Earthquake Response Cooperation Program for Energy Supply Systems

Seismic Codes and Standards of Energy Supply System

Report for
Asia-Pacific Economic Cooperation
Energy Working Group
2003

Energy Commission
Ministry of Economic Affairs
Chinese Taipei

Industrial Technology
Research Institute

ACKNOWLEDGEMENTS

We would like to appreciate all those who have been working very hard in the project. The development of the project might not have been accomplished without the contributions of many persons. The full list of people associated with the project is given in the following. We thank all members of steering committee, seminar speakers, government officials, and other experts for their assistance with the work. We also wish to express our appreciation to the participants at the APEC Earthquake Disaster Management of Energy Supply System seminar who met with us and provided invaluable insight into the issues. The administrative support of Energy Commission, Ministry of Economic Affairs (Chinese Taipei) is also gratefully acknowledged.

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FOREWORD

I am pleased to present the project report of the Earthquake Response Cooperation Program for Energy Supply Systems. This program was based on the Earthquake Response Cooperation Initiative proposed by Chinese Taipei at APEC EWG 18.

Many APEC member economies are located in a region suffering from frequent earthquakes. In the past decades, several member economies, such as China, Japan, Mexico, Chinese Taipei, the Philippines, Indonesia and the USA, have experienced a series of severe earthquakes that resulted in serious damages to energy supply infrastructure and economic development in addition to loss of lives and properties. In January 1995, a severe earthquake hit Kobe and Osaka, Japan. A conflagration that subsequently resulted from leakage of natural gas caused severe damage. It became a major case of calamity to the energy facility.

In the early morning of September 21, 1999, an earthquake struck the central region of Chinese Taipei and resulted in mass destructions. Due to the collapse of transformer substations and several extra-high voltage electricity transmission towers, the electricity supply over half of Chinese Taipei was shut down for over one week. Furthermore, rotation of electricity supply took another two weeks. Moreover, many energy supply systems other than electricity were damaged, including natural gas pipelines, service stations and oil storage tanks. After this major disaster, Chinese Taipei felt a cross-economy cooperative mechanism for energy supply systems would be necessary to many APEC member economies in sharing the experiences with each other.

In April 2000, the APEC EWG 19 endorsed the Earthquake Response Cooperation Initiative launched by Chinese Taipei in addressing earthquake preventative and response measures for energy supply systems, noting that the program development should consider the existing APEC framework for emergency preparedness. The initiative was also endorsed in the APEC Energy Ministers Declaration on May 12, 2000. Taking the above into consideration, a 3-year Implementation Program— the Earthquake Response

Cooperation Program for Energy Supply Systems — was developed to meet the objectives of the Initiative.

Mainly, this program is to establish a cooperative and information sharing a cooperation mechanism among the APEC member economies for energy supply systems in response to earthquakes. It is being accomplished by establishing a comprehensive information system on the Internet, by exchanging information and experiences of preventing collapse of energy supply systems during earthquakes, and by lessons from restoration efforts after earthquake. Certain topics of the issues on earthquake reponse of energy facility will be studied and databases will also be setup. The study on the codes and standards on building the energy facilities has been one of the main topic. It will provide the reference for APEC economies in energy facility building and also discussion for further cooperation issue to prevent earthquake events.

This report is a main outcome of this three-year program. Its contents include collecting existed energy facility codes and guidelines from APEC economies as refernce for the development of energy facilities in against the earthquake. It is believed that to response esrthquake harzard should emphase on “4R” risk management. “4R” risk management include reduction, readiness, response and recovery. Codes and guideline are the basic principles for the framework of the energy facility for “4R”risk assessment. It provide an overview of those on the developed codes on guidelines of APEC economies for advanced development on the energy infrustructure, especially on lifeline facility. It is believed that this report can become an integrated approach to the codes and guidelines for the development of energy facilities in the safety of the energy facilities for some APEC Economies.

It is hopefully that this report can regarded as the prelimilary collection of the codes and guidelines for energy infrustructure development. Codes and guidelins are complicated in the development process that associated with different earthquake situation of each economy. It may not be a completed collection at this stage due to abundance codes and gudelines in different section of facility buidings yet to be uncovered. We hope through incessant collecting of those existed codes and guidelines the cooperation in revention, reduction, prepardness, response and recovery can be further advanced among APEC region. It is also hoped that study topics of codes and guideline can be further developed for international standarization for mutual benefit either in against earthquake and rapid economic development.

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Summary

Asian Pacific Rim is the most earthquake sensitive area in the word. Most area are suffered major earthquake hazards with economic loss both direct and indirect which causses stagnant in economic development. In April 2000, the APEC EWG 19 endorsed the Earthquake Response Cooperation Initiative launched by Chinese Taipei in addressing earthquake preventative and response measures for energy supply systems to avoid harzard against earthquake from energy facility.

Developing codes and standards for energy facilities have been one of the efficient measure to secure energy supply. In this report study of energy system and development of codes and standards within decades has been surveyed. More than 120 existed codes and standards of building, electric power system, oil and natural system were surveyed and collected. An understanding of thies material could be helpful to maintain and develop energy facilities in against earthquake hazards. Furthermoer it could become collaboration among economies for the earthquake rescue activity.

Developing codes and standards for buildings need advanced knoledge in science and engineering. It is imperative most codes and standards adopted currently are developed by the US and some by Japan due to high activities in academy and energeering associations. It is hopefully that this report could provide basic view for other economies on this regard.

PART ONE

FUNDAMENTAL BUILDINGS

"Tremor below the surface of the Earth which causes shaking to occur in the crust. Shaking lasts for only a few seconds, but widespread devastation can result. According to plate tectonics, earthquakes are caused by the movement of crustal plates, ..."

--- *World Encyclopedia* ---

Chapter 1 Reducing hazard to energy infrastructure

Earthquakes have long been major problems for mankind, cost numerous lives historically. A statistic data from USGSNEIC reveals that in the twentieth century there are about 18 major earthquakes with magnitude (M) 7.0 or larger each year that cause an average of almost 17,000 persons killed per year. It is also reported on the statistics that, If selecting 109 earthquakes with fatalities greater than 1,000 damages, it has caused more than 1,740,000 dead in the 20th century. Countless properties were lost in the disasters including energy infrustures, such as electric power facilities, oil refinery facilities and lifeline facilities other than lives and buildings, and cause serious devastation on the economy growth.

Earthquakes are multifaceted. Phenomenon of earthquake damages include aftershocks, amplification, liquefaction, landslides, conflagrations, and tsunami. It also cause death and destruction in variety of ways, from building collapse to mass destruction. All these could make infructructure in seriously hazardous situation like energy facilities. The calamity could happen that damages to lifeline system that are highly depended by modern urban and suburban areas to sustain the economic life. The lifeline system includes energy from electrical power systems and pipelines. Disrupting of these lifeline systems could cause economic losses. For maintenance of a healthy economy requires prevention planning for the effects of major earthquakes.

Earthquakes in APEC Area

The Pacific Rim countries are located in the most eathquake sensitive areas. Most large earthquakes occur on long fault zones around the margin of the Pacific Ocean. From Table 1 we have list of the 10 most biggest earthquakes, in magnitudes, in the World since 1900. It is obvious that 9 of these earthquakes are located in the Pacific Rim area except the one occurred a little distance away in India-China Border in 1950. Statistically, nearly 70% of the earthquakes in the world occure in the Pacific Rim region. This situation makes APEC Area become the most earthquake sensitive and harassed region in the world. Economic losses from urban earthquakes in the last decade have risen dramatically. with direct economic losses (damage to the built environment, building contents, inventory and ensuing business disruption) and indirect losses (supply shortages and other ripple effects to economic sectors not sustaining direct damage). Earthquake losses will rise at an escalating rate in future years unless major loss reduction programs are undertaken.

Currently, APEC's economies are the most powerful economic region in the world with a combined gross national product (GNP) of more than 14 trillion dollars. The members of APEC also represent the world's fastest growing economies with the greatest market potential. Combined together, APEC Economies have the largest industry production facilities that contain the most advanced technologies. Therefore, prevention, immediate reponse and restoration of the earthquake damages become a major issure to all APEC economies, and relevant activities could become cooperation themes that can be the Earthquake Response Cooperation Initiative. Eventually we wish activities would expand to all natural disasters.

Table 1. 10 Biggest Earthquake in the World since 1900

	Location	Date	Magnitude	Coordinates	
1.	Chile	1960 05 22	9.5	38.26 S	72.15 W
2.	Prince William Sound, Alaska	1964 03 28	9.2	61.02 N	147.65 W
3.	Andreanof Islands, Aleutian Islands	1957 03 09	9.1	51.57 N	175.34 W
4.	Kamchatka	1952 11 04	9.0	52.75 N	159.50 E
5.	Off the Coast of Ecuador	1906 01 31	8.8	1.0 N	81.5 W
6.	Rat Islands, Aleutian Islands	1965 02 04	8.7	51.23 N	178.52 E
7.	India-China Border	1950 08 15	8.6	28.5 N	96.5 E
8.	Kamchatka	1923 02 03	8.5	54.0 N	161.0 E
9.	Banda Sea, Indonesia	1938 02 01	8.5	5.25 S	130.5 E
10.	Kuril Islands	1963 10 13	8.5	44.9 N	149.6 E

Source from USGS

Recent Significant Hazards of Earthquakes on Energy Facility

Major earthquakes would occur in the urban, suburban and industry areas which cause damages to the developing energy infrustructure for modern society, mainly the life line facilities. It is unavoidable that ravage on electricity would cause heavy loss production to industries. This includes most types of industry from light manufacturing to high-technology and heavy industry. Recent cases of energy facility damages in APEC Economies could mainly include following events:

U.S. NORTHRIDGE, California 1994 (Mw 6.7)

On January 17, 1994, an M 6.7 earthquake shook the Los Angeles (Northridge) area. Several buildings and freeway bridges collapsed, with 71 death and thousands injured. Damage were reported at the range of 40 billion USD. Published estimates of lifeline damage were reported in excess of $2 billion on those costs associated with the repair of damaged lifeline systems excluding other costs such on business losses due to lifeline disruption or fire damage that may be several factors higher.

- This event made the United States experience a major earthquake with lifeline damage in a major urban area since 1906. The Northridge Earthquake showed that even moderate events can cause billions of dollars of damage.
- The Northridge Earthquake ruptured gas pipelines, causing flames to shoot up out of flowing water.
- It is reported that on Balboa Boulevard, buried steel pipelines of high ductility survived the quakes. However, the older, corroded pipelines failed.
- It is reported that the City of Los Angeles experienced a complete loss of electric power for the first time in its history due to several substation damage. The damage occurred to high-voltage substation power apparatus (230 and 500 kV) supported by brittle ceramic insulators. While the damage of units in power plants and cogeneration systems were minor.
- This earthquake revealed that how deep our society and our way of life depend on a complex network of infrastructure systems and the vulnerability.

Japan Hanshin (Kobe), 1995 (M_w 6.8)

The earthquake occurred in January 17, 1995 with moment magnitude of 6.9, about

20 km southwest of Kobe. The earthquake killed nearly 6,300 people (including direct and indirect causes by the earthquake), injured more than 40,000 people, destroyed nearly 94,000 buildings and heavily damaged nearly 107,000 buildings. More than 7,500 buildings were burnt by fire after the earthquake. The property losses were mounted exceeding $120 billion including losses in buildings amounted to 58.5 % of the total loss. Performance of lifelines in this earthquake was regarded very poor. This event became a reminder of what could happen in the urban areas if mitigation efforts are not continued. Briefs of vulnerability on energy system as follow:

- **Electric Power**
    - 1 million customers were without power for a few hours in the event.
    - The greatest damage occurred at 187- and 275-kV substations, a few of the fossil plants, and a gas turbine plant.
    - Some power-generating stations were damaged during the earthquake. It was reported at the number of 10, with a total capacity of 1,631 MW.
    - Broken arresters at the Itami Substation.
    - The most significant damage was the failure of seismic ties between the boiler and its support structure. Observations indicated that the ties were not loaded linearly, resulting in dramatic failure of the ties near the top of the structure. U.S. fossil plants with suspended boilers have undergone similar ground motion but have seismic stops rather than ties.
    - The stops absorb energy by deforming during an earthquake, while ties are stronger but less ductile. Both the seismic ties observed at Amagasaki No. 3 and the stops found at U.S. stations have had substantial damage from moderate ground motion, although stops do appear to prevent damage to the boiler.
    - Amagasaki No. 3 also had a small pipe failure caused by steam drum displacement relative to the structure and miscellaneous failures from ground settlement. Pipe and electrical raceway supports adjacent to the building foundation were damaged by ground settlement. The piping and raceways remained functional.
    - Higashi Nada includes two gas turbine units that were constructed in 1974 on

reclaimed land. The soil conditions at the site consist of 7 to 8 meters of very soft clay overlying a layer of sediment more than 10 meters thick.

- The plant underwent a peak ground acceleration of about 0.6g during the earthquake, but it was not operating at the time because the plant is used only during peak demand periods, typically in the summer months.
- The buildings and equipment at the plant withstood the earthquake without direct damage. However, differential settlement of foundation slabs did result in misalignment of equipment on adjacent foundations.
- At several locations, ground settlement exceeded a meter relative to the pile-supported foundations. Piping systems had substantial deformation, but the only failure was associated with a clamped mechanical coupling.
- In several cases, the ground settled to such an extent that several pipe supports and their concrete foundation blocks were left dangling in the air, supported by the pipes to which they were attached. Virtually all damage was related to ground settlement and relative displacement between foundations.
- Nine 275-kV substations were damaged, including bus disconnect switch failure, transformer oil leaks, transformer anchorage failure, transformer bushing failure, and other miscellaneous damage. Liquefaction and ground settlement were evident. The extensive use of dead-tank gas-insulated and oil-filled circuit breakers resulted in positive circuit breaker performance.
- The earthquake location also spared a cluster of fossil fuel plants to the southeast from the high ground motion and did not affect the nuclear power plants located more than 100 kilometers to the north.

Gas System

- The population in the heavily impacted areas was notified to expect no gas service for about two months.
- The gas system had at least 1,400 breaks in its underground distribution system, primarily at service lines, with general curtailment of service by Osaka Gas Company to 834,000 households.
- Japanese buildings and homes have automatic gas shutoff systems, but many

failed to work because of building collapses, other building damage, and broken pipes.

- There are a number of petroleum and other at-grade fuel tanks in the port area, the largest being perhaps 25 meters in diameter and 15 meters high. Only a few were observed to have any damage, and only one was observed to have collapsed. Many of these tanks were at-grade and freestanding, while some were bolted to their foundations. Most appeared to have fixed roofs.
- Several liquefied petroleum gas (LPG) tanks exist in the port area, and one was reported to have cracked, resulting in the temporary evacuation of 70,000 people.
- Two groups of three large spherical tanks were seen along the waterfront in Kobe. They were well braced with heavy diagonal pipe bracing between column supports and appeared to have no damage. There were no reports of liquid fuel pipe breaks, with the exception of one line at Kansai International Airport.

Taiwan CHI-CHI 1999 (Mw7.3)

As of October 13, 1999, the Taiwan's Interior Department record shows that the death toll is 2,333 and 10,002 people were injured. The total economic loss resulting from this earthquake totaled approximately 0.33 billion USD.

- The impact of this Earthquake to lifeline systems was mainly concentrated in cities and towns along one pf a mai high way, the Route Tai-3rd, and the Taichung Metro-polis and Puli Town.
- Most of the damages were of pipes and joints (water and sewer systems, natural gas, etc.) as a result of damages of buildings and roads.
- Parts were due to strong ground motions directly (water treatment plants, oil tanks, gas stations, etc.), and parts were due to the outage of electric power (telecommunication and cellular phones).
- Damages in lifeline systems were severe but tolerable. The only exception was those in electric power system. The loss in extra-high voltage (EHV) transmission system, including 28 345KV-lines and the Chungliao Switch-yard,

had caused the worst blackout event ever in Taiwan.

- **Electric Power**

  - The whole Middle and North of Taiwan was blackouted immediately.
  - Substations: Ground shaking tore anchor bolts and damaged several transformers and circuit breakers in substations. Switchyards and substations of hydro plants were damaged too, especially the EHV substation at Tienlun. In addition, strong ground motions and soil liquefaction at the Chungliao Switchyard caused foundations displaced and subsided, and damaged equipment severely.
  - Transmission lines were severely damaged, causing interruption of power transmission from the South to North. Landslides and ground failures damaged the transmission towers in the mountainous areas.
  - Equipment in thermal power plants were only slightly damaged.

- **Natural Gas and Liquid Fuel System**

  - Two gas pipes of the CPC (Chinese Petro-leum Corp.) were bent and broken due to ground rupture.
  - Typical damages of middle- and low-pressure pipelines were observed as:
    1. bend and buckle due to ground subsidence or rupture;
    2. failure at subscriber ends as a result of building damages;
    3. failure at old thread-type joints due to lack of flexibility.
  - Liquid fuel system performed well in this Earthquake. Only some tank roofs were deformed, and roofs of some gas stations collapsed due to poor seismic design.
  - Regarding the electric power system: immediate retrofit of towers of the 345KV Transmission Lines 1 and 2 in the mountainous areas, especially for those with foundations on slopes; relief of the reliance upon EHV system and long-distance transmission; increase in system’s redundancy to reduce the possible seismic risk.
  - There are five natural gas vendors in the affected area. No damage was observed in gas reservoirs and high-pressure pipelines, and no secondary disaster was reported.

Japan Hokkaido, 2003 (M_w8.3)

On September 25, 2003, a very powerful earthquake hit Hokkaido with magnitude of 8.3 and a storage tank caught fire at an oil refinery as aftershocks rocked the region following a earthquake and a second flame in another high storage tank was occurred two days later. About 570 people were injured, but most of the injuries were minor. According to news reports firefighters at the scene said tremors started the blaze.

- The first flame was set off a fire in a separate tank that consumed 30,000 kiloliters, or 188,700 barrels, of crude oil.
- Two days later an aftershocks as strong as magnitude 5.4 hit the same place and a 24-meter- (80-foot-) high storage tank containing naphtha, a flammable liquid produced when petroleum is distilled, was caught fire and last for more than eight hours. It sent a plume of black smoke into the air.
- The lid of the tank was shaken partly open, and the naphtha ignited when it was exposed to the air, national broadcaster NHK and Kyodo News reported.
- Northern Japan has been rattled by several magnitude-7-class earthquakes in the past few decades.

Cooperation in Nonlinear earthquakes

Nonlinear — Earthquakes where the demand for resources greatly exceeds available capacity. Since manpower and repair resources will be overextended, restoration times will be stretched and delayed. Resources will eventually have to come from areas very distant from the affected areas, even other economies. In addition, damage to local and regional transportation systems may also add an additional dimension to response times. This situation could be significant in APEC Region. To avoid disasters and quick retrofit a cooperation mechanism should be contructed among APEC Region for common welfare and sustainable economic development.

Chapter 2 Building Codes APEC Economies

For a long time earthquake risk has been considered to be unavoidable. It was accepted that buildings would be damaged as a result of an earthquake's ground shaking anyhow. Preventive measures for earthquakes were therefore mostly limited to disaster management preparedness. Although measures related to construction methods had already been proposed at the beginning of the 20th century and the first morden code was published in 1925, it is only during the 20 years that improved and intensified research has revealed how to effectively reduce the vulnerability of structures to earthquakes.

The primary purpose of the seismic building codes is to provide a uniform method to determine the seismic forces for any location with enough accuracy to ensure a safe and economical design. Different should adopted different codes to deal with the differing levels of seismic risk. Some codes provide effctive measure to protect life, others seek to protect life and property both, by minimizing damage sustained during an event. Seismic design provisions are based on the law or provisions recommended or adopted for New Buildings and other structures. The codes adopted are modified or improved by experience from seiemic event investigations and studies. New codes are also developed or design due to new requirement.

Basic Building Codes

Energy facilities contain many buildings, including building structures of plants, substation, control houses, control center, and engineering and administrative offices. The purpose of building codes is originally to promote and protect the public welfare and building codes accomplish this purpose by setting minimum standards for the materials of construction that may be used for structures of different types and occupancies, the minimum permissible strength of these structures, and the amount of deformation that may be tolerated under design loading. Governments have the authority to enforce these standards through the code adoption process, like converting the code into a legal standard.

Typically design loading levels are set by building codes at levels that have a moderate to low probability of occurrence during the life of the structure. The significant difference in recurrence intervals adopted by codes for these various hazards is a function of the hazard itself, and the adequacy of a given return period to capture a maximum, or near maximum, credible event. Building code provisions for earthquake-resistant design are unique in that, unlike the provisions for other load conditions, they do not intend that structures be capable of resisting design loading within the elastic, or near-elastic range of response — that is, some level of damage is permitted. Building codes intend only that buildings resist large earthquake loading without life-threatening damage and, in particular, without structural collapse or creation of large, heavy falling debris hazards.

