



U.S. NUCLEAR REGULATORY COMMISSION
STANDARD REVIEW PLAN
OFFICE OF NUCLEAR REACTOR REGULATION

3.7.3 SEISMIC SUBSYSTEM ANALYSIS

REVIEW RESPONSIBILITIES

Primary - ~~Structural~~Civil Engineering and Geosciences Branch (ESGBECGB¹)

Secondary - None

I. AREAS OF REVIEW

The following areas related to the seismic subsystem analysis are reviewed:

1. Seismic Analysis Methods

The information reviewed is similar to that described in subsection I.1 of Standard Review Plan (SRP) Section 3.7.2 but as applied to seismic Category I subsystems.

2. Determination of Number of Earthquake Cycles

Criteria or procedures used to establish the number of earthquake cycles during one seismic event and the maximum number of cycles for which applicable Category I subsystems and components are designed are reviewed.

3. Procedures Used for Analytical Modeling

The criteria and procedures used for modeling the seismic subsystems are reviewed.

4. Basis for Selection of Frequencies

As applicable, criteria or procedures used to separate fundamental frequencies of components and equipment from the forcing frequencies of the support structure are reviewed.

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USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants. These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required. The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

5. Analysis Procedure for Damping

The information reviewed is similar to that described in subsection I.13 of SRP Section 3.7.2 but as applied to Category I subsystems.

6. Three Components of Earthquake Motion

The information reviewed is similar to that described in subsection I.6 of SRP Section 3.7.2 but as applied to Category I subsystems.

7. Combination of Modal² Responses

The information reviewed is similar to that described in subsection I.7 of SRP Section 3.7.2 but as applied to Category I subsystems.

8. Interaction of Other Systems With Category I Systems

The seismic analysis procedures to account for the seismic motion of non-Category I systems in the seismic design of Category I systems are reviewed.

9. Multiply-Supported Equipment and Components with Distinct Inputs

The criteria and procedures for seismic analysis of equipment and components supported at different elevations within a building and between buildings with distinct inputs are reviewed.

10. Use of Equivalent Vertical Static Factors

The information reviewed is similar to that described in subsection H.10³ of SRP Section 3.7.2 but as applied to Category I subsystems.

11. Torsional Effects of Eccentric Masses

The criteria and procedures that are used to consider the torsional effects of eccentric masses in seismic subsystem analyses are reviewed.

12. Category I Buried Piping, Conduits, and Tunnels

For Category I buried piping, conduits, tunnels, and auxiliary systems, the seismic criteria and methods which consider the compliance characteristics of soil media, dynamic pressures, settlement due to earthquake and differential movements at support points, penetrations, and entry points into structures provided with anchors are reviewed.

13. Methods for Seismic Analysis of Category I Concrete Dams

The analytical methods and procedures that will be used for seismic analysis of Category I concrete dams are reviewed. The assumptions made, the boundary conditions used, the hydrodynamic effects considered, and the procedures by which strain-dependent material properties of foundation are incorporated in the analysis are reviewed.

14. Methods for Seismic Analysis of Above-Ground Tanks

For Category I above-ground tanks, the seismic criteria and methods that consider hydrodynamic forces, tank flexibility, soil-structure interaction, and other pertinent parameters are reviewed.

II. ACCEPTANCE CRITERIA

The acceptance criteria for the areas of review described in subsection I of this SRP section are given below. Other criteria which can be justified to be equivalent to or more conservative than the stated acceptance criteria may be used. The staff accepts the design of subsystems that are important to safety and must withstand the effects of earthquakes if the relevant requirements of General Design Criterion (GDC) 2 ~~(Ref. 1)~~⁴ and Appendix A to 10 CFR Part 100 ~~(Ref. 2)~~⁵ concerning material phenomena are complied with. The relevant requirements of GDC 2 and Appendix A to 10 CFR Part 100 are:

