U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD for NuScale SMR DESIGN

3.7.1 SEISMIC DESIGN PARAMETERS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for seismic and structural analysis reviews

Secondary - Organization responsible for review of seismic ground motion development

I. AREAS OF REVIEW

The specific areas of review are as follows:

1. Design Ground Motion. For the seismic design of nuclear power plants, it is customary to specify the design ground motions that are exerted on the plant structures and used in soil-structure interaction (SSI) analyses. The design ground motion, also known as the seismic input motion or control motion, is based on the seismicity and geologic conditions at the site and expressed in such a manner that it can be applied to the dynamic analysis of structures, systems, and components (SSCs).

   Two levels of design ground motions are considered: (1) operating-basis earthquake (OBE) and (2) safe-shutdown earthquake (SSE). The three spatial components of the design ground motions (two horizontal and one vertical) are reviewed. The process for determining design ground motions for the OBE and SSE should be consistent with the process for determining the free-field ground motions at the site provided in NUREG-0800 Standard Review Plan (SRP) Section 2.5.2. SRP Section 2.5.2 includes consideration of the variation in and distribution of ground motions in the free field, the sources and directions of the motion, the propagation and transmission of seismic waves, and other site response characteristics including the variation of this seismic motion over the depth of the facility. The seismic free-field ground motions can be developed based on Regulatory Guides (RGs) 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," or 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion" and are reviewed under SRP Section 2.5.2. These guides provide procedures that are acceptable to the staff for defining the design response spectra in the free field for use in developing the OBE and SSE design ground motion needed for the design of nuclear power plant SSCs.

   A. Design Response Spectra. For a standard plant design, the design response spectra used for design certification (DC) can be a smooth-shaped broadband spectra consistent with the conditions postulated for the standard design. The postulated seismic design response spectra will become the certified seismic design response spectra (CSDRS) when the Commission certifies the design

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under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." For a combined license application (COLA), the site-specific design response spectra are typically developed from the site-specific ground motion response spectra (GMRS).

The GMRS reviewed under SRP Section 2.5.2 are site-specific horizontal and vertical free-field ground motion response spectra determined at the ground surface or at the free-field outcrop of the uppermost in situ competent material using performance-based procedures in accordance with RG 1.208. The performance-based site-specific GMRS transferred to the foundation level in the free field is referred to as the foundation input response spectra (FIRS). Therefore, the FIRS satisfy the same performance criteria as the GMRS. Both the GMRS and the FIRS are defined as free-field outcrop [1] response spectra. The FIRS is the starting point for conducting an SSI analysis and for making a one-to-one comparison of the seismic design capacity of the standard design and the site-specific seismic demand for a site. The FIRS for the vertical direction is obtained with the vertical to horizontal (V/H) ratios appropriate for the site. GMRS are those derived from the global understanding of the site soil layers above the rock condition as determined from the site exploration activities and, therefore, are unique to a particular site.

Competent material is generally considered to be in situ material having a minimum shear wave velocity of 1,000 feet per second (fps). If noncompetent material is present, any excavation and/or backfilling should not alter the development or location of the GMRS; however, the development of the FIRS uses the site profiles, including the effect of backfill. The remaining soft soil or backfill material needs to be considered in the SSI or other analyses. Further information on the development of the GMRS and FIRS is provided in DC/COL-ISG-01, "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications," and DC/COL-ISG-17, "Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses."

In addition to the FIRS, additional performance-based response spectra (PBRS) need to be developed at one or more intermediate depths between the foundation and ground surface. The PBRS need to be probabilistically determined using procedures that are consistent with the development of the FIRS. The PBRS are performance-based free-field outcrop response spectra generated using the soil column corresponding to the building for which the performance-based FIRS are also generated. The properties of the soil column are used to generate 60 or more randomized sets of properties similar to those used in the probabilistic seismic hazard analysis (PSHA) process as described in

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[1] Outcrop Evaluation—An outcrop assumption implies that the outcrop surface is a free surface at which the boundary condition for seismic waves is no shear stress, leading to a complete reflection of the incident wave. However, in reality, there may be layers of soil above the assumed outcrop elevation. In these situations, the GMRS or FIRS is computed at depth in a soil profile that includes the effect that the soil layers above have on the properties of soil layers below.