This unique earthquake design philosophy evolved over time based primarily on two factors. First, even in zones of relatively frequent seismic activity, such as regions around the Pacific Rim, intense earthquakes are rare events, affecting a given region at intervals ranging from a few hundreds to thousands of years. Most buildings will never experience a design earthquake and, therefore, design to resist such events without damage would be economically impractical for most structures. The second reason for this design approach relates to the development history for building code seismic provisions.

Building code provisions typically require design for such loading to accomplish two main objectives. The first is to provide a low probability of failure under any likely occurrence of the loading type. This is typically accomplished through prescription of minimum required levels of structural strength. The second is to provide sufficient stiffness such that deflections do not affect the serviceability of the structure, or result in cracking or other damage that would require repair following routine loading. For most structural elements and most loading conditions, these dual design criteria result in structures that are capable of resisting the design loading with either elastic or near-elastic behavior. Consequently, engineered buildings rarely experience structural damage as a result of the effects of dead, live, wind, or snow loads, and rarely completely fail under such loading.

Although most countries develop and enforce their own building codes, the seismic provisions currently used generally follow one of four basic models:

1. US NEHRP Recommended Provisions
2. Building Standards Law of Japan
3. New Zealand Building Standards Law
4. Eurocode 8

1. US NEHRP Recommended Provisions

NEHRP — Earthquake Hazards Reduction Program established by US Congress in 1977 (Public Law 95–124) to "reduce the risks life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program" [amended 1990 Public Law 101–614]. There are four NEHRP agencies: FEMA (Federal Emergency Management Agency), NIST (National Institute of Standards and Technology), NSF (National Science Foundation), and the USGS (United States Geological Survey).

The NEHRP Recommended Provisions, developed by the US Building Seismic Safety Council, which, together with related publications by the Structural Engineers Association of California, forms the basis for most building codes in use in the United States today, and probably in other parts of the world.

The building design community and, in particular, structural engineers — primarily through the SEAOC, the American Society of Civil Engineers (ASCE), the Building Seismic Safety Council (BSSC), and other similar groups — have historically taken a leadership role in the development of these building code provisions in the world. These structural engineers have consistently tempered and moderated the information obtained from the experience and theoretical bases, with their independent design judgment, assuring political acceptability of the building code within the design community, if not completely rational or justifiable provisions.

NEHRP's mission includes improved understanding, characterization and prediction of hazards and vulnerabilities; improved model building codes and land use practices; risk reduction through postearthquake investigations and education; development and improvement of design and construction techniques; improved mitigation capacity; and accelerated application of research results.

The Act designates FEMA as the lead agency of the program, and assigns several planning, coordinating, and reporting responsibilities. NEHRP has been a major pillar in the building of a national lifelines seismic risk reduction program.

The first modern code containing seismic provisions was published in 1925 after the M6.2 Santa Barbara earthquake occurred on June 29, 1925. It was the first edition of the Uniform Building Code(UBC), published by the Pacific Coast Building Officials(PCBO) in 1927. The seismic provisions of the UBC were based primarily on the SEAOC recommendations and remained in a leadership role over the full 70 years.

The 1958 Uniform Building Code was a very ifluential publication. Researchers at the California Institute of Technology began to formalize the concepts of dynamic spectral response. In 1952 these researchers, acting under the auspices of the American Society of Civil Engineers, together with practicing structural engineering members of the Structural Engineers Association of California, formed a joint volunteer committee to develop recommendations for incorporation of these concepts into the 1958 edition of the UBC.

A turning point in 1970 after San Fernando earthquake that a major change in UBC due to geotechnical and structural engineers. The lifeline earthquake engineering was started addressed seismic vulnerabilities in urban infrastructure failures of power, pipeline and other infrastructure. The National Earthquake Hazards Reduction Act of 1977 was passed in California, USA as Public Law in 1977. And the major reshaping of building code earthquake provisions was undertaken through the report “Tentative Provisions for the Development of Seismic Regulations for Buildings (ATC-3–06)” by Applied Technology Council.

Model Code Organizations, agencies whose codes are widely adopted to regions in the United States:

1. Building Officials & Code Administrators International (BOCA)

2. International Code Council (ICC)
3. International Conference of Building Officials (ICBO)
4. Southern Building Code Congress International (SBCCI)

Other Entities, include professional organizations that create, by consensus agreement, guidelines for specific design and construction practices, involved with Codes and Standards:

1. American Concrete Institute (ACI)
2. American National Standards Institute (ANSI)
3. Applied Technology Council (ATC)
4. Federal Emergency Management Agency (FEMA)
5. National Conference of States on Building Codes and Standards (NCSBCS)
   Portland Cement Association (PCA)
6. Precase/Prestressed Concrete Institute (PCI)
7. Structural Engineers Association of California (SEAOC)

Main Handbooks on Codes & Provisions

1. FEMA-302 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, 1997 Edition. Part 1: Provisions.
2. FEMA-303 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, 1997 Edition. Part 2: Commentary.
3. International Building Code 2003.
4. International Building Code (IBC).
5. Seismic Design for Buildings (SDB)
6. Uniform Building Code: Structural Engineering Design Provisions (UBC).

NEW BUILDING STANDARDS LAW OF JAPAN

The Building Standard Law of Japan (BSL) was enacted in 1950 by Ministry of Construction to safeguard the life, health, and property of people by providing minimum standards concerning the site, structure, equipment, and the use of buildings, and to contribute to the promotion of the public welfare. In order to ensure the safety of buildings, among other things, technical standards have been established based upon experience from disasters such as earthquakes, typhoons, and fires that have struck Japan. Since the enactment of the Law, it has been continually amended to reflect changes in technology, ensuring that they do not diverge from the technical level generally expected by Japanese society.

The law also prescribes zoning concerning the height, area, volume, structure, interior and exterior finishes, and use of buildings (including housing) constructed in City Planning Areas.

The Law consists of three parts, namely, general provisions, building codes and zoning codes. General provisions stipulate administrative provisions such as building confirmation and inspection. The building codes stipulate structural safety, fire safety, hygienic safety. The zoning codes stipulate land-use zoning regulations, building height-bulk-shape control, restriction in fire protection districts and others. Major points of the amendment of the Law in 1998 are as follows:

1. Rationalization of building confirmation procedures
2. Incorporation of performance-based-regulations
3. Ensuring effective enforcement of regulations

Composition of the Building Standard Law

■ **WHOLE AREA OF JAPAN**

□ General Provisions

1. Administrative Provisions
2. Miscellaneous Provisions
3. Penal Provisions

□ Building Codes (enforced throughout Japan)

1. Fire Section
2. Structural Section
3. Building Equipment Section

■ **CITY PLANNING AREAS**

- ☐ Zoning codes (enforced within “City Planning Areas”)
    1. Relation between Sited and Roads
    2. Land-Use Zoning Regulation
    3. Building Height-Bulk-Shape Control
    4. Restrictions in Fire Protection District

THE BUILDING CENTER OF JAPAN

The Building Center of Japan(BCJ) is a nonprofit foundation which was established in 1965 during a construction boom of super-high-rise buildings. Its purpose is to conduct research projects in the architecture and in the building construction fields, evaluate newly developed building techniques, gather information, and make it available to the public. Over the years, the BCJ has been actively involved not only in developing new materials and construction methods but also in evaluating new technologies as a technical appraisal organization.

New Zealand building code

The national performance-based New Zealand building code has been in force since 1 January 1993.

Mandatory requirements

The building code was introduced as part of a new building control system established by an Act of Parliament, namely the Building Act 1991. The Act requires all new building work to satisfy the performance criteria specified in the building code. The building code was made, and is amended from time to time, by Cabinet on the recommendation of the Building Industry Authority. The Authority was established under the Act to provide the central focus for the building control system. The Act is enforced by local territorial authorities (city and district councils). Private sector building certifiers approved by the Authority compete with territorial authorities for the tasks of checking and inspection of building work. The territorial authority is the office of record, required to keep all relevant plans and specifications and other documents available for public inspection for the life of the building. Doubts and disputes about whether particular building work complies with the building code (usually arising out of technical decisions by territorial authorities and building certifiers) may be submitted to the Authority for binding determinations. The Authority also issues accreditations of proprietary items.

The building code itself is part of mandatory regulations, namely the First Schedule to the Building Regulations 1992. The building code covers stability, durability, fire safety, access, moisture, safety of users, services and facilities (including electricity, gas, plumbing, and drainage), energy efficiency, and access and facilities for use by people with disabilities.

Structure

The building code contains two general clauses and 35 technical clauses. Each technical clause covers a specific topic and sets out "objectives" (which correspond to the purposes and principles specified in the Act), "functional requirements" (based on the "user requirement categories" of ISO 6241-1984E), and the mandatory "performance criteria" specified mainly, but not entirely, in qualitative terms.

Supporting material

The Act provides that certain documents issued or approved by the Authority are to be accepted by territorial authorities and building certifiers as establishing compliance with the building code. However, those documents are not the only ways of establishing compliance.

There are 35 "Approved Documents" (one for each functional requirement) that specify "acceptable solutions" and "verification methods" either directly or by reference to other documents, mainly New Zealand Standards. In effect, the acceptable solutions are simple "cook-book" specifications suitable for use without specific engineering design, whereas the verification methods consist of design Standards and the like suitable for use by qualified professionals. Other documents issued by the Authority that must be accepted as establishing compliance with the building code are accreditations of proprietary products and determinations of matters of doubt or dispute.

An accreditation is granted on the basis of an appraisal by a competent independent organisation, but there is no provision for any general approval of such organisations themselves. A product that complies with an accreditation must also be accepted as complying with the building code. Determinations of technical doubts and disputes amount to "case law" about the application of the building code.

Innovative products or systems

The Act requires territorial authorities and building certifiers to be "satisfied on reasonable grounds" that building work complies with the building code. Usually, that means being satisfied on reasonable grounds that the work complies with the Approved Documents.

However, complying with such a document is not the only way of complying with the building code. Other ways are referred to as "alternative solutions". A territorial authority or building certifier presented with a proposal that does not comply with the Approved Documents, must decide whether the proposal complies with the building code. In doing so, they must have due regard to various matters listed in the Act. Reasonable grounds for such a decision might include:

1. Comparison with the Approved Documents.
2. Expert opinions, including peer reviews and appraisals.
3. A history of successful use.
4. Compliance with overseas Standards or the like.
5. Tests.
6. Any other grounds that are reasonable in the circumstances.

NEW ZEALAND BUILDING CONTROL DOCUMENTS

THE LAW
mandatory

THE BUILDING ACT 1991

Legal provisions:

- Definitions.
- Purposes and principles.
- Functions etc of the Building Industry Authority.
- Functions etc of territorial authorities.
- Building work: building consents and code compliance certificates.
- Maintenance of certain systems and features in buildings: compliance schedules, building warrants of fitness.
- National building code.
- Documents for establishing compliance with the building code.
- Building certifiers.
- Accreditations.
- Dangerous and insanitary buildings
- Legal proceedings: offences, civil actions against the Authority, territorial authorities, and building certifiers.

THE BUILDING REGULATIONS 1992

Administrative provisions:

- Application of building code.
- Inspections.

First Schedule:

- The building code
- Classified uses
- Definitions
- Technical clauses
- Objectives (descriptive)
- Functional requirements (descriptive)
- Performance criteria (mandatory)

Second Schedule:

- Forms
- the mandatory line

DOCUMENTS FOR ESTABLISHING COMPLIANCE WITH THE BUILDING CODE

non-mandatory

THE APPROVED DOCUMENTS

numerous references to Standards and similar documents
Acceptable solutions.
Verification methods.

ACCREDITATIONS

Proprietary items:

Materials

Methods of construction

Designs

Components

DETERMINATIONS

Doubts and disputes about whether certain building work complies with the building code.

EN EUROCODES

Table 3 Eurocodes

EN 1998 Eurocode 8	**Design provisions for earthquake resistance of structures**
EN 1998-1	General rules, seismic actions and rules for buildings
EN 1998-2	Bridges
EN 1998-3	Strengthening and repair of buildings
EN 1998-5	Foundations, retaining structures and geotechnical aspects
EN 1998-6	Towers, masts and chimneys

As an application of the new Eurocode 8 (EC 8) in zones of low seismicity, different seismic design cases of a six-story office building laterally stiffened by structural walls are presented. The building is located in the intermediate seismic zone of Switzerland with a design ground acceleration ag of 0.10 g. The following three design cases of the building were investigated:

1. Ductility class low (DCL) according to Eurocode 8, Part 1-3.

2. Ductility class high (DCH) according to Eurocode 8, Part 1-3.

3. Nominal ductility (SIA) according to Swiss Standard SIA 160.

The design case SIA according to the current Swiss Standard SIA 160 serves as a reference case for the comparison with the EC 8 design cases DCL and DCH. The essential results of the comparative study can be summarized as follows:

- Design bending moments of case DCH are nearly the same as for case SIA. However, design bending moments of case DCL are approximately the double compared to case SIA.
- Design shear forces of cases DCL and DCH can reach up to three times the corresponding values of case SIA.
- The EC 8 rules for ductility class high demand a considerable wall thickness for wall length over 4 m, resulting in a wall thickness of 55 cm for case DCH.
- The EC 8 detailing rules for the confinement reinforcement are rather complicated and lead to a very strong reinforcement for ductility class high.
- The design according to EC 8 ductility class low is about as complicated as for ductility class high, but a lot of the clauses were not governing in the case DCL.
- The EC 8 detailing rules for walls of ductility class low should be simplified and drafted independently from the rules for columns.

For both ductility classes, the design according to EC 8 is more intricate and requires substantially more concrete and reinforcement steel compared to SIA.

Building Codes in APEC Economies

Due to increasingly globalization, policy makers, researchers, engineers and other practitioners may seek international seismic code information either for design purposes or as a reference in drawing up seismic regulations. This table referred from MCEER cites a comprehensive listing of the information sources available in APEC economies.

Table 2. Listing of seismic codes refferd to different sources

Member Economies	**Sources:**					
	RSD	SUP	IHEE	PEHA	SDB	UBC
Argentina	X		X	X	X	X
Australia	X		X	X	X	X
Brunei					X	X
Canada	X		X	X	X	X
Chile	X	X	X	X	X	X
China	X		X	X	X	X
Hong Kong					X	
Indonesia	X		X		X	X
Japan	X	X	X	X	X	X
Korea	X	X			X	X
Malaysia				X	X	X
Mexico	X		X		X	X
New Zealand	X		X	X	X	X
Papua New Guinea				X	X	X
Peru	X		X		X	X
Philippines	X				X	X
Russian Federation			X	X	X	X
Singapore					X	X
Chinese Taipei	X		X	X	X	X
Thailand	X		X	X		X
USA	X	X	X	X	X	X
Vietnam				X	X	X

* Source: Multidisciplinary Center for Earthquake Engineering Research

- RSD :

  Regulations for Seismic Design: A World List-1996 Prepared by the International Association for Earthquake Engineering (IAEE)
- SUP

  Supplement 2000 (Additions to Regulations for Seismic Design: A World List-1996). Prepared by the International Association for Earthquake Engineering (IAEE)
- IHEE

  International Handbook of Earthquake Engineering: Codes, Programs, and Examples. Edited by Mario Paz. Dordrecht: Kluwer Academic Publishers, 1995.
- PEHA

  Practice of Earthquake Hazard Assessment. Edited by Robin K. McGuire. International Association of Seismology and Physics of the Earth's Interior (IASPEI)
- SDB

  Seismic Design for Buildings (Army: TM 5-809-10; Navy: NAVFAC P-355; USAF: AFM-88-3, Chapter 13). Washington, DC: Departments of the Army, Navy, and Air Force
- UBC

  Uniform Building Code: Structural Engineering Design Provisions. Whittier, CA: International Conference of Building Officials, 1997.

References list above provide complete information about the information sources themselves. These sources should include: actual codes, listings of seismic zones, zoning/epicentral maps, seismic histories, and other relevant information.

Chapter 3 Existed Building Codes associated to Earthquakes

International Standards

ISO

IEC

EUROCODES

National Standards in APEC Economies

CODE	ORGANIZATION
ANSI	American National Standards Institute
AS	Standards Australia
CNS	Chinese National Standard
CSA	Canadian Standards Association
GB	China Standards Service Net
JIS	Japanese Standards Association
NZS	Standards New Zealand

Other Industry Codes and Standards

1. American Concrete Institute (ACI)
   a. ACI 313, Recommended Practice for the Design and Construction of Concrete Bins, Silos, and Bunkers for Storage of Granular Materials
   b. ACI 318, Building Code Requirements for Reinforced Concrete and Commentary
   c. ACI 349, Code Requirements for Nuclear Related Structures
   d. ACI 530, Building Code Requirements for Masonry Structures
   e. ACI 530.1, Specifications for Masonry Structures
2. American Institute of Steel Construction (AISC)
   a. Manual of Steel Construction — Allowable Stress Design

    b. Load and Resistance Factor Design Specification for Structural Steel Buildings

3. American Iron and Steel Institute (AISI)
    a. Criteria for Structural Application of Steel Cable for Buildings
    b. Specification for the Design of Cold-Formed Steel Structural Members
4. American National Standards Institute (ANSI)
    a. ANSI B31.3, Chemical Plant Refinery Petroleum Piping
    b. ANSI B31.4, Liquid Petroleum Transportation Piping Systems
    c. ANSI B31.8, Gas Transmission and Distribution Piping Systems
5. American Petroleum Institute (API)
    a. API 650, Welded Steel Tanks for Oil Storage
    b. API 653, Tank Inspection, Repair, Alteration, and Reconstruction
6. American Society of Civil Engineers (ASCE)
    a. ASCE 7, Minimum Design Loads for Buildings and Other Structures
    b. ASCE 8, Specification for the Design of Cold-Formed Stainless Steel Structural Members
    c. Guidelines for the Seismic Design of Oil and Gas Pipeline Systems, Committee on Gas and Liquid Fuel
    d. Guidelines for Seismic Evaluation and Design of Petrochemical Facilities, Petrochemical Energy Committee
7. American Society of Mechanical Engineers (ASME)
    a. Boiler and Pressure Vessel Code
    b. ASME A17.1, *Safety* Code *of Elevators and Escalators*
8. American Society for Testing and Materials (ASTM)
    a**.** ASTM D32.99, Standard Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Chemical-Resistant Tanks
    b. ASTM C635, Standard Specification for the Manufacture, Performance and Testing of Metal Suspension Systems for Acoustical Tile and Lay-in Ceiling Panels
    c. ASTM C636, Standard Practice for the Installation of Metal Suspension Systems for Acoustical *Tile and Lay-in Ceiling Panels*
9. American Water Works Association (AWWA)

a. AWWA D100, AWWA Standard for Welded Steel Tanks for Water Storage

b. AWWA D110, AWWA Standard for Wire-Wound Circular Prestressed-Concrete Water Tanks

10. Applied Technology Council (ATC)

a. ATC-14, Evaluating the Seismic Resistance of Existing Buildings

b. ATC-3-06, Tentative Provisions for the Development of Seismic Regulations for Buildings

c. ATC-33.03, Guidelines for the Seismic Rehabilitation of Buildings

11. Federal Emergency Management Agency (FEMA)

a. FEMA 154/ATC-21, Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook

b. FEMA 155/ATC-21-1, Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation

c. FEMA 172, NEHRP Handbook for the Seismic Rehabilitation of Existing Buildings, Building Seismic Safety Council

d. FEMA 178, NEHRP Handbook for the Seismic Evaluation of Existing Buildings, Building Seismic Safety Council

e. FEMA 222, NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings - Provisions, Building Seismic Safety Council

f. FEMA 223, NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings: Commentary, Building Seismic Safety Council

g. FEMA 74, Reducing the Risks of Nonstructural Earthquake Damage

h. FEMA 368, NEHRP Recommended Provisions for the Seismic Regulations for New Buildings and Other Structures, 2000 Edition — Part 1: Provisions, Building Seismic Safety Council

i. FEMA 369, NEHRP Recommended Provisions for the Seismic Regulations for New Buildings and *Other Structures, 2000 Edition — Part 2: Commentary*, Building Seismic Safety Council

12. Institute of Electrical and Electronic Engineers (IEEE)

a. IEEE Standard 344, Recommended Practice for Seismic Qualification of Class 1E Equipment for *Nuclear Power Generating Stations*

