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CURRENT USAEC SEISMIC REQUIREMENTS FOR NUCLEAR POWER PLANTS

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INTRODUCTION

General Design Criterion 2 of Appendix A of 10 CFR Part 50[1] requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of earthquakes without loss of capability to perform their safety functions. It is the purpose of these criteria to set forth the principal seismic and geologic considerations which guide the Atomic Energy Commission in its evaluation of the suitability of proposed sites for nuclear power plants and the suitability of the plant design bases established in consideration of the seismic and geologic characteristic of the proposed sites.

Appendix A of 10 CFR Part 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," requires the following two types of earthquakes for the analysis and design of nuclear power plants.

The safe shutdown earthquake (SSE) is that earthquake which is based upon an evaluation of the maximum earthquake potential, considering regional and local geology and seismology and specific characteristics of local subsurface material. It is that earthquake which produces the maximum vibratory ground motion for which certain structures, systems, and components are designed to remain functional. These structures, systems, and components are those necessary to assure:

1. The integrity of the reactor coolant pressure boundary
2. The capability to shut down the reactor and maintain it in a safe shutdown condition
3. The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures of 10 CFR Part 100

The operating basis earthquake (OBE) is that earthquake which, considering the regional and local geology and seismology and specific characteristics of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant; it is that earthquake which produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to health and safety of the public are designed to remain functional.

AEC Regulatory Guide 1.29 (Revision 1, August 1973) designates as seismic Category I those structures, systems, and components that should be designed to remain functional if the SSE occurs. The pertinent quality assurance requirements of Appendix B to 10 CFR Part 50 should be applied to the seismic Category I structures, systems, and components.

Table I shows a typical list for seismic Category I structures, systems, and components for the nuclear power plant.

Historical development in the field of seismic requirements in the United States for the nuclear power plant is discussed in References 2 and 3.

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TABLE I
List of Seismic Category I
Structures, Systems, and Components

Structures*	Systems*
Containment	Reactor coolant system
Auxiliary building	Radioactive waste treatment system
Diesel generator building	Chemical and volume-control system
Intake structure	Emergency core-cooling system
Safety-related outdoor tanks	Residual heat-removal system
	Containment spray system
Control building	Containment isolation system
Cable tunnel structure	Containment cooling system
Cable tray supports	Spent fuel cooling system
Crane supports	Liquid recycle and waste system

Components		
Mechanical*	Electrical*	Instrumentation*
Reactor vessel	Switchgears	Instrument panels
Pressurizer	Transformers	Nuclear instrumentation
Pumps	Batteries and Battery Charger Load centers	System cabinets
Steam generator	Motor control centers	Instrument valves
Valves	Motors	Panel devices
Heat Exchanger	Batteries and battery chargers	Control valves
Charcoal filters		
Heat exchangers		
Diesel generator tanks		

* Associated with engineered safeguard systems.

REGULATIONS, STANDARDS, AND OTHER INDUSTRY DOCUMENTS

Earthquake effects on Category I structures have become the general structural design requirement for nuclear power plant structures. The general requirements associated with such design have become reasonably well standardized with the typical design parameters specified in the following AEC documents.

The following documents are part of the USAEC seismic requirements for nuclear power plants:

CODE OF FEDERAL REGULATIONS (CFR)

1. 10 CFR Part 100-Reactor Site Criteria
2. 10 CFR Part 100-Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants"
3. 10 CFR Part 50-Licensing of Production and Utilization Facilities
   a. General Design Criterion 2 of Appendix A, "Design Bases for Protection Against Natural Phenomena"
   b. Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants"

DIVISION 1—USAEC REGULATORY GUIDES—POWER REACTORS

1.12 Instrumentation for Earthquakes (Revision 1, April 1974)
1.29 Seismic Design Classification (Revision 1, August 1973)
1.48 Design Limits and Loading Combinations for Seismic Category I Fluid System Components (May 1973)
1.60 Design Response Spectra for Seismic Design of Nuclear Power Plants (Revision 1, December 1973)
1.61 Damping values for Seismic Design of Nuclear Power Plants (October 1973)
1.70 Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants[4] (Revision 1, October 1972)