SRP Section 2.5.2. The resulting PBRS described above are the PBRS for the horizontal direction and may be established at various elevations in the free field. The PBRS developed at the ground surface is referred to as the performance-based surface response spectra (PBSRS) as described in DC/COL-ISG-017. The PBRS for the vertical direction can be obtained with the appropriate V/H ratios used to develop the FIRS. In addition, the methodology for developing V/H ratios for deep soil site conditions is reviewed on a case-by-case basis. The PBRS are used to verify and ensure that the soil columns to be used in a deterministic SSI analysis produce response spectra at the surface and other locations in the free field, which envelope the corresponding PBRS. Additional guidance for demonstrating the adequacy of the soil columns is provided in Design-Specific Review Standard (DSRS) Section 3.7.2 II.4. The FIRS and PBRS are associated with subsurface conditions localized to a specific building.

In addition, 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," is applicable to applications for a DC or combined license (COL) pursuant to 10 CFR Part 52 or a construction permit (CP) or operating license (OL) pursuant to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," submitted on or after January 10, 1997. Applications subject to this appendix must:

- Demonstrate that the SSE ground motion in the horizontal direction in the free field at the foundation level of the structures (i.e., the FIRS) must be an appropriate response spectrum with a peak ground acceleration (PGA) of at least 0.1g.

- Design SSCs to the OBE and SSE loadings. However, if the OBE is set at one-third or less of the SSE, an explicit response 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 for the OBE to demonstrate that the applicable stress, strain, and deformation limits of the SSCs are satisfied.

- Establish the OBE level earthquake ground motion. The OBE ground motion is associated only with plant shutdown and inspection unless specifically selected by the applicant as a design input. The magnitude of the OBE level earthquake in the application is reviewed to determine whether a seismic analysis is required for this earthquake level. Throughout this DSRS section, whenever the OBE is discussed, it is understood that the OBE level earthquake may not apply as a seismic design input to the particular application being reviewed, depending on the magnitude of the OBE as defined above.

For structures with either surface or shallowly embedded foundations, the seismic input motions to the SSI analyses can typically be placed at the free ground surface or at the foundation level using the guidance in this DSRS section, as supplemented by DC/COL-ISG-017. However, the input motions defined at locations other than the foundation level may not be appropriate for deeply embedded structures. In these situations, the seismic input should be specified only at the foundation level as FIRS.

For the site-specific deterministic SSI analysis, based on the procedure described in DSRS Section 3.7.2, the PBRS are used to ensure the adequacy of the soil columns used. For sites that have relatively uniform variation of shear wave velocity with depth, it is anticipated that the PBRS developed at the surface and at a central depth between the surface and foundation level of the deeply embedded facility should be adequate for verifying the adequacy of the soil columns. For sites that have unusual velocity characteristics with depth such as those containing significant inversions in the layer profiles, one or more additional depths are selected at which PBRS are developed that maximize the effects of the variation in input motion on facility response. The process for selecting the number and locations of these intermediate depths is reviewed on a case-by-case basis.

The proposed design response spectra at the foundation at both the OBE and SSE levels are reviewed. The design response spectra, in general, are relatively smooth plots not exhibiting random peaks and valleys. The use of smooth spectra is preferred in the design and is needed for generic site seismic hazard evaluation, as in the design of a standard plant. The use of unsmoothed design response spectra to develop the input ground motions (design time histories) is reviewed on a case-by-case basis.

A review is also made of the approach used to demonstrate that the horizontal component of the SSE ground motion in the free field at the foundation level of seismic Category I structures is an appropriate response spectrum with a PGA of at least 0.1g, as required by Appendix S to 10 CFR Part 50.

