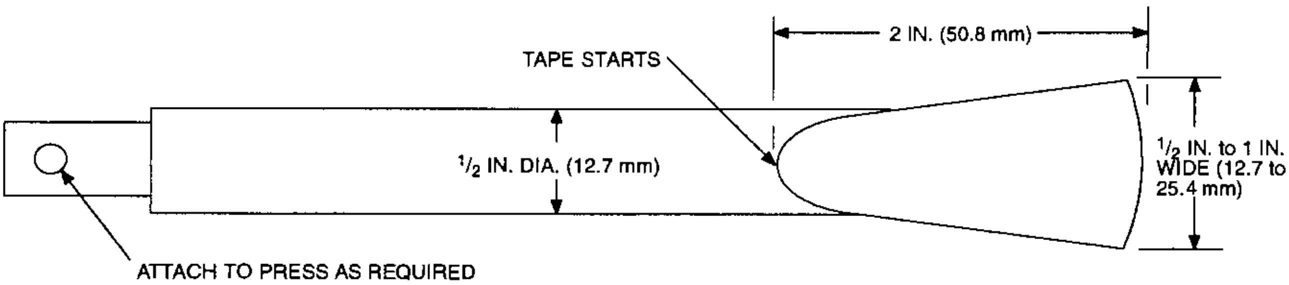


FIGURE 23-2-6—WEDGE OR CHISEL FOR CLEAVAGE TEST

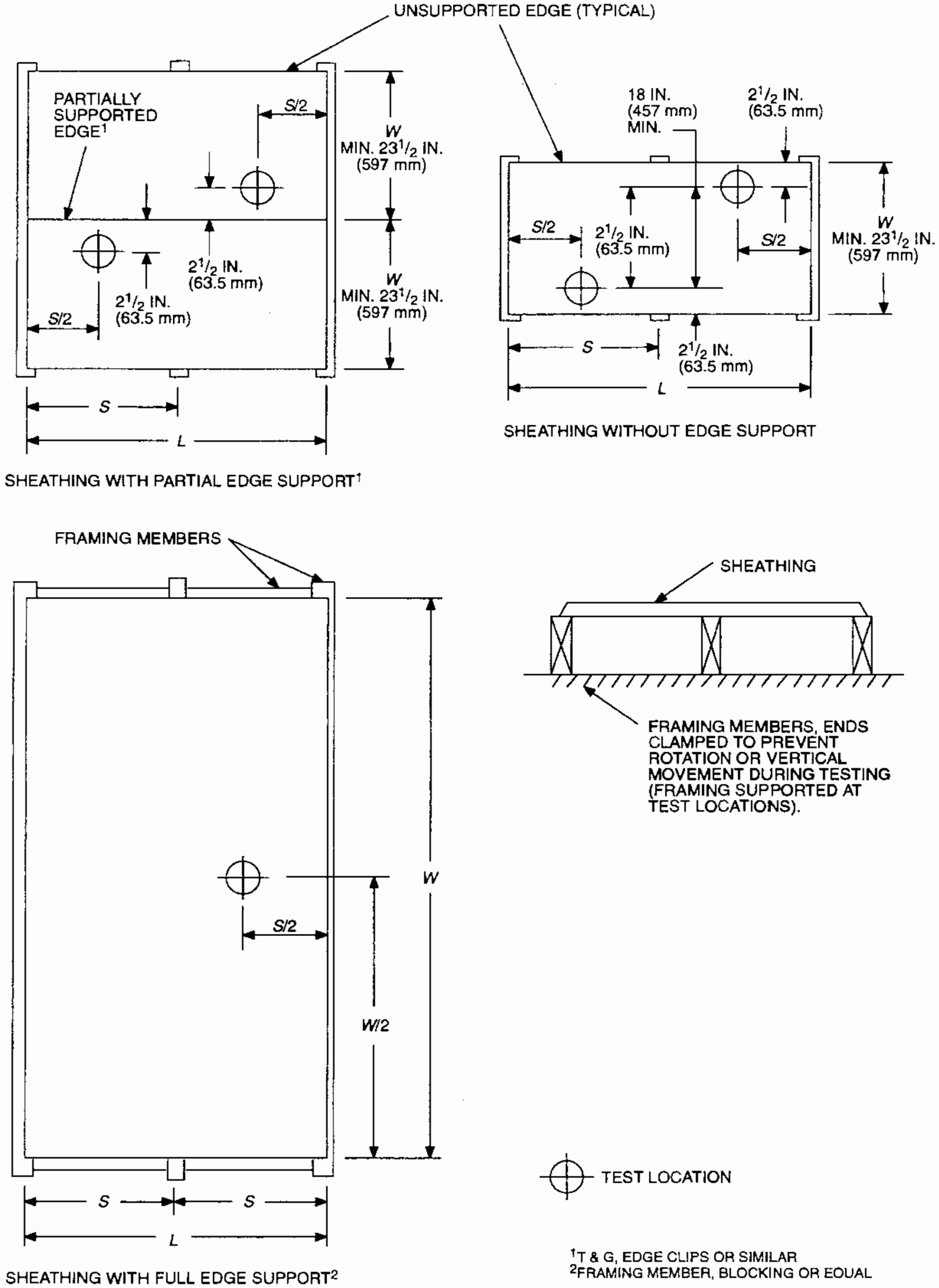
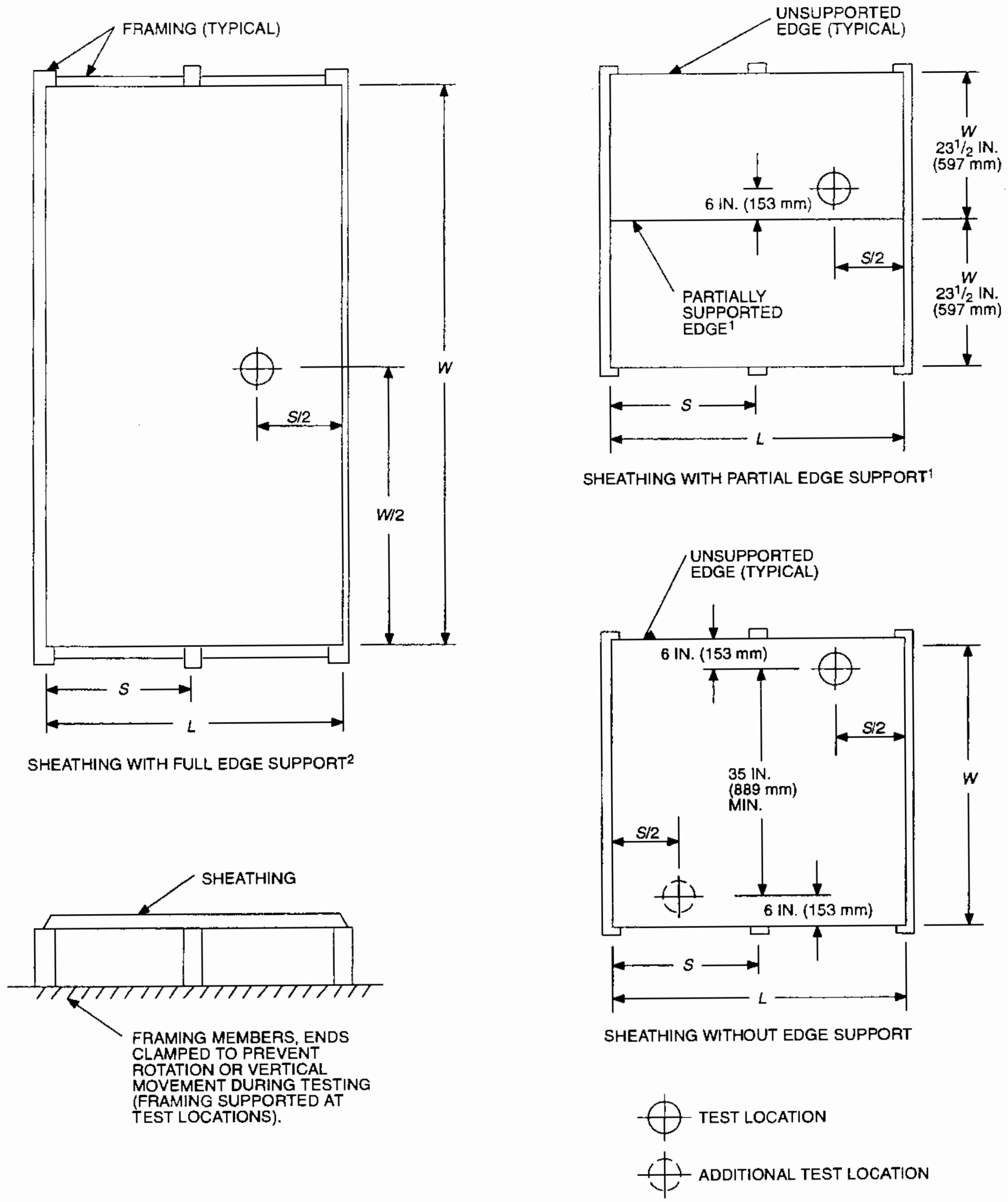


FIGURE 23-2-7—CONCENTRATED STATIC LOAD TEST SPECIMENS



[1]T & G, edge clips or similar.
[2]Framing member, blocking or equal.

FIGURE 23-2-8—IMPACT LOAD TEST SPECIMENS

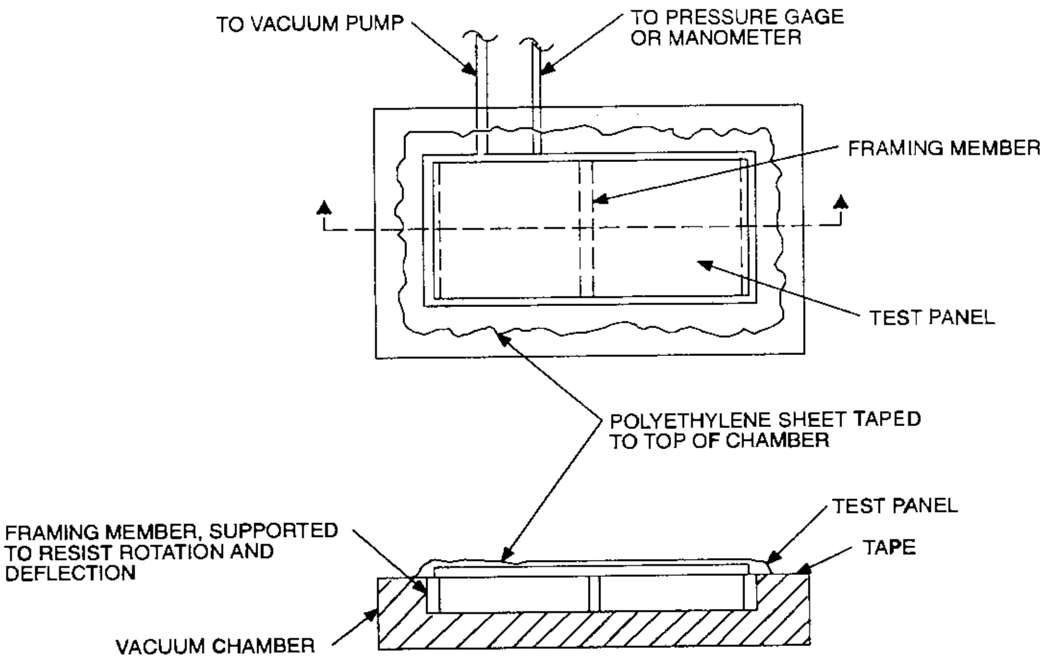
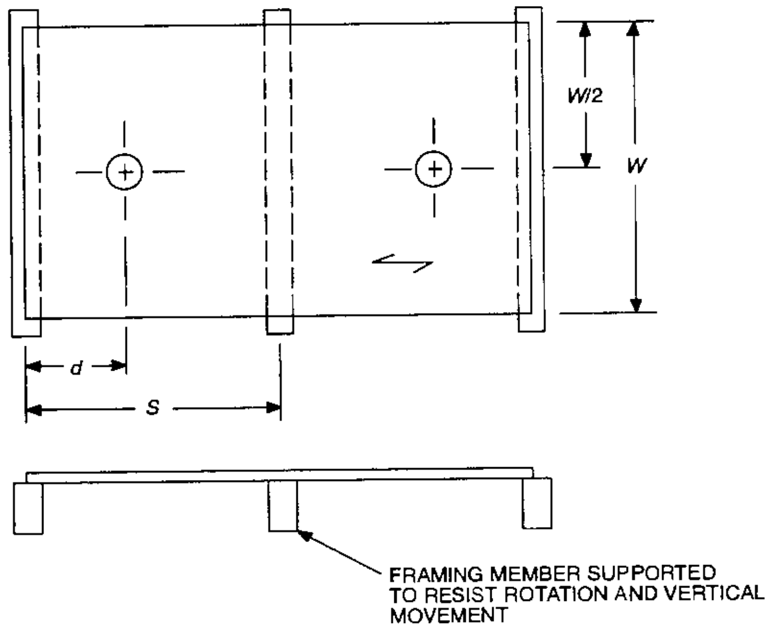


FIGURE 23-2-9—VACUUM CHAMBER TEST EQUIPMENT



S = Center-to-center support spacing.
d = 0.4215(S) for two span.
W = Panel width, minimum = 23.5 inches (597 mm).
⊕ = Location of deflection measurement.

FIGURE 23-2-10—UNIFORM LOAD TEST SPECIMENS

TABLE 23-2-A—CLASSIFICATION OF SPECIES

GROUP 1	GROUP 2		GROUP 3	GROUP 4
Aptiong[1,2] Beech, American Birch Sweet Yellow Douglas fir 1[3] Kapur[1] Keruing[1,2] Larch, western Maple, sugar Pine Caribbean Ocote Pine, southern Loblolly Longleaf Shortleaf Slash Tanoak	Cedar, Port Oxford Cypress Douglas fir 2[3] Fir Balsam California red Grand Noble Pacific silver White Hemlock, western Lauan Almon Bagtikan Mayapis Red lauan Tangile	White lauan Maple, black Mengkulang[1] Meranti, red[1,4] Mersawa[1] Pine Pond Red Virginia Western White Spruce Black Red Sitka Sweetgum Tamarack Yellow-poplar	Alder, red Birch, paper Cedar, Alaska Fir, subalpine Hemlock, eastern Maple, bigleaf Pine Jack Lodgepole Ponderosa Spruce Redwood Spruce Engelmann White	Aspen Bigtooth Quaking Cativo Cedar Incense Western red Cottonwood Eastern Black (western poplar) Pine Eastern white Sugar

[1]Each of these names represents a trade group of woods consisting of a number of closely related species.

[2]Species from the genus Dipterocarpus are marked collectively: Aptiong if originating in the Philippines; Keruing if originating in Malaysia or Indonesia.

[3]Douglas fir from trees grown in the states of Washington, Oregon, California, Idaho, Montana, Wyoming, and the Canadian provinces of Alberta and British Columbia shall be classed as Douglas fir No. 1. Douglas fir from trees grown in the states of Nevada, Utah, Colorado, Arizona and New Mexico shall be classed as Douglas fir No. 2.

[4]Red meranti shall be limited to species having a specific gravity of 0.41 or more based on green volume and oven-dry weight.

TABLE 23-2-B—CHARACTERISTICS PROHIBITED OR RESTRICTED IN CERTAIN PANEL GRADES

PANEL GRADE DESIGNATION	DESCRIPTION AND NUMBER OF CHARACTERISTICS PER PANEL
N-N, N-A	No crossband laps adjacent to faces and backs
N-B	No crossband laps adjacent to N faces No more than 2 crossband laps adjacent to B grade side Laps are limited to $^3/_{16}$ inch (4.8 mm)
N-D	No crossband laps adjacent to faces No more than a total of 2 of any combination of the following: — Knothole in D veneer over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Split in D veneer over $^1/_2$ inch (13 mm) [not over 1 inch (25 mm)] — Crossband lap adjacent to backs
Underlayment and C-C Plugged	No knotholes in veneer adjacent to face over 1 inch (25 mm) across the grain where C grade is required per Tables 23-2-D and 23-2-E No knotholes in veneer adjacent to face over $2^1/_2$ inches (64 mm) where D grade is permitted or $1^1/_2$ inches (38 mm) where C grade is permitted per Section 23.205.6 No laps adjacent to face
Structural I C-D	No splits in faces over $^1/_4$ inch (6.4 mm) No splits in backs over $^1/_2$ inch (13 mm) No more than a total of 2 of any combination of the following: — Knothole in C veneer over 1 inch (25 mm) but not over $1^1/_2$ inches (38 mm) — Knot in D backs over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Knothole in D veneer over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Crossband lap adjacent to faces per Section 23.205.4 — Crossband lap adjacent to backs per Section 23.205.4
Structural I C-D Plugged	No splits in backs over $^1/_2$ inch (13 mm) No more than a total of 2 of any combination of the following: — Knot in D backs over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Knothole in D veneer over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Crossband lap adjacent to faces per Section 23.205.4 — Crossband lap adjacent to backs per Section 23.205.4
Structural I Underlayment	No knotholes in core veneer next to face over 1 inch (25 mm) No crossband laps adjacent to faces No splits in backs over $^1/_2$ inch (13 mm) No more than a total of 2 of any combination of the following: — Knot in D backs over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Knothole in D veneer over $2^1/_2$ inches (64 mm) but not over 3 inches (76 mm) — Crossband lap adjacent to backs per Section 23.205.4

TABLE 23-2-C—PANEL CONSTRUCTIONS

PANEL GRADES	FINISHED PANEL NOMINAL THICKNESS RANGE (inch) × 25.4 for mm	MINIMUM NUMBER OF PLIES	MINIMUM NUMBER OF LAYERS
Exterior Marine Special Exterior (See Section 23.205.4) B-B concrete form High Density Overlay High Density concrete form overlay	Through $^3/_8$ Over $^3/_8$, through $^3/_4$ Over $^3/_4$	3 5 7	3 5 7
Interior N-N, N-A, N-B, N-D, A-A, A-B, A-D, B-B, B-D Structural I (C-D, C-D Plugged and Underlayment) Exterior A-A, A-B, A-C, B-B, B-C Structural I C-C and C-C Plugged (See Section 23.205.4) Medium Density and Special Overlays	Through $^3/_8$ Over $^3/_8$, through $^1/_2$ Over $^1/_2$, through $^7/_8$ Over $^7/_8$	3 4 5 6	3 3 5 5
Interior (including grades with Exterior glue) Underlayment Exterior C-C Plugged	Through $^1/_2$ Over $^1/_2$, through $^3/_4$ Over $^3/_4$	3 4 5	3 3 5
Interior (including grades with Exterior glue) C-D C-D Plugged Exterior C-C	Through $^5/_8$ Over $^5/_8$, through $^3/_4$ Over $^3/_4$	3 4 5	3 3 5

TABLE 23-2-D—INTERIOR-TYPE GRADES

PANEL GRADES DESIGNATIONS	MINIMUM VENEER QUALITY			SURFACE
	Face	Back	Inner Plies	
N-N	N	N	C	Sanded 2 sides
N-A	N	A	C	Sanded 2 sides
N-B	N	B	C	Sanded 2 sides
N-D	N	D	D	Sanded 2 sides
A-A	A	A	D	Sanded 2 sides
A-B	A	B	D	Sanded 2 sides
A-D	A	D	D	Sanded 2 sides
B-B	B	B	D	Sanded 2 sides
B-D	B	D	D	Sanded 2 sides
Underlayment[1]	C Plugged	D	C and D	Touch-sanded
C-D Plugged	C Plugged	D	D	Touch-sanded
Structural I C-D	See Section 23.205.4			Unsanded[2]
Structural I C-D Plugged, Underlayment	See Section 23.205.4			Touch-sanded
C-D	C	D	D	Unsanded[2]
C-D with Exterior glue (See Section 23.215)	C	D	D	Unsanded[2]

[1]See Section 23.205.6 for special limitations.

[2]Except for decorative grades, panels shall not be sanded, touch-sanded, surface textured or thickness sized by any mechanical means.

TABLE 23-2-E—EXTERIOR-TYPE GRADES[1]

PANEL GRADES DESIGNATIONS	MINIMUM VENEER QUALITY			SURFACE
	Face	Back	Inner Plies	
Marine, A-A, A-B, B-B, HDO, MDO		Section 23.205.1		See regular grades
Special Exterior, A-A,				See regular grades
A-B, B-B, HDO, MDO		Section 23.205.5		Sanded 2 sides
A-A				Sanded 2 sides
A-B	A	A	C	Sanded 2 sides
A-C	A	B	C	
B-B (concrete form)	A	C	C	Sanded 2 sides
B-B		Section 23.205.3		Sanded 2 sides
B-C	B	B	C	Touch-sanded
C-C Plugged[2]	B	C	C	Unsanded[3]
C-C	C Plugged	C	C	
A-A High Density Overlay	C	C	C	
B-B High Density Overlay	A	A	C Plugged	
B-B High Density Concrete Form Overlay (See Section 23.205.3)	B	B	C Plugged[4]	
B-B Medium Density Overlay	B	B	C Plugged	
Special Overlays	B	B	C	
	C	C	C	

[1]Available also in Structural I classification as provided in Section 23.205.4.
[2]See Section 23.205.6 for special limitations.
[3]Except for decorative grades, panels shall not be sanded, touch-sanded, surface textured or thickness sized by any mechanical means.
[4]C centers may be used in panels of five or more plies.

TABLE 23-2-F—PREMIUM GRADES

GRADE	GLUE BOND	SPECIES
Structural I C-D[1.1] C-D Plugged[1] Underlayment[1]	Shall meet the requirements of Section 23.215	Face, back and all inner plies limited to Group 1 species
Structural I All Exterior grades (see Table 23-2-E)	Exterior	Face, back and all inner plies limited to Group 1 species

[1]Special limitations applying to Structural (C-D, C-D Plugged, Underlayment) grade panels are:

1.1 In D grade veneers white pocket in any area larger than the size of the largest knot hole, pitchpocket or split specifically permitted in D grade shall not be permitted in any ply.

1.2 Sound tight knots in D grade shall not exceed $2^1/_2$ inches (64 mm) measured across the grain, except as provided in Table 23-2-B.

1.3 Plugs, including multiple repairs, shall not exceed 4 inches (102 mm) in width.

1.4 Panel construction shall be as specified in Section 23.203.1.

TABLE 23-2-G—SPAN RATINGS FOR SHEATHING AND SINGLE-FLOOR PANELS
(For special ply-layer and species requirements applicable to STRUCTURAL panels, see Section 23.205.4 and Tables 23-2-C and 23-2-F. For crossband and total inner-ply thickness proportion requirements, see Section 23.203.1.)

SPAN RATING[1]	NOMINAL PANEL THICKNESS (inch)[2]	MINIMUM NUMBER OF PLIES-LAYERS	MINIMUM FACE AND BACK VENEER THICKNESS BEFORE PRESSING, FOR SPECIES GROUP[3] (inches)				INNER-PLY SPECIES GROUP
	× 25.4 for mm		× 25.4 for mm				
			1	2	3	4	
SHEATHING PANELS (C-D, C-C)							
12/0	5/16	3-3	1/12	1/12	1/12	1/12	1, 2, 3 or 4
16/0	5/16	3-3	1/12	1/12	1/12	[4]	1, 2, 3 or 4
	11/32	3-3	1/12	1/12	1/12	1/12	1, 2, 3 or 4
20/0	5/16	3-3	1/12	[4]	[4]	[4]	1, 2, 3 or 4
	11/32	3-3	1/12	1/12	1/10	[4]	1, 2, 3 or 4
	3/8	3-3	1/10	1/10	1/10	1/10	1, 2, 3 or 4
24/0	3/8	3-3	1/10	[4]	[4]	[4]	1, 2, 3 or 4
	13/32	3-3	1/10	1/10	[4]	[4]	1, 2, 3 or 4
	1/2	3-3	1/10	1/10	1/10	1/10	1, 2, 3 or 4
32/16	1/2	3-3	1/10	1/6	[4]	[4]	1, 2, 3 or 4
	17/32	3-3	1/10	1/10	1/6	[4]	1, 2, 3 or 4
	5/8	3-3	[5]	[5]	[5]	[5]	1, 2, 3 or 4
40/20	5/8	3-3	[5]	1/6	[4]	[4]	1, 2, 3 or 4
	21/32	3-3	1/10	1/8	1/6	[4]	1, 2, 3 or 4
	3/4	4-3	1/10	1/10	1/10	1/8	1, 2, 3 or 4
	25/32	4-3	1/10	1/10	1/10	1/10	1, 2, 3 or 4
48/24	3/4	4-3	1/10	1/6	[4]	[4]	1, 2, 3 or 4
	25/32	4-3	1/10	1/8	1/6	[4]	1, 2, 3 or 4
	7/8	5-5	1/10	1/10	1/10	[4]	1, 2, 3 or 4
	29/32	5-5	1/10	1/10	1/10	1/8	1, 2, 3 or 4
SINGLE-FLOOR PANELS (UNDERLAYMENT, C-C PLUGGED)							
16 o.c.	1/2	3-3	1/10	[4]	[4]	[4]	1, 2, 3 or 4
	19/32	4-3	[5]	[5]	[5]	1/6	1, 2, 3 or 4
	5/8	4-3	[5]	[5]	[5]	[5]	1, 2, 3 or 4
20 o.c.	19/32	4-3	[5]	1/6	[4]	[4]	1, 2, 3 or 4
	5/8	4-3	[5]	1/8	1/6	[4]	1, 2, 3 or 4
	23/32	4-3	1/10	1/10	1/10	1/8	1, 2, 3 or 4
	3/4	4-3	1/10	1/10	1/10	1/10	1, 2, 3 or 4
24 o.c.	23/32	4-3	1/10	1/6	3/16	[4]	1, 2, 3 or 4
	3/4	4-3	1/10	1/8	1/6	[4]	1, 2, 3 or 4
	7/8	5-5	1/10	1/10	1/10	1/8	1, 2, 3 or 4
48 o.c.	1 1/8	7-5	1/8	1/6	[4]	[4]	1 or 2
	1 1/8	7-5	1/7	1/6	[4]	[4]	1, 2 or 3
	1 1/8	7-7	1/10	1/6	3/16	[4]	1
	1 1/8	7-7	1/8	1/6	3/16	[4]	1, 2 or 3

[1]See Section 23.209 for description.

[2]Panels for which there is no span rating shall be identified by largest species group number of the face and back, or by the span rating of the next thinner comparable panel. Sheathing panels manufactured 1/32-inch (0.8 mm) over standard thickness may be identified as the standard thickness.

[3]Intermixing between species groups and/or thicknesses in the faces and backs of panel is permitted. Use the lowest applicable span rating to identify the panel.

[4]Not permitted.

[5]One-eighth-inch minimum for 3-, 4- and 5-ply three-layer panels per Section 23.204.1. May be 1/10 inch (2.5 mm) minimum for five-ply, five-layer panels.

TABLE 23-2-H—FACE PLIES OF DIFFERENT SPECIES GROUP THAN INNER PLIES (Includes all standard grades except those noted in Table 23-2-I)

NOMINAL THICKNESS (inches)	APPROXIMATE WEIGHT (psf)	EFFECTIVE THICKNESS FOR SHEAR (inches)	STRESS APPLIED PARALLEL TO FACE GRAIN				STRESS APPLIED PERPENDICULAR TO FACE GRAIN			
			A Area (in.^{2}/ft.)	*I* Moment of Inertia (in.^{4}/ft.)	*KS* Eff. Section Modulus (in.^{3}/ft.)	*Ib/Q* Rolling Shear Constant (in.^{2}/ft.)	*A* Area (in.^{2}/ft.)	*I* Moment of Inertia (in.^{4}/ft.)	*KS* Eff. Section Modulus (in.^{3}/ft.)	*Ib/Q* Rolling Shear Constant (in.^{2}/ft.)
× 25.4 for mm	× 4.882 for kg/m^2	× 25.4 for mm	× 2.117 for mm^2/mm	× 1365.6 for mm^4/mm	× 53.76 for mm^3/mm	× 2.117 for mm^2/mm	× 2.117 for mm^2/mm	× 1365.6 for mm^4/mm	× 53.76 for mm^3/mm	× 2.117 for mm^2/mm
Unsanded Panels										
$^5/_{16}$-U	1.0	0.268	1.491	0.022	0.112	2.569	0.660	0.001	0.023	4.497
$^3/_8$-U	1.1	0.278	1.866	0.037	0.154	3.110	0.799	0.002	0.031	5.444
$^{15}/_{32}$ and $^1/_2$-U	1.5	0.298	2.292	0.074	0.247	3.921	1.007	0.004	0.051	2.450
$^{19}/_{32}$ and $^5/_8$-U	1.8	0.319	2.330	0.146	0.355	5.273	1.354	0.010	0.091	3.126
$^{23}/_{32}$ and $^3/_4$-U	2.2	0.445	3.247	0.227	0.496	6.544	1.563	0.033	0.208	3.613
$^7/_8$-U	2.6	0.607	3.509	0.340	0.678	7.175	1.950	0.112	0.397	5.097
1-U	3.0	0.842	3.916	0.493	0.859	9.244	3.611	0.210	0.660	7.115
1$^1/_8$-U	3.3	0.859	4.725	0.676	1.047	9.960	3.079	0.288	0.768	8.821
Sanded Panels										
$^1/_4$-S	0.8	0.267	0.996	0.008	0.059	2.010	0.348	0.001	0.009	2.019
$^{11}/_{32}$-S	1.0	0.284	0.996	0.019	0.093	2.765	0.417	0.001	0.016	2.589
$^3/_8$-S	1.1	0.288	1.307	0.027	0.125	3.088	0.626	0.002	0.023	3.510
$^{15}/_{32}$-S	1.4	0.421	1.947	0.066	0.214	4.113	1.251	0.006	0.067	2.832
$^1/_2$-S	1.5	0.425	1.947	0.077	0.236	4.466	1.409	0.009	0.087	3.099
$^{19}/_{32}$-S	1.7	0.546	2.423	0.115	0.315	5.471	1.389	0.021	0.137	2.861
$^5/_8$-S	1.8	0.550	2.475	0.129	0.339	5.824	1.528	0.027	0.164	3.119
$^{23}/_{32}$-S	2.1	0.563	2.822	0.179	0.389	6.717	1.737	0.050	0.231	3.818
$^3/_4$-S	2.2	0.568	2.884	0.197	0.412	7.121	2.084	0.063	0.285	4.079
$^7/_8$-S	2.6	0.586	2.942	0.278	0.515	8.182	2.841	0.122	0.470	5.078
1-S	3.0	0.817	3.721	0.423	0.664	8.882	3.163	0.185	0.591	7.031
1$^1/_8$-S	3.3	0.836	3.854	0.548	0.820	9.883	3.180	0.271	0.744	8.428
Touch-sanded Panels										
$^1/_2$-T	1.5	0.342	2.698	0.083	0.271	4.252	1.159	0.006	0.061	2.746
$^{19}/_{32}$ and $^5/_8$-T	1.8	0.408	2.354	0.122	0.291	5.350	1.555	0.017	0.138	3.220
$^{23}/_{32}$ and $^3/_4$-T	2.2	0.439	2.715	0.196	0.398	6.589	2.014	0.032	0.219	3.635
1$^1/_8$-T	3.3	0.839	4.548	0.633	0.977	11.258	4.067	0.272	0.743	8.535

TABLE 23-2-I—STRUCTURAL I AND MARINE WITH ALL PLIES FROM SAME SPECIES GROUP

NOMINAL THICKNESS (inches)	APPROXIMATE WEIGHT (psf)	EFFECTIVE THICKNESS FOR SHEAR (inches)	STRESS APPLIED PARALLEL TO FACE GRAIN				STRESS APPLIED PERPENDICULAR TO FACE GRAIN			
			A Area (in.^{2}/ft.)	*I* Moment of Inertia (in.^{4}/ft.)	*KS* Eff. Section Modulus (in.^{3}/ft.)	*Ib/Q* Rolling Shear Constant (in.^{2}/ft.)	*A* Area (in.^{2}/ft.)	*I* Moment of Inertia (in.^{4}/ft.)	*KS* Eff. Section Modulus (in.^{3}/ft.)	*Ib/Q* Rolling Shear Constant (in.^{2}/ft.)
× 25.4 for mm	× 4.882 for kg/m^2	× 25.4 for mm	× 2.117 for mm^2/mm	× 1365.6 for mm^4/mm	× 53.76 for mm^3/mm	× 2.117 for mm^2/mm	× 2.117 for mm^2/mm	× 1365.6 for mm^4/mm	× 53.76 for mm^3/mm	× 2.117 for mm^2/mm
Unsanded Panels										
$^5/_{16}$-U	1.0	0.356	1.619	0.022	0.126	2.567	1.188	0.002	0.029	6.037
$^3/_8$-U	1.1	0.371	2.226	0.041	0.195	3.107	1.438	0.003	0.043	7.307
$^{15}/_{32}$ and $^1/_2$-U	1.5	0.535	2.719	0.074	0.279	4.206	2.175	0.014	0.127	2.408
$^{19}/_{32}$ and $^5/_8$-U	1.8	0.707	3.464	0.154	0.437	5.685	2.742	0.045	0.240	3.072
$^{23}/_{32}$ and $^3/_4$-U	2.2	0.739	4.219	0.241	0.572	6.148	2.813	0.064	0.299	3.540
$^7/_8$-U	2.6	0.776	4.388	0.346	0.690	6.948	3.510	0.192	0.584	5.086
1-U	3.0	1.088	5.200	0.529	0.922	8.512	6.500	0.366	0.970	7.052
1$^1/_8$-U	3.3	1.118	6.654	0.751	1.164	9.061	5.542	0.503	1.131	8.755
Sanded Panels										
$^1/_4$-S	0.8	0.342	1.280	0.012	0.083	2.009	0.626	0.001	0.013	2.723
$^{11}/_{32}$-S	1.0	0.365	1.280	0.026	0.133	2.764	0.751	0.001	0.023	3.397
$^3/_8$-S	1.1	0.373	1.680	0.038	0.177	3.086	1.126	0.002	0.033	4.927
$^{15}/_{32}$-S	1.4	0.537	1.947	0.067	0.247	4.107	2.251	0.009	0.093	2.807
$^1/_2$-S	1.5	0.545	1.947	0.078	0.271	4.457	2.536	0.014	0.123	3.076
$^{19}/_{32}$-S	1.7	0.709	3.018	0.116	0.338	5.566	2.501	0.034	0.199	2.811
$^5/_8$-S	1.8	0.717	3.112	0.131	0.361	5.934	2.751	0.045	0.238	3.073
$^{23}/_{32}$-S	2.1	0.741	3.735	0.183	0.439	6.707	3.126	0.085	0.338	3.780
$^3/_4$-S	2.2	0.748	3.848	0.202	0.464	7.146	3.751	0.108	0.418	4.047
$^7/_8$-S	2.6	0.778	3.952	0.288	0.569	7.539	5.114	0.212	0.692	5.046
1-S	3.0	1.091	5.215	0.479	0.827	7.978	5.693	0.321	0.870	6.981
1$^1/_8$-S	3.3	1.121	5.593	0.623	0.955	8.841	5.724	0.474	1.098	8.377
Touch-sanded Panels										
$^1/_2$-T	1.5	0.543	2.698	0.084	0.282	4.511	2.486	0.020	0.162	2.720
$^{19}/_{32}$ and $^5/_8$-T	1.8	0.707	3.127	0.124	0.349	5.500	2.799	0.050	0.259	3.183
$^{23}/_{32}$ and $^3/_4$-T	2.2	0.739	4.059	0.201	0.469	6.592	3.625	0.078	0.350	3.596

TABLE 23-2-J—VALUES OF *G* FOR USE WITH EFFECTIVE THICKNESS FOR SHEAR (TABLES 23-2-H AND 23-2-I) IN CALCULATING DEFLECTION OF PLYWOOD DIAPHRAGMS

PLYWOOD GRADES OR SPECIES GROUP NOS.	*G*—(MODULUS OF RIGIDITY—psi)[1]
	× 0.00689 for N/mm^2
Group 1	90,000
Group 2	75,000
Group 3	60,000
Group 4	50,000
Structural I	90,000
Exterior C-C and C-D with Exterior glue	
The combination of Identification Index designation and panel thickness determines the minimum species group and, therefore, the modulus of rigidity to be used: $^5/_{16}$ (7.9 mm)—20/0; $^3/_8$ (9.5 mm)—24/0; $^{15}/_{32}$, $^1/_2$ (12, 13 mm)—32/16; $^{19}/_{32}$, $^5/_8$ (16 mm)—42/20; $^{23}/_{32}$, $^3/_4$ (18, 19 mm)—48/24	90,000
All other combinations of C-C and C-D with Exterior glue	50,000

[1]Values of "*G*" shown apply to plywood bonded with Exterior glue. For plywood bonded with Interior glue, multiply by 0.91.

TABLE 23-2-K—"e_n" VALUES (INCHES) FOR USE IN CALCULATING DIAPHRAGM DEFLECTION DUE TO NAIL SLIP (STRUCTURAL I)[1]

LOAD PER NAIL (pounds)	NAIL DESIGNATION		
	6d	8d	10d
× 4.448 for N	× 25.4 for mm		
60	0.012	0.008	0.006
80	0.020	0.012	0.010
100	0.030	0.018	0.013
120	0.045	0.023	0.018
140	0.068	0.031	0.023
160	0.102	0.041	0.029
180	—	0.056	0.037
200	—	0.074	0.047
220	—	0.096	0.060
240	—	—	0.077

[1]Increase "e_n" values 20 percent for plywood grades other than Structural I.
Values apply to common wire nails.
Load per nail = maximum shear per foot divided by the number of nails per foot at interior panel edges.
Decrease values 50 percent for seasoned lumber.

TABLE 23-2-L—CONCENTRATED STATIC AND IMPACT TEST PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.216—SHEATHING

END USE—SPAN RATING	TEST EXPOSURE CONDITIONS[1]	PERFORMANCE REQUIREMENTS		
		Minimum Ultimate Load (lb.)		Maximum Deflection (in.) under 200-Lb. (890 N) Load[3]
		× 4.448 for N		
		Static	Following Impact[2]	× 25.4 for mm
Roof—16	Dry	400	300	$^{7}/_{16}$ (0.438)
	Wet	400	300	[4]
Roof—20	Dry	400	300	$^{15}/_{32}$ (0.469)
	Wet	400	300	[4]
Roof—24	Dry	400	300	$^{1}/_{2}$ (0.500)
	Wet	400	300	[4]
Roof—32	Dry	400	300	$^{1}/_{2}$ (0.500)
	Wet	400	300	[4]
Roof—40	Dry	400	300	$^{1}/_{2}$ (0.500)
	Wet	400	300	[4]
Roof—48	Dry	400	300	$^{1}/_{2}$ (0.500)
	Wet	400	300	[4]
Subfloor—16	Dry	400	400	$^{3}/_{16}$ (0.188)
	Wet/redry	400	400	$^{3}/_{16}$ (0.188)
Subfloor—20	Dry	400	400	$^{7}/_{32}$ (0.219)
	Wet/redry	400	400	$^{7}/_{32}$ (0.219)
Subfloor—24	Dry	400	400	$^{1}/_{4}$ (0.250)
	Wet/redry	400	400	$^{1}/_{4}$ (0.250)

[1]Wet/redry is exposure to three days continuous wetting followed by testing dry. Wet conditioning is exposure to three days continuous wetting and tested wet.
[2]Impact shall be 75 foot-pounds (102 N·m) for span ratings up to 24 on center (610 mm), 90 foot-pounds (122 N·m) for 32 on center (813 mm), 120 foot-pounds (163 N·m) for 40 on center (1016 mm), and 150 foot-pounds (203 N·m) for 48 on center (1219 mm).
[3]Criteria apply under static concentrated load according to Section 23.216. They do not apply following impact.
[4]Not applicable.

TABLE 23-2-M—UNIFORM LOAD PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.217—SHEATHING

END USE—SPAN RATING	TEST EXPOSURE CONDITIONS[1]	PERFORMANCE REQUIREMENTS	
		Average Deflection (in.) under Load (psf)	Minimum Ultimate Uniform Load (psf)
		× 25.4 for mm × 0.0000479 for N/mm²	× 0.0000479 for N/mm²
Roof—16	Dry	0.067 at 35 psf	150
Roof—20	Dry	0.080 at 35 psf	150
Roof—24	Dry	0.100 at 35 psf	150
Roof—32	Dry	0.133 at 35 psf	150
Roof—40	Dry	0.167 at 35 psf	150
Roof—48	Dry	0.200 at 35 psf	150
Subfloor—16	Dry	0.044 at 100 psf	330
	Wet/Redry	0.044 at 100 psf	330
Subfloor—20	Dry	0.053 at 100 psf	330
	Wet/Redry	0.053 at 100 psf	330
Subfloor—24	Dry	0.067 at 100 psf	330
	Wet/Redry	0.067 at 100 psf	330

[1]Wet/redry is exposure to three days continuous wetting followed by testing dry.

TABLE 23-2-N—CONCENTRATED STATIC AND IMPACT TEST PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.216—SINGLE FLOOR

		PERFORMANCE REQUIREMENTS		
		Minimum Ultimate Load (lb.)		Maximum Deflection (in.) (mm) Under 200-Lb. (890 N) Load[2]
		× 4.45 for N		
SPAN RATING	TEST EXPOSURE CONDITIONS[1]	Static	Following 75 Ft.-Lb. (102 N•m) Impact	× 25.4 for mm
16	Dry	550	400	$^5/_{64}$ (0.078)
	Wet/redry	550	400	$^5/_{64}$ (0.078)
20	Dry	550	400	$^6/_{64}$ (0.094)
	Wet/redry	550	400	$^6/_{64}$ (0.094)
24	Dry	550	400	$^7/_{64}$ (0.108)
	Wet/redry	550	400	$^7/_{64}$ (0.108)

[1]Wet/redry is exposure to three days continuous wetting followed by testing dry.

[2]Criteria apply under static concentrated load and following a 75 foot-pounds (102 N·m) impact according to Section 23.216.

TABLE 23-2-O—UNIFORM LOAD PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.217—SINGLE FLOOR

		PERFORMANCE REQUIREMENTS	
		Average Deflection (in.) (mm) under Load (psf) (N/mm²)	Minimum Ultimate Uniform Load (psf)
SPAN RATING	TEST EXPOSURE CONDITIONS[1]	× 25.4 for mm × 0.00689 for N/mm²	× 0.00689 for N/mm²
16	Dry or wet/redry	0.044 at 100 psf	330
20	Dry or wet/redry	0.053 at 100 psf	330
24	Dry or wet/redry	0.067 at 100 psf	330

[1]Wet/redry is exposure to three days continuous wetting followed by testing dry.

UNIFORM BUILDING CODE STANDARD 23-3
PERFORMANCE STANDARD FOR WOOD-BASED STRUCTURAL-USE PANELS

See Sections 2302.1, 2303, 2304.2 and 2502, and Tables 23-II-H, 23-II-I-1 and 23-II-E-2, *Uniform Building Code*

SECTION 23.301 — ADOPTION OF USVPS CODE

Wood-based structural-use panels shall be in accordance with United States Voluntary Product Standard PS 2-92, "Performance Standard for Wood-Based Structural-Use Panels," published by the Department of Commerce, the American Plywood Association, copyright 1992, Post Office Box 11700, Tacoma, Washington 98411 and TECO, 2401 Daniels Street, Madison, Wisconsin 53704, as if set out at length herein.

UNIFORM BUILDING CODE STANDARD 23-4
FIRE-RETARDANT-TREATED WOOD TESTS ON DURABILITY AND HYGROSCOPIC PROPERTIES

Based on American Society for Testing and Materials Standard Test Methods ASTM D 2898-81 and D 3201-79. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428, and American Wood Preservers Association Standards C 20-83 and C 27-83

See Sections 201, 207 and 2303, *Uniform Building Code*

SECTION 23.401 — SCOPE

These methods cover the (1) durability of a fire-retardant treatment of wood and wood-base products under exposure to accelerated weathering, (2) measurement of the hygroscopic properties of fire-retardant-treated wood, and (3) identification classifications for material having qualified under these tests. The fire-retardant treatment for lumber and plywood is by pressure impregnation.

SECTION 23.402 — ACCELERATED WEATHERING

23.402.1 Scope. This section describes the conditioning method for a test specimen prior to subjecting that specimen to an appropriate fire test. The condition simulates effects of leaching, drying and temperature such as might reasonably be anticipated on a wood element exposed to the weather over a long term.

23.402.2 Apparatus. The test apparatus shall be capable of subjecting the specimen uniformly to the test conditions described in Section 23.402.4.

No special means of protecting the specimen back and edges are required, but water shall not impinge directly on those surfaces which are not exposed either to the weather in the assembled form, or to fire in the subsequent test. Water spray nozzles shall be provided and arranged so as to distribute water evenly over the exposed specimen surface.

Heating shall be thermostatically controlled. Forced-air movement shall be uniform across the specimen surface, with provisions made for adequate air changes to assure thorough drying.

23.402.3 Test Specimen. The test specimen shall include all those essential parts of the corresponding fire test specimen that may be subjected to weather exposure in normal use.

Specimens may be mounted in sections which can be reassembled subsequently without trimming into the appropriate fire test specimen.

The specimen surface shall have a slope of 4 in 12.

23.402.4 Exposure Cycle. Subject the specimens to an exposure cycle consisting of twelve one-week cycles. Each cycle is to consist of 96 hours of water exposure and 72 hours of drying.

Apply water in a moderately fine spray uniformly over the exposed specimen surfaces by spray nozzles that deliver an average of 0.7 inch of water (174 Pa) per hour [0.0073 gallons per minute per square foot (0.000307 m^3/minute/m^2) of specimen surface] at a temperature between 35°F and 60°F (1.7°C to 15.6°C). Do not recirculate the water.

Dry at a thermostatically controlled temperature of 135°F to 140°F (57.2°C to 60.0°C) in a room or cell. The controlling temperature shall be the air temperature measured 1 inch (25.4 mm) above the specimen surface. Accompany drying with the air movement directed across the face of the specimens at a rate of at least 25 feet (7620 mm) per minute.

At the end of each cycle, change the position of each specimen within the apparatus so that each specimen or segment occupies approximately an equal number of cycles in each location used.

23.402.5 Conditioning. Upon completion of the prescribed exposure, the specimen shall be conditioned to a moisture content specified by the applicable fire test standard.

SECTION 23.403 — HYGROSCOPIC PROPERTIES OF FIRE-RETARDANT WOOD

23.403.1 Scope. This section prescribes the method for determining the moisture content of fire-retardant-treated wood samples after exposure to a standard high relative humidity condition of 92 ± 2 percent at 27°C ± 2°C.

23.403.2 Apparatus. Conditioning room or chamber with air circulation and controlling instruments capable of being maintained at 27°C ± 2°C and a relative humidity of 92 ± 2 percent. Other suitable means of maintaining these conditions are also acceptable.

Oven, air-circulated and vented, capable of maintaining a temperature of 103°C ± 2°C.

A weighing scale or balance that will weigh a specimen within an accuracy of ± 0.2 percent.

23.403.3 Test Specimens. Specimens shall be selected that represent the lot. Unless otherwise specified, specimens shall be full cross sections, no less than 25.4 millimeters along the grain, but longer as needed to provide a minimum volume of 33 cubic centimeters.

The specimens shall be penetrated by the chemical to be representative for the treated product.

The specimens shall be in moisture equilibrium with a laboratory ambient condition of 30 to 65 percent relative humidity or shall be exposed for at least seven days at such a condition prior to high-humidity exposure.

Untreated specimens, when available, of the same species or wood-base product and of the same size, shall be exposed to the preconditioning, high-humidity exposure, and drying along with the treated specimens.

23.403.4 Procedure. Weigh each specimen to an accuracy of ± 0.2 percent.

Expose all specimens under constant humidity conditions of 92 ± 2 percent at 27°C ± 2°C for seven days. Specimens shall be suitably suspended so that all surfaces are exposed.

Weigh each specimen immediately to an accuracy of ± 0.2 percent one at a time as they are removed from the conditioning chamber. Observe and record the general appearance of the specimens.

Dry each specimen in an oven at 103°C ± 2°C until approximately constant weight is attained, and reweigh. Constant weight can be assumed when two consecutive readings taken two hours apart agree within 0.2 percent. Avoid drying for periods longer than necessary to achieve constant weight, since thermal decomposition of chemical or wood might occur reflecting a higher than actual moisture content.

23.403.5 Calculations. Calculate the "apparent" moisture content of each sample prior to high-humidity exposure as follows:

$$\text{Moisture content: percent} = [(A - B)/B] \times 100$$

WHERE:

A = weight prior to high-humidity exposure.

B = oven-dry weight.

Calculate the "apparent" moisture content of each sample after high-humidity exposure as follows:

$$\text{Moisture content: percent} = [(C - B)/B] \times 100$$

WHERE:

B = oven-dry weight.

C = weight after high-humidity exposure.

The change in the "apparent" moisture content of the specimens shall be calculated as the difference between the average moisture content for the treated and untreated specimens as calculated in this section.

23.403.6 Report. The report shall include the following:

Complete identification of the fire-retardant product as to species of wood, wood product, and treatment.

Description of sampling procedure and number and dimensions of test specimens.

General description of humidity chamber and controls used for the test.

The average moisture content of the untreated specimens shall be reported.

The average "apparent" moisture content for the treated specimens, both before and after high-humidity exposure, including the basis of the computation; treated specimen (wood and chemical) or wood-only basis, shall be reported. The change in the average moisture content after high-humidity exposure compared to the moisture content of untreated specimens shall also be reported.

Report any change in the appearance of the specimen during exposure, including surface wetness, chemical exudation, or crystals on surface.

SECTION 23.404 — CLASSIFICATION

23.404.1 Scope. This part establishes the classification of fire-retardant-treated wood.

23.404.2 Classifications.

23.404.2.1 Interior Type A. Material that has been fire tested in accordance with Section 207 of the code to qualify as fire-retardant-treated wood and has an equilibrium moisture content of not over 28 percent when tested at 92 ± 2 percent relative humidity when conditioned as specified in Section 23.403.

23.404.2.2 Interior Type B. Material that has been fire tested in accordance with Section 207 of the code to qualify as fire-retardant-treated wood, but does not qualify as Interior Type A when conditioned as specified in Section 23.403.

23.404.2.3 Exterior type. Material that has been subjected to the weathering test of Section 23.402 and then fire tested in accordance with Section 207 of the Building Code to qualify as fire-retardant-treated wood.

UNIFORM BUILDING CODE STANDARD 23-5
FIRE-RETARDANT-TREATED WOOD
Design Values for Fire-retardant-treated Lumber
See Sections 207 and 2303, *Uniform Building Code*

SECTION 23.501 — SCOPE

This standard establishes the test protocol, acceptance criteria, and quality control procedure for assuring that fire-retardant treatments qualify for the design values assigned and that appropriate treating and redrying methods are used. Only lumber pressure impregnated with fire-retardant chemicals that is identified by the quality mark of an approved inspection agency shall be eligible for the design values specified in the Building Code.

Part I—Test Protocol

SECTION 23.502 — TYPE OF MATERIAL

The effects of fire-retardant treatment shall be determined on the basis of tests on matched samples of clear, straight-grain material. This is consistent with procedures presently used to establish design values and modifications for condition of use for visually graded sawn lumber.

SECTION 23.503 — NUMBER OF SPECIES

The effects of fire-retardant treatment may vary depending upon species. Because evaluation of such treatment for all species and properties is considered prohibitive, testing of three species representative of a range of wood density and treating characteristics is recommended. A specific treatment may be evaluated for only one of these species, but testing of three species representative of a range of wood density and treated characteristics is recommended.

Qualification may be obtained for any one species by evaluation of that species.

SECTION 23.504 — IDENTIFICATION

Each fire-retardant treatment shall be identified by the commercial name assigned by the developer of the treatment and each specimen shall be marked to identify the drying temperatures and relative humidity schedules used.

SECTION 23.505 — STRENGTH TESTING

Material to be subjected to strength testing shall be treated to the penetration and retention level required for that treatment and species to meet the definition of fire-retardant-treated wood given in Section 207.

To allow for variability in treatment especially for species classified as moderate to difficult to treat, it may be necessary to treat up to twice the number of samples required for test. Equal numbers of samples of low and high treatability may be excluded from strength testing to ensure that material of average treatability is evaluated.

Following treatment, strength test material shall be dried at a maximum temperature of 160°F (71.1°C) with relative humidity schedules and air velocities that will simulate commercial conditions. A record of the operating conditions of the kiln shall be kept for the entire run and shall include humidity conditions and temperature in the hottest part of the kiln.

SECTION 23.506 — SAMPLING AND TREATMENT

23.506.1 Species. For each fire-retardant treatment to be evaluated for general qualification, strength test material shall be selected from each of the following species:

Southern pine (*Pinus taeda or echinata*)

Coast Douglas fir

White spruce (*Picea glauca*)

The southern pine material shall be all sapwood. Where a treatment is to be evaluated only for a particular species, strength test material shall be selected from each such species.

23.506.2 Number of Samples, Size and Quality. For each species to be evaluated, 25 essentially clear, straight-grained 2 by 4s (51 by 102), 8 feet (2438 mm) or longer shall be selected from the production of one or more mills. All pieces shall be identified as being Surfaced Dry and shall have an average specific gravity within ± 10 percent of the average specific gravity (green volume basis) of the species.

23.506.3 Sample Identification. From each 2-inch-by-4-inch (51 mm by 102 mm) member selected for sampling, two end-matched 4-foot (1219 mm) blanks shall be cut for strength testing. One blank shall be designated for treatment and the other as control. All blanks shall be coded as to member number and treatment or control.

23.506.4 Pressure Treatment of Samples. All blanks to be fire-retardant treated shall be processed in accordance with the specific procedures established for the treatment being evaluated. Blanks shall be pressure treated and dried to a maximum moisture content of 19 percent in 2-inch by 4-inch (51 mm by 102 mm) by 4-foot (1219 mm) size. The same treatment and drying times, stickering practices, and other procedures to be employed in commercial charges shall be used.

23.506.5 Conditioning of Blanks. After redrying to a maximum moisture content of 19 percent, treated blanks and untreated controls shall be conditioned at 68°F ± 6°F (20°C ± 3.3°C) and 65 percent ± 1 percent relative humidity until approximate equilibrium weight is attained.

SECTION 23.507 — STRENGTH TESTS

23.507.1 Type and Number of Specimens. One- and one-half-inch-by-1$^1/_2$-inch-by-23-inch (38 mm by 38 mm by 584 mm) static bending specimen, two 1-inch-by-$^1/_4$-inch-by-16-inch (25 mm by 6.4 mm by 406 mm) tension specimens, one 1$^1/_2$-inch-by-1$^1/_2$-inch-by-6-inch (38 mm by 38 mm by 152 mm) compression specimen, one 1$^1/_2$-inch-by-1$^1/_2$-inch-by-2$^1/_2$-inch (38 mm by 38 mm by 64 mm) shear specimen, and 1$^1/_2$-inch-by-1$^1/_2$-inch-by-2-inch (38 mm by 38 mm by 51 mm) specific gravity specimen shall be cut from each treated and untreated blank. Bending and compression specimens from both treated and control blanks shall be cut such that three sides of the specimen represent the original surfaces or edge of the 2-inch-by-4-inch (51 mm by 102 mm) member. Two sides of the shear and specific gravity specimens shall represent original surfaces. One of the 1-inch-wide (25 mm) faces of one of the tension specimens shall represent one original surface of the blank and one of the wide surfaces of the other specimen shall represent the opposite original blank surface.

One method of selecting specimens to obtain the required placement of original surfaces is shown in Figure 23-5-3. Any orientation of growth rings relative to the edge of the specimens shall be acceptable.

Tension specimens shall be further machined to the size and shape shown in Figure 23-5-2. Shear specimens shall be notched as shown in Figure 23-5-1.

23.507.2 Slope of Grain. The slope of grain in all bending specimens and in the critical section of tension specimens shall be 1 in 20 or less. Compression and shear specimens shall have a slope of grain of 1 in 16 or less.

23.507.3 Identification and Conditioning. The blank identification of each treated and control specimen shall be retained. After final machining, test specimens shall be reconditioned to constant weight before test.

SECTION 23.508 — TESTING PROCEDURE

23.508.1 General. Testing procedures of an approved nationally recognized test standard shall be used. Load deformation curves shall be taken for static bending tests only. Maximum load shall be observed in all tests.

23.508.2 Order of Testing. The treated specimen and the matching untreated control from each blank shall be tested consecutively.

23.508.3 Measurement. The dimensions of the critical cross-sectional area, or in the case of the shear specimen the area of the shear plane of each specimen, shall be measured to an accuracy of at least 0.01 inch (0.254 mm).

23.508.4 Static Bending. Bending specimens shall be center loaded at span of 21 inches (533 mm). A machine cross-head speed of 0.075 inch per minute (1.9 mm per minute) shall be used. Bending specimens shall be positioned in the testing machine such that two opposite original surfaces represent the compression and tension faces of the beam.

23.508.5 Moisture Samples. All moisture samples selected from each specimen after test shall be oven dried at 103°C ± 2°C until approximately constant weight of the untreated control is reached.

23.508.6 Specific Gravity. Dimensions of the specific gravity samples shall be measured after final conditioning to determine volume at 65 percent relative humidity. Samples shall be dried at 103°C ± 2°C until approximate constant weight of the untreated control is reached.

SECTION 23.509 — REPORT

The treatment and redrying procedures shall be described in accordance with Section 23.505.

The species evaluated and testing procedures followed shall be fully described.

