



## U.S. NUCLEAR REGULATORY COMMISSION

# STANDARD REVIEW PLAN

### 3.7.3 SEISMIC SUBSYSTEM ANALYSIS

#### REVIEW RESPONSIBILITIES

**Primary** - Organization responsible for seismic and structural analysis reviews

**Secondary** - None

#### I. AREAS OF REVIEW

The review scope of this [NUREG-0800](#), Standard Review Plan (SRP) section (seismic subsystems) covers all seismic Category I substructures such as platforms; support frame structures; yard structures; buried piping, tunnels, and conduits; concrete dams; and atmospheric tanks. For distribution systems, including their supports (e.g., cable trays, conduit, heating, ventilation, and air conditioning (HVAC), and piping) and equipment supports, which are reviewed under [NUREG-0800](#), SRP Sections 3.9.2 and 3.9.3, supplementary seismic analysis criteria are presented in this SRP section. Intervening structural elements between these [distribution systems and equipment](#) supports and [the](#) building structural steel/concrete are also reviewed under this SRP section.

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#### USNRC STANDARD REVIEW PLAN

This Standard Review Plan (SRP), NUREG-0800, has been prepared to establish criteria that the U.S. Nuclear Regulatory Commission (NRC) staff responsible for the review of applications to construct and operate nuclear power plants intends to use in evaluating whether an applicant/licensee meets the NRC regulations. The SRP is not a substitute for the NRC regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide an acceptable method of complying with the NRC regulations.

The SRP sections are numbered in accordance with corresponding sections in Regulatory Guide (RG) 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Not all sections of RG 1.70 have a corresponding review plan section. The SRP sections applicable to a combined license application for a new light-water reactor (LWR) are based on RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

These documents are made available to the public as part of the NRC policy to inform the nuclear industry and the general public of regulatory procedures and policies. Individual sections of NUREG-0800 will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience. Comments may be submitted electronically by email to [NRR\\_SRP@nrc.gov](mailto:NRR_SRP@nrc.gov)

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The specific areas of review are as follows:

1. 1. Seismic Analysis Methods. The information reviewed is similar to that described in Subsection I.1 of SRP Section 3.7.2 but as applied to seismic Category I subsystems.
2. 2. Determination of Number of Earthquake Cycles. Criteria or procedures used to establish the number of earthquake cycles resulting from the seismic events and the maximum number of cycles for which applicable seismic Category I subsystems and components are designed are reviewed.
3. 3. Procedures Used for Analytical Modeling. The information reviewed is similar to that described in Subsection I.3 of SRP Section 3.7.2 but as applied to seismic Category I subsystems.
4. 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.
5. 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 seismic Category I subsystems.
6. 6. Three Components of Earthquake Design Ground Motion. The information reviewed is similar to that described in Subsection I.6 of SRP Section 3.7.2 but as applied to seismic Category I subsystems.
7. Combination of Modal Responses. The information reviewed is similar to that described in Subsection I.7 of SRP Section 3.7.2 but as applied to seismic Category I subsystems.
8. Interaction of Other Systems With Non-Seismic Category I Systems/Subsystems with Seismic Category I SSCs. The information reviewed is similar to that described in Subsection I.8 of SRP Section 3.7.2 but as applied to non-seismic Category I subsystems.
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 I.10 of SRP Section 3.7.2 but as applied to seismic Category I subsystems.
11. Torsional Effects of Eccentric Masses. The information reviewed is similar to that described in subsection Subsection I.11 of SRP Section 3.7.2 but as applied to seismic Category I subsystems.
12. Seismic Category I Buried Piping, Conduits, and Tunnels. For seismic Category I buried piping, conduits, tunnels, and other subsystems, 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 Seismic Category I Concrete Dams. The analytical methods and procedures that ~~will beare~~ used for seismic analysis of seismic 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 seismic Category I above-ground tanks, the seismic analysis criteria and methods that consider hydrodynamic forces, tank flexibility, soil-structure interaction, (SSI), and other pertinent parameters are reviewed.
15. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the structures, systems, and components (SSCs) (if any are identified related to this SRP section) in accordance with SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this SRP section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.
16. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review ~~will also addressaddresses~~ COL action items ~~and~~ requirements, and restrictions (e.g., interface requirements and site parameters-~~).~~