- 1A.⁶ General Design Criterion 2 - The design basis shall reflect appropriate consideration of the most severe earthquakes reported to have affected the site and surrounding area with sufficient margin for the limited accuracy, quantity, and period of time in which historical data have been accumulated.
- 2B.⁷ Appendix A to 10 CFR Part 100⁸ - Two earthquake levels⁹, the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE), shall be considered in the design of safety-related structures, systems, and components (SSCs)¹⁰, ~~and systems~~. Appendix A to 10 CFR Part 100 further states that the design used to ensure that the required safety functions are maintained during and after the vibratory ground motion associated with the safe shutdown earthquake shall involve the use of either a suitable dynamic analysis or a suitable qualification test to demonstrate that ~~structures, systems, and components~~ SSCs¹¹ can withstand the seismic and other concurrent loads, except where it can be demonstrated that the use of an equivalent static load method provides adequate conservatism.

Specific criteria necessary to meet the relevant requirements of GDC 2 and Appendix A to Part 100 are as follows:

1. Seismic Analysis Methods

The acceptance criteria provided in SRP Section 3.7.2, subsection II.1, are applicable.

2. Determination of Number of Earthquake Cycles

During the plant life at least one safe shutdown earthquake (SSE) and five operating basis earthquakes (OBEs) should be assumed. The number of cycles per earthquake should be obtained from the synthetic time history (with a minimum duration of 10 seconds) used for the system analysis, or a minimum of 10 maximum stress cycles per earthquake may be assumed.

3. Procedures Used for Analytical Modeling

The acceptance criteria provided in SRP Section 3.7.2, subsection II.3, are applicable.

4. Basis for Selection of Frequencies

To avoid resonance, the fundamental frequencies of components and equipment should preferably be selected to be less than 1/2 or more than twice the dominant frequencies of the support structure. Use of equipment frequencies within this range is acceptable if the equipment is adequately designed for the applicable loads.

5. Analysis Procedure for Damping

The acceptance criteria provided in SRP Section 3.7.2, subsection II.13, are applicable.

6. Three Components of Earthquake Motion

The acceptance criteria provided in SRP Section 3.7.2, subsection II.6, are applicable.

7. Combination of Modal Responses

The acceptance criteria provided in SRP Section 3.7.2, subsection II.7, are applicable.

8. Interaction of Other Systems With Category I Systems

To be acceptable, each non-Category I system should be designed to be isolated from any Category I system by either a constraint or barrier, or should be remotely located with regard to the seismic Category I system. If it is not feasible or practical to isolate the Category I system, adjacent non-Category I systems should be analyzed according to the same seismic criteria as applicable to the Category I system. For non-Category I systems attached to Category I systems, the dynamic effects of the non-Category I systems should be simulated in the modeling of the Category I system. The attached non-Category I systems, up to the first anchor beyond the interface, should also be designed in such a manner that during an earthquake of SSE intensity it will not cause a failure of the Category I system.

The acceptance criteria provided in SRP Section 3.7.2, subsection II.8, are applicable to all seismic Category I SSCs at the system and subsystem level.¹²

9. Multiply-Supported Equipment and Components With Distinct Inputs

Equipment and components in some cases are supported at several points by either a single structure or two separate structures. The motions of the primary structure or structures at each of the support points may be quite different.

A conservative and acceptable approach for analyzing¹³ equipment items supported at two or more locations is the uniform response spectrum (URS) technique:¹⁴ to use an An upper bound envelope of all the individual response spectra for these locations is used¹⁵ to calculate maximum inertial responses of multiply-supported items. In addition, the relative displacements at the support points should be considered. Conventional static analysis procedures are acceptable for this purpose. The maximum relative support displacements can be obtained from the structural response calculations or, as a conservative approximation, by using the floor response spectra. For the latter option the maximum displacement of each support is predicted by $S_d = S_a g / \omega^2$, where S_a is the spectral acceleration in "g's" at the high-frequency end of the spectrum curve (which, in turn, is equal to the maximum floor acceleration), g is the gravity constant, and ω is the fundamental frequency of the primary support structure in radians per second. The support displacements can then be imposed on the supported item in the most

unfavorable combination. The responses due to the inertia effect and relative displacements should be combined by the absolute sum method.