13. National Fire Protection Agency (NFPA)
    a. NFPA-13, Standard for the Installation of Sprinkler Systems
    b. NFPA-59A, Standard for the Production, Handling, and Storage of Liquefied Natural Gas (LNG)
14. Rack Manufacturer's Institute (RMI)
    a. Specification for the Design, Testing, and Utilization of Industrial Steel Storage Racks
15. Risk Management and Prevention Program (RMPP) Committee
    a. Proposed Guidance for RMPP Seismic Assessments
16. Sheet Metal and Air Conditioners National Association (SMACNA)
    a. HVAC Duct Construction Standards, Metal and Flexible
    b. Rectangular Industrial Duct Construction Standards
    c. Guidelines for Seismic Restraint of Mechanical Systems and Plumbing Piping Systems
17. Steel Joist Institute
    a. Standard Specification Load Tables and Weight Tables for Steel Joists and Joist Girders
18. Structural Engineers Association of California
    a. Recommended Lateral Force Requirements and Commentary
19. United States Department of Defense
    a. Tri-Service Manual TM 5-809-10, Seismic Design for Buildings
    b. Tri-Service Manual TM 5-809-119.1, Seismic Design Guidelines for Essential Buildings
    c. Tri-Service Manual TM 5-809-119.2, Seismic Design Guidelines for Upgrading Essential Buildings
20. United States Department of Energy
    a. DOE-STD-1020, Natural Phenomena Hazards Design and Evaluation Criteria for Department *of Energy Facilities*
21. United States Nuclear Regulatory Commission
    a. Generic Letter 87-02, Verification of Seismic Adequacy of Mechanical and Electrical Equipment in Operating Reactors, Unresolved Safety Issue (USI)

A-46

b. Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment [Winston and Strawn, et al.]

c. NRC Regulatory Guide 1.60, Design Response Spectra for Seismic Design of Nuclear Power Plants

Existed building codes and guideline in APEC Economies

【001】

ISO 3010, ICS 91.080.01	Building
"Basis for design of structures -- Seismic actions on structures"	
Publisher: ISO (International Organization for Standardization)	
Date: 01-Dec-2001	International
Reference Web: http://www.iso.ch/iso/en/ISOOnline.frontpage	

【002】

NEHRP-2000	Building
"Recommended Provision for Seismic Regulations for New Building" NEHRP-2000 (National Earthquake Hazards Reduction Program)	
Publisher: FEMA(Federal Emergency Management Agency)	
Date: 2001	USA
Reference Web: http://www.fema.gov/	

【003】

ACI SP-176	Building
"High-Strength Concrete in Seismic Regions"	
In May of 1993, approximately twenty researchers and five representatives from	

construction firms met in Kyoto, Japan, for the First Multilateral Meeting on Structural Performance of High-Strength Concrete in Seismic Regions. The 3-day meeting divided into eight sessions covering current research programs and applications of high-strength concrete in the respective countries. The objectives of the meeting were to exchange information and to develop a coordinated program for further information exchange, evaluation of information, and development of design guidelines for the use of high-strength concrete in seismic regions. The Second Multilateral Meeting on Structural Performance of High-Strength Concrete in Seismic Regions consisted of thirteen sessions. Six of the sessions concentrated on the following behavioral topics: bond and anchorage, confinement, flexural members, axially-loaded members (columns and walls), beam-column joints, and shear and torsion. An additional session was devoted to presentation and discussion of design concepts and applications of high-strength concrete (HSC) in seismic regions. The remaining six sessions consisted of large and small working group sessions. During the small group sessions, participants were divided into groups of five to ten members to discuss the results of the previous sessions. Summaries of the small working group were then presented to the entire group for additional comments and conclusion during the large working group sessions. This ACI Special Publication comprises selected papers that were the outcome of the Second Multilateral Meeting on Structural Performance of High-Strength Concrete in Seismic Regions. The working group discussion summaries are also included in this special publication.
Publisher: American Concrete Institute
Date: 01-Jan-1998 / USA
Reference Web: http://www.concrete.org/BOOKSTORE/bkstr.htm

【004】

ISO/CD 24314	Building
“Seismic improved structural steels for building -- Technical delivery	

conditions"
Publisher: ISO(International Organization for Standardization)
Date: 27-03-2002 | International
Reference Web: http://www.iso.ch/iso/en/ISOOnline.openerpage

【005】

ANSI/AISC 341-02	Building
"Seismic Provisions for Structural Steel Buildings"	
This ANSI-approved specification is a companion to AISC 350-99 that extends coverage to the connection detailing and member design requirements for structural steel and composite structural steel and reinforced concrete systems in high- seismic applications. It is an update of the 1997 Seismic Provisions for Structural Steel Buildings that incorporates Supplements No. 1 (February 15, 1999) and No. 2 (November 10, 2000) as well as additional revisions resulting from new information generated by the FEMA/SAC project and other sources.	
Publisher: AISC(American Institute of Steel Construction)	
Date: 1997	USA
Reference Web: http://www.constructionbook.com/	

【006】

BSL	Building
"The Building Standard Law of Japan"	
Publisher: Ministry of Construction, Japan	

Date: 1950	Japan
Reference Web: http://www.basic.or.jp/aicbh/src/aicbh01e.htm	

【007】

NZS 3404, parts 1 and 2	Building
"Steel Structures Standards"	
Part 1 sets out minimum requirements for the design, fabrication, erection and modification of steelwork in structures in accordance with the limit state design method or in accordance with the alternative design method. Part 2 provides background material to the requirements of Part 1. Gives the origin of certain requirements, departures from previous practices, and explains the application of certain clauses.	
Publisher: Standards New Zealand	
Date: 1997	New Zealand
Reference Web: http://www.standards.co.nz/home/body.htm	

【008】

NZS 4104 **ICS Number 13.120, 13.200, 91.120.25**	Building
"Seismic restraint of building contents"	
This Standard aims to reduce the risk of injury to people and ensure access within a building after an earthquake by securing building contents. The second aim is to reduce the risk of damage to building contents. This standard provides the basis for the design for restraints and provides sketches of many simple, practical details for a range of common items including computer equipment, storage racks, cabinets, ornaments, appliances etc. It is applicable to items that are required to	

survive an earthquake to be available to rescue and recovery services to businesses and general public. Applies only to items less than 300kg in weight.
Publisher: Standards New Zealand

Date: 1994	New Zealand
Reference Web: http://www.standards.co.nz/home/body.htm	

【009】

NZS 4203	Building
"General Structural design and Design Loadings for buildings"	
Sets out in limit state format requirements for general structural design and design loadings for buildings, including the supports for services entering and within buildings, parts of buildings and pedestrian bridges within building sites. Design loadings include those from dead and live loads, earthquake forces, wind forces, snow loads, rainwater ponding loads, ice loads, soil loads and ground water loads. Revocation of the 1984 edition has been held over until proposed new limit state design material Standards come into being. Approved electrical safety Standard.	
Publisher: Standards New Zealand	
Date: 1992	New Zealand
Reference Web: http://www.standards.co.nz/home/body.htm	

【010】

NZS 4219 **ICS Number 91.120.25, 91.140, 91.200**	Building
"Specification for seismic resistance of engineering systems in buildings" Seismic Resistance of Engineering Systems in Buildings (Extract) Amendment	

1: 1990; Amendment 2: 1992	
Specifies requirements for the design, installation and restraint of engineering systems in buildings. Systems covered include tanks and vessels, flues and stacks, piping for water, steam, gas and fuel, ducting, heat producing appliances and electrical communication and control systems.	
Publisher: Standards New Zealand	
Date: 1983	New Zealand
Reference Web: http://www.standards.co.nz/home/body.htm	

【011】

AS 1170.4	Building
"Minimum Design Loads on Structures, Part 4: Earthquake Loads."	
This Standard sets out data and procedures for determining minimum earthquake loads on structures and their components. It also sets out minimum detailing requirements for structures. It does not consider related phenomena such as settlement, slides, subsidence, liquefaction or faulting in the immediate vicinity of a structure. This Standard is intended to apply to structures, particularly buildings, non-building structures, fixings and non-structural components including building services and architectural elements. Special structures including nuclear reactors, dams, transmission towers, bridges, piers and wharves may require special considerations, and are not covered by this Standard. NOTE: The date of application of this Standard on a mandatory basis is a matter for the relevant regulatory authorities. With the publication of this Standard, AS 2121 ù 1979 becomes an available superseded Standard and will be withdrawn following substantial regulatory implementation of this edition, or within two years of publication of this edition, whichever is the earlier.	
Publisher: Standards Australia	
Date: 1993	Australia

Reference Web: http://www.standards.com.au/catalogue/script/search.asp

【012】

NBC 1995	Building
"National Building Code of Canada 1995"	
Widely referred to as the "bible" of the construction industry, the National Building Code of Canada (NBC) is designed to ensure that buildings are structurally sound, safe from fire, free of health hazards, and accessible. The NBC, prepared by the Canadian Commission on Building and Fire Codes, is used as a model for virtually all regulations in Canada and pertains whether you are constructing a building or renovating or altering it.	
Publisher: National Research Council, Canada	
Date: 1995	Canada
Reference Web: http://irc.nrc-cnrc.gc.ca/catalogue/nbc1.html	

【013】

CSA S832-01	Building
"Guideline for Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings"	
This Guideline provides information and methodology to identify and evaluate hazards caused by earthquake forces acting on operational and functional components (OFCs) and to undertake appropriate mitigation strategies and techniques. It is important to note that seismic risk reduction of OFCs is affected by the structural performance of the building, although the Guideline does not address the structural integrity of the building. This Guideline is intended for use by building owners, building inspectors, facility managers, engineers, architects,	

and other stakeholders whose primary focus is to ensure the safety, serviceability, and durability of OFCs when subjected to earthquakes.	
Publisher: CSA (Canadian Standards Association)	
Date: 28-Mar-2002	Canada
Reference Web: http://www.csa-intl.org/onlinestore/	

【014】

GB 50191—93	Building
"Design code for anti-seismic of special structures"	
Publisher: GB (China Standard)	
Date: 1993	China
Reference Web: http://www.cssn.net.cn/	

【015】

GB 50023—95	Building
"Standard for seismic appraiser of building"	
Publisher: GB (China Standard)	
Date:1995	China
Reference Web: http://www.cssn.net.cn/	

【016】

GB 50011—2001	Building
"Code for seismic design of buildings"	
Publisher: GB (China Standard)	
Date: 2001	China
Reference Web: http://www.cssn.net.cn/	

【017】

GB 50007—2002	Building
"Code for design of building foundation"	
Publisher: GB (China Standard)	
Date: 2002	China
Reference Web: http://www.cssn.net.cn/	

【018】

ISBN: 008043021X	Building
"Comparative Performances of Seismic Design Codes for Concrete Structures" (2-Volume Set)	
Preface. General Concept and Design Principles. JSCE code (A. Machida). USA codes (J. Moehle). EU code (P. Pinto). NZ code (R. Park). General comments and comparison (A. Mori). Earthquake Loading and Analysis. JSCE code (A. Machida). USA codes (J. Moehle). EU code (P. Pinto). NZ code (R. Park). General comments and comparison (T. Higai). Ductility Consideration for Single Element and for Frame Structures. JSCE code (A. Machida). USA codes (J.	

Moehle). EU code (P. Pinto). NZ code (R. Park). General comments and comparison (N. Matsumoto). Design Method for Shear Failing Elements. JSCE code (A. Machida). USA codes (J. Moehle). EU code (P. Pinto). NZ code (R. Park). General comments and comparison (T. Higai). Detailing Consideration. JSCE code (A. Machida). USA codes (J. Moehle). EU code (P. Pinto). NZ code (R. Park). General comments and comparison (J. Niwa). Comparison of RC Pier Dimensions Designed by The Four Codes. General design considerations, loadings and subground conditions (J.Niwa). RC piers designed by JSCE code (JSCE Working Group). Design flow of JSCE code (JSCE Working Group). Determined dimensions of the pier by JSCE code (JSCE Working Group). RC pier dimensions designed by Caltrans code (Caltrans Working Group). Design flow of Caltrans code (Caltrans Working Group). Determined dimensions designed by Caltrans code (Caltrans Working Group). RC pier dimensions designed by Eurocode 8 (Eurocode 8 Working Group). Design flow of Eurocode 8 (Eurocode 8 Working Group). RC pier dimensions designed by NZ code (NZ Working Group). Design flow of NZ code (NZ Working Group). Determineddimensions designed by NZ code (NZ Working Group).
Publisher: ACI(American Concrete Institute)
Date: 01-03r-1999 / USA
Reference Web: http://www.concrete.org/BOOKSTORE/bkstr.htm

【019】

ACI SP-17-97	Building
"Design Handbook: Beams, One-Way Slabs, Brackets, Footings, Pile Caps, Two-Way Slabs, and Seismic Design in accordance with the Strength Design Method of 318-95"	
Formerly 3 separate books - The ACI Design Handbook is intended for use by individuals having a general familiarity with the strength design method and with "Building Code Requirements for Reinforced Concrete (ACI 318-95)". This	

publication provides information for the engineering design and analysis of beams, one-way slabs, brackets, footings, pile caps, columns, two-way slabs, and seismic design. Information is presented on three sections: Design Aids, Design Examples, and Commentary on Design Aids. The Design Examples illustrate the use of the Design Aids, which are tables and graphs intended to eliminate routine and repetitious calculations. The Commentary explains the analytical basis for the Design Aids.
Publisher: ACI(American Concrete Institute)
Date: 01-Jan-1997 | USA
Reference Web: http://www.concrete.org/BOOKSTORE/bkstr.htm

【020】

MSS SP-127-2001	Building
"Bracing for Piping Systems Seismic - Wind - Dynamic Design, Selection, Application"	
Piping systems shall be protected to reduce the risk of piping overstress where subject to seismic, wind and other dynamic forces.	
Publisher: MSS (Manufacturers Standardization Society)	
Date: 01-Feb-2001	USA
Reference Web: http://www.powerengbooks.com/booklsts/mss1.html	

【021】

ISO/DIS 22762-1	Building
"Elastomeric seismic-protection isolators - Part 1: Test methods" – DRAFT	
Publisher: International Organization for Standardization/Draft International Standard	

Date: 01-May-2003	International
Reference Web: http://www.iso.ch/iso/en/ISOOnline.frontpage	

【022】

ISO/DIS 22762-3	Building
"Elastomeric seismic-protection isolators - Part 3: Applications for buildings; Specifications" - DRAFT	
Publisher: International Organization for Standardization/Draft International Standard	
Date: 01-May-2003	International
Reference Web: http://www.iso.ch/iso/en/ISOOnline.frontpage	

【023】

IEC 60068-3-3 **ICS codes: 19.040** **JIS C 0055 (2000)**	Building
"Environmental testing - Environmental testing - Part 3: Guidance. Seismic test methods for equipment" Edition: 1.0	
Guidance is included in each of the three test methods referred to in this standard but it is specific to the test method. The guidance in this standard is directed towards choosing the appropriate test method and applying it to seismic testing.	
Publisher: IEC (International Electrotechnical Commission)	
Date: 28-Feb-1991	International Japan
Reference Web: http://www.iec.ch/	

【024】

ANSI/SMACNA 001-2000	Building
"Seismic Restraint Manual: Guidelines for Mechanical Systems"	
This American National Standard is an updated set of flexible guidelines that shows designers and contractors how to determine the correct restraints for sheet metal ducts, piping and conduit, so that they are more likely to remain attached to the building during an earthquake. Shows how very low-risk and very high-risk areas of the country can be easily and equally accommodated. New are additional reader aids, alternate-bracing details, and details for floor supported piping and ductwork. Also included are details for seismic joints in pipes, transverse bracing for steam pipes and a suggested detail for variable air volume terminals.	
Publisher: SMACNA(Sheet Metal and Air- Conditioning Contractors' National Association)	
Date: 7/31/2000, ANSI Approval 7/31/2000	USA
Reference Web: http://www.smacna.org/bookstore/	

【025】

UBC 1997	Building
"1997 Uniform Building Code"	
Volume 1 contains the administrative, fire- and life-safety, and field inspection provisions, including all nonstructural provisions and those structural provisions necessary for field inspections. **Volume 2** contains provisions for structural engineering design, including those design provisions formerly in the UBC Standards. These design provisions have been incorporated into the applicable chapter as divisions of the chapter.	

Volume 3 contains the remaining material, testing and installation standards previously published in the UBC Standards
Publisher: ICBO(International Conference of Building Officials)

Date: 1997	USA
Reference Web: http://www.icbo.org/About_ICBO/	

【026】

CBC-IBC03	Building
“CBC - International Building Code 2003”	
Internationally, code officials recognize the need for a modern, up-to-date building code addressing the design and installation of building systems through requirements emphasizing performance. The International Building Code, in this 2003 edition, is designed to meet these needs through model code regulations that safeguard the public health and safety in all communities, large and small.	
Publisher: ICBO(International Conference of Building Officials)	
Date: 2003	USA
Reference Web: http://www.icbo.org/About_ICBO/	

PART TWO

CODES & GUIDES for ENERGY FACILITIES

> "**Code in law**, in its widest sense any body of legal rules expressed in fixed and authoritative written form. A statute thus may be termed a code. Codes contrast with customary law (including common law), which is susceptible of various nonbinding formulations, as in the legal opinions of judges. ..."
>
> --- *The Columbia Encyclopedia, Sixth Edition. 2001.* ---

Chapter 4 Lifeline Codes Development

> Definition of Lifelines — Utilities (water, wastewater, electric power, gas, telecommunications) and transportation (highways, railroads, air, and water transport) systems whose loss of function in an urban area results in major disruption and potential loss of life.

Lifelines facilities

Earthquakes are unavoidable. Reducing disaster risk is a top priority not only for engineers and disaster managers, but also for development planners and policy-makers around the world.

Energy infrastructure, such as electric power, liquid fuel storages and suppliy stations, and natural gas systems constitute main items of the lifeblood in modern society to sustain the economic activities. Deprived of this infrastructure, such as in a major urban earthquake, humankind would be reduced to a primitive existence as status of 100 years before. It is significantly important to the developing APEC economies. Most economies are under rapid development and expanding in urbans and suburban to accommodate growing population in the communities of these districts. From cases above the lifelines have been shown to be extremely vulnerable to earthquakes and failures of these systems can result in significant direct and indirect loss. It has been emphasize that "Lifelines cost and generate money and they also represent capital assets for the community". Recent disasters in Northdrodge, Kobe and Chi-Chi have highlighted the need to assess the vulnerability of lifeline systems to natural hazard effects. To accentuate the harzards of earthquake on lifelines we have to know the history of lifelines engineering development. The American Lifelines Alliance has been the model in cooperation of hazard prevention against earthquakes with the industry.

American Lifelines Alliance (ALA)

The U.S. federal government has historically played a major role in facilitating research and seismic evaluation programs for lifelines. With the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP), Congress mandated that the Federal Emergency Management Agency (FEMA), in consultation with National Institute of Standards and Technology (NIST), develop a plan for assembling and adopting national seismic design standards for all lifelines, public and private. This plan was developed and was released in the mid-1990s. Important in this plan was the recommendation that public and private partnerships be developed in order to effect implementation.

In 1998, FEMA, in partnership with the American Society of Civil Engineers (ASCE), formed the American Lifelines Alliance (ALA). The goal of the ALA is to establish methodologies for assessing lifeline performance and to identify actions to reduce their risk from earthquakes. The ALA is currently soliciting, funding, and managing specific projects that will improve or extend industry practices in the design and construction of utility systems (electric power, gas and liquid fuels, telecommunications, water and wastewater) and transportation systems (highways, waterways, rail, ports and harbors). The end products will be incorporated into national consensus guidelines that will be administered by different organizations.

Several major descriptions can be regarded from this brief look at lifeline earthquake engineering:

1. Lifelines have been shown to be extremely vulnerable to earthquakes and failures of these systems can result in significant direct and indirect loss.

2. This recognition began over 30 years ago, and steady progress has been maintained to develop broad, practical mitigation programs.

3. The United States has been fortunate in that recent damaging earthquakes have been moderate in size and/or have not occurred in highly urban areas. The Kobe earthquake is a guide for how restoration may be affected by inadequate resources, illustrating the nonlinear effects of earthquakes.

4. Indirect losses resulting from the failure or disruption of lifelines are many times the losses associated with the repair of the damaged systems.

5. Mitigation of future risks through cost-effective retrofit or design strategies has been shown to be effective, as demonstrated by the performance of Caltrans facilities during the 1994 Northridge earthquake.

6. One important initiative that is being administered by FEMA and ASCE has the potential for significantly improving the earthquake performance of lifelines in future events. This initiative — the American Lifelines Alliance — calls for the development and adoption of seismic design standards for all public and private lifelines.

Milestone of Lifeline Development

The following chronology provides a brief look at some of the more important milestones related to lifeline earthquake engineering. As can be seen, the major impetus to examine seismic design procedures for lifeline facilities was the 1971 San Fernando earthquake. Even though there had been prior earthquakes in the United States that highlighted the importance of lifeline systems after major disasters (e.g., the 1906 San Francisco earthquake), the 1971 San Fernando event resulted in a widespread and profound recognition of the lifeline seismic risk problem, and led to important changes in design and construction.