Individual values of treated and control specimens shall be reported for specific gravity, moisture content, modulus of elasticity, modulus of rupture, maximum tensile stress, maximum compression stress, and maximum shear stress. Average values, standard deviations, average ratios of treated to control values, and median ratios of treated to control values shall be reported for each strength and stiffness property and each species.

Part II—Acceptance Criteria

SECTION 23.510 — MINIMUM PROPERTY RATIO

A fire-retardant treatment evaluated for a particular species under this standard shall qualify for the design value adjustments in Section 2304.3 of the Building Code if the median ratio of treated to untreated strength or stiffness for each of the following properties equals or exceeds the specified adjustment factor for that property:

Extreme fiber in bending

Modulus of elasticity

Maximum stress in tension parallel to grain

Maximum stress in compression parallel to grain

Maximum stress in horizontal shear

Qualification of the adjustment factor for compression perpendicular to grain shall be based on the median factor for maximum stress in compression parallel to grain. Qualification of the adjustment factor for fastener loads shall be based on the lower of the median ratio for maximum stress in compression parallel to grain and the median ratio for maximum stress in horizontal shear.

SECTION 23.511 — RESAMPLING

Where marginal results occur for one property, a second 25-piece sample may be taken for that property and the combined results of the first and second samples be used to determine qualification.

SECTION 23.512 — GENERAL QUALIFICATION

A treatment meeting the requirements of Section 23.510 for each of the three species identified in Section 23.506 of this standard shall be considered qualifying for the design value adjustments in Section 2304.3 of the Building Code for all species.

Part III—Identification

SECTION 23.513 — PRODUCT ELIGIBILITY

Only lumber pressure impregnated with fire-retardant chemicals that is identified by the quality mark of an approved inspection agency shall be eligible for the design value adjustments given in Section 2304.3 of the Building Code. Such agency shall maintain continuing supervision, testing and inspection over the quality of the treated product as necessary to (1) ensure compliance with the fire performance requirements for fire-retardant-treated wood in Section 207 and (2) ensure eligibility for strength classification under the provisions of this standard.

SECTION 23.514 — QUALIFICATION COMPLIANCE

The approved agency shall review and analyze the test data developed in accordance with Part I of this standard and shall attest to the following:

1. Competency of the personnel and the adequacy of the facilities of the testing laboratory.

2. Conformance of reported sampling and testing procedures to Part I of this standard.

3. Compliance of test results with acceptance criteria in Part II of this standard.

SECTION 23.515 — QUALITY MARK

The quality symbol shall indicate that the treated lumber bearing the mark has been treated and redried in conformance with the procedures established by the manufacturer of the treatment which were used in the evaluation and qualification of that treatment under Parts I and II of this standard.

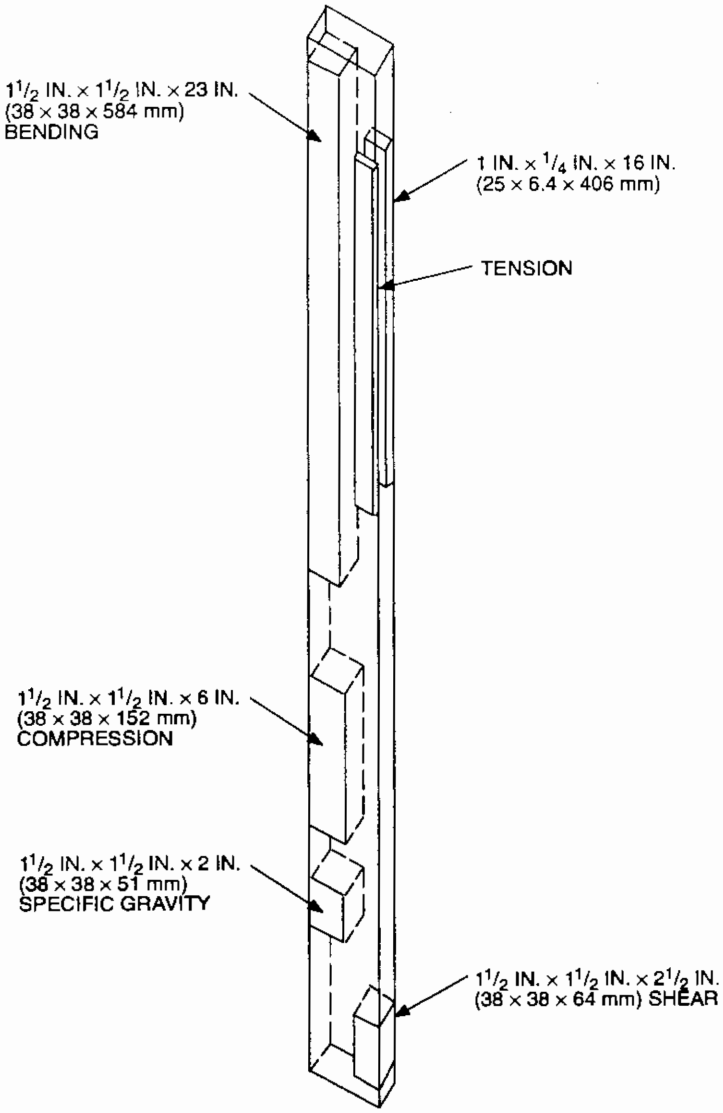


FIGURE 23-5-1—MATCHING DIAGRAM

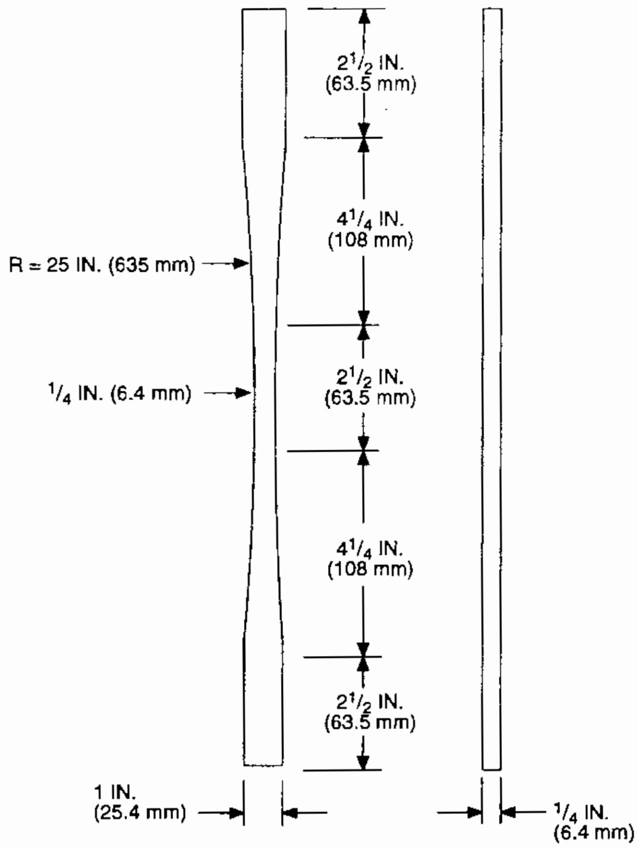


FIGURE 23-5-2—TENSION SPECIMEN

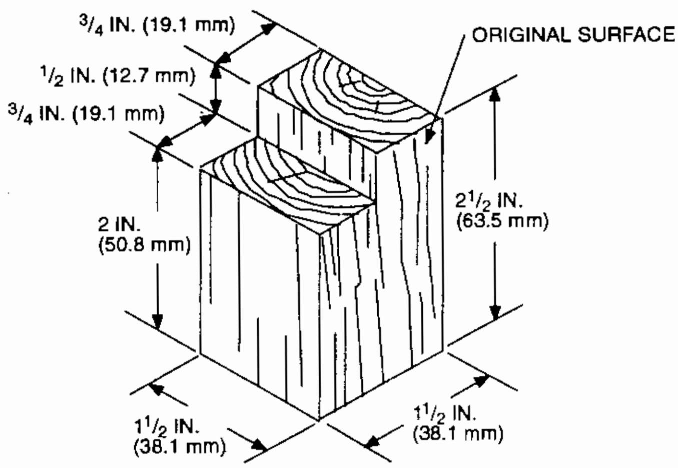


FIGURE 23-5-3—SHEAR SPECIMEN

UNIFORM BUILDING CODE STANDARD 24-1

FLAT GLASS

Based on ASTM Standard C 1036-85, Standard Specification for Flat Glass. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 2401.2 and 2401.4, *Uniform Building Code*

SECTION 24.101 — SCOPE

This standard provides general material requirements for glass regulated by the Building Code.

SECTION 24.102 — DEFINITIONS

For the purpose of this standard, certain terms are defined as follows:

FLOAT GLASS is glass formed in a continuous ribbon by floating molten glass on a bath of molten tin in a controlled atmosphere; the glass is smooth with parallel surfaces and requires no further treatment.

FULLY TEMPERED GLASS is regular glass that has been heated and quenched in a controlled operation to provide a high level of surface compression; its strength is roughly four times that of regular glass for most types of loads; when fractured, it breaks into small, relatively harmless particles; it is a safety glazing material.

HEAT-STRENGTHENED GLASS is regular glass that has been heated and quenched in a controlled operation to provide a degree of surface compression; its strength is roughly two times that of regular glass; when fractured, this glass breaks into large fragments, much like regular glass; it is not a safety glazing material.

INSULATING GLASS is factory-fabricated double glazing with the periphery of the air space sealed to minimize infiltration of water vapor.

LAMINATED GLASS is a sandwich of two or more glass plies bonded together with a resilient plastic interlayer, normally polyvinyl butyral; when this glass breaks, the fragments are held together by the plastic interlayer.

PATTERNED GLASS is rolled glass with a pattern or texture impressed on one or both surfaces; some glasses with shallow patterns can be tempered or heat strengthened.

REGULAR (ANNEALED) GLASS is sheet (window) glass and plate glass with smooth surfaces that have not been modified after manufacture; it breaks into large pieces; although the terms "sheet" and "plate glass" are commonly used, they are misnomers since virtually all glass is made by the float process; this glass may be clear or tinted.

SAFETY GLASS is glass designed to minimize cutting and piercing injuries when impacted by people; fully tempered glass, laminated glass and wired glass are recognized safety glazing materials.

TEMPERED GLASS. See "fully tempered glass."

WIRED GLASS is a single sheet of glass which has had a wire mesh embedded in roughly the thickness center during production; this glass, coupled with a suitable framing system, is fire rated; for low levels of impact, the wire in the glass will retain the broken fragments.

SECTION 24.103 — DESIGN CRITERIA

The maximum allowable areas of glass subjected to wind loads, snow loads and dead loads shall not be greater than those determined from Table 24-A of this code.

Table 24-1-A lists the coefficients of variation for various glass types. These values are used as part of the basis for Table 24-A of this code. Each value applies for all glass products using each glass type. For example, the value for annealed glass would apply for laminated annealed glass and insulating glass units using annealed glass panes, as well as for single annealed glass.

In cases where more than one glass type is used in a fabricated glass product (e.g., laminated glass, insulating glass), the more conservative values from Table 24-1-A apply.

SECTION 24.104 — FLOAT GLASS

24.104.1 Thickness. For each nominal thickness, the furnished glass thickness shall not be less than that listed in Table 24-1-B.

24.104.2 Allowable Imperfections. Imperfections shall not exceed those allowed in Table 24-1-C.

SECTION 24.105 — WIRED GLASS

24.105.1 Wire. The diameter of wires shall be from 0.017 inch to 0.025 inch (0.43 mm to 0.64 mm). Discoloration and slight distortion of wire is permissible.

24.105.2 Mesh. Diamond mesh shall be welded and the opening in mesh shall not exceed $1^1/_4$ inches (31.8 mm) measured across diagonals of the diamond; square mesh shall be welded and the openings in mesh shall not exceed $^5/_8$ inch (15.9 mm) measured along a side of the square; parallel stand—spacing as specified.

24.105.3 Thickness. The minimum thickness shall not be less than that listed in Table 24-1-D.

SECTION 24.106 — PATTERNED GLASS

24.106.1 Thickness. The thickness shall not be less than that listed in Table 24-1-E for each nominal thickness.

24.106.2 Fire Cracks and Stones. Glass shall not have continuous fire cracks and stones that can cause spontaneous breakage in annealed glass.

SECTION 24.107 — A GLOSSARY OF TERMS FOR GLASS IMPERFECTIONS

For the purpose of this standard, certain terms are defined as follows:

CRUSH is a lightly pitted area resulting in a dull gray appearance over the region.

DIGS are deep, short scratches.

DIRT is a small particle of foreign matter embedded in the glass surface.

GASEOUS INCLUSIONS are round or elongated bubbles in the glass.

KNOT is a transparent area of incompletely assimilated glass having an irregular knotty or tangled appearance.

LINES are fine cords or strings, usually on the surface of sheet glass.

OPEN GASEOUS INCLUSIONS are bubbles at the surface of glass which are open, leaving a cavity in the finished surface.

PROCESS SURFACE DEFECTS. The surfaces of plate glass have very fine surface defects remaining from the grinding and polishing process, consisting of fine pits and cracks which are denoted as "finish." When this condition is visible it is called "short finish." Float glass can also have some slight surface defects which originate in the process. These can be small particles of foreign materials on either surface or slight defects in the bottom (float) surface.

REAM is inclusions within the glass or layers or strings of glass which are not homogeneous with the main body of the glass.

RUBS are abrasions of the glass surface producing a frosted appearance. A rub differs from a scratch in having appreciable width.

SCRATCHES are any marking or tearing of the surface produced in manufacturing or handling which appear as though they were done by a sharp or rough instrument.

SMOKE is streaked areas appearing as slight discoloration.

STONES are any crystalline inclusions embedded in the glass.

STRINGS are transparent lines appearing as though a thread of glass had been incorporated into the sheets.

WAVES are defects resulting from irregularities of the surface of the glass, making objects viewed at varying angles appear wavy or bent.

TABLE 24-1-A—COEFFICIENTS OF VARIATION FOR GLASS STRENGTH

GLASS TYPE	COEFFICIENT OF VARIATION
Regular (annealed)	0.25
Heat-strengthened	0.15
Fully tempered	0.10

TABLE 24-1-B—MINIMUM ALLOWABLE THICKNESSES FOR FLOAT GLASS

NOMINAL THICKNESS OR DESIGNATION (inch)	MINIMUM ALLOWABLE THICKNESS (inch)
× 25.4 for mm	
Single	0.085
Lami	0.102
Double-$^1/_8$ in.	0.115
$^5/_{32}$ in.	0.149
$^3/_{16}$ in	0.180
$^7/_{32}$ in.	0.200
$^1/_4$ in.	0.219
$^5/_{16}$ in.	0.292
$^3/_8$ in.	0.355
$^1/_2$ in.	0.469
$^5/_8$ in.	0.595
$^3/_4$ in.	0.719
$^7/_8$ in.	0.844

TABLE 24-1-C—MAXIMUM ALLOWABLE IMPERFECTIONS FOR THICKNESSES OF 1/4 INCH (6.4 mm) OR LESS[1]

IMPERFECTIONS	UP TO 2.5 m^2		2.5 TO 7.0 m^2		OVER 7.0 m^2	
	Central[2]	Outer[2]	Central[2]	Outer[2]	Central[2]	Outer[2]
Gaseous inclusions, maximum size[3]	1.6 mm[4,5]	2.4 mm[4,5]	3.2 mm[4,5]	4.8 mm[4,5]	6.4 mm[4,5]	6.4 mm[4,5]
Open or translucent gaseous inclusions, maximum size[3]	1.2 mm[4,5]	1.6 mm[4,5]	1.2 mm[4,5]	1.6 mm[4,5]	6.4 mm[4,5]	6.4 mm[4,5]
Knots, dirt and stones, maximum size[3]	0.4 mm[4]	0.8 mm[4]	1.6 mm[4]	1.6 mm[4]	3.2 mm[4]	3.2 mm[4]
Scratches and rubs (intensity)	medium[6]	medium[6]	medium[6]	heavy[6]	heavy[6]	heavy[6]
Crush (intensity, maximum length)	medium[6] <1.6 mm	medium[6] <2.4 mm	medium[6] <3.2 mm	heavy[6] <4.8 mm	heavy[6] <6.4 mm	heavy[6] <6.4 mm
Digs, maximum length	1.6 mm[7]	2.4 mm[7]	3.2 mm[4]	4.8 mm[4]	6.4 mm[4]	6.4 mm[4]
Ream, strings, lines and other linear distortion (maximum angle or intensity)	45°[8] or medium[9]		90°[8] or heavy		90°[8] or heavy	
Wave (intensity)	medium[10]	medium[10]	medium[10]	heavy[10]	heavy[10]	heavy[10]
Process surface imperfections (intensity)	medium[11]	medium[11]	medium[11]	heavy[11]	heavy[11]	heavy[11]

[1]Glass greater than 6.0 mm (1/4 in.) in thickness may contain proportionally more and larger imperfections.

[2]The central area is considered to form an oval or circle centered on the light whose axes or diameters do not exceed 80 percent of the overall dimension. The remaining area is considered the outer area.

[3]Gaseous inclusions, knots, dirt and stones may be round or elongated. For elongated imperfections of this type(s) the maximum size specified shall be determined by adding the length and width of the imperfection and dividing by two, for example $(l + 11)/2$.

[4]Separated by at least 305 mm (12 in.).

[5]For imperfections of a smaller size or of less intensity, the minimum separation shall be proportionately less. The larger of the two imperfections shall govern the separation. Imperfections not specifically mentioned shall be compared to the imperfection they most closely resemble.

[6]*Intensity (scratches, rubs and crush)*—When looking through the glass and perpendicular to it, using daylight without direct sunlight or with background light suitable for observing each type of imperfection, the imperfection shall not be detectable at distances greater than the following, except for heavy intensity (see Note 3).

Intensity	Distance
Faint	203 mm
Light	914 mm
Medium	3.3 m
Heavy	detected at distances greater than 3.3 m

[7]Separated by at least 610 mm (24 in.).

[8]Vision interference angle (see Note 1).

[9]*Intensity (ream, strings, lines and other linear distortion)*—When evaluated using the shadowgraph, the intensities of these imperfections are defined as having a shadowgraph readout at distances greater than or equal to the following (see Note 2).

Intensity	Minimum Distance, mm
Light	76
Medium	51
Heavy	25

[10]*Intensity (wave)*—When evaluated using the shadowgraph, the intensities of wave are defined as having shadowgraph readouts at distances greater than or equal to the following (see Note 2).

Intensity	Minimum Distance, mm
Medium	254
Heavy	152

[11]*Intensity (process surface imperfections)*—When viewed in normal reflected light, the imperfections are classified as follows: faint—visible only to the trained eye; light—just noticeable; medium—visible as a slight grayish haze; and heavy—readily visible as a cloudy surface.

NOTE 1: *Ream, Strings and Distortion (Method A)*—Place specimen in a vertical position at a distance of approximately 914 mm from a brick wall or similar background showing straight lines. The viewer shall look through the sample at a distance of 914 mm from the sample using daylight without direct sunlight or with background light suitable for observing each type of imperfection. View the sample at an angle to the surface of not less than vision interference angle in Table 24-1-C, for the applicable glass. The line of vision shall be perpendicular to the wall.

NOTE 2: *Ream, Strings, Lines and Wave (Method B, Shadowgraph)*—Focus a light projector with a 500-W lamp, or equivalent, and an objective lens with an approximate 51-mm aperture and an approximate 305-mm focal length on a flat white projection screen positioned 8 m from the light source in a dark room. Place the glass in a vertical position parallel to the screen between the light and the screen. Move the glass slowly toward the screen with a circular motion in the plane perpendicular to the light beam. The shadowgraph readout is the distance at which the distortion just blends with the general shadow of the glass on the screen.

NOTE 3: *Scratches, Rubs, Stones and Gaseous Inclusions*—Place samples in a vertical position approximately 914 mm from the viewer's position. The viewer shall look through the sample using daylight without direct sunlight or with background light suitable for observing each type of imperfection.

TABLE 24-1-D—MINIMUM ALLOWABLE THICKNESSES FOR WIRED GLASS

NOMINAL THICKNESS (inch)	MINIMUM ALLOWABLE THICKNESS (inch)
× 25.4 for mm	
$^7/_{32}$	0.203
$^1/_4$	0.250
$^3/_8$	0.328

TABLE 24-1-E—MINIMUM ALLOWABLE THICKNESSES FOR PATTERNED GLASS

NOMINAL THICKNESS OR DESIGNATION (inch)	MINIMUM ALLOWABLE THICKNESS (inch)
× 25.4 for mm	
SS	0.085
DS	0.110
$^1/_8$	0.110
$^5/_{32}$	0.142
$^3/_{16}$	0.172
$^7/_{32}$	0.203
$^1/_4$	0.234
$^5/_{16}$	0.281
$^3/_8$	0.344

UNIFORM BUILDING CODE STANDARD 24-2
SAFETY GLAZING

Part I—Based on Safety Standard for Architectural Glazing Materials (16 C.F.R., Part 1201) of the United States Consumer Product Safety Commission

See Sections 2401.2, 2401.4, 2406.2, 2406.3, 2406.5 and 2408.1, *Uniform Building Code*

SECTION 24.201 — SCOPE

Part I of this standard covers safety glazing materials for use in areas subject to human impact as specified in this code. Part I is applicable to safety glazing material other than polished wired glass or glazing in wardrobe doors.

SECTION 24.202 — DEFINITIONS

For the purpose of this part, the definitions in Section 24.102 of UBC Standard 24-1 are applicable.

SECTION 24.203 — IDENTIFICATION

Each light of safety glazing material shall be identified in accordance with Sections 2402 and 2406.2 of this code and in addition with the following:

1. The category class as noted in Table 24-2-A shall be specified as part of a permanent label.

2. Safety plastic that only meets the requirements of Section 24.206.4 entitled "Aging Tests (for plastic used in indoor applications only)" shall bear a statement INDOOR USE ONLY as part of a permanent label.

3. Organic-coated glass that meets the requirements of Section 24.206.3.2, entitled "Specimen weathering and test—organic-coated glass" and tested for exposure from one side only, shall bear a permanent label on the coating stating GLAZE THIS SIDE IN and shall bear in the central 50 percent of the surface area the following message in letters at least $^1/_4$ inch (6.4 mm) high: SEE PERMANENT LABEL FOR IMPORTANT MOUNTING INSTRUCTION. The latter message shall be attached to either side of the glazing by any means which shall ensure the message will remain in place until installation.

SECTION 24.204 — CATEGORY CLASSIFICATION

Glazing required to conform with Part I of this standard shall be classified as Category I or II glazing in accordance with the impact test requirements in Section 24.206.1. Glass classified as Category I glazing shall not be used where Category II glass is required by Table 24-2-A. The categories noted in the table are based on the maximum size in square feet of the largest single glazing in the unit and the intended use of the unit.

SECTION 24.205 — SPECIMENS TO BE TESTED

24.205.1 Thickness. The thickness of the samples to be tested shall be recorded as a nominal thickness for glass as set forth in UBC Standard 24-1.

24.205.2 Specimens.

24.205.2.1 Classification. Safety glazing panels shall be classed in accordance with their size as "limited" or "unlimited" as set forth in Table 24-2-B.

24.205.2.2 Condition of specimens. All specimens shall be tested as supplied by the manufacturer following removal of any temporary protective masking materials. Tests shall not commence before the specimens have been stored in the laboratory for four hours. Specimens shall be arranged to permit free circulation of air to all surfaces during this period.

24.205.2.3 Number of specimens. For impact test of any safety glazing material, four specimens of the thickness and size described in Section 24.205.2.1 shall be provided.

For impact test after aging of plastic used in indoor applications, four specimens of the thickness and size described in Section 24.205.2.1 shall be provided.

For boil test, three specimens 12 inches by 12 inches (305 mm by 305 mm), manufactured in a manner identical to the impact specimens and of like thickness, shall be provided.

For weathering test, the number of test specimens shall comply with the following and be of identical manufacture as the impact specimens and of like thickness: For plastic, 10 specimens, $^1/_2$ inch by 5 inches (13 mm by 127 mm); for orientation specified, six organic-coated glass specimens, 2 inches by 6 inches (51 mm by 152.4 mm); for orientation unspecified, nine organic-coated glass specimens, 2 inches by 6 inches (51 mm by 152.4 mm), except that when the glazing material is symmetric across its thickness, six specimens may be used.

Samples for boil and weathering tests shall be cut from production samples of the size and thickness submitted for impact testing.

SECTION 24.206 — TEST SPECIFICATIONS

24.206.1 Impact Test.

24.206.1.1 General. Unless it has been established that specimens have a modulus of elasticity less than 750,000 psi (5171 MPa) and a Rockwell hardness less than 140 M or R scale, four specimens shall be impact tested in accordance with this section.

24.206.1.2 Apparatus. The test apparatus consists of two basic parts: (1) the test frame, and (2) the impactor.

24.206.1.2.1 Test frame. The test frame shall be designed to minimize movement and deflection of its members during testing. For this purpose, the structural framing and bracing members shall be steel angles [L5 × 3 × $^1/_4$ (L127 × 76 × 6.4)] or channels [C4 × 7.25 (C100 × 11)], or other sections and materials of equal or greater rigidity, as shown in Figure 24-2-1.

This structural framing shall be welded or securely bolted at the corners to minimize racking or twisting during testing. Also, it shall be securely bolted to the floor and braced by one of the alternate methods shown in Figure 24-2-1.

The clamping frame for securing the test specimen on all four edges shall be reinforced at the corners. See Detail A of Figure 24-2-1. Other materials may be used, provided there is positive assurance that the test specimen will contact only the neoprene strips.

Pressures on the test specimen shall be controlled, and the compression of the neoprene strips shall be between 10 and 15 percent of the original thickness of the neoprene. Securing methods such as wing bolts as shown in Detail A of Figure 24-2-1 and clamps shall be uniformly spaced no greater than 18 inches (457.2 mm) apart with no fewer than two on any edge. To limit the compression of the neoprene and prevent distortion of the clamping frame, metal shims of an appropriate thickness shall be used as shown in Detail A of Figure 24-2-1.

Any reasonable means may be used to secure the clamping frame to the test frame so long as the mounting is secure and the pressure on the glazing in the clamping frame is not significantly altered when the clamping frame is removed.

24.206.1.2.2 Impactor. The impactor shall be a standard leather punching bag modified as shown in Figure 24-2-3. The bag shall be filled with No. $7^1/_2$ [0.095 inch (2.4 mm) diameter] chilled lead shot to a total weight of completed assembly of 100 pounds ± 4 ounces (45.4 kg ± 0.11 kg). The rubber bladder shall be left in place and filled through a hole cut into the upper part. After filling the rubber bladder, the top shall either be twisted around the threaded metal rod below the metal sleeve or pulled over the metal sleeve and tied with a cord or leather thong. Note that the hanging strap shall be removed. The bag shall be laced in the normal manner. The exterior of the bag shall be completely covered with $^1/_2$-inch (12.7 mm) tape as indicated in Figure 24-2-3.

24.206.1.3 Procedure. The impacting object (shot bag), constructed in accordance with Figure 24-2-3, shall be suspended from an overhead support so located that the impacting object, when at rest will, at its maximum diameter, be no more than $^1/_2$ inch (13 mm) from the surface of the specimen and no more than 2 inches (50.8 mm) from the center of the specimen (see Figure 24-2-1).

Each specimen shall be centered within the neoprene mounting strips before impacting, such that approximately $^3/_8$-inch (9.53 mm) grip is provided on each edge of the specimen.

Specimens for Category I shall be impacted one time from a drop height of 18 inches to $18^1/_2$ inches (457 mm to 469.9 mm). Specimens for Category II shall be impacted one time from a drop height of 48 inches to $48^1/_2$ inches (1219 mm to 1231.9 mm). For all specimens that are not symmetric from surface to surface, an equal number of specimens shall be impacted on each side. The drop height is to be measured from the maximum diameter of the impacting object to the horizontal center line of the specimen (see Figure 24-2-1). The impacting object shall be stabilized before release.

24.206.1.4 Interpretation of results. A glazing material shall be judged to pass the impact test if each of the four specimens tested meets any one of the following criteria:

1. When breakage occurs (numerous cracks and fissures may occur), no opening shall develop in the test sample through which a 3-inch-diameter (76.2 mm) solid steel sphere, weighing 4 pounds ± 3 ounces (18.14 kg ± 0.085 kg), passes when placed (not dropped) in the opening and permitted to remain for a period of one second. For this criterion, the sample, after being impacted, shall be placed, while remaining in the clamping frame, in a horizontal, impact side-up position with a minimum of 1 foot (305 mm) of free space immediately beneath the specimen.

2. When breakage occurs, what appear to be the 10 largest particles shall be selected within five minutes subsequent to the test and shall weigh no more than the equivalent weight of 10 square inches (6452 mm^2) of the original specimen. For the purposes of this section, "particle" means a portion of a broken test specimen which is determined by identifying the smallest possible perimeter around all points in the portion of the broken test specimen, always passing along cracks or exposed surfaces.

3. The specimen remains intact after the drop test, though not necessarily remaining within the clamping frame.

24.206.2 Boil Test (for laminated glass only).

24.206.2.1 General. The test is made to determine the probable effect of exposure to high temperature and humidity conditions for a long period of time.

24.206.2.2 Procedure. Three 12- by 12-inch (305 mm by 305 mm) flat specimens, as submitted, shall be immersed vertically on edge in water at 150°F ± 5°F (65.5°C ± 3°C) for three minutes and then quickly transferred to and similarly immersed in boiling water. The rack shall be positioned so that each specimen is surrounded by at least 1 inch (25.4 mm) of water. The specimen shall be kept in the boiling water for two hours and then removed.

24.206.2.3 Interpretation of results. The glass itself may crack in this test, but bubbles or other defects shall not develop more than $^1/_2$ inch (12.7 mm) from the outer edge of the specimen or from any cracks that may develop. Any specimen in which the glass cracks to such an extent that the results are confused shall be discarded without prejudice and another specimen shall be tested in its stead.

24.206.3 Weathering Tests (for organic-coated glass used in exterior exposure applications only).

24.206.3.1 Purpose. The purpose of these tests is to determine whether these safety glazing materials will successfully retain their safety characteristics after exposure to weathering conditions for an extended period of time. Specimens shall be exposed to weathering and then tested in accordance with this subsection.

24.206.3.2 Specimen weathering and tests—organic-coated glass.

24.206.3.2.1 Weathering.

24.206.3.2.1.1 Apparatus. The specimens shall be subject to exposure in a xenon arc (water-cooled) Weather-Ometer employing a lamp rated at 6,500 watts and automatic light-monitoring and control systems. Borosilicate inner and outer filters shall be used. An appropriate water-spray cycle shall be used. Operating procedures shall be in accordance with ASTM Recommended Practice for Operating Light- and Water-exposure Apparatus (Xenon-arc Type) for Exposure of Nonmetallic Materials.

24.206.3.2.1.2 Procedure. The specimens shall be retained in the Weather-Ometer for a period of 1,200 ± 1 hour, and exposed to a radiant flux of 50 microwatts per square centimeter (12 calories per second per square centimeter) while monitoring at a wavelength of 340 nanometers.

For organic-coated glass having orientation specified, three specimens shall be mounted with the surface that is intended to be oriented indoors faced away from the radiation source; the other three specimens shall be kept in darkness at 73°F (23°C) for use as controls.

For organic-coated glass having orientation unspecified, three specimens shall be mounted with one of the surfaces toward the radiation, three specimens shall be mounted with the other surface toward the radiation, and three specimens shall be kept in darkness at 73°F (23°C) for use as controls. When the glazing material is symmetic across its thickness, three specimens shall be irradiated.

24.206.3.2.2 Interpretation of results. Specimens shall be judged satisfactory if they pass the adhesion test and the tensile strength test.

24.206.3.2.2.1 Adhesion test. The specimens for this test are the six 2-inch by 6-inch (51 mm by 152.4 mm) specimens prepared for the weathering test. The specimens shall be conditioned just prior to the performance of the adhesion test at 73.5°F ± 3.5°F (23°C ± 2°C) and 50 percent ± 2 percent relative humidity for 24 hours.

The test apparatus shall consist of a constant rate of extension (CRE)-type tensile tester with the moving crosshead set to move at 12 inches per minute (305 mm/min.) and load range such that the average peel force will fall at 30 percent to 50 percent of full scale, and a cutter containing new razor blades for cutting 1-inch-wide (25.4 mm) specimens (use blades one time only).

Using the 1-inch (25.4 mm) razor cutter, cut a straight strip of the organic coating in the lengthwise direction of the glass sample. Peel back about 2 inches (51 mm) of one end of the 1-inch-wide (25.4 mm) organic strip. Attach a strip of pressure-sensitive tape to the side of the organic strip opposite the adhesive to extend this free end to about 8 inches (203.2 mm) in length. Place the end of the glass panel from which the organic strip was removed in the lower clamp of the tensile tester and the free end of the tape in the upper clamp. Peel the remainder of the organic strip from the glass mechanically and obtain a record of the peel value. Determine the average pull for each specimen from the chart record.

The organic-coated glass adhesion shall be judged satisfactory if the average adhesion value of the three exposed specimens is no less than 90 percent of the average of the adhesion value of the three control specimens.

24.206.3.2.2.2 Tensile strength test. The samples for this test are the same six 2-inch by 6-inch (50.8 mm by 152.4 mm) specimens used in the adhesion test and conditioned as in Section 24.206.3.2.1.

The CRE tensile tester shall be set as follows: gage length—2 inches (50.8 mm); crosshead speed—2 inches per minute (50.8 mm/min.); load range—set full-scale load so that specimens will break at 30 percent to 60 percent of full scale.

Using a $^1/_2$-inch (13 mm) razor cutter (use blade one time only), cut a straight strip of the organic coating in the lengthwise direction of the glass sample for the full 6-inch (152.4 mm) length. Carefully peel this strip from the glass panel and test it for breaking strength in the tensile tester.

The organic coating tensile strength shall be judged satisfactory if the average tensile value of the three exposed specimens is no less than 75 percent of the average of the three control specimens.

24.206.4 Aging Tests (for plastics used in indoor applications only.)

24.206.4.1 Purpose. The purpose of this test is to determine whether plastic for indoor use only will successfully retain its safety characteristics after exposure to simulated aging conditions for an extended period of time.

24.206.4.2 Apparatus. The safety glazing materials shall be subjected to exposure to warm, humid and dry cycles, using the following apparatus:

24.206.4.2.1 Balance. A balance capable of weighing accurately of 0.05 percent for a test specimen weighing 0.250 pound (0.113 kg) or less, and to 0.1 percent for a test specimen weighing over 0.250 pound (0.113 kg).

24.206.4.2.2 Oven. A circulating-air oven capable of maintaining the required temperature of test within ± 1.8°F (± 1°C).

24.206.4.2.3 Containers. Noncorroding containers with a shelf to support the test specimen above the solution used for maintaining the required humidity. The container shall be tightly sealed except for a small capillary which permits release of vapor pressure that might otherwise lift the top off the container. Each test specimen shall be tested, preferably in a separate container.

24.206.4.2.4 Desiccator. A clean, dry, uncharged desiccator or equivalent closed container in which to bring test specimens to room temperature.

24.206.4.2.5 Absorbent cloth. Clean, nonlinting absorbent cloth for use in wiping exudation or condensed moisture from test specimens.

24.206.4.2.6 Micrometer. A micrometer capable of measuring dimensions of test specimens to 0.001 inch (0.0254 mm).

24.206.4.2.7 Cold box. A cold box capable of maintaining the required temperature of test within ± 5.4°F (± 3°C).

24.206.4.3 Procedure. The four plastic specimens shall be subjected to 10 complete humid/dry test cycles (480 hours) in accordance with the following:

1. The test cycle shall be as follows: 24 hours at 140°F (60°C) and 95 percent humidity, followed by 24 hours at 140°F (60°C) in the oven.

2. Condition the specimen, weigh and measure dimensions as follows. One additional specimen shall be retained unexposed as a control for the effects of the exposure cycling.

   2.1 **Conditioning.** Condition the test specimens at 73.4°F ± 3.6°F (23°C ± 2°C) and 50 ± 5 percent relative humidity for not less than 40 hours prior to test.

   2.2 **Test conditions.** Conduct tests in the Standard Laboratory Atmosphere of 73.4°F ± 3.6°F (23°C ± 2°C) and 50 ± 5 percent relative humidity, unless otherwise specified in the test methods or in this specification. In cases of disagreement, the tolerances shall be 1.8°F (1°C) and ± 2 percent relative humidity.

   2.3 **Measurements of test specimens.** The following measurements shall be made on conditioned test specimens prior to testing, after reconditioning at the end of a test procedure, and at any intermediate stage as prescribed in the test procedures:

   Weight—The weight within 0.05 percent if the specimen weighs 0.250 pound (0.113 kg) or less, and within 0.1 percent if the specimen exceeds 0.250 pound (0.113 kg) in weight.

   Dimensions—The thickness to 0.001 inch (0.03 mm), the plane dimension in the direction of injection or transfer to 0.001 inch (0.03 mm), and the plane dimension across the direction of injection or transfer to 0.001 inch (0.03 mm).

   Dimensions of compression-molded specimen—The thickness to 0.001 inch (0.03 mm), and the perpendicular dimensions in the plane at right angles to the direction of molding to 0.001 inch (0.03 mm).

3. Expose the specimen for 24 hours on the shelf of a container maintained at 140°F ± 1.8°F (60°C ± 1°C) in the oven, and containing a saturated solution of sodium sulfate to maintain a relative humidity of 95 percent.

4. Remove the specimen from the container, place it in the uncharged desiccator and bring to room temperature.

5. Wipe the specimen with the absorbent cloth, then weigh, measure dimensions and examine visually. Noticeable qualitative changes in surfaces, outline and general appearance of the test specimen shall be recorded after each stage of the testing procedure. These changes include color, surface irregularities, odor and

splits. Changes shall also be noted as they occur, especially those which alter the shape so that intended dimensions are no longer significant.

6. Within two hours after completion of the operation described in Item 3, expose the specimen for 24 hours in the oven at 140°F ± 1.8°F (60°C ± 1°C).

7. Place the specimen in the uncharged desiccator and bring to room temperature.

24.206.4.4 Interpretation of results. Specimens shall be judged satisfactory if, after the indoor aging test, they again pass the impact test in Section 24.206.1.

Part II—Based on Performance Specifications and Methods of Test for Transparent Safety Glazing Material Used in Buildings, ANSI Z97.1-1975 of the American National Standards Institute, Inc.

See Sections 2401.2, 2401.4, 2406.3 and 2406.5, *Uniform Building Code*

SECTION 24.207 — SCOPE

Part II of this standard covers safety glazing materials for use in areas subject to human impact as specified in this code. Part II is applicable to polished wired glass and glazing in wardrobe doors.

SECTION 24.208 — DEFINITIONS

For the purpose of this part, the definitions in Section 24.102 of UBC Standard 24-1 are applicable.

SECTION 24.209 — IDENTIFICATION

Each light of safety glazing material shall be identified in accordance with Sections 2402 and 2406.2 of this code and, in addition, safety plastic that only meets the requirements of Section 24.211.4 entitled "Aging Tests (for plastics used in indoor applications only)" shall bear the statement INDOOR USE ONLY as part of a permanent label.

SECTION 24.210 — SPECIMENS TO BE TESTED

The specimens, size and number shall be in accordance with the requirements of Section 24.205.

SECTION 24.211 — TEST SPECIFICATIONS

24.211.1 Impact Test.

24.211.1.1 General. The specimens tested shall be in accordance with the requirements of Section 24.206.1.1

24.211.1.2 Apparatus. The test apparatus requirements for the impact test shall be in accordance with Section 24.206.1.2.

24.211.1.3 Procedure. The test procedure requirements for the impact test shall be in accordance with Section 24.206.1.3, except the specimen shall be struck with the impactor object swinging in a pendulum arc from a drop height of 12 inches (305 mm). When no breakage occurs, the same specimen shall again be impacted at a drop of 18 inches (457 mm), and if no breakage occurs, again at 48 inches (1219 mm).

24.211.1.4 Interpretation of results. The impact test shall be judged to have been satisfactorily completed if any one of the following safety criteria shall be met by each of the four specimens tested:

1. When breakage occurs at 12 inches (305 mm), 18 inches (457 mm) or 48 inches (1219 mm), numerous cracks and fissures may occur, but a 3-inch-diameter (76 mm) sphere shall not be freely passed.

2. When disintegration occurs at 12 inches (305 mm), 18 inches (457 mm) or 48 inches (1291 mm), the 10 largest crack-free particles selected five minutes subsequent to the test shall weigh no more than the equivalent weight of 10 square inches (6452 mm^2) of the original test specimen.

NOTE: Breakage by other means could produce particles exceeding this weight.

3. When breakage occurs at 12 inches (305 mm), 18 inches (457 mm) or 48 inches (1291 mm), the stiffness and hardness of the specimen shall be determined. A modulus of elasticity less than 750,000 psi (5171 MPa) and a Rockwell hardness less than 140 M or R scale shall indicate satisfactory compliance.

4. The specimen remains intact after one 48-inch (1219 mm) drop test, though not necessarily remaining within the clamping frame.

24.211.2 Boil Test (for laminated glass only). The boil test shall be in accordance with the requirements of Section 24.206.2.

24.211.3 Weathering Tests (for plastic and organic-coated glass used in exterior exposure applications only).

24.211.3.1 General. The purpose of these tests is to determine whether these safety glazing materials will successfully retain their safety characteristics after exposure to weathering conditions for an extended period of time. Specimens shall be exposed to simulated weathering and then tested in accordance with this subsection.

24.211.3.2 Specimen weathering and tests—organic-coated glass.

24.211.3.2.1 Weathering.

24.211.3.2.1.1 Apparatus. The specimens shall be subject to exposure in a twin enclosed carbon-arc lamp apparatus, such as specified as Type D or DH in ASTM Recommended Practice for Operating Light- and Water-exposure Apparatus (Carbon-arc Type) for exposure of nonmetallic materials, or equivalent.

24.211.3.2.1.2 Procedure. The specimens shall be exposed for 2,000 hours in accordance with ASTM Recommended Practice for Operating Light- and Water-exposure Apparatus (Carbon-arc Type). For the organic-coated glass, three specimens with the side marked for exterior exposure shall be exposed to the energy source. The other three specimens of organic-coated glass are controls and shall be held in darkness at 73.5°F ± 3.5°F (23°C ± 2°C) until needed.

24.211.3.2.2 Interpretation of results. The specimen test after weathering shall be in accordance with the requirements of Section 24.206.3.2.2.

24.211.3.3 Specimen weathering and test—plastic material.

24.211.3.3.1 Weathering.

24.211.3.3.1.1 Apparatus. The specimen shall be subjected to exposure by any one of the following methods:

1. Twin enclosed carbon-arc such as specified as Type D or DH in ASTM G23-69 (1975).

2. 6,000 or 6,500 watt xenon-arc light exposure apparatus as specified as Type B or BH in ASTM G26-77.

3. Fixed-rack outdoor exposure in south Florida.

24.211.3.3.1.2 Procedure. Depending upon the exposure method chosen in Section 24.211.3.3.1.1, the appropriate procedure from the following shall apply:

1. **Twin-carbon arc.** The panel shall be exposed for 2,000 hours in accordance with ASTM D1499-64.

2. **Xenon-arc apparatus.** The panel shall be exposed for 2,900 hours in accordance with ASTM G 26-77 using method A with 102 minutes of light-only exposure and 18 minutes of water spray and light exposure.

3. **Outdoor exposure.** The unbacked panel shall be exposed for one year on a fixed rack at station latitude in south Florida.

24.211.3.3.2 Tests after weathering. Specimens shall be evaluated before and after exposure in accordance with the Charpy unnotched impact test. The exposed specimen shall be tested with the exposed surface subjected to tension. In the case of thin materials, the span of the specimen shall be reduced to 2 inches (51 mm) to avoid having the specimen bend enough to slip between the supports without breaking. The average of five specimens shall be reported. Plastic material shall be acceptable for safety glazing if the impact strength is not reduced by more than 25 percent after exposure. Some discoloration may develop, but defects other than this discoloration shall not develop. Bubbles or other noticeable decomposition shall not develop in the irradiated portion.

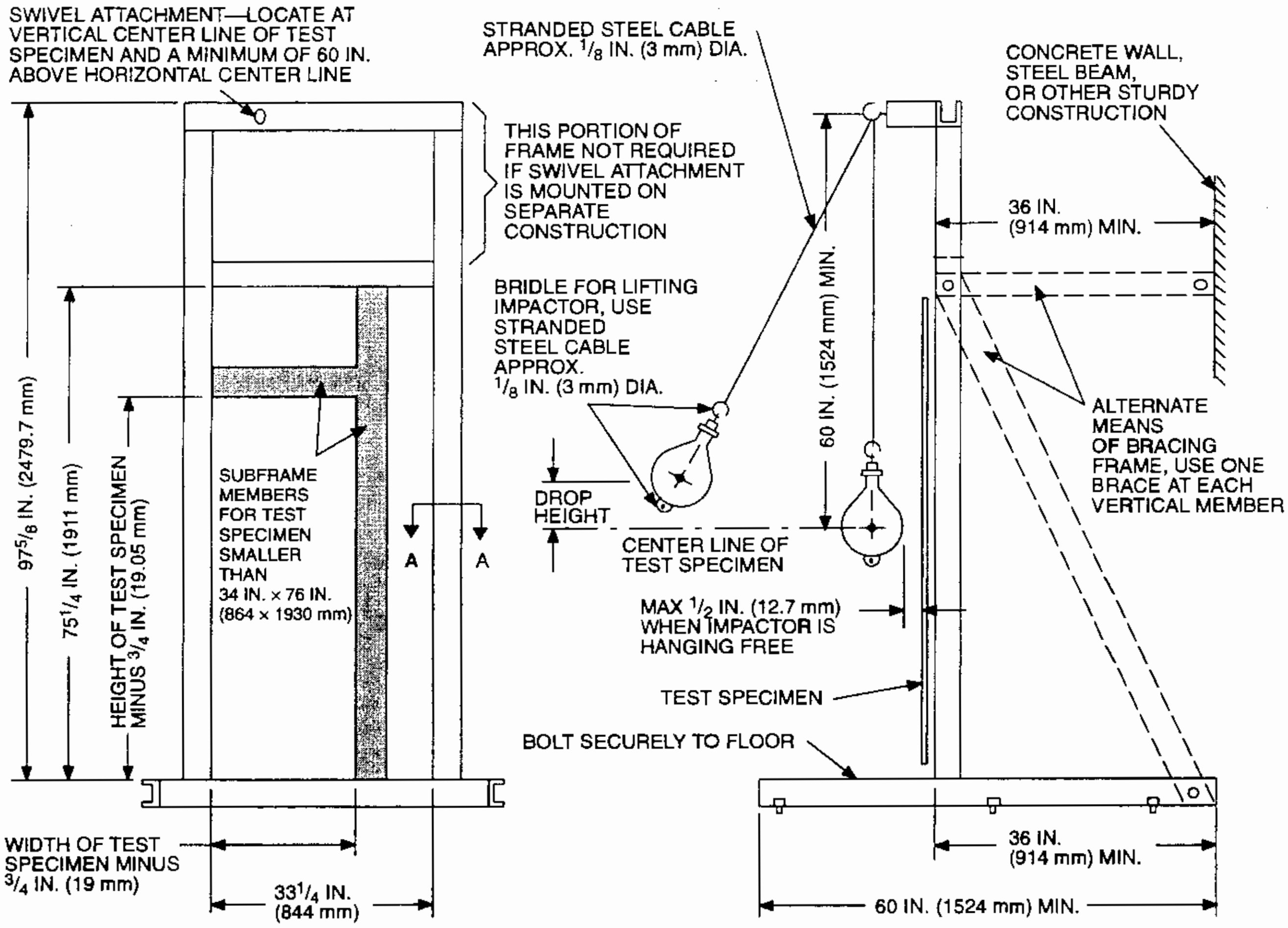
24.211.4 Aging Tests (for plastic used in indoor applications only). The aging tests shall be in accordance with the requirements of Section 24.206.4.3, Item 3, except that the humidity shall be 88 percent in Section 24.206.4.3, Item 3 and 85 to 95 percent in Section 24.206.4.3, Item 3.

TABLE 24-2-A—MINIMUM CATEGORY CLASSIFICATION OF GLAZING

SURFACE AREA OF ONE SIDE OF SINGLE GLAZING IN THE UNIT	GLAZING IN STORM OR COMBINATION DOORS (Category Class)	GLAZING IN DOORS (Category Class)	FIXED GLAZED PANELS (Category Class)	GLAZING IN DOORS AND ENCLOSURES FOR BATHTUBS AND SHOWERS (Category Class)	SLIDING GLASS DOORS PATIO TYPE) (Category Class)
9 square feet (0.837 m^2) or less of surface area	I	I	I	II	II
More than 9 square feet (0.837 m^2) of surface area	II	II	II		

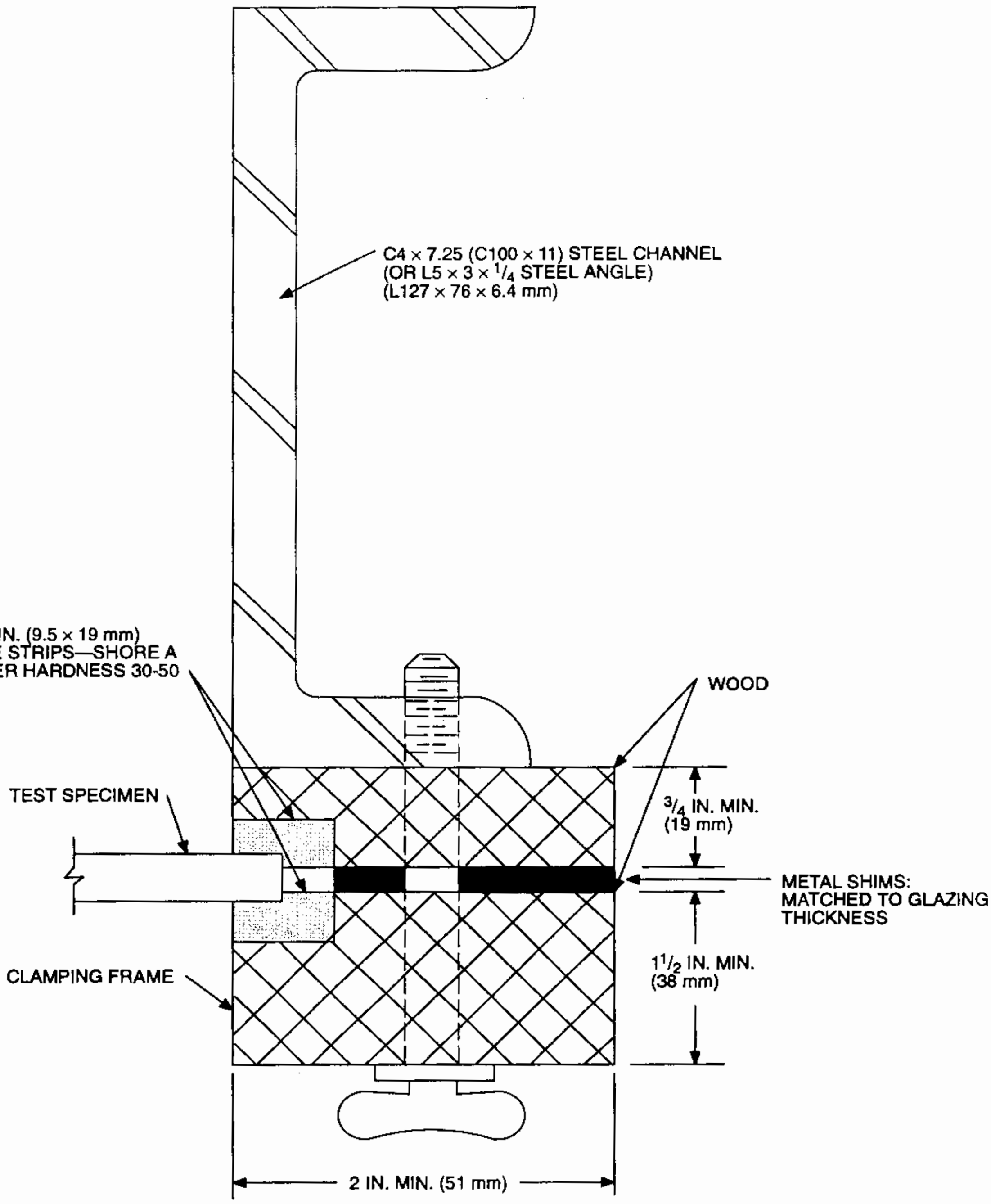
TABLE 24-2-B—DESCRIPTION OF SPECIMENS

CLASSIFICATION	DIMENSIONS OF SPECIMEN
Limited (for all sizes up to and including dimensions of specimens tested)	Largest size commercially produced by the manufacturer up to 34 inches by 76 inches (864 mm by 1930 mm)
Unlimited (for all sizes)	34 inches by 76 inches (864 mm by 1930 mm)



NOTE: Clamping frame for holding test specimen not shown.

FIGURE 24-2-1—TEST FRAME



DETAIL A

SECTION A-A OF FIGURE 24-2-1

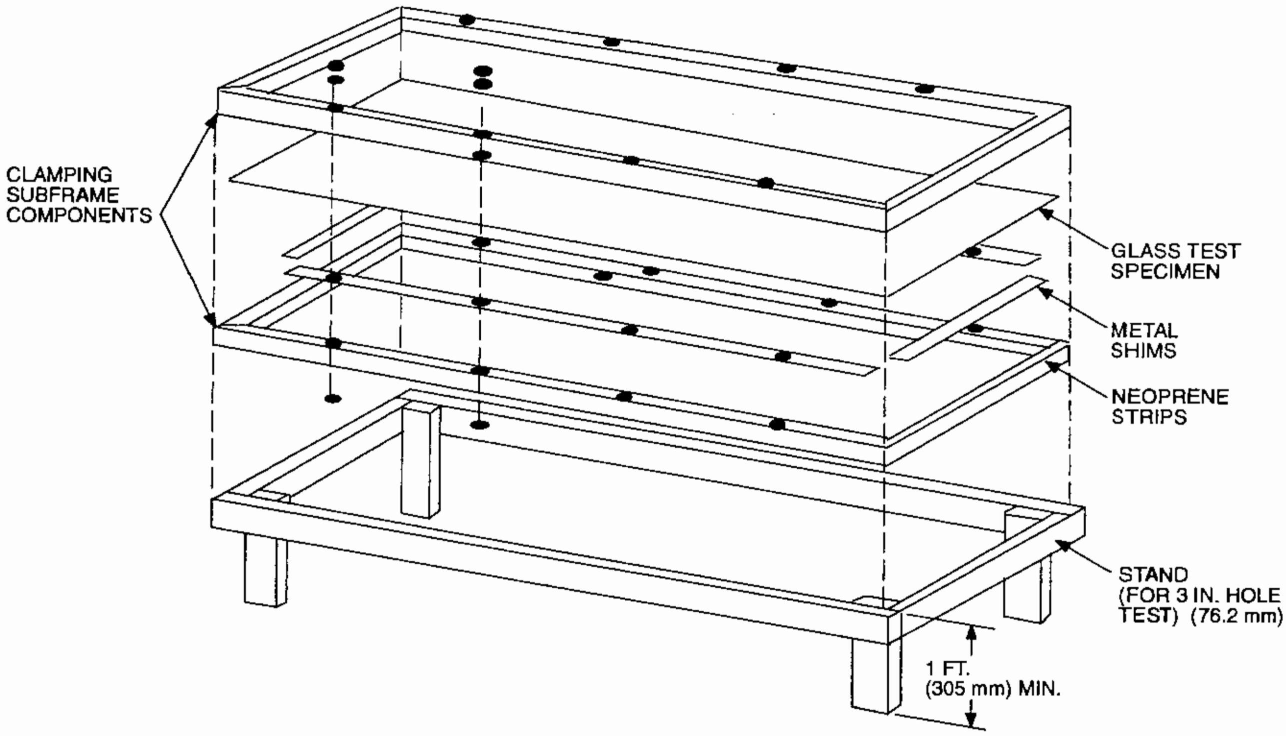


FIGURE 24-2-2—GLASS TEST SPECIMEN CLAMPING FRAME (EXPLODED) AND STAND

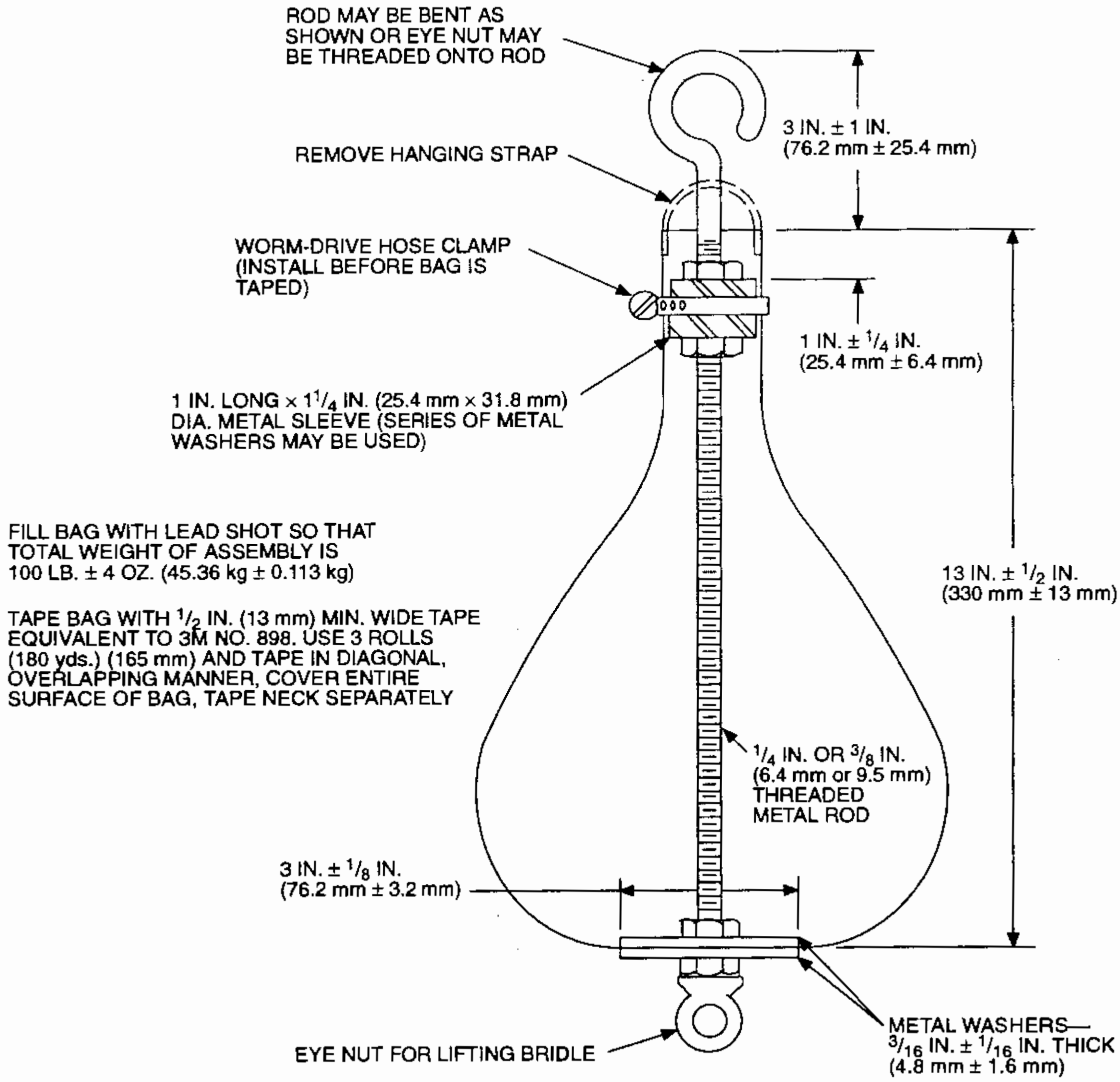


FIGURE 24-2-3—IMPACTOR

UNIFORM BUILDING CODE STANDARD 25-1
PLASTIC CEMENT

See Sections 2102.2, Item 2, and 2508.1, *Uniform Building Code*

SECTION 25.101 — SCOPE

This standard covers plastic cement for use in plastering.