DIVISION 3—USAEC REGULATORY GUIDES— FUELS AND MATERIALS FACILITIES

3.14 Seismic Design Classification for Plutonium Processing and Fuel Fabrication Plants (October 1973)
3.17 Earthquake Instrumentation for Fuel Processing Plants (February 1974)

The following regulatory guides are under development for the Division 1, Directorate of Regulatory Standards:

1. Seismic Input Motion to Uncoupled Structural Model
2. Seismic Qualifications of Class I Electric Equipment
3. Seismic Response Combinations of Modes and Spatial Components
4. Requirements for Assessing Ability of Material Underneath Nuclear Power Plant Foundations to Withstand Safe Shutdown Earthquake
5. Analysis of Seismic Recorded Data

Seismic Category I structures, systems, and components are currently being designed in accordance with the above requlations and regulatory guides in addition to the following industrial codes, standards, or manuals which are either being supplemented, prepared, or revised in light of the latest state-of-the-art literature by the American

National Standards Institute (ANSI), American Nuclear Society (ANS), American Society of Mechanical Engineers (ASME), Institute of Electrical and Electronics Engineers (IEEE) American Society of Civil Engineers (ASCE), and American Concrete Institute (ACI).

Working Group	ANSI Number	Title
ANS 2.1	N 18.4	Vibratory Ground Motion for the Design Earthquake
ANS 2.2	N 18.5	Earthquake Instrumentation Criteria for Nuclear Power Plants
ANS 2.7	N 180	Guidelines for Assessing Likelihood of Surface Faulting at Power Reactor Sites
ANS 2.10	N 643	Guidelines for Retrieval, Review, Processing and Evaluations of Records Obtained from Seismic Instrumentation
ANS 2.11	N 174	Guidelines for Determining Foundation Soil and Geological Characteristics at Power Reactor Sites
ANS 2.12	N 635	Guidelines for Combining Severe Environmental Phenomena
ASME Section III	N 166	Seismic Qualifications for Nuclear Power Plant Structures and Mechanical Equipment
ASME Section III	N 167	Seismic Analysis of Category I Structures, Systems and Components
ASCE	N 168	Design and Analysis of Concrete Seismic Category I Structures Other Than Containment Vessels
ASCE	N 175	Geologic Design Criteria
ACI-349	—	Standard Requirements for Nuclear Safety-Related Concrete Structures
IEEE-344	N 41.7	Guide for Seismic Qualification of Class IE Electric Equipment for Nuclear Power Generating Stations

In addition to industry standards, several topical reports are incorporated by reference as part of the application of the nuclear power plant construction or operating permit. These topicals are prepared by reactor manufacturers or architects-engineers and filed separately with the AEC in support of the application. Topical report, "Seismic Analyses of Structures and Equipment for Nuclear Power Plants"[5] (BC-TOP-4, Revision 2, June 1974), has been filed with the AEC by Bechtel Power Corporation, San Francisco. This report describes the general practice within Bechtel Power Corporation for the seismic analysis of nuclear power plant structures and components.

USAEC REGULATORY GUIDES

Regulatory guides are issued to describe methods applicable to the AEC regulatory staff of implementing specific parts of the Commission's regulations to delineate techniques used by the staff in evaluating specific postulated accidents or to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions different from specified in the guides are acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the commission.

Regulatory Guide 1.60 provides the AEC requirements for the shape of the horizontal and vertical design response spectra. The horizontal-component ground-design response spectra of the SSE or the OBE on sites underlain by rock or soil, without soil-structure interaction effects, should be linearly scaled from Figure 1 in proportion to the maximum horizontal ground acceleration specified for the earthquake. The applicable multiplication factors and control points are given in Table II.

