ANSI/AISC N690L-03
An American National Standard

Load and Resistance Factor Design Specification for Safety-Related Steel Structures for Nuclear Facilities

December 17, 2003

Approved by the
AISC Committee on Specifications
and issued by the AISC Board of Directors

AMERICAN INSTITUTE OF STEEL CONSTRUCTION, INC.

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Printed in the United States of America

PREFACE

The AISC *Load and Resistance Factor Design (LRFD) Specification for Safety-Related Steel Structures for Nuclear Facilities* addresses the design, fabrication, and erection of steel safety-related structures for nuclear facilities. This document supplements the AISC *Load and Resistance Factor Design Specification for Structural Steel Buildings* dated December 27, 1999. It also provides an alternate method of design to that given in the ANSI/AISC N690-1994, *Specification for the Design, Fabrication, and Erection of Safety-Related Steel Structures for Nuclear Facilities*, including Supplement No. 1, which is based on allowable stress design.

Safety-related steel structures in nuclear facilities, which provide support and protective functions to equipment vital to the facility, are subjected to certain unique design forces and loads resulting from postulated accidents (such as turbine generated missiles and jet forces from high energy line breaks) and from extreme natural phenomena (tornadoes and earthquakes). The relevant regulatory and jurisdictional authorities (e.g. the Nuclear Regulatory Commission, the Department of Energy) dictate special quality assurance requirements and additional design requirements associated with these structures. As such, safety related nuclear structures require special LRFD design provisions. The provisions specified herein are to be used in conjunction with the AISC *LRFD Specification for Structural Steel Buildings*. This Specification consists of modifications (additions, deletions and replacements) of the 1999 AISC *Load and Resistance Factor Design Specification for Structural Steel Buildings*, referred to as the AISC LRFD Specification.

This Specification has been developed as a consensus document to provide uniform practice in the design of steel-framed structures for nuclear facilities. The AISC Committee on Specifications, Task Committee 12—Nuclear Facilities Design, is responsible for the ongoing development of this Specification. TC 12 membership is as follows:

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A non-mandatory Commentary provides background for the Specification provisions and the user is encouraged to consult it.

The reader is cautioned that professional judgment must be exercised when data or recommendations in this Specification are applied. The publication of the material contained herein is not intended as a representation or warranty on the part of the American Institute of Steel Construction, Inc. or any other person named herein that this information is suitable for general or particular use, or freedom from infringement of any patent or patents. Anyone making use of this information assumes all liability arising from such use. The design of safety related structures for Nuclear Facilities is within the scope of expertise of a competent licensed structural engineer, architect, or other licensed professional, for the application of principles to a particular structure.

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SYMBOLS

The symbols listed below shall be used in addition to those in the AISC LRFD Specification. Where there is a duplication of symbols between this Specification and the AISC LRFD Specification the symbols herein shall take precedence. The section number in the right hand column refers to the section where the symbol is first used.

Symbol	Definition	Section
C	Rated capacity of crane	NA4.1
D	Dead loads due to the weight of the structural elements, fixed-position equipment, and other permanent appurtenant items; weight of crane trolley and bridge	NA4.1
E_o	Loads generated by the *operating basis earthquake*	NA4.2
E_{ss}	Loads generated by the *safe shutdown or design basis earthquake*	NA4.3
L	Live load due to occupancy and moveable equipment, including their impact	NA4.1
P_a	Maximum differential pressure load generated by the postulated accident	NA4.4
R_a	Pipe and equipment reactions generated by the postulated accident, including R_o	NA4.4
R_o	Pipe reactions during normal operating, start-up, or shutdown conditions, based on the most critical transient or steady-state condition	NA4.1
S	Snow load as stipulated in *ASCE 7* for Category IV facilities	NA4.1
T_a	Thermal loads generated by the postulated accident, including T_o	NA4.4
T_o	Thermal effects and loads during normal operating, start-up, or shutdown conditions, based on the most critical transient or steady-state condition	NA4.1
W	Wind load as stipulated in *ASCE 7* for Category IV facilities	NA4.2
W_t	Loads generated by the *specified design tornado*, including wind pressures, pressure differentials, and *tornado-borne missiles*	NA4.3
Y_j	*Jet impingement load* generated by the postulated accident	NA4.4
Y_r	Loads on the structure generated by the reaction of the broken high-energy pipe during the postulated accident	NA4.4
Y_m	*Missile impact* load, such as pipe whipping generated by or during the postulated accident	NA4.4
ε_{st}	Strain corresponding to the onset of strain hardening	NA5.5
ε_u	Strain corresponding to elongation at failure (rupture)	NA5.5
ε_y	Strain corresponding to yield stress	NA5.5
μ	Ductility factor	NA5.6

GLOSSARY

The terms listed below shall be used in addition to those in the AISC LRFD Specification. Where there is a duplication of terms between this Specification and the AISC LRFD Specification the definitions herein shall take precedence. Glossary terms are *italicized* where they appear in the text.

Authority having jurisdiction (AHJ). A federal government agency (or agencies), such as the Nuclear Regulatory Commission or the Department of Energy, that is empowered to issue and enforce regulations affecting the design, construction and operation of nuclear facilities.

Certificate of compliance. A document written specifically for the raw materials used. It must specifically identify the job order and component where these materials are to be used. In addition, this certification must be traceable to the applicable *certified mill test report* for the raw materials used in fabrication.

Certified mill test report (CMTR). A document identifying the actual chemical analysis, physical test data and any other testing necessary to show compliance for the actual item for which the CMTR is supplied.

Design basis earthquake (DBE). See safe shutdown earthquake (SSE). (Term used in connection with DOE facilities; also used interchangeably for older nuclear power facilities.)

Ductility factor. Ratio of permitted strain or deformation to the strain or deformation at yield.

Engineer. An individual or an organization, designated by the *owner*, responsible for the preparation of the plans and specifications for the nuclear facility structures, or for the evaluation of the existing structure(s). The *engineer* as an individual or part of an organization shall be a licensed professional engineer, qualified to fulfill the assigned responsibility.

Impactive force. Time-dependent loads due to collision of masses that are associated with finite amounts of kinetic energy. The impactive load is determined by the inertia and stiffness properties of the missile and the target structure. Impactive loads include the following examples/types: *tornado-borne missiles*, whipping pipes, aircraft missiles, and other internal and external missiles.

Impulsive force. Time-dependent loads which are not associated with collision of solid masses. The loads are not dependent on the target mass or stiffness properties. Impulsive loads include the following examples/types: jet impingement, blast pressure, compartment pressurization, and *jet shield* reactions.

Jet impingement load. A force-time history depicting the forces resulting from the direct strike by a dense, high velocity jet of steam or water onto a structure, system or component.

Jet shield. A device used to protect adjacent structures, systems, or components from the effects of a dense, high velocity jet of steam or water, resulting from a rupture of a high energy pipe line.

Missile impact. The collision of a projectile (e.g. *tornado-borne missile* (see definition) or plant generated missile) with a structure, system, or component.

Operating basis earthquake, OBE. An earthquake that could reasonably be expected to occur at the plant site during the operating life of the plant considering the regional and local geology and seismology and specific characteristics of local subsurface material. It is that earthquake that produces the vibratory ground motion for which the features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional. An earthquake greater than OBE is associated with plant shutdown and inspection.

Owner. The organization responsible for the design, construction, operation, maintenance, and safety of the nuclear facility.

Pipe whip impact barrier. An energy absorbing device used to protect *safety-related* structures, systems, or components from the potentially damaging forces of a whipping, high energy pipe.

Pipe whip restraint. An energy absorbing device used to limit the potentially damaging motion of a whipping, high energy pipe, resulting from a pipe break/rupture, through the confining effects of the device.

Quality assurance program. A program identifying the planned or systematic actions necessary to provide adequate confidence that an item or facility will be designed, fabricated, and constructed in accordance with the plans and specification.

Response spectrum. A plot of the maximum responses (acceleration, velocity, or displacement) of idealized single-degree-of-freedom oscillators as a function of the natural frequencies of the oscillators for a given damping value. The *response spectrum* is calculated for a specified vibratory motion input at the oscillators' supports.

Safe shutdown earthquake, SSE. An earthquake that produces the vibratory ground motion for which certain structures, systems, and components in the nuclear power plant must be designed to remain functional.