SECTION 25.102 — PHYSICAL REQUIREMENTS

Plastic cement shall conform to the requirements set forth in Table 25-1-A.

SECTION 25.103 — PACKAGE LABELING

Plastic cement packages shall carry a statement indicating that the product conforms to requirements of this standard and shall include the brand, name of manufacturer and net weight of the package in pounds.

SECTION 25.104 — CERTIFICATION

Certification shall be submitted upon request of the building official and shall certify compliance with the requirements of this standard.

SECTION 25.105 — TEMPERATURE AND HUMIDITY

The temperature of the air in the vicinity of the mixing slab and dry materials, molds, base plates and mixing bowl shall be maintained between 68°F and 81.5°F (20°C and 27.5°C). The temperature of the mixing water, moist cabinet or moist room, and water in the storage tank shall not vary from 73.4°F by more than 3°F (23°C ± 1.7°C).

The relative humidity of the laboratory air shall not be less than 50 percent. The moist cabinet or moist room atmosphere shall have a relative humidity of not less than 90 percent.

The moist cabinet or moist room shall conform to applicable standards.

SECTION 25.106 — FINENESS

The fineness of the cement shall be determined from the residue on the No. 325 sieve (45 μm).

SECTION 25.107 — NORMAL CONSISTENCY

Determine normal consistency by the Vicat apparatus.

SECTION 25.108 — AUTOCLAVE EXPANSION

The autoclave expansion of plastic cement shall be determined. After molding, the specimens shall be stored in the moist cabinet or moist room for 48 hours ± 30 minutes before removal.

SECTION 25.109 — TIME OF SETTING

The time of setting shall be determined by the Gillmore needle method.

SECTION 25.110 — DENSITY

The density of the plastic cement shall be determined by using kerosene as the liquid. Use the density so determined in the calculation of the air content of the specimens.

SECTION 25.111 — APPARATUS FOR MORTAR TESTS

The apparatus for mortar tests shall be in accordance with applicable standards.

SECTION 25.112 — BLENDED SAND

The sand shall be a blend of equal parts by weight of graded standard sand and Standard 20-30 sand.

SECTION 25.113 — PREPARATION OF MORTAR

25.113.1 Proportions for Mortar. Mortar for air entrainment, compressive strength, and water retention tests shall be proportioned to contain a mass of cement, in grams, equal to six times the net bag weight in pounds, representing a nominal 1 cubic foot (0.0283 m^3) of plastic cement and 1,440 grams of sand. The sand shall consist of 720 grams of graded standard sand and 720 grams of 20-30 standard sand. The quantity of water measured in millimeters shall be such as to produce a flow of 110 ± 5 as determined by the flow table.

25.113.2 Mixing of Mortars. The mortar shall be mixed in accordance with applicable standards.

25.113.3 Determination of Flow. The flow shall be determined in accordance with applicable standards.

SECTION 25.114 — AIR ENTRAINMENT

25.114.1 Procedure. If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the mass of the 400 milliliters of the mortar.

25.114.2 Calculation. Calculate the air content of the mortar and report it to the nearest 0.1 percent as follows:

$$D = (W_1 + W_2 + V_w)/[(W_1/S_1) + (W_2/S_2) + V_w]$$

$$A = 100 - (W_m/4D)$$

WHERE:

A = volume percent of entrained air.
D = density of air-free mortar, g/ml.
S_1 = density of cement, g/ml.
S_2 = density of standard sand, 2.65 g/ml.
V_w = milliliters-grams of water used.
W_1 = mass of cement, g.
W_2 = mass of sand, g.
W_m = mass of 400 ml.

SECTION 25.115 — COMPRESSIVE STRENGTH

25.115.1 Test Specimens.

25.115.1.1 Molding. Immediately after determining the flow and the mass of 400 milliliters of mortar, return all the mortar to the mixing bowl and remix for 15 seconds at the medium speed. Then mold test specimens, except that elapsed time for mixing mortar, determining flow, determining air entrainment and starting the molding of cubes shall be within eight minutes.

25.115.1.2 Storage. Store all test specimens immediately after molding in the molds on plane plates in a moist cabinet or moist room for 48 to 52 hours, in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds and place in the moist cabinet or moist room for five days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of seven days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrodible materials.

25.115.2 Procedure. Test the cube specimens immediately after their removal from the moist cabinet or moist room for seven-day specimens and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist cabinet or moist room for seven-day tests, cover these cubes with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, place these cubes in a pan of water at a temperature of 73.4°F ± 3°F (23°C ± 1.7°C) and of sufficient depth to completely immerse each cube until time of testing.

The remainder of the testing procedure shall conform to applicable standards.

SECTION 25.116 — WATER RETENTION

25.116.1 Apparatus. For the water-retention test, an apparatus essentially the same as that shown in Figure 25-1-1 shall be used. This apparatus consists of a water-aspirator or other source of vacuum controlled by a mercury-relief column and connected by way of a three-way stopcock to a funnel upon which rests a perforated dish. The perforated dish shall be made of metal not attacked by plastic mortar. The metal in the base of the dish shall have a thickness of 1.7 mm to 1.9 mm and shall conform to the requirements given in Figure 25-1-1. The stopcock bore shall have a 4.0 mm ± 0.5 mm diameter, and the connecting glass tubing shall have a minimum inside diameter of 4 mm. A mercury manometer, connected as shown in Figure 25-1-1, indicates the vacuum. The contact surfaces of the funnel and perforated dish shall be placed and may need to be lapped to ensure intimate contact. An airtight seal shall be maintained between the funnel and the dish during a test. This shall be accomplished by either of the following procedures:

A. A synthetic (grease-resistant) rubber gasket may be permanently sealed to the top of the funnel using petrolatum or light grease to ensure a seal between the basket and dish.

B. The top of the funnel may be lightly coated with petrolatum or light grease to ensure a seal between the funnel and dish.

Care shall be taken to ensure that none of the holes in the perforated dish are clogged. Hardened, very smooth, not rapid, filter paper shall be used. It shall be 150 mm in diameter and be placed so as to completely cover the perforations in the dish.

A steel straightedge not less than 8 inches (203 mm) long and not less than $^{1}/_{16}$ inch (1.6 mm) or more than $^{1}/_{8}$ inch (3.2 mm) in thickness.

Other apparatus required for the water-retention test shall conform to the requirements of Section 25.111.

25.116.2 Procedure. Adjust the mercury-relief column to maintain a vacuum of 51 mm ± 3 mm as indicated by the manometer. Seat the perforated dish on the greased gasket or greased rim of the funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum to the funnel and check the apparatus for leaks and to determine that the required vacuum is obtained. Then turn the stopcock to shut off the vacuum from the funnel.

Mix the mortar to a flow of 110 ± 5 percent in accordance with applicable standards. Immediately after making the flow test, return the mortar on the flow table to the mixing bowl and remix the entire batch for 15 seconds at medium speed. Immediately after remixing the mortar, fill the perforated dish with the mortar to slightly above the rim. Tamp the mortar 15 times with the tamper. Apply 10 of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish and with the long axis of the tamping face held at right angles to the radius of the dish. Apply the remaining five tamping strokes at random points distributed over the central area of the dish. The tamping pressure shall be just sufficient to ensure filling of the dish. Upon completion of the tamping, the top of the mortar will extend slightly above the rim of the dish. Smooth off the mortar by drawing the flat side of the straightedge (with leading edge slightly raised) across the top of the dish. Then cut off the mortar to a plane surface flush with the rim of the dish by drawing the straightedge with a sawing motion across the top of the dish in two cutting strokes, starting each cut from near the center of the dish. If the mortar is pulled away from the side of the dish during the process of drawing the straightedge across the dish, gently press the mortar back into contact with the side of the dish using the tamper.

Turn the stopcock to apply the vacuum to the funnel. The time elapsed from the start of mixing the cement and water to the time of applying the vacuum shall not exceed eight minutes. After suction for 60 seconds, quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off from the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then, using the bowl scraper, plow and mix the mortar in the dish for 15 seconds. Upon completion of mixing, place the mortar in the flow mold and determine the flow. The entire operation shall be carried out without interruption and as quickly as possible, and shall be completed within an elapsed time of 11 minutes after the start of mixing the cement and water for the first flow determination. Both flow determinations shall be made in accordance with applicable standards.

25.116.3 Calculation. Calculate the water-retention value for the mortar as follows:

$$\text{Water-retention value} = (A/B) \times 100$$

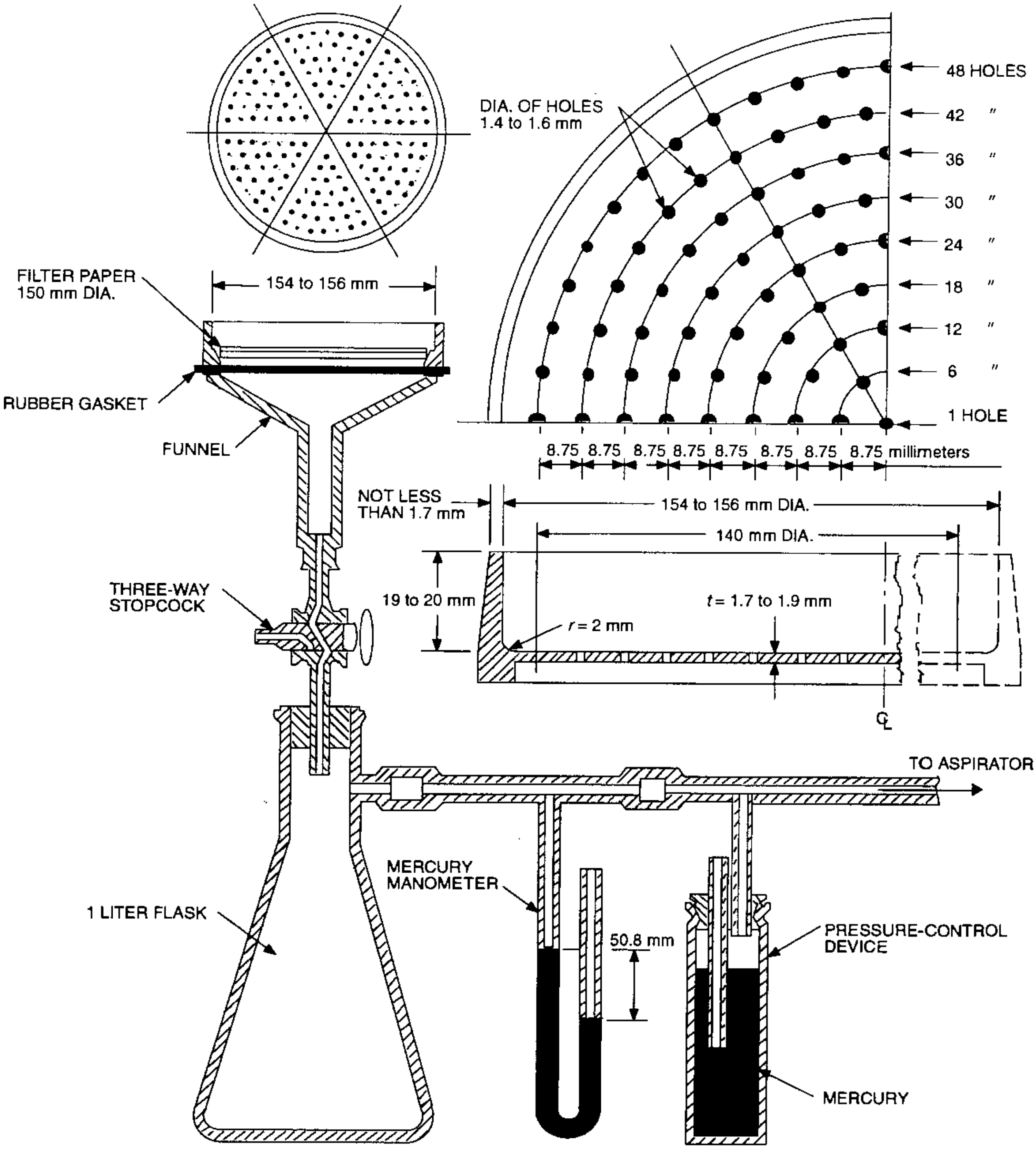
WHERE:

A = flow after suction.

B = flow immediately after mixing.

TABLE 25-1-A—PHYSICAL REQUIREMENTS

Fineness, residue on a No. 325 sieve (45 μm), maximum, percentage	24
Soundness: Autoclave expansion, maximum, percentage	1.0
Time of setting, Gillmore method: Initial set, minimum, hour Final set, maximum, hour	 $1^1/_2$ 24
Compressive strength (average of three cubes): Initial compressive strength of mortar cubes, composed of one part cement and three parts blended sand (half graded Ottawa sand, and half Standard 20-30 Ottawa sand) by volume, prepared and tested in accordance with this specification shall be equal to or higher than the values specified for the ages indicated below: seven days, psi (kPa) 28 days, psi (kPa)	 1,800 (12 402 kPa) 2,900 (19 981 kPa)
Air content of mortar: Minimum percentage by volume	8
Maximum percentage by volume	20
Water retention, flow after suction, minimum, percentage of original flow	70



NOTE: The gasket is to be synthetic rubber. The stopcock and the bore of the tubing should measure at least 4 mm. A check valve or water trap, or both, are suggested for the connection to the aspirator.

FIGURE 25-1-1—APPARATUS ASSEMBLY FOR THE WATER-RETENTION TEST

UNIFORM BUILDING CODE STANDARD 25-2
METAL SUSPENSION SYSTEMS FOR ACOUSTICAL TILE AND FOR LAY-IN PANEL CEILINGS

Based on Standard Specification C 635-69 and Standard Recommended Practice C 636-69 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Table 25-A, *Uniform Building Code*

Part I—General

SECTION 25.201 — SCOPE

This standard covers metal ceiling suspension systems used primarily to support acoustical tile or acoustical lay-in panels.

SECTION 25.202 — CLASSIFICATION

The structural performance required from a ceiling suspension system shall be in accordance with its structural classification.

The load-carrying capacity shall be the maximum uniformly distributed load (pounds per linear foot) that a simply supported main runner section having a span length of 4 feet 0 inch (1219 mm) is capable of supporting without a midspan deflection exceeding 0.133 inch (3.4 mm) or $^1/_{360}$ of the 4-foot 0-inch (1219 mm) span length.

The structural classification listed in Table 25-2-A shall be determined by the capability of main runners or nailing bars to support a uniformly distributed load. These classifications shall be:

1. **Light-duty systems.** Used primarily for residential and light commercial structures where ceiling loads other than acoustical tile or lay-in panels are not anticipated.

2. **Intermediate-duty systems.** Used primarily for ordinary commercial structures where some ceiling loads, due to light fixtures and air diffusers, are anticipated.

3. **Heavy-duty systems.** Used primarily for commercial structures in which the quantities and weights of ceiling fixtures (lights, air diffusers, etc.) are greater than those for an ordinary commercial structure.

Cross runners shall be capable of carrying the design load as dictated by job conditions without exceeding the maximum allowable deflection equal to $^1/_{360}$ of its span. A cross runner that supports another cross runner is a main runner for the purpose of structural classification and shall be capable of supporting a uniformly distributed load at least equal to the intermediate classification.

SECTION 25.203 — DIMENSIONAL TOLERANCE

25.203.1 Straightness. The amount of bow, camber or twist in main runners, cross runners, wall molding, splines or nailing bars of various lengths shall not exceed the values shown in Table 25-2-B.

Main runners, cross runners, wall moldings, splines or nailing bars of ceiling suspension systems shall not contain local kinks or bends.

Straightness of structural members shall be measured with the member suspended vertically from one end.

25.203.2 Length. The variation in the specified length of main runner sections or cross runner sections that are part of an interlocking grid system shall not exceed ± 0.010 inch/4 feet (± 0.25 mm/1219 mm).

The variation in the specified spacing of slots or other cutouts in the webs of main runners or cross runners that are employed in assembling a ceiling suspension grid system shall not exceed 0.010 inch (0.25 mm).

25.203.3 Overall Cross-section Dimensions. For steel systems, the overall height of the cross section of main runners, cross runners, wall molding or nailing bar shall be the specified dimensions ± 0.030 inch (0.76 mm). The width of the cross section of exposed main runners or cross runners shall be the specified dimension ± 0.008 inch (0.20 mm).

25.203.4 Section Squareness. Intersecting webs and flanges of structural members (I, T, or Z sections) shall form angles between them of 90 degrees ± 2 degrees. If deviations from squareness at more than one such intersection are additive with respect to their use in a ceiling, the total angle shall not be greater than 2 degrees.

The ends of structural members that abut or intersect other members in exposed grid systems shall be cut perpendicular to the exposed face, 90 degrees +0, -2 degrees.

25.203.5 Suspension System Devices. Suspension system assembly devices shall satisfy the following requirements and tolerances:

A joint connection shall be judged suitable both before and after ceiling loads are imposed if the joint provides sufficient alignment so that:

The horizontal and the vertical displacements of the exposed surfaces of two abutting main runners do not exceed 0.015 inch (0.38 mm).

There shall be no visually apparent angular displacement of the longitudinal axis of one runner with respect to the other.

Assembly devices shall provide sufficient spacing control so that horizontal gaps between exposed surfaces of either abutting or intersecting members shall not exceed 0.020 inch (0.5 mm).

Spring wire clips used for supporting main runners shall maintain tight contact between the main runners and the carrying channels when the ceiling loads are imposed on the runners.

SECTION 25.204 — COATINGS AND FINISHES FOR SUSPENSION SYSTEM COMPONENTS

25.204.1 Protective Coatings for Normal Environments. Component materials that oxidize or corrode when exposed to normal-use environments shall be provided with protective coatings except for cut or punched edges fabricated after the coating is applied.

Components fabricated from sheet steel shall be given an electrogalvanized, hot-dipped galvanized, cadmium or equal protective coating.

Components fabricated from aluminum alloys shall be anodized or protected by other approved techniques.

Components formed from other materials shall be provided with an approved protective coating.

25.204.2 Adhesion and Resilience. Finishes shall exhibit good adhesion properties and resilience so that chipping or flaking does not occur as a result of the manufacturing process.

25.204.3 Protective Coatings for Severe Environment. Protected components for acoustical ceilings shall be suitable for their environment. When they are subject to the severe environmental conditions of high humidity and salt spray (fog), or both, they shall be ranked according to their ability to protect the components of suspension systems from deterioration. A salt spray (fog) test conducted in accordance with the following test conditions shall be performed:

1. **Salt solution.** Five parts by weight NaCl to 95 parts distilled water.

2. **Humidity in chamber.** Ninety percent relative humidity.

3. **Temperature in chamber.** 90°F (32°C).

4. **Exposure period.** Ninety-six hours continuous.

5. **Report.** Upon request, the photographs shall be provided showing worst corrosion conditions on components and shall provide comments regarding corrosion that occurs on cut metal edges, on galvanized surfaces without paint, on galvanized and painted surfaces, at edges rolled after being painted, and on any change of paint color or gloss that is apparent at the conclusion of the test. Color and gloss inspection of the component shall be made after washing in a mild soap solution.

25.204.4 High-humidity Test. The test and inspection shall be identical to that of the salt spray test, except that distilled water instead of salt solution shall be used.

SECTION 25.205 — STRUCTURAL MEMBERS

The manufacturer shall determine the load-deflection performance. The structural members tested shall be identical to the sections used in the final system design. All cutouts, slots, etc., as exist in the system component shall be included in the sections evaluated.

Load-deflection studies of structural members shall utilize sections fabricated in accordance with the system manufacturers' published metal thicknesses and dimensions.

SECTION 25.206 — SECTION PERFORMANCE

The performance of structural members of suspension systems shall be represented by individual load-deflection plots obtained from tests performed at each different span length used in service.

The results of replicate tests of three individual sections, each tested on the same span length, shall be plotted and averaged to obtain a characteristic load-deflection curve for the structural member.

The average load-deflection curve shall be used to establish the maximum uniformly distributed load that the structural member can successfully sustain prior to reaching the deflection limit of $^1/_{360}$ of the span length in inches.

The load-deflection curve shall be used to establish the maximum loading intensity beyond which the structural member begins to yield.

SECTION 25.207 — SUSPENSION SYSTEM PERFORMANCE

Published performance data for individual suspension systems shall be developed by the manufacturer on the basis of results obtained from load-deflection tests of its principal structural members. Where a ceiling design incorporates a number of components, each of which experiences some deflection as used in the system, the additive nature of these displacements shall be recognized in setting an allowable system deflection criteria.

Part II—Installation

SECTION 25.208 — SCOPE

This part describes procedures for the installation of suspension systems for acoustical tile and lay-in panels.

SECTION 25.209 — INSTALLATION OF COMPONENTS

25.209.1 Hangers. Hangers shall be attached to the bottom edge of the wood joists or to the vertical face of the wood joists near the bottom edge. Bottom edge attachment devices shall be an approved type.

In concrete construction, mount hangers using cast-in-place hanger wires, hanger inserts, or other hanger attachment devices shall be an approved type. If greater center-to-center distances than 4 feet 0 inch (1219 mm) are used for the hangers, the load-carrying capacity of the ceiling suspension system shall be reduced commensurate with the actual center-to-center hanger distances.

Hangers shall be plumb and shall not press against insulation covering ducts or pipes. If some hangers must be splayed, countersplaying or other approved means shall be used to offset the horizontal force.

Hangers formed from galvanized sheet metal shall be suitable for suspending carrying channels or main runners from an existing structure provided that the hangers do not yield, twist or undergo other objectionable movement.

Wire hangers for suspending carrying channels or main runners from an existing structure shall be a minimum of No. 12 gage (2.7 mm), galvanized, soft annealed, mild steel wire.

Special attachment devices that support the carrying channels or main runners shall be approved to support five times the design load.

25.209.2 Carrying Channels. The carrying channels shall be installed so that they are level to within $^1/_8$ inch in 12 feet (3.2 m in 3660 mm). Leveling shall be performed with the supporting hangers taut. Local kinks or bends shall not be made in hanger wires as a means of leveling carrying channels. In installations where hanger wires are wrapped around carrying channels, the wire loops shall be tightly formed to prevent any vertical movement or rotation of the member within the loop.

25.209.3 Main Runners. Main runners shall be installed so that they are all level to within $^1/_8$ inch in 12 feet (3.2 mm in 3660 mm). Where main runners are supported directly by hangers, leveling shall be performed with the supporting hanger taut. Local kinks or bends shall not be made in hanger wires as a means of leveling main runners. In installations where hanger wires are wrapped through or around main runners, the wire loops shall be tightly wrapped and sharply bent.

25.209.4 Cross Runners. Cross runners shall be supported by either main runners or by other cross runners to within $^1/_{32}$ inch

(0.79 mm) of the required center distances. This tolerance shall be noncumulative beyond 12 feet (3528 mm). Intersecting runners shall form a right angle. The exposed surfaces of two intersecting runners shall lie within a vertical distance of 0.015 inch (0.38 mm) of each other with the abutting (cross) member always above the continuous (main) member.

25.209.5 Splines. Splines used to form a concealed mechanical joint seal between adjacent tiles shall be compatible with the tile kerf design so that the adjacent tile will be horizontal when installed. Where splines are longer than the dimension between edges of supporting members running perpendicular to the splines, place the splines so that they rest either all above or all below the main running members.

25.209.6 Assembly Devices. Abutting sections of main runner shall be joined by means of suitable connections such as splices, interlocking ends, tab locks, pin locks, etc. A joint connection shall be judged suitable both before and after ceiling loads are imposed if the joint provides sufficient alignment so that the exposed surfaces of two abutting main runners lie within a vertical distance of 0.015 inch (0.38 mm) of each other and within a horizontal distance of 0.015 inch (0.38 mm) of each other.

There shall be no visually apparent angular displacement of the longitudinal axis of one runner with respect to the other.

Assembly devices shall provide sufficient spacing control so that horizontal gaps between exposed surfaces of either abutting or intersecting members shall not exceed 0.020 inch (0.51 mm).

Spring wire clips used for supporting main runners shall maintain tight contact between the main runners and the carrying channels when the ceiling loads are imposed on the runners.

25.209.7 Ceiling Fixtures. Fixtures installed in acoustical tile or lay-in panel ceilings shall be mounted in a manner that will not compromise ceiling performance.

Fixtures shall not be supported from main runners or cross runners if the weight of the fixtures causes the total dead load to exceed the deflection capability of the ceiling suspension system. In such cases, the fixture load shall be supported by supplemental hangers within 6 inches (152.4 mm) of each corner, or the fixture shall be separately supported.

Fixtures shall not be installed so that main runners or cross runners will be eccentrically loaded except where provision is inherent in the system (or is separately provided for) to prevent undesirable section rotation or displacement, or both. In any case, runners supporting ceiling fixtures shall not rotate more than 2 degrees after the fixture loads are imposed.

Where fixture installation would produce rotation of runners in excess of 2 degrees, the fixtures shall be with the use of suitable accessory devices. These devices shall support the fixture in such a manner that the main runners and cross runners will be loaded symmetrically rather than eccentrically.

Part III—Lateral Design Requirements

SECTION 25.210 — SCOPE

Suspended ceilings which are designed and constructed to support ceiling panels or tiles, with or without lighting fixtures, ceiling-mounted air terminals or other ceiling-mounted services shall comply with the requirements of this standard.

EXCEPTIONS: 1. Ceiling area of 144 square feet (13.38 m^2) or less surrounded by walls which connect directly to the structure above are exempt from the lateral load design requirements of this standard.

2. Ceilings constructed of lath and plaster or gypsum board, screw or nail attached to suspended members that support a ceiling on one level extending from wall to wall are exempt from this standard.

SECTION 25.211 — MINIMUM DESIGN LOADS

25.211.1 Lateral Forces. Ceiling systems and their connections to the building structure shall be designed and constructed to resist the lateral force specified in Chapter 16, Part III of the Building Code.

Where the ceiling system provides lateral support for nonbearing partitions, it shall be designed for the prescribed lateral force reaction from the partitions as specified in Section 25.215.

Connection of lighting fixtures to the ceiling system shall be designed for a lateral force of 100 percent of the weight of the fixture in addition to the prescribed vertical loading as specified in Section 25.213.

25.211.2 Grid Members, Connectors and Expansion Devices. The main runners and cross runners of the ceiling system and their splices, intersection connectors and expansion devices shall be designed and constructed to carry a mean ultimate test load of not less than 180 pounds (801 N) or twice the actual load, whichever is greater, in tension with a 5-degree misalignment of the members in any direction, and in compression. In lieu of 5-degree misalignment, the load may be applied with a 1-inch (25.4 mm) eccentricity on a sample not more than 24 inches (610 mm) long on each side of the splice. The connections at splices and intersections shall all be of the mechanical interlocking type.

When the composition or configuration of ceiling systems members or assemblies and their connections are such that calculations of their allowable load-carrying capacity cannot be made in accordance with established methods of analysis, their performance shall be established by test.

Evaluation of test results shall be made on the basis of the mean values resulting from tests of three or more identical specimens, provided the deviation of any individual test result from the mean value does not exceed plus or minus 10 percent. The allowable load-carrying capacity as determined by test shall not exceed one half of the mean ultimate test value.

25.211.3 Substantiation. The ceiling systems manufacturer shall furnish lateral loading capacity and displacement or elongation characteristics, indicating the following:

1. Maximum bracing pattern and minimum wire sizes.

2. Tension and compression force capabilities of main runner splices, cross runner connections and expansion devices.

Tests shall be conducted by an approved testing agency.

SECTION 25.212 — INSTALLATION

25.212.1 Vertical Hangers. Suspension wires shall not be smaller than No. 12 gage (2.7 mm) spaced at 4 feet (1219 mm) on center or No. 10 gage (3.4 mm) at 5 feet (1524 mm) on center along each main runner unless calculations justifying the increased spacing are provided.

Each vertical wire shall be attached to the ceiling suspension member and to the support above with a minimum of three turns. Connection devices at the supporting construction shall be capable of carrying not less than 100 pounds (445 N).

Suspension wires shall not hang more than 1 in 6 out-of-plumb unless countersloping wires are provided.

Wires shall not attach to or bend around interfering material or equipment. A trapeze or equivalent device shall be used where obstructions preclude direct suspension. Trapeze suspensions shall be a minimum of back-to-back $1^1/_4$-inch (31.75 mm) cold-rolled channels for spans exceeding 48 inches (1219 mm).

25.212.2 Perimeter Hangers. The terminal ends of each cross runner and main runner shall be supported independently a maximum of 8 inches (203.2 mm) from each wall or ceiling discontinuity with No. 12 gage (2.7 mm) wire or approved wall support.

25.212.3 Lateral Force Bracing. Where substantiating design calculations are not provided, horizontal restraints shall be effected by four No. 12 gage (2.7 mm) wires secured to the main runner within 2 inches (50.8 mm) of the cross runner intersection and splayed 90 degrees from each other at an angle not exceeding 45 degrees from the plane of the ceiling. A strut fastened to the main runner shall be extended to and fastened to the structural members supporting the roof or floor above. The strut shall be adequate to resist the vertical component induced by the bracing wires. These horizontal restraint points shall be placed not more than 12 feet (3658 mm) on center in both directions with the first point within 6 feet (1829 mm) from each wall. Attachment of the restraint wires to the structure above shall be adequate for the load imposed.

Lateral-force bracing members shall be spaced a minimum of 6 inches (154 mm) from all horizontal piping or ductwork that is not provided with bracing restraints for horizontal forces. Bracing wires shall be attached to the grid and to the structure in such a manner that they can support a design load of not less than 200 pounds (890 N) or the actual design load, whichever is greater, with a safety factor of 2.

25.212.4 Perimeter Members. Unless perimeter members are a structural part of the approved system, wall angles or channels shall be considered as aesthetic closures and with no structural value. Ends of main runners and cross members shall be tied together to prevent their spreading.

25.212.5 Attachment of Members to the Perimeter. To facilitate installation, main runners and cross runners may be attached to the perimeter member at two adjacent walls with clearance between the wall and the runners maintained at the other two walls or as otherwise shown or described for the approved system.

SECTION 25.213 — LIGHTING FIXTURES

Intermediate or heavy-duty ceiling systems as defined in Section 25.202 shall be used for the support of lighting fixtures.

All lighting fixtures shall be positively attached to the suspended ceiling system. The attachment device shall have a capacity of 100 percent of the lighting fixture weight acting in any direction.

When intermediate systems are used, No. 12 gage (2.7 mm) hangers shall be attached to the grid members within 3 inches (76 mm) of each corner of each fixture. Tandem fixtures may utilize common wires.

When heavy-duty systems are used, supplemental hangers are not required if a 48-inch (1219 mm) modular hanger pattern is followed. When cross runners are used without supplemental hangers to support lighting fixtures, these cross runners shall provide the same carrying capacity as the main runner.

Lighting fixtures weighing less than 56 pounds (25.4 kg) shall have, in addition to the requirements outlined above, two No. 12 gage (2.7 mm) hangers connected from the fixture housing to the structure above. These wires may be slack.

Lighting fixtures weighing 56 pounds (25.4 kg) or more shall be supported directly from the structure above by approved hangers.

Pendant-hung lighting fixtures shall be supported directly from the structure above with No. 9 gage (3.8 mm) wire or approved alternate support without using the ceiling suspension system for direct support.

SECTION 25.214 — MECHANICAL SERVICES

Ceiling-mounted air terminals or services weighing less than 20 pounds (9.07 kg) shall be positively attached to the ceiling suspension main runners or to cross runners with the same carrying capacity as the main runners.

Terminals or services weighing 20 pounds (9.07 kg), but not more than 56 pounds (25.4 kg), in addition to the above, shall have two No. 12 gage (2.7 mm) hangers connected from the terminal or service to the ceiling system hangers or to the structure above. These wires may be slack.

Terminals or services weighing more than 56 pounds (25.4 kg) shall be supported directly from the structure above by approved hangers.

SECTION 25.215 — PARTITIONS

Where the suspended ceiling system is required to provide lateral support for permanent or relocatable partitions, the connection of the partition to the ceiling system, the ceiling system members and their connections, and the lateral force bracing shall be designed to support the reaction force of the partition from prescribed loads applied perpendicular to the face of the partition. These partition reaction forces shall be in addition to the loads described in Section 25.211. Partition connectors, the suspended ceiling system and the lateral-force bracing shall be engineered to suit the individual partition application and shall be shown or defined in the drawings or specifications.

SECTION 25.216 — DRAWINGS AND SPECIFICATIONS

The drawings shall clearly identify all systems and shall define or show all supporting details, lighting fixture attachment, lateral-force bracing, partition bracing, etc. Such definition may be by reference to this standard, or approved system, in whole or in part. Deviations or variations shall be shown or defined in detail.

TABLE 25-2-A—MINIMUM LOAD-CARRYING CAPABILITIES OF MAIN RUNNER MEMBERS

MAIN RUNNER MEMBERS	SUSPENSION SYSTEM (pounds per linear foot) × 14.59 for N/m		
	Direct-hung	Indirect-hung	Furring Bar
Light-duty	5.0	2.0	4.5
Intermediate-duty	12.0	3.5	6.5
Heavy-duty	16.0	8.0	—

TABLE 25-2-B—STRAIGHTNESS TOLERANCES OF STRUCTURAL MEMBERS OF SUSPENSION SYSTEMS

DEFORMATION	STRAIGHTNESS TOLERANCES
Bow	$^1/_{32}$ in. in any 2 ft. (1.3 mm in any 1 m), or $^1/_{32}$ in. × (total length, ft.)/2 [1.3 mm × (total length, m)/2]
Camber	$^1/_{32}$ in. in any 2 ft. (1.3 mm in any 1 m), or $^1/_{32}$ in. × (total length, ft.)/2 [1.3 mm × (total length, m)/2]
Twist	1 degree in any 2 ft. (610 mm), or 1 degree × [total length, ft. (m)]/2

UNIFORM BUILDING CODE STANDARD 26-1
TEST METHOD TO DETERMINE POTENTIAL HEAT OF BUILDING MATERIALS

Test Standard of the International Conference of Building Officials

See Sections 601.3, 2602.4 and 2602.5.2, *Uniform Building Code*

SECTION 26.101 — SCOPE

26.101.1 General. This method of test defines a means of determining the potential release of heat of materials (typically involved in building fires) under specified conditions. The method is applicable to a variety of materials including metals and especially materials with low combustible content. Determinations may be made on simple materials or on composite assemblies of materials from a which a representative sample can be taken and pulverized into a homogeneous mixture.

26.101.2 Definition of Potential Heat. Potential heat of a material is the difference between the heat of combustion of a representative specimen of the material and the heat of combustion of any residue remaining after exposure to a specified standard fire using combustion, calorimetric techniques.

SECTION 26.102 — TEST PROCEDURES

26.102.1 General. One of two specimens removed from the material to be tested shall be pulverized, pelleted and burned in a high-pressure-oxygen atmosphere in accordance with approved standard procedures for determination of the heat of combustion. Caution should be observed when performing bomb calorimetric measurements on materials containing significant proportions of metallic ingredients. Apart from the high reaction temperatures which may occur with the resulting possible involvement of portions of the bomb, consideration should be given to the possibility of electrical shorts in the ignition system.

26.102.2 Test Specimens. Two air-dry specimens representative of the material or assembly involved are required for each determination. A specimen is considered "air dry" when it has reached constant weight in an atmosphere maintained at 73°F ± 2°F (23°C ± 1°C) and 50 ± 5 percent relative humidity. The two specimens are subject to separate test procedures as set forth in Sections 26.102.3 and 26.102.4.

26.102.3 Procedure for Direct Bomb Test. The following steps shall be used for the direct bomb test:

Step 1. All or a representative portion of this specimen shall be pulverized into a form suitable to pass a No. 60 sieve (250 µm).

Step 2. A 1-gram pellet of a representative sample of the powder formed in Step 1 is prepared.

Step 3. The pellet formed in Step 2 shall be used as the test specimen following the procedures described in Section 26.102.1. The usual sulfur and acid corrections shall be made. These take into account the oxidation of sulfur and nitrogen, if present, which would not normally occur during fire exposure.

Step 4. If after being fired in the oxygen bomb the pellet is found to have burned completely or to have left no significant amount of residue or ash, the heat of combustion on an air-dry basis shall be computed, and Steps 5, 6 and 7 shall be omitted.

Step 5. If the pellet does not burn or a residue remains after the firing, another 1-gram pellet shall be prepared with a mixture of the powdered sample and a standard sample of benzoic acid combustion promoter in approximately equal weight proportions.

Step 6. The pellet prepared in Step 5 shall be used as a test specimen following the same procedures as for the original specimen.

Step 7. A correction for the heat of combustion of the benzoic acid present in the pellet is supplied to the measured heat release by the specimen. The heat of combustion of the specimen material on an air-dry basis is then computed.

26.102.4 Procedure for Muffle Furnace and Bomb Test. The following steps shall be used for the muffle furnace and bomb test:

Step 1. An air-dry specimen representative of the test material or assembly shall be cut in the form of a rectangular prism $^1/_2$ inch by $^3/_4$ inch by 3 inches (13 mm by 19 mm by 76 mm). Sheet materials may be folded or laminated to these dimensions.

Step 2. The muffle furnace is preheated to 1,382°F ± 18°F (750°C ± 10°C) The weighed specimen is supported in a fused silica or ceramic container of $1^1/_4$-inch (32 mm) inside diameter by 4 inches (102 mm) in length. The specimen, container cap and the tube for supply air to the bottom of the container are assembled. The assembly is then placed on a firebrick support within the electric muffle furnace. Firing is continued for two hours with a regulated air flow of $^1/_{10}$ cubic foot per minute (0.47 L/s) measured under laboratory conditions to assist in oxidation of the specimen. In cases where ignition occurs immediately, application of air is delayed until initial flaming has stopped.

Step 3. The container with the specimen shall be cooled in a desiccator, after which the weight of the residue is determined.

Step 4. If the residue from the muffle-firing procedure is less than 5 percent of the initial weight of the specimen, Steps 5 through 7 following shall be omitted, and the heat of combustion previously determined under the direct bomb test shall be reported as the potential heat of the material.

Step 5. If the residue after the muffle firing is in excess of 5 percent of the original specimen weight, the residue shall be pulverized, mixed with an equal weight of benzoic acid and treated as specified in the procedure for direct bomb test. The resulting heat of combustion is reported as that of the residue.

Step 6. The heat of combustion of the residue is multiplied by the ratio of the residue weight to the original specimen weight.

Step 7. The resulting difference in the heats of combustion is a measure of the gross heat released during the firing process in the muffle furnace and is reported as the potential heat.

26.102.5 Reporting Potential Heat. The potential heat determined either as a result of Step 4 or 7 of Section 26.102.4 shall be reported as the potential heat of the material. The potential heat shall be reported in either Btu per pound (kJ/kg) or Btu per cubic foot (kJ/kg).

UNIFORM BUILDING CODE STANDARD 26-2
TEST METHOD FOR THE EVALUATION OF THERMAL BARRIERS

Standard of the International Conference of Building Officials

See Sections 601.3 and 2602.4, *Uniform Building Code*

SECTION 26.201 — SCOPE

This method of test for thermal barriers is applicable to building construction assemblies which incorporate foamed plastics which are required to be covered by a protective membrane.

The purpose of the test is to evaluate the temperature use or thermal transmission performance of the thermal barrier when the assembly is subjected to a standard fire exposure condition. This method does not evaluate the performance of the thermal barrier material with respect to its ability to remain in place under all actual fire exposure conditions.

SECTION 26.202 — TEST SPECIMEN

The thermal barrier material and method of securing the thermal barrier shall be representative of the construction for which the thermal barrier index rating is required.

If the thermal barrier material incorporates joints, at least one such joint shall be incorporated in the test specimen.

SECTION 26.203 — SPECIMEN CONDITIONING

Prior to fire test, assemblies shall be conditioned so as to provide a moisture conditioning within the specimen approximately representative of that likely to exist in similar construction in buildings. For that purpose of standardization, this condition is to be considered as that which would be established at equilibrium resulting from conditioning in an ambient atmosphere of 50 ± 5 percent relative humidity and 73.4°F ± 5°F (23°C ± 3°C).

SECTION 26.204 — TEST CONDITIONS

26.204.1 General. The dimensions of the furnace shall be as shown in Figure 26-2-1 entitled "Small-scale Horizontal Exposure Furnace."

The thermal barrier shall be installed in a manner representative of the construction for which the thermal barrier index rating is required. The specimen exposed to the fire shall have minimum horizontal dimensions of 28 inches by 28 inches (711 mm by 711 mm).

The calcium-silicate board shall be installed as shown in Figure 26-2-2, shall have a thickness of $^1/_2$ inch (13 mm) and a density of 46 pounds per cubic foot (736 kg/m^3).

26.204.2 Furnace Temperature. The furnace temperature, as recorded by the thermocouples specified in Section 26.204.3, shall follow the standard time-temperature curve specified in UBC Standard 7-1 for which the temperatures at 5, 10 and 15 minutes following the commencement of the test are as given in Table 26-2-A.

26.204.3 Accuracy of Furnace Control. The accuracy of the furnace control shall be such that the area under the time-temperature curve given by the average of the specified thermocouples shall be within 10 percent of the corresponding area under the standard time-temperature curve specified in Section 26.204.2.

26.204.4 Thermocouple Location. The furnace temperature shall be registered by three or more thermocouples located so as to monitor the uniformity of the exposure to the thermal barrier. They shall be located 12 inches (305 mm) away from the face of the specimen and shall have a length of lead exposed within the furnace of not less than 12 inches (305 mm). They shall be enclosed in sealed porcelain tubes $^3/_4$ inch (19 mm) in outside diameter and $^1/_8$ inch (3.2 mm) in wall thickness or, as an alternative in the case of base metal thermocouples, enclosed in sealed, standard-weight, $^1/_2$-inch (13 mm) black wrought-steel or black wrought-iron pipe.

The temperature of the interface of the thermal barrier and the calcium-silicate board shall be sensed by at least nine thermocouples as shown in Figure 26-2-2 located at the center of the specimen, at the center of each quarter of the specimen and at potentially critical locations such as joints in the material. The leads to each thermocouple shall be in the plane of this interface for a length of not less than 1$^1/_2$ inches (38 mm). The wires for the thermocouples shall not be heavier than No. 20 AWG (0.032 inch) (0.81 mm).

26.204.5 Furnace Pressures. Furnace pressures shall be kept as close to atmospheric pressure as possible during the test.

26.204.6 Duration of Test. The test shall be continued for 15 minutes or until the thermal barrier has fallen away or disintegrated.

26.204.7 Recording Temperatures. Throughout the period of test, the temperature registered at each of the thermocouples required by Section 26.204.4 shall be recorded at intervals not exceeding one minute.

SECTION 26.205 — DETERMINATION OF THERMAL BARRIER INDEX

The thermal barrier index shall be determined as the number of minutes at which the temperature rises above initial temperature at the interface of the thermal barrier and the calcium-silicate board has not exceeded 250°F (121°C) average or 325°F (163°C) at any one of the thermocouples specified in Section 26.204.4.

TABLE 26-2-A—FURNACE TEMPERATURES

TIME	TEMPERATURE	
	°F	°C
5 minutes	1000	538
10 minutes	1300	704
15 minutes	1399	760

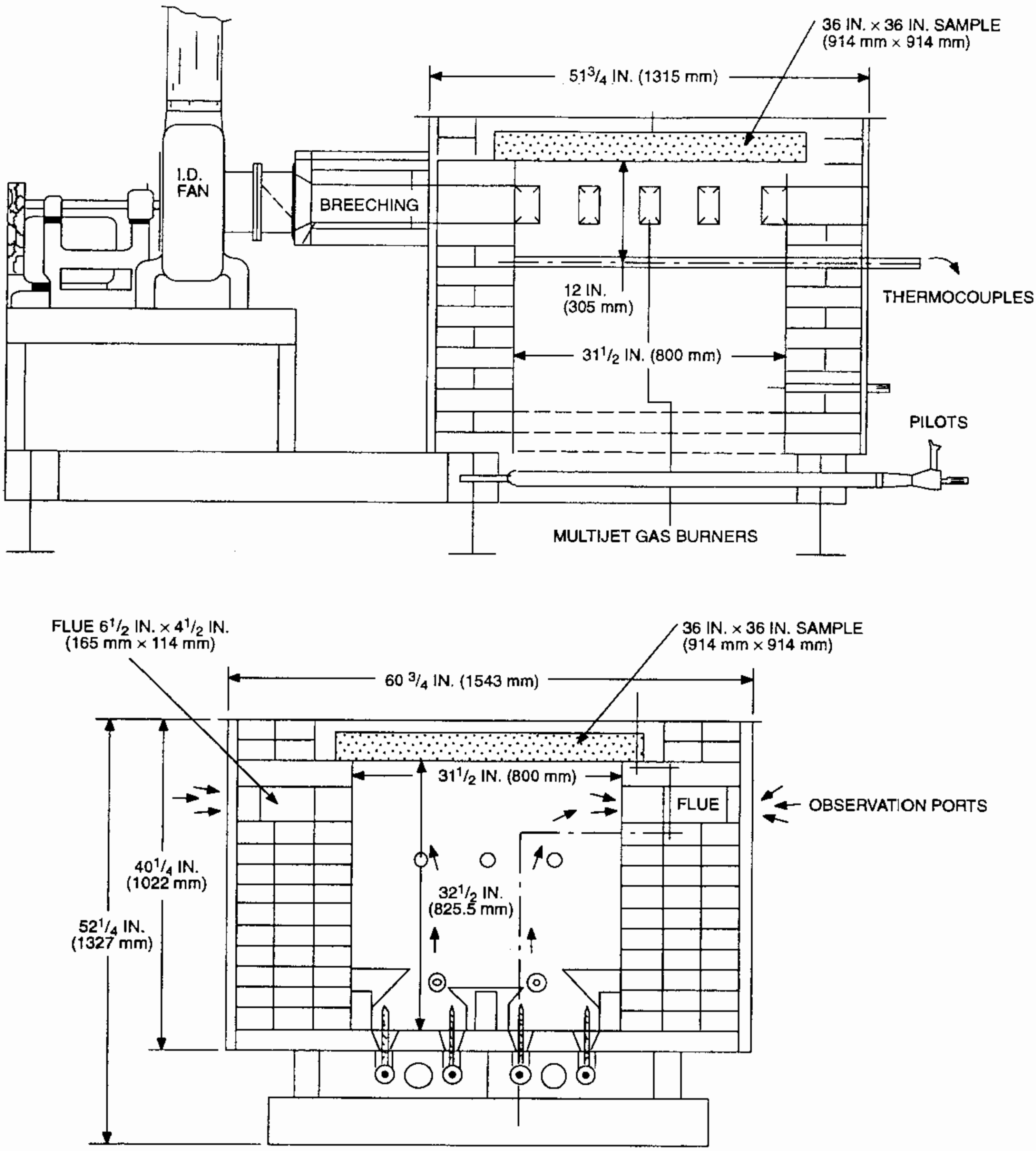
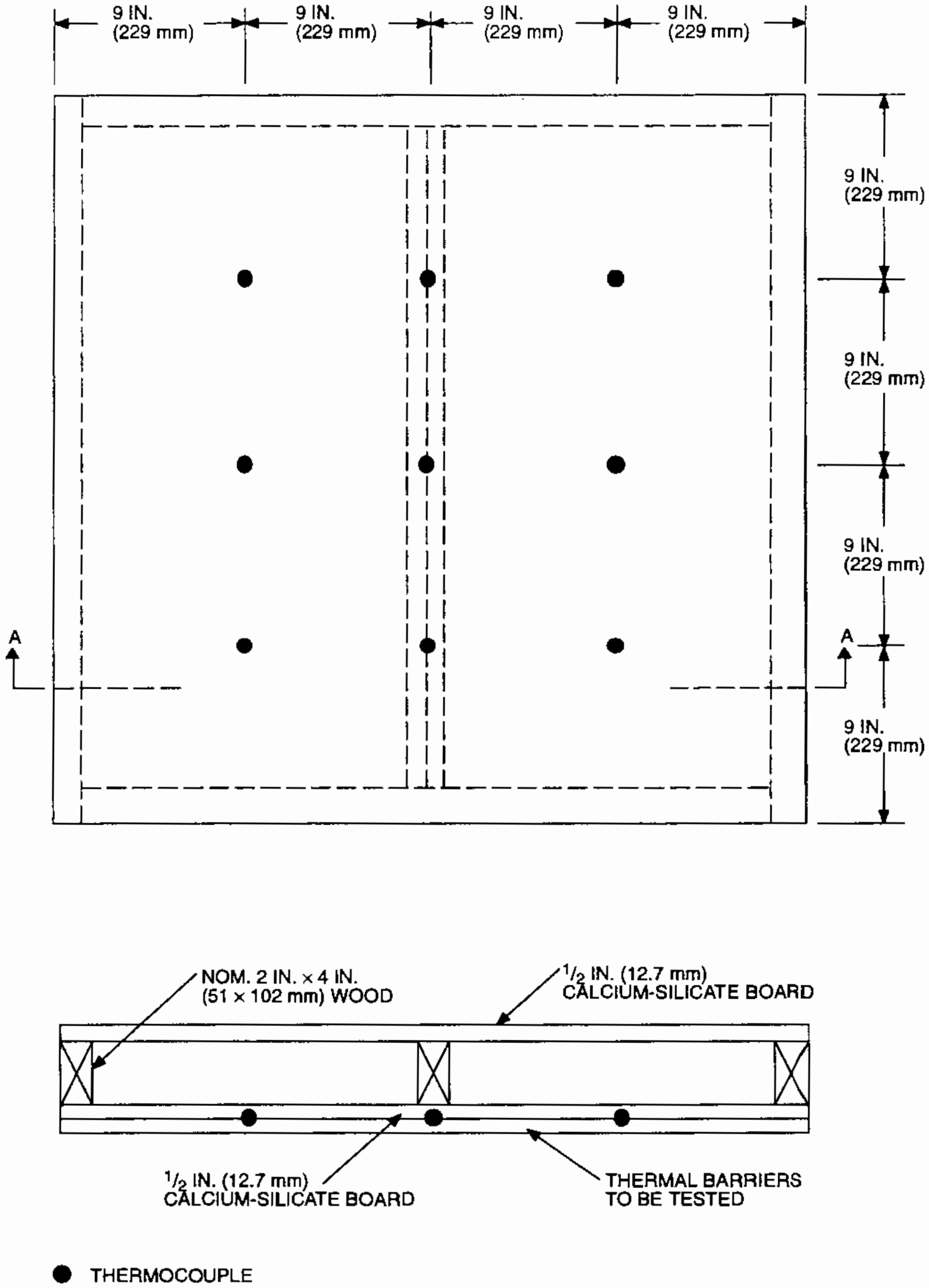


FIGURE 26-2-1—SMALL-SCALE HORIZONTAL EXPOSURE FURNACE



SECTION A–A

FIGURE 26-2-2—THERMOCOUPLE LOCATIONS

UNIFORM BUILDING CODE STANDARD 26-3

ROOM FIRE TEST STANDARD FOR INTERIOR OF FOAM PLASTIC SYSTEMS

Test Standard of the International Conference of Building Officials

See Sections 601.3 and 2602.6, *Uniform Building Code*

SECTION 26.301 — SCOPE

This standard details a test method to evaluate the burning characteristics of foam plastic assemblies in a standard room configuration. It is intended to be a test for use under Section 2602.6 of this code.

SECTION 26.302 — FIRE TEST STRUCTURE

The fire test structure shall consist of a room with interior dimensions of 8 feet ± 1 inch (2438 mm ± 25 mm) by 12 feet ± 1 inch (3658 mm ± 25 mm) having a ceiling height of 8 feet ± 0.5 inch (2438 mm ± 13 mm) located in an enclosed building. A doorway 2 feet 6 inches ± 0.5 inch (762 mm ± 13 mm) by 7 feet 0 inches ± 0.5 inch (2134 mm ± 13 mm) shall be centered in one of the 8-foot-long (2438 mm) walls of the test structure. See Figure 26-3-1.

The wall test area shall consist of wall sections 8 feet (2438 mm) square intersecting at the corner opposite the doorway. Ceiling specimens shall cover an area 8 feet (2438 mm) square with two edges resting on or adjoining the intersecting wall test sections. Vertical and horizontal joints shall be included in the test wall and ceiling specimens to represent field conditions.

Except for composite panels, the construction of the walls and ceiling beyond the test area which serve as a substrate for foam plastic shall consist of $^1/_2$-inch (13 mm) glass-reinforced cement board or $^1/_2$-inch (13 mm) gypsum wallboard supported by suitable framing.

Composite wall and ceiling or roof panels with structural foam plastic cores shall be installed without a substrate and in the manner intended for use, including connections along all joints and perimeters. Panels intended to support superimposed loads shall be fire tested with the panels loaded in a manner resulting in conditions of maximum allowable stress.

EXCEPTION: Testing under loaded conditions may be waived in Type V construction when the panels need not be fire resistive.

When the test concerns nonstructural protective material, the foam plastic base shall be applied to the maximum thickness anticipated and have a minimum flame-spread rating of 75.

Material and fabrication of test assemblies must be certified by the testing agency as complying with descriptions or details that are a part of the report of tests.

The building containing the test structure shall have a temperature between 60°F and 90°F (15.6°C and 32.2°C) at the start of the fire test and shall be free of excessive drafts.

SECTION 26.303 — TEST PROCEDURE

26.303.1 Cribs. The fuel for the room test shall be a wood crib constructed of $1^1/_2$-inch (38 mm) square white fir, Douglas fir or spruce-pine fir fire sticks cut to 15-inch (381 mm) lengths. The equivalency of other types of wood shall be based on comparative full-scale tests. At a 12 percent moisture content, the crib shall weigh 30 pounds (13.6 kg) and be 15 inches (381 mm) square in plan. One 8d nail shall be driven at each corner of each tier. Each interior stick shall be attached at each end to a perimeter stick with one 8d nail. Approximately 45 to 50 sticks will be involved and must be assembled in nine or 10 tiers with five sticks in each tier. The placement of sticks in each tier shall be oriented at 90 degrees to sticks in adjacent tiers. After fabrication the crib shall be conditioned to a maximum constant moisture content of 8 percent. Standard bricks cut in half and placed at each corner of the crib shall be used to support the crib not less than 3 inches (76 mm) above the floor located as described in Section 26.303.3.

26.303.2 Starter Material. One pound of shredded, fluffed wood excelsior is distributed around the bricks with the excelsior extending from the wall surfaces and covering an area approximately 21 inches by 21 inches (533 mm by 533 mm). To start the test, the wood excelsior is soaked with 4 ounces (0.12 L) of reagent ethyl alcohol or absolute ethyl alcohol, except for a triangular area approximately 6 inches by 6 inches (153 mm by 153 mm) diametrically opposite the intersection of the walls. The crib is then located 1 inch (25 mm) from the intersecting wall surfaces on the bricks.

26.303.3 Ignition. A match is placed in the excelsior to initiate burning. Under proper conditions for ignition, flames typically progress slowly through the dry excelsior for only 10 seconds until the soaked alcohol portion is reached, whereupon flames flash through the entire excelsior, providing uniform application of the ignition flame beneath the entire crib.