The URS method described above can result in considerable overestimation of seismic responses. Acceptable analysis methods that provide more realistic estimation of seismic responses are discussed in Section 2 of NUREG-1061 (Reference 4).¹⁶

In the case of multiple supports located in a single structure, an alternative acceptable method using the floor response spectra involves determination of dynamic responses due to the worst single floor response spectrum selected from a set of floor response spectra obtained at various floors and applied identically to all the floors, provided there is no significant shift in frequencies of the spectra peaks. In addition, the support displacements should be imposed on the supported item in the most unfavorable combination using static analysis procedures.

In lieu of the response spectrum approach, time histories of support motions may be used as excitations to the subsystems. Because of the increased analytical effort compared to the response spectrum techniques, usually only a major equipment system would warrant a time history approach. The time history approach does, however, provide more realistic results in some cases as compared to the response spectrum envelope method for multiply-supported systems.

10. Use of Equivalent Vertical Static Factors

The acceptance criteria provided in SRP Section 3.7.2, subsection II.10, are applicable.

11. Torsional Effects of Eccentric Masses

For seismic Category I subsystems, when the torsional effect of an eccentric mass is judged to be significant, the eccentric mass and its eccentricity should be included in the mathematical model. The criteria for judging the significance will be reviewed on a case-by-case basis.

12. Category I Buried Piping, Conduits, and Tunnels

For Category I buried piping, conduits, tunnels, and auxiliary systems, the following items should be considered in the analysis:

- a. Two types of groundshaking-induced loadings must be considered for design.
 - (i) Relative deformations imposed by seismic waves traveling through the surrounding soil or by differential deformations between the soil and anchor points.
 - (ii) Lateral earth pressures and ground-water effects acting on structures.
- b. The effects of static resistance of the surrounding soil on piping deformations or displacements, differential movements of piping anchors, bent geometry and curvature changes, etc., should be adequately considered. Procedures using the principles of the theory of structures on elastic foundations are acceptable.
- c. When applicable, the effects due to local soil settlements, soil arching, etc., should also be considered in the analysis.

- d. Actual methods used for determining the design parameters associated with seismically induced transient relative deformations are reviewed and accepted on a case-by-case basis. Additional information, for guidance purposes only, can be found on page 26 of NUREG/CR-1161 (Reference 35)¹⁷ and in Section 3.5.2 of ASCE Std 4-86 (Reference 46)¹⁸.

13. Methods for Seismic Analysis of Category I Concrete Dams

For the analysis of all Category I concrete dams, an appropriate approach that takes into consideration the dynamic nature of forces (due to both horizontal and vertical earthquake loadings), the behavior of the dam material under earthquake loadings, soil-structure interaction (SSI) effects, and nonlinear stress-strain relations for the soil, should be used. Analysis of earthen dams is reviewed under SRP¹⁹ Section 2.5.6.

14. Methods for Seismic Analysis of Above-Ground Tanks

Most above-ground fluid-containing vertical tanks do not warrant sophisticated, finite element, fluid-structure interaction analyses for seismic loading. However, the commonly used alternative of analyzing such tanks by the "Housner-method" described in TID-7024 (Reference: 58)²⁰ may be inadequate in some cases. The major problem is that direct application of this method is consistent with the assumption that the combined fluid-tank system in the horizontal impulsive mode is sufficiently rigid to justify the assumption of a rigid tank. For flat-bottomed tanks mounted directly on their bases, or tanks with very stiff skirt supports, the assumption leads to the usage of a spectral acceleration equal to the zero-period base acceleration. Recent studies (References: 96, 7, 8, 9, and 10 through 13)²¹ have shown that for typical tank designs the frequency for this fundamental horizontal impulsive mode of the tank shell and contained fluid is such that the spectral acceleration may be significantly far greater than the zero-period acceleration. Thus, the assumption of a rigid tank could lead to inadequate design loadings. The SSI effects may also be very important for tank responses, and they may be considered for both horizontal and vertical motions.

The acceptance criteria below are based upon the information contained in ~~References 1 through 3 and Reference 5~~ Appendix A to 10 CFR 50, Appendix A to 10 CFR 100, NUREG/CR-1161, and in TID-7024.²² These references also contain acceptable calculational techniques for the implementation of these criteria. The use of other approaches meeting the intent of these criteria can also be considered if adequate justification is provided.