For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

### Review Interfaces

Other SRP sections interface with this section as follows:

1. Review of geological and seismological information to establish the free-field ground motion over the complete depth of the embedded facility is performed under SRP Sections 2.5.1 through 2.5.3.
2. The geotechnical parameters and methods employed in the analysis of free field soil media and the soil properties are reviewed under SRP section 2.5.4.
3. The development of the design ground motion (response spectra and time histories) is reviewed under SRP Section 3.7.1.
4. The seismic system analysis, which includes the seismic SSI analysis, is reviewed under SRP Section 3.7.2.
5. The design of seismic Category I structures for all applicable load combinations is reviewed under SRP Sections 3.8.1 through 3.8.5.

6. [For DC applications and COL applications referencing a DC, review of the site parameters in the Design Control Document \(DCD\) Tier 1 and Chapter 2 of the DCD Tier 2 submitted by the applicant is performed under SRP Section 2.0, "Site Characteristics/Site Parameters."](#)
7. [Review of the Probabilistic Risk Assessment is performed under SRP Section 19.0 in conjunction with DC/COL-ISG-020, "Interim Staff Guidance on Implementation of a Probabilistic Risk Assessment-Based Seismic Margin Analysis for New Reactors," for potential risk significance of SSCs and the risk-based susceptibility of risk significant SSCs to failure due to seismic hazards.](#)

## II. ACCEPTANCE CRITERIA

### Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, General Design Criterion (GDC) 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.
2. ~~10 CFR Part 400, Subpart A, which 50, Appendix S, is applicable to power reactor site applications before January 10, 1997, refers to Appendix A of this part for seismic criteria. 10 CFR Part 100, Appendix A indicates that the safe shutdown earthquake (SSE) and the operating basis earthquake (OBE) shall be considered in the design of safety related SSCs. 10 CFR Part 100, Appendix A, 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 SSE shall involve the use of either a suitable dynamic analysis or a suitable qualification test to demonstrate that SSCs 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.~~  
~~10 CFR Part 100, Subpart B, which is applicable to power reactor site applications on or after January 10, 1997, refers to 10 CFR 100.23 of this part for seismic criteria. 10 CFR 100.23 describes the criteria and nature of investigations required to obtain the geologic and seismic data necessary to determine the suitability of the proposed site and the plant design bases. 10 CFR 100.23 also indicates that applications to engineering design are contained in 10 CFR Part 50, Appendix S.~~
3. ~~10 CFR Part 50, Appendix S, is applicable to applications for a design certification or combined license DC or COL to 10 CFR Part 52 or a construction permit (CP) or operating license (OL) pursuant to 10 CFR Part 50 on or after January 10, 1997. For Appendix S requires that for safe shutdown earthquake (SSE) ground motions, certain SSCs will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of these SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account soil structure interaction (SSI) effects and the expected duration of the vibratory motion. If the operating basis earthquake (OBE) is set~~

at one-third or less of the SSE, an explicit [response analysis](#) or design ~~analysis~~ is not required. If the OBE is set at a value greater than one-third of the SSE, an analysis and design must be performed to demonstrate that [the when subjected to the effects of the OBE in combination with normal operating loads, all SSCs of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public must remain functional and within](#) applicable stress, strain, and deformation limits ~~are satisfied~~.

~~3.~~ 4. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a ~~plant facility~~ that incorporates the ~~design certification is built~~ [DC has been constructed](#) and will ~~operate~~ [be operated](#) in ~~accordance~~ [conformity](#) with the ~~design certification~~ [DC](#), the provisions of the Atomic Energy Act (~~AEA~~), and the ~~U.S. Nuclear Regulatory Commission (NRC)~~ [Commission's rules and](#) regulations.

~~54.~~ 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the ~~combined license~~ [COL](#), the provisions of the ~~AEA~~ [Atomic Energy Act, Commission's rules](#) and ~~the NRC~~ regulations.

### SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the ~~NRC Commission's~~ regulations identified above are as follows for ~~the~~ review described in this SRP section. The SRP is not a substitute for the ~~NRC Commission's~~ regulations, and compliance with it is not required. However, an applicant is required to identify differences between [this SRP section and](#) the design features, analytical techniques, and procedural measures proposed for ~~its~~ [the facility and the SRP acceptance criteria](#), and ~~evaluated~~ [discussing](#) how the proposed alternatives ~~to the SRP acceptance criteria~~ provide acceptable methods of ~~compliance~~ [complying](#) with the ~~NRC~~ regulations [that underlie the SRP acceptance criteria](#).

1. Seismic Analysis Methods. The acceptance criteria provided in SRP Section 3.7.2, ~~subsection~~ [Subsection](#) II.1 are applicable.
2. Determination of Number of Earthquake Cycles. During the plant life at least one SSE and five OBEs, if applicable, should be assumed. The number of cycles per earthquake should be obtained from the time history used for the system analysis, or a minimum of 10 maximum stress cycles per earthquake may be assumed.

When the OBE is defined as less than one-third the SSE (and therefore the OBE does not need to be considered in design), there may be certain structural elements which still need to be evaluated for fatigue due to the OBE induced stress cycles. In these instances, the guidance for determining the number of earthquake cycles for use in fatigue calculations should be the same as the guidance provided in Staff Requirement Memorandum (SRM) for SECY-93-087 dated July 21, 1993 for piping systems- [\(Agencywide Document Access and Management System \(ADAMS\) Accession Number ML003708056\)](#). The number of earthquake cycles to consider is ~~the~~ two SSE events

with 10 maximum stress cycles per event. This is considered to be equivalent to the cyclic load basis of one SSE and five OBEs. Alternatively, 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 Institute of Electrical and Electronics Engineers (IEEE ) Standard 344-1987, Appendix D.

3. Procedures Used for Analytical Modeling. The acceptance criteria provided in SRP Section 3.7.2, subsection 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 ~~two~~one-half 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 Subsection II.13, are applicable.
6. Three Components of Earthquake Design Ground Motion. The acceptance criteria provided in SRP Section 3.7.2, subsection Subsection II.6, are applicable.
7. Combination of Modal Responses. The acceptance criteria provided in SRP Section 3.7.2, subsection Subsection II.7, are applicable.
8. Interaction of Other Systems With Non-Seismic Category I Systems/Subsystems with Seismic Category I SSCs. To be acceptable, each non-seismic Category I system/subsystem should be designed to be isolated from any seismic Category I system/SSC by either a constraint or barrier, or should be remotely located with regard to the seismic Category I system/SSC. If this is not feasible or practical, then adjacent non-seismic Category I system/subsystems should be analyzed according to the same seismic criteria as applicable to the seismic Category I system/SSC. For non-seismic Category I system/subsystems attached to seismic Category I systems/SSCs, the dynamic effects of the non-seismic Category I system/subsystems should be simulated in the modeling of the seismic Category I system/SSC. The attached non-seismic Category I system/subsystems, 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 seismic Category I system/SSC.
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 analyzing equipment items supported at two or more locations is to define a uniform response spectrum (URS) that envelopes all of the individual response spectra at the various support locations. The URS is applied at all locations to calculate the maximum inertial responses of the equipment. This is referred to as the uniform support motion (USM) method. 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 building structural response calculations. The support displacements can then be imposed on the supported equipment 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. In the case of multiply-supported equipment in a single structure and/or spanning between structures, an alternate method that can be used is the independent support motion (ISM) approach. Guidance and criteria for the use of the ISM method is given in NUREG-1061, [Volume 4](#), Section 2, ~~Volume 4~~. If the ISM method is utilized, all of the criteria presented in NUREG-1061 related to the ISM method ~~must~~should be followed.

In lieu of the response spectrum approach, time histories of support motions may be used as input excitations to the subsystems. The ~~staff expects the~~ time history approach ~~is considered~~ to provide more realistic results ~~as compared to~~than the USM or ISM methods.