26.303.4 Extinguishment. Fire extinguishment is permitted 15 minutes after crib ignition. Charring of the test panels must not be affected by the extinguishing procedures.

26.303.5 Temperature Readings. Temperature readings at locations shown in Figure 26-3-2 shall be taken at maximum two-minute intervals and at 15 minutes from crib ignition with properly calibrated thermocouples of the type described in UBC Standard 7-1.

26.303.6 Smoke Measurement. Smoke generated during the 15-minute test period shall be measured by photoelectric instrumentation if there is sufficient available data to establish a basis of acceptance. In lieu of this, the test report shall include films taken during the test.

SECTION 26.304 — CONDITIONS OF ACCEPTANCE

A foam plastic wall or ceiling assembly shall be considered as meeting the requirements for acceptable performance within the following conditions:

1. Charring of the foam plastic shall not extend to the outer extremities of the test area within a 15-minute period after ignition of the excelsior. Discoloration extending not more than $^1/_4$ inch (6 mm) into the foam plastic shall not be considered as charring.

2. Smoke levels generated during the test period shall not be excessive.

3. Structural panels shall sustain the applied load during the test period.

SECTION 26.305 — REPORT OF TEST

The report of test shall include the following:

1. A detailed description of the foam plastic assembly including specifications on all components and manner of fabrication and installation.

2. A statement by the testing agency that preparation, fabrication and installation of the foam plastic assembly was in accordance with Item 1 and this standard.

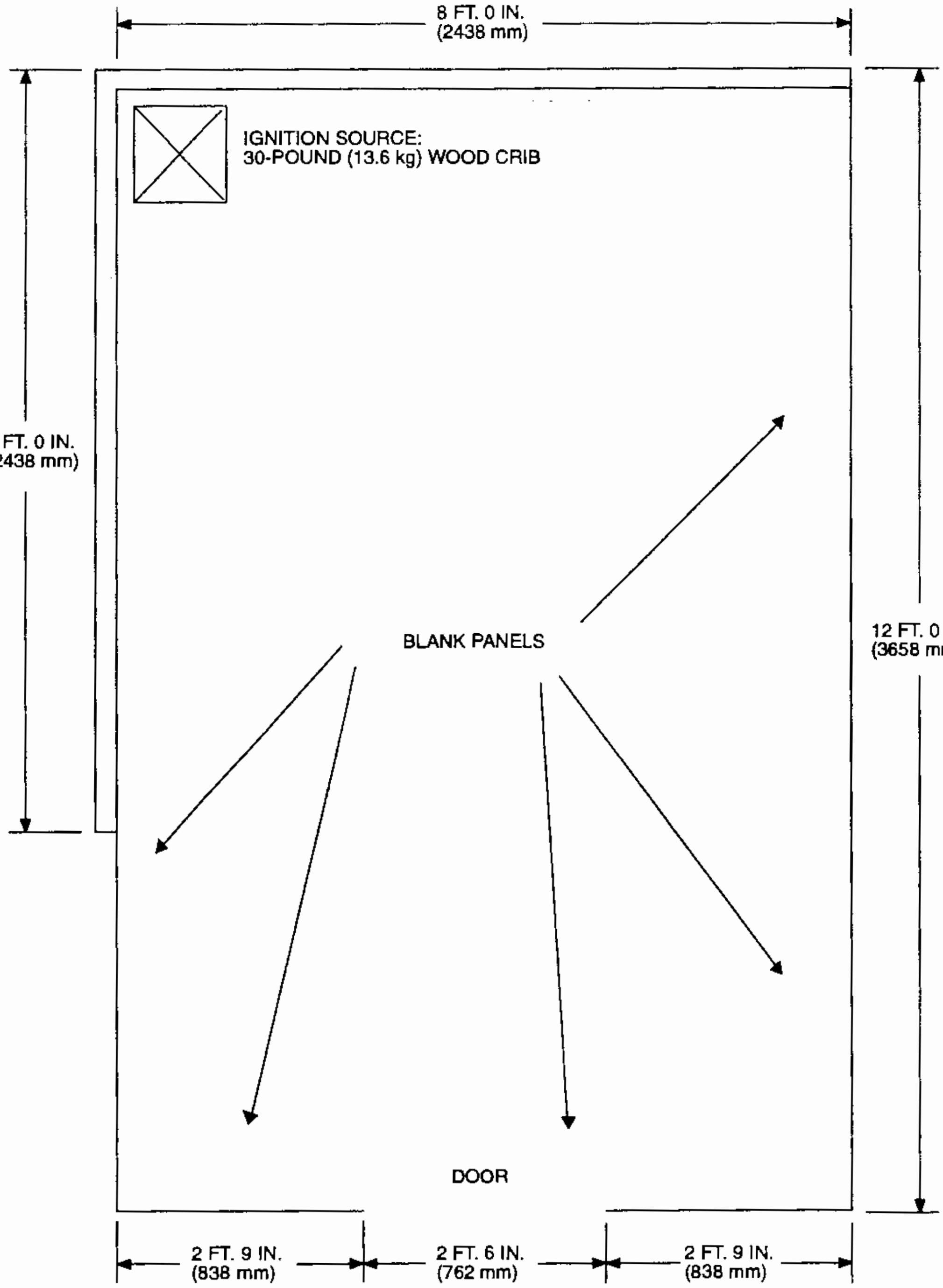
3. A statement of compliance or specific points of deviation from test procedures set forth in this standard.

4. An account of visual observation of the foam plastic assemblies during the test.

5. Location and extent of charring in the foam plastic assemblies at the conclusion of the test.

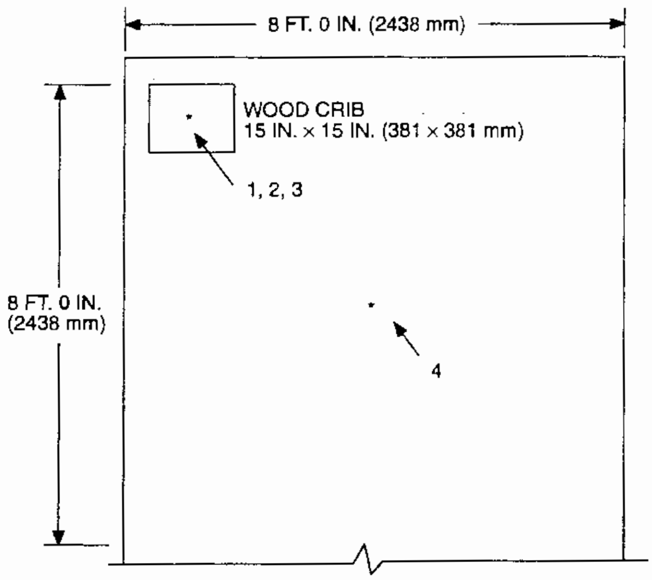
6. Temperature readings during the test as set forth in Section 26.303.5.

7. Smoke measurement during the test or films of the test.

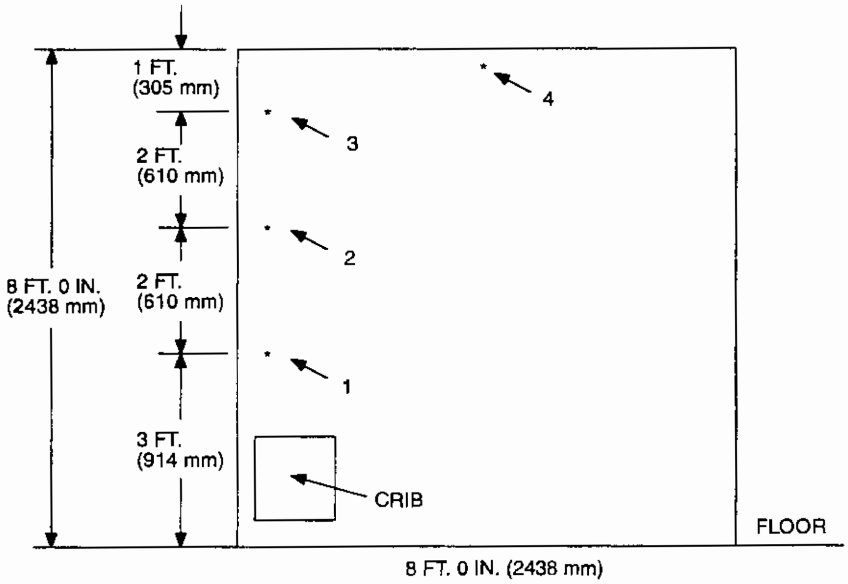


[DOOR: 2 FT. 6 IN. (762 mm) WIDE BY 7 FT. 0 IN. (2134 mm) HIGH]

FIGURE 26-3-1—ROOM TEST CONFIGURATION



PLAN VIEW



* THERMOCOUPLE LOCATIONS ELEVATION

NOTES:
1. Thermocouples 1, 2 and 3 located 3 inches (76 mm) from adjacent wall surfaces.
2. Thermocouple 4 located 1 inch (25 mm) below the ceiling, 4 feet (1219 mm) from each of three walls.

FIGURE 26-3-2—THERMOCOUPLE LOCATIONS

UNIFORM BUILDING CODE STANDARD 26-4
METHOD OF TEST FOR THE EVALUATION OF FLAMMABILITY CHARACTERISTICS OF EXTERIOR, NONLOAD-BEARING WALL PANEL ASSEMBLIES USING FOAM PLASTIC INSULATION

Test Standard of the International Conference of Building Officials

See Sections 601.3 and 2602.5.2, *Uniform Building Code*

SECTION 26.401 — SCOPE

This test provides a method of determining the flammability characteristics of foam plastic insulated, exterior, nonload-bearing wall panel assemblies. The test structure is intended to simulate a "full-scale" multistory building installation. Test assemblies are evaluated on a "full-scale" basis.

The primary performance characteristics to be evaluated are:

1. Capability of the test panels to resist vertical spread of flame within the core of the panel from one story to the next;

2. Capability to resist flame propagation over the exterior face of the panels;

3. Capability to resist vertical spread of flame over the interior (room side) surface of the panels from one story to the next; and

4. Capability to resist lateral spread of flame from the compartment of fire origin to adjacent spaces.

SECTION 26.402 — FIRE TEST STRUCTURE

The fire test structure shall consist of a two-story, 24-foot-high (7315 mm) building having unfinished/unprotected inside room dimensions of (edge of slab to concrete block) 15 feet ± 2 inches (4572 mm ± 51 mm) wide by 15 feet ± 2 inches (4572 mm ± 51 mm) deep. See Figures 26-4-1A through 26-4-1D. Floor-to-floor height (unfinished/unprotected) shall be 12 feet ± 2 inches (3658 mm ± 51 mm). Floors and roof shall be of reinforced concrete or similar construction supported with columns. The first-floor slab shall be 12 inches ± 1 inch (305 mm ± 25 mm) thick, whereas the second floor and roof shall be 8 inches ± 0.5 inch (203 mm ± 13 mm) thick. Permanent walls of the structure shall be of 8-inch-thick (200 mm) concrete block or similar construction. The concrete block shall completely close two walls of the test structure, except for a 3-foot, 4-inch ± 3 inches (1016 mm ± 76 mm) wide by 6-foot, 8-inch ± 3 inches (2032 mm ± 76 mm) high access opening at the first- and second-floor levels. Additional access openings in the second-floor area are permitted, but must be closed off prior to test.

Spandrel beams on the underside of the second floor shall be designed to be replaceable and are required only when the mounting of the test sample requires them to be present. When used, the spandrel beams shall be of W10 by 12 (W250 by 18) and shall be installed as shown in Figures 26-4-1A through 26-4-1D.

Test panels shall be secured to the test structure using a girt system of replaceable 4-inch-by-4-inch-by-$^3/_{16}$-inch (102 mm by 102 mm by 4.8 mm) steel angles. The test panels shall completely close the two walls of the test structure, except for a window opening in one of the test walls. One of the test walls shall be fabricated with a 4-foot ± 0.5 inch (1219 mm ± 13 mm) high by 8-foot ± 0.5 inch (2438 ± 13 mm) long window opening in the first story. The window opening shall have a sill height of 3 feet ± 1 inch (914 mm ± 25 mm). The window opening shall be the only opening in the first-story burn room enclosure at the time of test.

Test panels shall be secured to the test structure using a method of fastening including all joints and perimeters to represent actual field conditions. Details of erection shall follow the manufacturer's instructions and shall be typical of actual product use. When a product may have vertical or horizontal joints, joints typical of normal construction, including caulking, backing and other details as appropriate, shall be incorporated in the test panels.

Prior to the start of a test, the access opening in the burn room shall be closed using an assembly having a minimum of three layers of $^5/_8$-inch-thick (15.9 mm) Type X gypsum wallboard on the burn room side of any supports. The access door opening in the second story may remain open during testing, but any additional access openings shall be closed.

In the first-floor burn room prior to each test, the two concrete block walls and the ceiling are to be protected with three layers of $^5/_8$-inch (15.9 mm) Type X gypsum wallboard. A framing/attachment system may be used between the concrete block/Type X gypsum wallboard and the concrete ceiling/Type X gypsum wallboard with the provision that the framing/attachment system not be thicker than 1.5 inches (38 mm). The floor is protected with at least one layer of $^5/_8$-inch (15.9 mm) Type X gypsum wallboard. The column located within the burn room shall be protected with appropriate fireproofing and boxed in with a single layer of $^5/_8$-inch (15.9 mm) Type X gypsum wallboard. Spandrel beams if used may or may not be protected at the discretion of the testing laboratory or client. The outriggers and the girt angles are not protected.

In the second story, prior to each test, the concrete block walls and ceiling are protected by one layer of Marinite board or $^5/_8$-inch (15.9 mm) Type X gypsum wallboard. The floor is protected by one layer of $^5/_8$-inch-thick (15.9 mm) Type X gypsum wallboard. The interior steel column shall be appropriately protected and boxed with one layer of $^5/_8$-inch (15.9 mm), Type X gypsum wallboard. Girt angles are left unprotected.

Material and fabrication of test assemblies must be certified by the testing agency as complying with the description or details that are a part of the report of test. The test laboratory shall retain a 1-foot-by-1-foot-square (305 mm by 305 mm) sample of the test system.

For outdoor facilities a windshield shall be utilized (see Figure 26-4-2) to minimize wind action across the face of the test structure.

SECTION 26.403 — INSTRUMENTATION AND DOCUMENTATION

26.403.1 Instrumentation. In this procedure, test instrumentation consists primarily of temperature measurements placed in the following locations:

1. Inside room of fire origin—underside of second-story floor and underside of structural steel members.

2. Window opening—6 inches (153 mm) below top of window opening.

3. On exterior face of wall panels.

4. On interior face of wall panels—at floors and in panel cores at second-floor level and above.

Temperature measurements are made using 20-gage Type K thermocouples.

Specific thermocouple locations are provided in Figures 26-4-3 through 26-4-7. Temperatures shall be recorded at intervals not to exceed 15 seconds.

26.403.2 Documentation. Documentation of tests is provided by:

1. Color videotape of exterior, and
2. Color 35 mm slides of exterior.

In order to facilitate documentation of flame penetration (if any) into the second-floor level, a video camera is placed looking inside the second floor. The camera is aimed at the test wall/floor intersection and observations relating to flame penetration and/or smoke development are made.

After the test is terminated by extinguishment of the fire in the wood crib, special note shall be made of the extent and duration of any residual burning in the test panel.

After a cool-down period, the interior and exterior sides of the test walls shall be described as to visual appearance and shall be photographed. The test walls shall then be dismantled and dissected to determine height and depth of char damage within the cavity and condition of panel facings.

SECTION 26.404 — TEST PROCEDURE

26.404.1 Crib Fire Exposure. The burn room shall be provided with a 1,285-pound (583 kg) wood crib fuel load which, when burned, produces the standard time/temperature curve described in Sections 7.102 and 7.103 of UBC Standard 7-1 as measured using the average of thermocouples (see Figure 26-4-3) inside the burn room for a period of not less than 30 minutes. The crib shall generate a fire exposure producing an intermittent flame plume similar to that generated in an actual fire discharging out of the burn room window. During the test the plume shall periodically attach itself to and shall expose the face of the test panel for a minimum of 5 feet (1524 mm) above the top of the burn room window. Makeup air for combustion of the crib shall be supplied solely through the 4-foot-by-8-foot (1219 mm by 2438 mm) window opening. No other ventilation is provided. Control temperatures are measured at the underside of the second floor and at the underside of the spandrel beams if used.

The fuel for the fire exposure shall be a 1,285-pound (583 kg) wood crib. The crib shall be constructed of dried 2-inch-by-4-inch (51 by 102 mm) No. 1 select grade Douglas fir members having a moisture content of 11 percent plus or minus 1 percent. Crib members are cut into 4-foot and 8-foot (1219 and 2438 mm) lengths. The 2-inch-by-4-inch (51 by 102 mm) members shall be nailed into a lattice-type crib consisting of full tiers and one partial tier of three 8-foot (2438 mm) 2 by 4's (51 mm by 102 mm). Overall crib dimensions shall be 48 inches deep (1219 mm), 96 inches (2438 mm) wide and $28^1/_2$ inches (724 mm) high. See Figure 26-4-9. The determining factor in the crib construction shall be the weight; however, in no case shall less than 18 tiers be used.

The crib shall be centered on the burn room window but located off center toward the window. See Figure 26-4-9.

The crib shall be supported above floor level by 8-inch concrete blocks. A layer of $^5/_8$-inch-thick (15.9 mm) Type X gypsum wallboard is placed between the crib and the concrete block support. See Figure 26-4-10.

26.404.2 Starter Material. Prior to ignition, 1 gallon (3.8 L) of kerosene is equally divided into eight pans ($7^1/_4$ inches in diameter, $^{15}/_{16}$ inch deep) (184 mm in diameter, 24 mm deep) and the pans are placed under the crib. The pans are interconnected using kerosene-soaked rags that have been soaked sufficiently to facilitate ignition. Additionally, 2 pints (1 L) of kerosene are poured over the crib just prior to ignition. The kerosene is to provide quick ignition of the crib and also cause an initial rapid increase in temperature within the burn room.

26.404.3 Ignition. After proper operation of all instrumentation and documentation equipment is verified, the pans containing kerosene are placed under the crib.

A match or torch is used to ignite a kerosene-soaked rag which, in turn, causes flames to spread to the kerosene in the eight pans located under the crib. The start of the test is ignition of the kerosene in one of the pans. The fire develops quickly with flames reaching the ceiling of the burn room within several minutes. Flames begin to emerge from the burn room window in three to five minutes.

26.404.4 Control. During the last several minutes of the test, the crib fire may produce higher temperatures than those described in UBC Standard 7-1. Should the average temperature in the burn room as measured by the thermocouples described in Figure 26-4-3 exceed 1,800°F (982°C) for a period greater than one minute, then a control measure may be used at the discretion of the testing laboratory or the client to maintain the temperatures within the room in accordance with Section 26.404.1. One example of a control measure is the use of water fog such that approximately 1 gallon (3.8 L) of water is applied directly to the wood crib.

26.404.5 Duration. The test is continued for 30 minutes. At the conclusion of the test, the crib fire is extinguished using a hose line. Any residual burning in or on the surface of the test panels shall be noted and panels shall be allowed to burn freely until self-extinguishment occurs or fire spreads to the limits of the test panels.

26.404.6 Weather Conditions. Outdoor tests shall not be conducted if, at the start of the test, the average wind velocity exceeds 10 miles per hour (16 km/h), if the relative humidity is 100 percent or if there is fog or precipitation present at the test site.

SECTION 26.405 — CONDITIONS OF ACCEPTANCE

The performance of a test assembly shall be judged on the basis of visual observations both during and after the test in conjunction with temperature data. An exterior wall assembly shall be considered as meeting the requirements for acceptable performance if during the 30-minute test period:

1. Flames do not propagate over the surface of the test walls beyond the immediate area of crib flame impingement on the exterior face of the wall panels.

2. Flame propagation does not occur vertically or laterally through the core insulation. Flame propagation may be judged to occur within the test panels when temperatures within the insulation core as measured by Thermocouples 28, 29, 30, 42, 18, 46, 56, 55, 54, 38, 20, 53, 73, 65, 74, 66, 78 and 64, as shown in Figures 26-4-4 and 26-4-5, exceed 750°F (400°C) above ambient.

3. Flame propagation shall not occur to the first-floor wall panels extending beyond the concrete block walls of the test fixture either through core insulation or over the exterior or interior panel surfaces. Where the flame cannot be directly observed, flame propagation shall be assumed to occur where the temperatures as measured by Thermocouples 58, 57, 79 and 80 within the insulation core exceed 750°F (400°C) above ambient.

4. Temperatures measured 1 inch (25 mm) from the interior surfaces of the wall assembly within the second story do not exceed 350°F (180°C) above ambient.

5. Flames do not enter the second-story room.

SECTION 26.406 — REPORT OF TEST

The report of test shall contain the following:

1. Description of test wall assembly to include:

   1.1 Drawings showing structural design, plan, elevation, principal cross section plus other sections as needed for clarity and joint locations and details.

   1.2 Details of attachment of walls to test facility.

   1.3 Flame-spread and smoke-developed values of foam plastic per UBC Standard 8-1.

   1.4 Ignition temperature of foam plastic.

2. Location of thermocouples.

3. General ambient condition at test time.

4. Temperature data obtained during the test for all thermocouple locations.

5. Visual observations made during the test.

6. Photographs of the following:

   6.1 Test walls prior to test.

   6.2 Test in progress.

   6.3 Test walls exterior—posttest.

   6.4 Test walls interior—posttest.

   6.5 Core insulation of both walls—posttest.

7. Performance of wall system with respect to:

   7.1 Damage to the walls and core.

   7.2 Flame advance over exterior faces.

   7.3 Flame advance over interior faces.

   7.4 Flame penetration into second floor.

   7.5 Smoke accumulation inside the second-story room.

   7.6 Extent of residual burning.

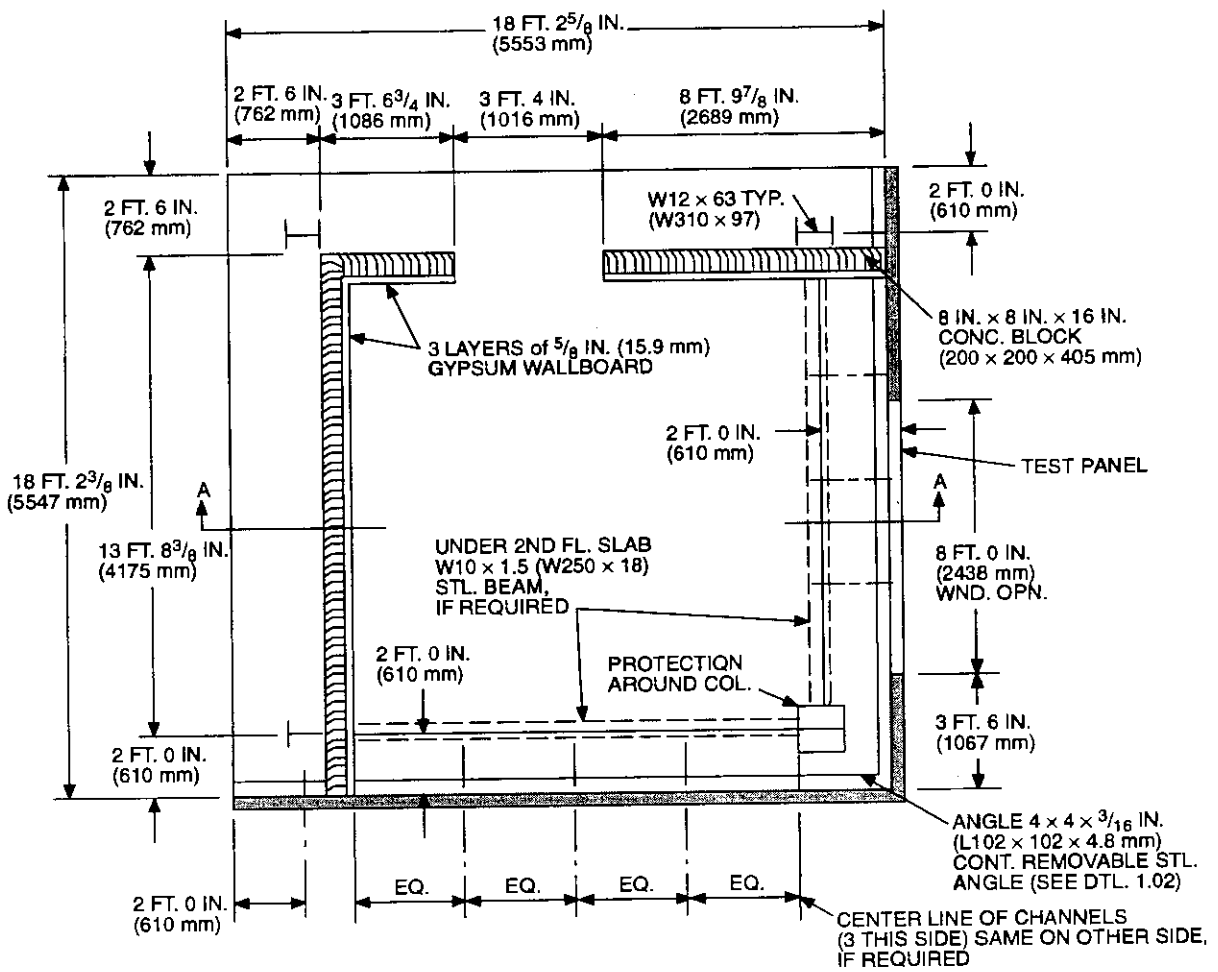


FIGURE 26-4-1A—FIRST/SECOND FLOOR PLAN

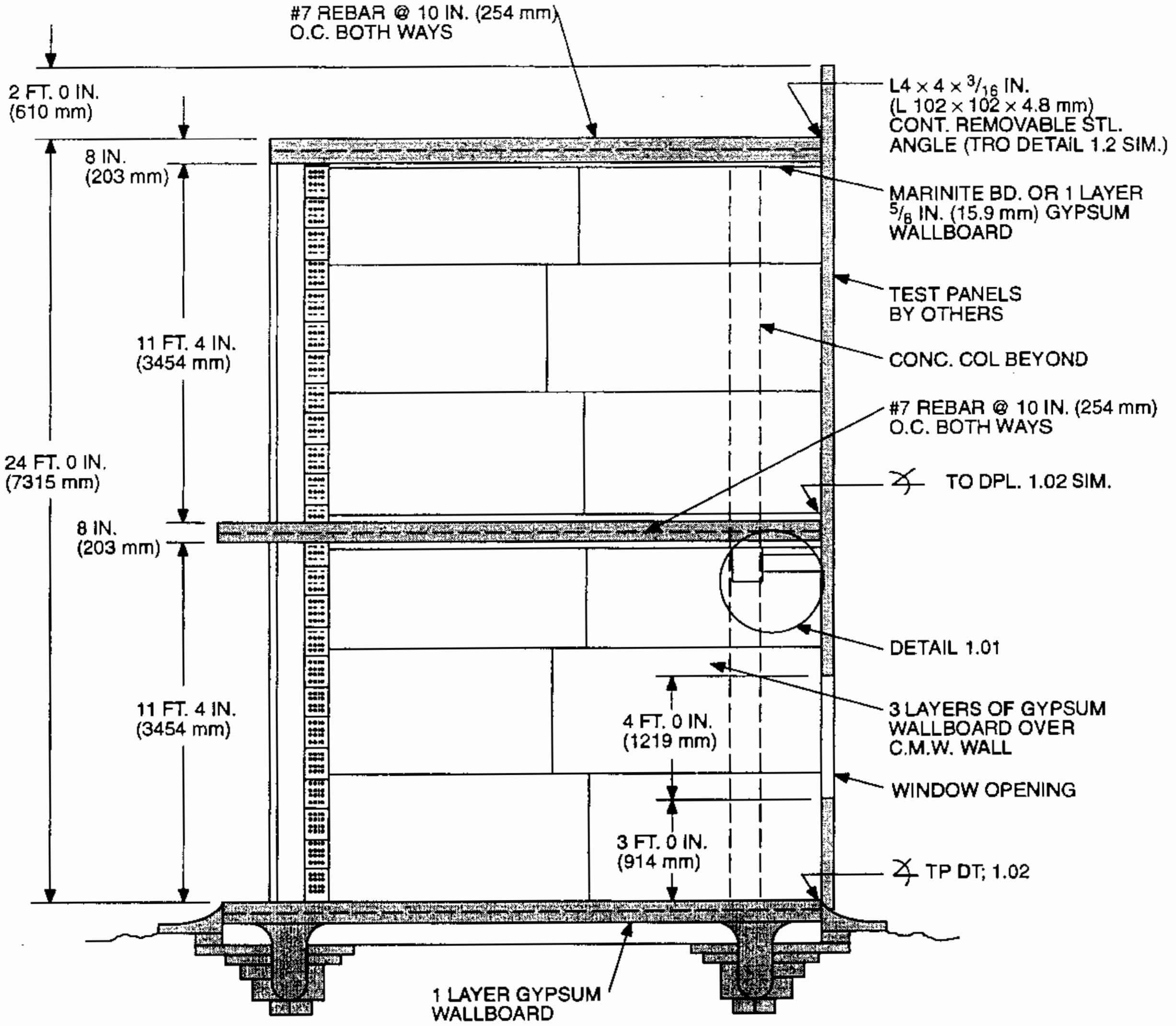


FIGURE 26-4-1B—SECTION A–A

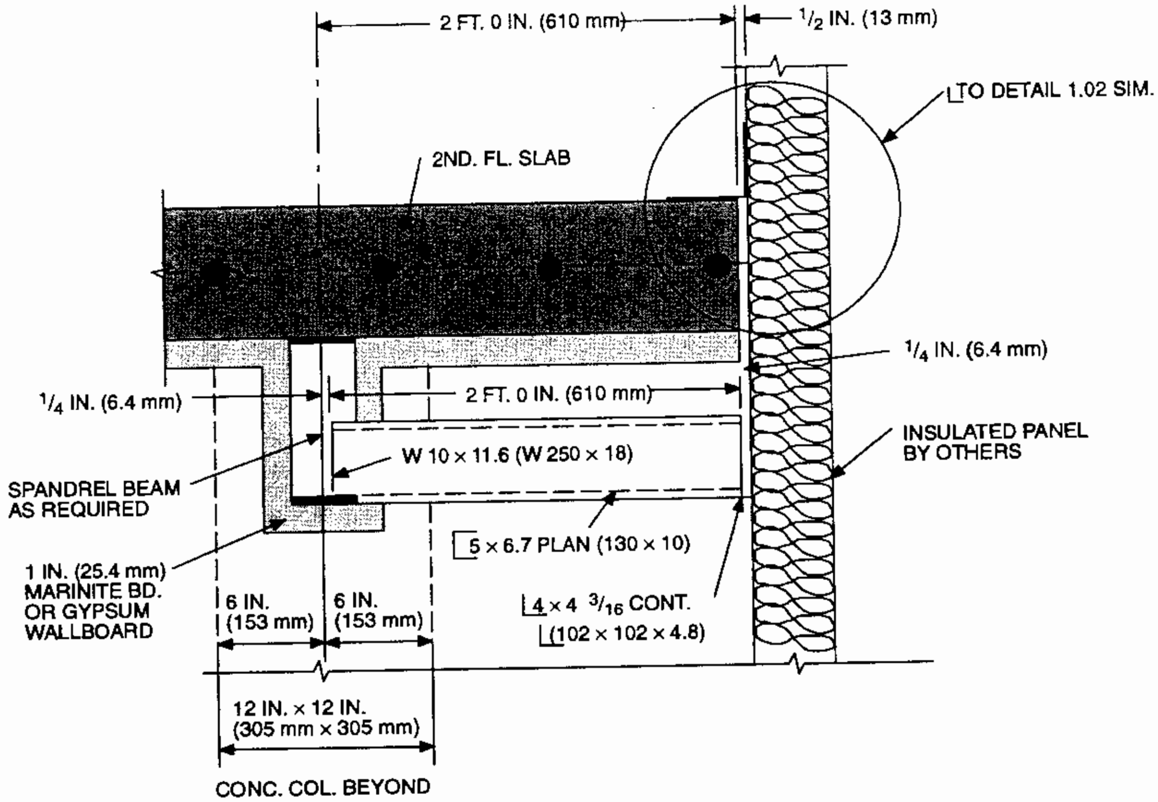


FIGURE 26-4-1C—1.01 SECTION DETAIL

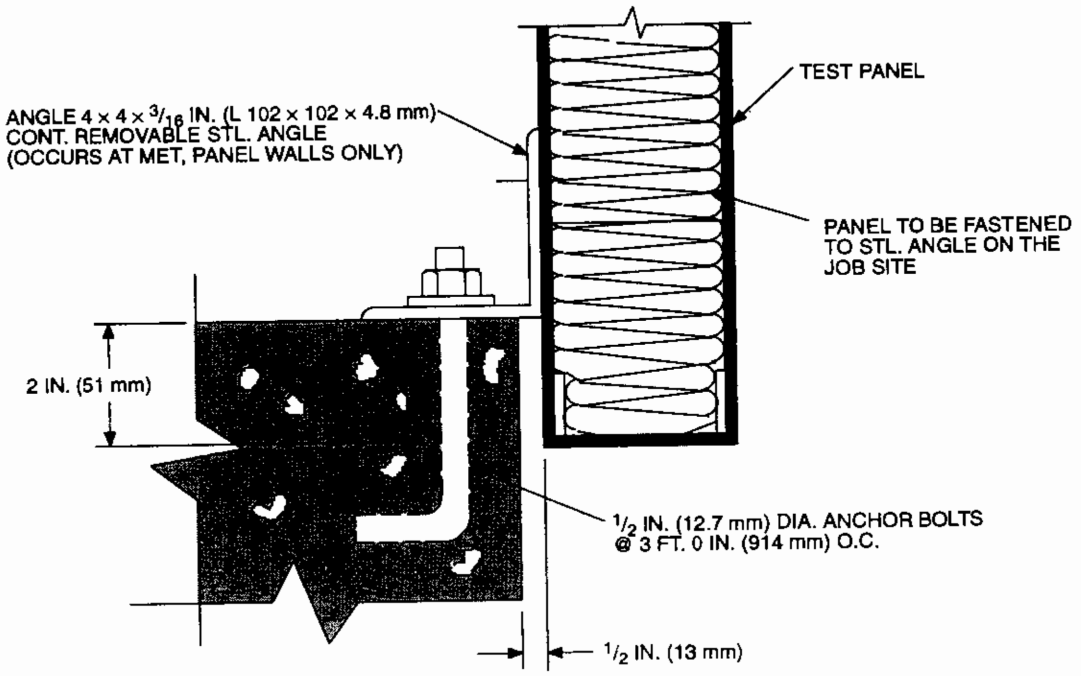


FIGURE 26-4-1D—1.02 SECTION DETAIL

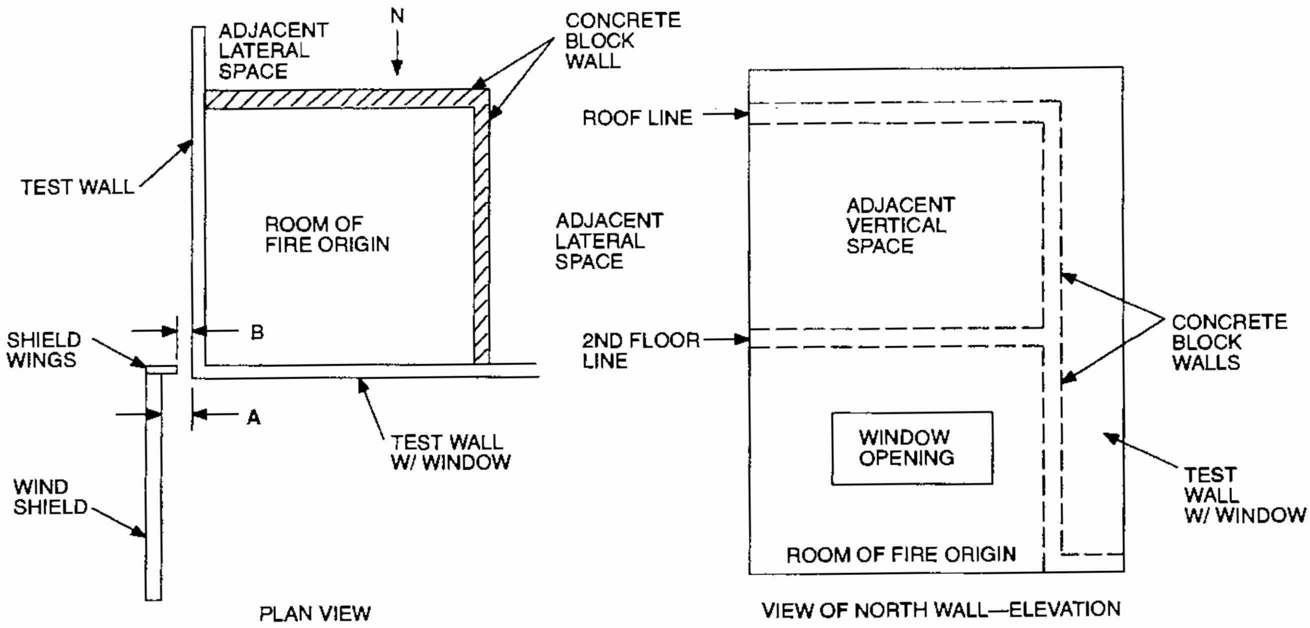
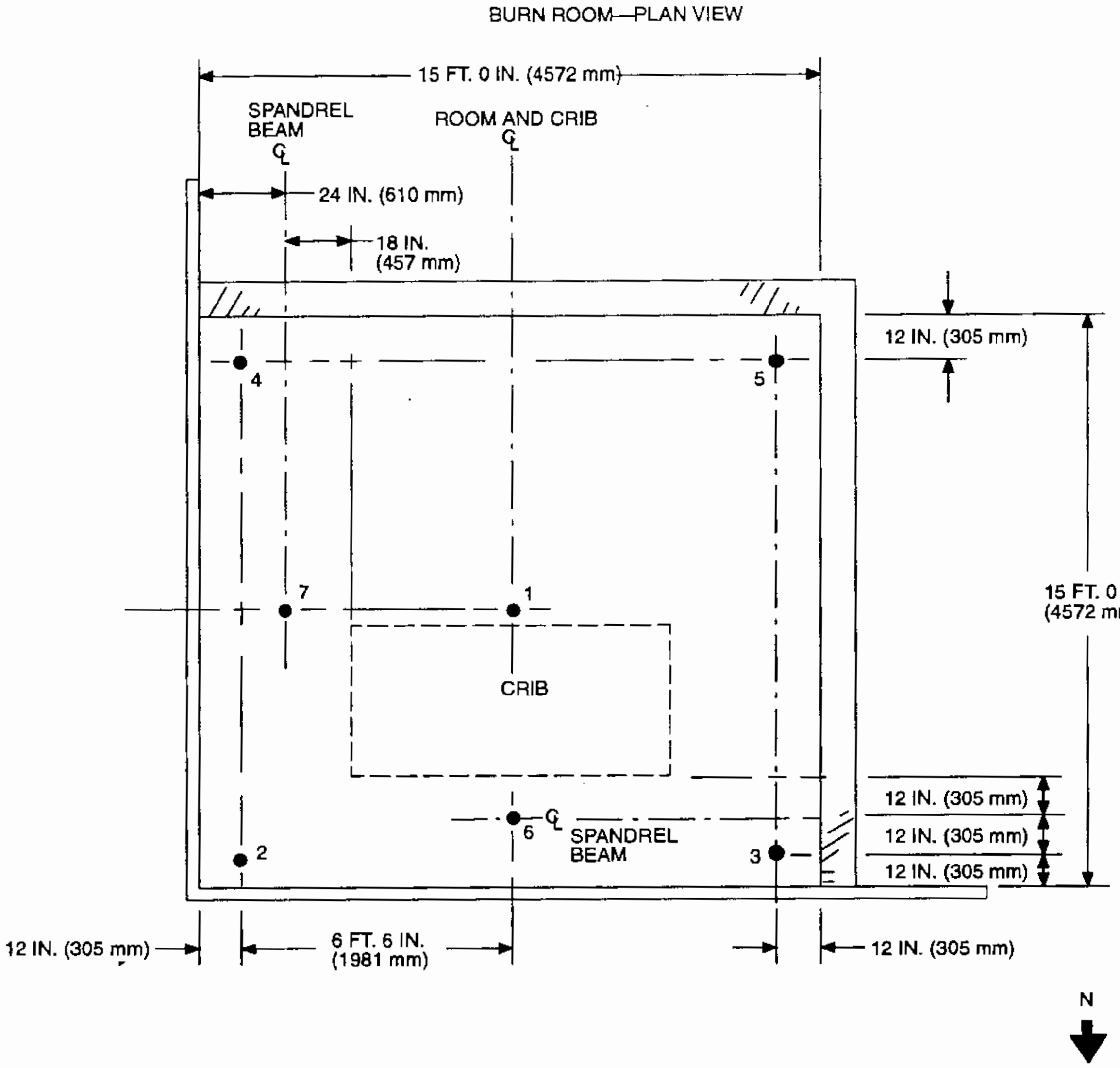


FIGURE 26-4-2—TEST ARRANGEMENT



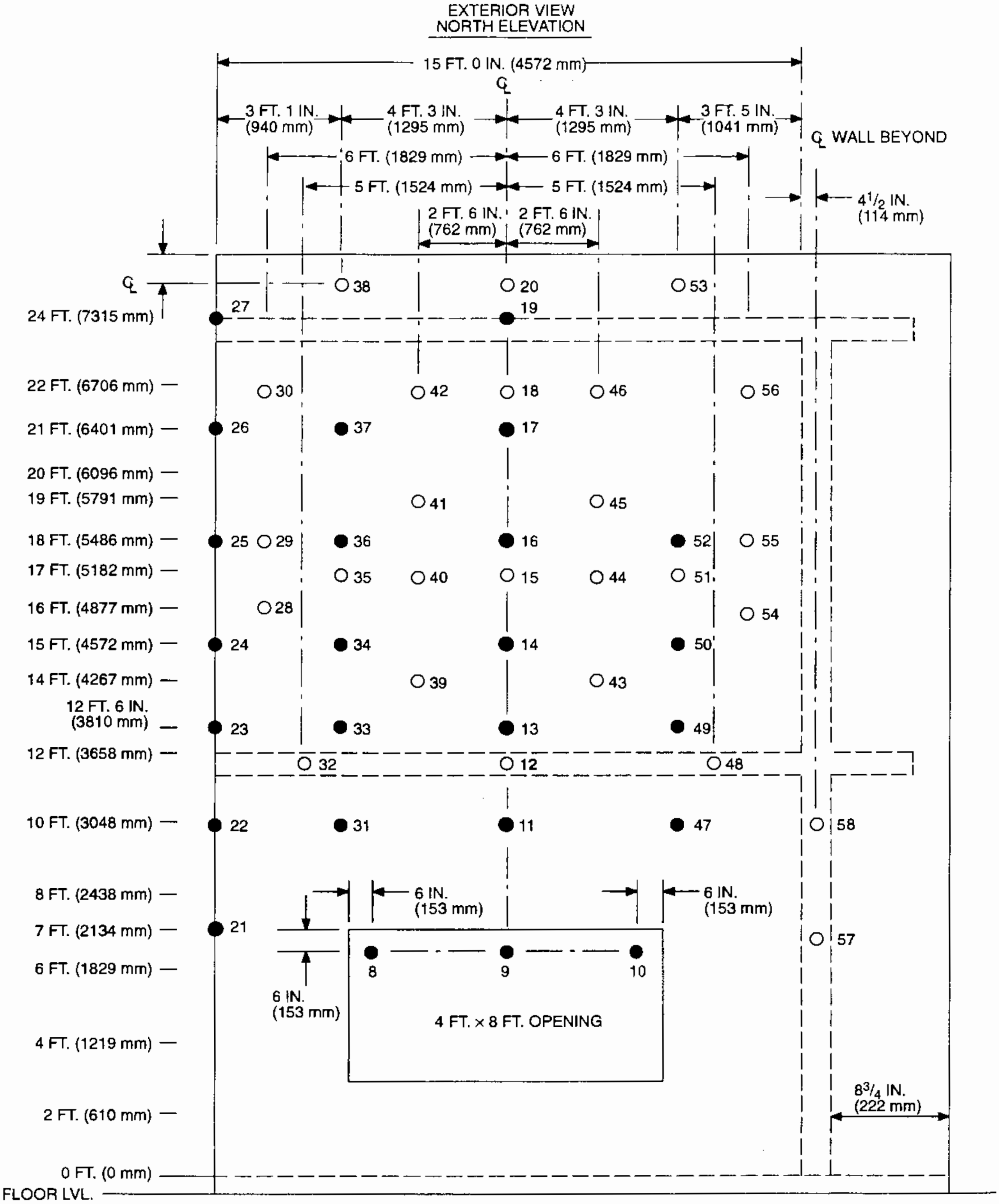
Thermocouples 1 and 5 are 6 in. (153 mm) below ceiling

Thermocouples 2, 3 and 4 are 2 in. (51 mm) below spandrel beam and centered between wall and beam

Thermocouples 6 and 7 are 1 in. (25 mm) below bottom surface of spandrel beam

NOTE: If no spandrel beam is used, then Thermocouples 2, 3, 4, 6 and 7 are to be 6 inches (153 mm) below ceiling.

FIGURE 26-4-3—THERMOCOUPLE LAYOUT

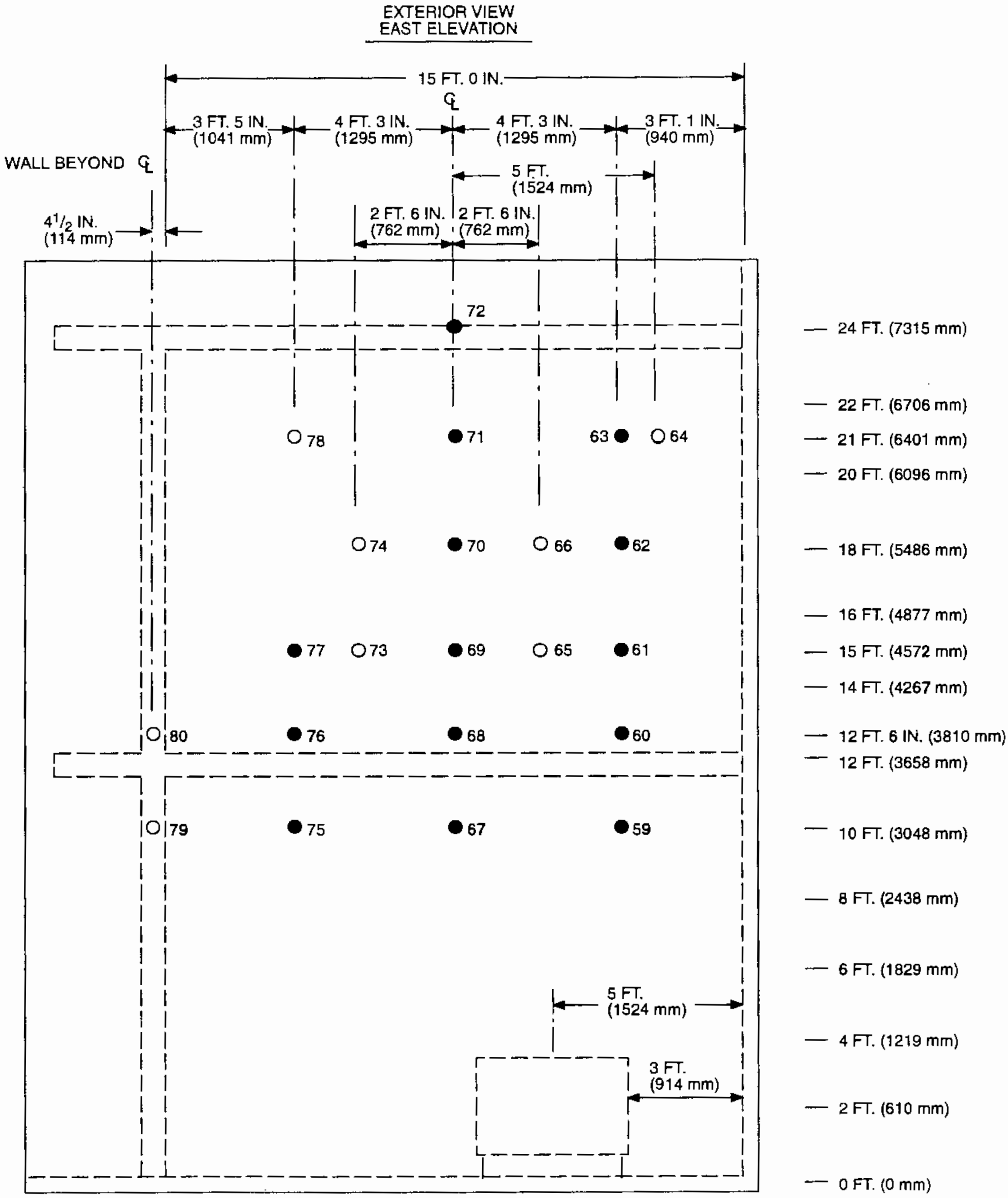


NOTES:

● Thermocouples placed 1 in. (25 mm) from wall surfaces except nos. 8, 9 and 10.

○ Thermocouples placed 1 in. (25 mm) into core of panel or into core material beyond external coating surface.

FIGURE 26-4-4—THERMOCOUPLE LAYOUT

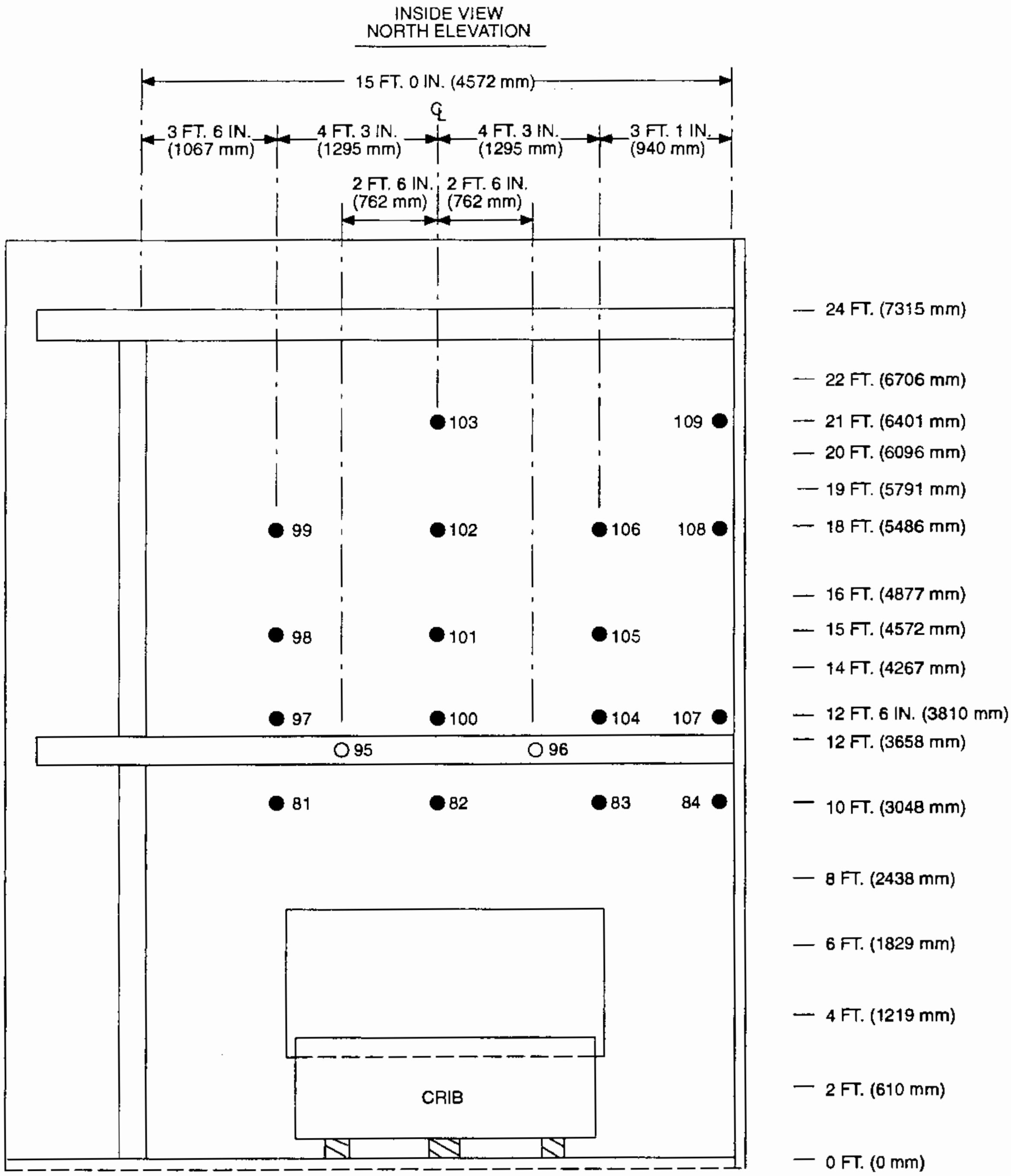


NOTES:

● Thermocouples placed 1 in. (25 mm) from wall surfaces.

○ Thermocouples placed 1 in. (25 mm) into core of panel.

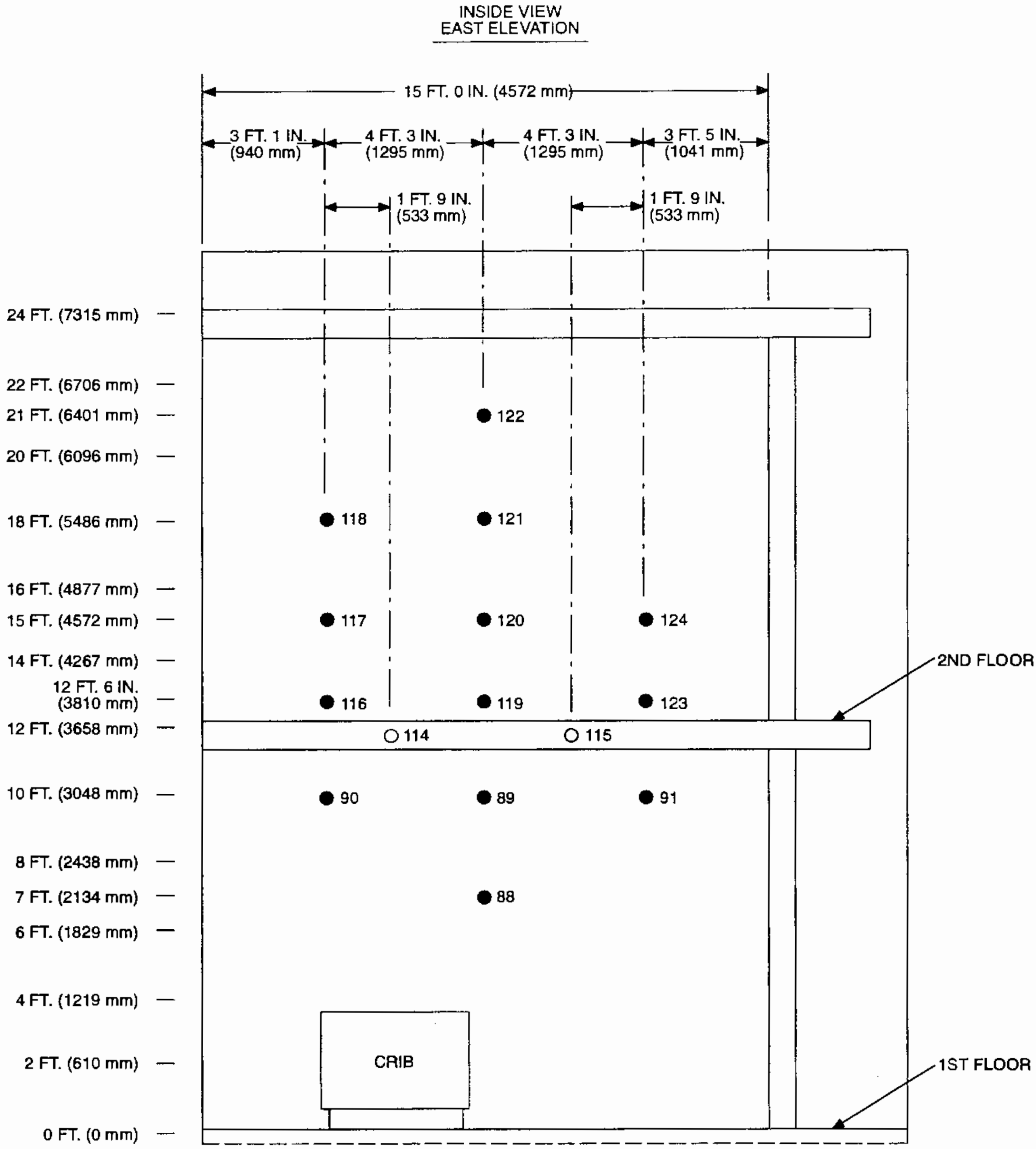
FIGURE 26-4-5—THERMOCOUPLE LAYOUT



NOTES:

- ● Thermocouples placed 1 in. (25 mm) from wall surfaces.
- ○ Thermocouples placed in safing material—center of floor level.