- a. A minimum acceptable analysis must incorporate at least two horizontal modes of combined fluid-tank vibration and at least one vertical mode of fluid vibration. The horizontal response analysis must include at least one impulsive mode in which the response of the tank shell and roof are coupled together with the portion of the fluid contents that moves in unison with the shell. Furthermore, at least the fundamental sloshing (convective) mode of the fluid must be included in the horizontal analysis.
- b. The fundamental natural horizontal impulsive mode of vibration of the fluid-tank system must be estimated giving due consideration to the flexibility of the supporting medium and to any uplifting tendencies for the tank. It is unacceptable to assume a rigid tank unless the assumption can be justified. The horizontal impulsive-mode spectral acceleration, S_{a1} , is then determined using this frequency and the appropriate damping for the fluid-tank system. Alternatively,

the maximum spectral acceleration corresponding to the relevant damping may be used.

- c. Damping values used to determine the spectral acceleration in the impulsive mode shall be based upon the system damping associated with the tank shell material as well as with the SSI, as specified in NUREG/CR-1161 and Veletsos and Tang (References 3 and 103)²³.
- d. In determining the spectral acceleration in the horizontal convective mode, S_{a2} , the fluid damping ratio shall be 0.5 percent of critical damping unless a higher value can be substantiated by experimental results.
- e. The maximum overturning moment, M_o , at the base of the tank should be obtained by the modal and spatial combination methods discussed in subsection II of SRP Section 3.7.2. The uplift tension resulting from M_o must be resisted either by tying the tank to the foundation with anchor bolts, etc., or by mobilizing enough fluid weight on a thickened base skirt plate. The latter method of resisting M_o must be shown to be conservative.
- f. The seismically induced hydrodynamic pressures on the tank shell at any level can be determined by the modal and spatial combination methods in SRP Section 3.7.2. The maximum hoop forces in the tank wall must be evaluated with due regard for the contribution of the vertical component of ground shaking. The beneficial effects of soil-structure interaction may be considered in this evaluation, see ASCE Std 4-86, Haroun and Tayel (Reference 14), Veletsos and Tang (Reference 15), and Veletsos and Tang (References 4, 11, 12, and 136).²⁴ The hydrodynamic pressure at any level must be added to the hydrostatic pressure at that level to determine the hoop tension in the tank shell.
- g. Either the tank top head must be located at elevation higher than the slosh height above the top of the fluid or else must be designed for pressures resulting from fluid sloshing against this head.
- h. At the point of attachment, the tank shell must be designed to withstand the seismic forces imposed by the attached piping. An appropriate analysis must be performed to verify this design.
- i. The tank foundation (see also SRP Section 3.8.5) must be designed to accommodate the seismic forces imposed on it. These forces include the hydrodynamic fluid pressures imposed on the base of the tank as well as the tank shell longitudinal compressive and tensile forces resulting from M_o .
- j. In addition to the above, a consideration must be given to prevent buckling of tank walls and roof, failure of connecting piping, and sliding of the tank.

Technical Rationale:²⁵

The technical rationale for application of the above acceptance criteria to the seismic subsystem analysis is discussed in the following paragraphs.

1. General Design Criterion 2 requires, in relevant part, that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, without loss of capability to perform their intended safety functions. GDC 2 further requires that the design bases reflect appropriate consideration for the most severe natural phenomena that

have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated in the past. This SRP section reviews methods for seismic analysis and modeling of piping systems and components to assure that they accurately and/or conservatively represent the behavior of SSCs during postulated seismic events, thus assuring that GDC 2 is being met. Meeting the requirements of General Design Criterion 2 assures that fundamental safety functions, such as core cooling, are adequately protected, so that the plant can be safely brought to a shutdown condition following a seismic event.