Safety-related. A classification that applies to structures, systems, or components used in a nuclear power plant that are relied upon during or following design basis events to assure:

- The integrity of the reactor coolant pressure boundary

- The capability to shut down the reactor and maintain it in a safe shut down condition, or
- The capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures of 10CFR100.11.

Specified design (basis) tornado. Those combinations of translational speed, rotational speed, and prescribed pressure drop related to the environmental effects of a tornado (as defined by the licensing basis, design basis, and/or regulatory requirements (USNRC Regulatory Guide 1.76)).

Specified design (basis) wind. Combination of wind speed and exposure conditions, as defined by the facility specific document and/or other design basis documents, used to establish the forces acting on a structure from wind effects. The methodology of determining such forces should be in accordance with industry accepted practices (e.g. ASCE 7).

Tornado-borne missiles. Missiles of specific weight and velocity that are assumed to impact structures after becoming airborne as a result of tornado winds and pressures. These missiles are defined by the AHJ at the facility site.

CHAPTER NA

GENERAL PROVISIONS

Modify Chapter A of the AISC LRFD Specification as follows.

NA1. SCOPE

Replace section with the following:

This Specification contains Load and Resistance Factor Design (LRFD) criteria for the design, fabrication, and erection of steel *safety-related* structures and structural elements for nuclear facilities. It is intended to be compatible with, and a supplement to, the 1999 AISC *Load and Resistance Factor Design Specification for Structural Steel Buildings* hereafter referred to as the AISC LRFD Specification.

Unless stated otherwise, provisions of the AISC LRFD Specification are applicable. Only those sections that differ from the AISC LRFD Specification provisions are stated within this Specification. Section designations within this Specification are preceded by the letter N to denote nuclear facility design provisions.

This specification includes the list of additional symbols, the glossary of additional definitions, and the appendices.

Additional provisions for stainless steel sections are provided in Section NA5.3. Specifically excluded from this Specification are pressure retaining components, e.g., pressure vessels, valves, pumps, and piping.

In the design of members and connections of Seismic Force Resisting Systems, the AISC *Seismic Provisions for Structural Steel Buildings*, in general, are not applicable. However, the detailing requirements of Sections 6 and 7 of the provisions shall be appropriately considered when designing for plastic analysis.

Single angle members shall comply with the *Load and Resistance Factor Design Specification for Single-Angle Members* and with this Specification.

Hollow structural sections (HSS) shall comply with the *Load and Resistance Factor Design Specification for Steel Hollow Structural Sections* and with this Specification.

The sponsors of any system or construction within the scope of this Specification, the adequacy of which has been shown by successful use or by analysis or test, but which does not conform to or is not covered by this specification, shall have the right to present the data on which their design is based to the *authority having jurisdiction* for review and approval.

Structures and structural elements subject to this Specification are those steel structures which are parts of a *safety-related* system or which support, house, or protect *safety-related* systems or components, the failure of which would impair the *safety-related* functions of these systems or components.

Safety categorization for nuclear facility steel structures and structural elements shall be the responsibility of the *owner*.

As used in this Specification, the term *structural steel* refers to the steel elements of the structural steel frame essential to the support of the required loads. Such elements are enumerated in Section 2.1 of the AISC *Code of Standard Practice for Steel Buildings and Bridges*. For the design of cold-formed steel structural members, whose profiles contain rounded corners and slender flat elements, the provisions of the American Iron and Steel Institute *North American Specification for the Design of Cold-Formed Steel Structural Members* shall be applicable.

NA3. MATERIAL

1. Structural Steel

1a. ASTM Designations

Add the following:

Seamless Carbon Steel Pipe for High-Temperature Service, ASTM A106

Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip, ASTM A167

Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels, ASTM A240/A240M

Stainless Steel Bars and Shapes, ASTM A276

Seamless and Welded Austenitic Stainless Steel Pipes, ASTM A312/A312M

Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels, ASTM A479/A479M

Pressure Vessel Plates, Carbon Steel, for Intermediate and Higher Temperature Service, ASTM A515/A515M

TABLE NA3.1

Specified Minimum Yield Strength	Charpy V-notch Energy Value	
	Avg. 3 Specimens Minimum	1 Individual Specimen Minimum
Equal to or less than 36 ksi [250 MPa]	15 ft-lbs [21 J]	10 ft-lbs [14 J]
Greater than 36 ksi [250 MPa], less than 44 ksi [300 MPa]	20 ft-lbs [27 J]	15 ft-lbs [21 J]
Equal to or greater than 44 ksi [300 MPa]	30 ft-lbs [41 J]	25 ft-lbs [34 J]

Pressure Vessel Plates, Carbon Steel, for Moderate and Lower Temperature Service, ASTM A516/A516M

Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar, ASTM A666

Exception: Types 301, 302 and 302B of ASTM A167, martensitic stainless steel grades of ASTM A276 and Class 1 stainless steel of ASTM A607 shall not be used in welded applications.

Replace the last paragraph with the following:

In addition to satisfying the appropriate ASTM specification, the specification of the material of those structures or structural components which may be subject to suddenly applied impact loads, e.g., *jet shields*, pipe restraint supports, *pipe whip impact barriers*, etc., shall be supplemented by the requirement that the material be subjected to Charpy V-notch impact tests, using the procedures described in ASTM A20/A20M. The Charpy V-notch impact test shall be conducted at a temperature not less than 30 °F (17 °C) below the lowest service metal temperature of the structural component. The acceptance criteria shall be that the material withstand not less than the energy values (average of three specimens value and individual specimen value) indicated in Table NA3.1, in addition to satisfying the appropriate ASTM specification.

Certified mill test reports or certified reports of tests made by the fabricator or a qualified testing laboratory in accordance with ASTM A6/A6M, A20/A20M, or A568/A568M, as applicable, and the governing ASTM Standards shall validate that the material meets the specification.

In lieu of the above, the material supplier or fabricator shall, if approved by the *owner*, provide a *certificate of compliance* stating that the steel furnished has been tested and conforms to the specification.

Traceability by heat is not required unless stipulated by the plans and/or specifications.

1b. Unidentified Steel

Replace with the following:

Use of unidentified steel is prohibited.

1c. Heavy Shapes

Add the following to the end of the section:

The specification covering material for structural components which, as a result of proposed welding procedures, design details, etc., may be subject to lamellar tearing (where, as determined by the *engineer*, welding high heat input/or high restraint can exist), shall include the requirement that the material shall be either ultrasonically examined in accordance with ASTM A435/A435M or tested in tension in the through-thickness direction (Z-direction). The resulting percentage reduction in area in the Z-direction shall not be less than 90 percent of that in the direction of material rolling.

2. Steel Castings and Forgings

Add the following:

Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service, ASTM A216/A216M

Martensitic Stainless Steel and Alloy-Steel Castings for Pressure-Containment Parts Suitable for High-Temperature Service, ASTM A217/A217M

Replace the last sentence with the following:

Certified mill test reports or certified reports of tests made by the fabricator or a qualified testing laboratory shall validate that the material meets the specification.

In lieu of the above, the material supplier or fabricator shall, if approved by the *owner*, provide *a certificate of compliance* stating that the steel furnished has been tested and conforms to the specification.

Traceability by heat number is not required unless stipulated by the plans and/or specifications.

3. Bolts, Washers, and Nuts

Add the following:

Alloy Steel Bolting Materials for Low-Temperature Service, ASTM A320/A320M

Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes, ASTM A564/A564M

Replace the last sentence with the following:

Certified mill test reports or certified reports of tests made by the fabricator or a qualified testing laboratory shall validate that the material meets the specification.

In lieu of the above, the material supplier or fabricator shall, if approved by the *owner*, provide a *certificate of compliance* stating that the steel furnished has been tested and conforms to the specification.

Traceability by heat number is not required unless stipulated by the plans and/or specifications.

4. Anchor Rods and Threaded Rods

Replace the last sentence with the following:

Certified mill test reports or certified reports of tests made by the fabricator or a qualified testing laboratory shall validate that the material meets the specification.

In lieu of the above, the material supplier or fabricator shall, if approved by the *owner*, provide a *certificate of compliance* stating that the steel furnished has been tested and conforms to the specification.

Traceability by heat number is not required unless stipulated by the plans and/or specifications.

5. Filler Metal and Flux for Welding

Add the following:

Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes, AWS A5.4

Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes, AWS A5.9

Replace the last paragraph with the following:

Filler material and fluxes that are suitable for the intended application shall be selected.

The material supplier or fabricator shall, if approved by the *owner*, provide a *certificate of compliance* stating that the steel furnished has been tested and conforms to the specification.