FIGURE 26-4-6—THERMOCOUPLE LAYOUT

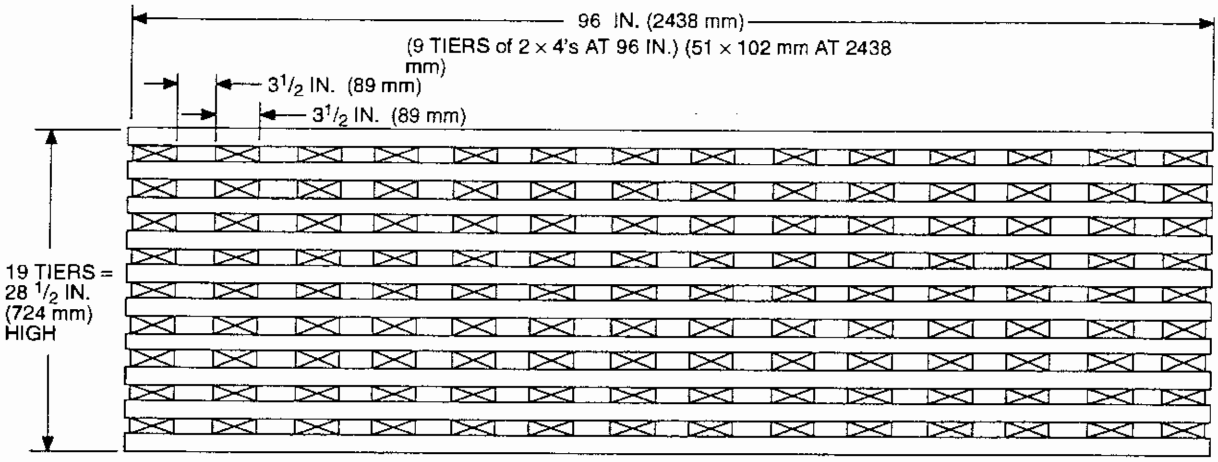


NOTES:

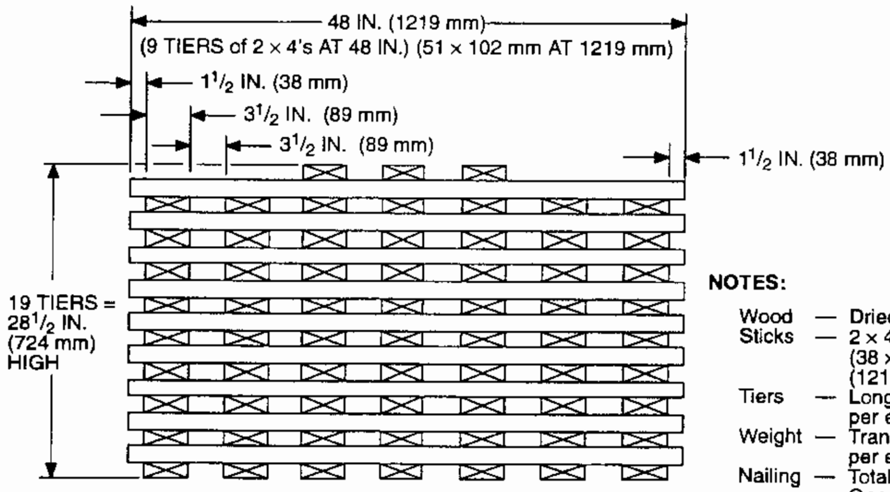
● Thermocouples placed 1 in. (25 mm) from wall surfaces.

○ Thermocouples placed in safing material—center of floor level.

FIGURE 26-4-7—THERMOCOUPLE LAYOUT



FRONT VIEW OF CRIB



END VIEW OF CRIB

NOTES:

Wood — Dried Douglas fir
Sticks — 2 × 4 inches (51 × 102 mm) ($1^1/_2 \times 3^1/_2$ inches) (38 × 89 mm) 8-foot (2438 mm) and 4-foot (1219 mm) length
Tiers — Longitudinal: 7 at 8 feet (2438 mm) per each tier
Weight — Transverse: 14 at 4 feet (1219 mm) per each tier
Nailing — Total crib weight to be 1285 pounds (583 kg)
One 8-penny nail per connection

FIGURE 26-4-8—CRIB CONSTRUCTION

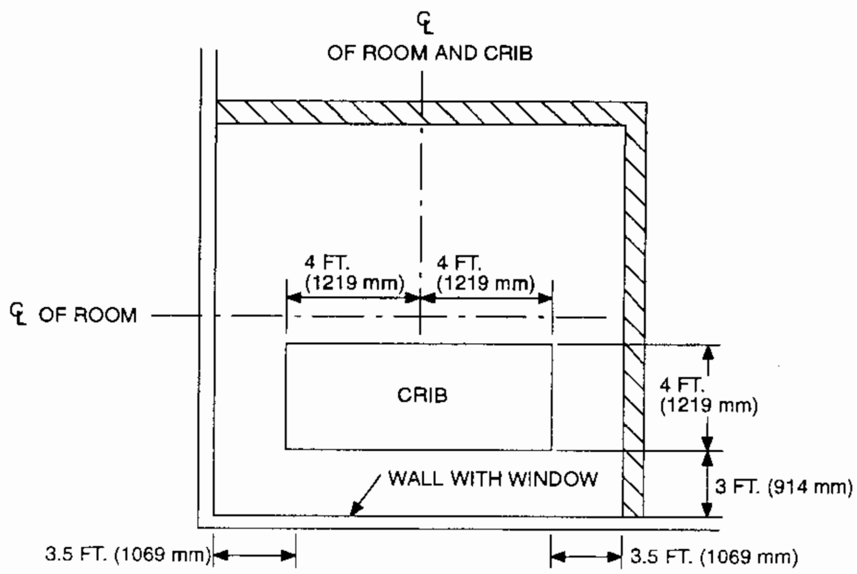


FIGURE 26-4-9—PLACEMENT OF CRIB IN ROOM

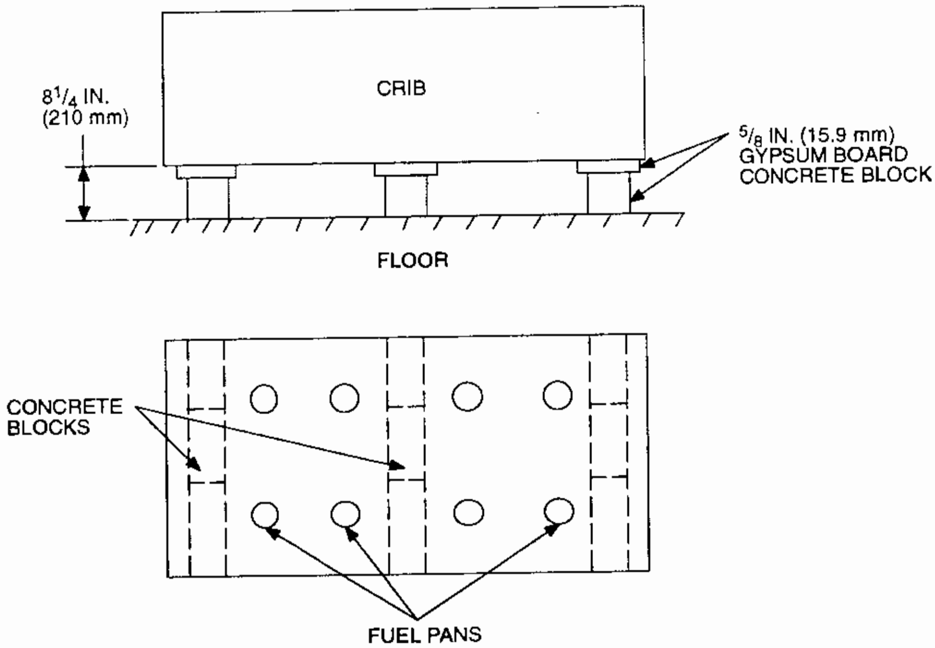


FIGURE 26-4-10—CRIB ARRANGEMENT

UNIFORM BUILDING CODE STANDARD 26-5

CHAMBER METHOD OF TEST FOR MEASURING THE DENSITY OF SMOKE FROM THE BURNING OR DECOMPOSITION OF PLASTIC MATERIALS

Based on Standard Test Method D 2843-70 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 217 and 2603.1.6, *Uniform Building Code;* and Section 212, *Uniform Sign Code*

SECTION 26.501 — SCOPE

This test method covers a procedure for measuring and observing the relative amounts of smoke produced by the burning or decomposition of plastics. It is intended to be used for measuring the smoke-producing characteristics of plastics under controlled conditions of combustion or decomposition. The measurements are made in terms of the loss of light transmission through a collected volume of smoke produced under controlled, standardized conditions. The apparatus is constructed so that the flame and smoke can be observed during the test.

SECTION 26.502 — SUMMARY OF METHOD

A 1-inch-by-1-inch (25 mm by 25 mm) specimen of the thickness intended for use is placed on a supporting metal screen and is burned in a laboratory test chamber (see Figure 26-5-1) under active flame conditions using a propane burner operating at a pressure of 40 psi (276 kPa). The 12-inch-by-12-inch-by-31-inch (300 mm by 300 mm by 791 mm) test chamber is instrumented with a light source, a photoelectric cell, and a meter to measure light absorption horizontally across the 12-inch (300 mm) light beam path. The chamber is closed during the four-minute test period except for the 1-inch-high (25 mm) ventilation openings around the bottom.

The light absorption data are plotted versus time. A typical plot is shown in Figure 26-5-2.

SECTION 26.503 — SIGNIFICANCE

This test method is designed to permit the measurement of smoke generation and its visibility-obscuring effects (density). Results of tests made on a plastic material under conditions herein prescribed can be used to evaluate the smoke-production characteristics by determining the smoke density rating of the material. The smoke density rating shall represent the total amount of smoke present in the chamber for the four-minute time interval. It is the area under the curve of light absorption versus time divided by the total area of the graph times 100.

The visual and instrumental observations from this test compare well with the visual observations of the smoke generated by plastic materials when added to a freely burning, large outdoor fire (burning conditions that are favorable to minimum smoke production). Hence, this method serves as a reliable method of identifying materials which could be expected to smoke excessively under almost all conditions of burning and decomposition.

The basic assumption underlying this procedure is that the hazard associated with smoke in human occupancies will be significant only if a material is burning or decomposing in the presence of flame. Therefore, the test specimen is exposed to flame for the duration of the test, and the smoke is substantially trapped in the chamber in which combustion occurs. The usefulness of this test procedure is in its ability to measure the amount of smoke produced, which is done in a simple, direct and meaningful manner.

SECTION 26.504 — APPARATUS

26.504.1 Chamber. The chamber shall consist of a 0.064-inch (1.63 mm) (No. 14 B.&S. gage) 12-inch-by-12-inch-by-31-inch (300 mm by 300 mm by 790 mm) aluminum box to which is hinged a heat-resistant glazed glass door. This box shall be mounted on a 14-inch-by-16-inch-by-$2^1/_4$-inch (350 mm by 400 mm by 57 mm) base which houses the controls. Depending on the materials tested, the metal may require protection from corrosion.

The chamber shall be sealed except for 1-inch-by-9-inch (25.4 mm by 229 mm) openings on the four sides of the bottom of the chamber. A 60 cfm (1700 L/min.) blower shall be mounted on one side of the chamber. The inlet duct to the blower shall be equipped with a close-fitting damper. The outlet of the blower shall be connected through a duct to the laboratory exhaust system.

The two sides adjacent to the door shall be fitted with $2^3/_4$-inch-diameter (70 mm) smoketight glazed areas centered $19^3/_4$ inches (502 mm) above the base. Boxes containing the optical equipment and additional controls shall be attached at these locations and outside the chamber.

A removable white plastic plate shall be attached to the back of the chamber. There shall be a $3^1/_2$-inch-by-6-inch (90 mm by 150 mm) clear area centered about $19^3/_4$ inches (502 mm) above the bottom of the chamber through which is seen an illuminated white-on-red exit sign. The white background permits observation of the flame, smoke and burning characteristics of the material. The viewing of the exit sign helps to correlate visibility and measured values.

26.504.2 Specimen Holder. The specimen shall be supported on a $2^1/_2$-inch (64 mm) square of $^1/_4$-inch-by-$^1/_4$-inch (6 mm by 6 mm), 0.035-inch-gage (0.9 mm) stainless steel wire cloth 8 inches (203.2 mm) above the base and equidistant from all sides of the chamber. This screen shall lie in stainless steel bezel supported by a rod through the right side of the chamber. From the same rod, a similar bezel shall be located 3 inches (76 mm) below and it shall support a square of asbestos paper which catches any particles that may drip from the specimen during the test. By rotating the specimen holder rod, the burning specimen can be quenched in a shallow pan of water positioned below the specimen holder.

26.504.3 Ignition System. The specimen shall be ignited by a propane flame from a burner operating at a pressure of 40 psi (276 kPa). The fuel shall be mixed with air which has been propelled through the burner by the venturi effect of the propane [commercial grade 85.0 percent minimum, gross heating value 2,590 Btu per cubic foot (23 000 cal/L) propane meets the requirements] as it passes from a 0.006-inch-diameter (0.152 mm) orifice. The burner shall be assembled as shown in the exploded view of the burner in Figure 26-5-3. The burner must be designed to provide adequate outside air. Since the orifice provides the metering effect proportionate to the supply pressure, care must be taken that the orifice is the only means of fuel egress.

The burner shall be capable of being quickly positioned under the specimen so that the axis of the burner falls on a line passing through a point $^3/_{10}$ inch (8 mm) above the base at one back corner of the chamber, extending diagonally across the chamber and sloping upward at an angle of 45 degrees with the base. The exit opening of the burner shall be $10^7/_{32}$ inches (259.56 mm) from the reference point at the rear of the chamber.

A duct at least 6 inches (150 mm) outside of the chamber shall provide the air piped to the burner.

Propane pressure shall be adjustable and preferably automatically regulated. Propane pressure shall be indicated by means of a Bourdon tube gage.

26.504.4 Photometric System. A light source, a barrier-layer photoelectric cell and a temperature-compensated meter shall be used to measure the proportion of a light beam which penetrates a 12-inch (300 mm) path through the smoke. The light path shall be arranged horizontally as shown in Figure 26-5-4.

A light source shall be mounted in a box (4 B1 in Figure 26-5-1) extending from the left side of the chamber at the mean height of $19^3/_4$ (502 mm) inches above the base. The light source shall be a compact filament microscope lamp No. 1493 operated at 5.8 volts and a spherical reflector, with power supplied by a voltage-regulating transformer. (Microscope lamps No. 1493 are manufactured by General Electric Company, Westinghouse and others.) A $2^1/_2$-inch (63.5 mm) focal length lens shall focus a spot of light on the photocell in the right-hand instrument panel.

Another box containing the photometer (4 B2 in Figure 26-5-1) shall be attached to the right-hand side of the chamber. The barrier-layer photoelectric cell shall have standard observer spectral response. An egg-crate grid in front of the photocell shall be used to protect the cell from stray light. The grid shall be finished in dull black and have openings at least twice as deep as they are wide. The current produced by the photocell is indicated in terms of percent light absorption on a meter. The photocell linearity decreases as the temperature increases; compensations shall therefore be made.

The meter may have two ranges. The range change shall be accomplished by shunting the meter to one-tenth its sensitivity. When enough smoke accumulates to absorb 90 percent of the light beam, a momentary switch shall be depressed returning the meter to its basic sensitivity. By doing this, the meter scale now reads 90 to 100 percent instead of 0 to 100 percent.

26.504.5 Timing Device. A clock to indicate 15-second intervals shall be used. If the time intervals are audible, it will be convenient for the operator to record observations.

26.504.6 Planimeter. A planimeter or other suitable means shall be used for measuring the area under the light absorption curve.

SECTION 26.505 — TEST SPECIMENS

The specimen shall be 1 inch by 1 inch (25.4 mm by 25.4 mm) by the thickness intended for use. Thicknesses other than those intended for use may be tested, and the thickness should be reported with the smoke density values.

The specimens shall be sanded, machined or die cut in a manner that produces a cut surface that is free from projecting fibers, chips and ridges.

The test sample shall consist of three specimens.

SECTION 26.506 — CONDITIONING

Specimens shall be preconditioned and tested in accordance with Procedure A of the ASTM Method D618-61 for Method of Conditioning Plastics and Electrical Insulating Materials for Testing, unless otherwise specified.

Tests shall be conducted in a hood which has a window for observing the test.

SECTION 26.507 — PROCEDURE

Turn on photometer lamp, exit sign, and exhaust blower.

Turn on propane, ignite burner and adjust the propane pressure to 40 psi (276 kPa). Caution: Do not fail to light burner immediately.

Set temperature compensation.

Adjust lamp control to zero percent light absorption.

Lay the test specimen flat on the screen in such a position that the burner flame will be directly under the specimen when the burner is swung into position.

Set the timer to zero.

Shut off the exhaust blower, close the smoke chamber door, and immediately position the burner under the specimen and start the timer.

Close the hood door to within 2 inches (50 mm) of the bottom of the hood.

Record the percent light absorbed at 15-second intervals for four minutes.

Record observations during the conduct of the test. Include the time it takes for the sample to burst into flame, time for flame extinguishment or specimen consumption, obscuration of the exit sign by smoke accumulation and any general or usual burning characteristics noted, such as melting, dripping, foaming or charring.

Upon completion of the test, turn on exhaust blower to ventilate the combustion products from the chamber. (It should be noted that for some materials the product of burning may be toxic, and care should be taken to guard the operator from the effects of these gases. The ventilating fan in the hood should be turned on and the damper opened immediately after the test is completed and before opening the hood door in order to remove any irritating products of the test. The exhaust fan is turned off and the hood damper closed during the test to prevent backdraft.)

Open the door and clean the combustion deposits from the photometer, exit sign and door glass with detergent and water. Burn off any material remaining on the screen or replace the screen and asbestos square for the next test.

Run all tests in triplicate.

SECTION 26.508 — OPTIONAL PROCEDURES

The output of the photocell may be recorded versus time on an appropriate graphic recorder.

With a suitably sensitive meter, more than one decade change may be used to separate readings in the very dense smoke range.

SECTION 26.509 — TREATMENT OF DATA

The readings of 15-second intervals of light absorption for the three specimens per group shall be averaged. The average light absorption shall be plotted against time on linear paper. Figure 26-5-2 is a sample curve.

The total smoke produced shall be determined by measuring the area under the curve. The smoke density rating shall represent the total amount of smoke present in the chamber for the four-minute time interval. It is the area under the curve of light absorption versus time, divided by the total area of the graph times 100.

SECTION 26.510 — REPORT

The report shall include the following:

Identification of the material.

Thickness of the specimen.

Readings of light absorption at 15-second intervals for each test and average.

Plots of average light absorption versus time.

Area in percent under the light absorption-time curve (smoke density rating).

Observations on behavior of material.

Observations on obscurement of exit sign.

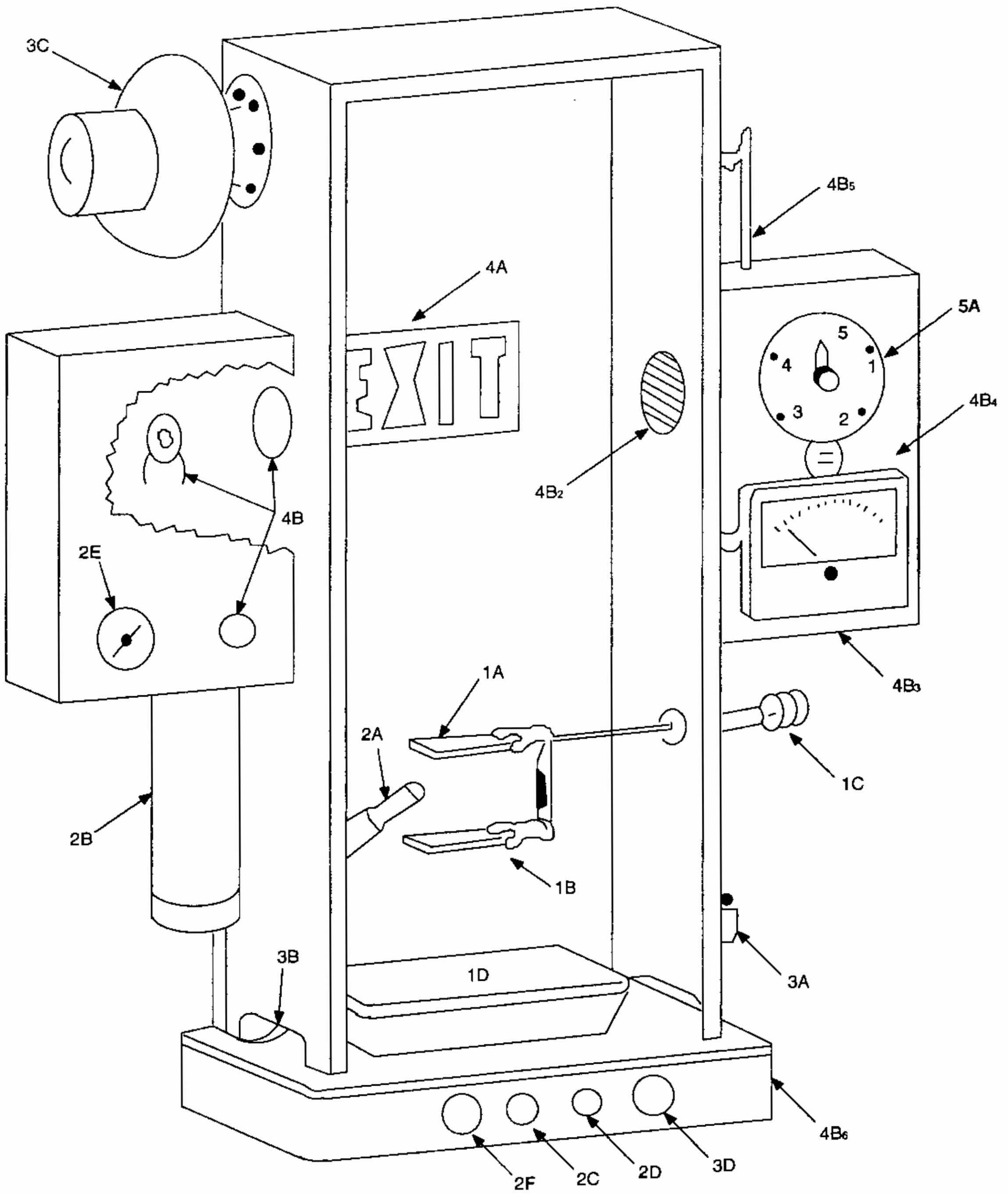
The details of any departure from the specifications of the method of testing.

EXAMPLE: In the light absorption-time plot in Figure 26-5-2, the plot has been made using 1 inch (25.4 mm) equal to 30 percent as the ordinate and 1 inch (25.4 mm) equal to 0.75 minute as the abscissa. The graph area for four minutes is found to be 17.78 square inches (11 470.94 mm^2). The area under the curve is found to be 14.02 square inches (9045.14 mm^2). The smoke density rating is then computed as follows:

$$\text{Smoke Density Rating in percent} = \frac{14.02}{17.78} \times 100 = 78.8$$

For **SI**:

$$\text{Smoke Density Rating in percent} = \frac{9045.14}{11\,470.94} \times 100 = 78.8$$



1. Specimen Holder
   - A. Stainless Steel Screen
   - B. Asbestos Sheet
   - C. Adjusting Knob
   - D. Quench Pan
2. Ignition
   - A. Burner
   - B. Propane Tank
   - C. Gas Shutoff Valve
   - D. Pressure Regulator Adjustment
   - E. Pressure Indicator
   - F. Burner Positioning Knob
3. Cabinet (Shown without door)
   - A. Hinges (Door gasketed three sides)
   - B. Vents [1-inch (25.4 mm) high opening four sides]
   - C. Blower (Damper on mounting side)
   - D. Control (Blower on when damper is open)
4. Photometer
   - A. Visual System (Exit sign)
   - B. Measuring System
     1. Light Source and Adjusting Transformer
     2. Photronic Cell and Grid (To block stray light)
     3. Meter (Indicating percent to light absorbed)
     4. Temperature Compensation
     5. Photocell Temperature Monitor
     6. Range Change
5. Timer
   - A. Indicator, 0 to 5 minutes (Friction reset)

FIGURE 26-5-1—SCHEMATIC DIAGRAM OF SMOKE CHAMBER

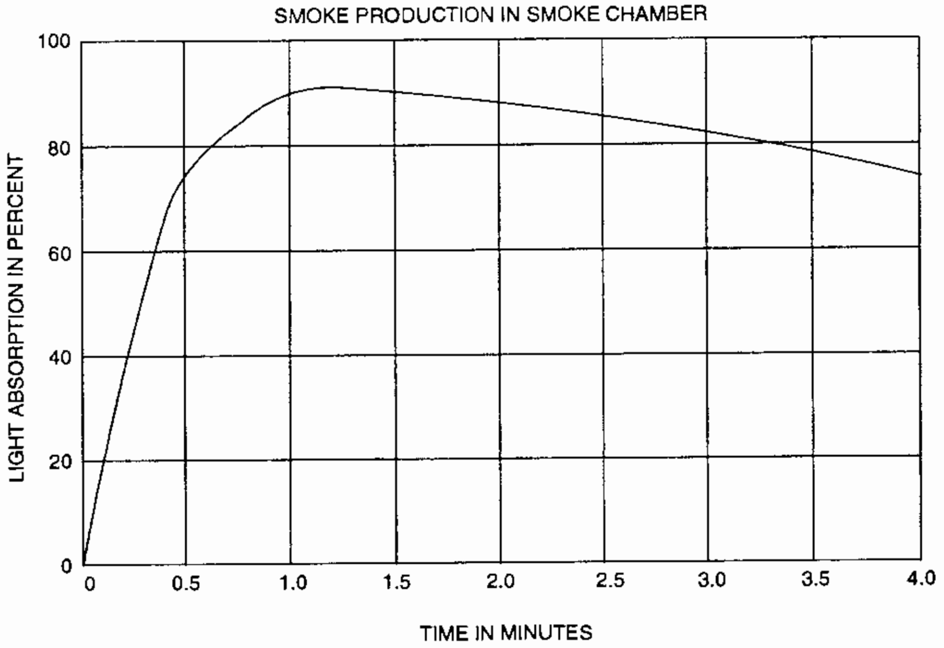


FIGURE 26-5-2—LIGHT ABSORPTION VERSUS TIME

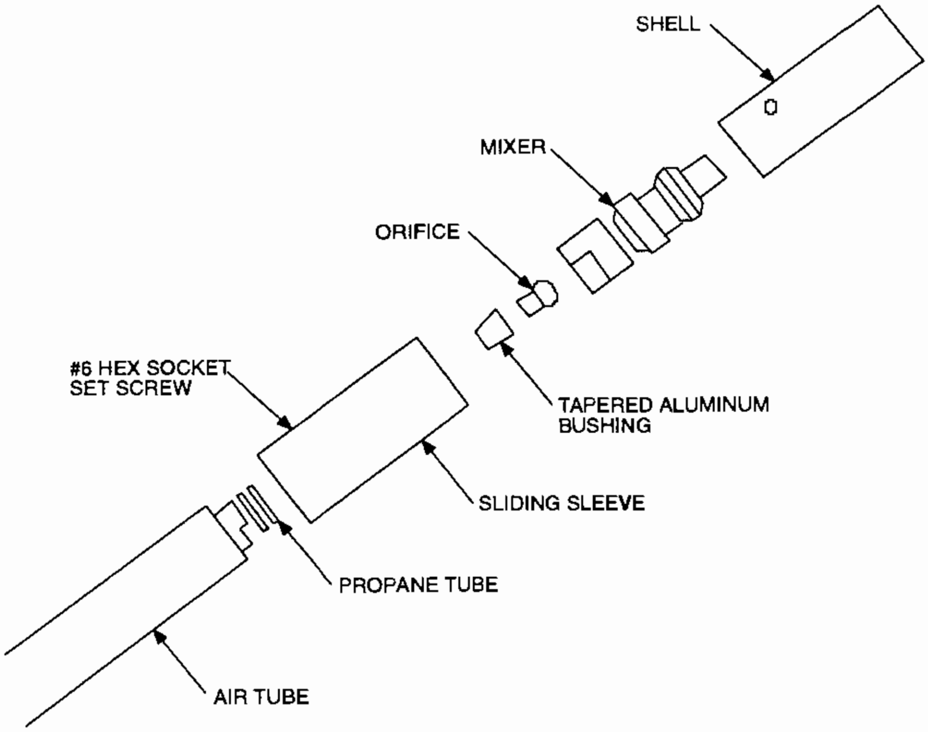
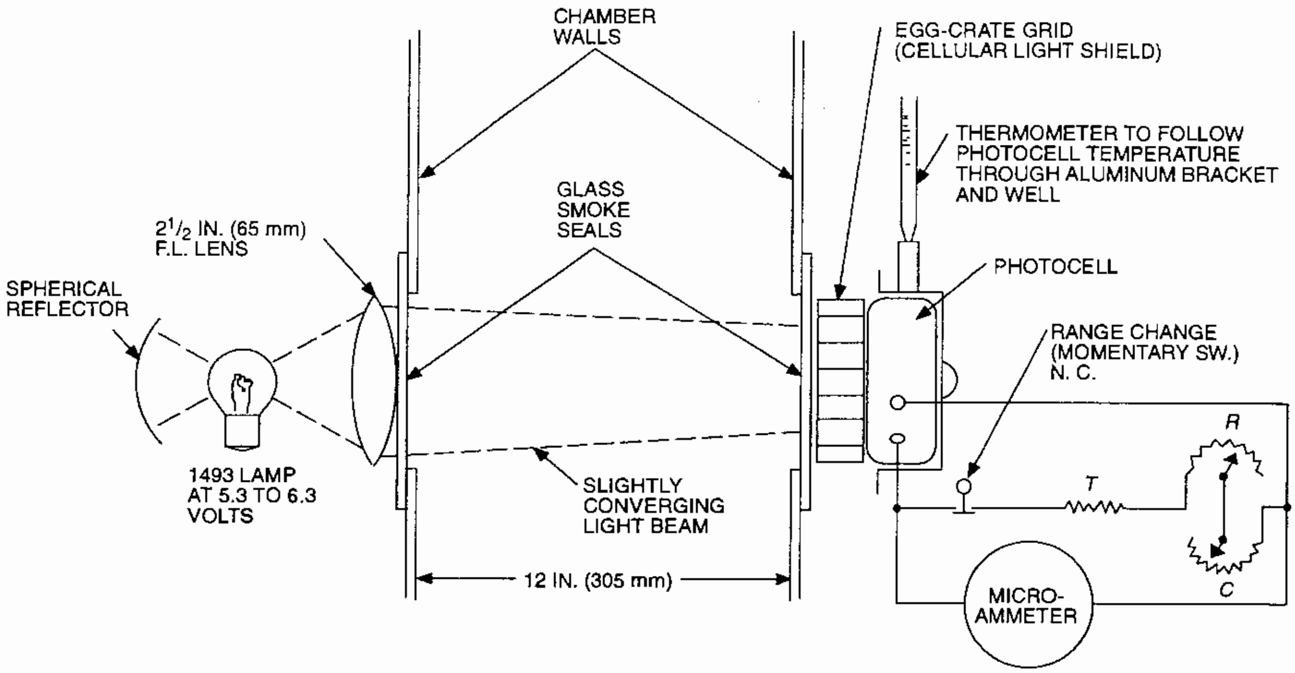


FIGURE 26-5-3—EXPLODED VIEW OF THE BURNER



T = Temperature sensitive winding in or on meter case to increase in resistance in proportion to increase in meter resistance with temperature.
R = Potentiometer with calibrated scale to reduce resistance in proportion to decrease in photocell output with rise in temperature.
C = Potentiometer to calibrate total resistance of shunt to change meter sensitivity exactly by 10:1 ratio.

FIGURE 26-5-4—SMOKE DENSITY TEST CHAMBER PHOTOMETER

UNIFORM BUILDING CODE STANDARD 26-6

IGNITION PROPERTIES OF PLASTICS

Based on Standard Test Method D 1929-68 (1975) of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 217, 2602.6 and 2603.8.1, Item 1, *Uniform Building Code;* and Section 212, *Uniform Sign Code*

SECTION 26.601 — SCOPE

This method of test covers a laboratory procedure for determining the self-ignition and flash-ignition temperatures of plastics using a hot-air ignition furnace.

SECTION 26.602— SIGNIFICANCE

Tests made under conditions herein prescribed can be of considerable value in comparing the relative ignition characteristics of different materials. Values obtained represent the lowest ambient air temperature that will cause ignition of the material under the conditions of this test. Test values are expected to rank materials according to ignition susceptibility under actual use conditions.

This test is not intended to be the sole criterion for fire hazard. In addition to ignition temperatures, fire hazard includes such other factors as burning rate or flame spread, intensity of burning, fuel contribution, products of combustion and others.

SECTION 26.603 — DEFINITIONS

FLASH-IGNITION TEMPERATURE is the lowest initial temperature of air passing around the specimen at which a sufficient amount of combustible gas is evolved to be ignited by a small external pilot flame.

SELF-IGNITION BY TEMPORARY GLOW. In some cases slow decomposition and carbonization of the plastic result only in glow of short duration at various points in the specimen without general ignition actually taking place. This is a special case of self-ignition temperature defined as "self-ignition by temporary glow."

SELF-IGNITION TEMPERATURE is the lowest initial temperature of air passing around the specimen at which, in the absence of an ignition source, the self-heating properties of the specimen lead to ignition or ignition occurs of itself as indicated by an explosion flame or sustained glow.

SECTION 26.604 — APPARATUS

The apparatus shall be a hot-air ignition furnace as shown in Figure 26-6-1 and shall consist primarily of the following parts:

26.604.1 Furnace Tube. A vertical tube with an inside diameter of 4 inches (102 mm) and a length of $8^1/_2$ inches to 10 inches (216 mm to 254 mm) made of a ceramic that will withstand 1382°F (750°C) and with an opening at the bottom fitted with a plug for the removal of accumulated residue.

26.604.2 Inner Ceramic Tube. A ceramic tube with inside diameter of 3 inches (76 mm), length of $8^1/_2$ inches to 10 inches (216 mm to 254 mm) and thickness of about 0.125 inch (76 mm) placed inside the furnace tube and positioned $^3/_4$ inch (19 mm) above the furnace floor on three small spacer blocks. The top shall be covered by a disk of heat-resistant material with a 1-inch (25 mm) diameter opening which is used to insert thermocouple leads for observation and for passage of smoke and gases. The pilot flame shall be located immediately above the opening.

26.604.3 Air Source. An outside air source to admit clean air tangentially near the top of the annular space between the ceramic tubes through a copper tube at a steady and controllable rate. Air shall be heated and circulated in the space between the two tubes and enter the inner furnace tube at the bottom. Air shall be metered by a rotameter or other suitable device; refer to air calibration curves (Figure 26-6-2) for proper furnace air velocities.

26.604.4 Heating Unit. An electrical heating unit made of 50 turns of No. 16 B.&S. (1.3 mm) wire. (Nichrome V alloy wire.) The wires, contained within an asbestos sleeve, shall be wound around the furnace tube and shall be embedded in cement.

26.604.5 Insulation. Consisting of a layer of asbestos wool approximately $2^1/_2$ inches (64 mm) thick and covered by a sheet iron jacket.

26.604.6 Pilot Flame. Consisting of $^1/_{16}$-inch (1.6 mm) diameter copper tubing attached to a gas supply and placed horizontally $^1/_4$ inch (6.4 mm) above the top surface of the divided disk. The pilot flame shall be adjusted to $^3/_4$ inch (19 mm) in length and centered above the opening in the disk.

26.604.7 Specimen Support and Holder. A convenient specimen holder, measuring $1^1/_2$ inches (38 mm) in diameter by $^1/_2$ inch (13 mm) in depth, is a $^1/_2$-ounce (14.2 g) metal container of approximately 5-mil (0.13 mm) thick steel. One-half of the container shall be used as a specimen holder and shall be held in a ring of $^1/_{16}$-inch (1.6 mm) stainless steel welding rod. The ring shall be welded to a length of the same type rod extending through the cover of the furnace as shown in Figure 26-6-1. The specimen holder shall be located 7 inches to $7^1/_2$ inches (178 mm to 191 mm) down from the top of the furnace.

26.604.8 Thermocouples. Chromel-alumel or iron-constantan [0.020-inch (0.51 mm)] thermocouples for temperature measurement. These shall be conveniently connected to a multiple-point recorder and each thermocouple temperature shall be recorded at least every 15 seconds. Thermocouple 1 (T_1) measures the temperature of the specimen. It should be located as near the center of the specimen as possible when the specimen is in place in the furnace. Thermocouple 2 (T_2) measures the temperature of the air traveling past the specimen. It shall be located slightly below and to the side of the specimen holder. Thermocouple 3 (T_3) measures the temperature of the heating coil. Thermocouple 1 is used also for measuring initial air temperature in constant-temperature runs before insertion of the specimen.

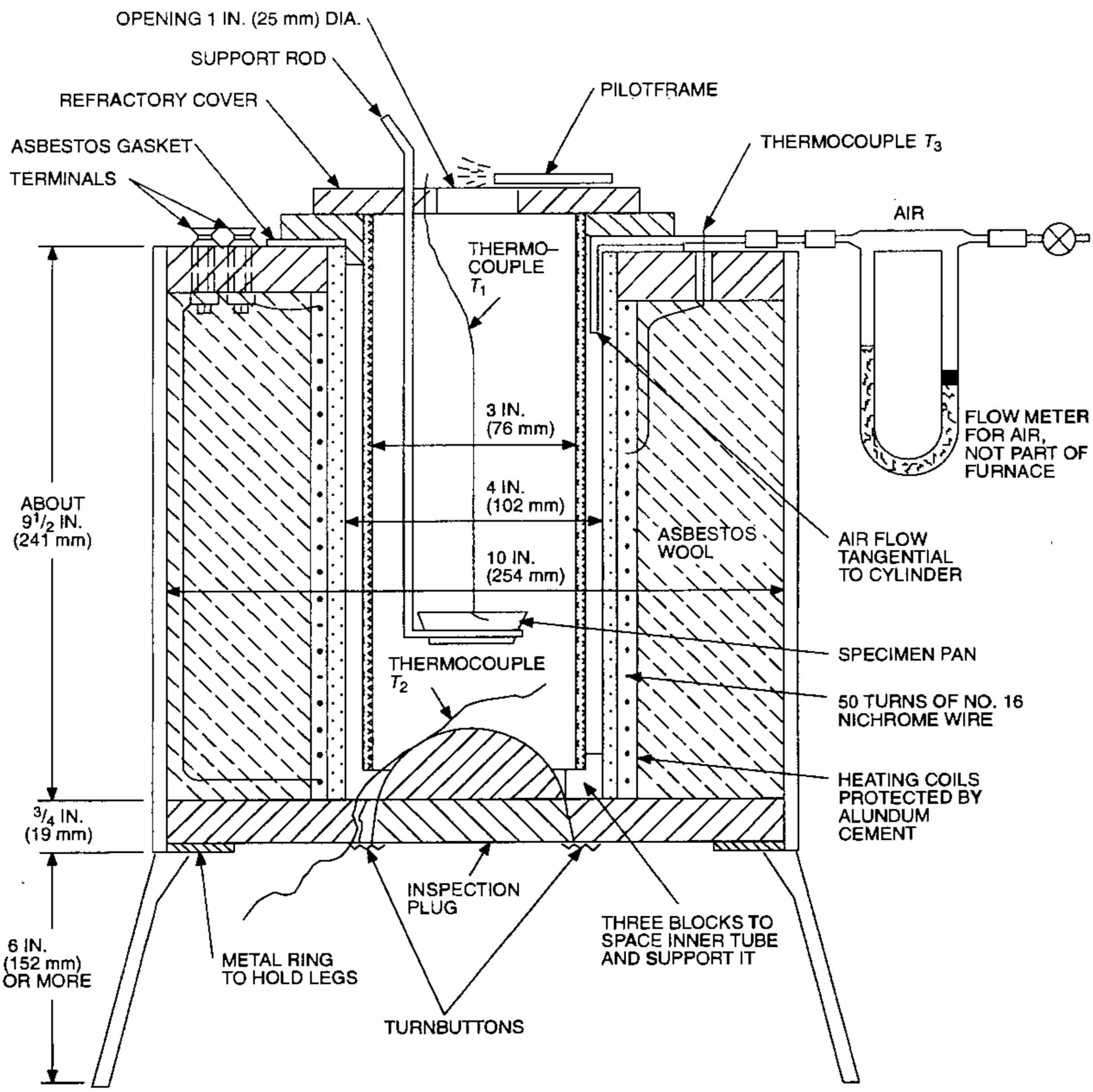


FIGURE 26-6-1—CROSS SECTION OF HOT-AIR IGNITION FURNACE ASSEMBLY

SECTION 26.605 — TEST SPECIMENS

Thermoplastic materials may be tested in pellet form normally supplied for molding. Where only sheet samples are available or for thermosetting materials $^3/_4$-inch-by-$^3/_4$-inch (19 mm by 19 mm) squares of the available sheet or film shall be bound together with fine wire. A specimen weight of 3 grams ± 0.5 gram is required.

SECTION 26.606 — CONDITIONING

26.606.1 General. Measurements of temperature and relative humidity during conditioning and testing of specimens shall be recorded and such measurement shall be taken within 2 feet (610 mm) of the specimen.

26.606.2 Conditioning. Condition test specimens at 73.4°F ± 1.8°F (23°C ± 1°C) and 50 ± 2 percent relative humidity. Specimens 0.25 (6.4 mm) or less in thickness shall be conditioned for 40 hours immediately prior to testing. Specimens with a thickness greater than 0.25 (6.4 mm) shall be conditioned for 88 hours immediately prior to testing.

Adequate air circulation on all sides of the test specimen shall be provided by placing them in suitable racks, hanging them from metal clips, or laying them on wiremesh, wire screen frames with at least 1 inch (25 mm) between the screen and the surface of the bench.

26.606.3 Test Conditions. Conduct tests in the standard laboratory atmosphere of 73.4°F ± 1.8°F (23°C ± 1°C) and 50 ± 2 percent relative humidity.

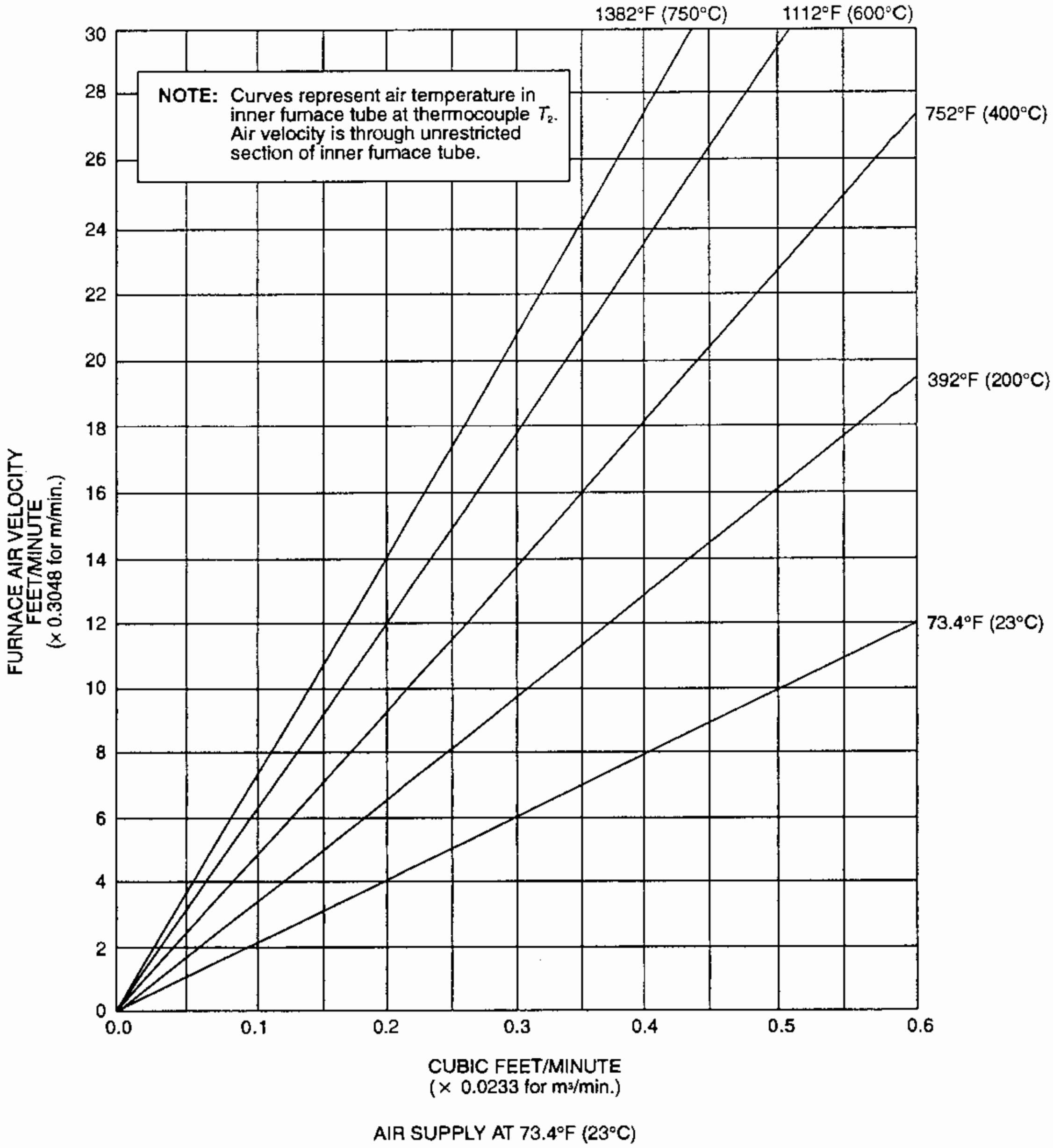


FIGURE 26-6-2—AIR CALIBRATION CURVES FOR HOT-AIR IGNITION FURNACE

SECTION 26.607 — PROCEDURE A

26.607.1 First Approximation of Flash-ignition Temperature (Effect of Airflow Rate).

26.607.1.1 Low airflow determination. Raise the cup to the cover opening and place the specimen in the furnace. Set the airflow at 5 feet per minute (1.5 m/min). Adjust the transformer controlling current to the furnace coils to provide a rise in the temperature (T_2) of approximately 1080°F (582°C) per hour (± 10 percent). Light the gas pilot flame and place it across the hole in the top of the furnace. Note the air temperature (T_2) at which the combustible gases are ignited. This point is evidenced by a rapid rise in the specimen temperature (T_1). This is an approximation of the flash-ignition temperature.

26.607.1.2 Medium airflow determination. Repeat paragraph 1, but with an air setting of 10 feet per minute (3.0 m/min).

26.607.1.3 High airflow determination. Repeat paragraph 1, but with an air setting at 20 feet per minute.

26.607.2 First Approximation of Self-ignition Temperature (Effect of Airflow Rate). Repeat Section 26.607.1.1, but without the pilot flame. Note the recorded air temperature (T_2) at which the specimen flames, explodes or glows.

Repeat Section 26.607.1.2, but without the pilot flame. Note the recorded air temperature (T_2) at which the specimen flames explodes or glows.

Repeat Section 26.607.1.3, but without the pilot flame. Note the recorded air temperature (T_2) at which the specimen flames, explodes or glows.

26.607.3 Second Approximation of Flash-ignition Temperature. Choose the air setting from Section 26.607.1 that gives the lowest flash temperature, and repeat the appropriate determination, Sections 26.607.1.1, 26.607.1.2 or 26.607.1.3, using a temperature rise of 540°F (282°C) per hour (± 10 percent).

26.607.4 Second Approximation of Self-ignition Temperature. Choose the air setting from Section 26.607.2 that gives the lowest self-ignition temperature, and repeat the appropriate determination, Section 26.607.1.1, 26.607.1.2 or 26.607.1.3, using a temperature rise of 540°F (282°C) per hour (± 10 percent).

26.607.5 Constant-temperature Tests to Determine Minimum Ignition Temperatures.

26.607.5.1 Minimum flash-ignition temperature. Start the furnace with the air setting user in Section 26.607.3. Adjust the transformer setting until the initial air temperature (T_1) stays constant as indicated by the recorded temperature reading for a 15-minute period. The initial temperature should be maintained not more than 18°F (10°C) below the flash temperature found in Section 26.607.3. Place the specimen in the furnace, ignite the pilot flame and watch for ignition of gases from the specimen. If ignition occurs, repeat this run with temperature (T_1) maintained at an 18°F (10°C) lower setting. Repeat at successively lower temperatures until there is not ignition in 30 minutes. When temperature (T_1) is reached at which no ignition occurs, it is suggested that a second run be made to ensure that this is truly below the self-ignition temperature. Report the lowest air temperature (T_1) setting at which ignition occurred as the minimum flash-ignition temperature.

26.607.5.2 Minimum self-ignition temperature. Repeat paragraph 1 but without the pilot flame. Start with an air temperature 18°F (10°C) lower than the ignition temperature found in Section 26.607.4.

SECTION 26.608 — PROCEDURE B (SHORT METHOD)

26.608.1 Minimum Flash-ignition Temperature. Set the airflow rate to provide a velocity of 5 feet/minute (1.5 m/min) at 752°F (400°C) in the test chamber of the furnace. Adjust the current to the heating coil until the initial air temperature (T_2) remains constant at 752°F for 15 minutes.

NOTE: The temperature of 752°F (400°C) is used when no prior knowledge of the probable ignition temperature range is available. Other starting temperature may be selected if information about the material indicates better choice.

Locate thermocouple T_1 centrally in the specimen holder intimately surrounded by the test material and lower the unit into the furnace. Start a timer, ignite the gas pilot flame and watch for ignition. Flash ignition will be evidenced by a flash or mild explosion of combustible gases which may be followed by continuous burning of the specimen. If the specimen burns, by flaming or glowing, a rapid rise will be observed in the temperature at thermocouple T_1 above that at T_2.

If at the end of five minutes ignition has or has not occurred, lower or raise the temperature (T_1) 122°F (68°C) as required and repeat the test with a fresh specimen. When the minimum ignition temperature has been bracketed, tests are begun 50°F (28°C) below the lowest ignition temperature observed and repeated, dropping the temperature in 50°F (28°C) intervals until the temperature is reached at which there is no ignition during 13 minutes. A repeat run may be desirable at this temperature using an air velocity of 10 feet/minute (3.0 m/min) to verify the use of 5 feet/minute (1.5 m/min) as optimum.

The lowest air temperature (T_2) at which a flash is observed is recorded as the minimum flash-ignition temperature.

26.608.2 Minimum Self-ignition Temperature. Follow the same procedure as in Section 26.608.1 but without the gas pilot flame.

Self-ignition will be evidenced by flaming or glowing of the specimen. It may be difficult, with some materials, to detect self-ignition visually when burning is by glowing rather than flaming. In such cases, the rapid rise in temperature at thermocouple T_1 above that at T_2 is the more reliable reference.

The lowest air temperature (T_2) at which the specimen burns is recorded as the minimum self-ignition temperature.

SECTION 26.609 — REPORT

The report shall include the following:

1. Designation of material, including name of manufacturer, composition and state of subdivision (granules, sheet, etc.).
2. Air velocities used. If air velocity is not critical, this should be noted.
3. Flash-ignition temperature.
4. Self-ignition temperature.
5. Visual observation (melting, bubbling, smoking, etc.).

UNIFORM BUILDING CODE STANDARD 26-7
METHOD OF TEST FOR DETERMINING CLASSIFICATION OF APPROVED LIGHT-TRANSMITTING PLASTICS

Based on Standard Test Method D635-74 of the American Society for Testing and Materials. Extracted, with permission, from the *Annual Book of ASTM Standards,* copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428

See Sections 217 and 2603.1.3, *Uniform Building Code,* and Section 212, *Uniform Sign Code*

SECTION 26.701 — SCOPE

This method of test covers a small scale laboratory test for the purpose of classifying approved light-transmitting plastics in the form of bars, molded or cut from sheets, plates or panels tested in the horizontal position. This method should be used to establish the proper classification of approved light-transmitting plastics and should not be used as a fire hazard test method.

SECTION 26.702 — SUMMARY OF METHOD

A bar of the material to be tested is supported horizontally at one end; the free end is exposed to a specified gas flame for 30 seconds. The time and extent of burning are measured and reported if the specimen does not burn more than 4 inches (102 mm). An average burning rate is reported for a material if it burns beyond the 4-inch (102 mm) mark from the ignited end.

SECTION 26.703 — APPARATUS

26.703.1 Test Chamber. The test chamber is to be a laboratory hood totally enclosed with a heat-resistant glass window for observing the test. A mirror is to be provided within the chamber to provide a rear view of the specimen during the test. The exhaust fan is turned off during the test and turned on immediately following the test in order to remove products of combustion which may be toxic when testing some materials. Alternatively, the test may be made in a metal cabinet placed inside the hood leaving the hood exhaust fan turned on. The cabinet must have air holes on the bottom and top. The holes must allow ample passage of air for characteristic burning but must not allow drafts across the burning specimen.

26.703.2 Specimen Holder. The specimen shall be supported in the proper position by laboratory ring stands with two small clamps adjustable, by means of a check nut, to any angle.

26.703.3 Ignition Source. The ignition source shall be a standard $^3/_8$-inch (9.5 mm) diameter Bunsen burner with a laboratory gas supply.

SECTION 26.704 — TEST SPECIMEN

At least 10 test specimens 5 inches (127 mm), plus or minus $^1/_4$ inch (6.4 mm) in length, by $^1/_2$ inch (13 mm), plus or minus 0.008 inch (0.20 mm) in width and of the thickness of material normally supplied, shall be cut from sheets or molded from each of the samples to be tested.

The specimens shall normally be tested in the as-received condition unless otherwise specified.

Each test specimen shall be marked by scribing a line 4 inches (102 mm) from end of the specimen.

The edges of the test specimen shall be smooth. Sawed edges should be fine sanded to a smooth finish.

SECTION 26.705 — PROCEDURE

Clamp the specimen at the marked end in a support with its longitudinal axis horizontal and its transverse axis inclined at 45 degrees to the horizontal. Under the test specimen, clamp a screen of 20-mesh wire gauze, about 4 inches (102 mm) square, in a horizontal position $^3/_8$ inch (9.5 mm) below the edge of the specimen and with about $^1/_2$ inch (13 mm) of the specimen extending beyond the edge of the wire gauze (see Figure 26-7-1). Any material remaining on the screen from the previous test must be burned off on a new screen used for each test. A pan of water should be placed on the floor of the hood in a position to catch any burning particles that may drop during the test.

Adjust a standard $^3/_8$-inch (9.5 mm) diameter Bunsen burner, with air ports open, to produce a blue flame approximately 1 inch (25 mm) high. Place the burner so that the tip of the outer cone of the flame contacts the end of the test specimen starting the stopwatch simultaneously. Apply the flame for 30 seconds. If the specimen warps, melts or shrinks away from the flame, move the flame to keep it in contact with the specimen. Excessive distortion of the specimen during the test may invalidate the results. At the end of 30 seconds, remove the flame and place it at least 18 inches (457 mm) from the specimen to reduce the effects of draft in the hood while the specimen is allowed to burn.

Stop the watch when burning (flame) or glowing combustion (visible glow without flame) ceases, or when it has proceeded to the mark 4 inches (102 mm) from the free end. Record the time in seconds on the watch as burning time, t.

If the burning has not reached the mark, measure the unburned length to the nearest 0.04 inch (1.0 mm) along the lower edge of the specimen from the mark. The extent of burning is defined as 4 inches (102 mm) minus the unburned length in the same units.

If specimen has burned to or beyond the mark, calculate the burning rate as $240/t$ [inches/minute ($6096/t$ mm/min)].

Repeat the procedure above until three specimens have burned to or beyond the mark or 10 specimens have been tested. If only one of 10 specimens tested burns to the mark or beyond, repeat the procedure above with 10 additional specimens.

SECTION 26.706 — REPORT

26.706.1 Burning Rate. If two or more specimens have burned to the gage mark, average burning rate (inches/minute) (mm/min) shall be reported as the average of the burning rates of all specimens which have burned to the mark.

26.706.2 Average Time of Burning and Average Extent of Burning. The average time of burning and average extent of burning of the samples shall be reported if none of 10 or no more than one of 20 specimens has burned to the mark.

26.706.3 Average Time of Burning. The average time of burning shall be equal the sum of t minus 30 seconds divided by the number of specimens [Σ (t – 30)/number of specimens] rounded (after averaging) to the nearest multiple of five seconds; that is, "less than five seconds" would be reported if burning or flowing continued less than three seconds after removal of flame. In no case is an average time of burning of "zero" to be recorded.

26.706.4 Average Extent of Burning. The average extent of burning is equal to the summation of the quantity of 4 inches (102 mm) minutes the unburned length divided by the number of specimens [Σ (4 inches (102 mm) – unburned length/number of specimens)] rounded (after averaging) to the nearest 0.2 of an inch (5.1 mm); extent of burning less that $^1/_8$ of an inch (3.2 mm), report as "less than 0.2 of an inch (5.1 mm)," in no case reporting "zero." Extent of burning of a single specimen that burns to the mark is counted as 4 inches (102 mm).

26.706.5 Classification. Approved light-transmitting plastic materials shall be classified as either CC1 or CC2 in accordance with the following requirements:

CC1: Plastic materials which have a burning extent of 1 inch (25 mm) or less when tested in nominal 0.060-inch (1.5 mm) thickness (or in the thickness intended for use) by this test.