2. Appendix A to 10 CFR 100 provides definitions for the OBE and the SSE and requires that the engineering methods used to ensure that the required safety functions are maintained during and after the vibratory ground motion associated with the SSE shall involve the use of either a suitable dynamic analysis or an appropriate qualification test methodology to demonstrate that all SSCs important to safety are capable of withstanding the seismic and other concurrent loads, including postulated accident loads, except where it can be demonstrated that the use of an equivalent static load analysis methodology provides adequate conservatism. The requirements of Appendix A to 10 CFR 100 assure that the applicable levels of vibratory ground motion corresponding to the OBE and the SSE are properly defined, and that adequate accuracy and/or conservatism are being applied in defining the system data being used for input into the seismic subsystem analysis. This SRP section reviews the methods utilized for seismic subsystem analysis and thereby assures that the requirements of Appendix A to Part 100 are being met. Compliance with the requirements detailed in Appendix A to 10 CFR 100 in conjunction with implementation of the requirements provided in General Design Criterion 2, as discussed above, assures that the plant can be operated without undue risk to the health and safety of the public, and that it can be safely brought to a shutdown condition, with its fundamental safety functions intact, following a seismic event.

III. REVIEW PROCEDURES

For each area of review, the following review procedure is followed. The reviewer will select and emphasize material from the procedures given below, as may be appropriate for a particular case. The review procedures are such as to satisfy the requirements of acceptance criteria stated in subsection II.

1. Seismic Analysis Methods

The seismic analysis methods are reviewed to determine that these are in accordance with the acceptance criteria of SRP Section 3.7.2, subsection II.1.

2. Determination of Number of Earthquake Cycles

Criteria or procedures used to establish the number of earthquake cycles are reviewed to determine that they are in accordance with the acceptance criteria as given in subsection II.2 of this SRP section. Justification for deviating from the acceptance criteria is requested from the applicant, as necessary.

In the FSERs for the ABWR and the System 80+ design certifications the staff accepted an exemption from the 10 CFR 100 Appendix A requirement that all safety-related structures, systems, and components be designed to remain functional and within applicable stress and deformation limits when subjected to an OBE. This exemption was based on the licensees' alternative analyses performed for the SSE and procedural requirements to perform an inspection of the plant following an earthquake at or above

one-third the SSE. The licensees' alternative analyses met one or both of the following approaches in determining the number of earthquake cycles to be used in the fatigue analysis of piping systems:

- a. use two SSE events with 10 maximum stress cycles per event (20 full cycles of the maximum SSE stress range), or alternatively,
- b. the number of fractional vibratory cycles equivalent to that of 20 full SSE vibratory cycles may be used (but with an amplitude not less than one third of the maximum SSE amplitude) when derived in accordance with Appendix D to IEEE Std 344-1987 (Reference 7).

These alternative analyses accomplish the design objectives of the OBE design analyses and meet the Commission-approved staff recommendations in SECY 93-087 (Reference 3).²⁶

3. Procedures Used for Analytical Modeling

The criteria and procedures used for modeling for the seismic subsystem analysis are reviewed to determine that these are in accordance with the acceptance criteria of SRP Section 3.7.2, subsection II.3.

4. Basis for Selection of Frequencies

As applicable, criteria or procedures used to separate fundamental frequencies of components and equipment from the forcing frequencies of the support structure are reviewed to determine compliance with the acceptance criteria of subsection II.4 of this SRP section.

5. Analysis Procedure for Damping

The analysis procedure to account for damping in different elements of the model of a coupled system is reviewed to determine that it is in accordance with the acceptance criteria of SRP Section 3.7.2, subsection II.13.

6. Three Components of Earthquake Motion

The procedures by which the three components of earthquake motion are considered in determining the seismic response of subsystems are reviewed to determine compliance with the acceptance criteria of SRP Section 3.7.2, subsection II.6.

7. Combination of Modal Responses

The procedures for combining modal responses are reviewed to determine compliance with the acceptance criteria of SRP Section 3.7.2, subsection II.7 when a response spectrum modal analysis method is used.

8. Interaction of Other Systems with Category I Systems

The criteria used to design the interfaces between Category I and non-Category I systems are reviewed to determine compliance with the acceptance criteria of subsection II.8 of this SRP section.