Year	Milestone	Significance
1971	San Fernando Earthquake (M6.4)	Significant damage to lifeline systems. Start of long-term research program to study the effects of earthquakes on all lifeline systems (primarily funded by the National Science Foundation). Many changes to lifeline seismic design and construction initiated by this event.
1974	TCLEE	The Technical Council on Lifeline Earthquake Engineering (TCLEE) of the American Society of Civil Engineers was formed to address general issues regarding the state-of-the-art and practice of lifeline earthquake engineering in the United States. Since its formation, TCLEE has sponsored reconnaissance of major earthquakes, held five major quadrennial conferences on lifeline earthquake engineering, endowed the C. Martin Duke Lifeline Earthquake Engineering award, and published numerous monographs, design guideline documents, and special reports on lifeline earthquake engineering.
1977	NEHRP	National Earthquake Hazards Reduction Program established by Congress in 1977 (Public Law 95–124) to "*reduce the risks to life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program*." [amended 1990 Public Law101–614]. NEHRP's mission includes improved understanding, characterization and prediction of hazards and vulnerabilities; improved model building codes and land use practices; risk reduction through postearthquake investigations and education; development and improvement of design and construction techniques; improved mitigation capacity; and accelerated application of research results. The Act designates FEMA as the lead agency of the program, and assigns several planning, coordinating, and reporting responsibilities. NEHRP has been a major pillar in the building of a national lifelines seismic risk reduction program.

Year	Milestone	Significance
1985	BSSC Lifeline Workshop	As a result of this major workshop held by the Building Seismic Safety Council, an action plan for abating seismic hazards to lifelines was developed. The workshop had recommendations in four areas: public policy, legal, and financial strategies; information transfer and dissemination; emergency planning; and scientific and engineering knowledge.
1986	NCEER*	In order to address socioeconomic issues related to the seismic performance of lifeline systems, the NSF awarded a multi-year contract to the State University of New York at Buffalo to form the National Center for Earthquake Engineering Research (NCEER). This center has brought together researchers from many different technical disciplines to focus on multi-dimensional issues (e.g., socioeconomic impacts caused by the disruption of lifeline service).
1989	Loma Prieta Earthquake (M7.1)	This earthquake reaffirmed the programs initiated in 1971, and the need to assess and improve seismic design and construction procedures for all lifeline facilities. Particular attention was subsequently given to the performance of highway bridge structures, due in part to the damage to the San Francisco–Oakland Bay Bridge.
1990	Port of Los Angeles (POLA) Seismic Workshop	The purpose of this workshop was to develop a set of guidelines to be used by the Port to address seismic design issues in the design and construction of new landfill areas within the Port. This workshop reflected the culmination of many months of preparation and meetings among scientists, engineers, and policy makers.
1990	Public Law 101–614 (Reauthorization of the National Earthquake Hazards Reduction Program)	Passage of this law required the director of the Federal Emergency Management Agency (FEMA), in consultation with the National Institute of Standards and Technology (NIST), to submit to Congress a plan for developing and adopting seismic design and construction standards for all lifelines.
1991	Lifeline Standards Workshop	The purpose of this workshop was to (1) obtain comments and suggestions for revising draft plans prepared in response to

Year	Milestone	Significance
		Public Law 101–614, examining lifeline issues, and (2) obtain priorities for various standard development and research activities.
1991	Workshop Sponsored by the National Science Foundation and the National Communications System	This was one of the first workshops to focus on the effects of earthquakes on communication lifeline systems. This workshop was followed by a second meeting in 1992 where different approaches to communication lifeline modeling was discussed.
1994	Northridge Earthquake (M6.7)	Performance of lifelines had significantly improved compared to prior earthquakes in this region (e.g., 1971 San Fernando earthquake). However, concern continued over the performance of highway bridges structures. Other lifelines were generally deemed to have performed satisfactorily even though the City of Los Angeles experienced a complete loss of electric power for the first time in its history.
1995	Kobe, Japan Earthquake (M6.9)	Performance of lifelines in this earthquake was extremely poor. Considerable damage was observed in virtually every type of lifeline system with restoration taking as long as several months in certain cases. This event was a reminder of what could happen in the United States if mitigation efforts are not continued.
1996	FEMA/NIST Plan for Developing and Adopting Seismic Design Guidelines and Standards for Lifelines	This plan was the result of Public Law 101–614. This plan emphasized the importance of forming public and private partnerships to implement its recommendations.
1997	ASCE Lifelines Policymakers Workshop	Workshop held in Washington, D.C. to solicit input on how to implement the recommendations of the FEMA/NIST plan.
1997	Deregulation of the Electric Power Industry	The first real test in examining the impact of deregulation on seismic mitigation activities. In the past, these programs were mandated or strongly encouraged by state Public Utilities Commissions. Without these requirements and with economics playing a more important role in capital expenditures, the future

		of pro-active seismic mitigation programs is placed in jeopardy.
1998	American Lifelines Alliance	Formed as a partnership between FEMA and ASCE, this nonprofit entity was assigned the responsibility for implementing the FEMA/NIST plan. To date, there have been a number of documents published by the ALA that help form the basis of evaluation or design guidelines for different lifelines.

Chapter 5 Electrical Power Systems

The earthquakes of Kobe(1995) and Chi-Chi(1999) showed power systems are very vulnerable to damage. These earthquakes have magnitudes of 7 shows that major earthquakes or even greater earthquakes, magnitude larger than 8, currently unknown, may need further studies on the damage scales to improve the earthquake response of electric power systems. Historical records show damages mainly on substations, transformers, and the network disrupting. Most earthquake damage to electrical systems has been due to the failure of porcelain elements in highvoltage substation equipment.. Performance is strongly influenced by specific equipment designs and installation practices. There has also been damage to substation buildings, conductor support structures, cast aluminum hardware used on both low- and high-voltage equipment, equipment support structures, equipment anchorage, and parts of power generating stations. The performance of some communication and control systems has also been impaired following earthquakes.

On February 9, 1971, an earthquake measuring 6.6 on the Richter scale hit the Los Angeles area. In its wake, major substations were left decimated. After months of repairs and millions of dollars in expenditures, the last substation knocked out finally returned to service. Prior to this earthquake, most utilities had no seismic requirements for equipment or, at best, included very simplistic statements in their specifications. This earthquake was the electric utility's wake-up call that seismicity must be given serious consideration in the design of substations, particularly in the design of electrical equipment.

Following that earthquake, utilities threw out the old specification clauses and began formulating new seismic electrical equipment criteria. The utilities' initial attempts at seismic qualification were as tentative as a baby's first steps. Because utility equipment seismic qualification experts were nonexistent, engineers experienced in general seismicity and dynamics were pressed into duty to tackle the problem of how to make equipment seismically rugged. The early generations of seismic criteria were very general, a "one size fits all" tactic. One specification clause was used for almost all electrical equipment.

With the passage of time and a number of additional earthquakes, it became clear that one size does not fit all. Because each type of equipment is different structurally, specifically regarding its fragility and the way it acts dynamically, each type must have its own unique set of requirements. For these reasons, the requirements for a transformer must be different from the disconnect switches and so on.

Historical Response of Electrical Power Systems to Earthquakes

Most earthquake damage to electrical systems has been due to the failure of porcelain elements in high-voltage substation equipment. Performance is strongly influenced by specific equipment designs and installation practices. There has also been damage to substation buildings, conductor support structures, cast aluminum hardware used on both low- and high-voltage equipment, equipment support structures, equipment anchorage, and parts of power generating stations. The performance of some communication and control systems has also been impaired following earthquakes.

In this chapter, power systems have been grouped into three types of facilities: transmission and distribution facilities, power generating stations, and control and communications facilities. Facilities that do not immediately impact system operations, such as design offices and maintenance facilities, are not discussed here. The overall performance of the entire system and of each of these types of facilities is discussed. A detailed discussion of the performance of individual equipment and facilities is given in subsequent sections.

Configuration of a Typical Power System

Electric power systems are very vulnerable to damage. Most damage is due to the failure of porcelain elements in high-voltage substation equipment, although, performance is also strongly influenced by specific equipment designs and installation practices. Damage to various lifelines and structures has impaired the performance of some communication and control systems after earthquakes. In this chapter, power systems have been grouped into three types of facilities: transmission and distribution facilities, power generating stations, and control and communications facilities.

It deals with major power system elements-power generating stations, transmission and distribution lines, substations, system communications and control, and ancillary facilities and functions. A large portion of the document is devoted to high-voltage substations, as this is where most power system damage has been concentrated. Topics include sources and effects of earthquakes; overview of earthquake performance of power systems and facilities; approach to improved earthquake performance; substations; transmission and distribution lines and support structures; power generating facilities; system control; communication systems; and ancillary facilities and functions.

Three of the generalizations given above are not strictly true. Some utilities do have pumped-storage facilities that can store energy. A limited number of DC transmission facilities within the United States have the ability to control the power flowing over their lines. Many transformers have load tap changers that can make small changes in their output voltage and have minor control over power flows. However, the overall significance of the above points is valid.

For the purpose of earthquake evaluation and mitigation, power systems can be divided into six major parts:

1. Power generating facilities
2. Transmission and distribution lines
3. Transmission and distribution substations
4. Control and data acquisition systems
5. Communications
6. Ancillary facilities and functions

Overall Power System Seismic Performance

Before the seismic performance of power facilities can be properly understood and interpreted, four factors must be kept in mind:

1. No data from a major or great earthquake centered in a modern metropolitan area exist. The evaluation of system performance is based primarily on several moderate and two strong California earthquakes.
2. Seismic practices in utilities and knowledge about earthquakes in California have been evolving since the 1920s. Since 1933, a stronger impetus has been given to the seismic design of power facilities, starting with 0.1 *g* static analysis, which was later revised to 0.2 *g*. This has been a slow process, because changes in design take a long time to be reflected in most facilities in the field. However, the vast majority of facilities subjected to earthquakes since 1970 have had significantly higher seismic specifications (particularly anchorage of substation equipment) than most such facilities outside of California. In the early 1970s, 0.5 *g* dynamic analysis methods were used, followed shortly thereafter by dynamic testing of vulnerable equipment. While some utilities may have more severe design specifications, such as those for high wind loads, the requirements typically have little effect on improving the seismic performance of substation equipment.
3. The moderate magnitude of most recent earthquakes and the high attenuation of seismic energy in California, as compared with most of the eastern United States, mean that in California relatively small areas have been exposed to damaging ground motions. As a result, the damage to power systems in most earthquakes has been confined to one or two facilities. In the eastern United States, earthquakes of equivalent magnitude will impact much larger areas that may have a high potential for soil liquefaction. Thus, an eastern earthquake may affect several facilities and be more disruptive to the network, and soil liquefaction at a

power facility can be more damaging.

4. Large coal-fueled plants, with their heavy coal-storage silos located high in the steam-generation (boiler) structure, have not been put to the test by damaging earthquakes, so their seismic performance is unknown. Within California, all large fossil-fuel power-generating stations burn gas or oil rather than coal. No earthquake data on the performance of coal-fueled generating stations in seismic regions in other countries are available.

Given these caveats, it can be said that system performance, as measured by power disruption, has been very good. Thus, to date, network redundancy has been adequate to overcome the extensive damage to isolated high-voltage substations. In the case of the Loma Prieta and Northridge earthquakes, where several substations were damaged, the character of the damage and the use of emergency procedures allowed expeditious service restoration.

Power Generation Facilities

In general, the overall seismic performance of power-generating stations has been good, although coal-fueled plants and large oil- and gas-fueled plants (500 MW and above) have had limited exposure. It is significant, many generating stations are relatively small and old. Structural design practices used by most utilities have been based on the Uniform Building Code and structural performance has been good. Some equipment and facilities not causing the plant to shut down have been damaged. Some elements, e.g., water- and liquid-fuel-storage tanks, have had mixed performance. Generating stations have been forced off line by switchyard and substation damage, and have experienced delays in getting back on line.

The switchyards associated with power plants are grouped with transmission and distribution facilities. Peaking generating units, which are often designated to serve as **black start** units, have consistently failed to operate in this role because of inappropriately designed control systems.

Power Transmission and Distribution Systems

The transmission and distribution system can be grouped into three types of elements: transmission lines, distribution lines, and substations.

Transmission Lines

Transmission lines have been very resistant to earthquake damage; their main vulnerabilities are foundation failure of transmission towers or the loss of a tower due to a landslide. Both occurrences are relatively rare in the United States. It would appear that the low natural frequencies of lines decouple their mass from the high energy content of earthquakes, and the design for extreme wind, ice, and longitudinal load combinations is adequate for earthquakes. The 1999 Chi-Chi earthquake demonstrated that, even with conservative transmission-tower foundation construction, 11 high-voltage transmission towers were lost and hundreds were damaged, causing long-term blackouts in Taipei, which is located far from the epicenter and generally experienced minor earthquake damage.

Distribution Lines

Distribution lines are also seismically robust. Their main vulnerability is from burn-down when earthquake-induced vibrations cause adjacent phases of a circuit to come in contact. If they are energized, they will arc and may burn through the line, causing it to fall. Burned-down lines can be a significant source of fires; they have generated large numbers of calls by the general public to the emergency response system. While repair can be labor intensive, only limited numbers of customers are impacted by any given downed line and spare parts are usually not needed to effect a repair. The shorting-together of adjacent phases can also cause fuse cutouts to blow and disrupt service. In the aggregate, restoration of this type of damage can be lengthy. The main cause of pole failure has been soil failure.

Substations

Damage to porcelain members of high-voltage substation equipment has been a recurring problem. The damage can be attributed to equipment vulnerability and lack of slack in conductors connecting the equipment. The damage can also be attributed to inadequate anchorage that allowed the transformers to fall from their pedestals, damaging bushings, radiators, and possibly internal components. Equipment operating at voltages of 115 kV and below performs very well when good seismic installation practices of anchorage and conductor interconnection flexibility are followed. Some types of equipment operating at voltages of 161 kV and above are vulnerable. Generally, the higher the operating voltage, the more vulnerable the equipment. The highest-voltage equipment to be subjected to earthquakes is 500 kV. Several types of failures are frequently observed:

1. Inadequately anchored rail-supported transformers have fallen from their elevated platforms and have been severely damaged.
2. Leaking transformer bushings and radiator piping are common and broken bushings have been observed.
3. Lack of adequate slack in conductors connecting equipment can load and damage bushings and post insulators.
4. Flexible equipment supports have allowed large relative displacements; this tends to aggravate problems with the lack of sufficient slack. Some equipment designs appear to be inherently vulnerable, while other equipment that serves the same function and operates at the same voltage can be quite rugged, e.g., some live-tank circuit breakers are very vulnerable, while dead-tank circuit breakers are robust.
5. Current transformers, capacitive coupled voltage transformers, and line traps have been damaged; their loss has been disruptive to system function protection.

One of the main difficulties when substation equipment is damaged is that there are limited numbers of spare parts or spare replacement equipment available. Also, repair and replacement of damaged equipment is a time-consuming and labor-intensive task.

Seismic Considerations

A Historical Perspective

Prior to 1970, seismic requirements for substation components were minimal. In the 1970s and 1980s, several large-magnitude earthquakes struck California, causing millions of dollars in damage to substation components and lost revenue. As a result of these losses, it became apparent to owners and operators of substation facilities in seismically active areas that the existing seismic requirements for substation components were inadequate. The 1997 version of the Institute of Electrical and Electronic Engineers(IEEE) Standard 693, *Seismic Design for Substations* (1997), and the document presently being produced by the American Society of Civil Engineers (ASCE), entitled *Substation Structure Design Guide*, have enhanced the current state of knowledge in this area and promote seismic standardization of substation power equipment in the electric power industry.

The requirements necessary to qualify power equipment developed from research into seismic activity and how it relates to substation equipment have proven to be complex. Because of the complexities, the IEEE 693 committee has attempted to simplify the application of the quali.cation process for the end user by providing a single set of requirements that can be applied by specifying a few simple instructions. These instructions will be discussed further, but briefy they are:

1. Note the equipment type, such as surge arresters or circuit breakers.

2. Select the quali.cation level — *Low*, *Moderate*, or *High*.

3. Note the equipment *in-situ* con.guration, such as mounting information, etc.

Another IEEE 693 committee goal was to minimize testing costs, for by using one set of seismic quali.cations the cost of the quali.cations could be amortized over all purchasers, similar to what is done in the development of new equipment.

The purpose of this document is to guide the substation designer with little or no familiarity with substation seismic design considerations by illustrating the basic steps required for securing and protecting substation components within a given substation. It is only a guide and it is not intended to be allinclusive or to provide all the necessary details to undertake this work. For further details and information on this topic, it is recommended that the documents listed at the end of this discussion be reviewed.

Relationship Between Earthquakes and Substations

To secure and protect substation equipment from a seismic event, the relationship between earthquakes and substation components must first be clarified. Earthquakes occur when there is a sudden rupture along a pre-existing geologic fault. Shock waves that radiate from the fracture zone amplify, and depending on the surficial geology, these waves will arrive at the surface as a complex set of multifrequency vibratory ground motions, with horizontal and vertical components.

The response of structures and buildings to this ground motion depends on their construction, ductility, dynamic properties, and design. Lightly damped structures that have one or more natural modes of oscillation within the frequency band of the ground motion excitation can experience considerable movement which can generate forces and de.ections that the structures were not designed to accommodate, while mechanisms that absorb energy in a structure in response to its motion can provide damping of these forces. If two or more structures or pieces of equipment are rigidly linked, they will interact with one another, producing a modified response. If they are flexibly linked, an ideal situation, then no forces are transferred between the two components; however, the link must be designed with sufficient flexibility to accommodate the relative displacements.

For electrical reasons, many pieces of substation power equipment are interconnected and contain porcelain, which is a relatively brittle, low-strength, and low-damping material compared to steel. Furthermore, unless instructed to do otherwise, construction personnel may not install .exible bus conductors used to electrically connect this equipment with sufficient slack so that small differential motions of one piece of equipment can easily impact an adjacent piece of equipment.

Substation equipment whose natural frequencies lie in the range of earthquake ground motions are especially vulnerable to this type of damage by seismic events.

Applicable Documents

Once the relationship between substation components and earthquakes is understood, the substation designer should become familiar with the standards and references currently available (see reference list below). It is important for the user to appreciate how the various documents interrelate. Although the title of IEEE 693 is *Recommended Practice for Seismic Design of Substations,* it was clear to the IEEE 693 committee that other documents had already addressed many of the aspects of seismic design substations. Therefore, IEEE 693 simply refers the users to the appropriate document if the information is not contained therein. It was also clear that a single set of seismic quali.cation requirements was needed; therefore, the IEEE 693 emphasizes those aspects associated with the seismic qualification of power equipment.

Special attention also needs to be given to the ASCE' s *Substation Structure Design Guide*. This guide provides information for all of the structures within a substation, such as A-frames, buildings, racks, etc. Since these two documents, IEEE 693 and ASCE, were developed at about the same time, the two committees collaborated so that the two documents would complement each other. Simply stated, IEEE 693 addresses the equipment and its first support structure and ASCE addresses all the other structures.

Decision Process for Seismic Design Consideration

Once document familiarization is complete, the designer can follow the steps, which was created with the assumption that each substation component will be reviewed independently. The first step in the decision-making process is to determine whether the substation component under consideration is classi.ed as power equipment or not. Assuming the component is classi.ed as nonpower equipment, the next step is to determine what type of nonpower equipment the component is. For example, a structure such as a bus support may require foundation modification or anchor design work.

Once the component type is determined, the appropriate references can be accessed and the required engineering work carried out. The decision-making process for substation components classified as nonpower equipment is then complete.

If the substation component under consideration is found to be a piece of power equipment, the next step in the power equipment decision process stream is to determine if this equipment is classified as Class 1E, equipment for nuclear power generating stations. IEEE 693 does not cover Class 1E equipment, but this information is available in IEEE 344 (1993).

The next step of the power equipment stream is to determine if this equipment’ s voltage class is more or less than 15,000 volts. If it is less than 15,000 volts, there is a possibility that it could be seismically qualified by experience data as indicated in IEEE 693 and IEEE 344. If the power equipment’s voltage class is greater than or equal to 15,000 volts, it must be determined if there are any secondary support, foundation, or anchor design issues, and if the equipment is existing or to be installed, for although IEEE 693 was written primarily for new installations, it can be used to assist designers in the analysis of seismic requirements for existing equipment as well. Anchor design issues should be addressed as per the ASCE document and IEEE 693 as indicated in IEEE 693.

Performance Levels and Required Spectra

Following the voltage classification, determination of the appropriate performance level for seismic qualification of the site in question must be selected.

The performance level of earthquake motion is represented by response spectra that reasonably envelop response spectra from anticipated ground motions determined using historical earthquake records. The shape of the performance level is a broadband response spectrum that envelopes the effects of earthquakes in different areas for site conditions ranging from rock to soft soils as described in the National Earthquake Hazard Reduction Program (NEHRP) (1997).