In lieu of the above, *certified mill test reports* or certified reports of tests made by the fabricator or a qualified testing laboratory shall validate that the material meets the specification.

Traceability by heat number is not required unless stipulated by the plans and/or specifications.

NA4. LOADS AND LOAD COMBINATIONS

Replace section with the following:

1. Normal Loads

Normal loads are those loads that are encountered during normal plant start-up, operation and shutdown, and include:

D = dead loads due to the weight of the structural elements, fixed-position equipment, and other permanent appurtenant items; weight of crane trolley and bridge

L = live load due to occupancy and moveable equipment, including their impact

S = snow load as stipulated in *ASCE 7* for Category IV facilities

R_o = pipe reactions during normal operating, start-up, or shutdown conditions, based on the most critical transient or steady-state condition

T_o = thermal effects and loads during normal operating, start-up, or shutdown conditions, based on the most critical transient or steady-state condition

C = rated capacity of crane (shall include the maximum wheel loads of the crane and the vertical, lateral, and longitudinal forces induced by the moving crane)

2. Severe Environmental Loads

Severe environmental loads are those loads that may be encountered infrequently during the service life, and include:

E_o = loads generated by the *operating basis earthquake*, as defined in the Nuclear Regulatory Commission document, "Earthquake Engineering Criteria for Nuclear Power Plants, Appendix S, 10 CFR, Part 50", where required as part of the design basis.

W = wind load as stipulated in *ASCE 7* for Category IV facilities.

3. Extreme Environmental Loads

Extreme environmental loads are those loads that are highly improbable but are used as a design basis, and include:

E_s = loads generated by the Safe Shutdown, or *design basis earthquake*, as specified for the facility

W_t = loads generated by the *specified design tornado*, including wind pressures, pressure differentials, and *tornado-borne missiles*, as defined in U.S. Nuclear Regulatory Commission Standard Review Plan 3.3.2 (NUREG-0800)

4. Abnormal Loads

Abnormal loads are those loads generated by a postulated high-energy pipe break accident used as a design basis, and include:

P_a = maximum differential pressure load generated by the postulated accident

T_a = thermal loads generated by the postulated accident, including T_o

R_a = pipe and equipment reactions generated by the postulated accident, including R_o

Y_r = loads on the structure generated by the reaction of the broken high-energy pipe during the postulated accident

Y_j = *jet impingement load* generated by the postulated accident

Y_m = *missile impact* load, such as pipe whipping generated by or during the postulated accident

5. Load Factors and Load Combinations

The required strength of the structure and its elements shall be determined from the appropriate critical combination of factored loads. The most critical structural effect may occur when one or more of the loads are not acting. The following load combinations shall be investigated:

1. Normal Load Combinations

$$1.4(D + R_o) + T_o \quad \text{(NA4-1)}$$

$$1.2(D + R_o) + 1.6L + 1.4C + 0.5S + 1.2T_o \quad \text{(NA4-2)}$$

$$1.2(D + R_o) + 1.6S + 0.8L + 1.4C + 1.2T_o \quad \text{(NA4-3)}$$

2. Severe Environmental Load Combinations

$$1.2(D + R_o) + 1.6W + 0.8L + 0.5S + T_o \quad \text{(NA4-4)}$$

$$1.2(D + R_o) + 1.6E_o + 0.8L + 0.2S + T_o \quad \text{(NA4-5)}$$

3. Extreme Environmental and Abnormal Load Combinations

$$D + 0.8L + T_o + R_o + E_{ss} \quad \text{(NA4-6)}$$

$$D + 0.8L + T_o + R_o + W_t \quad \text{(NA4-7)}$$

$$D + 0.8L + C + 1.2\,P_a + R_a + T_a \quad \text{(NA4-8)}$$

$$D + 0.8L + (P_a + R_a + T_a) + (Y_r + Y_j + Y_m) + E_{ss} \quad \text{(NA4-9)}$$

In applying T_o and T_a, the thermal gradient and structural restraint effects shall be considered, as appropriate.

In combinations NA4-7, NA4-8 and NA4-9, the maximum values of P_a, T_a, R_a, Y_j, Y_r, Y_m, and W_t, including an appropriate dynamic load factor, shall be used unless a time-history analysis is performed to justify otherwise. Combination NA4-9, and the required strength criteria of Section NA5, shall first be satisfied without Y_r, Y_j, and Y_m. When considering these concentrated loads or tornado-borne missiles, local section strength may be exceeded, as per Section NA5.5, provided that there is no loss of function of any *safety-related* system.

When any load reduces the effects of other loads and if it can be demonstrated that the load is always present or occurs simultaneously with other loads, the corresponding coefficient for that load shall be taken as 0.90. Otherwise, the coefficient for that load shall be taken as zero.

Where the structural effect of differential settlement is significant, it shall be included with the dead load.

NA5. DESIGN BASIS

Modify section as follows:

1. Required Strength at Factored Loads

Replace section with the following:

The required strength of structural members and connections shall be determined by structural analysis for each applicable load combination, as stipulated in Section NA4.

Design by either elastic or plastic analysis is permitted, except that design by plastic analysis is permitted only if: (1) steels with specified yield strengths not exceeding 65 ksi (448 MPa) are used; and (2) the design meets the additional provisions of NB5.2, NC1.1, NC2.1a, NC2.2a, NE1.2, NF1.3, NH1, and NI1.

Beams and girders composed of compact sections, as defined in Section B5.1, and satisfying the unbraced length requirements of AISC LRFD Specification Section NF1.3 (including composite members) which are continuous over supports or are rigidly framed to columns may be proportioned for nine-tenths of the negative moments produced by gravity loading at points of support, provided that the maximum positive moment is increased by one-tenth of the average negative moments. This reduction is not permitted for hybrid beams, members of A514/A514M steel, or moments produced by loading on cantilevers. If the negative moment is resisted by a column rigidly framed to the beam or girder, the one-tenth reduction may be used in proportioning the column for combined axial force and flexure, provided that the axial force does not exceed ϕ times $0.15A_gF_y$,

where

A_g = gross area, in.^{2} (mm^2)

F_y = specified minimum yield stress, ksi (MPa)

ϕ = resistance factor for compression

3. Design for Strength

Replace section with the following:

The required strength shall be determined for each applicable load combination as stipulated in Section NA4.

The design strength of each structural component or assemblage shall equal or exceed the required strength based on the factored loads. The design strength, ϕR_n, for each applicable limit state is calculated as the nominal strength, R_n, multiplied by a resistance factor, ϕ. Nominal strengths, R_n, and resistance factors, ϕ, are given in Chapters ND through NK.

The yield strength and modulus of elasticity of steel shall be reduced for temperatures in excess of 250 °F (121 °C).

TABLE NA5.1
***Ductility Factor*, μ, for Design of Structural Components for Abnormal Loads**

Description of Element	*Ductility Factor*
Structural steel tension member	$\mu \le 0.25\, \varepsilon_u/\varepsilon_y \le 0.1/\varepsilon_y$ [a]
Structural steel flexural members Open sections (W, S, WT, etc) Closed sections (pipe, box, etc.) Members where shear governs design	 $\mu \le 10$ $\mu \le 20$ $\mu \le 5$
Structural steel columns	$\mu = 0.225/\lambda^2 \le \varepsilon_{st}/\varepsilon_y$ not to exceed 10
[a] ε_u = strain corresponding to elongation at failure (rupture); ε_y = strain corresponding to yield stress [b] $\lambda = (KL/r)\sqrt{F_y/\pi^2 E}$	

Design strength for stainless steel members, assemblies, and connections shall be in accordance with the requirements in Sections 3, 4, and 5 of ANSI/ASCE 8.

4. Design for Serviceability and Other Considerations

Modify the last sentence to read:

Provisions for design for serviceability are given in Chapter NL. The effect of elevated temperature on stiffness shall be considered, where appropriate, in calculating structural deformations under sustained operating or abnormal conditions.

Add the following new section:

5. Design Based on Ductility, Local Effects, and Elevated Rates of Strain

In load combinations NA4-7 to NA4-9 of Section NA4.5, it is permitted to determine the load effects for impact or *impulsive forces* using inelastic analysis with limits on *ductility factors*, μ, equal to one-half the values at the onset of plastic instability, but not to exceed the values given in Table NA5.1. For the noncompact structural elements the limiting width-thickness ratios in flexure or compression shall conform to Table NA5.2. Members in flexure or flexure and compression shall conform to the lateral bracing requirements of Section F1.3.