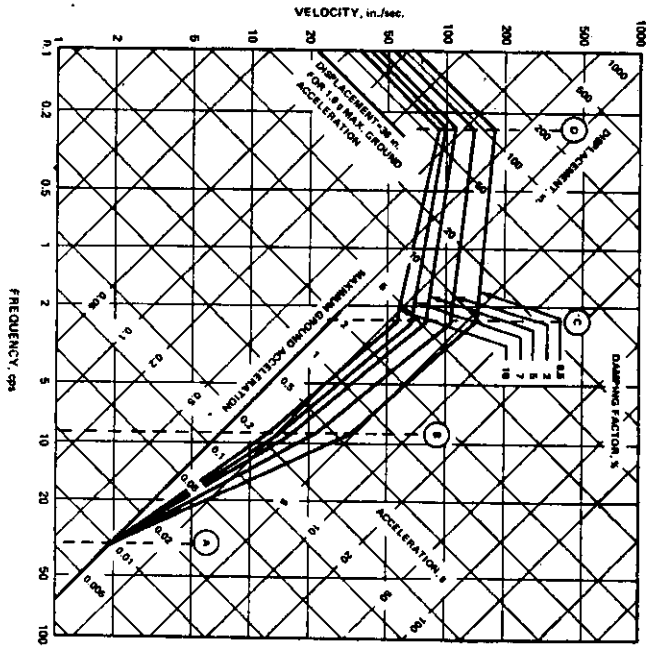

Fig. 1. Horizontal Design Response Spectra—Scaled to 1g Horizontal Ground Acceleration

TABLE II
Horizontal Design Response Spectra Relative Values of Spectrum Amplification Factors for Control Points

Percent of Critical Damping	Amplification Factors for Control Points			
	Acceleration[1,2]			Displacement[1,2]
	A (33 cps)	B (9 cps)	C (2.5 cps)	D (0.25 cps)
0.5	1.0	4.96	5.95	3.20
2.0	1.0	3.54	4.25	2.50
5.0	1.0	2.61	3.13	2.05
7.0	1.0	2.27	2.72	1.88
10.0	1.0	1.90	2.28	1.70

1. Maximum ground displacement is taken proportional to maximum ground acceleration, and is 36 inches for ground acceleration of 1.0 gravity.

2. Acceleration and displacement amplification factors are taken from recommendations given in Reference 7.

The design basis for maximum vibratory ground motion and acceleration is determined by evaluation of the detailed geology and seismic history of the site and its nearby region. Minimum required value of the horizontal ground acceleration for any site is 0.1 g for the SSE.

The maximum vertical ground acceleration of the SSE is equal to the maximum horizontal ground acceleration of the SSE specified for the site. The vertical component ground-design response spectra of the SSE or OBE on sites underlain by rock or soil, without soil-structure interaction effects, should be linearly scaled from Figure 2 in pro-

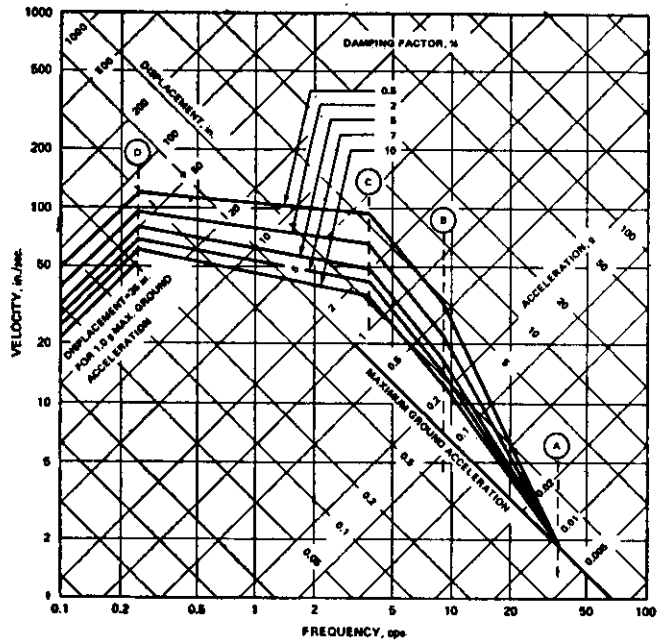

Fig. 2. Vertical Design Response Spectra—Scaled to 1g Horizontal Ground Acceleration

portion to the maximum horizontal ground acceleration specified for the earthquake. The applicable multiplication factors and control points are given in Table III.

Based on the extensive study by Newmark and Blume[7,8,9], the AEC regulatory staff has determined the above-mentioned design response spectra. These design spectra are based on a statistical evaluation of the actual response spectra of many strong-motion earthquakes recorded at sites underlain by various geologic materials.