Control, Protection, and Communications Facilities

In general, control, protection, and communications equipment have performed well. The exceptions are high-voltage equipment used for protection (instrument transformers, circuit breakers, line traps), uninterruptible power supplies, and emergency power supplies. Inadequate restraint of station batteries at power plants and substations has been a common problem. Protective relays have tripped due to earthquake-induced vibrations. The loss of instrumentation transformers has also disrupted or limited system protection. Damage to substation equipment may result in poorer system protection. For example, damage to instrumentation transformers may limit protection to just over-current conditions and prevent the determination of the location of faults.

Public switched network telephone systems and cellular telephone systems are typically congested after an earthquake, so they cannot be counted on during the emergency response period. Utility-owned communication systems can also become congested, but the earthquake performance of these facilities has been good. Radio repeaters used to dispatch repair crews can lose power and stop operating; this impedes the dispatch and control of repair crews.

Code Provision, Standards and Guidelines for Electrical Systems

A broad range of facilities make up a power system; the construction and operation of many are governed by codes and standards. However, from a seismic design perspective, there are few mandatory codes or regulations. Power systems contain many buildings, including powe rplants, substation control houses, control center structures, and engineering and administrative offices. The construction of all is governed by the local building codes, which now require seismic provisions to be applied in regions with seismic risk.

While facilities are not governed by local building codes, they must conform to national codes. The design of liquid-storage tanks is controlled by the American Water Works Association, AWWA D100 [ANSI/AWWA, 1997] or the American Petroleum Institute, API 650 [ANSI/API, 1995] for water or liquid-fuel tanks, respectively. Many utility facilities are seismically vulnerable because they predate the use of seismic requirements or were constructed using less stringent requirements. Several national standards or guidelines are directed at earthquake effects on power systems, but these are voluntary rather than mandatory. Of particular note is the Institute of Electrical and Electronics Engineers Standard, IEEE Standard 693–1997, IEEE Recommended Practices for Seismic Design of Substations[IEEE, 1998].

While this standard covers many issues in seismic design of substations, its main focus is on establishing criteria and methods for seismically qualifying substation equipment. Utilities throughout the country are using these procedures, which should result in improved earthquake performance of equipment that conforms to the recommended practices.

The American Society of Civil Engineers (ASCE)'s Manual No. 96, Guide to Improved Earthquake Performance of Electric Power System [Schiff, 1999], forms the basis of this chapter. It contains a detailed review of the seismic performance of power system facilities and equipment and provides recommendations for retrofitting or new construction to address observed equipment failures. ASCE is also preparing a guide, Substation Structure Design Guide [Kempner], which will provide design criteria for equipment support structures in substations.

Existed Codes on Electric System

【027】

GB 50049—94	Power Plant
"Code for design of small thermal power plant"	
Publisher: GB (China Standard)	
Date: 1994	
Reference Web: http://www.cssn.net.cn/	

【028】

ASME BPV Code	Power Plant
"The ASME International Boiler and Pressure Vessel (BPV) Code"	
The ASME International Boiler and Pressure Vessel (BPV) Code establishes rules of safety governing the design, fabrication, and inspection of boilers and pressure vessels, and nuclear power plant components during construction. The ASME Boiler and Pressure Vessel Code is in a class of its own. As well, utilization of the ASME Code Symbol Stamp is a means of complying with the laws and regulations in 49 states in the U.S., and all of the provinces of Canada. In addition, according to the British Standards Institute (BSI), over 70 countries accept the ASME Boiler and Pressure Vessel Code in whole or in part, as a means of meeting their government safety regulations.	
Publisher: (ASME)The American Society of Mechanical Engineers	
Date: 2001	USA
Reference Web: http://www.asme.org/bpvc/	

【029】

IEEE P693	Substation
"IEEE Recommended Practices for Seismic Design of Substations"	
Recommendations for seismic design of substations, including qualification of each equipment type, are discussed. Design recommendations consist of seismic criteria, qualification methods and levels, structural capacities, performance requirements for equipment operation, installation methods, and documentation. Presently, IEEE P693, Draft Recommended Practices for Seismic Design of Substations, is being entirely revised to incorporate the latest design developments. IEEE P693 addresses all aspects of the seismic design of substations. It achieves this by either providing requirements directly or providing a reference document. Qualification of electrical equipment is provided directly within IEEE P693. Seismic design requirements for non-equipment, such	

as A-frames, buildings, and racks, are provided by referring to other documents, mainly the American Society of Civil Engineers (ASCE) Substation Guide, which is presently being developed as a "sister" document to IEEE P693. This has been a case of two organizations--IEEE and ASCE--working jointly, with each emphasizing its strengths to complement the other.

The current revision of IEEE Std 693 is equipment specific, meaning that each type of equipment will be provided with its own uniquely designed set of requirements. For example, since many of the requirements that are applicable to transformers do not apply to a disconnect switch, each must have its own unique set of requirements.

The following are some of the criteria used in establishing equipment qualification requirements:

Fragility. Equipment that is inherently rugged need not be subjected to a very rigorous qualification, while fragile equipment normally needs a more rigorous approach.

Criticality. The qualification method needs to recognize the criticality of the equipment. For example, a transformer or a circuit breaker, which is critical to the function of a substation, must be more reliable than a battery charger.

Alternatives. There needs to be enough flexibility in the standard so that the utility can select the appropriate "level of ruggedness." At the same time, utilities want some degree of uniformity within their system. Also, the fewer the levels, the more opportunities to amortize the cost of the equipment. The P693 committee has decided that three "levels of ruggedness" provide the balance between flexibility, uniformity, and cost. In general terms, the three levels are: 1) nominal requirements (low seismic activity expected); 2) moderate ruggedness; and 3) high ruggedness.

The following are some of the considerations utilities must evaluate when deciding which level is appropriate: 1) the expected magnitude of an earthquake at the substation; 2) the criticality of the substation as it pertains to the utility's total system; 3) the speed at which equipment can be replaced; 4) safety considerations; 5) the possibility and acceptability of bypassing the equipment should the equipment fail; and 6) the overall reliability of the system. For these reasons, zone maps are provided as an aid to guide the utility in selecting the

appropriate level, not as a requirement. The utility must evaluate the site and all the other considerations to determine which level is appropriate. The P693 committee hopes that through standardization, the cost of qualification will be reduced by the use of common criteria and the present confusion to manufacturers will be minimized. At this moment, each utility's criteria are different despite the common bottom line--they all want rugged equipment that will reasonably survive earthquakes. As a result of each utility having its own unique criteria, each utility must pay for its unique requirements. How much better it would be if the cost of qualification were shared with other utilities. The results of P693 affords one of those rare opportunities where everyone wins. The utilities win because the cost of qualification can be reduced by amortizing the cost over all the buyers. The manufacturers win because they will have standards and order where chaos, for now, rules.
Publisher: IEEE (Institute of Electrical and Electronics Engineers)
Date: 1997   USA
Reference Web: http://www.ieee.org/portal/index.jsp

【030】

Guide	Substation
"ASCE Substation Structure Design Guide" 2003	
The ASCE Committee on Electrical Transmission Structures, CETS, has been developing a design guide on electrical substation structures. The guide addresses structural loading, deflection criteria, design codes, and anchorage to foundations. The document is intended to be used with companion documents, such as IEEE's Standard 693 "Recommended Practice for Seismic Design of Substations," and Standard 605 "Guide for the Design of Rigid-Bus Structures." This class will provide an overview of the significant topics covered by the ASCE Substation Structure Design Guide. Handouts include a draft version of the Substation Structure Design Guide. Speakers to be determined.	
Publisher: ASCE(American Society of Civil Engineers)	

Date: 2000 published, 2003(Developing)	USA
Reference Web: http://www.asce.org/conferences/tclee2003/workshops.cfm	

【031】

TP.DS 61.03	Substation
"Seismic Design Guide"	
Publisher: Transpower	
Date: Drafting	New Zealand
Reference Web: http://www.transpower.co.nz/	

【032】

GB 50059—92	Substation
"Code for design of 35 ~ 110Kv transformer substation"	
Publisher: GB (China Standard)	
Date: 1992	China
Reference Web: http://www.cssn.net.cn/	

【033】

GB 50052—95	Substation
"Code for design of 10Kv or lower than 10Kv transformer substation"	
Publisher: GB (China Standard)	

Date: 1995	China
Reference Web: http://www.cssn.net.cn/	

【034】

RUS bulletin 1724E-300	Substation
"Design Guide for Rural Substations"	
Basic design guide and reference tool for designing rural substations. Replaces REA Bulletin 65-1 (1978). This bulletin covers rural transmission and distribution with air-insulated, outdoor substations 345 kV (phase-to-phase) and below. Possible design responsibilities of the engineer are covered, including preparation of construction drawings, material, equipment and labor specifications, and any other engineering design services that may be required.	
Publisher: USDA Rural Utilities Service (RUS)	
Date: June 2001	USA
Reference Web: http://www.usda.gov/rus/electric/regs/index.htm	

【035】

ASCE Manuals and Reports on Engineering Practice No. 96	Power System
"Guide to Improved Earthquake Performance of Electric Power Systems"	
Recent moderate and strong California earthquakes demonstrate that parts of electric power systems are very vulnerable to damage. Most damage is due to the failure of porcelain elements in high-voltage substation equipment, although, performance is also strongly influenced by specific equipment designs and installation practices. Damage to various lifelines and structures have impaired the performance of some communication and control systems after earthquakes. This Manual issues methods to improve the earthquake response of electric power systems. It deals with major power system elements-power generating	

stations, transmission and distribution lines, substations, system communications and control, and ancillary facilities and functions. A large portion of the document is devoted to high-voltage substations, as this is where most power system damage has been concentrated. Topics include sources and effects of earthquakes; overview of earthquake performance of power systems and facilities; approach to improved earthquake performance; substations; transmission and distribution lines and support structures; power generating facilities; system control; communication systems; and ancillary facilities and functions.

Publisher: ASCE(American Society of Civil Engineers)	
Date: 1999	USA
Reference Web: http://www.pubs.asce.org/BOOKdisplay.cgi?9990556	

【036】

IEC 62271-2 - Ed. 1.0 (TC17A) ICS codes: 29.130.10	Power System
"High voltage switchgear and controlgear - Part 2: Seismic qualification for rated voltages of 72,5 kV and above Maintenance" Result Date: 2005-12-31	
Applies to all switchgear and their assemblies for alternating current of rated voltages of 72,5 kV and above for indoor and outdoor installation, including their supporting structure rigidly connected to the ground. Where switchgear and their assemblies are not ground mounted, e.g. in a building, conditions for application are subject to agreement between users and manufacturers. The seismic qualification of the switchgear and their assemblies take into account any auxiliary and control equipment either directly mounted or as a separate structure. This standard provides procedures to seismically qualify ground mounted switchgear and their assemblies for rated voltages of 72,5 kV and above. The seismic qualification of the switchgear and their assemblies is only performed upon request. This standard specifies seismic severity levels and gives a choice of methods that may be applied to demonstrate the performance of	

high-voltage switchgear and their assemblies for which seismic qualification is required.	
Publisher: IEC (International Electrotechnical Commission)	
Date: 11-02-2003	International
Reference Web: http://www.iec.ch/	

【037】

IEC/TS 61463, Amd 1 for ed. 1.0 ICS codes: 29.080.20	Power System
"Bushings - Seismic qualification" Consolidated Edition 1.1	
Is applicable to alternating current and direct current bushings for rated voltages above 52 kV, mounted on transformers, other apparatus of buildings. It is accepted that for bushings for rated voltages less than or equal to 52 kV, due to their characteristics (resonance frequency greater than 25 Hz) seismic qualification is not required. Has the status of a technical report type 2.	
Publisher: IEC (International Electrotechnical Commission)	
Date: 18-04-2000	International
Reference Web: http://www.iec.ch/	

【038】

IEC 61166 ICS codes: 29.130.10	Power System
"High-Voltage Alternating Current Circuit-Breakers Guide for Seismic Qualification of High- Voltage Alternating Current Circuit- Breakers"	
Specifies seismic severity levels and gives a choice of methods that can be applied to demonstrate the performance of HV circuit-breakers for which seismic qualification is required.	

Publisher: IEC (International Electrotechnical Commission)	
Date: 07-04-1993	International
Reference Web: http://www.iec.ch/	

【039】

IEC 60255-21-3 **ICS codes: 29.120.70**	Power System
"Electrical relays - Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section 3: Seismic tests"	
Specifies the vibration, shock, bump and seismic tests applicable to electromechanical and static measuring relays and protection equipment, with or without output contacts.	
Publisher: IEC (International Electrotechnical Commission)	
Date: 09-1993	International
Reference Web: http://www.iec.ch/	

【040】

ISO 8042 **JIS B0909 (1993)** **ICS 17.160**	Power System
"Shock and vibration measurements -- Characteristics to be specified for seismic pick-ups"	
ISO 8042 defines quality as the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.	
Publisher: ISO (International Organization for Standardization)	
Date: 7/14/1988	International, Japan
Reference Web: http://www.iso.ch/iso/en/ISOOnline.frontpage	

【041】

B 5517	Power System
“Shock and Vibration Measurements Characteristics to Be Specified for Seismic Pick-Ups”	
Publisher: KSA (Korean Standards Association)	
Date: 00-00-1994	Korea
Reference Web: http://www.ksa.or.kr/	

【042】

ANSI/ASA S2.46-1989 (R2001)	Power System
“American National Standard Characteristics to be Specified for Seismic Transducers”	
This standard specifies the characteristics of a seismic transducer (pickup) which can serve as an adequate description of the capabilities of the pickup to perform a shock or vibration measurement in various environments. It is intended as a guide to instrument manufacturers for indicating the characteristics of their transducers that are critical in specifying, selecting, or preparing performance description by users. This standard is the national counterpart of ISO 8042-1988 Shock and Vibration Measurements--Characteristics to be Specified for Seismic Pick-ups.	
Publisher: American National Standards of the Acoustical Society of America	
Date: 01-01-1989	USA
Reference Web: https://asastore.aip.org/	

【043】

GB 50217—94	Power System
“Code for design of cable of electric power project”	

Publisher: GB (China Standard)	
Date: 1993	China
Reference Web: http://www.cssn.net.cn/	

【044】

IEEE C37.81	Power System
"IEEE Guide for Seismic Qualification of Class 1E Metal-Enclosed Power Switchgear Assemblies"	
This IEEE Standards product is part of the C37 family on Switchgear, Substations and Protective Relays. This standard provides specific requirements and guidance for seismic qualification of metal-enclosed power switchgear assemblies. This guide may also be used in other applications in which seismic response of metal-enclosed power switchgear assemblies is a consideration. You will receive an email from Customer Service with the URL needed to access this publication online.	
Publisher: IEEE(Institute of Electrical and Electronics Engineers)	
Date: 01-05-1989	USA
Reference Web: http://www.ieee.org/portal/index.jsp	

【045】

IEEE C37.98-1987	Power System
"IEEE Standard Seismic Testing of Relays"	
This IEEE Standards product is part of the C37 family on Switchgear, Substations and Protective Relays. The procedures to be used in the seismic testing of relays used in power system facilities are specified. The concern is with determining the seismic fragility level of relays. Recommendations for proof testing are given. Documentation and generalization of test results are discussed.	

You will receive an email from Customer Service with the URL needed to access this publication online. (Formerly IEEE Standard 501-1978, Standard for Seismic Testing of Relays)

Publisher: IEEE(Institute of Electrical and Electronics Engineers)	
Date: 01-05-1987	USA
Reference Web: http://www.ieee.org/portal/index.jsp	

【046】

ASCE 10-97 **ANSI/ASCE 10**	Power System
"Design of Latticed Steel Transmission Structures"	
This updated standard, Design of Latticed Steel Transmission Structures (ASCE 10-97), provides requirements for the design of guyed and self-supporting latticed steel electrical transmission structures. They are applicable for hot-rolled and cold-formed steel shapes. Analysis techniques are outlined for the geometrical configurations presently in use. Procedures for the design of individual members reflect extensive experience and test data on steels with yield points up to 65 ksi. Connection design procedures allow the engineer to match connection capability to the most suitable end and edge distances for detailing. If full scale structure testing is required procedures are outlined to assist in obtaining critical information. Design procedures cover structural steel members and connections used in foundations. The commentary provides supporting background data.	
Publisher: ASCE(American Society of Civil Engineers)	
Date: 2000	USA
Reference Web: http://www.pubs.asce.org/WWWdisplay.cgi?9203030	

【047】

ASCE Manual 72	Power System

“Guide for Design of Steel Transmission Pole Structures”	
Design of Steel Pole Transmission Structures, ASCE Manual No. 72, provides a uniform basis for the design and fabrication of steel pole structures. This revised and updated version of the 1978 ASCE publication is necessary due to the many new manufacturing methods and improvements in design technology that have developed over the years. These changes are incorporated into the various sections of the manual. The volume begins with a discussion of the initial design considerations involved in such projects. It then goes on to explore such subjects as design methods, suitable materials, load tests, assembly and erection, quality assurance, and foundations. Included in this manual is a glossary of terms and an appendix with design examples.	
Publisher: ASCE(American Society of Civil Engineers)	
Date: 1990	USA
Reference Web: http://www.pubs.asce.org/BOOKdisplay.cgi?9002926	

【048】

ASCE Manual 74	Power System
“Guidelines for Electrical Transmission Line Structural Loading”	
This manual presents detailed guidelines and procedures for developing transmission line structure loads. It is divided into four sections. The first section is concerned with the load/strength design format. It introduces a reliability-based design methodology that forms the framework for the loading guidelines. A load and resistance factor design (LRFD) format is presented for the design of any transmission structure. The nature and variability of loads are given along with detailed procedures for the selection of the load and resistance factors. The next section discusses weather related loads. It gives specific procedures and formulas for determining weather related loadings on transmission line structures that can be used in the reliability-based design methodology described in section one. The third part presents a detailed discussion on special loadings such as longitudinal loads, construction and maintenance loads, line galloping, and structure vibration.	

The final section provides a detailed numerical example of the loading computations based on the procedures given in this guide.
Publisher: ASCE(American Society of Civil Engineers)

Date: 2003	USA
Reference Web: http://www.pubs.asce.org/BOOKdisplay.cgi?9990528	

【049】

ASCE Manual 91	Power System
"Design of Guyed Electrical Transmission Structures"	
This new document covers many aspects of the design of guyed structures, from simple wood poles to more complex latticed towers.	
Publisher: ASCE(American Society of Civil Engineers)	
Date: 1997	USA
Reference Web: http://www.pubs.asce.org/BOOKdisplay.cgi?9705366	

【050】

RUS Bulletin 1724e-200	Power System
"Design Manual for High Voltage Transmission Lines"	
The primary purpose of this bulletin is to furnish engineering information for use in designing wood-type transmission lines for voltages 230 kV and below. Good line design should result in high continuity of service, long life of physical equipment, low maintenance costs, safe operation and acceptability from an environmental standpoint.	
Publisher: RUS (USDA Rural Utilities Service)	
Date: 09-1992	USA
Reference Web: http://www.usda.gov/rus/electric/regs/index.htm	

【051】

IEEE-691	Power System
“Guide for Transmission Structure Foundation Design and Testing”	
Pertains to the design of foundations for conventional transmission line structures, which include lattice towers, single or multiple shaft poles, H-frame structures, and anchors for guyed structures. It discusses the mode of loads which those structures impose on their foundations and applicable foundation performance criteria.	
Publisher: IEEE (Institute of Electrical and Electronics Engineers)	
Date: 2000	USA
Reference Web: http://www.ieee.org/portal/index.jsp	

【052】

ANSI/TIA 222-F-1996	Power System
“Structural Standards For Steel Antenna Towers And Supporting Structures”	
The objective of this document is to provide minimum criteria for specifying and designing steel antenna towers and antenna supporting structures. This Standard is not intended to supersede applicable codes. The information contained in this Standard was obtained from sources as referenced and noted herein and represents, in the judgement of the subcommittee, the accepted industry practices for minimum standards for the design of steel antenna supporting structures. This document contains a county by county listing of minimum basic wind speeds, as well as, a commentary on ice and other design criteria. It is for general information only.	
Publisher: TIA (Telecommunications Industry Association)	
Date: 01-03-1996	USA
Reference Web: http://www.tiaonline.org/standards/search_n_order.cfm	

【053】

RUS 160-2	Power System
"Mechanical Design Manual for Overhead Distribution Lines"	
RUS Bulletin 160-2 "Mechanical Design Manual for Overhead Distribution Lines" (1982) is being re-written as the following four technical guide bulletins. These bulletins are being published by RUS. (Upon completion of these bulletins, Bulletin 160-2 will be rescinded.) RUS Bulletin 1724E-153, "Electric Distribution Guys and Anchors." This project is complete and has been published by RUS New RUS Bulletin 1724E-152, "The Mechanics of Overhead Distribution Line Conductors." This project is virtually completed. We are awaiting final RUS approvals, signatures and publication. New RUS Bulletin 1724E-150, "Loading on Wood Distribution Poles." The first draft of this new bulletin is nearly completed; however, the author has encountered computer software problems that have delayed completion. It is hoped that a draft will be completed and ready for comments later this year. New RUS Bulletin 1724E-151, "Mechanical Loading on Distribution Crossarms." The first draft of this bulletin has been written and routed for comments.	
Publisher: RUS (Rural Utilities Service)	
Date: 1982	USA
Reference Web: http://www.usda.gov/rus/electric/index.htm	