TABLE NA5.2
Limiting Width-Thickness Ratios for Compression Elements

	Description of Element	Width Thick-ness Ratio	Limiting Width-Thickness Ratios
Unstiffened Elements	Flanges of I-shaped rolled, hybrid or welded beams [a]	b/t	$0.30\sqrt{E_s / F_y}$
	Flanges of I-shaped rolled, hybrid or welded columns [a]	b/t	$0.30\sqrt{E_s / F_y}$
	Flanges of channels, angles and I-shaped rolled, hybrid or welded beams and braces [a]	b/t	$0.30\sqrt{E_s / F_y}$
	Flanges of I-shaped rolled, hybrid or welded columns [a]	b/t	$0.38\sqrt{E_s / F_y}$
	Flanges of H-pile sections	b/t	$0.45\sqrt{E_s / F_y}$
	Flat bars	b/t	2.5
	Legs of single angle, legs of double angle members with separators, or flanges of tees	b/t	$0.30\sqrt{E_s / F_y}$
	Webs of tees	d/t	$0.30\sqrt{E_s / F_y}$
Stiffened Elements	Webs in flexural compression	h/t_w	$2.45\sqrt{E_s / F_y}$
	Webs in combined flexure and axial compression	h/t_w	for $P_u / \phi_b P_y \le 0.125$ $3.14\sqrt{\frac{E_s}{F_y}}\ 1-1.54\frac{P_u}{\phi_b P_y}$ for $P_u / \phi_b P_y > 0.125$ $1.12\sqrt{\frac{E_s}{F_y}}\ 2.33-\frac{P_u}{\phi_b P_y}$
	Round HSS in axial and/or flexural compression	D/t	$0.044\ E/F_y$
	Rectangular HSS in axial and/or flexural compression	b/t or h/t_w	$0.64\sqrt{E_s / F_y}$
	Webs of H-Pile sections	h/t_w	$0.94\sqrt{E_s / F_y}$

[a] For hybrid beams, use the yield strength of the flange F_{yf} instead of F_y.

In designing for impact and impulsive loads, it is permitted to increase the yield stress used in the determination of nominal strength, R_n. The increase in yield stress shall be determined from supporting experimental data. In the absence of such data, it is permitted to increase the specified yield stress by 10 percent. Impact and impulsive loads shall be considered concurrent with other loads in determining the required strength of structural elements.

Areas local to missile and jet impact may be evaluated by means of empirical penetration relationships and no evaluation of local response is required, provided that overall structural stability is assured.

NA6. REFERENCED CODES AND STANDARDS

Delete the following:

American Institute of Steel Construction (AISC)
Seismic Provisions for Structural Steel Buildings, 1997
Seismic Provisions for Structural Steel Buildings Supplement No. 1, 1999

American Iron and Steel Institute (AISI)
Specification for the Design of Cold-Formed Steel Structural Members, 1996
Specification for the Design of Cold-Formed Steel Structural Members, Supplement No. 1, 1999

American Society of Civil Engineers (ASCE)
Minimum Design Loads for Buildings and Other Structures, ASCE 7-98

Research Council on Structural Connections (RCSC)
Load and Resistance Factor Design Specification for Structural Joints Using ASTM A325 or A490 Bolts, 1994

Add the following:

American Institute of Steel Construction (AISC)
Seismic Provisions for Structural Steel Buildings, May 21, 2002

ACI International (ACI)
Standard Code Requirements for Nuclear Safety Related Concrete Structures, ACI 349-01

American Iron and Steel Institute (AISI)
North American Specification for the Design of Cold-Formed Steel Structural Members, 2001

American Society of Civil Engineers (ASCE)
Minimum Design Loads for Buildings and Other Structures, ASCE 7-02
Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members, ASCE 8-90

American Society of Mechanical Engineers (ASME)
ASME *Boiler and Pressure Vessel Code*, Section IX, QW-214, 1995
ASME NQA-1, Subpart 2.7, "Quality Assurance Requirements of Computer Software for Nuclear Facility Applications," 1994
ASME NQA-1, Supplement 11S-2, "Supplemental Requirements for Computer Program Testing," 1994

American Society for Testing and Materials (ASTM)

ASTM A20/A20M-99	ASTM A106-99
ASTM A167-99	ASTM A216/A216M-93
ASTM A217/A217-99	ASTM A240/A240M-99b
ASTM A276-98b	ASTM A312/A312M-99
ASTM A320/A320M-99	ASTM A435/A435M-90
ASTM A479/A479M-99a	ASTM A515/A515M-92
ASTM A516/A516M-90	ASTM A564/A564M-99
ASTM A666-03	ASTM D3843-00

American Welding Society (AWS)

AWS A5.4-92	AWS A5.9-93
AWS D1.6-99	

Crane Manufacturers Association of America
CMAA-70 "Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes," 2000

Electric Power Research Institute
Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants (NCIG-01, Revision 2), Electric Power Research Institute, NP-5380, Volume 1, September 1987

Nuclear Regulatory Commission
U.S. Nuclear Regulatory Commission Regulatory Guide 1.54, "Service Level I, II, and III Protective Coatings Applied to Nuclear Power Plants," July 2000

U.S. Nuclear Regulatory Commission, NUREG-0800, Standard Review Plan, April 1989

Office of the Federal Register, National Archives and Records Administration
Title 10 of the *Code of Federal Regulations*, Part 50, (10CFR50), Appendix B and Appendix S

Research Council on Structural Connections
Specification for Structural Joints Using ASTM A325 or A490 Bolts, June 23, 2000

NA7. DESIGN DOCUMENTS

Add the following to the first paragraph:

Plans for structural elements shall indicate material, special fabrication and erection requirements, notation of working points for fabrication, and offset dimensions. Members with varying and reversible loads shall be so indicated as well as the number of cycles, when applicable.

Change A2 to NA2 in the second paragraph.

Add the following as the eighth paragraph:

The construction specification shall include:

1. Appropriate code references
2. Material specifications
3. Material shipping, handling and storage requirements
4. Surface preparation and protective coating requirements
5. Requirements for fabrication and/or erection
6. Welding and bolting requirements
7. Tests and inspection requirements
8. Requirements for shop drawings
9. Documentation and retention of records

NA8. QUALITY ASSURANCE

Add the following new section:

A *quality assurance program* covering *safety-related* steel structures shall be developed prior to starting any work. The general requirements and guidelines for establishing and executing the quality assurance program during the design and construction phases of nuclear facilities are those established by Title 10 of the Code of Federal Regulations, Part 50 (10CFR50), Appendix B for Nuclear Power Stations.

Calculations pertinent to the design shall be documented and shall include a statement of the applicable design criteria. All computer programs used in analysis and design shall be covered by a Quality Assurance Program, as provided in the following:

> ASME NQA-1, Subpart 2.7, “Quality Assurance Requirements of Computer Software for Nuclear Facility Applications,” American Society of Mechanical Engineers
>
> ASME NQA-1, Supplement 11S-2, “Supplemental Requirements for Computer Program Testing,” American Society of Mechanical Engineers

CHAPTER NB

DESIGN REQUIREMENTS

No changes to Chapter B of the AISC LRFD Specification.

CHAPTER NC

FRAMES AND OTHER STRUCTURES

No changes to Chapter C of the AISC LRFD Specification.

CHAPTER ND

TENSION MEMBERS

No changes to Chapter D of the AISC LRFD Specification.

CHAPTER NE

COLUMNS AND OTHER COMPRESSION MEMBERS

No changes to Chapter E of the AISC LRFD Specification.

CHAPTER NF

BEAMS AND OTHER FLEXURAL MEMBERS

No changes to Chapter F of the AISC LRFD Specification.

CHAPTER NG

PLATE GIRDERS

No changes to Chapter G of the AISC LRFD Specification.

CHAPTER NH

MEMBERS UNDER COMBINED FORCES AND TORSION

No changes to Chapter H of the AISC LRFD Specification.

CHAPTER NI

COMPOSITE MEMBERS

No changes to Chapter I of the AISC LRFD Specification.

CHAPTER NJ

CONNECTIONS, JOINTS, AND FASTENERS

NJ1. GENERAL PROVISIONS

Modify Chapter J of the AISC LRFD Specification as follows:

5. Splices in Heavy Sections

Change the last paragraph to read:

Alternatively, splicing of such members subject to compression, including members which are subject to tension due to wind, seismic or other dynamic loads, shall be accomplished using splice details which do not induce large weld shrinkage strains; for example, partial-joint-penetration flange groove welds with fillet-welded surface lap plate splices on the web, bolted lap plate splices, or combination bolted/fillet-welded lap plate splices.