B. Design Time Histories. Acceleration time histories for computing the response of seismic Category I SSCs are reviewed. The extent to which these time histories are compatible with the design response spectra is reviewed.

When an appropriate recorded or specified time history is not available as input ground motion for seismic system analysis, the three spatial components of artificial time histories may be generated from the design response spectra for the purpose of carrying out a time history analysis of the SSCs. In demonstrating the statistical independence of the three components of ground motion, the correlation coefficients between the time histories are reviewed. The response spectra obtained from such artificial time histories of ground motion should generally envelop the design response spectra. The procedures used to generate response spectra from the artificial time histories and the comparisons of these response spectra with the design response spectra are reviewed.

In addition to the comparison of the response spectra derived from the ground motion time histories with the design response spectra, the frequency intervals at which the spectral values are calculated are also reviewed.

When time history analyses are performed, either of the following options may be considered. In either case, the time histories may be real or artificial.

Option 1: Single Set of Time Histories. The justification for the use of the single set of time histories is reviewed. The approach used to demonstrate that the response spectra generated from the time histories envelop the design response spectra is reviewed. Depending on the approach (Approach 1 or Approach 2 as discussed later in this section) used, the application of the response spectra enveloping criteria as well as the criteria for adequately matching a power spectral density (PSD) function may also need to be reviewed.

Option 2: Multiple Sets of Time Histories. In lieu of the use of a single time history, multiple artificial or real ground motion time histories may be used for the seismic analyses and design of the SSCs. The parameters describing the time histories and the number of time histories are reviewed. The approach used to demonstrate the adequacy of the set of multiple time histories, in terms of the enveloping criteria and having sufficient power over the frequency range of interest, is reviewed.

In some instances, a nonlinear analysis of the SSCs may be appropriate (e.g., stability analysis and evaluation of existing structures). Multiple time history analyses using artificial or real earthquake time histories may be used when nonlinear analyses are proposed. The adequacy of the time histories used for the nonlinear analyses is reviewed.

2. Percentage of Critical Damping Values. The percentage of critical damping values used for the seismic analysis of seismic Category I SSCs is reviewed for both the OBE and the SSE. Critical damping is the amount of damping that would completely eliminate free vibration and is an important measure of the damping capacity of a structure.

Vibrating SSCs have energy losses that depend on numerous factors, such as material characteristics, stress levels, and geometric configurations. This dissipation of energy, or damping effect, occurs because a part of the excitation input is transformed into heat, sound waves, and other energy forms. The response of a system to dynamic loads is a function of the amount and type of damping inherent in the system. Knowledge of appropriate values to represent this characteristic is essential for obtaining realistic results in any dynamic analysis.

In practical seismic analysis, which usually employs linear methods of analysis, damping is also used to account for many nonlinear effects such as changes in boundary conditions, joint slippage, concrete cracking, gaps, and other effects that tend to alter response amplitudes. In real structures, it is often impossible to separate “true” material damping from system damping, which is the measure of the total energy dissipation. Overall structural damping used in design is normally determined by observing experimentally the total response of the structure.

Damping values assigned to members of seismic Category I SSCs, including material damping and system damping, are reviewed. When applicable, the basis for any damping values that differ from those given in RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," is reviewed.

3. Supporting Media for Seismic Category I Structures. The description of the supporting media for each seismic Category I structure is reviewed, including foundation embedment depth, depth of soil over bedrock, soil layering characteristics, highest groundwater elevation, dimensions of the structural foundation, total structural height, topographical conditions of the sites, and soil properties (including strain-dependent properties) and their assumed variability. The purpose of this review is to determine the acceptability of the subsurface foundation model used in the SSI analyses.

4. Review Considerations for DC and COL Applications. For a DC application, the postulated seismic design response spectra are reviewed. The input or control location for the postulated seismic design response spectra is also reviewed. The postulated seismic design response spectra will become the CSDRS when the Commission certifies the design under 10 CFR Part 52. For a COL application referencing a certified design, the demonstration that the CSDRS, when transferred to the foundation level, envelops the site-specific FIRS is reviewed.

5. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For DC and COL reviews, the staff reviews the applicant's proposed ITAAC associated with the SSCs (if any are identified related to this DSRS 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 DSRS 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.

6. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review also addresses COL action items, requirements, and restrictions (e.g., interface requirements and site parameters).

   For a COL application referencing a DC or early site permit (ESP) or both, a COL applicant must address COL action items included in the referenced DC or ESP. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements, site parameters, and permit conditions) included in the referenced DC or ESP.

   COL action items related to seismic design parameters include soil layering assumptions used in the certified design, the range of soil parameters considered, and shear wave velocity values.

Review Interfaces

The reviewer should consider other SRP and DSRS sections which interface with this DSRS section as appropriate in the safety evaluation. The SRP and DSRS sections interfacing with this DSRS section are described 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 seismic system analysis, which utilizes the design ground motion developed in this DSRS section, is reviewed under DSRS Section 3.7.2.

4. The seismic subsystem analysis for some components that utilize the design ground motion developed in this DSRS section (e.g., buried piping, tunnels, and atmospheric tanks) is reviewed under DSRS Section 3.7.3.

5. For DC applications, the applicant's proposed site parameters in Tier 1 of the design control document (DCD) and in Chapter 2 of Tier 2 of the DCD are reviewed in accordance with the guidance in SRP Section 2.0, "Site Characteristics/Site Parameters." For COL applications referencing a DC, the applicant's site characteristics in COLA Final Safety Analysis Report (FSAR) Section 2.0 are reviewed in accordance with the guidance in SRP Section 2.0, "Site Characteristics/Site Parameters."

6. 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.

The results of the reviews for the OBE and the SSE site-specific free-field ground motion, soil properties, etc. are used as an integral part of the seismic analysis review of seismic Category I SSCs.

II. ACCEPTANCE CRITERIA

Requirements

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

1. 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2—The design basis shall reflect appropriate consideration of the most severe earthquakes 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 historical data have been accumulated.

2. 10 CFR Part 50, Appendix S, is applicable to applications for a DC or COL pursuant to 10 CFR Part 52 or a CP or OL pursuant to 10 CFR Part 50 on or after January 10, 1997. Appendix S requires that, for 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 associated with the SSE 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 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 remain functional and within applicable stress, strain, and deformation limits. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation level of the structures must be an appropriate response spectrum with a PGA of at least 0.1g.

3. 10 CFR 52.47(a)(1) requires a DC applicant to provide site parameters postulated for the design and an analysis and evaluation of the design in terms of those site parameters.

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 facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

5. 10 CFR 52.79(b)(1) lists requirements for a COL referencing an ESP as it relates to information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

6. 10 CFR 52.79(d)(1) lists requirements for a COL referencing a DC as it relates to information sufficient to demonstrate that the characteristics of the site fall within the site parameters specified in the DC.

7. 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 COL, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the U.S. Nuclear Regulatory Commission's (NRC's) regulations identified above are set forth below. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required.

As an alternative, and as described in more detail below, an applicant may identify the differences between a DSRS section and the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and discuss how the proposed alternative provides an acceptable method of complying with the NRC regulations that underlie the DSRS acceptance criteria.

1. Design Ground Motion

   A. Design Response Spectra. The site-specific FIRS and PBRS reviewed under this DSRS section are determined as free-field outcrop motions at the foundation level, the surface, and other appropriate intermediate depths. FIRS and associated deterministic soil profiles developed using the PBRS to meet the performance goal will establish the design basis for the site-specific SSI analysis; this design basis is developed using the guidance provided in SRP Section 2.5.2.