10. Use of Equivalent Vertical Static Factors. The acceptance criteria provided in SRP Section 3.7.2, ~~subsection~~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~~determined on a case-by-case basis.
12. Seismic Category I Buried Piping, Conduits, and Tunnels. For seismic Category I buried piping, conduits, tunnels, and any other subsystems, the following items should be considered in the analysis:
  - A. Two types of ground shaking-induced loadings ~~must~~should be considered ~~for~~in the design analysis.
    - 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 in NUREG/CR-1161, page 26~~;~~; in American Society of Civil Engineers

(ASCE) Standard 4-98, Section 3.5.2 and in [the ASCE Report](#)—“Seismic Response of Buried Pipes and Structural Components.”

13. Methods for Seismic Analysis of Seismic Category I Concrete Dams. For the analysis of all seismic 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 design ground motion](#) loadings, SSI effects, and nonlinear stress-strain relations for the soil, should be used. Analysis of earthen dams is reviewed under SRP Section 2.5.5, “Stability of Slopes.”
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 may be inadequate in some cases. The major problem is that direct application of this method [is consistent with](#) [relies on](#) 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](#) ([Studies by](#) Veletsos (1974 and 1984), Veletsos and Yang (1977), Veletsos and Tang (1989), and Haroun and Housner (1981), 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 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 need to be considered for both horizontal and vertical motions.

The acceptance criteria below are based upon the information contained in TID-7024 and NUREG/CR-1161. Additional guidance is provided in ASCE Standard 4-98, Section 3.5.4. These references also contain acceptable calculation 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](#) [should](#) 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](#) [should](#) 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. In addition, the fundamental sloshing (convective) mode of the fluid [must](#) [should](#) be included in the horizontal analysis.
- B. The fundamental natural horizontal impulsive mode of vibration of the fluid-tank system [must](#) [should](#) 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~~should 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 (1989-~~)).~~.
- D. In determining the spectral acceleration in the horizontal convective mode,  $S_{a2}$ , the fluid damping ratio ~~shall~~should 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~~should 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~~should 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~~should be evaluated with due regard for the contribution of the vertical component of ground shaking. The effects of SSI should be considered in this evaluation unless justified otherwise. The hydrodynamic pressure at any level ~~must~~should 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~~should be located at ~~an~~ elevation higher than the slosh height above the top of the fluid or else ~~must~~should be designed for pressures resulting from fluid sloshing against this head.
- H. At the point of attachment, the tank shell ~~must~~should be designed to withstand the seismic forces imposed by the attached piping. An appropriate analysis ~~must~~should be performed to verify this design.
- I. The tank foundation (see also SRP Section 3.8.5) ~~must~~should 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~~the tank should be ~~given~~designed to ~~prevent~~not allow buckling of tank walls and roof, failure of connecting piping, and sliding of the tank.

### Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this SRP section is discussed in the following paragraphs:

1. 10 CFR Part 50, Appendix A, GDC 2 requires, in the relevant parts, 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. These data shall ~~be used~~ be used to specify the design requirements of nuclear power plant components to be evaluated as part of ~~construction permit (CP), operating license (OL), CP, OL, COL,~~ early site permit (ESP) reviews, or for site parameter envelopes in the case of DCs, thereby ensuring that components important to safety will function in a manner that will maintain the plant in a safe condition.

SRP Section 3.7.3 describes acceptable methods for the seismic analysis of seismic Category I subsystems such as platforms; support frame structures; yard structures; buried piping, tunnels, and conduits; concrete dams; and atmospheric tanks. Criteria ~~is are~~ is are provided for the static and dynamic analysis of these subsystems subjected to ~~earthquake design ground motion~~ earthquake design ground motion loadings. These criteria include acceptable methods/procedures for analytical modeling, selection of damping, determination of the number of earthquake cycles, interaction of other systems with seismic Category I ~~systems subsystems~~, and evaluation of multiply-supported equipment.

Meeting these ~~requirements criteria~~ requirements criteria provides assurance that seismic Category I subsystems will be adequately designed to withstand the effects of earthquakes, and thus, will be able to perform their intended safety ~~function functions~~.