9. Multiply-Supported Equipment and Components With Distinct Inputs

The criteria for the seismic analysis of multiply-supported equipment and components with distinct inputs are reviewed to determine that the criteria are in accordance with the acceptance criteria of subsection II.9 of this SRP section.

10. Use of Equivalent Vertical Static Factors

Use of equivalent static factors as response loads in the vertical direction for the seismic design of any Category I subsystems in lieu of a detailed dynamic method is reviewed to determine that constant static factors are used only if the structure is rigid in the vertical direction.

11. Torsional Effects of Eccentric Masses

The procedures for seismic analysis of Category I subsystems are reviewed to determine compliance with the acceptance criteria of subsection II.11 of this SRP section.

12. Category I Buried Piping, Conduits, and Tunnels

The analysis procedures for Category I buried piping, conduits, tunnels, and auxiliary systems are reviewed to determine that they are in accordance with the acceptance criteria of subsection II.12 of this SRP section. The analysis includes review of the procedures used to consider the inertial effects of soil media and the differential displacements at structural penetrations, etc. Any procedures that are not adequately justified are so identified, and the applicant is requested to provide additional justification.

13. Methods for Seismic Analysis of Category I Concrete Dams

Methods for the seismic analysis of Category I concrete dams are reviewed to determine compliance with the acceptance criteria of subsection II.13 of this SRP section.

14. Method for Seismic Analysis of Above-Ground Tanks

Methods for seismic analysis of Category I above-ground tanks are reviewed to determine compliance with the acceptance criteria of subsection II.14 of this SRP section.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.²⁷

IV. EVALUATION FINDINGS

Evaluation findings for SRP Section 3.7.3 have been combined with those of SRP Section 3.7.2 and are given under SRP Section 3.7.2, subsection IV.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.²⁸ Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with the Commission's regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section. ~~The provisions of this SRP section apply to reviews of construction permit (CP), preliminary design approval (PDA), final design approval (FDA), and combined license (CP/OL) applications docketed after the date of issuance of this SRP section.~~²⁹ Operating license (OL) and final design approval (FDA) applications, whose CP and PDA reviews were conducted prior to the issuance of ~~this~~ Revision 2 (dated August 1989) to SRP Section 3.7.3, will be reviewed in accordance with the acceptance criteria given in the SRP Section 3.7.3, Revision 1, dated July 1981. Operating license (OL) and final design approval (FDA) applications, whose CP and PDA reviews were conducted after August of 1989 but prior to the issuance of Revision 3 to SRP Section 3.7.3, will be reviewed in accordance with the acceptance criteria given in the SRP Section 3.7.3, Revision 2, dated August 1989.³⁰

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomenon."
2. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."
3. SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," April 2, 1993; SRM-93-087 issued on July 21, 1993.³¹
4. NUREG-1061, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee; Volume 4: Evaluation of Other Loads and Load Combinations," December 1984.³²
- 35.³³ NUREG/CR-1161, ~~D. W. Coats~~, "Recommended Revisions to Nuclear Regulatory Commission Seismic Design Criteria," ~~NUREG/CR-1161~~,³⁴ May 1980.
46. ASCE Standard 4-86, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety-Related Nuclear Structures," American Society of Civil Engineers, September 1986.
7. IEEE Standard 344-1987, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," Appendix D, "Test Duration and Number of Cycles," Institute of Electrical and Electronics Engineers, June 1987.³⁵
58. TID-7024, "Nuclear Reactors and Earthquakes," Division of Reactor Development, U.S. Atomic Energy Commission, August 1963.