【054】

GB 50054—95	Power System
"Code for design of distribution line and low voltage installations"	
Publisher: GB (China Standard)	

Date: 1994	China
Reference Web: http://www.cssn.net.cn/	

【055】

SP1126-TBR	Power System
“2002 National Electrical Code(R) (NEC) Handbook”	
Written by the professionals who publish the NEC, the NEC Handbook is the official “user’s Guide” to the NEC . Packed with powerful information, it pulls together the extra facts, figures and explanations you need to interpret the Code and apply it to real situations. The Handbook contains the entire text of the new NEC plus commentary, examples, diagrams and illustrations that clarify requirements. This edition also contains a new easy-to-use index that references article numbers to be consistent with the Code.	
Publisher: IEEE-NEC	
Date: 2002	USA
Reference Web: http://shop.ieee.org/store/product.asp?prodno=SP1126	

【056】

ANSI/IEEE standards C57.94, C37.81 & 344-I 987 UL standard 1591	Power System
Several ANSI/IEEE standards apply to installing dry-type transformers. Standard C57.94 is the general standard, Standard 344-I 987 deals with seismic issues, and C37.81 covers seismic capabilities of equipment in nuclear plants. UL has standard 1591 for the installation of dry-type transformers.	
Publisher: IEEE	

Date: 1987	USA
Reference Web: http://shop.ieee.org/store/	

【057】

IEC 60068-3-3 (1991) **ICS codes: 19.040** **JIS C 0055:2000**	Power Equipment
"Environmental Testing Part 3: Guidance Seismic Test Methods for Equipments"	
Guidance is included in each of the three test methods referred to in this standard but it is specific to the test method. The guidance in this standard is directed towards choosing the appropriate test method and applying it to seismic testing.	
Publisher: IEC (International Electrotechnical Commission)	
Date: 1993	International, Japan
Reference Web: http://www.iec.ch/	

【058】

IEC 61587-2 **ICS codes: 31.240**	Power Equipment
"Mechanical structures for electronic equipment - Tests for IEC 60917 and IEC 60297 - Part 2: Seismic tests for cabinets and racks"	
Specifies seismic requirements for cabinets or racks as defined in the IEC 60917 and IEC 60297 series. Ensures physical integrity and environmental performance in mechanical cabinets or racks, taking into account the need for different levels of performance in different applications and geographical regions. This part of IEC 61587 specifies seismic requirements for cabinets or racks as defined in the IEC 60917 and IEC 60297 series. It applies, in whole or in part, only to the mechanical structures of cabinets or racks for electronic equipment, according to the IEC 60297 and the IEC 60917 series, and does not apply to	

electronic equipment or systems within the mechanical structures.
Publisher: IEC (International Electrotechnical Commission)

Date: 21-12-2000	International

Reference Web: http://www.iec.ch/

【059】

ICBO-AC 184	Power Equipment

Acceptance Criteria for Attachment Devices for Recessed Lighting Fixtures (Luminaries) in Suspended Ceiling Systems
The purpose of this criteria is to establish requirements for attachment devices, recognized in ICBO Evaluation Service, Inc. (ICBO ES), evaluation reports, that are used to attach recessed lighting fixtures (luminaires) to suspended ceiling systems under Part III of UBC Standard 25-2, in the 1997 *Uniform Building Code*™ (UBC), and under CISCA 3-4-91 as referenced in Section 1621.2.5.2.2 of the 2000 *International Building Code*® (IBC). The attachment devices are used to provide positive attachment of the lighting fixtures to the suspended ceiling framing as required by Section 25.213 of UBC Standard 25-2 and CISCA 3-4-91.
Publisher: ICBO EVALUATION SERVICE, INC.

Date: 09-2002	USA

Reference Web:http://www.icc-es.org/Criteria/pdf/ac184.pdf

【060】

GB 50260—96	Power Equipment

“Code for design of seismic of electrical installations”
Publisher: GB (China Standard)

Date: 1996	China
Reference Web: http://www.cssn.net.cn/	

【061】

SL 203—97	Hydraulic power
"Code for seismic design of hydraulic engineering"	
Publisher: GB (China Standard)	
Date: 1997	China
Reference Web: http://www.cssn.net.cn/	

【062】

Guideline	Hydraulic power
"CDA Dam Safety Guidelines"	
To define requirements and outline guidelines so that the safety of existing dams can be evaluated in a consistent and adequate manner across Canada, and new dams can be designed and constructed to be safe To enable the consistent evaluation of dam safety deficiencies leading to the construction of improvements which contribute to dam safety To provide a basis for dam safety legislation and regulation	
Publisher: The Canadian Dam Association	
Date: 01-1999	Canada
Reference Web: http://www.cda.ca/	

Nuclear Power Plants and the codes

Nuclear power plants are the most highly regulated facilities for seismic design throughout the United States. The seismic acceptance and performance criteria are subject to change, and are under the jurisdiction of the Nuclear Regulatory Commission (NRC). In general, equipment is designed for functionality if it has safety implications for the shutdown of the facility. Functionality requirements are often satisfied by shake table testing of the specific equipment items prior to installation. Requalification may be done by other methods, such as the use of seismic experience data.

【063】

ANSI/ANS 2.10-2003	Nuclear Facility
"Criteria for the Handling and Initial Evaluation of Records from Nuclear Power Plant Seismic Instrumentation"	
This standard provides criteria for the timely retrieval and the subsequent processing, handling and storage of data obtained from seismic instrumentation specified in ANS-2.2. Also included are initial evaluation criteria to determine whether earthquake motion at the site has exceeded the plant's operating basis earthquake ground motion (OBE).	
Publisher: ANS (American Nuclear Society)	
Date: 4-14-2003	USA
Reference Web: http://store.ans.org/	

【064】

BSR/ANS 2.26-200x	Nuclear Facility
"Categorization of Nuclear Facility Structures, Systems and Components for Seismic Design"	

Provides: (i) criteria and guidelines for selecting an SSC Limit State based on its safety and performance requirements and (ii) criteria for selecting the Seismic Design Category (SDC) for nuclear facility structures, systems, and components (SSCs) for the purpose of designing SSCs to withstand earthquakes using methods specified in ASCE XX. The standard outlines the essential facility data and safety analyses necessary to support the seismic design categorization process. The SSC seismic design categories that this standard establishes shall be used by the facility owner and the facility designer, in conjunction with ANS 2.27, Guidelines for Investigations of Nuclear Facility Sites for Seismic Hazard Analysis, ANS 2.29 Probabilistic Seismic Hazards Analysis, and American Society of Civil Engineers standard ASCE XX, Seismic design Criteria for Structures and Seismic Input for Systems and Components in Nuclear Facilities. Application of these standards will produce: (i) the design basis earthquake response spectra; (ii) SSC Limit State necessary to achieve adequate safety performance during and following earthquakes; and (iii) SSC designs that achieve the desired Limit States.
Publisher: ANS (American Nuclear Society)

Date: In DevelopmentReview End Date: 7/7/2003	USA
Reference Web: http://store.ans.org/	

【065】

IEC 60980 ICS codes: 27.120.10, 27.120.20	Nuclear Facility
"Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations" Edition: 1.0	
Publisher: IEC(International Electrotechnical Commission)	

Date: 15-06-1989	USA
Reference Web: http://www.iec.ch/	

【066】

IEEE 344-1987(R1993) ANSI/IEEE 344-1987	Nuclear Facility
"IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations"	
1987 Recommended practices for establishing procedures that will yield data that verify that the Class 1E equipment can meet its performance requirements during and following one safe shutdown earthquake preceded by a number of operating-basis earthquakes are provided. This recommended practice may be used to establish tests or analyses that will yield data to substantiate performance claims or to evaluate and verify performance of representative devices and assemblies as part of an overall qualification effort. Two approaches to seismic analysis are described, one based on dynamic analysis and the other on static coefficient analysis. Common methods currently in use for seismic qualification by test are presented. (R1993)	
Publisher: IEEE (Institute of Electrical and Electronics Engineers)	
Date: 01-01-1987, 01-05-1987	USA
Reference Web: http://shop.ieee.org/store/	

【067】

ISO 6258 **ICS 27.120.20**	Nuclear Facility
"Nuclear power plants -- Design against seismic hazards"	
Specifies the requirements for designing and the data required and the way in which they should be used in order to determine the earth motions to be taken as the design basis earthquake (DBE), moreover the way in which the proof of	

seismic design adequacy should be established and documented. Determination of DBE is covered by both probabilistic and deterministic methods. Is entirely applicable when the DBE is greater than or equal to intensity VII on the MSK scale. When the DBE is less, the structural analysis could also be performed by using simpler rules.
Publisher: ISO

Date: 01-02-1985	USA
Reference Web: http://www.iso.ch/iso/en/ISOOnline.frontpage	

【068】

Regulatory Guide 1.165	Nuclear Facility
Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion	
This guide has been developed to provide general guidance on procedures acceptable to the NRC staff for (1) conducting geological, geophysical, seismological, and geotechnical investigations, (2) identifying and characterizing seismic sources, (3) conducting probabilistic seismic hazard analyses, and (4) determining the SSE for satisfying the requirements of 10 CFR 100.23 This guide contains several appendices that address the objectives stated above. Appendix A contains a list of definitions of pertinent terms. Appendix B describes the procedure used to determine the reference probability for the SSE exceedance level that is acceptable to the staff. Appendix C discusses the development of a seismic hazard information base and the determination of the probabilistic ground motion level and controlling earthquakes. Appendix D discusses site-specific geological, seismological, and geophysical investigations. Appendix E describes a method to confirm the adequacy of existing seismic sources and source parameters as the basis for determining the SSE for a site. Appendix F describes procedures to determine the SSE.	
Publisher: U.S. Nuclear Regulatory Commission	
Date: 03-1997	USA

Reference Web: http://store.ans.org/

【069】

Regulatory Guide 1.12	Nuclear Facility
"Nuclear Power Plant Instrumentation For Earthquakes" Rev.2	
In 10 CFR Part 20, "Standards for Protection Against Radiation," licensees are required to make every reasonable effort to maintain radiation exposures as low as is reasonably achievable. Paragraph IV(a)(4) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that suitable instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly after an earthquake. Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 requires shutdown of the nuclear power plant if vibratory ground motion exceeding that of the operating basis earthquake ground motion (OBE) occurs.	
Publisher: U.S. Nuclear Regulatory Commission	
Date: 03-1997	USA
Reference Web: http://store.ans.org/	

【070】

Regulatory Guide 1.166	Nuclear Facility
"Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions"	
When an earthquake occurs, ground motion data are recorded by the seismic instrumentation.[1] These data are used to make a rapid determination of the degree of severity of the seismic event. The data from the nuclear power plant's free-field seismic instrumentation, coupled with information obtained from a plant walkdown, are used to make the initial determination of whether the plant must be shut down, if it has not already been shut down by operational	

perturbationsresulting from the seismic event. If on the basis of these initial evaluations (instrumentation data and walkdown) it is concluded that the plant shutdown criteria have not been exceeded, it is presumed that the plant will not be shut down (or could restart following a post-trip review, if it tripped off-line because of the earthquake). Guidance on postshutdown inspections and plant restart is contained in Regulatory Guide 1.167, "Restart of a Nuclear Power Plant Shut Down by a Seismic Event."
Publisher: U.S. Nuclear Regulatory Commission
Date: 03-1997 | USA
Reference Web: http://store.ans.org/

【071】

Regulatory Guide 1.61	Nuclear Facility
“Damping Values for Seismic Design of Nuclear Power Plants”	
Criterion 2, "Design Bases for Protection Against Natural Phenomena," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires, in part, that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of earthquakes. Proposed Appendix A, "Seismic and Geologic Siting Criteria," to 10 CFR Part 100, "Reactor Site Criteria," would require, in part, that suitable seismic dynamic analysis, such as a time-history or spectral response analysis, be performed to demonstrate that the structures, systems, and components important to safety will remain functional in the event of a Safe Shutdown Earthquake (5SF). This guide delineates damping values acceptable to the AEC Regulatory staff to be used in the elastic modal dynamic seismic analysis of Seismic Category I[1] structures, systems, and components. The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.	
Publisher: U.S. Nuclear Regulatory Commission	
Date: 03-1997	USA

Reference Web: http://store.ans.org/

【072】

Regulatory Guide 1.122	Nuclear Facility
"Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components" Rev. 1	
Nuclear facility structures can he approximated by mathematical models to permit analysis of responses to earthquake motions. Because of the large number of degrees of freedom that would be necessary and the possible ill-conditioning of the resulting stiffness matrix if the complete plant were treated in a single mathematical model. the plant is usually divided into several separate systems for analysis purposes. Thus it is usual that there are one or more mathematical models of supporting structures. Each supporting structure normally supports one or more systems or pieces of equipment. Also, different models of the same structure may be required for different purposes. For these reasons, the mathematical models used to generate the seismic excitation data for subsequent separate analyses of supported systems or equipment may not be suitable for the detailed localized analyses of the supporting structure.	
Publisher: U.S. Nuclear Regulatory Commission	
Date: 02-1978	USA
Reference Web: http://store.ans.org/	

【073】

Regulatory Guide 1.132	Nuclear Facility
"Site Investigations for Foundations of Nuclear Power Plants"	
This guide describes programs of site investigations that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundations and earthworks under most anticipated loading conditions, including earthquakes. It also describes site investigations required to	

evaluate geotechnical parameters needed for engineering analysis and design. The site investigations discussed in this guide are applicable to both land and offshore sites. This guide does not discuss detailed geologic fault investigations required under Appendix A to 10 CFR Part 100, nor does it deal with hydrologic investigations except for groundwater measurements. This guide provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, the spacing and depth of borings, and sampling. Because the depth of the actual site investigations program will be highly site dependent, the procedures described herein should be used only as guidance and should be tempered with professional judgment. Alternative and special investigative procedures that have been derived in a professional manner will be considered equally applicable for conducting foundation investigations.

Publisher: U.S. Nuclear Regulatory Commission	
Date: 03-1979	USA
Reference Web: http://store.ans.org/	

【074】

Regulatory Guide 1.142	Nuclear Facility
"Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)" Rev. 2	
This regulatory guide has been revised to provide guidance to licensees and applicants on methods acceptable to the NRC staff for complying with the NRC's regulations in the design, evaluation, and quality assurance of safety-related nuclear concrete structures, excluding concrete reactor vessels and concrete containments.	
Publisher: U.S. Nuclear Regulatory Commission	
Date: 11-2001	USA
Reference Web: http://store.ans.org/	

【075】

Regulatory Guide 4.7	Nuclear Facility
"General Site Suitability Criteria for Nuclear Power Stations" Rev. 2	
Nuclear power stations must be designed to prevent the loss of safety-related functions. Generally, the most restrictive safety-related site characteristics considered in determining the suitability of a site are surface faulting, potential ground motion and foundation conditions (including liquefaction, subsidence, and landslide potential), and seismically induced floods. Criteria that describe the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability have been set forth in 10 CFR Part 100, "Reactor Site Criteria," in Section 100.23, "Geologic and Seismic Siting Criteria" (59 FR 52255). Safety-related site characteristics are identified in Section 2.5 of Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," and Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants." In addition to geologic and seismic evaluation for assessing seismically induced flooding potential, Section 2.4 of Regulatory Guide 1.70 and Regulatory Guide 1.59 describe hydrologic criteria, including coincident flood events that should be considered.	
Publisher: U.S. Nuclear Regulatory Commission	
Date: 04-1998	USA
Reference Web: http://store.ans.org/	

【076】

Regulatory Guide 1.167	Nuclear Facility
"Restart of a Nuclear Power Plant Shut Down by a Seismic Event"	
This guide provides guidance acceptable to the NRC staff for performing inspections and tests of nuclear power plant equipment and structures prior to	

restart of a plant that has been shut down by a seismic event.	
Publisher: U.S. Nuclear Regulatory Commission	
Date: 03-1997	USA
Reference Web: http://store.ans.org/	

【077】

DG-3021	Nuclear Facility
"SITE EVALUATIONS AND DETERMINATION OF DESIGN EARTHQUAKE GROUND MOTION FOR SEISMIC DESIGN OF INDEPENDENT SPENT FUEL STORAGE INSTALLATIONS AND MONITORED RETRIEVABLE STORAGE INSTALLATIONS"	
This guide is being developed to provide general guidance on procedures acceptable to the NRC staff for (1) conducting a detailed evaluation of site area geology and foundation stability, (2) conducting investigations to identify and characterize uncertainty in seismic sources in the site region important for the PSHA, (3) evaluating and characterizing uncertainty in the parameters of seismic sources, (4) conducting PSHA for the site, and (5) determining the DE to satisfy the requirements of 10 CFR Part 72. This guide contains several appendices that address the objectives stated above. Appendix A contains definitions of pertinent terms. Appendix B describes the rationale used to determine the reference probability for the DE exceedance level that is acceptable to the staff. Appendix C discusses determination of the probabilistic ground motion level and controlling earthquakes and the development of a seismic hazard information base, Appendix D discusses site-specific geological, seismological, and geophysical investigations. Appendix E describes a method to confirm the adequacy of existing seismic sources and source parameters as the basis for determining the DE for a site. Appendix F describes procedures for determination of the DE.	
Publisher: U.S. Nuclear Regulatory Commission	
Date: 07-2002	USA

Reference Web: http://store.ans.org/

【078】

CAN3 N289.1-80 (R1998)	Nuclear Facility
"General Requirements for Seismic Qualification of CANDU Nuclear Power Plants"	
This Standard sets forth the general requirements for seismic qualification of CANDU Nuclear Power Plants. ,, It applies to all structures and systems of the CANDU Nuclear Power Plant that require seismic qualification based on nuclear safety considerations. This Standard may also be applied to such other structures and systems of a nuclear power plant as may be specified by the Owner, for reasons of economic concern or to meet additional requirements of the AECB. This will generally impose more restrictive design requirements than those of the National Building Code of Canada (NBCC). In any case, such other structures and systems shall be designed to meet at least the requirements of the NBCC, in order to ensure a minimum degree of resistance against collapse or failure, to mitigate the effects of earthquakes on nearby safety-related structures or systems. Certain clauses may be applied, as appropriate, to research reactors or other nuclear facilities coming within the jurisdiction of the Atomic Energy Control Act, e.g., heavy water plants and waste management disposal facilities.	
Publisher: Canada National Standard	
Date: 1998	Canada
Reference Web: http://www.csa.ca/	

【079】

CAN3 N289.2-M81 (R1998)	Nuclear Facility
"Ground Motion Determination for Seismic Qualification of CANDU Nuclear Power Plants"	

This Standard describes the investigations required to obtain the seismological and geological information necessary to determine, for a proposed CANDU nuclear power plant site, the seismic ground motion that will be utilized in seismic qualification of safety-related plant structures and systems, and the potential for seismically induced phenomena that may have a direct or indirect effect on plant safety or operation. Note: In this edition of the Standard a procedure for the determination of design seismic ground motion is described that differs in some details from procedures described in similar guides and codes of other countries. The recommended procedures described in Appendix A may be replaced by other procedures, provided they are based on an equivalent interpretation of the seismotectonics of the region and provided they present all of the appropriate information on the basis of which an independent estimate of the conservatism associated with the derived seismic ground motion can be made.
Publisher: Canada National Standard
Date: 1998 / Canada
Reference Web: http://www.csa.ca/

【080】

CAN3 N289.3-M81 (R1998)	Nuclear Facility
"Design Procedures for Seismic Qualification of CANDU Nuclear Power Plants"	
This Standard applies to those structures and components in CANDU nuclear power plants which require seismic qualification by analytical methods (see CSA Standard CAN3-N289.1, General Requirements for Seismic Qualification of CANDU Nuclear Power Plants). This Standard specifies the requirements, criteria, and methods for: (a) Determining the DBE or SDE ground response spectra and ground motion time-histories from the seismic ground motion parameters obtained from CSA Standard CAN3-N289.2, Ground Motion Determination for Seismic Qualification of CANDU Nuclear Power Plants; (b) Performing acceptable	

seismic analyses, including the effects of the foundation medium; (c) Establishing design criteria for structures, components, and supports that require seismic qualification.