7. Minimum Strength of Connections

Replace section with the following:

Connections providing design strength shall be designed to support a factored load not less than 10 kips (44 kN), except for lacing, sag rods, and girts. The *engineer* shall establish any minimum design loads for supports for piping, conduit, ducts and similar equipment.

9. Bolts in Combination with Welds

Replace section with the following:

Bolted joints shall not be designed to share load in combination with welds.

10. High Strength Bolts in Combination with Rivets

Delete this section.

11. Limitations on Bolted and Welded Connections

Replace section with the following:

Pretensioned high-strength bolts (see AISC LRFD Specification Table J3.1), or welds shall be used for the following connections:

All column splices.

Connections of beams and girders to columns in which the bracing of columns is dependent.

Roof-truss splices and connections of trusses to columns, column splices, column bracing, knee braces, and crane supports.

Connections for supports of running machinery, or of other live loads which produce impact or reversal of stress.

Any other connections stipulated on the design plans.

In other cases, connections are permitted to be made with A307 bolts or snug-tight high-strength bolts.

Bolted connections for members that are part of the seismic load resisting system, and/or are subjected to dynamic loads shall be configured such that a ductile limit state in either the member or the connection controls the design.

NJ3. BOLTS AND THREADED PARTS

Modify section as follows:

1. High-Strength Bolts

Delete the rows for A502 rivets in AISC LRFD Specification Table J3.2, Design Strength of Fasteners and Table J3.5, Nominal Tension Stress (F_t), ksi (MPa) Fasteners in Bearing-Type Connections.

5. Maximum Spacing and Edge Distance

Delete "or rivet" from the first line.

6. Design Tension or Shear Strength

Delete the rows for A502 rivets in Table J3.2, Design Strength of Fasteners.

7. Combined Tension and Shear in Bearing-Type Connections

Delete the rows for A502 rivets in AISC LRFD Specification Table J3.5, Tension Stress Limit (F_t), ksi—Fasteners in Bearing-Type Connections.

8. High-Strength Bolts in Slip-Critical Connections

Add the following as a second paragraph:

All faying surfaces shall be prepared as required for Class A or better slip-critical joints.

10. Bearing Strength at Bolt Holes

In Equation J3-2b replace "3.0" with "2.4."

NJ5. CONNECTING ELEMENTS

2. Design Strength of Connecting Elements in Tension

In the first line replace "welded, bolted, and riveted" with "welded and bolted."

NJ10. ANCHOR RODS AND EMBEDMENTS

In the fourth line replace "ACI 318" with "ACI 349" and "ACI 318, Appendix C" with "ACI 349, Appendix B."

CHAPTER NK

CONCENTRATED FORCES, PONDING, AND FATIGUE

No changes to Chapter K of the AISC LRFD Specification.

CHAPTER NL

SERVICEABILITY DESIGN CONSIDERATIONS

No changes to Chapter L of the AISC LRFD Specification.

CHAPTER NM

FABRICATION, ERECTION, AND QUALITY CONTROL

Modify Chapter M of the AISC LRFD Specification as follows:

NM2. FABRICATION

Modify section as follows:

2. Thermal Cutting

Modify the first paragraph to read as follows:

Thermally cut edges shall meet the requirements of AWS D1.1, Sections 5.15.1.2, 5.15.4.3 and 5.15.4.4. Unrepaired notches and gouges shall not result in a joint dimension tolerance that exceeds that specified in AWS D1.1. Notches or gouges 3/8 in. (10 mm) deep or greater shall be permitted to be repaired only with the approval of the *engineer*. Oxygen gouging shall be prohibited on quenched and tempered steels.

3. Planing of Edges and Sawing

Add the following as a second paragraph:

Saw cuts shall not vary by more than 1/8 in. (3 mm) from a true plane.

5. Bolted Construction

Add the following to the first paragraph:

The diameter of holes for column anchor rods shall be a minimum of 1½ times the rod diameter but not more than 1 in. (25 mm) greater than the diameter of the rod, unless specifically called for on the drawings.

7. Dimensional Tolerances

Replace section with the following:

Dimensional tolerances shall be in accordance with the AISC *Code of Standard Practice* as modified in the following:

Holes:
A variation from the detailed distance of 1/16 in. (2 mm) center-to-center of end holes is permissible for members 30 ft (9 m) or less, and 1/8 in. (4 mm) for members over 30 ft (9 m) in length.

In compression members, erection holes or holes mispunched or misdrilled may be left unfilled provided the net area is not less than 0.85 times the gross area. In the case of tension members they may be left unfilled provided the net area requirements are met.

Stiffeners:
Stiffeners serving as connections shall be located within ¼ in. (6 mm) of the detailed position. A variation of 1 in. (25 mm) is permissible for the location of other stiffeners except bearing stiffeners, which shall be within ½ of their thickness from the detailed position.

Add the following new sections:

9. Surface Condition

Procedures for correcting and inspecting surface defects in excess of the depth and area limitations of those specified in ASTM A6 or other applicable ASTM specification, shall include the inspection methods and acceptance criteria to be used.

10. Bending

The minimum bending radius for plates shall not be less than that specified for the bend test in the applicable material specification.

NM3. SHOP PAINTING

Modify sections as follows:

1. General Requirements

Replace the second paragraph with the following:

All other steelwork shall be given one coat of shop paint, except the steel work that will be in contact with concrete or is specifically excluded in the design documents.

Add the following new section:

6. Quality Assurance

The quality assurance requirements for painting (or coating) of structural steel shall be in accordance with ASTM D3843 as endorsed by Regulatory Guide 1.54.

NM4. ERECTION

Modify sections as follows:

4. Fit of Column Compression Joints and Base Plates

Add the following paragraph:

Base plates shall be set to within 1/16 in. (2 mm) of the correct elevation and leveled to within 1/16 in. (2 mm) on the bearing surface.

Add the following new section:

8. Tolerances

8a. Cranes

1. Column Base Lines

   Crane column base lines shall be established as parallel lines and the column centerlines maintained within 1/8 in. (3 mm) of the theoretical distance.

2. Crane Runway Girders

   Horizontal sweep in crane runway girders shall not exceed ¼ in. (6 mm) per 50 ft (15 m) length of girder spans. Camber shall not exceed ¼ in. (6 mm) per 50 ft (15 m) of girder span over that indicated on the design drawings.

3. Crane Rails

   Center to center distance of crane rails and the straightness of crane rails shall meet the tolerances prescribed by CMAA-70.

   Vertical misalignment of crane rails measured at center lines of columns shall meet the tolerances prescribed by CMAA-70.

   For polar cranes, the above tolerances shall apply except that the CMAA tolerances for crane span shall be applied for crane rail diameter.

   Crane rails shall be centered on crane girders wherever possible. In no case shall the rail eccentricity be greater than ¾ of the thickness of the girder web, unless such eccentricity is accounted for in design.

4. Correction of Errors

   Holes shall be permitted to be reamed subject to the approval of the *engineer*.

CHAPTER NN

EVALUATION OF EXISTING STRUCTURES

Replace AISC LRFD Specification Chapter N with the following:

This chapter applies to the evaluation of the strength and stiffness under static vertical (gravity) loads of existing structures by structural analysis, by load tests, or by a combination of structural analysis and load tests when specified by the *engineer* or in the contract documents. For such evaluation, the steel grades are not limited to those listed in Section NA3.1. This chapter does not address load testing for the effects of seismic and other dynamic loads.

NN1. GENERAL PROVISIONS

These provisions shall be applicable when the evaluation of an existing steel structure is specified for (a) verification of a specific set of design loadings or (b) determination of the design strength of a load resisting member or system. The evaluation shall be performed by structural analysis (Section NN3), by load tests (Section NN4), or by a combination of structural analysis and load tests, as specified in the contract documents. Where load tests are used, the *engineer* shall first analyze the structure, prepare a testing plan, and develop a written procedure to prevent deformation that could affect the integrity of the equipment and components supported by it or located in its vicinity during testing.

NN2. MATERIAL PROPERTIES

1. Determination of Required Tests

The *engineer* shall determine the specific tests that are required from Section NN2.2 through NN2.6 and specify the locations where they are required. Where available, the use of applicable design documents shall be permitted to reduce or eliminate the need for testing.