CC2: Plastic materials which have a burning rate of 2.5 inches per minute (64 mm/min) or less when tested in nominal 0.060-inch (1.5 mm) thickness (or in the thickness intended for use) by this test.

26.706.6 Items to be Reported. The complete report shall include the following:

1. Identification of the sample including method of preparation and condition.

2. Average thickness of the specimen to ± 1 percent.

3. Number of specimens tested.

4. Range of time of burning values.

5. Range of extent of burning values.

6. If a specimen does not burn to the mark because of dripping, flowing or falling burning particles, the report must so indicate.

7. If a specimens reignited by burning material on the wire gauze, the report must so state.

8. Classification of material in accordance with Section 26.706.5.

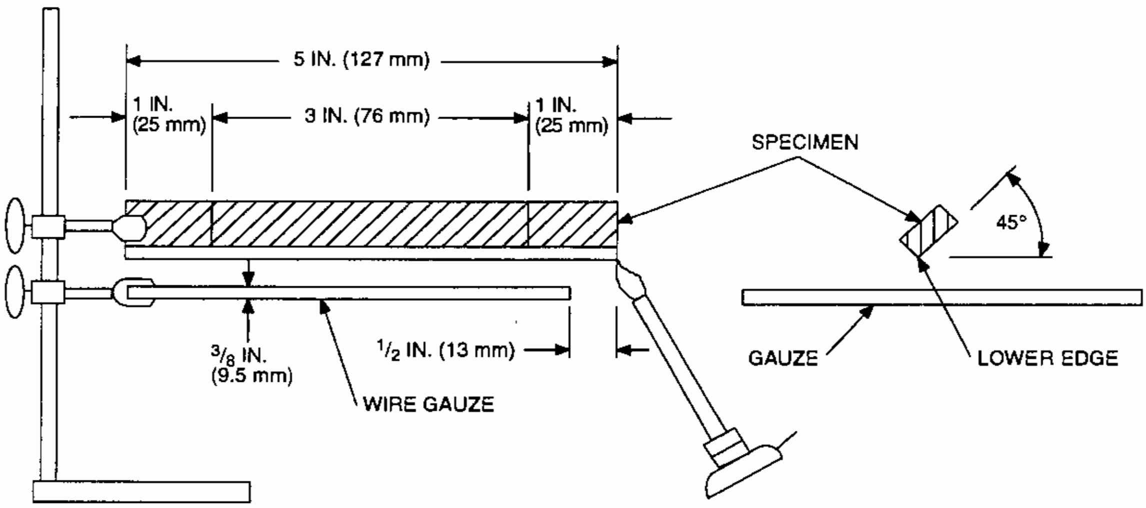


FIGURE 26-7-1—TEST APPARATUS

UNIFORM BUILDING CODE STANDARD 26-8
ROOM FIRE TEST STANDARD FOR GARAGE DOORS USING FOAM PLASTIC INSULATION

Test Standard of the International Conference of Building Officials

See Sections 601.3 and 2602.5.5, *Uniform Building Code*

NOTE: This is a new standard.

SECTION 26.801 — SCOPE

This standard is a test method designed to evaluate the contribution of garage doors using foam plastic insulation to the creation of fire hazard under specified fire exposure conditions. The method is conducted in a standard room configuration. This standard determines compliance of garage doors in accordance with Section 2602.5.5 of the *Uniform Building Code*.

This standard is to be used to evaluate the flammability characteristics of garage door assemblies using foam plastic insulation when the foam plastic is not separated from occupied spaces by a facing of minimum 0.3 mm (0.010 in.) steel or 3.2 mm ($^1/_8$ in.) wood in accordance with Section 2602.5.5 of the *Uniform Building Code.*

This standard is not intended to evaluate the fire endurance of assemblies, nor does it provide full information concerning the toxicity of combustion gases.

SECTION 26.802 — SIGNIFICANCE AND USE

This fire test measures fire performance characteristics of foam plastic insulated garage doors in an enclosure when the test specimen is subjected to a specified flaming ignition source under well-ventilated conditions. The method determines the extent to which foam plastic insulated garage doors contribute to the creation of fire hazard in a room under the conditions specified. The method also assesses the potential for fire spread beyond the room under the particular conditions simulated.

The test indicates the maximum extent of fire growth in a room, the rate of heat release, smoke obscuration, flame propagation tendencies, and, if they occur, the time to flashover and the time for flame extension beyond the doorway.

The effect of the fire on objects in or near the room, but remote from the ignition source, is evaluated by measurements of:

1. The total heat flux incident on the center of the floor.
2. The upper level gas temperature in the room.
3. The instantaneous peak rate of heat release.

The effects of the fire on areas remote from the room of origin are evaluated mainly by the measurement of total heat release of the fire.

Rate of heat release is measured by the principle of oxygen consumption. Measurements of the rate of production of carbon monoxide and carbon dioxide are normally taken. Where carbon dioxide or carbon monoxide is "scrubbed" and, therefore, not measured, Section 26.813 provides alternative calculation methods for rate of heat release.

Smoke obscuration is measured by an optical system within the fire room exhaust duct. Smoke obscuration measurement (as the rate of smoke release, total smoke released or the optical density of the smoke) is used to estimate the reduction in visibility caused by the smoke released during a test.

SECTION 26.803 — SUMMARY OF METHOD

A 2.13 m (7 ft.) high by 2.4 m (8 ft.) wide foam plastic insulated garage door is mounted adjacent to the rear wall of a 2.4 m (8 ft.) wide, 3.6 m (12 ft.) long by 2.4 m (8 ft.) high room enclosure. The test specimen covers the rear wall from floor level to 2.13 m (7 ft.) high.

This method uses a gas burner to produce a diffusion flame. The burner is located in the corner of the test room adjacent to the test specimen. The burner produces a prescribed rate of heat release output of 40 kW (38 Btu/s) for five minutes followed by 150 kW (142 Btu/s) for 10 minutes, for a total exposure period of 15 minutes. The contribution of the test specimen to room fire hazard is measured via constant monitoring of the rate of heat release, smoke release rate, the temperature of the gases in the upper part of the room, temperature rise in the core of the test sample, incident heat flux on the center of the floor and time to flashover. The test is conducted with natural ventilation to the room provided by a single doorway 0.76 m (30 in.) wide by 2.03 m (80 in.) high.

The combustion products are collected in a hood feeding into a plenum connected to an exhaust duct in which measurements are made of the gas velocity, temperature, percent light transmission and concentration of selected gases.

SECTION 26.804 — DEFINITIONS

For purposes of this standard, the following terms shall be defined as indicated:

AVERAGE UPPER GAS LAYER TEMPERATURE shall be based on the average of the four ceiling quadrant thermocouples and the center of the room ceiling thermocouple.

FLASHOVER shall be determined to have occurred when any two of the following conditions have been attained:

1. Heat flux at floor reaches 25 kW/m^2 (2.2 Btu/ft.^{2}·s).
2. Average upper air temperature exceeds 650°C (1200°F).
3. Flames exit doorway.
4. Spontaneous ignition of paper target on floor occurs.

SECTION 26.805 — IGNITION SOURCE

26.805.1 Burner Dimensions. The ignition source for the test shall be a gas burner with a nominal 0.3 m by 0.3 m (12 in. by 12 in.) porous top surface of refractory material. See Figure 26-8-1. A burner shall be constructed with a 25.4 mm (1 in.) thick porous ceramic fiberboard over a 152 mm (6 in.) plenum, or a minimum 102 mm (4 in.) layer of Ottawa sand shall be permitted to be used to provide the horizontal surface through which the gas is supplied.

26.805.2 Burner Location. The top surface of the burner through which the gas is applied shall be 0.3 m (12 in.) above the floor in the left rear corner of the room as viewed from the door. The burner enclosure shall be located such that the edge of the diffusion surface is located 51 mm (2 in.) from the left side wall and 51 mm (2 in.) from the facing over the foam plastic core of the test specimen. See Figure 26-8-2.

26.805.3 Burner Gas Supply. The gas supply to the burner shall be of C.P. grade propane (99 percent purity) or methane. The burner shall be capable of producing a gross heat output of 40 kW ± 1 kW (38 Btu/s ± 1 Btu/s) for five minutes followed by a gross heat output of 150 kW ± 5 kW (142 Btu/s ± 5 Btu/s) for 10 minutes. Heat release rates shall be calculated using propane's net heat of combustion, which is 46.5 MJ/kg (0.020 Btu/lb.) or methane's net heat of combustion, which is 50.0 MJ/kg (0.0215 Btu/lb.). The burner design shall allow switching from 40 kW (38 Btu/s) to 150 kW (142 Btu/s) within 10 seconds. Burner controls are permitted for automatic shutoff of the gas supply if flameout occurs. Two acceptable arrangements for a gas supply are illustrated by Figure 26-8-3.

26.805.4 Burner Ignition. The burner shall be ignited by a pilot burner or a remotely controlled ignitor.

SECTION 26.806 — COMPARTMENT GEOMETRY AND CONSTRUCTION

26.806.1 Fire Room Dimensions. The interior dimensions of the floor of the fire room, when the specimens are in place, shall measure 2.44 m ± 0.1 m by 3.66 m ± 0.1 m (8 ft. ± 3.9 in. by 12 ft. ± 3.9 in.). The finished ceiling shall be 2.44 ± 0.1 m (8 ft. ± 3.9 in.) above the floor. There shall be four walls at right angles defining the compartments. See Figure 26-8-4.

26.806.2 Doorway. There shall be a 0.76 m ± 6.4 mm by 2.03 m ± 6.4 mm (30 in. ± 0.25 in. by 80 in. ± 0.25 in.) doorway in the center of one of the 2.44 m by 2.44 m (8 ft. by 8 ft.) walls, and there shall be no other wall, floor or ceiling openings that allow ventilation. The door frame shall be constructed to remain unchanged during the test period to a tolerance of ± 1 percent in height and width.

26.806.3 Fire Room Construction. The fire room shall be permitted to be a framed or a masonry structure. The floor, ceiling, and walls of the test compartment shall be covered by calcium-silicate board or by gypsum wallboard. The inside surface of the wall containing the door shall be of calcium-silicate board of 736 kg/m^3 (46 lb./ft.^{3}) density and 12 mm (0.5 in.) in nominal thickness or 12 mm (0.5 in.) gypsum wallboard.

SECTION 26.807 — SPECIMEN MOUNTING

Specimen mounting details shall be comparable to that intended for actual product use. Specimens shall consist of full garage door assemblies incorporating inside and outside facings, gaskets, framing members, insulation, air gaps, and other details, as appropriate to the product being evaluated, and as follows:

1. A minimum 2.4 m (8 ft.) wide by 2.13 m (7 ft.) high test specimen shall be mounted adjacent to the gypsum wallboard rear wall of the fire room enclosure, as shown in Figure 26-8-2.

2. The garage door shall be mounted in the fire room so that the bottom of the door rests on the floor of the fire room and the top of the door is not more than 305 mm (12 in.) below the underside of the ceiling. Where a garage door in an actual installation may be installed with less than 305 mm (12 in.) separation between the top of the door and the underside of the ceiling, the door shall be mounted in the fire room using the minimum separation contemplated for the actual installation.

3. Test specimens are attached to the gypsum wallboard fire room enclosure using metal stud screws and fender washers at the edges of panels as indicated on Figure 26-8-2. Angle brackets are located at panel edges, so that one bracket attaches to, and secures, two panels in place. See Figure 26-8-5. The screws and angle brackets located directly above the burner are tightened to hold the test specimen securely in place. The angle bracket and metal stud screws placed in the slots of the angle bracket on the end of the panels remote from the burner are lightly tightened, allowing the specimen to expand during tests. The right side of the test specimen, as viewed from the room door, is to be separated up to a maximum of 38.1 mm (1$^1/_2$ in.) from the right side wall of the test room enclosure to allow for thermal expansion.

4. Test specimens are oriented such that the normally inside face of the garage door assembly faces the burner.

SECTION 26.808 — SPECIMEN CONDITIONING

Prior to testing, specimens shall be conditioned for a minimum of seven days or until the sample reaches a rate of weight change of less than 0.1 percent per day at a temperature of 49°C ± 2.8°C (70°F ± 5°F) and a relative humidity of 50 percent ± 5 percent.

SECTION 26.809 — ENVIRONMENTAL CONDITIONS

26.809.1 Fire Room Air Supply. The building in which the fire room is located shall have vents for the discharge of combustion products and have provision for fresh air intake, so that no oxygen deficient air is introduced into the fire room during the test. Prior to the start of the test, the ambient air at the mid-height entrance to the fire room shall have a velocity of less than 0.5 m/sec (100 ft./min.) in any direction. The building shall be of adequate size so that there shall be no smoke accumulation in the building below the level of the top of the fire room.

26.809.2 Ambient Temperature. The ambient temperature in the test building around the fire room shall be above 4°C (40°F) and the relative humidity shall be less than 75 percent for the duration of the test.

26.809.3 Ambient Conditions. If test samples are installed within the fire room for two or more hours prior to the test, the following ambient conditions shall be maintained:

1. The ambient temperature in the fire room measured by one of the thermocouples specified in Section 26.810.2.3 shall be 18°C to 24°C (65°F to 75°F).

2. The ambient relative humidity in the fire room shall be 50 percent ± 5 percent.

SECTION 26.810 — INSTRUMENTATION

The following instrumentation shall be provided for this test.

26.810.1 Total Heat Flux Gage.

26.810.1.1 Location. A gage shall be mounted a maximum of 51 mm (2 in.) above the floor surface, facing upward in the geometric center of the fire room. See Figure 26-8-6.

26.810.1.2 Specification. The gage shall be of the Gardon or Schmidt-Boetler type, with a circular flat black surface of 13 mm ($^1/_2$ in.) diameter and a 180-degree view angle. In operation, it shall be maintained at a constant temperature within 2.8°C (± 5 percent °F) above the dewpoint by water supplies at a temperature of 50°C to 65°C (120°F to 150°F). This will normally require a flow rate of at least 0.38 L/min. (0.1 gal./min.). The full scale output range shall be 50 kW/m^2 [4.4 Btu/(ft.^{2}·s)] for the gage.

26.810.2 Thermocouples.

26.810.2.1 Specification. Bare Type K thermocouples, 0.5 mm (20 mil) in diameter, shall be used at each required location. The thermocouple wire within 13 mm (0.5 in.) of the bead shall be run along expected isotherms to minimize conduction errors. The insulation between the chromel and alumel wires shall be stable to at least 1100°C (2000°F), or the wires shall be separated.

26.810.2.2 Location in doorway. A thermocouple shall be located in the interior plane of the door opening on the door centerline, 100 mm (4 in.) from the top. See Figure 26-8-6.

26.810.2.3 Location in room. Thermocouples shall be located 100 mm (4 in.) below the ceiling, at the center of the ceiling, at the center of each of the four ceiling quadrants and directly over the center of the ignition burner. The thermocouples shall be mounted on supports or penetrate through the ceiling with their junctions 100 mm (4 in.) away from a solid surface. See Figure 26-8-6. Any ceiling penetration shall be just large enough to permit passage of the thermocouples. Spackling compound or ceramic fiber insulation shall be used to backfill the holes around the thermocouple wire.

26.810.2.4 Location in canopy and exhaust duct. One pair of thermocouples shall be placed a minimum of 8.25 duct diameters downstream of the entrance to the horizontal duct. The pair of thermocouples shall straddle the center of the duct and be separated 50 mm (2 in.) from each other. See Figure 26-8-7.

26.810.2.5 Location in specimen foam core. One thermocouple shall be placed near the center of the foam plastic core, approximately 76.2 mm (3 in.) from the right side and 330 mm (13 in.) below the ceiling of the fire room. See Figure 26-8-2.

26.810.3 Canopy Hood and Exhaust Duct.

26.810.3.1 Location and design. A hood shall be installed immediately adjacent to the door of the fire room. The bottom of the hood shall be level with the top surface of the room. The face dimensions of the hood shall be a minimum of 2.44 m by 2.44 m (8 ft. by 8 ft.) and the minimum depth shall be 1.1 m (3.5 ft.). The hood shall feed into a plenum having a minimum 0.92 m by 0.92 m (3 ft. by 3 ft.) cross-section. The plenum shall have a minimum height of 0.92 m (3 ft.). This height shall be permitted to be increased to a maximum of 1.8 m (6 ft.) to satisfy building constraints. The exhaust duct connected to the plenum shall be a minimum of 0.4 m (16 in.) in diameter, horizontal and shall be permitted to have a circular aperture of at least 0.3 m (12 in.) at its entrance or mixing vanes in the duct. See Figures 26-8-7 and 26-8-8 for additional details.

26.810.3.2 Exhaust flow rate. The hood shall have sufficient draft to collect all of the combustion products leaving the room. This draft shall be capable of moving up to 3.4 m^3/sec (7,000 standard $ft.^3$/min.) equivalent to 7.25 m^3/s (16,100 cfm) at 399°C (750°F) during the test. Provision shall be made so that the draft can operate at 0.47 to 3.4 m^3/sec (1,000 to 7,000 standard $ft.^3$/min.). Mixing vanes shall be provided in the duct if concentration gradients are found to exist.

26.810.3.3 Alternative exhaust design. An alternative exhaust system design shall be permitted to be used if it meets the requirements of Section 26.811.

26.810.4 Duct Gas Velocity.

26.810.4.1 Specification. A bidirectional probe or an equivalent measuring system shall be used to measure gas velocity in the duct. The probe shall consist of a short, stainless steel cylinder 44 mm (1.75 in.) long and of 22 mm (0.875 in.) inside diameter with a solid diaphragm in the center or other design shown capable of measuring gas velocity in the duct. See Figure 26-8-9. The pressure taps on either side of the diaphragm support the probe. The axis of the probe shall run along the centerline of the duct a minimum of 8.25 duct diameters downstream from the entrance. See Figure 26-8-7. The taps shall be connected to a pressure transfuser that shall be able to resolve pressure differences of 0.25 Pa (0.001 in. water).

26.810.5 Oxygen Depletion Measurements.

26.810.5.1 Determination of rate of heat release. A stainless steel gas sampling tube shall be located a minimum of 8.63 duct diameters downstream from the entrance to the duct at the geometric center of the duct, ± 13 mm (± $^1/_2$ in.), to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time. See Figure 26-8-7. A suitable filter and cold trap shall be placed in the line ahead of the analyzer to remove particulates and water. The oxygen analyzer shall be of the paramagnetic or polarographic type and shall be capable of measuring oxygen concentration in a range of 21 percent to 15 percent, with a relative accuracy of 50 parts per million (ppm) in this concentration range. The signal from the oxygen analyzer shall be within 5 percent of its final value and occur within 30 seconds of introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

26.810.5.2 Duct carbon dioxide concentration. The gas sampling tube, described in Section 26.810.5.1, shall be used to provide a continuous sample for the measurement of the carbon dioxide concentration using an analyzer with a range not more than 0 to 6 percent (vol.), with a maximum relative error of 2 percent of full scale. The total system response time between the sampling inlet and the meter shall be no longer than 30 seconds.

26.810.5.3 Duct carbon monoxide concentration. The gas sampling tube, defined in Section 26.810.5.1, shall be used to provide a continuous sample for the measurement of the carbon monoxide concentration using an analyzer with a range not more than 0 to 1 percent (vol.), with a maximum relative error of 2 percent of full scale. The signal from the analyzer shall be within 5 percent of its final value and occur within 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

26.810.6 Smoke Obscuration Measurement.

26.810.6.1 Optical system. An optical system for measurement of light obscuration across the centerline of the exhaust duct shall be provided and shall be located a minimum of 9 duct diameters downstream from the entrance to the duct. See Figure 26-8-7. The optical density of the smoke shall be determined by measuring the light transmitted across the centerline of the exhaust duct with a photometer system consisting of a white light source and a photocell/detector or a laser system.

26.810.6.2 Specifications. The optical system shall consist of a lamp, plano convex lenses, an aperture, a photocell and an appropriate power supply. The lenses, lamp and photocell shall be mounted inside two housings, located on the exhaust duct, diametrically opposite each other. The system shall be constructed such that soot deposits on the optics during a test do not reduce the light transmission by more than 5 percent.

26.810.6.3 Lamp. A lamp of the incandescent filament type, which operates at a color temperature of 2900 ± 100 K (2627°C ± 100°C), shall be used. Supply the lamp with stabilized direct current, stable within ± 0.2 percent (including temperature, short-term and long-term stability). Center the resultant light beam on the photocell.

26.810.6.4 Lens system. Select the lens system such that lens L_2 has a diameter, *d*, chosen with regard to the focal length, *f*, of L_2 so that $d/f \geq 0.04$. Place the aperture in the focus of lens L_2. See Figure 26-8-10.

26.810.6.5 Detector. Use a detector with a spectrally distributed response according to the CIE photopic curve and linear within

5 percent over an output range of at least 3.5 decades. Check this linearity over the entire range of the instrument periodically with calibrated optical filters.

26.810.6.6 Optical system. Optical system design shall be one that is purged easily against soot deposits. Holes shall be provided in the periphery of the two housings as a means of achieving this objective.

26.810.6.7 Paper targets. Two paper target flashover indicators shall be placed on the floor of the test room. See Figure 26-8-12. The targets shall consist of a single piece of newsprint crumpled into an approximate 152 mm (6 in.) diameter ball.

26.810.6.8 Photographic documentation. Photographic or video equipment shall be used to record the fire spread in the fire room and the fire projection from the door of the room. The location of the cameras shall avoid interference with airflow. The interior wall surfaces of the fire room adjacent to the corner in which the burner is located shall be clearly marked. A clock shall appear in all photographic records, showing the time to at least the nearest one second from the start of the test. This clock shall be accurately synchronized with all other measurements, or other provision shall be made to correlate the photo record with time. Color slides or photographs shall be taken at intervals for the duration of the test, or a continuous video recording shall be made.

SECTION 26.811 — CALIBRATION

26.811.1 Heat Release, Temperature and Velocity. A calibration test shall be performed prior to and within 30 days of any fire test. The calibration test shall last for a minimum of 10 minutes. Take measurements a minimum of once every six seconds. The standard ignition source shall be used with inert wall and ceiling materials—calcium-silicate board of 736 kg/m^3 (56 lb./ft.^{3}) density, 13 mm (0.50 in.) thickness or gypsum wallboard.

26.811.1.1 Calibration factor. The data resulting from a calibration test shall provide:

1. The output as a function of time, after the burner is activated, of all instruments normally used for the standard fire test.

2. The maximum extension of the burner flame, as recorded by still photographs taken at approximately 30-second intervals or continuous video recording.

3. Calculation of C factor when either an orifice plate or bidirectional probe is used: The C factor in Formula (13-4) shall be determined in accordance with the following. Place the sand burner in the room/corner. Set the methane or propane flow to provide a constant heat release rate of 150 kW. Ignite the gas, and continue the burner for 10 minutes, and then switch off the gas. Then calculate the C factor as follows:

3.1 Estimate the initial calibration constant for C using the product 22.1 A, where "A" is the area of the duct (m^2). This gives a good estimation (generally within about 20 percent) of the final value one can expect for "C."

3.2 Burn either propane or methane fuel at 150 kW for a 10-minute interval. Measure the heat-release rate using oxygen consumption calorimetry, and Formula (13-3) using E and α values appropriate to the fuel. See E and α values contained within the list of defined symbols.

3.3 Calculate the total heat released (THR) from the mass loss of fuel and its heat of combustion, as specified in the standard (e.g., 1.8 kg of methane consumed = 90,000 kJ).

3.4 Adjust the calibration constant "C" so that the total rate of heat released, as determined by the oxygen consumption calculation, agrees with that from the mass of fuel consumed to within 5 percent.

$$C_{new} = \left[\frac{A * B * 1,000}{\int_0^t q(t)dt} \right] * C_{old}$$

WHERE:

A = the fuel value of the fuel being used (MJ/kg).

B = the total weight of fuel burned in the period T (kg).

$\int_0^t q(t)dt$ is in (kJ) and 1,000 is the conversion (kJ/MJ).

3.5 Use the new constant for subsequent tests for calculation of heat release rate and volumetric flow rate as noted in the example.

Example: An initial value of 6.6 is assigned to C. A 10-minute calibration burn uses 1.8 kg of methane (50 MJ/kg) at a fuel flow rate that corresponds to 150 kW. The oxygen consumption calculations reveal an average heat release rate of 160 kW during the burn period. Integrating the heat release rate curve over the 10-minute burn period shows that the total heat measured is 96 000 kJ. Applying the formula above, one finds:

$$C_{new} = [0.94] * C_{old}$$

The new calibration constant is 6.2. This will adjust the measured heat release rate (and THR) so that it agrees with the heat released from the fuel burned. Use the new calibration constant in all subsequent tests up until a new calibration burn is performed.

26.811.1.2 Calculated heat release. The total rate of heat production as determined by the oxygen consumption calculation, independent measurement of the volumetric flow rate, and weight loss of propane or methane supply shall agree to within 5 percent. The net heat of combustion is 46.5 MJ/kg (0.020 Btu/lb.) for propane and 50.0 MJ/kg (0.0215 Btu/lb.) for methane. This value shall be used for this calculation.

26.811.1.3 Smoke obscuration. The smoke meter shall be calibrated to read correctly for two neutral density filters at 0.5 and 1.0 values of optical density and at 100 percent transmission. The 0 value of extinction coefficient (100 percent transmission) shall be verified each day prior to testing.

26.811.1.4 Gas analysis. Gas analyzers shall be calibrated daily prior to testing, in accordance with ASTM E 800-88, Standard Guide for Measurement of Gases Present or Generated During Fires.

SECTION 26.812 — TEST PROCEDURE

The test procedure shall consist of the following:

1. Establish an initial volumetric flow rate of at least 0.47 m^3/sec (1,000 ft.^{3}/min.) through the duct and increase the volume flow rate of 3.4 m^3/sec (7,000 ft.^{3}/min.) as required to keep the oxygen content above 14 percent and to capture all effluents from the fire room.

2. Turn on all sampling and recording devices and take measurements a minimum of once every six seconds. Establish steady-state baseline readings for a minimum of one minute prior to starting a test.

3. Ignite the gas burner and simultaneously start the clock and increase flow rate to provide a rate of heat release of 40 kW ± 1 kW (38 Btu/s ± 1 Btu/s) by the burner. Continue the exposure at the 40 kW ± 1 kW (38 Btu/s ± 1 Btu/s) level for five minutes. Within 10 seconds following the five-minute exposure, increase the gas flow to provide a rate of heat release by the burner of 150 kW ± 5 kW (142 Btu/s ± 4.74 Btu/s) exposure for 10 minutes.

4. Take 35-mm color photographs at approximately 30-second intervals, or provide a continuous video recording to document the growth of the fire.

5. Provide a voice or written record of the fire, which documents the times of all significant events, such as time of ignition, escape of flames through the doorway, flashover, etc.

6. The ignition burner shall be shut off 15 minutes after start of the test and the test terminated at that time, unless safety considerations dictate an earlier termination.

7. Document damage after the test, using words, pictures and drawings.

SECTION 26.813 — CALCULATIONS

26.813.1 Heat Release. The calculation methods to determine the gross (total) rate of heat release (burner and specimen) shall be as follows:

Calculate mass flow rate using Formula (13-1):

$$\dot{m}_e = C * (\Delta p/T_e)^{1/2} \qquad (13\text{-}1)$$

Case 1: Only O_2 concentration measurements are used.

Calculate the mass flow rate according to Formula (13-1) and the oxygen depletion factor according to Formula (13-2):

$$\Phi = \frac{X^{Ao}{}_{O_2} - X^{A}{}_{O_2}}{\left[1 - X^{A}{}_{O_2}\right] * X^{Ao}{}_{O_2}} \qquad (13\text{-}2)$$

Then calculate the rate of heat release (q) according to Formula (13-3):

$$\dot{q} = E * \frac{M_{O_2}}{M_a} * \frac{\Phi}{1 + \Phi * (\alpha - 1)} * \dot{m}_e * X^{Ao}{}_{O_2} \qquad (13\text{-}3)$$

If only O_2 is measured, Formula (13-3) simplifies to Formula (13-4):

$$\dot{q} = E * 1.10 * C\sqrt{\frac{\Delta p}{T_e}} * \left[\frac{X^{Ao}{}_{O_2} - X^{A}{}_{O_2}}{1.105 - 1.5 * X^{A}{}_{O_2}}\right] \qquad (13\text{-}4)$$

Case 2: Only O_2 and CO_2 concentration measurements are used. Calculate the mass flow rate according to Formula (13-1) and the oxygen depletion factor according to Formula (13-5):

$$\Phi = \frac{X^{Ao}{}_{O_2} * \left[1 - X^{A}{}_{CO_2}\right] - X^{A}{}_{O_2} * \left[1 - X^{Ao}{}_{CO_2}\right]}{X^{Ao}{}_{O_2} * \left[1 - X^{A}{}_{O_2} - X^{A}{}_{CO_2}\right]} \qquad (13\text{-}5)$$

and the rate of heat release according to the same Formula (13-3).

Case 3: O_2 and CO_2 and CO concentration measurements are used:

Calculate the mass flow rate according to Formula (13-1), the moisture content of the incoming atmosphere according to Formula (13-3) and the oxygen depletion factor according to Formula (13-6):

$$\Phi = \frac{X^{Ao}{}_{O_2} * \left[1 - X^{A}{}_{CO_2} - X^{A}{}_{CO}\right] - X^{A}{}_{O_2} * \left[1 - X^{Ao}{}_{CO_2}\right]}{X^{Ao}{}_{O_2} * \left[1 - X^{A}{}_{O_2} - X^{A}{}_{CO_2} - X^{A}{}_{CO}\right]} \qquad (13\text{-}6)$$

Finally, calculate the rate of heat release according to Formula (13-7).

$$\dot{q} = \left[E * \Phi - \left[E_{CO} - E\right] * \frac{1 - \Phi}{2} * \frac{X^{A}{}_{CO}}{X^{A}{}_{O_2}}\right] * \frac{M_{O_2}}{M_e} * \frac{\dot{m}_e}{1 + \Phi * (\alpha - 1)} * X^{Ao}{}_{O_2} \qquad (13\text{-}7)$$

26.813.2 Smoke Release Rate. Smoke measurement calculation methods shall be as follows:

Optical density (OD) [Formula (13-8)]:

$$OD = \log\left[I_o/I\right] \qquad (13\text{-}8)$$

The volumetric flow rate is calculated as the product of the mass flow rate and the density of air, at the corresponding temperature. Both the volumetric flow and the density of air shall undergo temperature corrections. The volumetric duct flow rate (V) is adjusted because it is measured in the exhaust duct, but required at the temperature near the photodetector, as shown in Formula (13-9):

$$\dot{V}_s = V_e * \left(\frac{T_s}{T_e}\right) \qquad (13\text{-}9)$$

The density of air is adjusted between the literature value, measured at 273.15 K, and the value at the temperature in the exhaust duct, as shown in Formula (13-10):

$$\rho = \rho_o * 273.15/T_e \qquad (13\text{-}10)$$

Then the final formula for the volumetric flow rate is Formula (13-11):

$$\dot{V}_s = (\dot{m}_e/\rho_o) * (T_e/273.15) \qquad (13\text{-}11)$$

Rate of smoke release (RSR) is defined by Formula (13-12):

$$RSR = \dot{V}_s * OD * 1/L_p \qquad (13\text{-}12)$$

Total smoke released (TSR) is defined by Formula (13-13):

$$TSR = \int RSR\, dt \qquad (13\text{-}13)$$

WHERE:

A = cross-sectional area of duct (m^2).

C = orifice plate coefficient ($kg^{1/2}\, m^{1/2}\, K^{1/2}$).

E_{CO} = net heat released for complete combustion per unit of oxygen consumed, for CO (17 600 kJ/kg O_2).

E_m = net heat released for complete combustion of methane per unit of oxygen consumed (12 500 kJ/kg O_2).

E_P = net heat released for complete combustion of propane per unit of oxygen consumed (12 800 KJ/kg O_2).

E_{ts} = net heat released for complete combustion of test specimens, per unit of oxygen consumed (13 100 kJ/kg O_2).

$f(R_e)$ = Reynolds number correction (nondimensional).

I = light intensity for a parallel light beam having traversed a certain length of smoky environment and reaching photodetector (nondimensional).

I_o = light intensity for a beam of parallel light rays, measured in a smoke-free environment, with a detector having the same spectral sensitivity as the human eye and reaching the photodetector (nondimensional).

k_c = velocity profile shape factor (nondimensional).

L_p = light path length of beam through smoke environment (m).

M_a = molecular weight of incoming and exhaust air (29 kg/kmol).

M_{CO} = molecular weight of carbon monoxide (28 kg/kmol).

M_{CO_2} = molecular weight of carbon dioxide (44 kg/kmol).

M_{H_2O} = molecular weight of water (18 kg/kmol).

M_{n_2} = molecular weight of nitrogen (28 kg/kmol).

M_{O_2} = molecular weight of oxygen (32 kg/kmol).

m_e = $C(\Delta p/T_e)^{1/2}$ [mass flow rate, by measurement of pressure drop, in kg/s, according to Formula (13-1)].

OD = optical density (nondimensional).

q = rate of heat release (kW).

RSR = rate of smoke release (m^2/s).

TSR = total smoke released (m^2).

T_e = combustion gas temperature at the orifice plate (K).

T_s = combustion gas temperature (near photodetector) (K).

V_e = volumetric flow rate in exhaust duct (at measuring location of mass flow rate) (m^3/s).

V_s = volumetric flow rate at location of smoke meter (value adjusted for smoke measurement calculations) (m^3/s).

X^A_{CO} = measured mole fraction of CO in exhaust flow (nondimensional).

$X^A_{CO_2}$ = measured mole fraction of CO_2 in exhaust flow (nondimensional).

$X^A_{O_2}$ = measured mole fraction of O_2 in exhaust flow (nondimensional).

$X^{Ao}_{CO_2}$ = measured mole fraction of CO_2 in incoming air (nondimensional).

$X^{Ao}_{O_2}$ = measured mole fraction of O_2 in incoming air (nondimensional).

α_m = combustion expansion factor for methane (nondimensional; normally a value of 1.105).

α_p = combustion expansion factor for propane (nondimensional; normally a value of 1.084).

α_{ts} = combustion expansion factor for test specimens (nondimensional; normally a value of 1.105).

Δp = pressure drop across the orifice plate or bidirectional probe (Pa).

ρ = density of air at the temperature in exhaust duct (kg/m^3).

ρ_o = density of air at 273.15 K (1.293 kg/m^3).

Φ = oxygen depletion factor (nondimensional).

SECTION 26.814 — TEST REPORT

The test report shall include the following:

1. Name and address of testing laboratory.

2. Date and identification number of the report number.

3. Name and address of the test sponsor.

4. Materials:

   4.1 Product description. Identification of the product; foam plastic thickness, type and density; door facing materials, type and thickness; all other details of door construction necessary to accurately describe the product being tested.

   4.2 Mounting details. Product mounting details, including the height of the door tested.

   4.3 Conditioning. Product conditioning and time between removal of the specimen from the conditioning room and the start of testing.

   4.4 Room conditions. Relative humidity and temperature of the room and the test building prior to, and during, the test.

5. **Burner gas flow.** The burner gas flow is the fuel gas flow to the ignition burner and its calculated rate of heat output.

6. **Time history of the total heat flux to floor.** The time history of the total heat flux to floor is the total incident heat flux at the center of the floor for the heat flux gauge as a function of time starting a minimum of one minute prior to the test.

7. **Time history of the gas temperature.** The time history of the gas temperature is the temperature of gases in the room, in the doorway, and in the exhaust duct for each thermocouple; as a function of time starting a minimum of one minute prior to the test.

8. **Time history of the total rate of heat production of the fire, including burner output and specimen burning.** The total rate of heat production is calculated from the measured oxygen and carbon monoxide concentrations or measured oxygen, carbon monoxide, and carbon dioxide concentrations and the temperature and volumetric flow rate of the gas in the duct.

9. **Time history of the net rate of heat release from burning of the test specimen.** The net rate of heat release is calculated by subtracting the burner output from the total rate of heat production computed in accordance with Item 8.

10. **Time history of the smoke release rate.** The time history of the smoke release rate is calculated from the measured reduction in light transmission in the exhaust duct as a function of time starting a minimum of one minute prior to the test.

11. **Time history of the specimen core temperature.** The time history of the specimen core temperature is the temperature measured by the thermocouple in the specimen foam core as specified in Section 26.810.2.5, as a function of time starting a minimum of one minute prior to the test.

12. **Time history of the fire growth.** The time history of the fire growth is a transcription of the visual, photographic, audio and written records of the fire test. The records shall indicate the time of ignition of the test specimen, the approximate location of the flame front most distant from the ignition source at approximately 30-second intervals during the fire test and, if they occur, the time of flashover, and the time at which flames extend outside the doorway. In addition, still photographs taken at approximately 30-second intervals or continuous video recording shall be supplied.

13. Drawings and photographs or video recording shall be supplied to show the extent of the damage of the materials after the test.

14. Table of numerical results containing the following:

   14.1 Peak total rate of heat release (kW) and the time a which it occurred.

14.2 Peak net (specimen only) rate of heat release (kW) and the time at which it occurred.

14.3 Total heat released (MJ).

14.4 Maximum heat flux at floor level (kW/m^2) and the time at which it occurred.

14.5 Peak rate of smoke release (m^2/s) and the time at which it occurred.

14.6 Total smoke released (m^2).

14.7 Total smoke released at five minutes and at 7.5 minutes (m^2).

14.8 Peak specimen core temperature and the time at which it occurred.

14.9 Peak fire room temperatures (°C) and the time at which they occurred.

14.10 Formula used to calculate rate of heat release. Formula used to calculate rate of heat release.

SECTION 26.815 — ACCEPTANCE CRITERIA

Foam plastic insulated garage doors shall be considered as demonstrating satisfactory performance if the following conditions are met:

1. The maximum instantaneous net peak rate of heat release of the test sample shall not exceed 250 kW (237 Btu/s).

2. Flames shall not propagate for the full width of the test specimen. Propagation for the full width of the specimen shall be judged to occur:

If flames are visually observed to spread for the full width of the specimen, or

If the test specimen core temperature rise, determined by the thermocouple specified in Section 26.810.2.5, exceeds 400°C (750°F).

3. The total smoke released shall not exceed 60 m^2 (670 ft.^{2}) five minutes after the start of the test, nor shall the total smoke release exceed 150 m^2 (1,670 ft.^{2}) 7.5 minutes after the start of the test.

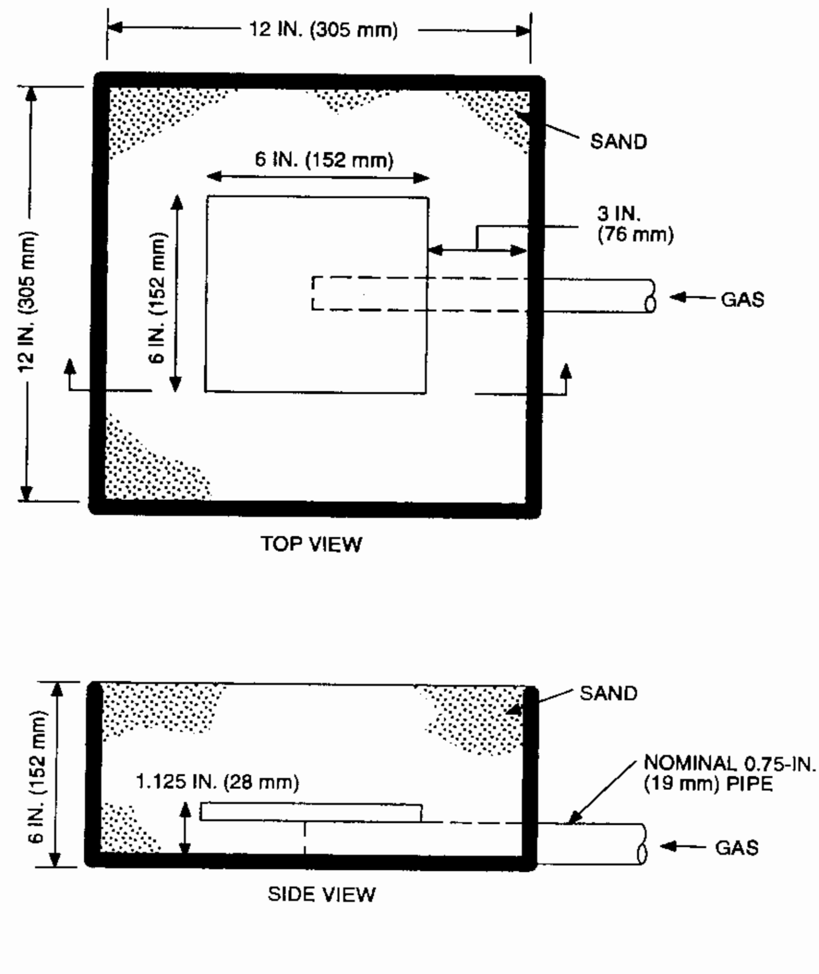
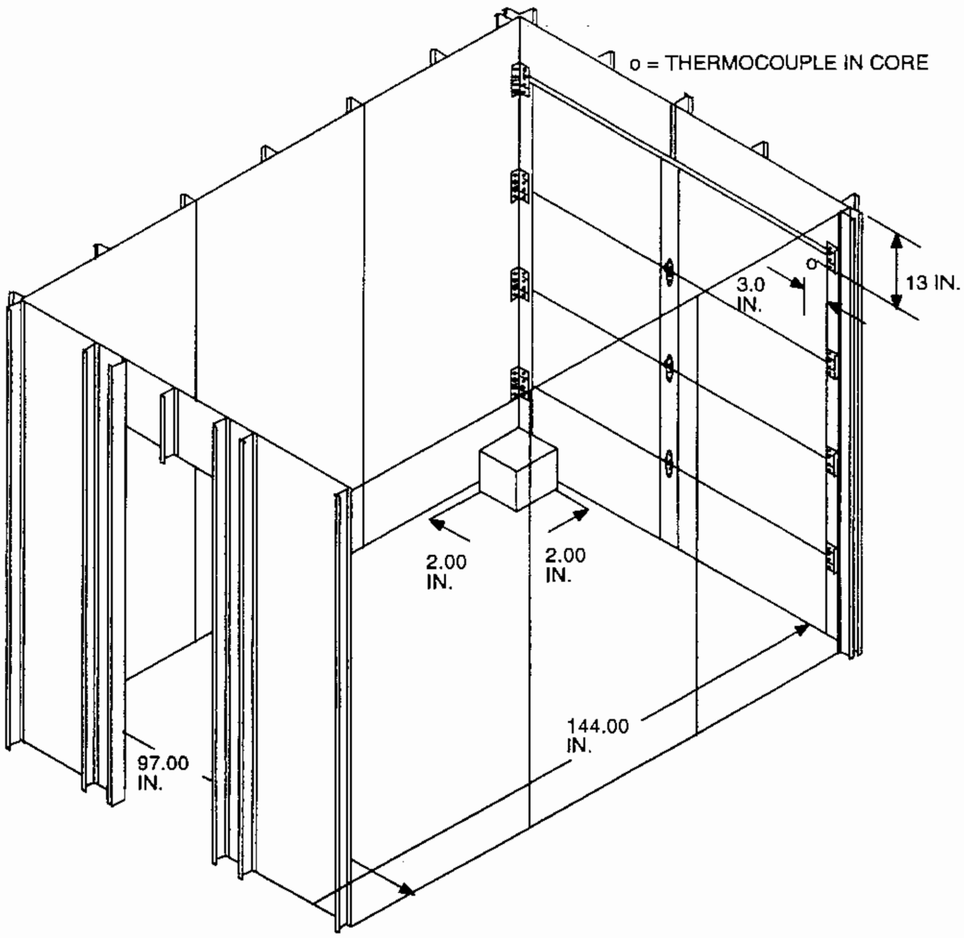
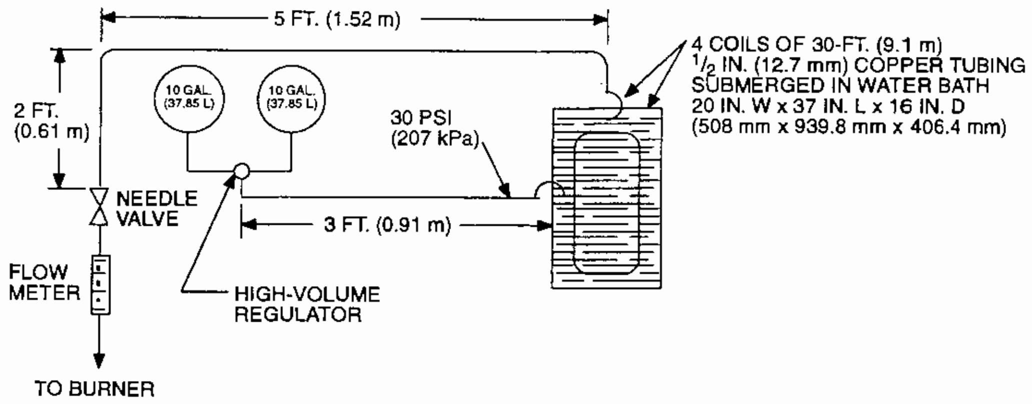


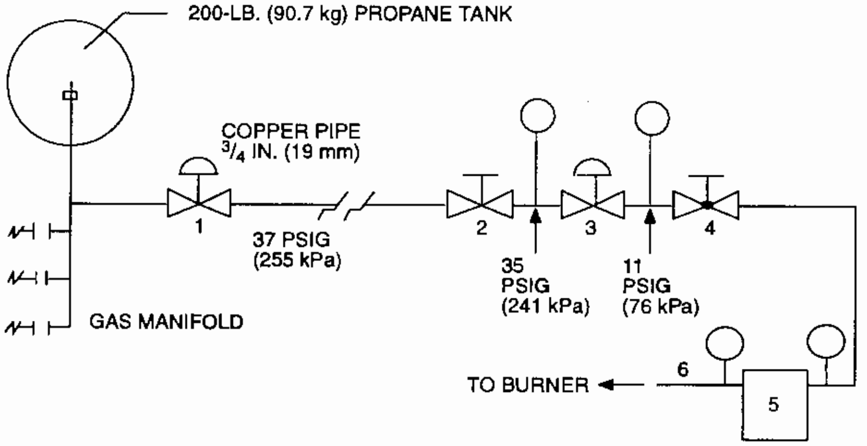
FIGURE 26-8-1—GAS BURNER



For **SI:** 1 inch = 25.4 mm.

FIGURE 26-8-2—BURNER LOCATION AND SPECIMEN MOUNTING DETAILS

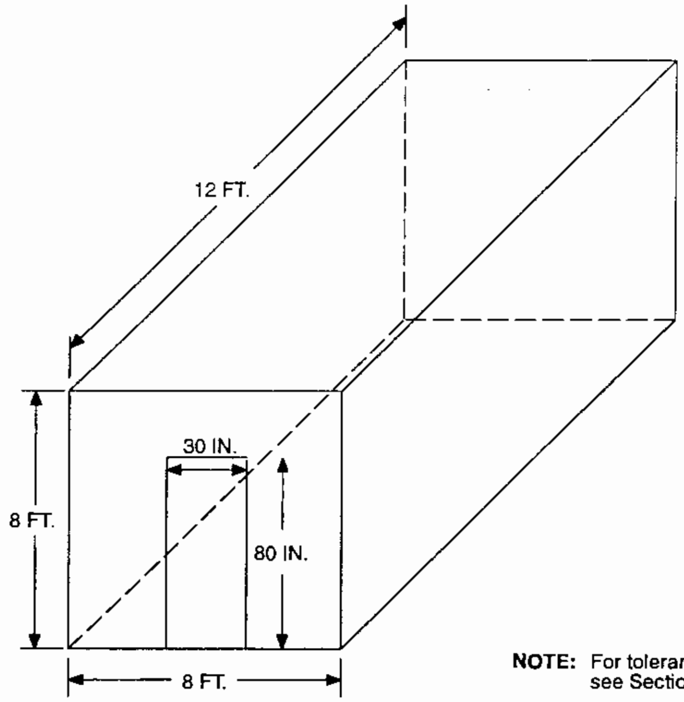




1. Propane gas regulator (high pressure) (main gas supply)
2. Shutoff valve
3. Regular (low pressure)
4. Adjustable valve for flow impedance
5. Volume meter
6. Steel braid over tubing to burner

Line pressures are shown.

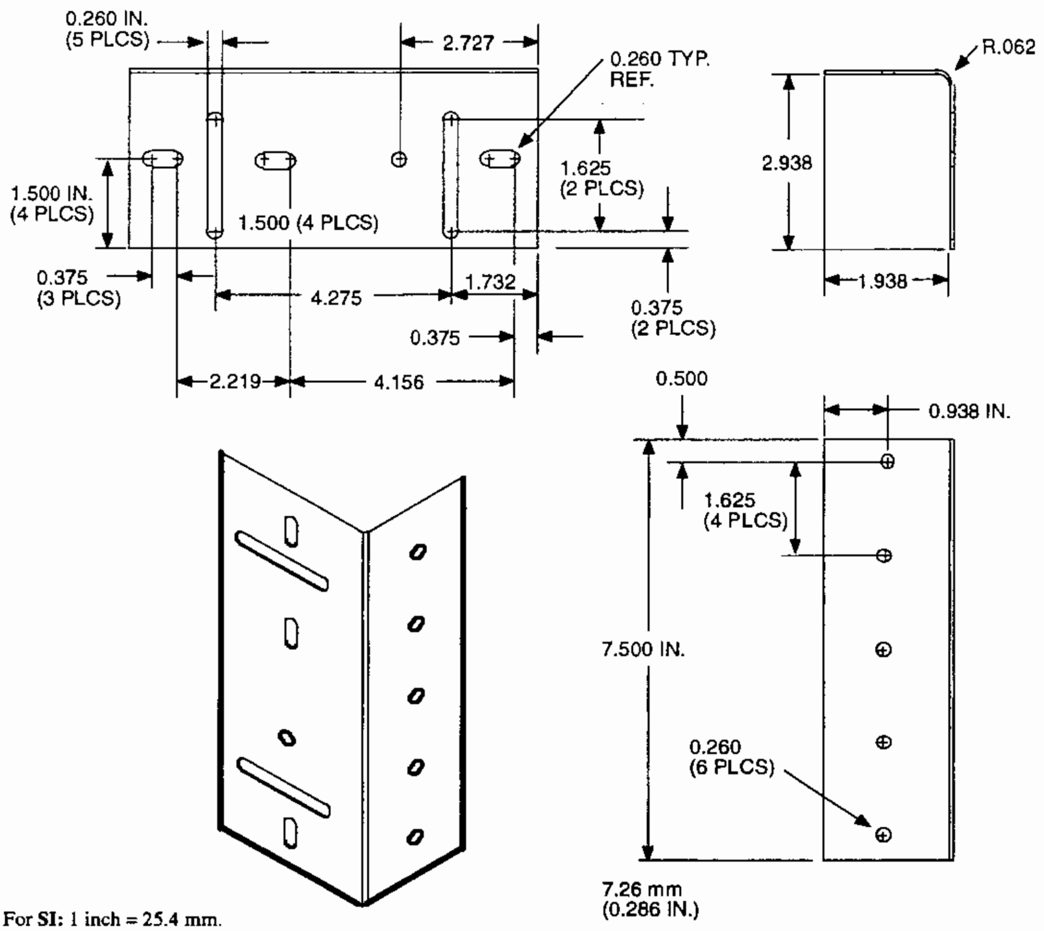
FIGURE 26-8-3—GAS FLOW REGULATION SYSTEMS



NOTE: For tolerances in dimensions, see Section 26.806.

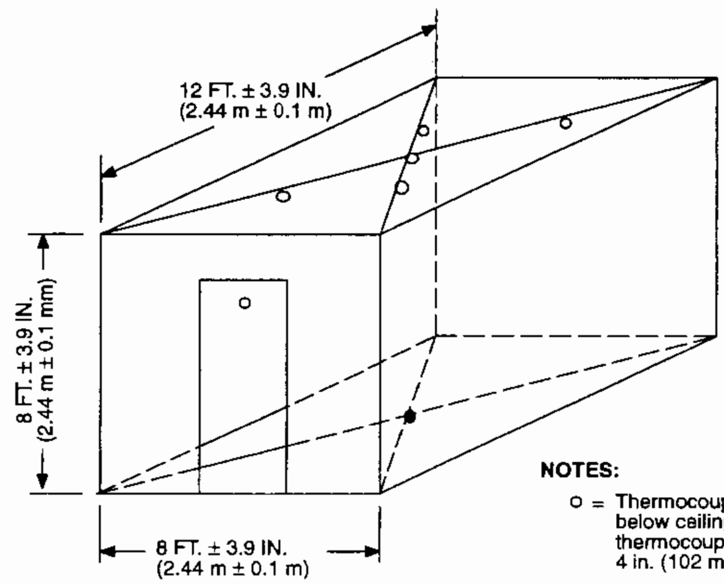
For **SI:** 1 inch = 25.4 mm, 1 foot = 304.8 mm.

FIGURE 26-8-4—INTERIOR ROOM AND DOORWAY DIMENSIONS



For **SI:** 1 inch = 25.4 mm.

FIGURE 26-8-5—ANGLE BRACKETS



NOTES:

○ = Thermocouples—each 4 in. (102 mm) below ceiling. Also one additional thermocouple over the burner and 4 in. (102 mm) below the ceiling.

● = Calorimeter on floor—2 in. (51 mm) above.