Publisher: Canada National Standard	
Date: 1998	Canada
Reference Web: http://www.csa.ca/	

【081】

CAN/CSA N289.5-M91 (R1998)	Nuclear Facility
"Seismic Instrumentation Requirements for CANDU Nuclear Power Plants	
This Standard outlines the requirements for seismic instrumentation systems for nuclear power plants where site- specific seismic responses are required to be determined and recorded.	
Publisher: Canada National Standard	
Date: 1998	Canada
Reference Web: http://www.csa.ca/	

【082】

CAN3 N289.4-M86 (R1998)	Nuclear Facility
"Testing Procedures for Seismic Qualification of CANDU Nuclear Power Plants"	
This Standard defines the consideration and requirements for performing an acceptable seismic qualification test and presents the different test methods that may be used. Note: Selected safety related systems are required to be seismically qualified. (See CSA Standard CAN3-N289.1.) Qualification may be by analysis or testing, or a combination thereof, depending on the nature and complexity of the equipment. CSA Standard CAN3-N289.3 specifies methods of qualification	

by analysis. This Standard is intended to provide a basis for developing specifications for seismic qualification by testing, and to aid equipment purchasers, suppliers, and testing laboratories in selecting the appropriate test methods for performing a seismic qualification test. This Standard presents several acceptable methods with the intent of permitting the user to make a judicious selection from among the various options. In making such a selection, the user of this Standard should choose those test methods which best reco gnize the characteristics of a particular piece of equipment. Note: It should be recognized that seismic qualification forms only a portion of the overall equipment qualification program. It is important that the qualification program for a component include consideration of all operational loadings (seismic, environmental, aging, thermal, and mechanical stresses, etc) for which the component must demonstrably meet its performance objectives.
Publisher: Canada National Standard

Date: 1998	Canada
Reference Web: http://www.csa.ca/	

【083】

GB 50267—97	Nuclear Facility
"Code for seismic design of nuclear power plants"	
Publisher: GB (China Standard)	
Date: 1997	China
Reference Web: http://www.cssn.net.cn/	

【084】

CNS 14372 J1012	Nuclear Facility

"General rules for seismic qualification of nuclear safety grade electrical equipment"	
General testing principles for analyzing electrical equipments in nuclear power plant to evaluate that system can maintain normal operation under seismic environment.	
Publisher: CNS(Chinese National Standard)	
Date: 08-1999	Chinese Taipei
Reference Web: http://www.cnsppa.com.tw/	

【085】

ASCE 4-98	Nuclear Facility
"Seismic Analysis of Safety-Related Nuclear Structures"	
This standard provides requirements for performing analyses of new structure design or existing structure evaluation to determine the reliability of structures under earthquake motions. Rules and analysis parameters that are expected to produce seismic responses with about the same probability of non-exceedance as the input are outlined. Specifications of input motions are provided. Analysis standards are given for: Modeling of structures; Analysis of structures; Soil-structure interaction modeling and analysis; Input for subsystem seismic analysis; and Special structures such as buried pipes and conduits, earth-retaining walls, above-ground vertical tanks, raceways, and seismic-isolated structures. Additionally, non-mandatory Appendix A provides a discussion on Seismic Probabilistic Risk Assessments and Seismic Margin Assessments.	
Publisher: ASCE	
Date: 01-01-2000	USA
Reference Web: http://www.pubs.asce.org/WWWdisplay.cgi?0002398	

Chapter 6 Oil Refinery Systems and Gas System

Oil Refineries and Chemical Plants

Most equipment and systems in petrochemical facilities are designed to the minimum standards of seismic provisions included in model codes, such as the UBC or IBC. Many of the specific designs may also be addressed by industry specific standards, especially those covered by the American Petroleum Institute (API). The typical design approach includes the following features and considerations:

5. Design for a single level of earthquake hazard with a low probability of occurrence (e.g., 500-year return period).
6. Design on a component-by-component basis. Redundancy may be added to equipment systems (e.g., spare pumps) but typically for reasons other than seismic concerns.
7. Design commonly addresses only anchorage of permanently fixed equipment and structural design of equipment support structures (e.g., support frames for elevated vessels).
8. Process piping typically designed for pressure loads using applicable American National Standards Institute (ANSI) codes, and may include seismic assessment.
9. Equipment not purchased with specifications for functionality during or after an earthquake.
10. Temporary and portable equipment often not restrained. Aware owners and tenants may use nonengineered restraints for temporary and portable equipment and items that could fall (e.g., bolting bookshelves to walls).
11. Equipment vulnerabilities not specifically covered by codes unlikely to be considered in design.
12. Equipment vulnerabilities can be introduced during the life of a refinery or chemical plant, such as when routine or emergency maintenance is performed or when equipment is overhauled during turnarounds.
13. Steel often subject to corrosion due to presence of chemicals. This may also happen to steel reinforcing within concrete structures.
14. Once built, usually never required to be upgraded to current code requirements.

Typically considered as “grandfathered.” Some jurisdictions may require reassessments as part of environmental evaluations for toxic releases. In reality, earthquakes are often considered a “minor” hazard in petrochemical facilities, relative to day-to-day operational risks that must be addressed.

Offshore Oil Platforms

The entire design process for offshore oil platforms is different than for other facilities. The specific design is typically addressed by industry-specific standards, such as those issued by Det norske Veritas (DnV) in Norway, the United Kingdom Health and Safety Executive (HSE), or the American Petroleum Institute (API) in the United States. Numerous platforms have been installed in seismic regions offshore California and Alaska, and the design and evaluation methods used by API are fairly mature. Platforms are now being built in other seismic regions of the world, such as the Caspian Sea, Sakhalin Island, Russia, Trinidad, and Indonesia.

The following features and considerations are incorporated into typical design using API criteria:

1. Definition of seismic hazards using site-specific hazards assessments.
2. Design for two levels of earthquake hazard. Design for little or no damage in an earthquake with a reasonable probability of occurrence within the lifetime of the platform. This earthquake, called the strength level earthquake (SLE), is typically a 200-year return period for offshore California.
3. Design for overall structural stability in a rare, intense earthquake. This ductility level earthquake (DLE) considers only overall collapse modes of the platform or equipment systems, and is typically based on earthquake return periods of 1000 to several thousand years.
4. Offshore platform structures are typically designed for the SLE, and checked for the DLE. The SLE analysis is typically a response spectrum analysis, while the DLE is a nonlinear time history analysis, checking for overall platform stability.
5. Process equipment on the deck of the platform is typically designed for only the SLE event. Lower allowable stress values are used in lieu of performing explicit ductility checks.
6. Current seismic design criteria for offshore platforms, as proposed in draft ISO standards, select a DLE event to achieve a target probability of failure. The SLE is then selected based on the expected reserve capacity of the platform and the ductility demand in order to achieve a cost-effective design.
7. Design may be governed by other significant loads, such as transportation.
8. Design of process equipment on a component-by-component basis. Redundancy

is typically not added to equipment systems (e.g., spare pumps) to address seismic concerns but may be included for other reasons.

9. Design of equipment commonly addresses only anchorage of permanently fixed equipment and structural design of equipment support structures (e.g., support frames for elevated vessels).
10. Process piping typically designed for pressure loads using applicable ANSI codes and may include seismic assessment.
11. Equipment not purchased with specifications for functionality during or after an earthquake.

Pipelines

Buried pipelines are designed primarily to resist the effects of permanent ground deformation (PGD) caused by major earthquakes, rather than the effects of ground shaking. PGD effects include liquefaction, spreading, and fault crossings. The pipelines are designed using strain-based criteria, with inelastic behavior allowed.

LNG Facilities

LNG facilities are typically designed using the criteria of NFPA 59A. These criteria require a two-level earthquake approach for essential systems. No damage should occur and functionality should be maintained for the operating basis earthquake (OBE). The OBE uses a return period similar to onshore building codes like the IBC and UBC.

The safe shutdown earthquake (SSE) is defined as an earthquake with a return period of up to 5000 years. The system is designed for no loss of containment, with the structural design controlled by using stress limits.

Existed Codes on Oil and Gas systems

【086】

ASCE 40264	Petrochemical Facility
"Guidelines for Seismic Evaluation and Design of Petrochemical Facilities"	
These guidelines are intended to provide practical recommendations on several areas, which affect the safety of a petrochemical facility during and following an earthquake. In the area of new design, these guidelines emphasize interpretations of the intent of building codes as applied to petrochemical facilities, and practical guidance on design details and considerations, which are not included in building codes. For existing facilities, these guidelines provide evaluation methodologies, which rely heavily on experience from past earthquakes, coupled with focused analyses. The guidelines emphasize methods to address seismic vulnerabilities which are not covered by building codes, but which can be identified by experienced engineers. This document also provides background information and recommendations in several areas related to seismic safety where the civil engineer may be interacting with other disciplines and with plant operations. These areas include seismic hazards, contingency planning, and post-earthquake damage assessment.	
Publisher: ASCE (American Society of Civil Engineers)	
Date: 01-01-1997	USA
Reference Web: http://www.pubs.asce.org/BOOKdisplay.cgi?9704517	

【087】

ASME/ANSI B31.3	Petrochemical Facility
"Chemical Plant and Petroleum Refinery Piping"	
This standard considers the type of piping typically found in petroleum refineries, chemical plants, pharmaceutical plants, textile works, paper manufacturers, semiconductor plants, cryogenic plants and other related	

processing plants and terminals. The standard presents the requirements for pressure piping systems in terms of : materials and components (including dimensional requirements and pressure-temperature ratings); design of components and assemblies, including piping supports; requirements and data for evaluation and limitation of stresses, reactions and movements associated with pressure, temperature changes and other forces; limitations on the selection of materials, components and jointing methods; requirements for fabrication, assembly and erection of piping; requirements for examination, inspection and testing
Publisher: ASME (American Society of Mechanical Engineers)

Date: 2002	USA
Reference Web: http://www.asme.org/	

【088】

AWWA D100 [ANSI/AWWA D100-96]	Petrochemical Facility
"Welded Steel Tanks For Water Storage"	
The purpose of this standard is to provide guidance to facilitate the design, manufacture, and procurement of welded steel tanks for the storage of water. This standard does not cover all details of design and construction because of the large variety of sizes and shapes of tanks. Where details for any specific design are not given, it is intended that the constructor, subject to the approval of the purchaser, shall provide details that are designed and constructed to be adequate and as safe as those that would otherwise be provided under this standard. This standard does not cover concrete steel composite tank construction. Section 1 covers general topics such as scope, definitions, guarantee, drawings to be furnished, and references. Section 2 discusses material specifications. Section 3 details general design. Section 4 addresses the sizing and design of elevated tanks. Accessories for elevated tanks are discussed in Section 5. Section 6 covers sizing of ground supported standpipes and reservoirs. Accessories for ground supported standpipes and reservoirs are detailed in Section 7. Sections 8 through 15 include welding, shop fabrication, erection, inspection and testing, foundation	

design, seismic design of water storage tanks, alternative design basis for standpipes and reservoirs, and structurally supported aluminum dome roofs, respectively. The major revisions in this edition of ANSI/AWWA D100-96 include the following: Section 2 includes new data on the types and thicknesses of materials and their uses in tank construction. Section 3 has been extensively revised in the area of design load definitions, and the reference tables, figures and equations used in the design of welded steel tanks. Minimum plate thicknesses, roofs, anchor bolts, and flush-type cleanouts have been defined. The buckling requirements of conical and double-curved shells have been clarified. Section 4 clarifies the design of tension members carrying wind and seismic loads and steel risers. Updates of criteria for accessories including safety grills, overflows, and screening have been added to Sec. 5. Section 7 includes updates similar to those found in Sec. 5. Section 8, concerning the quality control of welders, welding operators, and welding inspectors, has been expanded to improve quality control during construction. Critical joint details, materials, and sizes of welds are also clarified. Section 10 has been revised to better define temperature limits for welding and limits of weld reinforcement.' Section 11 includes extensive changes concerning the inspection of welded joints. Tank shell, tubular support, columns, tension member bracing, and large diameter riser joints are discussed, and radiograph requirements have been revised. The penetrometer techniques and details have also been revised to conform to ASME criteria. Section 12 has minor changes, and Sec. 12.6 concerning foundations for flat bottom tanks has been revised. Section 13 covering seismic design has extensive revisions updating the methods to calculate forces and stresses. A new seismic map of the United States is included along with new and revised equations for calculating such things as hydrodynamic seismic hoop tensile stresses, and sloshing wave height to determine minimum freeboard. Appendix C of the previous edition has been incorporated into the standard as Sec. 14. Reference standards have been moved to Sec. 1. Electrode criteria and requirements for permanent and temporary attachment criteria have been revised. The type of inspection and number of weld joint inspections have also been updated for better quality control. A new Section 15, entitled Structurally Supported Aluminum Dome Roofs, has been added. It provides the purchaser with the flexibility to choose an alternative roof system.

The entire standard was reviewed carefully, and minor changes were made in many of the section to improve understanding and readability. Tabulated values and equations throughout this standard have been revised to include English and SI units of measurement. In the event of a discrepancy between the values, the English values shall govern.

Publisher: AWWD (The American Water Works Association)	
Date: 01-01-1996	USA
Reference Web: http://www.awwa.org/	

【089】

API 2508	Petrochemical Facility
"Design and Construction of Ethane & Ethylene Installations at Marine and Pipeline Terminals, Natural Gas Processing Plants, Refineries, Petrochemical Plants, and Tank Farms"	
Publisher: API (American Petroleum Institute)	
Date: 1995	USA
Reference Web: http://api-ep.api.org/publications/	

【090】

ISO/DIS 19901-2	Offshore Platform
"Petroleum and natural gas industries - Specific requirements for offshore structures - Part 2: Seismic design procedures and criteria" - DRAFT	
Publisher: ISO (International Organization for Standardization)/Draft International Standard	
Date: 01-04-2003	International

Reference Web: http://www.iso.ch/iso/en/ISOOnline.frontpage

【091】

API RP 14E	Offshore Platform
"DESIGN AND INSTALLATION OF OFFSHORE PRODUCTION PLATFORM PIPING SYSTEMS"	
API RP 14E has been and is extensively in use to establish flow velocities i.e. internal diameters of piping between equipments. This code is developed on the background of long experience from American Process Industry. The recommended velocities in this code are partly from experienced economical friction losses, and partly from experienced max velocity limits in order to prevent cavitation, erosion or noise problems.	
Publisher: API (American Petroleum Institute)	
Date: 1992	USA
Reference Web: http://api-ep.api.org/publications/	

【092】

API REPORT 79-25	Offshore Platform
"Inelastic Structural Modeling of Braced Offshore Platforms for Seismic Loading"	
Publisher: API (American Petroleum Institute)	
Date: 01-1981	USA
Reference Web: http://api-ep.api.org/publications/	

【093】

API REPORT 85-22	Offshore Platform

“Seismic Load Effects Study Addendum”	
Publisher: API (American Petroleum Institute)	
Date: 14-11-1985	USA
Reference Web: http://api-ep.api.org/publications/	

【094】

API REPORT 91-67	Offshore Platform
“Seismic Safety Requalification of Offshore Platforms”	
Publisher: API (American Petroleum Institute)	
Date: 05-1992	USA
Reference Web: http://api-ep.api.org/publications/	

【095】

CSLC	Oil Terminal
“Seismic Criteria For California Marine Oil Terminals”	
This document presents guidance on the seismic design of marine oil terminals. The California State Lands Commission (CSLC) has oversight of over sixty marine oil terminals, some of which are over eighty years old and built to unknown standards. Typically, they were built to resist minor earthquake intensity. New earthquake hazard information from recent events such as Loma Prieta (1989) and Northridge (1994) indicate that much higher intensities are possible. It is prudent that these facilities be evaluated and unsafe deficiencies corrected. The goals are to: Ensure safe and pollution-free transfer of petroleum products between the ship and land based facilities.	

Ensure the best achievable protection of the public health, safety and the environment Maximize the utilization of limited resources. This document develops and expands on work that was begun by the US Navy to provide seismic design criteria for waterfront construction. It presents criteria that are intended to define a minimum level of acceptable performance for marine oil terminals. As such it recognizes the need to protect the environment from oil spills, the need to provide for the transfer of required natural resources into the State and the economics of operating a commercial facility in a competitive environment.
Publisher: CSLC (California State Lands Commission)
Date: 12-04-1999 — USA
Reference Web: http://www.slc.ca.gov/Regulations/Regulations_Default.htm

【096】

NFESC, TR-2103-SHR	Oil Terminal
“Seismic design criteria for California marine oil terminals.”	
This document presents guidance on the seismic design of marine oil terminals. The California State Lands Commission (CSLC) has oversight of over sixty marine oil terminals, some of which are over eighty years old and built to unknown standards. Typically, they were built to resist minor earthquake intensity. New earthquake hazard information from recent events such as Loma Prieta (1989) and Northridge (1994) indicate that much higher intensities are possible. It is prudent that these facilities be evaluated and unsafe deficiencies corrected. The goals are to: (1) Ensure safe and pollution-free transfer of petroleum products between the ship and land based facilities. (2) Ensure the best achievable protection of the public health, safety and the environment. (3) Maximize the utilization of limited resources	
Publisher: Naval Facilities Engineering Service Center	
Date: 02-1999	USA

Reference Web: http://www.nfesc.navy.mil/pub_news/abstract.htm

【097】

ASCE 7-98 Guide	Oil Terminal
"Guide to the Use of the Wind Load Provisions of ASCE 7-98"	
Guide to the Use of the Wind Load Provisions of ASCE 7-98 walks practicing professionals through the complicated process of assessing wind loads on a variety of buildings and other structures as set forth in ASCE Standard 7-98. This revised guide addresses new developments in the wind load provisions of ASCE 7-98, including analytical procedures, simplified procedures, terrain exposures, and internal pressures. In order to clearly identify the scope and limitations of the Standard, Guide to the Use of Wind Load Provisions of ASCE 7-98 provides a brief review of the background material that forms the basis for the Standard's provisions. It includes a discussion of the general format of an analytical procedure used to determine wind loads and the various wind load parameters involved in this determination, such as velocity pressure, gust response factor, and pressure coefficients. Multiple examples using this analytical procedure to determine wind load are also included and worked out in detail. A section for Frequently Asked Questions is included to help professionals to interpret the provisions. Guide to the Use of Wind Load Provisions of ASCE 7-98 will assist structural engineers who design buildings and structures following the wind load provisions.	
Publisher: ASCE (American Society of Civil Engineers)	
Date: 01-Jan-1998	USA
Reference Web: http://www.pubs.asce.org/WWWdisplay.cgi?0108251	

【098】

NFPA 54, NFPA 54/ANSI A223.1, SGC, IFG	Fuel Gas Station
"National Fuel Gas Code" Edition: 2002	

Applies to the installation of fuel gas piping systems, fuel gas utilization equipment, and related accessories.
Publisher: NFPA
Date: 2002 | USA
Reference Web: http://www.nfpa.org/Codes/NFPA_Codes_and_Standards/List_of_NFPA_documents/NFPA_54.asp

【099】

JIS B8501	Oil Storage
"Welded Steel tanks for oil storage"	
Publisher: JISC	
Date: 1995	Japan
Reference Web: http://www.jisc.go.jp/app/pager?id=11823	

【100】

CNS 12937 ICS 23.020.10	Oil Storage
"Structure of Welded Steel Tanks for Petroleum Oil Storage"	
Publisher: CNS (Chinese National Standard)	
Date: 14-06-1996 rev.	Chinese Taipei
Reference Web: http://www.cnsppa.com.tw/	

【101】

API 1978 Proceedings -- Refining Dept, Vol. 57	Oil Storage
"Basis of Seismic Design Provisions for Welded Steel Oil Storage Tanks"	
Publisher: American Petroleum Institute	
Date: 1978	USA
Reference Web: http://api-ep.api.org/publications/	

【102】

GBJ 74—84	Oil Storage
"Code for design of oil storage"	
Publisher: GB (China Standard)	
Date: 1984	China
Reference Web: http://www.cssn.net.cn/	

【103】

Guideline	Oil Storage
"Seismic Design of Storage Tanks"	
The New Zealand Society for Earthquake Engineering (NZSEE) has a study group working on the seismic design of storage tanks. The study group is preparing a revision of the widely acknowledged NZSEE 1986 document "Seismic Design of Storage Tanks". Revision and re-publishing of the 1986 Red Book Recommendations for Seismic Design of Storage Tanks.	
Publisher: New Zealand National Society for Earthquake Engineering Inc	
Date: Drafting of the revised document is in progress	New Zealand

Reference Web: http://www.nzsee.org.nz/PUBS/pubs.html

【104】

NZS/BS 2654 **ICS Number 23.020.10**	Oil Storage
"Specification for manufacture of vertical steel welded non-refrigerated storage tanks with butt-welded shells for the petroleum industry"	
Specifies materials, design, fabrication, erection, inspection and testing of vertical cylindrical steel welded storage tanks for service temperature down to -10 degrees C. Requirements for both fixed and floating roof designs as well as internal floating covers are included along with tank insulation systems, design for seismic disturbances, selection of foundations etc.	
Publisher: NZS	
Date: 1989	New Zealand
Reference Web: http://shop.standards.co.nz/index.jsp	