2. Tensile Properties

Tensile properties of members shall be considered in evaluation by structural analysis (Section NN3) or load tests (Section NN4). Such properties shall include the yield stress, tensile strength, and percent elongation. Where available, *certified mill test reports* (CMTR) or certified reports (CR) of tests made by the fabricator or a testing laboratory in accordance with ASTM A6/A6M or A568/A568M, as applicable, shall be permitted for this purpose. Otherwise, tensile tests shall be conducted in accordance with ASTM A370 from samples cut from components of the structure. In nuclear facilities, the use of the actual properties from CMTR, CR, and the results of tensile tests shall be permissible when it can be shown that (1) the coupons taken for CMTR or CR represent the structure being evaluated, and (2) the value selected is derived from a statistical analysis indicating high confidence level. If necessary, additional coupons from the as-built structure shall be tested to supplement the CMTR or CR results, as directed by the engineer.

3. Chemical Composition

Where welding is anticipated for repair or modification of existing structures, the chemical composition of the steel shall be determined for use in preparing a welding procedure specification (WPS). Where available, results from *certified mill test reports* or certified reports of tests made by the fabricator or a testing laboratory in accordance with ASTM procedures shall be permitted for this purpose. Otherwise, analyses shall be conducted in accordance with ASTM A751 from the samples used to determine tensile properties, or from samples taken from the same locations.

4. Base Metal Notch Toughness

Where welded tension splices in heavy shapes and plates as defined in Section NA3.1a or NA3.1c, the Charpy V-notch toughness shall be determined in accordance with the provisions of Section NA3.1a or NA3.1c. If the notch toughness so determined does not meet the provisions of the applicable Sections, the *engineer* shall determine if remedial actions are required.

5. Weld Metal

When specified by the *engineer*, representative samples of weld metal shall be obtained. The engineer shall specify the nature of the tests to be performed.

6. Bolts

Representative samples of bolts shall be inspected to determine markings and classifications. Where bolts cannot be properly identified visually, representative samples shall be removed and tested to determine tensile strength in accordance with ASTM F606 or ASTM F606M and the bolt classified accordingly. Alternatively, the assumption that the bolts are A307 shall be permitted.

NN3. EVALUATION BY STRUCTURAL ANALYSIS

1. Dimensional Data

All dimensions used in the evaluation, such as spans, column heights, member spacings, bracing locations, cross section dimensions, thicknesses, and connection details, shall be determined from a field survey. Alternatively, when available, it shall be permitted to determine such dimensions from applicable design documents with field verification of critical values.

2. Strength Evaluation

Forces (load effects) in members and connections shall be determined by structural analysis applicable to the type of structure evaluated. The load effects shall be determined for the loads and factored load combinations stipulated in Section NA4.

The design strength of members and connections shall be determined from applicable provisions of Chapters NB through NK of this Specification.

3. Serviceability Evaluation

Where required, the deformations at service loads shall be calculated and reported.

NN4. EVALUATION BY LOAD TESTS

1. Determination of Live Load Rating by Testing

To determine the live load rating of an existing floor or roof structure by testing, a test load shall be applied incrementally in accordance with the *engineer's* plan. In addition to the load-deformation monitoring, the structure shall be monitored and shall be visually inspected for signs of distress or imminent failure at each load level. Appropriate measures shall be taken if these or any other unusual conditions are encountered.

The tested design strength of the structure shall be taken as the maximum applied test load plus the in-situ dead load. The live load rating of a floor structure shall be determined by setting the tested design strength equal to $1.2D + 1.6L$, where D is the nominal dead load and L is the nominal live load rating for the structure. The nominal live load rating of the floor structure shall not exceed that which can be calculated using applicable provisions of the specification. For roof structures, L_r, S, or R as defined in the Symbols, shall be substituted for L. More severe load combinations shall be used where required by applicable regulatory and enforcement authorities.

Periodic unloading shall be considered once the service load level is attained and before the load combination $1.2D + 1.6L$ is placed on the structure. Deformations of the structure, such as member deflections, shall be monitored at critical locations during the test, referenced to the initial position before loading. It shall be demonstrated, while maintaining maximum test load for one hour, that the deformation of the structure remains essentially unchanged. It is permissible to repeat the sequence if necessary to demonstrate compliance.

Deformations of the structure shall also be recorded 24 hours after the test loading is removed to determine the amount of permanent set. Because the amount of acceptable permanent deformation depends on the specific structure, no limit is specified for permanent deformation at maximum loading. Where it is not feasible to load test the entire structure, a segment or zone of not less than one complete bay, representative of the most critical conditions, shall be selected.

2. Serviceability Evaluation

When load tests are prescribed, the structure shall be loaded incrementally to the service load level. Deformations shall be monitored for a period of one hour. The structure shall then be unloaded and the deformations recorded.

NN5. EVALUATION REPORT

After the evaluation of an existing structure has been completed, the *engineer* shall prepare a report documenting the evaluation. The report shall indicate whether the evaluation was performed by structural analysis, by load testing or by a combination of structural analysis and load testing. Furthermore, when testing is performed, the report shall include the loads and load combination used and the load-deformation and time-deformation relationships observed. All relevant information obtained from design drawings, mill test reports, and auxiliary material testing shall also be reported. Finally, the report shall indicate whether the design strength of the structure, including members and connections, is adequate to withstand the load combinations of Section NA4.5.

APPENDIX NB

DESIGN REQUIREMENTS

No changes to Appendix B of the AISC LRFD Specification.

APPENDIX NE

COLUMNS AND OTHER COMPRESSION MEMBERS

No changes to Appendix E of the AISC LRFD Specification.

APPENDIX NF

BEAMS AND OTHER FLEXURAL MEMBERS

No changes to Appendix F of the AISC LRFD Specification.

APPENDIX NG

PLATE GIRDERS

No changes to Appendix G of the AISC LRFD Specification.

APPENDIX NH

MEMBERS UNDER COMBINED FORCES AND TORSION

No changes to Appendix H of the AISC LRFD Specification.

APPENDIX NJ

CONNECTIONS, JOINTS, AND FASTENERS

Modify Appendix J of the AISC LRFD Specification as follows:

NJ3. BOLTS AND THREADED PARTS

7. Combined Tension and Shear in Bearing-Type-Connections

In Table A-J3.1, Nominal Tension Stress Limit (F_t), ksi (MPa) Fasteners in Bearing-Type Connections, delete the rows for A502 rivets.

APPENDIX NK

CONCENTRATED FORCES, PONDING, AND FATIGUE

No changes to Appendix K of the AISC LRFD Specification.

COMMENTARY

On the Load and Resistance Factor Design Specification for Safety-Related Steel Structures for Nuclear Facilities

December 17, 2003

INTRODUCTION

This Specification is intended to be complete for normal design usage in conjunction with the 1999 AISC LRFD Specification and Commentary (AISC, 1999).

This Commentary is non-mandatory and furnishes background information and references for the benefit of the engineer seeking further understanding of the derivation and limits of the specification.

The Specification and Commentary are intended for use by design professionals with demonstrated engineering competence.

CHAPTER NA

GENERAL PROVISIONS

Modify Chapter A of the AISC LRFD Specification Commentary as follows:

NA1. SCOPE

Replace section with the following:

The AISC *Seismic Provisions for Structural Steel Buildings* are intended for the design and construction of steel members and connections in the Seismic Force Resisting Systems in buildings for which the design forces resulting from earthquake motions have been determined on the basis of various levels of energy dissipation in the inelastic range of response.

Seismic force resisting systems of safety-related structures for nuclear facilities are determined from elastic analyses where energy dissipation in the inelastic range is neglected. Thus, in general, the AISC *Seismic Provisions* are not applicable to the design of safety-related structures for nuclear facilities. However, the detailing requirements of Sections 6 and 7 of the provisions should be appropriately considered when designing for plastic analysis.

NA3. MATERIAL

1. Structural Steel

1a. ASTM Designations

Add the following:

ASTM A167 - Types 301, 302 and 302B:
These materials have carbon content of 0.15 and relatively low chromium and nickel content, which creates a problem with hot cracking. Further these materials are susceptible to severe sensitization, and therefore, will require a final annealing to redissolve the carbides.

ASTM A607, Class 1:
Class 1 is not readily weldable. Class 2 offers similar strength and offers improved weldability over Class 1.