69. A. S. Veletsos, "Seismic Effects in Flexible Liquid Storage Tanks," Proceedings of Fifth World Conference on Earthquake Engineering, Rome, 1974.
710. A. S. Veletsos and J. Y. Yang, "Earthquake Response of Liquid Storage Tanks," Advances in Civil Engineering Through Engineering Mechanics, Proceedings of the Engineering Mechanics Division Specialty Conference, ASCE, Raleigh, North Carolina, pp. 1-24, 1977.
811. M. A. Haroun and G. W. Housner, "Seismic Design of Liquid Storage Tanks," Journal of the Technical Councils, ASCE, Vol. 107, No. TC1, pp. 191-207, 1981.
912. A. S. Veletsos, "Seismic Response and Design of Liquid Storage Tanks," Guidelines for the Seismic Design of Oil and Gas Pipeline Systems, Technical Council on Lifeline Earthquake Engineering, ASCE, pp. 255-370 and 443-461, 1984.³⁶
103. A. S. Veletsos and Y. Tang, "The Effects of Soil-Structure Interaction Effects for Laterally Excited Liquid-Storage Tanks," ~~to appear as an~~ EPRI Technical Report NP-6500 (Interim Report), Palo Alto, California, September 1989.³⁷
114. M. A. Haroun and M. A. Tayel, "Axisymmetrical Vibrations of Tanks- Numerical," Journal of Engineering Mechanics Division, ASCE, Vol. 111, No. 3, pp. 329-345, 1985.
125. A. S. Veletsos and Y. Tang, "Dynamics of Vertically Excited Liquid Storage Tanks," Journal of Structural Engineering, ASCE, Vol. 112, No. 6, pp. 1228-1246, 1986.
136. A. S. Veletsos and Y. Tang, "Interaction Effects in Vertically Excited Steel Tanks," Dynamic Response of Structures, G. C. Hart and R. B. Nelson, Editors, ASCE, pp. 636-643, 1986.

SRP Draft Section 3.7.3
Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Editorial - Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 3.7.3.
2.	Editorial.	Corrected typographical error, changing "Model" to "Modal."
3.	Editorial.	Corrected typographical error, changing "1.10" to "I.10."
4.	SRP-UDP format item.	Deleted parenthetical reference citation as this citation is not to be used when quoting parts of the Code of Federal Regulations, including General Design Criteria, and also Regulatory Guides.
5.	SRP-UDP format item.	Deleted parenthetical reference citation as this citation is not to be used when quoting parts of the Code of Federal Regulations, including General Design Criteria, and also Regulatory Guides.
6.	Editorial.	Changed numbering format from numerical to alphabetical format for general acceptance criteria to distinguish them from specific criteria, as numerical numbering format is being used for specific acceptance criteria.
7.	Editorial.	Changed numbering format from numerical to alphabetical format for general acceptance criteria to distinguish them from specific criteria, as numerical numbering format is being used for specific acceptance criteria.
8.	Integrated Impact # 1223.	Rulemaking has been proposed in 59 FR 52255 that will lead to amendments in 10CFR100 with regard to, among other items, seismic requirements. However, because this rulemaking is not yet final, no SRP change is being made at this time, based on this Integrated Impact.

SRP Draft Section 3.7.3
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
9.	Integrated Impacts # 1130 and # 1223.	Rulemaking is expected which will eliminate the OBE as an analysis requirement from the design basis, if its peak ground acceleration (PGA) level is set at 1/3 or less of the SSE PGA. However, no SRP change is being implemented at this time due to ROC # 1130. Additionally, rulemaking proposed in FR 52255 is expected to lead to amendments to 10CFR100 with regard to, among other items, seismic requirements. However, because said rulemaking is not yet final, no SRP change is being implemented at this time, due to ROC # 1223.
10.	Editorial.	Consistent with other SRP sections, changed word sequence slightly and added the acronym SSC for "structure system and component," to be used in lieu of the full expression.
11.	Editorial.	Substituted the acronym SSC for "structure, system and component." This acronym was introduced at the beginning of this SRP section, as its use is consistent with and widely used in other SRP sections.
12.	Integrated Impact # 583.	Included (by reference) the three criteria related to the failure of non-Category I SSCs and the potential for subsequent interaction with seismic Category I SSCs, provided in SRP Section 3.7.2, subsection II.8, for consistency. As stated in the evolutionary plant FSERs, this approach is consistent with Regulatory Guide 1.29 positions C.2 and C.3.
13.	Editorial.	Inserted missing word, for clarification.
14.	Integrated Impact # 581.	Inserted the name of the uniform response spectrum (URS) technique being described in this paragraph, so it can be referenced in the next paragraph. The term "URS" to describe the SRP analysis technique was taken from Section 2 of NUREG-1061, Volume 4.
15.	Editorial.	Added "is used" to clarify the meaning of the sentence.
16.	Integrated Impact # 581.	Added NUREG-1061 as source of alternate response spectrum methods, which may be used in lieu of the uniform response spectrum (URS) technique being described in the previous paragraph.
17.	Editorial.	Changed reference notation to standard format and updated parenthetical reference citation to the new item number in the reference list.