FIGURE 26-8-6—THERMOCOUPLE AND CALORIMETER PLACEMENT

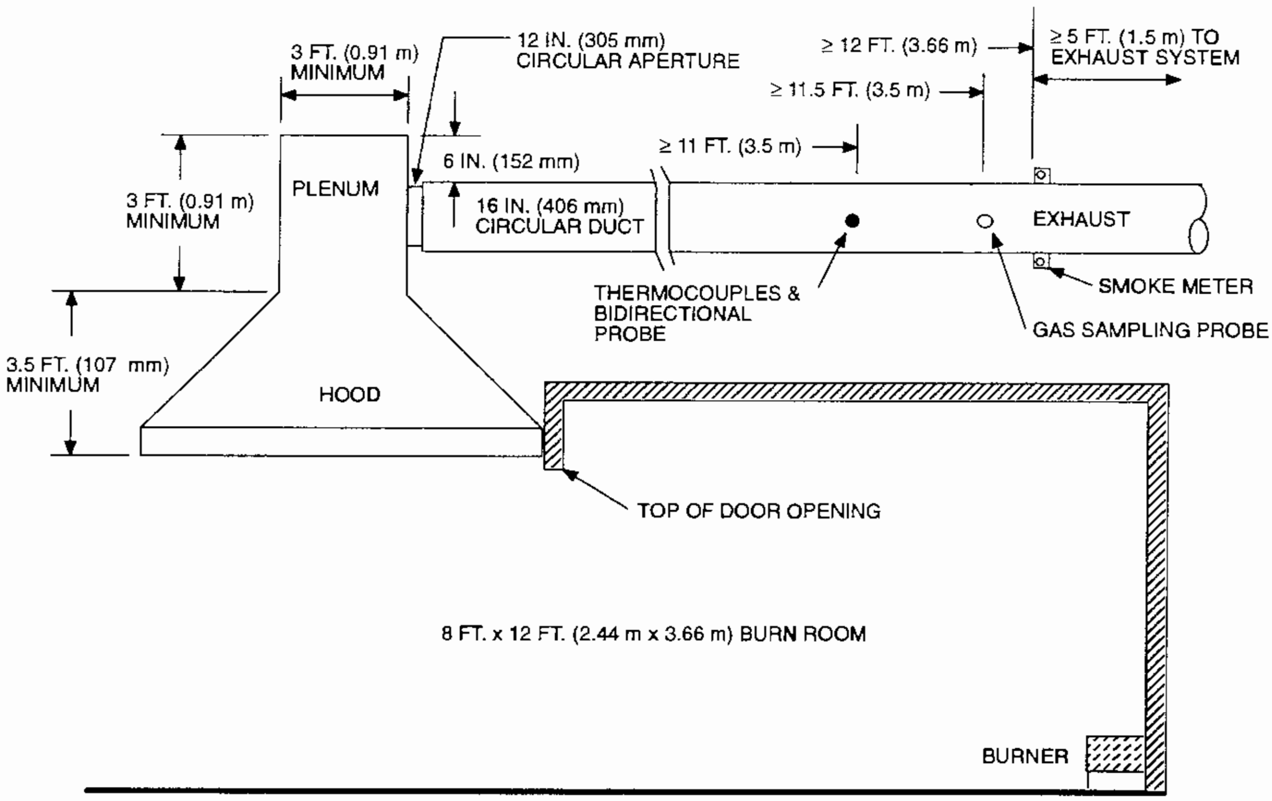


FIGURE 26-8-7—CANOPY HOOD AND EXHAUST DUCT

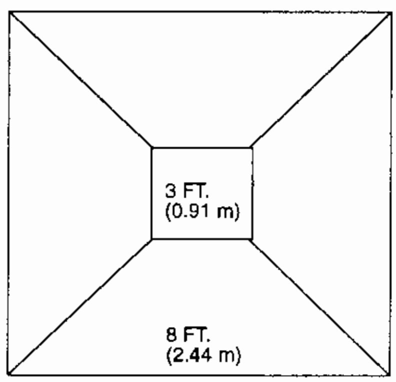


FIGURE 26-8-8—PLAN VIEW OF CANOPY HOOD

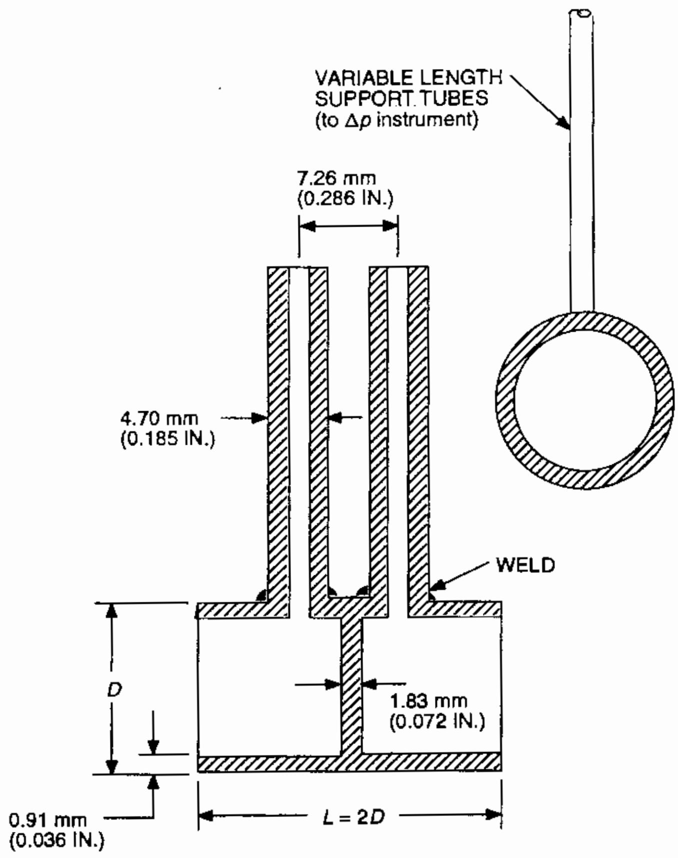


FIGURE 26-8-9—BIDIRECTIONAL PROBE

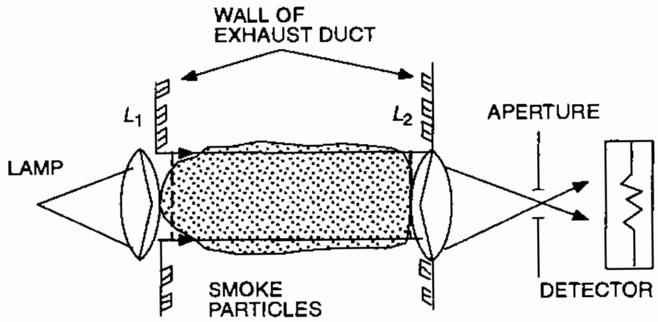


FIGURE 26-8-10—OPTICAL SYSTEM, USING A WHITE LIGHT

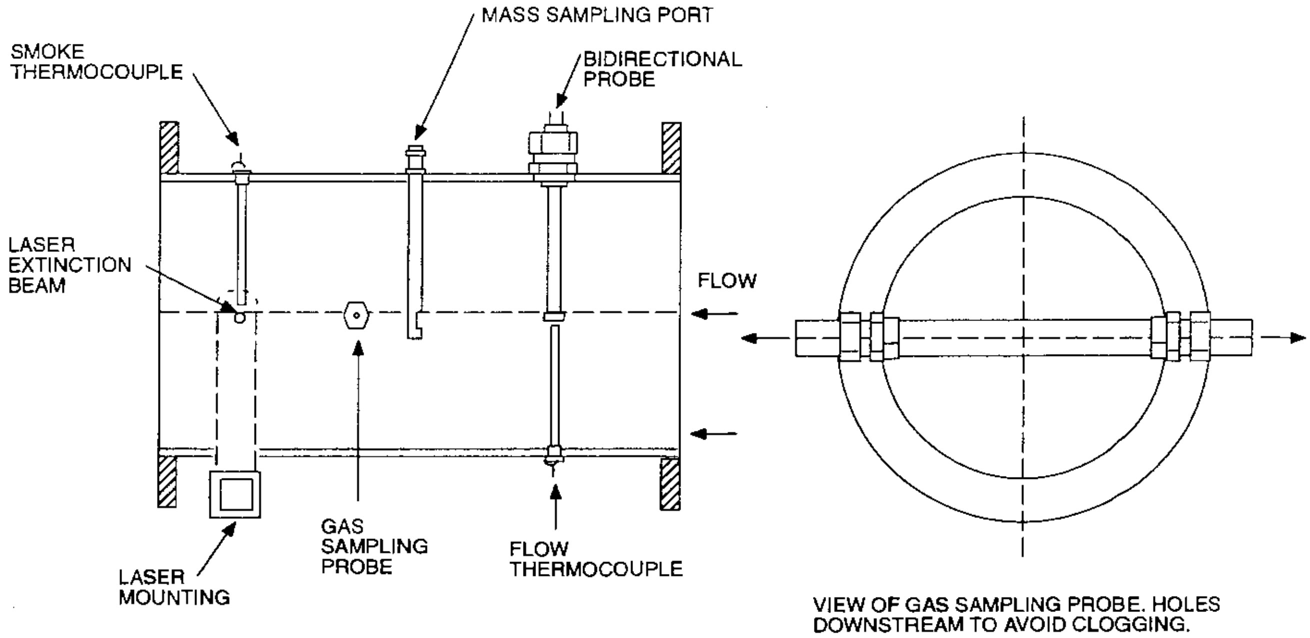


FIGURE 26-8-11—MOUNTING DETAILS FOR INSTRUMENTATION IN DUCT

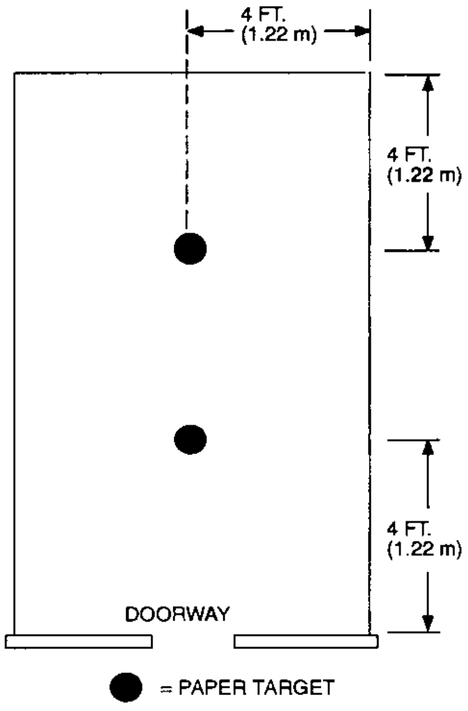


FIGURE 26-8-12—PAPER TARGET ARRANGEMENT—PLAN VIEW

UNIFORM BUILDING CODE STANDARD 26-9

METHOD OF TEST FOR THE EVALUATION OF FLAMMABILITY CHARACTERISTICS OF EXTERIOR, NONLOAD-BEARING WALL ASSEMBLIES CONTAINING COMBUSTIBLE COMPONENTS USING THE INTERMEDIATE-SCALE, MULTISTORY TEST APPARATUS

Test Standard of the International Conference of Building Officials

See Section 2602.5.2.2, *Uniform Building Code*

NOTE: This is a new standard.

SECTION 26.901 — SCOPE

This test provides a method of determining the flammability characteristics of exterior, nonload-bearing wall assemblies/panels which contain combustible components. The test structure used in this test is the intermediate-scale, multistory test apparatus. It is intended to simulate the tested wall assemblies' "full-scale" fire performance.

The primary performance characteristics to be evaluated in this test are as follows:

1. The capability of the test wall assembly to resist flame propagation over the exterior face of the system,

2. The capability of the test wall assembly to resist vertical spread of flame within the combustible core/component of the panel from one story to the next,

3. The capability of the test wall assembly to resist vertical spread of flame over the interior (room side) surface of the panels from one story to the next, and

4. The capability of the test wall assembly to resist lateral spread of flame from the compartment of fire origin to adjacent spaces.

The ability of the test wall assembly to meet these performance characteristics is determined by visual observations along with temperature data obtained during the test.

This test method is to be applied to wall assemblies/panels which contain combustible components such as those that contain foam plastic insulation or to wall assemblies/panels that contain plastic core materials. This method is not intended to apply to wall assemblies that contain, as the only combustible, insulation materials such as glass fiber and mineral wool.

This test is not an evaluation of the methods used to seal voids at the floor/wall intersection per se. While this test requires the use of materials to seal voids at the floor/wall intersection, the results of the test should not be restricted to the sealing method used but rather should encompass any approved sealing method suitable for the type of wall assembly tested.

SECTION 26.902 — TEST APPARATUS

26.902.1 Test Facility. The test apparatus described in Section 26.902.2 shall be located inside a test facility. The facility shall be a minimum of 40 feet by 40 feet by 25 feet high (12 192 mm by 12 192 mm by 7620 mm). The facility shall have provisions for supplying fresh combustion makeup air during the test. The facility shall also be constructed so as to allow for the exhaust of the combustion by-products during the test while not inducing an air flow on the exterior face of the test panels. The test facility shall protect the test apparatus and test samples from weather conditions such as wind and rain.

26.902.2 Test Apparatus. The intermediate-scale, multistory test apparatus (ISMA) consists of a two-story test structure having floor to top dimensions of 15 feet, 4 inches ± 1 inch (4674 mm ± 25 mm). Each room has inside dimensions (unfinished/unprotected) of 10 feet ± 0.5 inch by 10 feet ± 0.5 inch (3048 mm ± 13 mm by 3048 mm ± 13 mm) with floor to ceiling height (unfinished/unprotected) of 7 feet ± 0.5 inch (2134 mm ± 13 mm). See Figures 26-9-1 through 26-9-4 for diagrams of the test fixture.

The floors are constructed of reinforced concrete and are supported by steel columns of an appropriate size. The columns shall not be inside either the first- or second-story test rooms. The first floor slab shall be a minimum of 18 inches (457 mm) thick, and the second floor and third floor slabs shall be 8 inches ± 0.5 inch (203 mm ± 13 mm) thick.

The three permanent walls that form each room shall be constructed of 8 inches ± 0.5 inch (203 mm ± 13 mm) concrete block or similar construction.

The interior surfaces of the first floor burn room shall be insulated as follows:

1. Walls and ceiling—one layer of $^5/_8$ inch (15.9 mm) thick, Type X gypsum wallboard and one layer of $1^1/_2$ inches (38 mm) thick, 8 lb./ft.^{3} (128 kg/m^3) ceramic fiber insulation on the interior face. The insulation thickness on each individual wall or the ceiling shall not exceed $2^1/_2$ inches (64 mm).

2. Floor—two layers of $^5/_8$-inch (15.9 mm) thick, Type X gypsum wallboard.

No insulation is required in the second floor area.

Each floor level shall have one access opening approximately 3.5 feet wide by 6.75 feet high (1067 mm by 2057 mm). The access door opening on the first floor shall be capable of being closed during tests while the access opening on the second floor shall remain open during tests.

Additional access openings may be made in the second floor area for instrumentation and video; however, they shall be closed during tests.

Test wall assemblies may be built directly onto the test apparatus or they can be built into a movable frame system that is in turn fastened to the test apparatus.

26.902.3 Movable Test Frame. Figure 26-9-5 provides a sketch of the movable test frame. The frame is designed such that the 4 inches by 4 inches by $^3/_{16}$ inch (102 mm by 102 mm by 4.8 mm) angles will meet at the top of the respective floor lines on the test apparatus. The frame shall be sufficiently rugged so that no racking or movement will occur in the test wall assembly during movement and/or fastening. The frame system shown in Figure 26-9-5 will serve the minimum size test wall assembly. Larger frame assemblies are permitted.

26.902.4 Burners. The burner arrangement shall consist of two gas-fired burners. The first burner is positioned inside the first floor burn room while the second burner is positioned inside the window opening of the test wall assembly.

The burn room burner is constructed of 2 inch (51 mm) O.D. steel pipe with $^1/_8$-inch (3.2 mm) diameter holes placed 1 inch (25 mm) on center. The holes are positioned such that they face upward. The holes start at 3.5 feet (1067 mm) from the back wall on both sides of the gas supply pipes and continue across the front gas supply pipe.The entire gas supply pipe system is wrapped with a single layer of nominally 1 inch (25 mm) thick, 8 lb./ft.^{3} (128 kg/m^3) ceramic fiber blanket. The burner is supported such that its centerline is 2.5 feet ± 1.0 inch (762 mm ± 25 mm) above the floor. Figures 26-9-6 and 26-9-7 provide sketches of the burn room burner.

The window burner is similar to the burner used in the "Spread of Flame Test" portion of UBC Standard 15-2. The gas burner shall consist of a 60 inches ± 0.5 inch (1524 mm ± 13 mm) length of nominal 2-inch (51 mm) O.D. pipe having a 0.5 inch± 0.06 inch (13 mm ± 1.5 mm) wide by 44 inches ± 0.5 inch (1118 mm ± 13 mm) long slot. The burner is to be supplied with gas at both ends through nominal 1-inch (25 mm) O.D. pipe to provide uniform gas pressure at the burner slot. Figures 26-9-7 and 26-9-8 provide sketches of the window burner.

The burner is wrapped with a layer of nominally 1 inch (25 mm) thick, 8 lb./ft.^{3} (128 kg/m^3) ceramic fiber insulation. The burner is mounted on a movable trolley, positioned such that the slot is facing upward, and it is centered horizontally in the window opening. The horizontal centerline of the burner is 9 inches ± 0.5 inch (229 mm ± 13 mm) below the window header. The vertical centerline of the burner shall be placed such that it is 0 to 5 inches (127 mm) from the exterior face of the test wall assembly. The exact placement (inches from the exterior face) shall be based on information developed during the calibration procedure.

The burners shall be fired during the test according to the burner regime shown in Table 26-9-A. Each burner shall attain its assigned flow rate within 15 seconds of each change. If during the calibration procedure it is demonstrated that the burners need to follow slightly different flow rates to attain the prescribed burn room and/or exterior temperatures and heat fluxes, then the flows derived from the calibration tests shall be used.

SECTION 26.903 — TEST WALL ASSEMBLIES

The test wall assemblies shall be either built on the test apparatus or shall be built in a movable test frame. Figures 26-9-9 through 26-9-11 provide sketches of the test wall assembly mounting methods.

As a minimum, the test wall assembly shall be 17.5 feet high by 13.33 feet wide (5334 mm by 4064 mm). Larger wall assemblies are permitted.

The test wall assembly shall extend to the following:

1. Below the first floor a minimum of 2 inches (51 mm),

2. Above the top of the test apparatus a minimum of 2 feet (610 mm), and

3. Past the outside edges of both of the concrete block sidewalls a minimum of 1 foot (305 mm).

The test wall assembly shall completely close the front face of the test apparatus except for a simulated window opening in the first floor area. The window shall be 30 inches ± 0.5 inch high by 78 inches ± 0.5 inch wide (76 mm ± 13 mm by 1981 mm ± 13 mm) with a sill height of 30 inches ± 0.5 inch (76 mm ± 13 mm). It shall be centered horizontally with respect to the burn room. The window opening shall be the only opening in the first-story burn room area during the test.

The test wall assembly shall be secured to the test apparatus using a girt system of replaceable nominal 4 inches by 4 inches by $^3/_{16}$ inch (102 mm by 102 mm by 4.8 mm) steel angles.

A replaceable spandrel beam shall be mounted on the underside of the second floor when the attachment of the test wall assembly requires it to be present. The spandrel beam shall be W8 by 21 (W200 by 31) and shall be installed as shown in Figures 26-9-3 and 26-9-4. The spandrel beam shall extend across the burn room compartment from one protected interior wall surface to the opposite protected interior wall surface.

The spandrel beam, when used, shall be permitted to be either protected or unprotected at the discretion of the test laboratory or the client. If the spandrel beam is to be protected, then one layer of nominal 1 inch (25 mm) thick, 6 lb./ft.^{3} (96 kg/m^3) ceramic fiber shall be used. All outriggers and additional connections shall not be protected.

The test wall assembly shall be constructed and secured to the test apparatus using fastening and construction details representative of actual field conditions. Details of the erection shall follow the manufacturer's instructions and shall be typical of actual product use. When a product has vertical or horizontal joints/seams, joints/seams typical of normal construction including caulking, backing and other details as appropriate shall be incorporated into the test assembly.

Prior to test, the test wall assembly and its components shall be cured as required by the manufacturer. In the case of cementitious coatings/materials, a minimum of 28 days shall elapse from completion of construction to testing. During the cure time, the wall assemblies shall be protected from weather.

SECTION 26.904 — INSTRUMENTATION

The test instrumentation shall consist of the following:

1. Temperature measurements at the following locations:

   1.1 Exterior face of test wall assembly as shown in Figure 26-9-12,

   1.2 Core of the test wall assembly as shown in Figures 26-9-12 and 26-9-15,

   1.3 Interior surface of test wall system as shown in Figure 26-9-13, and

   1.4 Burn room ceiling area as shown in Figure 26-9-14.

The temperature measurements shall be made using 20 gage, Type K thermocouples except that those used to measure the temperatures shown in Figure 26-9-14 shall be 18 gage, Type K thermocouples.

2. Flow rate of gas to each of the burners shall be monitored and recorded.

All data shall be recorded at intervals not to exceed 15 seconds.

SECTION 26.905 — DOCUMENTATION

Documentation shall consist of the following:

1. Thirty-five mm color slides/photographs during construction of the test wall assembly, during actual test (at least once every minute), and posttest to include dissection of the test assembly;

2. Color videotape of the exterior face of the test wall assembly prior to, during and posttest;

3. Immediately prior to the start of the test, the exterior face of the assembly, the laboratory test report identification number and test date shall be filmed;

4. Color videotape of the test wall/floor intersection in the second floor level during the test period. This camera is used to assist in determination of flame penetration and/or smoke development; and

5. A clock or timer depicting "real time" shall be included in all videos. The timer may be integral to the video camera or a clock/timer may be used provided it can be clearly viewed throughout the test.

SECTION 26.906 — TEST PROCEDURE

The following test procedure shall be used:

1. Instrumentation on the completed test wall assembly shall be verified for operation;

2. Placement of window burner shall be verified;

3. Ambient conditions prior to test shall be as follows:

   3.1 Temperature: 50°F to 90°F (10°C to 32°C)

   3.2 Relative humidity: 20 percent to 80 percent

   3.3 Airflow across the exterior face of the test assembly shall be less than 4.4 ft./sec. (1.3 m/s) as determined by an anemometer placed at right angles to the exterior face;

4. Start video and data collection one minute prior to ignition of room burner;

5. Ignition of burn room burner;

6. Follow flow regime for burners;

7. Record visual observation of the performance of the wall assembly during the test period;

8. At 30 minutes after ignition of room burner, shut-off gas supply to both burners;

9. Continue data collection until residual burning has stopped or 10 minutes has elapsed after gas flow was shut off;

10. Allow any residual burning on the wall assembly to continue until extinguishment or until 10 minutes has elapsed after gas flow was shut off; and

11. The interior and exterior walls shall be photographed and visual observations taken. The test wall assembly shall be dismantled and dissected to determine height and depth of damage within the combustible core and the condition of the panel facings.

SECTION 26.907 — CALIBRATION PROCEDURE

An initial calibration test shall be performed to evaluate the flow rates of the gas burners and it shall be conducted prior to product testing.

The test wall assembly for the calibration test shall be constructed of two layers of $^5/_8$ inch (15.9 mm) thick, Type X gypsum wallboard applied to both sides of 18 gage steel studs that are at 24 inch (610 mm) centers. All joints shall be taped or caulked. Figure 26-9-16 provides a sketch of this construction. The test wall assembly shall extend 18 feet (5486 mm) above the first floor level and shall be 14 feet (4267 mm) wide.

The interior surface of the window opening shall be gypsum wallboard.

No spandrel beam shall be used.

Calibration instrumentation shall consist of the following:

1. As a minimum, temperature measurements at the locations shown in Figures 26-9-17 through 26-9-19 shall be made. The temperature measurements shall be made using 20 gage, Type K thermocouples except that those used to measure the temperatures shown in Figure 26-9-18 shall be 18 gage, Type K thermocouples.

2. A minimum of three 0-5 watt/cm^2 circular foil total heat flux gauges. Figure 26-9-17 provides the locations for these instruments; and

3. Flow rate measurements for each of the burners.

Prior to the conduct of the calibration test, the paper facing of the gypsum wallboard on the exterior face of the calibration wall assembly shall be burned away. This is accomplished by igniting both the room burner and the window burner and immediately adjusting the burners to their maximum flow rates as prescribed in Table 26-9-A. The burners shall be run for five minutes at these flows.

The calibration test shall be conducted such that the burners are fired during the test according to the burner regime shown in Table 26-9-A. Each burner shall be at its assigned flow rate within 15 seconds of each change.

The initial calibration test shall be conducted with the window burner positioned such that the vertical centerline of the burner is flush with the exterior face of the wall assembly.

At the conclusion of the test, the data obtained shall be compared to the specified values in Table 26-9-B. To prevent burner changes from affecting the data, determine the average values for each time period, using data from 15 seconds into the period through 15 seconds short of the end of the period. For example, if the average for the 5-10 minute time interval is being processed, use the data from the actual times of 5:15 through 9:45 for the average.

The allowable tolerances for the comparison of determined average values to the specified average values shall be ± 10 percent for temperatures and as shown in Table 26-9-B for the heat flux measurements. All of the determined average values for the locations shown in Table 26-9-B shall fall within the tolerances of those specified in Table 26-9-B. The values for Thermocouples 1 and 8 through 14, as shown in Figure 26-9-17, shall be reported, but they are not used in the calibration determination.

If the actual test values are not within the allowable tolerances, then the calibration shall be repeated and the gas flows or window burner position adjusted until the determined values are within the allowable tolerances.

If it is demonstrated that the burners must follow different flow rates to attain the prescribed burn room and/or exterior temperatures and heat fluxes, then the flows derived from the calibration test shall be used.

If it is demonstrated that the window burner must be repositioned within 0 to 5 inches (127 mm) of the exterior face of the calibration wall to attain the prescribed exterior temperatures and heat fluxes, then the position derived from the calibration shall be used in all subsequent testing.

The following calibrations shall be performed:

1. Initially, prior to the first wall assembly test,

2. When significant changes (i.e., new flow meters, etc.) to the gas flow systems are made, and

3. Within one year prior to the test of an actual product wall assembly.

SECTION 26.908 — CONDITIONS OF ACCEPTANCE

The performance of the test wall assembly shall be judged on the basis of visual observations both during and after the test in conjunction with the temperature data obtained during the test. An exterior nonload-bearing wall assembly shall be considered as meeting the requirements for acceptable performance if during the 30-minute test period:

1. Flame propagation does not occur either vertically or laterally beyond the area of flame plume impingement on the exterior face of the wall assembly. Propagation is judged to occur if

1.1 Temperatures of 1000°F (538°C) are attained at any of Thermocouples 11, 14, 15, 16 and 17 (Refer to Figure 26-9-12), or

1.2 Flames emitting from the surface of the exterior face reach a vertical elevation of 10 feet (3048 mm) above the top of the window opening, or

1.3 Flames emitting from the surface of the exterior face reach a lateral distance of 5 feet (1524 mm) from the vertical centerline of the window opening. Figure 26-9-20 provides a sketch showing these limits.

2. Flame propagation does not occur either vertically or laterally through the core components as determined by the following:

2.1 For wall systems constructed of exterior wall panels greater than $^1/_4$ inch (6.4 mm) thick having combustible components (refer to Figures 26-9-12 and 26-9-15, Details A and B), temperatures in the combustible components shall not exceed 750°F (399°C) above ambient as measured by Thermocouples 28, 34, 35, 39, 40, 31, 32, 33, 36, 37 and 38.

2.2 For wall systems constructed of exterior wall panels $^1/_4$ inch (6.4 mm) thick or less having combustible components and utilizing a wall cavity with an air space (refer to Figures 26-9-12 and 26-9-15, Detail C),

2.2.1 Temperatures in the air cavity shall not exceed 1000°F (538°C) as measured by Thermocouples 28, 34, 35, 39, 40, 31, 32, 33, 36, 37 and 38 and

2.2.2 Temperatures in the wall cavity insulation shall not exceed 750°F (399°C) above ambient as measured by Thermocouples 55, 56, 57, 58, 59, 60, 61, 62, 63, 64 and 65.

2.3 For wall systems constructed of exterior wall panels $^1/_4$ inch (6.4 mm) thick or less having combustible components and utilizing a wall cavity without an air space (refer to Figures 26-9-12 and 26-9-15, Detail D), temperatures in the cavity insulation shall not exceed 750°F (399°C) above ambient as measured by Thermocouples 28, 34, 35, 39, 40, 31, 32, 33, 36, 37 and 38.

3. Flame propagation does not occur laterally beyond the limits of the burn room. This determination shall be made based on

3.1 Flames do not occur over the surfaces of the exterior face beyond the concrete block fixture walls.

3.2 Flames do not occur beyond the intersection of the test wall assembly and the concrete block fixture walls.

3.3 Flame propagation does not occur laterally through the core components in the first floor area based on

3.3.1 For wall systems constructed of exterior wall panels greater than $^1/_4$ inch (6.4 mm) thick having combustible components (refer to Figures 26-9-12 and 26-9-15, Details A and B), temperatures in the combustible components shall not exceed 750°F (399°C) above ambient as measured by Thermocouples 18 and 19.

3.3.2 For wall systems constructed of exterior wall panels $^1/_4$ inch (6.4 mm) thick or less having combustible components and utilizing a wall cavity with an air space (refer to Figures 26-9-12 and 26-9-15, Detail C).

3.3.2.1 Temperatures in the air cavity shall not exceed 1000°F (538°C) as measured by Thermocouples 18 and 19, and

3.3.2.2 Temperatures in the wall cavity insulation shall not exceed 750°F (399°C) above ambient as measured by Thermocouples 66 and 67.

3.3.3 For wall systems constructed of exterior wall panels $^1/_4$ inch (6.4 mm) thick or less having combustible components and utilizing a wall cavity without an air space (refer to Figures 26-9-12 and 26-9-15, Detail D), temperatures in the cavity insulation shall not exceed 750°F (399°C) above ambient as measured by Thermocouples 18 and 19.

4. Temperatures 1 inch (25 mm) from the interior surface of the test wall assembly within the second floor area shall not exceed 500°F (260°C) above their initial ambient temperature. This criteria is based on Thermocouples 49, 50, 51, 52, 53 and 54 (refer to Figure 26-9-13).

5. Flames shall not occur in the second floor room.

SECTION 26.909 — TEST REPORT

The test report shall contain as a minimum the following:

1. Description of the test wall assembly to include the following:

1.1 Drawings showing structural design, plan, elevation, principal cross section plus other sections as needed for clarity and joint locations and details;

1.2 Details of attachment of walls to the test apparatus;

1.3 Flame spread and smoke developed values per UBC Standard 8-1 as required;

1.4 Self-ignition temperature of plastic materials per UBC Standard 26-6;

1.5 Potential heat value of plastic materials per UBC Standard 26-1 converted to Btu/ft.^{2} (MJ/m^2) for the assembly tested; and

1.6 Location of thermocouples.

2. Ambient conditions at the start of the test;

3. Temperature and burner flow data obtained during the test to include total gas flow of both burners for duration of test;

4. Comparison of burner flow data obtained during the test to the burner flow data obtained during the latest calibration test;

5. Position of vertical centerline of burner with respect to the exterior face of the wall assembly for both the actual test and the previous calibration test;

6. Visual observations made during the test;

7. Photographs of the following:

7.1 Test wall—prior to test—exterior face

7.2 Test wall—test in progress—exterior face

7.3 Test wall—posttest—exterior face

7.4 Test wall—posttest—interior face—both floors

7.5 Core insulation of wall—posttest

8. Damage sketch(es) of the wall assembly;

9. Extent of residual burning;

10. Smoke accumulation inside the second-story room; and

11. Performance of the wall assembly with respect to each of the Conditions of Acceptance.

TABLE 26-9-A—CALIBRATION FLOW RATES

TIME INTERVAL	ROOM BURNER SCFM (m^3/min)	ROOM BURNER kW (Btu/min.)	WINDOW BURNER SCFM (m^3/min)	WINDOW BURNER kW (Btu/min.)
0:00 - 5:00	38.0 (1.08)	687 (39,064)	0.0 (0.00)	0 (0)
5:00 - 10:00	38.0 (1.08)	687 (39,064)	9.0 (0.25)	163 (9,252)
10:00 - 15:00	43.0 (1.22)	777 (44,204)	12.0 (0.34)	217 (12,336)
15:00 - 20:00	46.0 (1.30)	831 (47,288)	16.0 (0.45)	289 (16,448)
20:00 - 25:00	46.0 (1.30)	831 (47,288)	19.0 (0.54)	343 (19,532)
25:00 - 30:00	50.0 (1.42)	904 (51,400)	22.0 (0.62)	398 (22,616)

TABLE 26-9-B—CALIBRATION AVERAGE VALUES ($\overline{X}$ values for time period indicated)

TIME	0-5	5-10	10-15	15-20	20-25	25-30
Burn Room $\overline{X}$ Temperature [°F (°C)]	1151 (622)	1346 (730)	1482 (806)	1600 (871)	1597 (869)	1648 (898)
Interior Wall Surface $\overline{X}$ of 3 [°F (°C)]	1065 (574)	1298 (703)	1433 (778)	1578 (859)	1576 (858)	1655 (902)
1 foot (305 mm) above Window [°F (°C)]	602 (317)	870 (466)	952 (511)	992 (533)	1046 (563)	1078 (581)
2 feet (610 mm) above Window [°F (°C)]	679 (359)	1015 (546)	1121 (605)	1183 (639)	1245 (674)	1296 (702)
3 feet (914 mm) above Window [°F (°C)]	646 (341)	971 (521)	1096 (591)	1174 (634)	1245 (674)	1314 (712)
4 feet (1219 mm) above Window [°F (°C)]	577 (302)	858 (459)	982 (528)	1063 (573)	1135 (613)	1224 (662)
5 feet (1524 mm) above Window [°F (°C)]	521 (272)	765 (407)	875 (469)	949 (509)	1007 (542)	1106 (597)
6 feet (1829 mm) above Window [°F (°C)]	472 (244)	690 (366)	787 (419)	856 (458)	913 (489)	1010 (543)
Calorimeter 2 feet (610 mm) above Window (W/cm^2)	0.9 ± 0.2	1.9 ± 0.4	2.5 ± 0.5	2.9 ± 0.6	3.4 ± 0.7	3.8 ± 0.8
Calorimeter 3 feet (914 mm) above Window (W/cm^2)	1.0 ± 0.2	2.0 ± 0.4	2.6 ± 0.5	3.2 ± 0.6	3.7 ± 0.7	4.0 ± 0.8
Calorimeter 4 feet (1219 mm) above Window (W/cm^2)	0.8 ± 0.2	1.5 ± 0.3	2.0 ± 0.4	2.5 ± 0.5	3.0 ± 0.6	3.4 ± 0.7

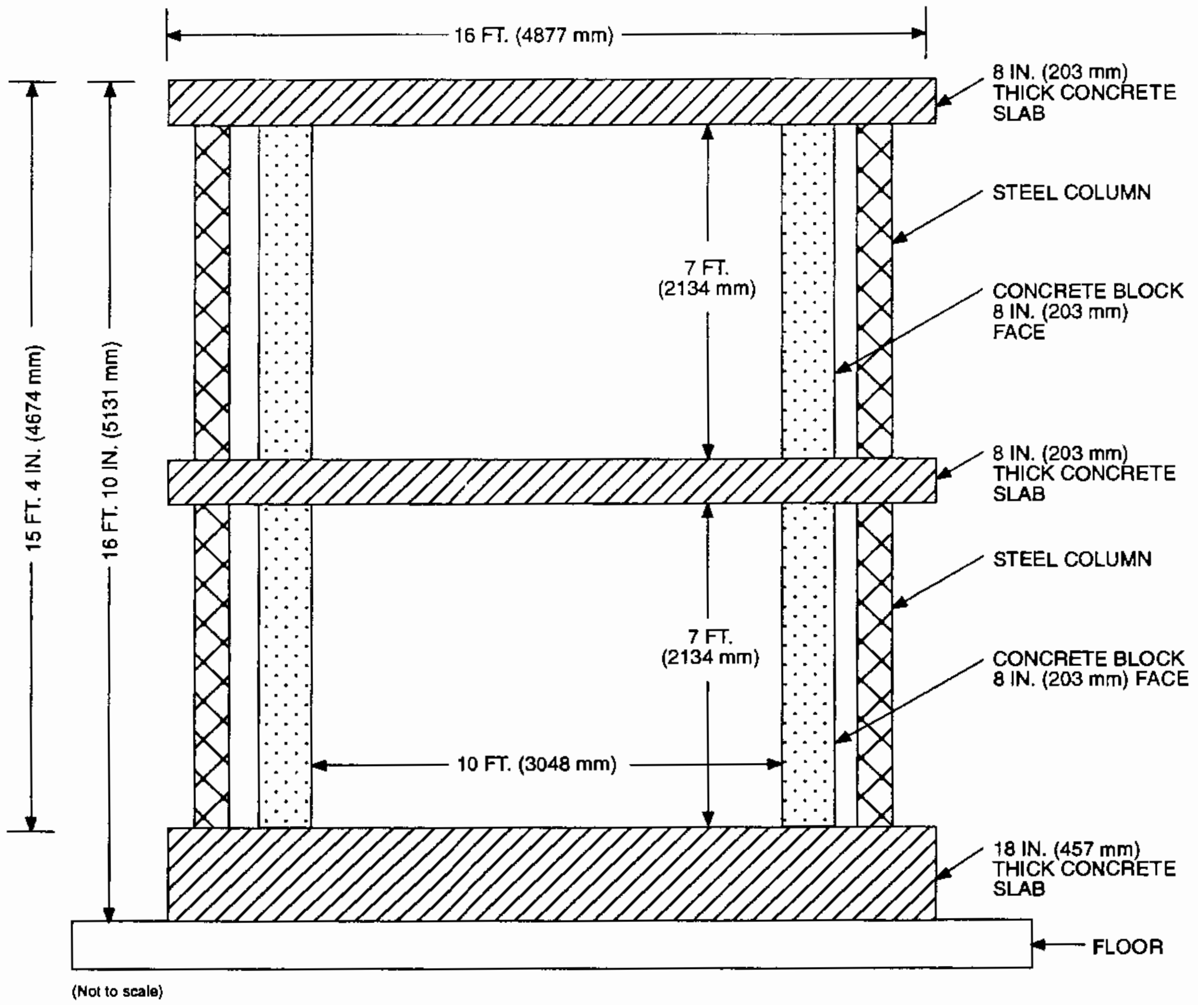


FIGURE 26-9-1—FRONT VIEW OF TEST STRUCTURE

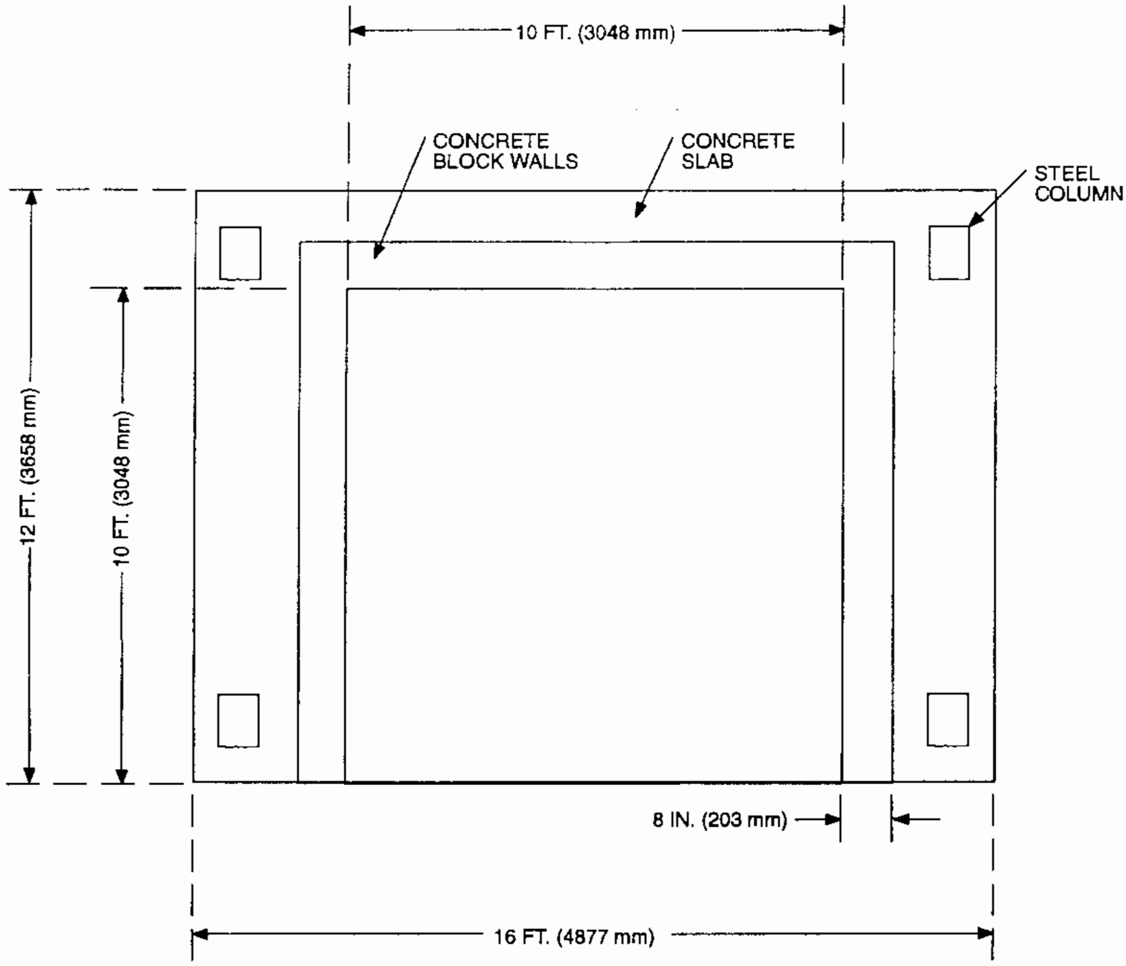


FIGURE 26-9-2—PLAN VIEW—BOTH FLOORS

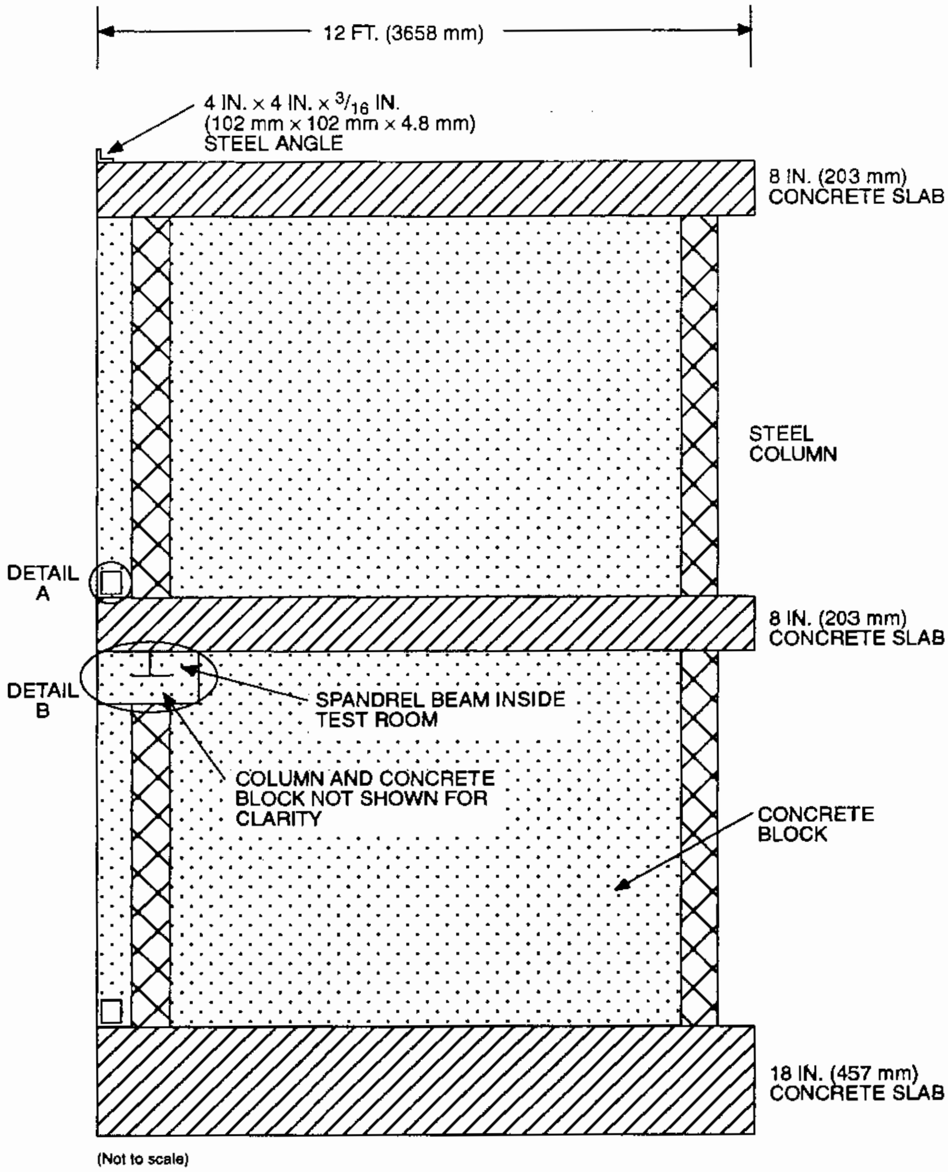
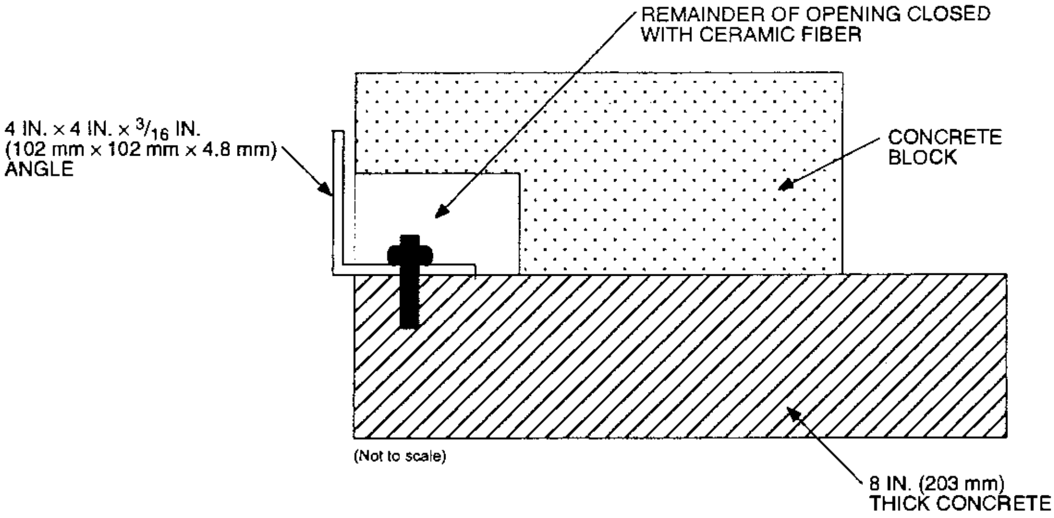
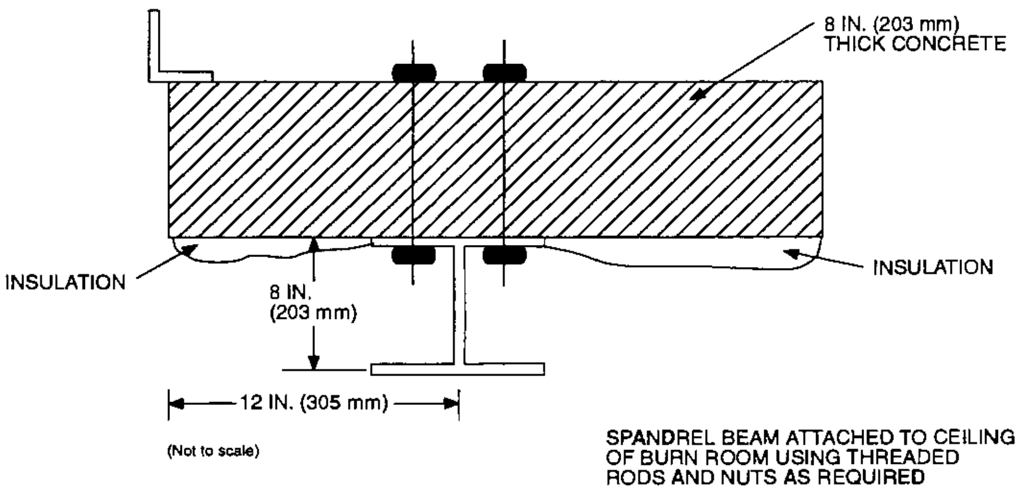