ASTM A276:
Unmodified martensitic grade of this material is not readily weldable. Martensitic steels are susceptible to excessive hardening with consequent risk of cracking during welding.

The Charpy V-Notch Energy Values in Table NA3.1 have been carried forward from the original N690-1984 version and are values that assure a level of notch-toughness suitable for most applications subjected to suddenly applied impact loads. For certain extreme applications where the structure is designed to absorb significant energy through deformation, the designer should review these criteria for appropriateness.

1c. Heavy Shapes

Add the following:

Heavy structural sections and plates with restrained weld joints that induce stresses in the through-thickness direction are susceptible to lamellar tearing. The factors that affect susceptibility to lamellar tearing include joint configuration, service stresses, material thickness, material properties, fabrication techniques, and fabrication local strains. Proper design, materials selection and specification, and fabrication techniques can prevent lamellar tearing.

Joint configuration is most important in prevention of lamellar tearing. Fabrication strains are the principal cause of lamellar tearing, although in some cases the tearing might not occur until initiated by service stresses. By avoiding highly restrained configurations, lamellar tearing can be minimized. If highly restrained configurations cannot be avoided, then specifying materials resistant to lamellar tearing and/or fabrication techniques that reduce fabrication strains should be considered.

The through-thickness tension testing acceptance criteria have been carried forward from the original N690-1984 version. They establish acceptance criteria based on the properties in the rolling direction rather than an absolute value, thereby adjusting the acceptance criteria to the material properties, since the material properties can vary significantly over the range of materials permitted.

Some Guidelines for minimizing potential problems are provided in American Institute of Steel Construction, Inc. “Commentary on Highly Restrained Welded Connections,” AISC *Engineering Journal*, 3rd Qtr. 1973. The figures from that commentary illustrate the advantages of improved joint configuration.

Additional information can also be found in Jones & Milek’s discussion on the Commentary in the AISC *Engineering Journal*, 1st Qtr. 1975 and Thornton “Quality Control in Design and Supervision Can Eliminate Lamellar Tearing,” AISC Engineering Journal, 4th Qtr. 1973.

NA4. LOADS AND LOAD COMBINATIONS

Replace section with the following:

1. Normal Loads

Dead and live loads form a generic category of normal loads. During initial design, most of the piping loads and suspended system loads (HVAC, cable trays, etc.) are not available, and the load allowance for these items is included in *L* as an area-averaged load. Once the final attachment loads are determined, the initial load assumptions should be confirmed. When designing for weights or pressures from fluids, either existing in the building or due to hydrostatic heads, both cases (with fluid present or absent) should be evaluated in order to establish the governing load condition. When a detailed dynamic analysis is performed for crane systems, elevators, or other moving machinery, the resulting load with dynamic amplification may be used in lieu of the load increases (dynamic impact factors) specified in ASCE 7, or similar documents.

Sections NA4.1 and NA4.2 state that the snow load, *S*, and wind load, *W*, are as stipulated in ASCE 7 for Category IV facilities. Category IV facilities are defined in Table 1-1 of ASCE 7 as those for which continued function following the occurrence of a natural phenomena hazard is essential for public health and safety. For such facilities, ASCE 7 requires that the nominal load otherwise determined for ordinary buildings and other structures be increased by an importance factor. This importance factor is 1.15 for wind load and 1.2 for snow load. These increases are tantamount to requiring Category IV facilities to be designed for 100-year mean recurrence interval wind and snow events.

4. Abnormal Loads

A design-basis accident may be postulated to result from:

a. A break in any of the high-energy piping existing in the plant. This can create compartment pressurization, short-term high temperatures, and dynamic loads of reaction and/or impingement associated with the postulated pipe rupture.

b. A break in a small line containing high-temperature fluids or steam. This would result in a long-term high temperature and associated pressure loading.

c. Other extreme load phenomena which have a probability of occurrence larger than 10^{-7} events per year, the consequence of which could lead to release of radiation in excess of 10CFR100 limits.

5. Load Factors and Load Combinations

These load combinations stem from a probability-based study of load combinations for design of nuclear power plants (Hwang, Ellingwood, Shinozuka, and Reich, 1987). The probabilistic methodology in that study is consistent with that used to develop the probability-based load combination requirements appearing in ASCE 7-98 (ASCE, 1998; Galambos, Ellingwood, MacGregor, and Cornell, 1982; Ellingwood, Galambos, MacGregor, and Cornell, 1982). The load statistics for operating and abnormal plant conditions were obtained from a consensus estimation survey of operating load in nuclear facilities (Hwang, Wang, Shooman, and Reich, 1983).

Load combination NA4-4 for severe environmental loads includes the wind load, W, from Section 6 of ASCE 7. This wind load addresses extreme nontornadic wind effects from extratropical storms and hurricanes. Tornadic wind effects are defined by W_t, and are addressed in load combination NA4-7 for extreme environmental effects.

Dynamic load effects should be considered with maximum values assumed acting simultaneously, unless actual time history analysis shows a different time-phase relationship, in which case loads may be combined as a function of time. Loads due to postulated accidents and natural phenomena often yield dynamic response of short duration and rapidly varying amplitude in the exposed structures and components. For some loading phenomena, the accident analysis provides a definitive time history response and allows a straightforward addition of responses where more than one load is acting concurrently. In other cases, no specified time-phase relationship exists, either because the loads are random in nature or because the loads have simply been postulated to occur together (e.g., LOCA and SSE) without a known or defined coupling. Where a defined time-phase relationship is lacking, system designers have utilized several approaches to account for the potential interaction of the loads. One approach, the so-called absolute or linear summation (ABS) method, linearly adds the absolute values of the peak structural response due to the individual dynamic loads. A second approach, referred to as the square root of the sum of the squares (SRSS) method, yields a combined response equal to the square root of the sum of the squares of the peak responses due to the individual dynamic loads. Research conducted over the past two decades shows that this method of combining dynamic responses is conservative unless the structural responses are stochastically dependent. The SRSS method of load combination is acceptable to the US Nuclear Regulatory Commission (NRC, 1980), contingent upon the performance of a linear elastic dynamic analysis. Thus, the loads from a loss of coolant accident (LOCA) and a seismic event combined in load combination NA4-8 may be combined by the SRSS method, provided that the responses are determined by elastic analysis. However, this does not prohibit the use of more conservative load combination schemes. In all cases, resultant dynamic loads shall be combined absolutely, considering both maximum positive and negative values, with applicable static loads.

NA5. DESIGN BASIS

Modify section as follows:

1. Required Strength at Factored Loads

Replace section with the following:

When using plastic design, adequate attention should be paid to the induced deflections of the structural steel member(s) as well as the effect of such deflections on supported components, such as piping, HVAC ducts, and cable trays. Increased deflections resulting from the utilization of plastic design may cause additional component loading and reduce component clearances (gaps) required to prevent vibration interaction.

3. Design for Strength

Replace section with the following:

The strength of steel decreases at elevated temperatures. Where the structural component or system is exposed to sustained temperature in excess of 250 °F (121 °C), the decrease should be taken into account in determining the design strength. Design values for steel strength at elevated temperature may be obtained from ASME Code Section II-Part D.

4. Design for Serviceability and Other Considerations

Replace section with the following:

The elastic modulus of steel decreases at elevated temperatures. Where the structural component or system is exposed to sustained temperatures in excess of 250 °F (121 °C), the effect of this decrease on structural stiffness and deformations should be taken into account.

Add the following:

5. Design Based on Ductility, Local Effects, and Elevated Rates of Strain

a. Local Allowance for Ductility Effects

1. Axial Tension

Steel members under axial tension exhibit a ductility equivalent to full strain at ultimate stress. In developing the permitted local *ductility factor*, the strain at ultimate stress has been assumed to equal one-half the minimum specified percentage elongation at fracture, a factor of safety of two has been applied to that limit, and the maximum permitted strain has been limited to 0.10.

2. Flexural Members

The ductility factor of 20 for closed sections is based on tests reported in Howland and Newmark (1953). For open sections, the ductility factor is reduced to 10 when flexure governs and 5 when shear governs. In order to achieve these ductility factors, local buckling and lateral buckling must be prevented by limiting width-thickness ratios and unbraced lengths of compression members.