【105】

API 620 **ANSI/API 620-2002**	Oil/Gas Storage
"Design and Construction of Large, Welded, Low-Pressure Storage Tanks, Tenth Edition"	
API Standard 620 covers the design and construction of large, welded, field-erected low-pressure carbon steel aboveground storage tanks (including flat-bottom tanks) with a single vertical axis of revolution. The rules presented in this standard cannot cover all details of design and construction because of the variety of tank sizes and shapes that may be constructed. Where complete rules for a specific design are not given, the intent is for the manufacturer-subject to the approval of the purchaser's authorized representative-to provide design and construction details that are as safe as those	

which would otherwise be provided by this standard. The tanks described in this standard are designed for metal temperatures not greater than 250 F and with pressures in their gas or vapor spaces not more than 15 pounds per square inch gauge. The basic rules in this standard provide for installation in areas where the lowest recorded one-day mean atmospheric temperature is -50 F. Appendix R covers low-pressure storage tanks for refrigerated products at temperatures from +40 F to -60 F. Appendix Q covers low-pressure storage tanks for liquefied hydrocarbon gases at temperatures not lower than -270 F. The rules in this standard are applicable to tanks that are intended to (a) hold or store liquids with gases or vapors above their surface or (b) hold or store gases or vapors alone. These rules do not apply to lift-type gas holders. Although the rules in this standard do not cover horizontal tanks, they are not intended to preclude the application of appropriate portions to the design and construction of horizontal tanks designed in accordance with good engineering practice. The details for horizontal tanks not covered by these rules shall be equally as safe as the design and construction details provided for the tank shapes that are expressly covered in this standard.
Publisher: API (American Petroleum Institute)
Date: 01-03-2002   USA
Reference Web: http://api-ep.api.org/publications/

【106】

API 650 [ANSI/API, 1995]	Oil/Gas Storage
"Welded Steel Tanks for Oil Storage" - Includes Addendum 1 and 2	
This standard is designed to provide the petroleum industry with tanks of adequate safety and reasonable economy for use in the storage of petroleum, petroleum products, and other liquid products commonly handled and stored by the various branches of the petroleum industry. It is intended to help purchasers and manufacturers in ordering, fabricating, and erecting tanks. Standard 650, Tenth Edition, covers material, design, fabrication, erection, and testing	

requirements for vertical, cylindrical, aboveground, closed- and open-top, welded steel storage tanks in various and capacities for internal pressures approximating atmospheric pressure, but a higher internal pressure is permitted when additional requirements are met. This standard applies only to tanks whose entire bottom is uniformly supported; and to tanks in nonrefrigerated service, that have a maximum operating temperature of 90 deg C (200 deg F). Includes addenda 1 (03/2000) and addenda 2 (11/2001).
Publisher: API (The American Petroleum Institute)

Date: 01-11-1998	USA
Reference Web: http://api-ep.api.org/publications/	

【107】

GB 50253—94	Oil Pipeline
"Design code for oil transportation pipeline engineering"	
Publisher: GB (China Standard)	
Date: 1994	China
Reference Web: http://www.cssn.net.cn/	

【108】

ASCE TCLEE	Oil/Gas Pipeline
"Guidelines for the Seismic Design of Oil and Gas Pipelines Systems, TCLEE Committee on Gas and Liquid Fuels"	
ASCE Technical Council on Lifeline Engineering (TCLEE) Earthquake Investigation Committee (EIC) members have participated in a number of lifeline earthquake investigations. Reports have been prepared on the performance of lifelines and published in ASCE publications (other than TCLEE Monographs), Earthquake Engineering Research Institute (EERI).	

Publisher: ASCE (American Society of Civil Engineers)	
Date: 1984	USA
Reference Web: http://www.pubs.asce.org/	

【109】

Guidelines	Oil/Gas Pipeline
"Guidelines for the Seismic Design of Oil and Gas Pipeline Systems"	
Publisher: ASCE (American Society of Civil Engineers)	
Date: 1991	USA
Reference Web: http://www.pubs.asce.org/	

【110】

ASME/ANSI B31.4	Oil/Gas Pipeline
"Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids"	
This Code prescribes requirements for the design, materials, construction, assembly, inspection, and testing of piping transporting liquids such as crude oil, condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, carbon dioxide, liquid alcohol, liquid anhydrous ammonia and liquid petroleum products between producers' lease facilities, tank farms, natural gas processing plants, refineries, stations, ammonia plants, terminals (marine, rail and truck) and other delivery and receiving points. Piping consists of pipe, flanges, bolting, gaskets, valves, relief devices, fittings and the pressure containing parts of other piping components. It also includes hangers and supports, and other equipment items necessary to prevent overstressing the pressure containing parts. It does not include support structures such as frames of buildings, buildings stanchions or foundations Requirements for offshore pipelines are found in Chapter IX. Also	

included within the scope of this Code are: (A) Primary and associated auxiliary liquid petroleum and liquid anhydrous ammonia piping at pipeline terminals (marine, rail and truck), tank farms, pump stations, pressure reducing stations and metering stations, including scraper traps, strainers, and prover loop; (B) Storage and working tanks including pipe-type storage fabricated from pipe and fittings, and piping interconnecting these facilities; (C) Liquid petroleum and liquid anhydrous ammonia piping located on property which has been set aside for such piping within petroleum refinery, natural gasoline, gas processing, ammonia, and bulk plants; (D) Those aspects of operation and maintenance of liquid pipeline systems relating to the safety and protection of the general public, operating company personnel, environment, property and the piping systems.
Publisher: ASME
Date: 2002 — USA
Reference Web: http://www.asme.org/

【111】

SYJ 4050—91	Oil/Gas Pipeline
"Code for seismic design of buried steel pipe for oil and gas transportation"	
Publisher: China Petrochemical Standard	
Date: 1991	China
Reference Web: http://www.cssn.net.cn/	

【112】

AWWA INF55786	Oil/Gas Pipeline
"Seismic Behavior of Pipe Joints" **Conference Proceeding**	
This paper describes the procedures and results of a static and dynamic testing	

program designed to determine the axial stiffness and force capacity of some typical restrained and unrestrained buried pipe joints. Pipelines have suffered damage and failure from past earthquakes and have been shown to be vulnerable to seismic motions. It has been well documented that a majority of the pipeline failures have occurred at unrestrained pipe joints and therefore, pipe joints, both unrestrained and restrained, need to be examined and their axial strength characteristics need to be investigated in order to help mitigate potential damage and failure. Five different material types with eight different joint types and several different pipe diameters were used in this testing program. The test results are given as load-displacement plots and tables listing the axial stiffness and force capacities. A comparison is made between static results and dynamic results to determine if static testing is sufficient to characterize the dynamic behavior of pipe joints. This paper also suggests methods to use test results for pipeline system analysis and for risk assessment evaluation. Includes 6 references, tables, figures.	
Publisher: AWWA (American Water Works Association)	
Date: 01-01-2002	USA
Reference Web: http://www.awwa.org/	

Ground pipelines

Evaluation Of Above Ground Piping Systems

The following is taken essentially verbatim from “Proposed Guidance for California Accidental Release Prevention Program Seismic Assessments” (1998). Evaluation of piping systems are primarily accomplished by field walkthroughs. Such qualitative evaluations of piping systems are best done by an engineer experienced in this area, visually inspecting the piping system under concern. This is preferred because some piping is field routed and in some instances, piping and supports have been modified from that shown on design drawings. This guidance is primarily intended for ductile steel pipe constructed to a national standard. Evaluation of other piping material is also discussed below.

The procedure for evaluating above ground piping systems should be as follows:

1. Identify piping systems to be evaluated.
2. Determine original design code basis and materials of construction, to the extent possible.
3. Assess extent of obvious corrosion/erosion.
4. Perform a walkthrough of the piping systems for seismic capability. Document the walkthrough and identify areas for detailed evaluation.
5. Complete the detailed evaluation of any identified areas and recommend remedial actions.

Damage to or failure of pipe supports should not be construed as a piping failure unless it directly contributes to a pressure boundary failure. The intention here is to preserve the essential pressure containing integrity of the piping system but not necessarily leak tightness. Therefore, this procedure does not preclude the possibility of small leaks at bolted flanged joints. Ductile piping systems have, in general, performed adequately in past earthquakes. Where damage has occurred, it has been related to the following aspects of piping systems:

1. Excessive seismic anchor movement.
2. Interaction with other elements.
3. Extensive corrosion effects.
4. Non-ductile materials such as cast iron1 fiberglass (PVC), glass, etc. combined with high stress or impact conditions.

Seismic anchor movements could result in relative displacements between points of support/attachment of the piping Systems. Such movements include relative displacements between vessels, pipe supports, or main headers for branch lines. Interaction is defined as the seismically induced impact of piping systems with adjacent structures, systems, or components, including the effects of the falling hazards. Corrosion could result in a weakened pipe cross section that could fail during an earthquake. Additional aspects of piping systems which should also be reviewed during the walkthrough for seismic capability are:

1. Large unsupported segment of pipe,
2. Brittle elements,
3. Threaded connections, flange joints, and special fittings, and
4. Inadequate supports, where an entire system or portion of piping may lose its primary support.

Special features or conditions to illustrate the above concerns include:

1. Inadequate anchorage of attached equipment,
2. Short/rigid spans that cannot accommodate the relative displacement of the supports, e.g., piping spanning between two structural systems,
3. Damaged supports including corrosion,
4. Long vertical runs subject to inter level drift,
5. Large unsupported masses (e.g., valves) attached to the pipe,
6. Flanged and threaded connections in high stress locations,
7. Existing leakage locations (flanges, threads, valves, welds),
8. External corrosion,
9. Inadequate vertical supports and/or insufficient lateral restraints,
10. Welded attachments to thin wall pipe,
11. Excessive seismic displacements of expansion joints,
12. Brittle elements, such as cast iron pipes,
13. Sensitive equipment impact (e.g., control valves), and
14. Potential for fatigue of short to medium length rod hangers which are restrained against rotation at the support end.

The walkthrough is the essential element for seismic evaluations of piping systems. Careful consideration needs to be given to how the piping system will behave during a seismic event, how nearby items will behave during a seismic event (if they can interact with the piping system) and how the seismic capacity will change over time. The walkthrough should be performed by a licensed engineer familiar with how equipment responds to earthquake loads. Detailed analysis of piping systems should not be the focus of this evaluation. Rather it should be on finding and strengthening weak elements.

However, after the walkthrough is performed and if an analysis is deemed necessary, the following general rules should be followed:

1. Friction resistance should not be considered for seismic restraint, except for the following condition: for long straight piping runs with numerous supports, friction in the axial direction may be considered,
2. Spring supports (constant or variable) should not be considered as seismic supports,
3. Unbraced pipelines with short rod hangers can be considered as effective lateral supports if justified,

4. Appropriate stress intensification factors ("i" factors) should be used, and
5. Allowable piping stresses should be reduced to account for fatigue effects due to significant cyclic operational loading conditions. In this case the allowables presented in the next section may need to be reduced.
6. Flange connections should be checked to ensure that high moments do not result in significant leakage.

Procedures for interaction evaluation of piping are as follows:

1) Regulated Substance (RS) piping should be visually inspected to identify potential interactions with adjacent structures, systems, or components. Those interactions which could cause unacceptable damage to piping, piping components (e.g., control valves), or adjacent critical items should be mitigated. Note that restricting piping seismic movement to preclude interaction may lead to excessive restraint of thermal expansion or inhibit other necessary operational flexibility.

2) The walkthrough should also identify the potential for interaction between adjacent structures, systems or components, and the RS piping being investigated. Those interactions which could cause unacceptable damage to RS piping should be mitigated. Note that falling hazards should be considered in this evaluation.

Procedures for corrosion evaluation of piping are as follows:

1. During walkthrough identify conditions conducive to external corrosion.
2. Wall thickness should be evaluated for potential reduction due to erosion or corrosion.
3. Extent of internal corrosion/erosion can be evaluated by any of the following methods:
   a. Review of existing corrosion inspection program for RS piping systems,
   b. Review of successful operating experience, or
   c. Wall thickness measurements.
4. Compare existing corrosion experience and anticipated corrosion to original design corrosion allowance.

The reader is should consult the "Proposed Guidance for California Accidental Release Prevention Program Seismic Assessments" (1998) for additional material not included here such as support design and inertia loads.

【113】

NFPA 59A **ANSI/NFPA 59A-1994**	Gas Plant Facility
"Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)" 2001 Edition	
Recently referenced in U.S. federal regulations by D.O.T. for LNG plants associated with pipelines, NFPA 59A provides for the site selection, design, construction, and fire protection of Liquefied Natural Gas facilities. Updates in this 2001 edition include an important new chapter on operations maintenance.	
Publisher: NFPA (National Fire Protection Association)	
Date: 1994	USA
Reference Web:	

【114】

NFPA 59 **ANSI/ NFPA 59-1995**	Gas Plant Facility
"Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants"	
Publisher: National Fire Protection Association	
Date: 1998	USA
Reference Web:	

【115】

API 2510	Gas Plant Facility
"Design and Construction of Liquefied Petroleum Gas Installations (LPG)"	
This standard covers the design, construction, and location of liquefied petroleum	

gas (LPG) installations at marine and pipeline terminals, natural gas processing plants, refineries, petrochemical plants, or tank farms. This standard covers storage vessels, loading and unloading systems, piping, or and related equipment. The size and type of the installation; the related facilities on the site; the commercial, industrial, and residential population density in the surrounding area; the terrain and climate conditions; and the type of LPG handled are discussed. Generally speaking, the larger the installation and the greater the population density of the surrounding area, the more stringent are the design requirements. Design and construction considerations peculiar to refrigerated storage, including autorefrigerated storage, are covered in Section 11 of this standard. The provisions of this standard are intended for application to new installations. This standard can be used to review and evaluate existing storage facilities. However, the feasibility of applying this standard to facilities, equipment, structures, or installations that were already in place or that were in the process of construction or installation before the date of this publication, must be evaluated on a case-by-case basis considering individual circumstances and sites.
Publisher: API (American Petroleum Institute)
Date: 01-05-2001 / USA
Reference Web: http://api-ep.api.org/publications/

【116】

ASME BPV	Gas Plant Facility
"2001 ASME Boiler and Pressure Vessel Code - Including Binders"	
This set includes all sections of the ASME Boiler and Pressure Vessel Code, over 25 volumes. Also includes current addenda and future updates through the year 2003, mailed direct to you at no extra cost. 26 Special 3-ring binders *included* in this package. For the full set without binders, see related set, below.	
Publisher: ASME (American Society of Mechanical Engineers)	

Date: 2001	USA
Reference Web: http://www.asme.org/bpvc/	

【117】

GBJ 44—82	Gas Plant Facility
"Standard for seismic appraiser of gas and thermal engineering"	
Publisher: GB (China Standard)	
Date: 1982	China
Reference Web: http://www.cssn.net.cn/	

【118】

NFPA 30 **ANSI/NFPA 30-2000**	Gas Plant Facility
"Flammable and Combustible Liquids Code" Edition: 2000	
Applies to all flammable and combustible liquids except those that are solid at 100oF or above. Covers tank storage, piping, valves and fittings, container storage, industrial plants, bulk plants, service stations and processing plants.	
Publisher: NFPA (National Fire Protection Association)	
Date: 2000	USA
Reference Web:	

【119】

ASCE TCLEE	Natural Gas Distribution
"Seismic Design Guide for Natural Gas Distributors"	

This monograph presents an overview of the sources and geographical distribution of earthquakes, identifies earthquake hazards, and gives the implications of these hazards to gas distribution systems. Past earthquake performance of gas systems is reviewed and lessons learned from system performance are identified. The steps needed to implement a formal earthquake preparedness program are discussed along with the critical issues that must be addressed in such a plan. Finally, a simpler approach to developing an earthquake mitigation program is presented which focuses on critical impacts of earthquakes on gas distribution systems.
Publisher: ASCE

Date: 1995	USA
Reference Web:	

【120】

ASCE LEE	Natural Gas Distribution
"Acceptable Risk Processes: Lifelines and Natural Hazards"	
This report provides the vital tools engineers and decision makers need to better understand acceptable risk processes and how those processes can enable them to develop risk reduction strategies and implement mitigation actions to reduce lifeline losses from future earthquakes. Because the disruption of lifelines from natural hazards has a direct impact on the world regional economies and the health of its citizens, it is important to understand natural hazards, how they can impact lifelines, and what can be done to minimize the impact when they occur. These three elements and the processes used to act upon them affect decisions that involve acceptable risk processes. The topic of 'acceptable risk' provides one way of bringing integrated systems risk evaluations for disaster explicitly into a decision-making context. Topics include technical issues; risk criteria issues; and communication, administration, and regulations issues.	
Publisher: ASCE	
Date: 2002	USA

Reference Web:

【121】

ASCE TCLEE	Natural Gas Distribution
"Guide to Post-Earthquake Investigation of Lifelines"	
This committee report, Guide to Post-Earthquake Investigation of Lifelines, will help the investigator become familiar with the overall operation of major lifeline systems, with the function and operation of lifeline facilities and equipment, with past seismic performance, and with methods to gather pertinent information. The beginning chapters describe how to prepare for a post-earthquake investigation and provide a summary of phenomena related to earthquakes and their effect on lifelines. Chapters 6 - 11 explain typical system configurations and overall operation of the following lifelines: power, water, sewage, transportation, communications, liquid fuel and natural gas systems. System facilities and equipment are described for each lifeline, including their role in overall system operation and their seismic performance. Detailed guidance is provided for their investigation. Chapter 12 discusses tanks and emergency power, facilities common to many lifelines. The appendices present check lists in a form that can be used as field guides during investigations. They also suggest formats for reconnaissance reports, tips on technical report writing, and references to reconnaissance reports.	
Publisher: ASCE	
Date: 1997	USA
Reference Web:	

【122】

ASME/ANSI B31.8	Natural Gas Distribution
"Gas Transmission Distribution and Piping Systems"	

This Code covers the design, fabrication, installation, inspection, testing, and safety aspects of operation and maintenance of gas transmission and distribution systems, including gas pipelines, gas compressor stations, gas metering and regulation stations, gas mains, and service lines up to the outlet of the customers meter set assembly. Included within the scope of this Code are gas transmission and gathering pipelines, including appurtenances, that are installed offshore for the purpose of transporting gas from production facilities to onshore locations; gas storage equipment of the closed pipe type, fabricated or forged from pipe or fabricated from pipe and fittings, and gas storage lines.
Publisher: ASME (American Society of Mechanical Engineers)

Date: 06-06-2000	USA
Reference Web:	

【123】

GB 50028	Natural Gas Distribution
"Design code for city gas"	
Publisher: GB (China Standard)	
Date: 1993	China
Reference Web: http://www.cssn.net.cn/	

【124】

TJ 23—78	Natural Gas Distribution
"Code for seismic design of water and gas engineering"	
Publisher: GB (China Standard)	
Date: 1978	China

Reference Web: http://www.cssn.net.cn/	

【125】

ANSI/ NFPA 58-1995	Gas Storage
"Storage and Handling of Liquefied Petroleum Gas"	
Applies to the highway transportation of LP-Gas and to the design, construction, installation and operation of all LP-Gas systems.	
Publisher: NFPA (National Fire Protection Association)	
Date: 1995	USA
Reference Web:	

【126】

Title 49CFR Part 193	Gas Pipeline
"Liquefied Natural Gas Facilities: Federal Safety Standard"	
Publisher: U.S. Department of Transportation (DOT)	
Date: 2000	USA
Reference Web:	

【127】

CSA Z223.1-M1977 (R1999) **ANSI Z223.1**	Gas Pipeline
"Method for the Determination of Particulate Mass Flows in Enclosed Gas Streams"	
This Standard describes test procedures and equipment which will permit accurate and reproducible determination of the particulate mass flows in enclosed	

gas streams. It is intended for use both before and after gas cleaning equipment (performance testing) or prior to emission of the gas stream into t he atmosphere. Note. It is recommended that the testing procedures in this Standard be undertaken by trained and experienced personnel in air pollution control work as noted in Appendix A This Standard may be used as a basis for evaluating modified sampling procedures. Note: One such modification is the in-duct filtration method described in Appendix C. Limitations It is recognized that there will be many processes and situations which may limit the application of this test procedure. Specifically, caution must be exercised when dealing with any of the following: (a) Corrosive or highly reactive components; (b) High vacuum or pressure; or (c) High temperature flows. Complications may arise in processes where the following conditions are encountered: (a) High moisture content streams; (b) Low velocity flows; (c) Small duct cross-sections (less than 0.02 m? (0.2 ft?)); (d) Complex flow patterns due to inadequate lengths of straight pipe before or after the sampling station; or (e) Fluctuations in velocity, particulate loading and temperature, due to uncontrollable process variations. Note: Guidelines for testing under such non-standard conditions are given in Appendix B.	
Publisher: Canadian Standard Association	
Date: 1999	Canada, USA
Reference Web:	

【128】

GB 50251—94	Gas Pipeline

“Design code for gas transmission pipeline engineering”	
Publisher: GB (China Standard)	
Date: 1994	China
Reference Web: http://www.cssn.net.cn/	

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