SRP Draft Section 3.7.3
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
18.	Editorial.	Changed reference notation to standard format and updated parenthetical reference citation to the new item number in the reference list.
19.	Editorial.	Added "SRP" to clarify the meaning of the sentence.
20.	Editorial.	Changed reference notation to standard format and updated parenthetical reference citation to the new item number in the reference list.
21.	Editorial.	Renumbered references to match the changed numbers in the reference list after adding a new items to the list.
22.	Editorial.	Changed reference notation to standard format for quoting the applicable documents.
23.	Editorial.	Changed reference notation to standard format and updated parenthetical reference citation to the new item number in the reference list.
24.	Editorial.	Changed reference notation to standard format and updated parenthetical reference citation to the new item number in the reference list.
25.	SRP-UDP Format Item, Develop Technical Rationale.	Added Technical Rationale for General Design Criterion GDC 2 and Appendix A to 10CFR100. Technical Rationale is a new feature added to the SRP.
26.	Integrated Impact 640	Added a discussion of alternative approaches that may be used for determining the number of cycles to be used in a fatigue analysis of piping systems in lieu of using the OBE to establish the number of cycles.
27.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
28.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
29.	SRP-UDP Guidance	Replaced the first sentence and added a standard blurb to indicate applicability of this section to reviews of future applications.
30.	Editorial.	Specified applicable revision numbers for SRP Section 3.7.1, to be used during the specified periods of time, accordingly.

SRP Draft Section 3.7.3
Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
31.	Integrated Impact 640.	Added SECY-93-087 as a reference to this SRP section.
32.	Integrated Impact # 581.	Added NUREG-1061 as a reference.
33.	Editorial.	Renumbered references in the reference list after adding new items to the list.
34.	Editorial.	Changed wording of reference slightly, for consistency with generally used format for referencing NUREG documents.
35.	Integrated Impact # 640.	Added IEEE Std 344-1987 as a reference.
36.	Reference Verification.	Within the time available, this reference could not be verified.
37.	Editorial - Reference verification.	Updated title and report number for existing reference.

SRP Draft Section 3.7.3
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
581	Revise Acceptance Criteria to add additional techniques for considering independent support movements.	II. Acceptance Criteria, Item 9 and VI. References, Item 3.
582	Consider qualified endorsement of industry standard ASCE 4-86 as a candidate for future work.	<u>No SRP change due to this ROC.</u> This item will be tracked with IPD-7.0 Form 3.7.2-1.
583	Revise Acceptance Criteria regarding analysis of non-Category I systems' effects on Category I systems.	II. Acceptance Criteria, Item 8.
640	Revise Acceptance Criteria regarding determination of the number of earthquake cycles.	III and VI
1130	Revise Acceptance Criteria, Review Procedures and Evaluation Findings, applicable to evolutionary plants, for review of seismic system analysis.	<u>No SRP change due to this ROC,</u> pending regulatory rulemaking. However, an explanatory note is provided in II. Acceptance Criteria, Item B, concerning Appendix A to 10 CFR 100.
1139	Revise Acceptance Criteria, Review Procedures, and Evaluation Findings, as necessary, to incorporate the guidance of proposed Draft Regulatory Guide DG-1015.	<u>No SRP change due to this ROC,</u> pending final approval of the Regulatory Guide.
1223	Revise the SRP to incorporate the new and revised requirements from proposed rulemaking in 59 FR 52255.	<u>No SRP change due to this ROC,</u> pending final approval of changes to 10 CFR 100, 10 CFR 50.34, 10 CFR 50.54, and of new Appendix S to 10 CFR 50.