~~2. 10 CFR Part 100, Subpart A, which is applicable to power reactor site applications before January 10, 1997, refers to appendix A of this part for seismic criteria. 10 CFR Part 100, A 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, involve the use of either a suitable dynamic analysis or an appropriate qualification test methodology. 10 CFR Part 100, Appendix A requires that the applicable levels of vibratory ground motion corresponding to the OBE and the SSE are properly defined, and that adequate methods are used to demonstrate that SSCs important to safety can withstand the seismic and other concurrently applied loads.~~

~~10 CFR Part 100, Subpart B, which is applicable to power reactor site applications on or after January 10, 1997, refers to 10 CFR 100.23 of this part for seismic criteria. 10 CFR 100.23 describes the criteria and nature of investigations required to obtain the geologic and seismic data necessary to determine the suitability of the proposed site and the plant design bases. 10 CFR 100.23 also indicates that applications to engineering design are contained in 10 CFR Part 50, Appendix S.~~

~~SRP Section 3.7.3 describes acceptable analytical methods for seismic evaluation of seismic Category I subsystems. Criteria for seismic qualification of mechanical and electrical equipment by test are provided in SRP Sections 3.9.2 and 3.10. The criteria in SRP 3.7.3 provide methods acceptable to the staff for performing static and dynamic seismic analysis of subsystems. Criteria for determination of the equivalent static coefficient of acceleration for the static method and criteria for performing response spectrum or time history analyses for dynamic methods are provided.~~

~~Meeting these requirements provides assurance that appropriate engineering methods will be used to seismically qualify subsystems important to safety, and thereby ensure~~

~~that they will be able to perform their intended safety function when subjected to the SSE and OBE (if applicable).~~

3. ~~10 CFR Part 50, Appendix S is applicable to applications for a design certification or combined license to 10 CFR Part 52 or a construction permit or operating license.~~  
10 CFR Part 50, Appendix S is applicable to applications for a DC or COL to 10 CFR Part 52 or a CP or OL pursuant to 10 CFR Part 50 on or after January 10, 1997. For SSE ground motions, 10 CFR Part 50, Appendix S requires that certain SSCs will remain functional and within applicable stress, strain, and deformation limits. The required safety functions of these SSCs must be assured during and after the vibratory ground motion through design, testing, or qualification methods. The evaluation must take into account SSI effects and the expected duration of the vibratory motion. If the OBE is set at one-third or less of the SSE, an explicit response analysis or design analysis is not required. If the OBE is set at a value greater than one-third of the SSE, an analysis and design must be performed to demonstrate that when subjected to the effects of the OBE in combination with normal operating loads, all SSCs of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public must remain functional and within the applicable stress, strain, and deformation limits ~~are satisfied~~.

SRP Section 3.7.3 describes acceptable analytical methods that are used to determine the seismic response of subsystems in terms of stresses, strains, and deformations. These responses are combined with the structural responses from other loads in accordance with the criteria in SRP Section 3.8. The criteria in SRP Section 3.7.3 ensure that the effects of SSI and expected duration of the earthquake are appropriately included in the evaluation. In addition, criteria ~~is~~are provided to indicate when the effects of the OBE are required to be considered explicitly in the seismic design of the subsystems.

Meeting these ~~requirements~~acceptance criteria provides assurance that appropriate methods will be used to determine the structural response of subsystems, under the SSE and OBE (if applicable), which will ensure that they will remain functional within applicable acceptance limits.

### III. REVIEW PROCEDURES

~~The reviewer will select material from the procedures described below, as may be appropriate for a particular case.~~ These review procedures are based on the identified SRP acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in SRP Subsection II.

In accordance with 10 CFR 52.47(a)(8), (21), and (22), and 10 CFR 52.79(a)(17) and (20), for new reactor license applications submitted under 10 CFR Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues which are identified in the version of NUREG-0933 current on the date up to 6 months before the docket date of the application and which are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v). These cross-cutting

review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding Safety Evaluation Report (SER) section.