3. Axial Compression

The strength of short ($\lambda < 0.15$) rolled or welded built-up columns is controlled by yielding rather than by buckling, and the permitted ductility factor is 10. However, in no case should the ductility limit be allowed to exceed $\varepsilon_{st}/\varepsilon_y$. As the slenderness increases, buckling controls. Research (Norris, Hansen, Holley, Biggs, Namvet, and Ninami, 1959) has indicated that for $\lambda > 0.47$, the ductility factor should not be taken to be greater than unity. Between the upper bound $\mu = 10$ when $\lambda = 0.15$ and lower bound $\mu = 1$ when $\lambda = 0.47$, the ductility factor is permitted to vary inversely with λ^2.

b. Elevated Rates of Strain

As the rate of strain from the application of dynamic loads increases, the yield strength and the yield-point strain increases. The modulus of elasticity remains nearly constant, while the strain at the onset of strain hardening and the tensile strength increase slightly. The most important of these effects for design under impulsive or impact loads is the increase in the yield stress. It is permitted to adjust the yield stress used to compute nominal strength, R_n, for strain rate effects.

ACI 349, Appendix C (ACI, 2001) recommends dynamic increase factors (DIF) of 1.20 for Grade 40 reinforcement and 1.10 for Grade 60 reinforcement. Similar DIFs are recommended in ASCE's *Structural Analysis and Design of Nuclear Plant Facilities* (ASCE, 1986) and in the *US NRC SRP 3.6.2* (NRC, 1989). Accordingly, in the absence of supporting experimental data, a 10 percent increase over the specified yield strength is recommended.

Add the following:

NA6. REFERENCED CODES AND STANDARDS

For stainless steel welding either ASME Section IX or AWS D1.6 may be used. However, the requirements of standards should not be mixed.

CHAPTER NJ

CONNECTIONS, JOINTS, AND FASTENERS

Modify Chapter J of the AISC LRFD Specification Commentary as follows:

NJ1. GENERAL PROVISIONS

10. High Strength Bolts in Combination with Rivets

Delete this section.

11. Limitations on Bolted and Welded Connections

Add the following:

The potential for full reversal of design load and likelihood of inelastic deformations of members and/or connected parts necessitates that fully-tensioned bolts be used in bolted joints in the Seismic Load Resisting System. However, earthquake motions are such that slip cannot be prevented in all cases, even with slip-critical connections. Accordingly, these Provisions call for bolted joints to be proportioned as fully-tensioned bearing joints but with faying surfaces prepared as for Class A or better slip-critical connections. That is, bolted connections can be proportioned with design strengths for bearing connections as long as the faying surfaces are still prepared to provide a minimum slip coefficient of 0.33. The resulting nominal amount of slip resistance will minimize damage in moderate seismic events. Additionally, the sharing of design load between welds and bolts on the same faying surface is not permitted.

Tension or shear fracture, bolt shear fracture, and block shear fracture, are examples of limit states that generally result in non-ductile failure of connections. As such, these limit states are undesirable as the controlling limit state for connections that are part of the Seismic Load Resisting System and/or are subjected to dynamic loads. Accordingly, it is required that these connections be configured such that a ductile limit state in the member or connection, such as yielding or bearing deformation, controls the design strength. The design documents should identify the connections which are subjected to seismic loads/dynamic loads, and also should identify the type of load, that is, axial force, shears, moments, or torsion.

NJ3. BOLTS AND THREADED PARTS

10. Bearing Strength at Bolt Holes

Add the following:

To prevent excessive deformations of bolted joints due to bearing on the connected material, the nominal bearing strength is limited to $2.4dtF_u$.

CHAPTER NM

FABRICATION, ERECTION, AND QUALITY CONTROL

Modify Chapter M of the AISC LRFD Specification Commentary as follows:

NM2. FABRICATION

2. Thermal Cutting

Add the following:

Arc-air gouging followed by clean-up grinding is suggested.

NM4. ERECTION

4. Fit of Column Compression Joints and Base Plates

Add the following:

The criteria for fit of column compression joints are equally applicable to joints at column splices and joints between columns and base plates.

8. Tolerances

8b. Cranes

The CMAA Specification tolerances have been adopted where appropriate. The criteria for column base lines, crane runway girders, and rail eccentricity provide tolerances not prescribed by the CMAA Specification. These additional tolerances, evolved from AISC N690, minimize secondary effects onto the building structure and provide assurance of additional quality control required in a nuclear facility.

CHAPTER NN

EVALUATION OF EXISTING STRUCTURES

Modify Chapter N of the AISC LRFD Specification as follows:

NN1. GENERAL PROVISIONS

The load combinations referred to in this chapter reflect gravity loading, and Section NN4 could be used when it is the most prevalent condition encountered. If other loading conditions are a consideration, such as lateral loads, the appropriate load combination from Section NA4.5 should be used. Guidelines for seismic evaluation are available in other publications (FEMA, 1997a and 1997b), and they should be used in conjunction with this specification. The engineer for a project is generally established by the *owner*.

NN2. MATERIAL PROPERTIES

Modify section as follows:

2. Tensile Properties

Add the following:

To utilize the actual tensile yield strength of the material in the evaluation of a structure, the goal should be to establish a 95 percent confidence level that 95 percent of the test results are above the selected yield strength.

4. Base Metal Notch Toughness

Replace this section with the following:

The engineer shall specify the location of samples. Samples shall be cored, flame cut, or saw cut. The *engineer* will determine if remedial actions are required, such as the possible use of bolted splice plates.

NN3. EVALUATION BY STRUCTURAL ANALYSIS

2. Strength Evaluation

Replace "Engineer of Record" with "engineer"

NN4. EVALUATION BY LOAD TESTS

1. Determination of Live Load Rating by Testing

Replace the 2nd paragraph with:

It is essential that the engineer take all necessary precautions to ensure that the structure does not deform to the extent that can affect the integrity of the equipment and components supported by it or located in its vicinity during testing. A careful assessment of structural conditions before testing is a fundamental requirement. This includes accurate measurement and characterization of the size and strength of members, connections, and details. All safety regulations of OSHA and other regulatory and enforcement authorities must be strictly adhered to. Shoring and scaffolding should be used as required in the proximity of the test area to mitigate against unexpected circumstances. Deformations must be carefully monitored and structural conditions must be continually evaluated. In some cases it may be desirable to monitor strains as well.

Replace the 3rd paragraph with:

The engineer must use judgment to determine when deflections are becoming excessive and terminate the tests at a safe level even if the desired loading has not been achieved. Incremental loading is specified so that deformations can be accurately monitored and the performance of the structure carefully observed. Load increments should be small enough initially so that the onset of significant yielding can be determined. The load rating should be determined at the onset of such yielding.

2. Serviceability Evaluation

Replace the last sentence with:

Where desirable, the applied load sequence can be repeated to demonstrate that the structure is elastic under service loads.

NN5. EVALUATION REPORT

No changes required for this section.

REFERENCES

Add to the reference list:

American Concrete Institute (ACI) (2001), *Code Requirements for Design of Reinforced Concrete Structures in Nuclear Facilities*, ACI 349-01.

American Institute of Steel Construction, Inc. (AISC) (1999), *Load and Resistance Factor Design Specification for Structural Steel Buildings*, Chicago, IL.

American Society of Civil Engineers (ASCE) (1980), “Structural Analysis and Design of Nuclear Plant Facilities,” (Manual No. 58) Reston, VA.

American Society of Civil Engineers (ASCE) (1998), *Minimum Design Loads for Buildings and Other Structures*, ASCE 7-98, Reston, VA.

Crane Manufacturers Association of America (CMAA) (2000), “Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes,” CMAA-70.

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Howland, F.L. and Newmark, N.M. (1953), “Static Load-Deflection Tests of Beam-Columns,” Civil Engineering Structural Research Series No. 65, University of Illinois, Urbana-Champaign.

Hwang, H., Ellingwood, B., Shinozuka, M., and Reich, M. (1987), Probability-based Design Criteria for Nuclear Plant Structures,” *Journal of Structural Engineering*, ASCE Vol. 113, No. 5, pp. 925-942.

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Norris, C.H., Hansen, R.J., Holley, Jr., M. J., Biggs, J.M., Namvet, S., and Ninami, J.K. (1959), *Structural Design for Dynamic Loads*, McGraw-Hill, New York.

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Nuclear Regulatory Commission (NRC) (1980), “Methodology for Combining Dynamic Responses,” *Report NUREG-0484*, Rev. 1, US Nuclear Regulatory Commission, Washington, D.C., May.

Nuclear Regulatory Commission (NRC) (2001), “Reactor Site Criteria,” 10CFR100, Washington DC.

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(05/04:1M:ML)