Regulatory Guide 1.61 states the regulatory position for the damping values for seismic design of nuclear power plants. Acceptable modal damping values, expressed as a percentage of critical damping, are shown in Table IV.

Regulatory Guide 1.12 specifies the regulatory position for the instrumentation required for earthquakes. It requires the installation of triaxial time-history accelerographs, triaxial peak accelerographs, and triaxial response-spectrum recorders at appropriate locations on the seismic Category I structures, systems, and components to provide data on the seismic input to containment and on the frequency, amplitude, and phase relationship of the seismic response of the containment structures and other seismic Category I structures, systems, and components.[10]

Regulatory Guide 1.29 provides the regulatory position for the seismic design classification (i.e., seismic Category I) requirements.

TABLE III
Vertical Design Response Spectra Relative Values of Spectrum Amplification Factors for Control Points

Percent of Critical Damping	Amplification Factors for Control Points			
	Acceleration[1,2]			Displacement[1,2]
	A (33 cps)	B (9 cps)	C (3.5 cps)	D (0.25 cps)
0.5	1.0	4.96	5.67	2.13
2.0	1.0	3.54	4.05	1.67
5.0	1.0	2.61	2.98	1.37
7.0	1.0	2.27	2.59	1.25
10.0	1.0	1.90	2.17	1.13

1. Maximum ground displacement is taken proportional to maximum ground acceleration, and is 36 inches for ground acceleration of 1.0 gravity.

2. Acceleration amplification factors for the vertical design response spectra are equal to those for horizontal design response spectra at a given frequency, whereas displacement amplification factors are 2/3 those for horizontal design response spectra. These ratios between the amplification factors for the two design response spectra are in agreement with those recommended in Reference 7.

TABLE IV
Damping Values[1]
(Percent of Critical Damping)

Structure or Component	Operating Basis Earthquake or 1/2 Safe Shutdown Earthquake[2]	Safe Shutdown Earthquake
Equipment and large-diameter piping systems[3], pipe diameter greater than 12 inches	2	3
Smaller-diameter piping systems, diameter equal to or less than 12 inches	1	2
welded steel structures	2	4
Bolted steel structures	4	7
Prestressed concrete structures	2	5
Reinforced concrete structures	4	7

1. Table IV is derived from the recommendations given in Reference 7.

2. In the dynamic analysis of active components as defined in Regulatory Guide 1.48, these values should also be used for SSE.

3. Includes both material and structural damping. If the piping system consists of only one or two spans with little structural damping, use values for small-diameter piping.

Regulatory Guide 1.48 provides the regulatory position for seismic Category I fluid system components to withstand loading combinations within the design limits specified in the appropriate ASME Code, depending on code classification for vessels, piping, pumps, acting valves, and nonacting valves.

Regulatory Guide 3.14 *and* 3.17 provide seismic design classification and earthquake instrumentation for fuel reprocessing plants.

In addition to regulatory guides, Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (Revision 1, October 1972), prepared by the regulatory staff of USAEC, requires detailed analytical and design techniques for load combinations combinations of horizontal and vertical components of the earthquake, soil-structure interaction, seismic analysis, and modeling technique. The following sections of this standard provide guidance for minimum requirements for the preparation of either preliminary and/or final safety analysis reports to be filed with USAEC :

2.5	Geology and Seismology
3.1	Conformance with AEC General Design Criteria
3.2.1	Seismic Classification
3.7	Seismic Design
3.9.12	Dynamic Testing Procedures (Mechanical Systems and Components)
3.10	Seismic Design of Category I Instrumentation and Electrical Equipment

CONCLUSIONS

The basic requirements of seismic design and analysis for seismic Category I structures, components, and systems important to public safety have been established in the USAEC regulatory guides and Code of Federal Regulations. Current state-of-the-art techniques, best available technology, and additional studies in the field of earthquake engineering should be utilized to resolve seismic concerns. Thus, seismic design requirements for nuclear plants to withstand postulated earthquakes can be standardized and will be a significant milestone in the continuing Nuclear Standardization Program.

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