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 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 Subsection II.2 of this SRP section. Justification for deviating from the acceptance criteria is requested from the applicant, as necessary.
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 Subsection II.3-4.
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 Subsection II.4 of this SRP section are met.
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 Subsection II.13.
6. Three Components of Earthquake Design Ground Motion: The procedures by which the three components of ~~earthquake design ground~~ motion are considered in determining the seismic response of subsystems are reviewed to determine ~~compliance with if~~ the acceptance criteria of SRP Section 3.7.2, subsection Subsection II.6 are met.
7. Combination of Modal Responses: The procedures for combining modal responses are reviewed to determine ~~compliance with if~~ the acceptance criteria of SRP Section 3.7.2, subsection Subsection II.7 are met when a response spectrum modal analysis method is used.
8. Interaction of ~~Other Systems with Non-~~Seismic Category I ~~Systems~~ Subsystems with Seismic Category I SSCs. The criteria used to design the interfaces between ~~seismic Category I and~~ non-seismic Category I ~~systems~~ subsystems and seismic Category I SSCs are reviewed to determine ~~compliance with if~~ the acceptance criteria of subsection Subsection II.8 of this SRP section are met.
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 Subsection II.9 of this SRP section.

10. Use of Equivalent Vertical Static Factors: The procedures for the use of equivalent vertical static factors are reviewed to determine ~~compliance with~~ the acceptance criteria of SRP Section 3.7.2, ~~subsection~~ Subsection II.10 ~~are met~~.
11. Torsional Effects of Eccentric Masses: The procedures for seismic analysis of seismic Category I subsystems are reviewed to determine ~~compliance with~~ the acceptance criteria of ~~subsection~~ Subsection II.11 of this SRP section ~~are met~~.
12. Seismic Category I Buried Piping, Conduits, and Tunnels: The analysis procedures for seismic Category I buried piping, conduits, tunnels, and any other subsystems are reviewed to determine that they are in accordance with the acceptance criteria of ~~subsection~~ Subsection II.12 of this SRP section.
13. Methods for Seismic Analysis of Seismic Category I Concrete Dams: Methods for the seismic analysis of seismic Category I concrete dams are reviewed to determine ~~compliance with~~ the acceptance criteria of ~~subsection~~ Subsection II.13 of this SRP section ~~are met~~.
14. Method for Seismic Analysis of Above-Ground Tanks: Methods for seismic analysis of seismic Category I above-ground tanks are reviewed to determine ~~compliance with~~ the acceptance criteria of ~~subsection~~ Subsection II.14 of this SRP section ~~are met~~.
- ~~15.~~ Design Certification 15. DC and COL Applications. For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site ~~Parameters,)~~ parameters), set forth in the Final Safety Analysis Report (FSAR) meets the acceptance criteria. DCs have referred to the FSAR as the ~~Design Control Document (DCD.)~~ DCD. The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an ESP or other NRC approvals (e.g., manufacturing license, site suitability report or topical report-~~).~~).

For review of both DC and COL applications, SRP Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

#### IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's ~~safety evaluation report.~~ SER. The reviewer also states the bases for those conclusions.

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~~ Subsection IV.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this SRP section.

In addition, to the extent that the review is not discussed in other ~~Safety Evaluation Report~~ ~~(SER)~~[SER](#) sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

## V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52.

~~Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the~~The staff will use the method described herein to evaluate conformance with ~~Commission~~the Commission's regulations.

~~The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision. Operating License and final design approval (FDA) applications, whose CP and preliminary design approval (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. OL and FDA applications, whose CP and PDA reviews were conducted prior to the issuance of Revision 2 (dated August 1989) to SRP Section 3.7.3, are reviewed in accordance with the acceptance criteria given in the SRP Section 3.7.3, Revision 1, dated July 1981.~~

The application must contain an evaluation of the standard plant design against the SRP revision in effect 6 months before the docket date of the application. The application must identify and describe all differences between this SRP section and the design features, analytical techniques, and procedural measures proposed for the facility, and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the SRP acceptance criteria.