FIGURE 26-9-3—SIDE VIEW



DETAIL A



DETAIL B

FIGURE 26-9-4—TEST FIXTURE DETAILS

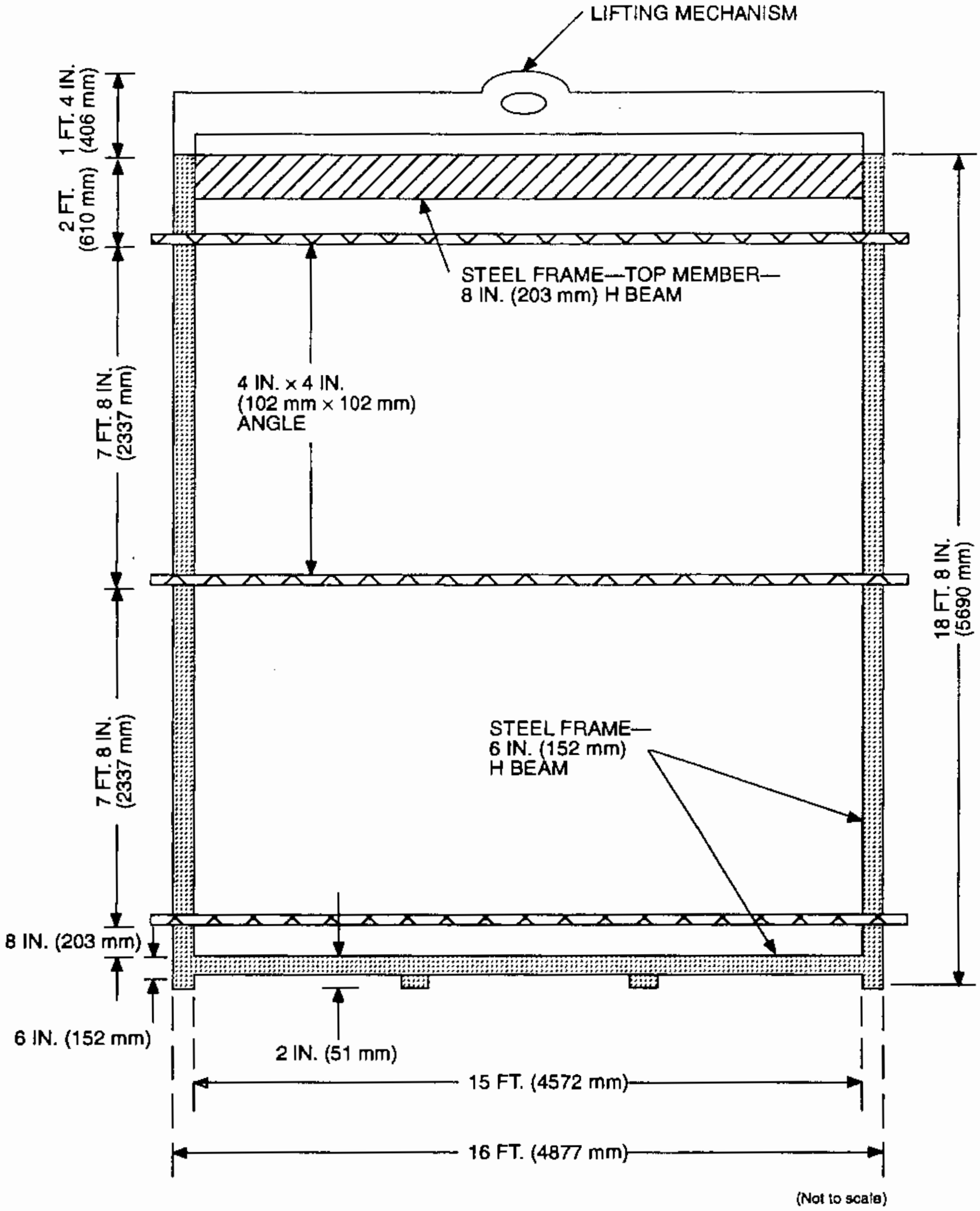


FIGURE 26-9-5—FRONT VIEW OF WALL FRAME

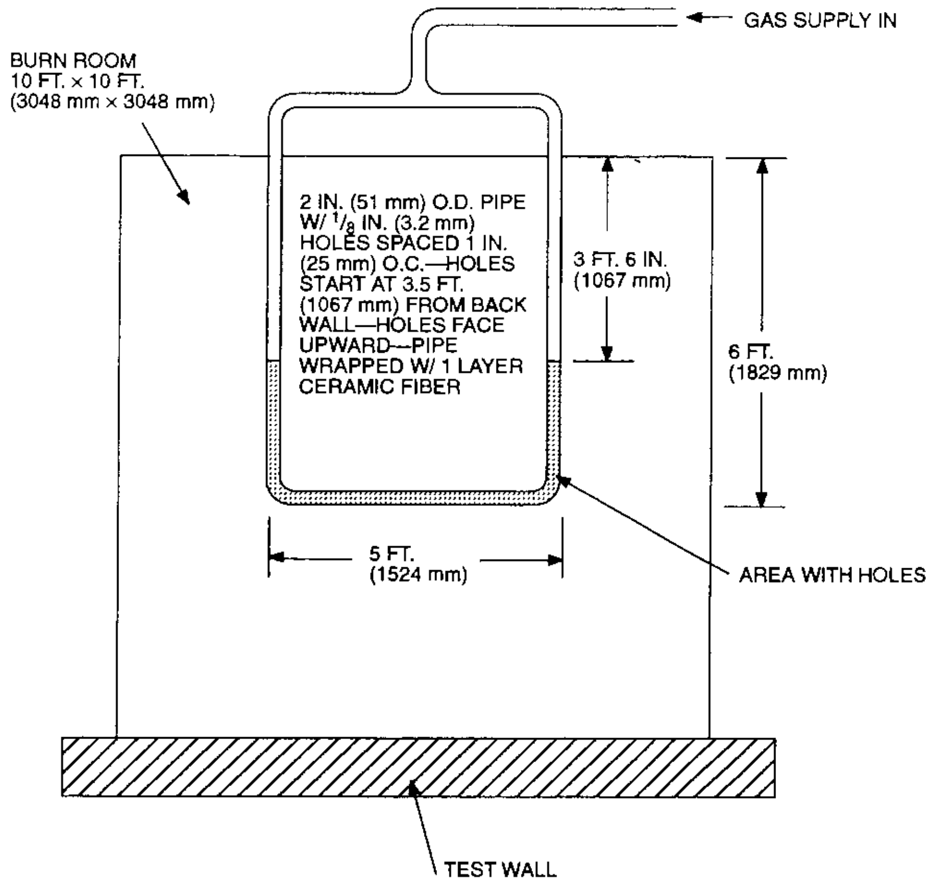


FIGURE 26-9-6—BURN ROOM BURNER—PLAN VIEW

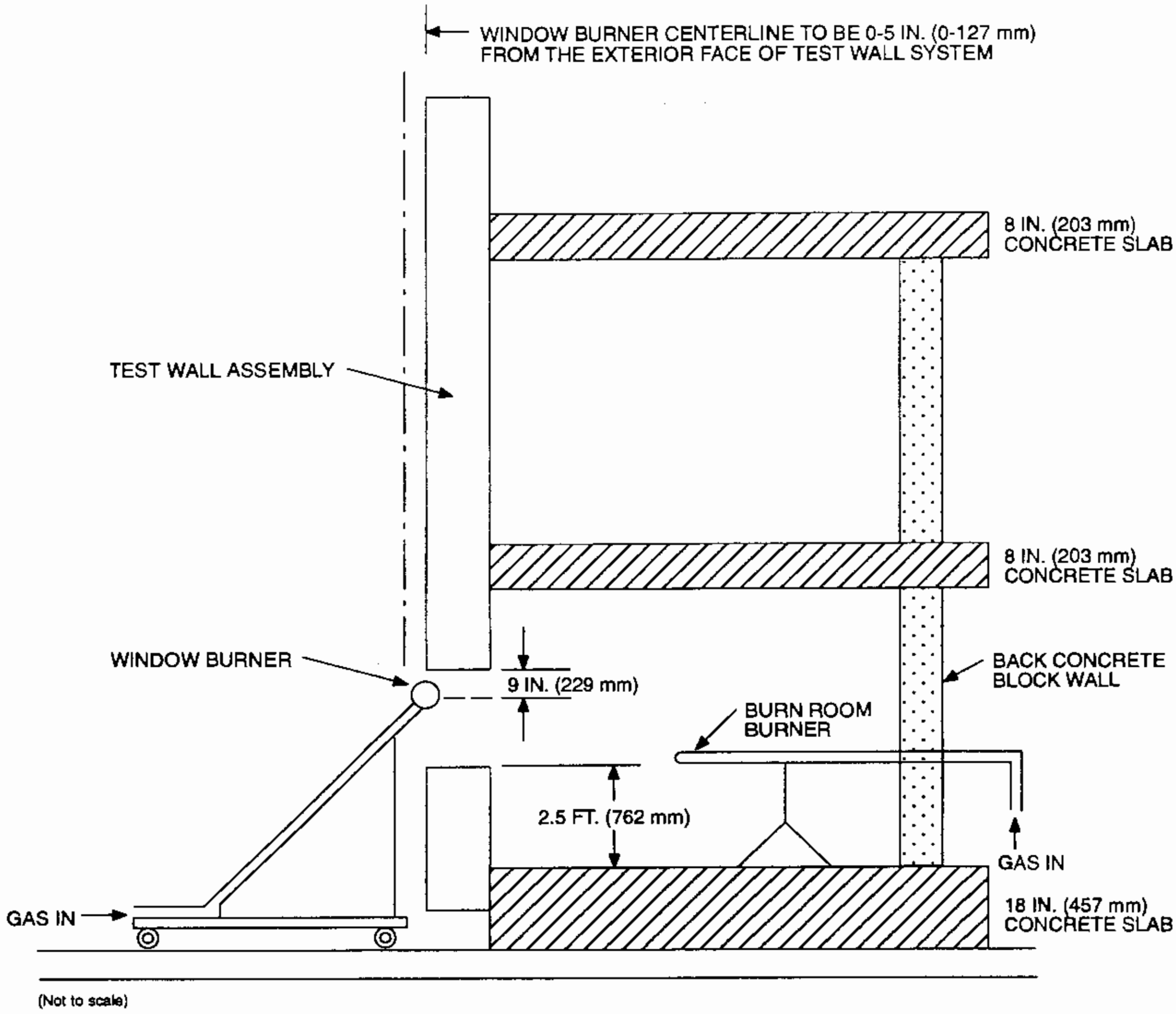


FIGURE 26-9-7—SIDE VIEW OF BURNER PLACEMENT

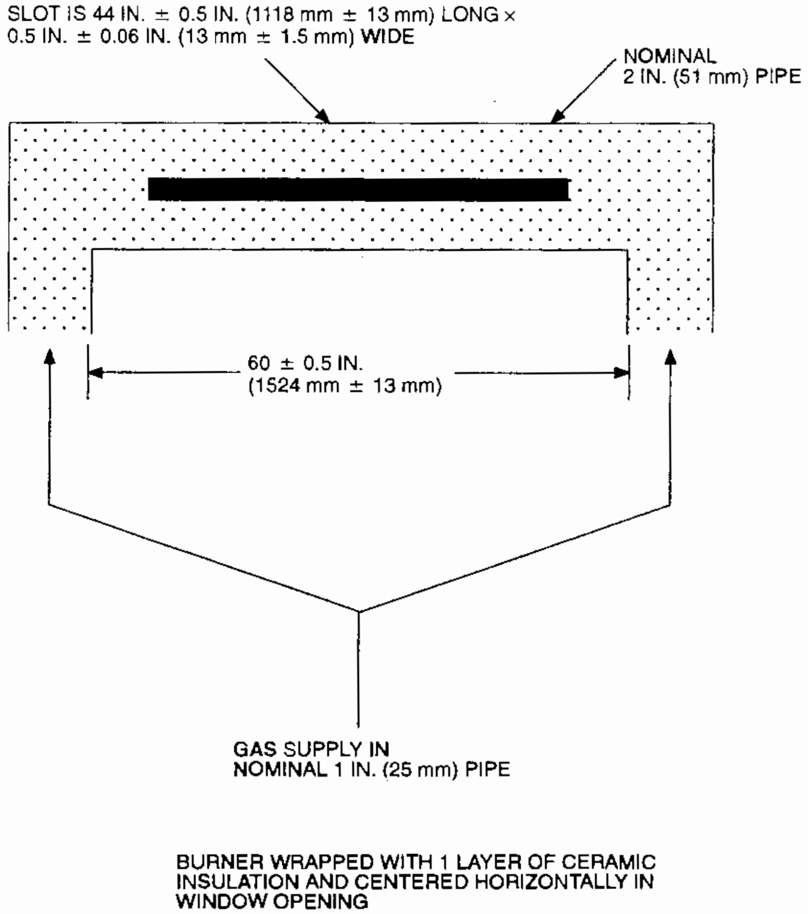


FIGURE 26-9-8—PLAN VIEW OF WINDOW BURNER

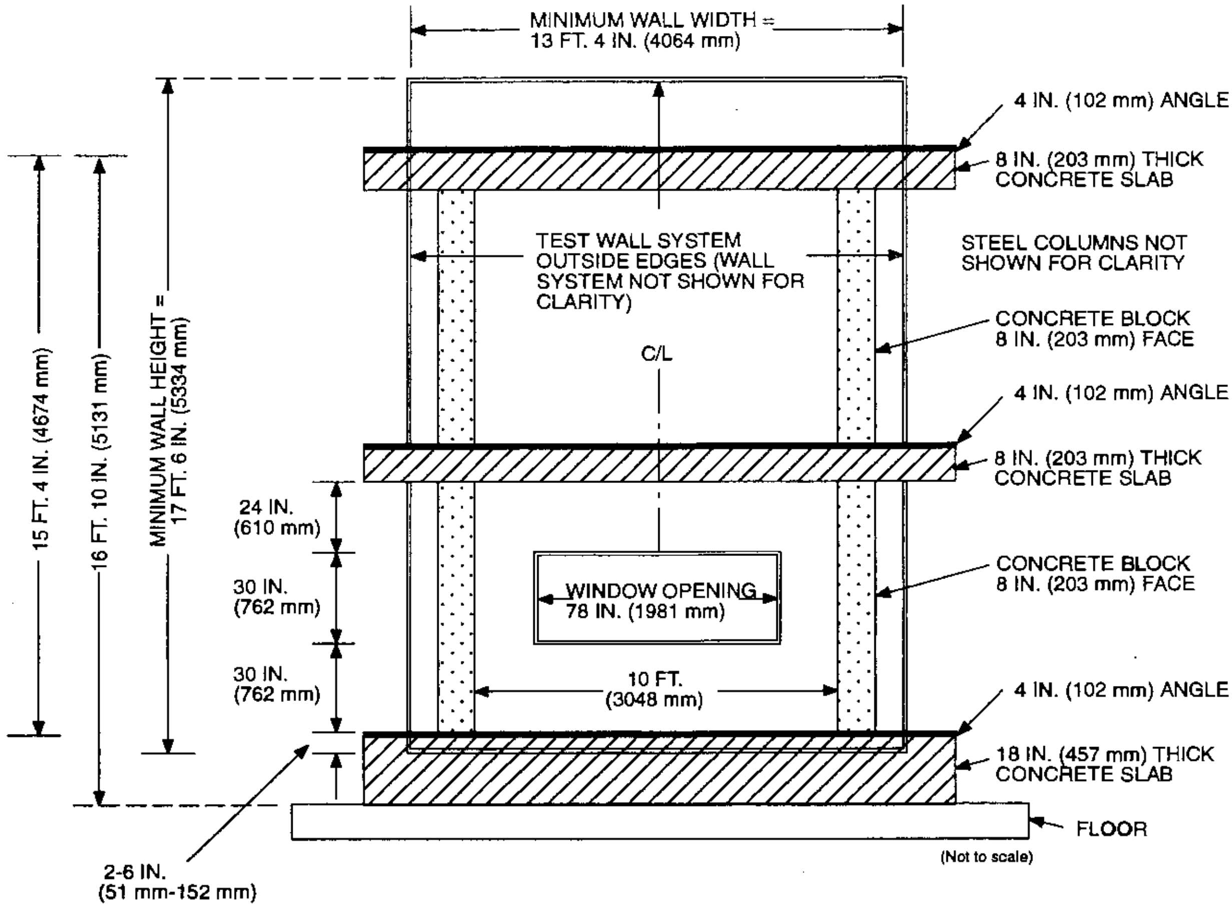


FIGURE 26-9-9—FRONT VIEW OF WALL SYSTEM BUILT IN PLACE ON TEST STRUCTURE

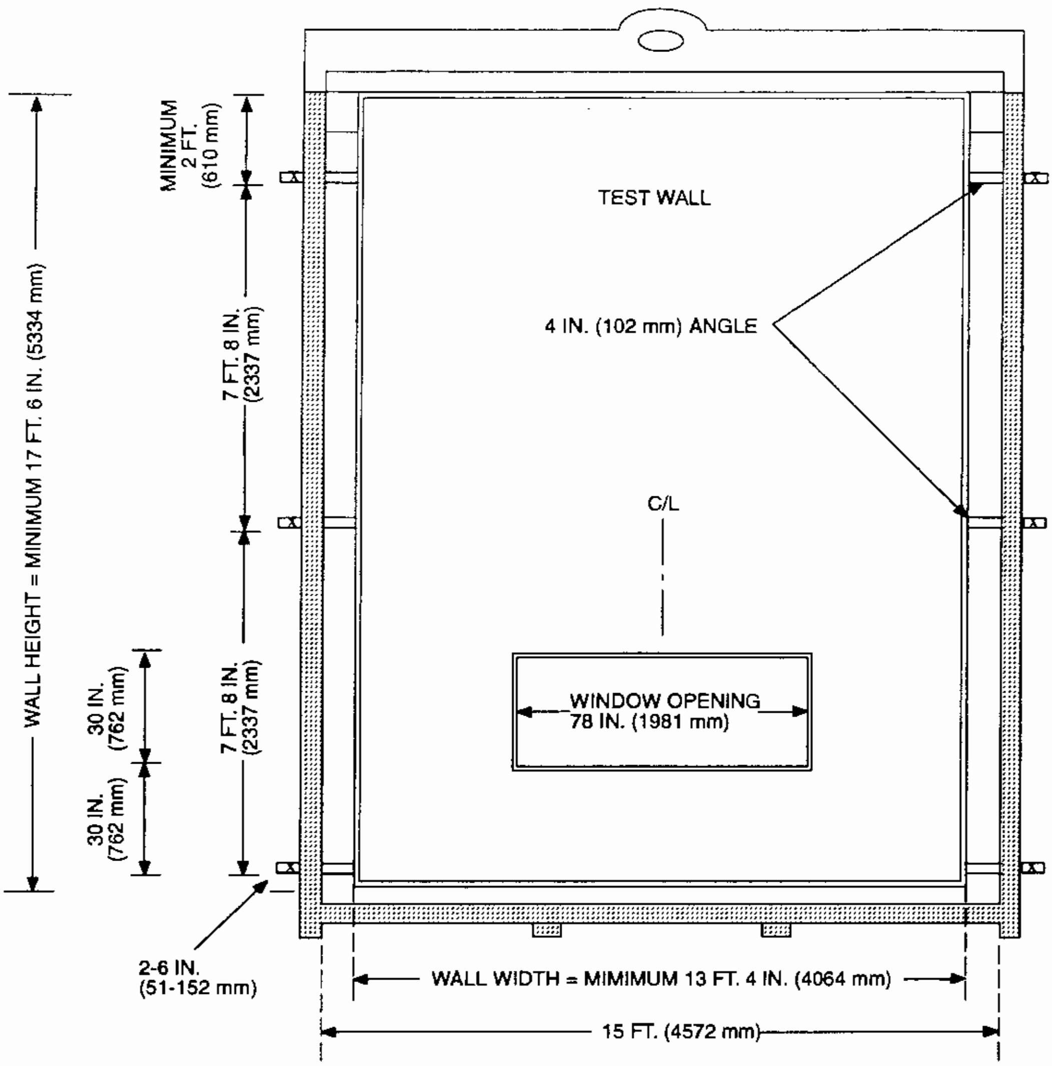
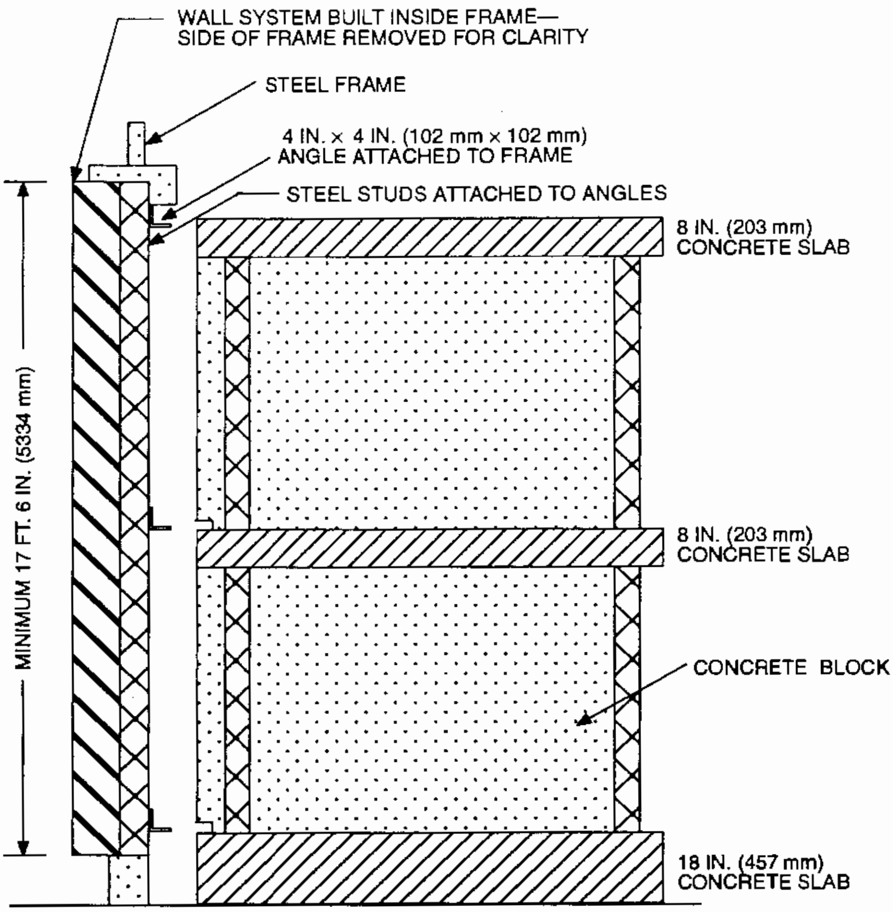
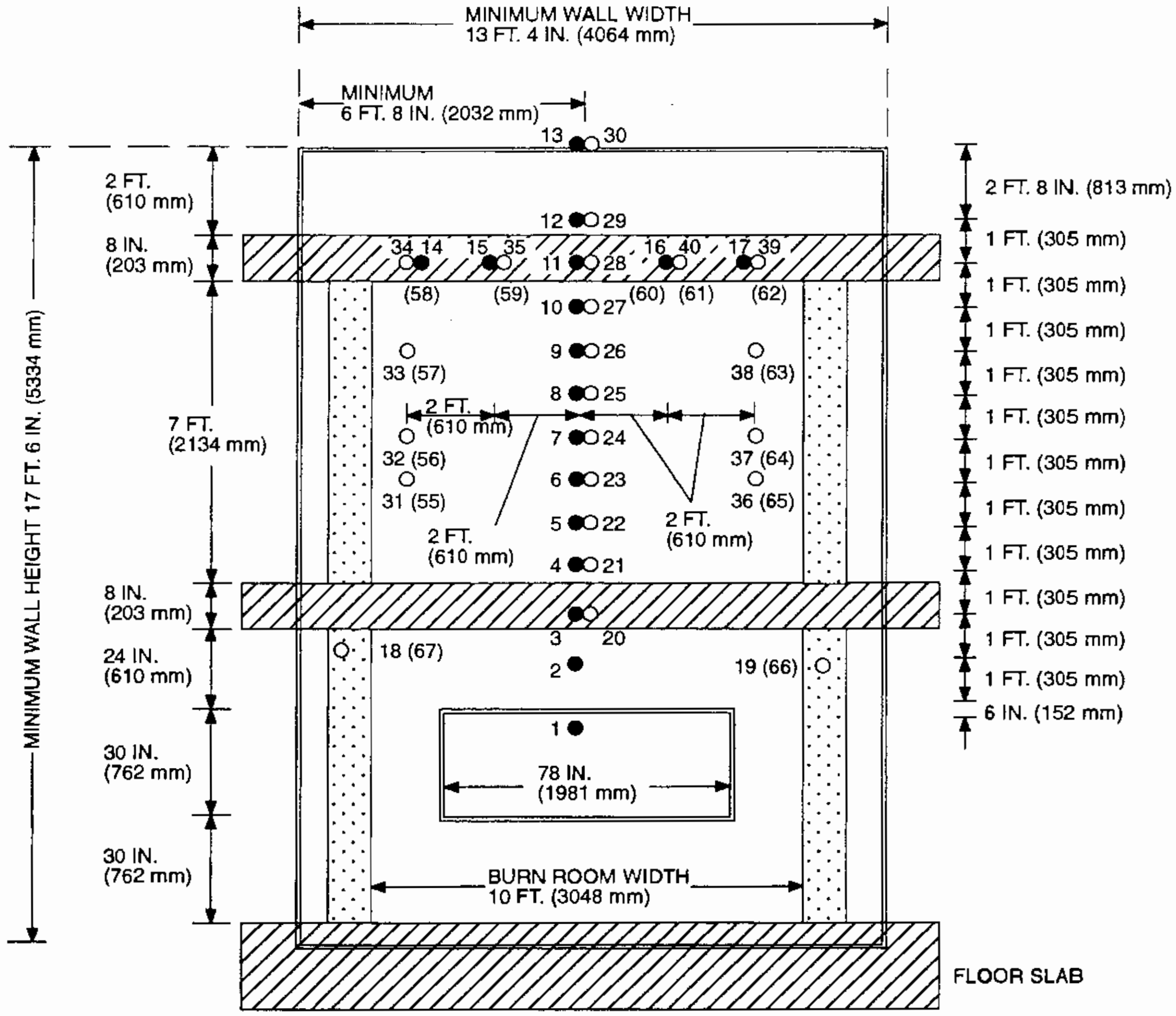


FIGURE 26-9-10—FRONT VIEW OF WALL SYSTEM IN FRAME



(Not to scale)

FIGURE 26-9-11—SIDE VIEW OF WALL SYSTEM IN FRAME



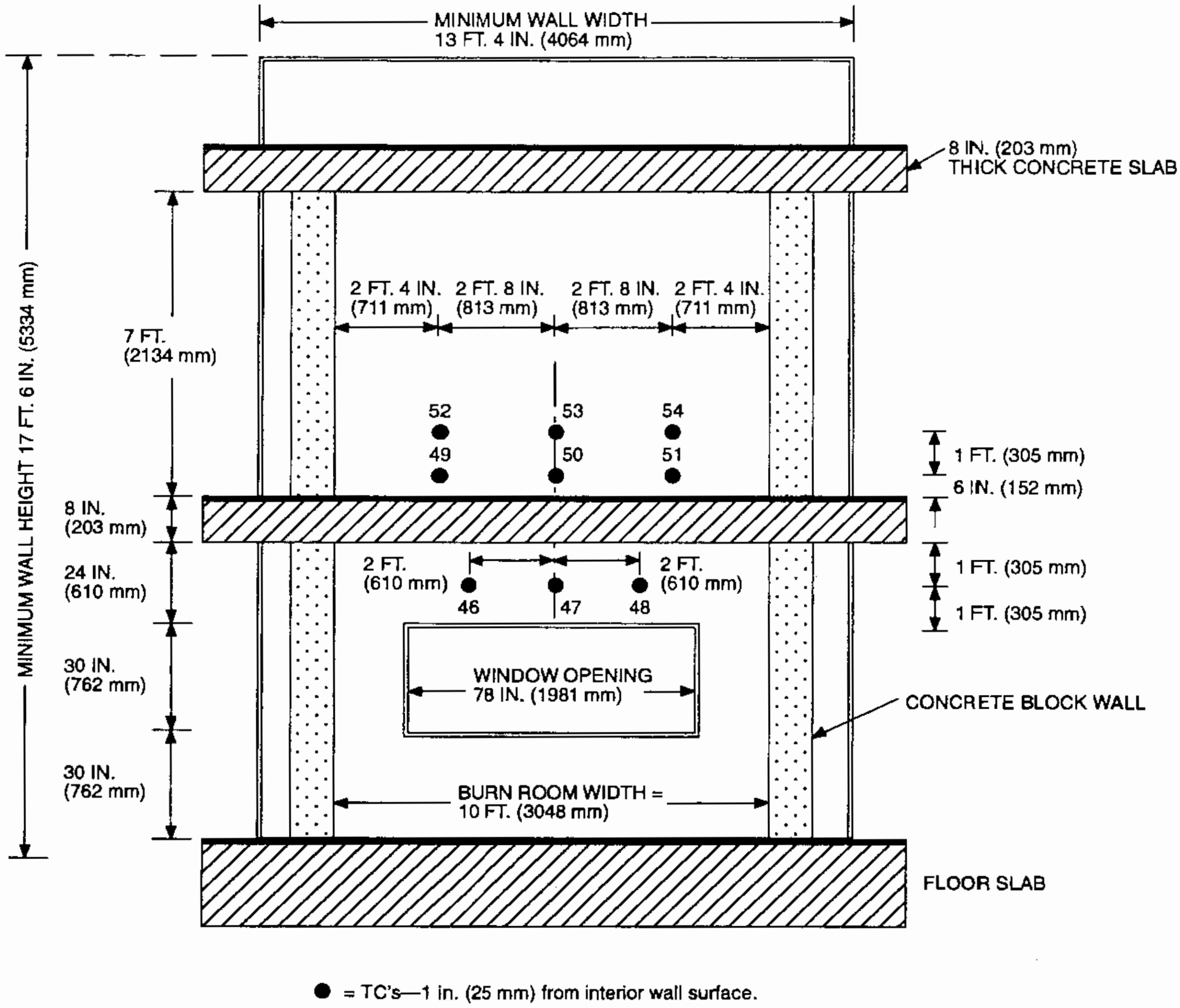
● = TC's—1 in. (25 mm) from exterior wall surface.

○ = TC's—In core/air space—see Part IV.

(TC's)—Additional TC's—see Part IV, C.

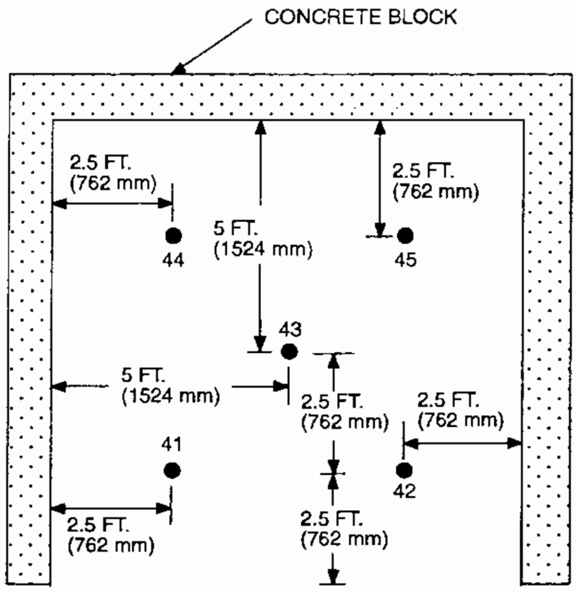
EXTERIOR VIEW OF EXTERIOR WALL

FIGURE 26-9-12—INSTRUMENTATION ARRANGEMENT—PART I



INTERIOR VIEW OF EXTERIOR WALL

FIGURE 26-9-13—INSTRUMENTATION ARRANGEMENT—PART II



● = Thermocouples (5) inside burn room 6 in. (152 mm) below ceiling.

PLAN VIEW LOOKING DOWN – BURN ROOM

FIGURE 26-9-14—INSTRUMENTATION ARRANGEMENT—PART III

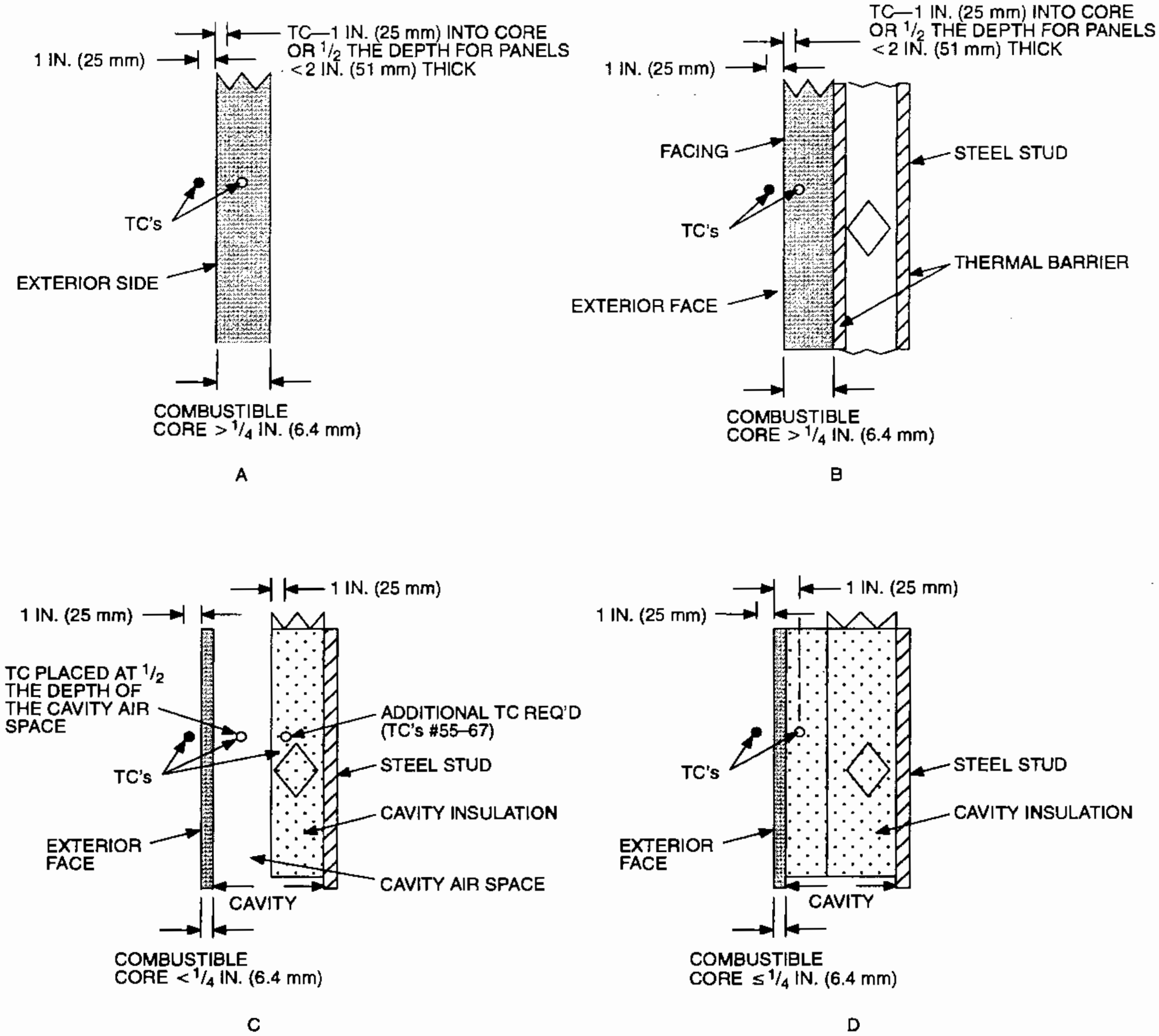


FIGURE 26-9-15—INSTRUMENTATION ARRANGEMENT—PART IV

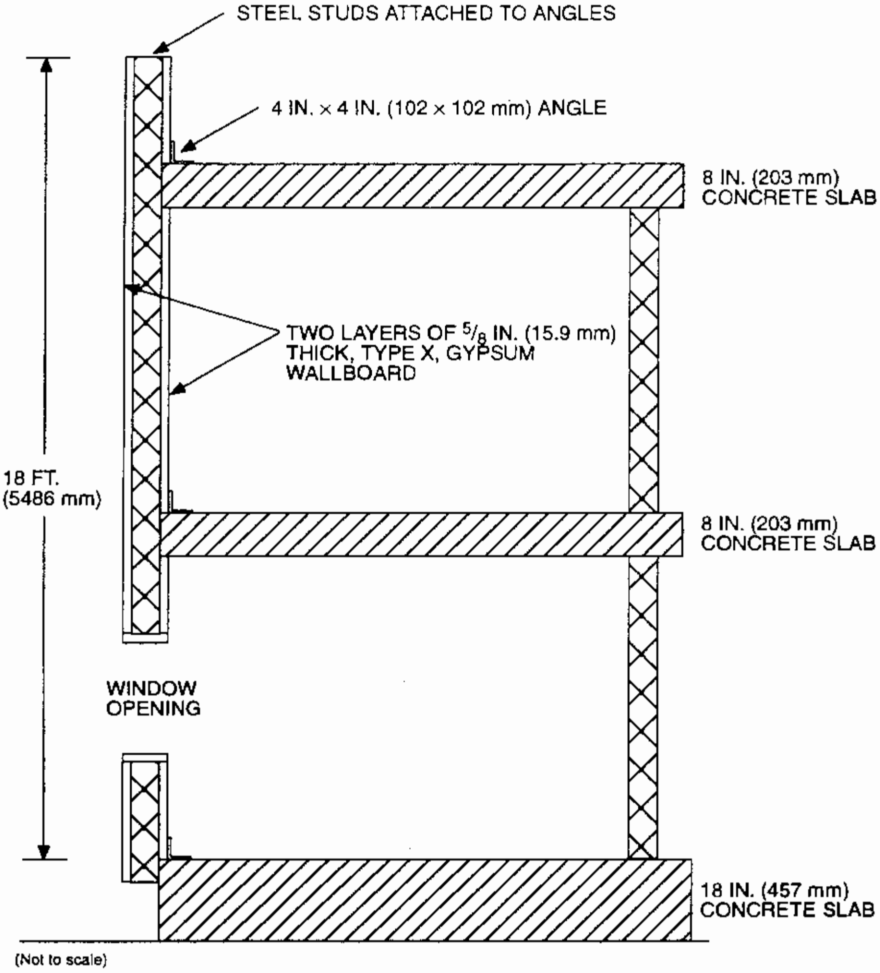
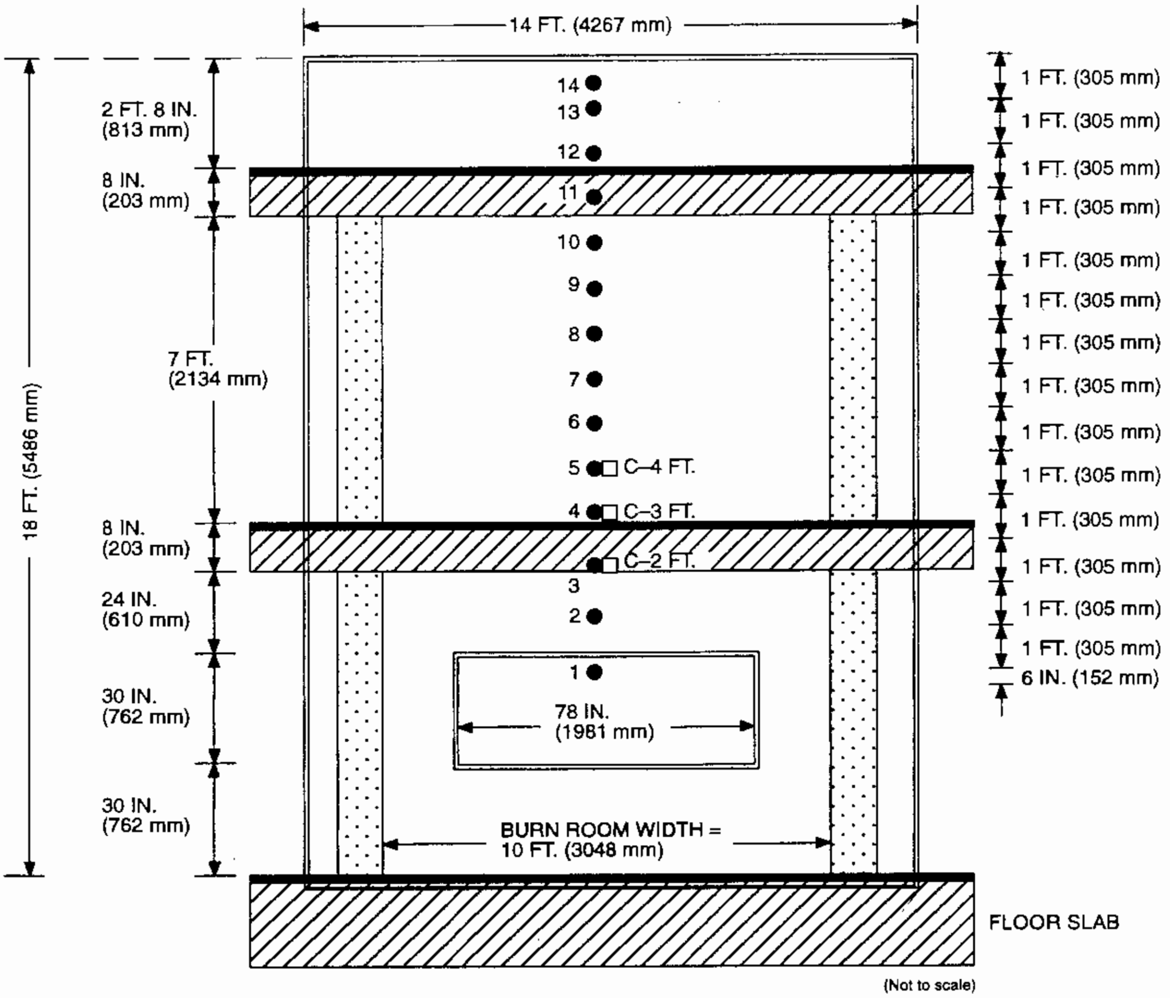


FIGURE 26-9-16—SIDE VIEW OF CALIBRATION WALL SYSTEM

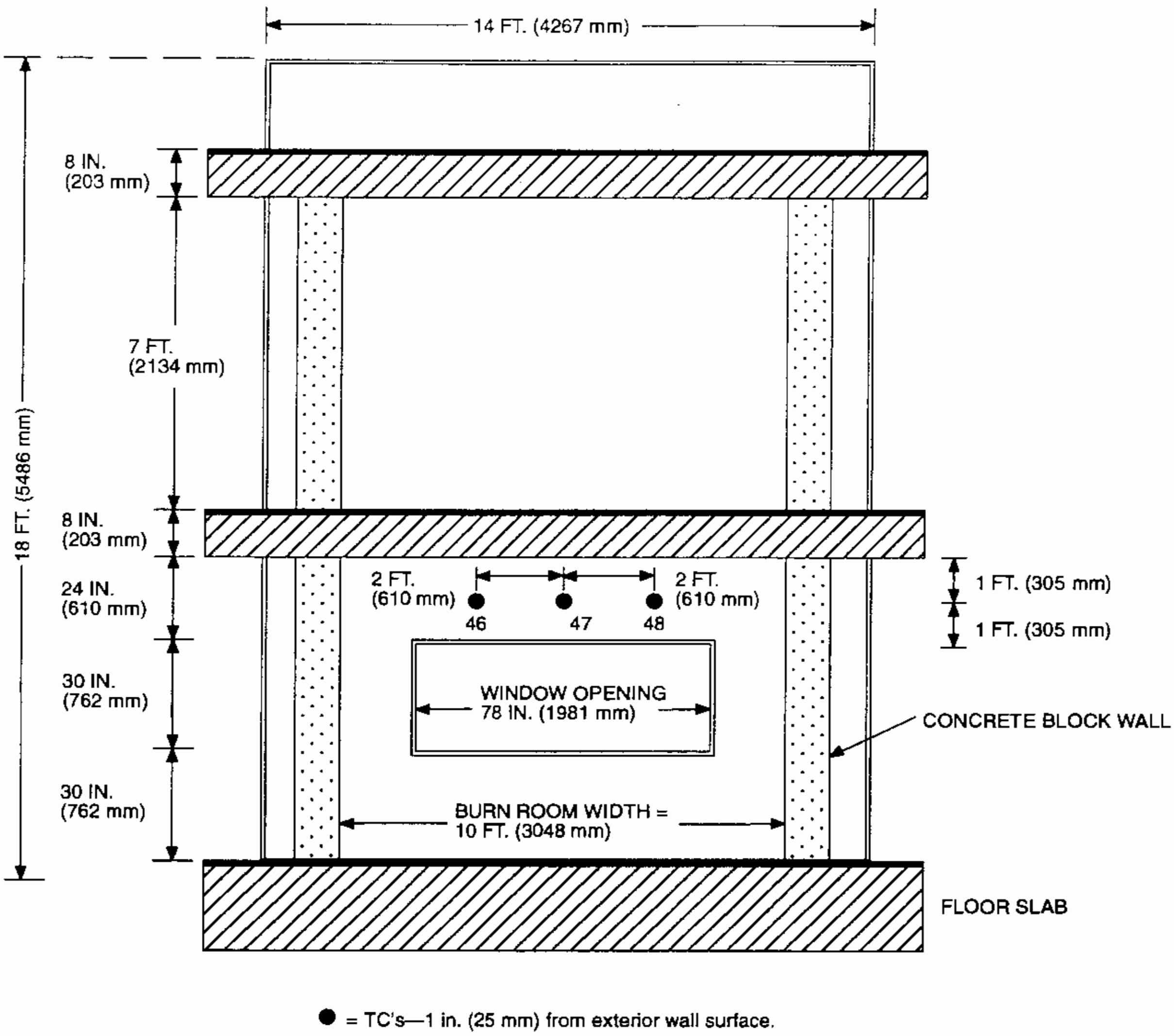


● = TC's—1 in. (25 mm) from exterior wall surface.

□ = Calorimeters in wall—flush w/ exterior wall surface.

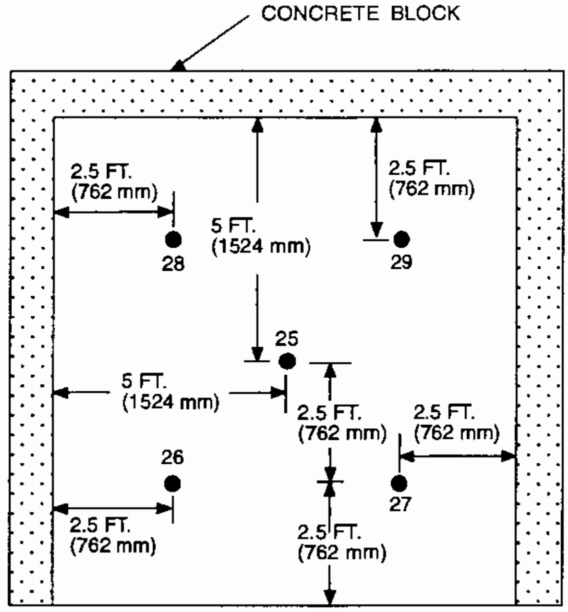
FRONT VIEW OF EXTERIOR WALL

FIGURE 26-9-17—CALIBRATION INSTRUMENTATION—PART I



INTERIOR VIEW OF EXTERIOR WALL

FIGURE 26-9-18—CALIBRATION INSTRUMENTATION—PART II



● = Thermocouples (5) inside burn room 6 in. (152 mm) below ceiling.

PLAN VIEW LOOKING DOWN—BURN ROOM

FIGURE 26-9-19—CALIBRATION INSTRUMENTATION—PART III

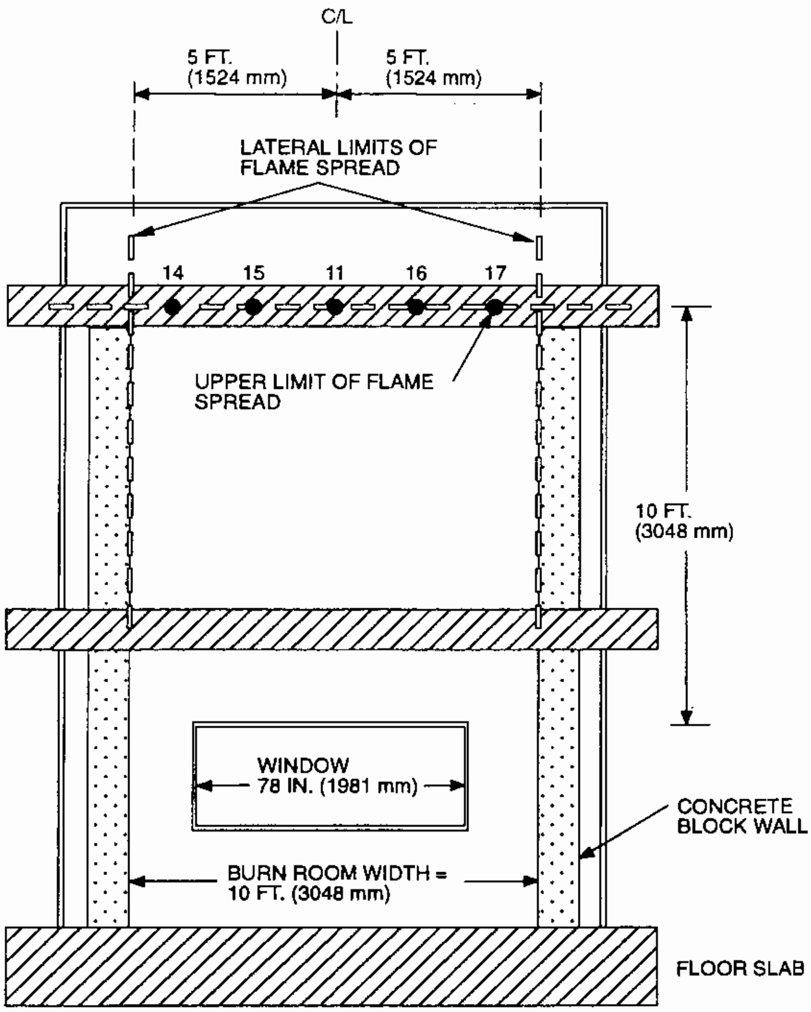


FIGURE 26-9-20—LIMITS OF FLAME PROPAGATION

UNIFORM BUILDING CODE STANDARD 31-1
FLAME-RETARDANT MEMBRANES

Test Standard of the International Conference of Building Officials

See Appendix Section 3112.2, *Uniform Building Code*

SECTION 31.101 — SCOPE

This standard covers requirements for flame-retardant membranes which are not noncombustible, intended for use in membrane structures as defined in this code.

SECTION 31.102 — TEST APPARATUS

The apparatus for conducting the flame test shall consist of a sheet-iron stack 12 inches (305 mm) square transversely, 7 feet (2134 mm) high and supported 1 foot (305 mm) above the floor on legs. The stack shall be open only at top and bottom and shall be provided with an observation window of wired glass extending the full length of the front.

The stack is to be arranged so that the specimen can be suspended vertically in the stack with its full width facing the observer with the bottom of the specimen 4 inches (101.6 mm) above the top of a Bunsen burner having $^3/_8$-inch-diameter (9.5 mm) tube and placed on the floor below the stack. The gas supply to the burner is to be natural gas or a mixture of natural and manufactured gases having a heat value of approximately 800 Btu to 1,000 Btu per cubic foot (29 807.1 kJ/m^3 to 37 258.9 kJ/m^3). With a gas pressure of 4$^1/_4$ inches of water (1058 Pa), the burner is to be adjusted to produce an 11-inch (279 mm) oxidizing flame having an indistinct inner cone. Guide wire and clamps are to be provided to lightly restrain the edges of the specimen.

SECTION 31.103 — SPECIMENS

At least 10 specimens 5 inches by 7 feet (127 mm by 2134 mm) shall be tested. Specimens shall be taken from as widely separated and symmetrically located sections as possible over the entire area of representative sample of the membrane. Where there is a grain to the sample, one-half of the specimen for each conditioning shall be taken parallel to the grain and the other one-half perpendicular to the grain. At least six of the specimens shall be conditioned as specified in Section 31.104.1 and at least four of the specimens shall be conditioned as specified in Section 31.104.2.

SECTION 31.104 — CONDITIONING

31.104.1 Accelerated Weathering. One of the two procedures described below shall be followed for at least six of the test specimens:

1. The apparatus shall consist of a vertical carbon arc with solid electrodes 0.5 inch (12.7 mm) in diameter (one cored electrode is used if the arc operates on alternating current) and uniform in composition throughout, mounted at the center of a vertical metal cylinder. The arc shall be surrounded by a clear globe of optical heat-resistant glass with a cutoff at 2750A, with an increase in transmission of 91 percent at 3700A, or other enclosure having equivalent absorbing and transmitting properties. The electrodes shall be renewed at intervals sufficiently frequent to insure full operative conditions of the lamp. The globe shall be cleaned when carbons are removed or at least once in each 36 hours of operation. The arc shall be operated on 13 amperes direct current or 17 amperes, 60 cycles alternating current with the voltage at the arc of 140 volts. The specimens for test shall be mounted on the inside of the cylinder facing the arc. The diameter of the cylinder shall be such that the distance of the face of the specimen holder from the center of the arc is 14$^3/_4$ inches (374.7 mm). The cylinder shall rotate about the arc at a uniform speed of approximately three revolutions per hour. A water spray discharging about 0.7 gallon per minute (2.7 L/min.) shall strike each specimen in turn for about one minute during each revolution of the cylinder. Specimens shall be subjected to this exposure for 360 hours. They shall then be allowed to dry thoroughly at a temperature between 70°F and 100°F (21°C and 38°C).

2. The apparatus shall consist of a vertical carbon arc mounted at the center of a vertical cylinder. The arc is designed to accommodate two pairs of carbons, No. 22, upper carbons, and No. 13, lower carbons; however, the arc burns between only one pair of carbons at a time. The arc shall be operated on 60 amperes and 50 volts across the arc for alternating current or 50 amperes and 60 volts across the arc for direct current. The specimens for test shall be mounted on a rotating rack inside the cylinder and facing the arc. The diameter of the rotating rack shall be such that the distance from the center of the arc to the face of the specimen is 18$^3/_4$ inches (476.3 mm). The rack shall rotate about the arc at a uniform speed of about one revolution in two hours. No filters or enclosures shall be used between the arc and the specimens. Spray nozzles shall be mounted in the cylinder so that the specimens shall be exposed to wetting once during each revolution of the rack. Specimens shall be subjected to this exposure for 100 hours. They shall then be allowed to dry thoroughly at a temperature between 70°F and 100°F (21°C and 38°C).

31.104.2 Unweathered Samples. At least four of the test specimens shall be conditioned in an oven having forced air circulation with free airflow around each specimen at temperatures of 140°F to 145°F (60°C to 63°C) for durations of not less than one hour nor more than one and one-half hours before testing. Materials which distort or melt at the above indicated oven exposure are to be conditioned at 60°F to 80°F (15.5°C to 26.7°C) and 25 to 50 percent relative humidity for not less than 24 hours. Specimens shall be removed from the oven one at a time and immediately subjected to the flame test described in Section 31.105.

SECTION 31.105 — TESTING

Suspend the specimen in the apparatus attaching clamps to the edges to retain the specimen in position. Position the burner so that the flame will be applied near the middle of the lower end of the specimen and fix the barrel of the burner at an angle of 25 degrees.

The test flame shall be applied to the specimen for two minutes, then withdrawn, and the duration of flaming combustion on the specimen recorded. After all flaming and afterglow on the specimen has ceased, the length of char shall be determined. For purposes of this test, the length of char is defined as the vertical distance on the specimen from the tip of the test flame to the top of the charred area resulting from spread of flame and afterglow. For synthetic membranes, the length of char is defined as the vertical distance from the tip of the test flame to a horizontal line, above which all material is sound and in essentially original condition.

SECTION 31.106 — CONDITION OF ACCEPTANCE

When subjected to the test described in Section 31.105, material shall not continue flaming for more than two seconds after the test flame is removed from contact with the specimen. The vertical spread of burning on the material shall not exceed 10 inches (254 mm) above the tip of the test flame. This vertical spread shall be measured as the distance from the tip of the test flame to a horizontal line above which all material is sound and in original condition, except for possible smoke deposits.

Portions or residues of textiles or films which break or drip from the test specimens shall not continue to flame after they reach the floor of the tester.

UNIT CONVERSION TABLES

SI SYMBOLS AND PREFIXES

BASE UNITS

Quantity	Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	cd

SI SUPPLEMENTARY UNITS

Quantity	Unit	Symbol
Plane angle	Radian	rad
Solid angle	Steradian	sr

SI PREFIXES

Multiplication Factor	Prefix	Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deka	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

SI DERIVED UNIT WITH SPECIAL NAMES

Quantity	Unit	Symbol	Formula
Frequency (of a periodic phenomenon)	hertz	Hz	1/s
Force	newton	N	$kg \cdot m/s^2$
Pressure, stress	pascal	Pa	N/m^2
Energy, work, quantity of heat	joule	J	N·m
Power, radiant flux	watt	W	J/s
Quantity of electricity, electric charge	coulomb	C	A·s
Electric potential, potential difference, electromotive force	volt	V	W/A
Capacitance	farad	F	C/V
Electric resistance	ohm	Ω	V/A
Conductance	siemens	S	A/V
Magnetic flux	weber	Wb	V·s
Magnetic flux density	tesla	T	Wb/m^2
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	cd·sr
Illuminance	lux	lx	lm/m^2
Activity (of radionuclides)	becquerel	Bq	l/s
Absorbed dose	gray	Gy	J/kg

CONVERSION FACTORS

To convert	to	multiply by
LENGTH		
1 mile (U.S. statute)	km	1.609 344
1 yd	m	0.9144
1 ft	m	0.3048
	mm	304.8
1 in	mm	25.4
AREA		
1 mile^2 (U.S. statute)	km^2	2.589 998
1 acre (U.S. survey)	ha	0.404 6873
	m^2	4046.873
1 yd^2	m^2	0.836 1274
1 ft^2	m^2	0.092 903 04
1 in^2	mm^2	645.16
VOLUME, MODULUS OF SECTION		
1 acre ft	m^3	1233.489
1 yd^3	m^3	0.764 5549
100 board ft	m^3	0.235 9737
1 ft^3	m^3	0.028 316 85
	L(dm^3)	28.3168
1 in^3	mm^3	16 387.06
	mL (cm^3)	16.3871
1 barrel (42 U.S. gallons)	m^3	0.158 9873
(FLUID) CAPACITY		
1 gal (U.S. liquid)*	L**	3.785 412
1 qt (U.S. liquid)	mL	946.3529
1 pt (U.S. liquid)	mL	473.1765
1 fl oz (U.S.)	mL	29.5735
1 gal (U.S. liquid)	m^3	0.003 785 412
*1 gallon (UK) approx. 1.2 gal (U.S.)	**1 liter approx. 0.001 cubic meter	
SECOND MOMENT OF AREA		
1 in^4	mm^4	416 231 4
	m^4	416 231 4 × 10^{-7}
PLANE ANGLE		
1° (degree)	rad	0.017 453 29
	mrad	17.453 29
1′ (minute)	urad	290.8882
1″ (second)	urad	4.848 137
VELOCITY, SPEED		
1 ft/s	m/s	0.3048
1 mile/h	km/h	1.609 344
	m/s	0.447 04
VOLUME RATE OF FLOW		
1 ft^3/s	m^3/s	0.028 316 85
1 ft^3/min	L/s	0.471 9474
1 gal/min	L/s	0.063 0902
1 gal/min	m^3/min	0.0038
1 gal/h	mL/s	1.051 50
1 million gal/d	L/s	43.8126
1 acre ft/s	m^3/s	1233.49
TEMPERATURE INTERVAL		
1°F	°C or K	0.555 556 $^5/_9$°C = $^5/_9$K
EQUIVALENT TEMPERATURE ($t_{°C} = T_K - 273.15$)		
$t_{°F}$	$t_{°C}$	$t_{°F} = {}^9/_5 t_{°C} + 32$

(Continued)

CONVERSION FACTORS—(Continued)

To convert	to	multiply by
MASS		
1 ton (short ***)	metric ton	0.907 185
	kg	907.1847
1 lb	kg	0.453 5924
1 oz	g	28.349 52
***1 long ton (2,240 lb)	kg	1016.047
MASS PER UNIT AREA		
1 lb/ft^2	kg/m^2	4.882 428
1 oz/yd^2	g/m^2	33.905 75
1 oz/ft^2	g/m^2	305.1517
DENSITY (MASS PER UNIT VOLUME)		
1 lb/ft^3	kg/m^3	16.01846
1 lb/yd^3	kg/m^3	0.593 2764
1 ton/yd^3	t/m^3	1.186 553
FORCE		
1 tonf (ton-force)	kN	8.896 44
1 kip (1,000 lbf)	kN	4.448 22
1 lbf (pound-force)	N	4.448 22
MOMENT OF FORCE, TORQUE		
1 lbf·ft	N·m	1.355 818
1 lbf·in	N·m	0.112 9848
1 tonf·ft	kN·m	2.711 64
1 kip·ft	kN·m	1.355 82
FORCE PER UNIT LENGTH		
1 lbf/ft	N/m	14.5939
1 lbf/in	N/m	175.1268
1 tonf/ft	kN/m	29.1878
PRESSURE, STRESS, MODULUS OF ELASTICITY (FORCE PER UNIT AREA) (1 Pa = 1 N/m^2)		
1 tonf/in^2	MPa	13.7895
1 tonf/ft^2	kPa	95.7605
1 kip/in^2	MPa	6.894 757
1 lbf/in^2	kPa	6.894 757
1 lbf/ft^2	Pa	47.8803
Atmosphere	kPa	101.3250
1 inch mercury	kPa	3.376 85
1 foot (water column at 32°F)	kPa	2.988 98
WORK, ENERGY, HEAT(1J = 1N·m = 1W·s)		
1 kWh (550 ft·lbf/s)	MJ	3.6
1 Btu (Int. Table)	kJ	1.055 056
	J	1055.056
1 ft·lbf	J	1.355 818
COEFFICIENT OF HEAT TRANSFER		
1 Btu/(ft^2·h·°F)	W/(m^2·K)	5.678 263
THERMAL CONDUCTIVITY		
1 Btu/(ft·h·°F)	W/(m·K)	1.730 735
ILLUMINANCE		
1 lm/ft^2 (footcandle)	lx (lux)	10.763 91
LUMINANCE		
1 cd/ft^2	cd/m^2	10.7639
1 foot lambert	cd/m^2	3.426 259
1 lambert	kcd/m^2	3.183 099

GAGE CONVERSION TABLE

APPROXIMATE MINIMUM THICKNESS (inch/mm) FOR CARBON SHEET STEEL CORRESPONDING TO MANUFACTURER'S STANDARD GAGE AND GALVANIZED SHEET GAGE NUMBERS

CARBON SHEET STEEL					GALVANIZED SHEET				
Manufacturer's Standard Gage No.	Decimal and Nominal Thickness Equivalent		Recommended Minimum Thickness Equivalent[1]		Galvanized Sheet Gage No.	Decimal and Nominal Thickness Equivalent		Recommended Minimum Thickness Equivalent[1]	
	(inch)	(mm)[2]	(inch)	(mm)[2]		(inch)	(mm)[2]	(inch)	(mm)[2]
8	0.1644	4.17	0.156	3.46	8	0.1681	4.27	0.159	4.04
9	0.1495	3.80	0.142	3.61	9	0.1532	3.89	0.144	3.66
10	0.1345	3.42	0.127	3.23	10	0.1382	3.51	0.129	3.23
11	0.1196	3.04	0.112	2.84	11	0.1233	3.13	0.114	2.90
12	0.1046	2.66	0.097	2.46	12	0.1084	2.75	0.099	2.51
13	0.0897	2.28	0.083	2.11	13	0.0934	2.37	0.084	2.13
14	0.0747	1.90	0.068	1.73	14	0.0785	1.97	0.070	1.78
15	0.0673	1.71	0.062	1.57	15	0.0710	1.80	0.065	1.65
16	0.0598	1.52	0.055	1.40	16	0.0635	1.61	0.058	1.47
17	0.0538	1.37	0.050	1.27	17	0.0575	1.46	0.053	1.35
18	0.0478	1.21	0.044	1.12	18	0.0516	1.31	0.047	1.19
19	0.0418	1.06	0.038	0.97	19	0.0456	1.16	0.041	1.04
20	0.0359	0.91	0.033	0.84	20	0.0396	1.01	0.036	0.91
21	0.0329	0.84	0.030	0.76	21	0.0366	0.93	0.033	0.84
22	0.0299	0.76	0.027	0.69	22	0.0336	0.85	0.030	0.76
23	0.0269	0.68	0.024	0.61	23	0.0306	0.78	0.027	0.69
24	0.0239	0.61	0.021	0.53	24	0.0276	0.70	0.024	0.61
25	0.0209	0.53	0.018	0.46	25	0.0247	0.63	0.021	0.53
26	0.0179	0.45	0.016	0.41	26	0.0217	0.55	0.019	0.48
27	0.0164	0.42	0.014	0.36	27	0.0202	0.51	0.017	0.43
28	0.0149	0.38	0.013	0.33	28	0.0187	0.47	0.016	0.41
					29	0.0172	0.44	0.014	0.36
					30	0.0157	0.40	0.013	0.33

[1]The thickness of the sheets set forth in the code correspond to the thickness shown under these columns. They are the approximate minimum thicknesses and are based on the following references:

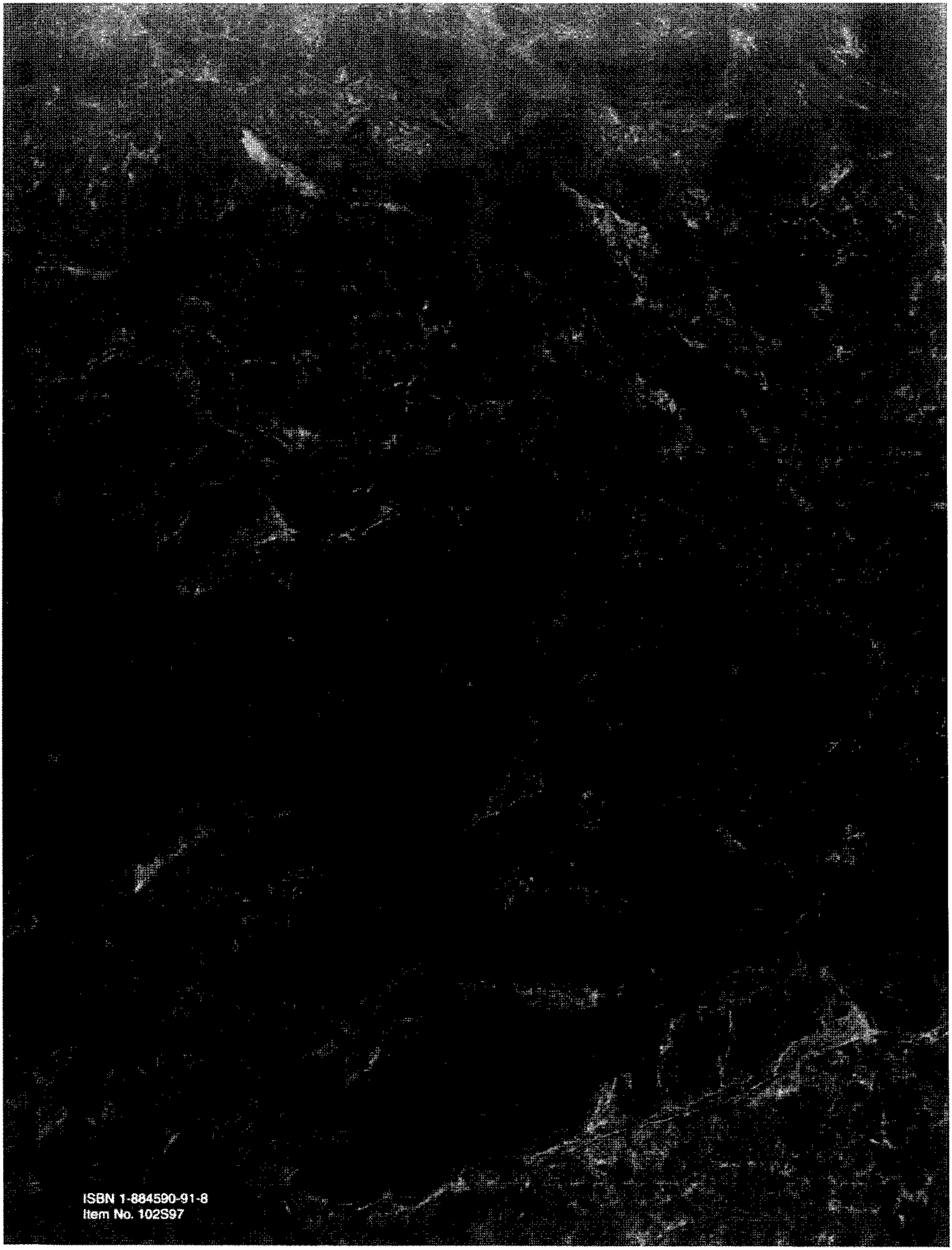
Carbon sheet steel—Thickness 0.071 inch and over:
ASTM A 568-74, Table 3, Thickness Tolerances of Hot-Rolled Sheet (Carbon Steel).

Carbon sheet steel—Thickness less than 0.071 inch:
ASTM A 568-74, Table 23, Thickness Tolerances of Cold-Rolled Sheet (Carbon and High Strength Low Alloy).

Galvanized sheet steel—All thicknesses:
ASTM A 525-79, Table 4, Thickness Tolerances of Hot-Dip Galvanized Sheet.

Minimum thickness is the difference between the thickness equivalent of each gage and the maximum negative tolerance for the widest rolled width.

[2]The SI equivalents are calculated and rounded to two significant figures following the decimal point.



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