## VI. REFERENCES

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."
2. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomenon."
3. 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants."
4. 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."
- ~~5. 10 CFR Part 100, Subpart A, "Evaluation Factors for Stationary Power Reactor Site Applications Before January 10, 1997 and for Test Reactors."~~
- ~~6. 10 CFR Part 100, Subpart B, "Evaluation Factors for Stationary Power Reactor Site Applications on or After January 10, 1997."~~
- ~~7. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."~~
- ~~8. 10 CFR 100.23, "Geological and Seismic Siting Criteria."~~

- | ~~9.5.~~ ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary," American Society of Civil Engineers, [Section 3.5.2 for buried pipes and conduits, and Section 3.5.4 for above-ground vertical tanks-[f](#)].
- | ~~10.6.~~ ASCE Report, "Seismic Response of Buried Pipes and Structural Components," American Society of Civil Engineers, 1983.
- | [7. DC/COL-ISG-020, "Interim Staff Guidance on Seismic Margin Analysis for New Reactors Based on Probabilistic Risk Assessment," March 15, 2010.](#)
- | ~~11.8.~~ Haroun, M. A., and Housner, G. W., "Seismic Design of Liquid Storage Tanks," Journal of the Technical Councils, ASCE, Vol. 107, No. TC1, pp. 191-207, 1981.
- | ~~12.9.~~ 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.
- | ~~13.10.~~ NUREG-1061, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee; Volume 4: Evaluation of Other Loads and Load Combinations," December 1984.
- | ~~14.11.~~ NUREG/CR-1161, "Recommended Revisions to Nuclear Regulatory Commission Seismic Design Criteria," May 1980.
- | ~~15.12.~~ RG 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."
- | ~~16.13.~~ RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."
- | ~~17.14.~~ SRM SECY 93-087, Staff Requirement Memorandum: "SECY-93-087 - Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs-"[" \(ADAMS Accession Number ML003708056\).](#)
- | ~~18.15.~~ TID-7024, "Nuclear Reactors and Earthquakes," Division of Reactor Development, U.S. Atomic Energy Commission, August 1963.
- | ~~19.16.~~ Veletsos, A. S., "Seismic Effects in Flexible Liquid Storage Tanks," Proceedings of Fifth World Conference on Earthquake Engineering. Rome. 1974.
- | ~~20.17.~~ Veletsos, A. S., "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, pp. 255-370 and 443-461. ASCE: Reston, VA. 1984.
- | ~~21.18.~~ Veletsos, A. S., and Yang, J. Y., "Earthquake Response of Liquid Storage Tanks," Advances in Civil Engineering Through Engineering Mechanics, Proceedings of the Engineering Mechanics Division Specialty Conference, pp. 1-24, 1977. ASCE, Raleigh, North Carolina



22-19. Veletsos, A. S., and Y. Tang, Y., "The Effects of [SSI/Soil-Structure Interaction](#) on Laterally Excited Liquid-Storage Tanks," EPRI Technical Report NP-6500 (Interim Report-[2](#)). Electric Power Research institute: Palo Alto, California, September 1989.

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**PAPERWORK REDUCTION ACT STATEMENT**

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part 50 and 10 CFR Part 52, and were approved by the Office of Management and Budget, approval number 3150-0011 and 3150-0151.

**PUBLIC PROTECTION NOTIFICATION**

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

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**SRP Section 3.7.3**  
**~~“Seismic Subsystem Analysis”~~**

**Description of Changes**

**Section 3.7.3 “SEISMIC SUBSYSTEM ANALYSIS”**

This SRP section affirms the technical accuracy and adequacy of the guidance previously provided in Revision 3, dated March 2007, of this SRP. See ADAMS Accession No. ML070640313.

II. ACCEPTANCE CRITERIA

1. Revised SRP Section 3.7.3 II.8 “Interaction of Non-Seismic Category I ~~Structures~~Subsystem with Seismic Category I SSCs” to eliminate potential inconsistency with the updated acceptance criteria in SRP Section 3.7.2 II.8. See item 8 in SRP Section 3.7.2, “Description of Changes, II Acceptance Criteria,” for the technical rationale for this change.