   For sites with soil layers near the surface that will be completely excavated (defined as excavations to distances sufficiently far from the structures to be considered infinitely far from the facility over the frequency range of interest) and replaced with compacted backfill, the FIRS and PBRS are determined using the site profiles including the replacement backfill. The competent material is generally considered to be in situ material having a minimum shear wave velocity of 1,000 fps. Any remaining soft soil or backfill material needs to be considered in the SSI or other analyses.

   According to Appendix S to 10 CFR Part 50, the minimum PGA for the horizontal component of the SSE at the foundation level in the free field should be 0.1g or higher. The response spectrum associated with this minimum PGA should be a smooth broadband response spectrum (e.g., RG 1.60, or other appropriate shaped spectra, if justified) and is defined as outcrop response spectra at the free-field foundation level. This response spectrum anchored to 0.1g is referred to in this DSRS section as the minimum required response spectrum.

      i. Certified Standard Plant Design. For a DC application, the postulated seismic design response spectra need to bound the minimum required response spectrum anchored to 0.1g (as specified in Appendix S to 10 CFR Part 50). These design response spectra are referred to as the CSDRS when the Commission certifies the design under 10 CFR Part 52.

      In addition, for a DC application, the CSDRS needs to envelop the minimum required spectrum at the foundation level. Foundation level response spectra consistent with the CSDRS are determined for each seismic Category I structure. These foundation level spectra are compared to the minimum required spectrum to ensure that they meet the 0.1g PGA requirement in accordance with Appendix S to 10 CFR Part 50. If the foundation level spectra do not bound the minimum required spectrum, then the CSDRS can be adjusted/modified in order to bound the minimum required spectrum. If the CSDRS are not modified, then the use of the two separate sets of spectra in the analysis and design of SSCs needs to be reviewed for adequacy.

For evaluation of soil liquefaction and soil/rock stability of slopes that may affect plant safety, the use of the site-specific GMRS rather than the CSDRS is reviewed on a case-by-case basis in accordance with SRP Section 2.5.4.

The free-field design response spectra (also referred to as the CSDRS for a DC) are usually developed for the 5-percent damping value. For the case of RG 1.60 response spectra, Tables 1 and 2 of RG 1.60 provide amplification factors at four frequencies for calculating response spectra corresponding to different damping values. For the case of the free-field design response spectra that are different from RG 1.60 response spectra, procedures to calculate response spectra for damping values other than 5 percent can utilize the latest available data and methods, such as those in PEER Report 2012/01 or NUREG/CR-6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines," issued October 2001. The procedures used are reviewed by the staff on a case-by-case basis.

To be acceptable, the seismic design response spectra should be specified for three mutually orthogonal directions—two horizontal and one vertical. Current practice is to assume that the design response spectra (including maximum ground accelerations) in the two horizontal directions are the same.

B. <u>Design Time Histories</u>. The CSDRS, SSE, and OBE design ground motion time histories can be either real time histories or artificial time histories. To be acceptable, the design ground motion time histories should consist of three mutually orthogonal directions—two horizontal and one vertical. For both horizontal and vertical input motions, either a single time history or multiple time histories can be used. When time histories are used, each of the three ground motion time histories should be shown to be statistically independent from the others. Each pair of time histories are considered to be statistically independent if the absolute value of their correlation coefficient does not exceed 0.16. Simply shifting the starting time of a given time history cannot be used to establish a different time history. When the seed time histories are selected from real earthquake records, the response spectra corresponding to the seed record should be similar in shape to the target spectra across the frequency range of interest to the analysis (e.g., Houston, et al., 2010), and phasing characteristics of the real earthquake records should not change significantly. If the target spectra include multiple characteristic events, a single recorded earthquake time history may not able to capture the response characteristics of the target spectra. To this end, the use of multiple time histories may be appropriate, in which individual time histories are developed from real earthquake records fairly representing the characteristic events embodied in the target spectra.

Alternatively, an artificial time history may be developed using random generation routines or through the use of multiple time history techniques. If a random time history generator technique is used to develop the seed time histories, then the acceptability of the seed will be reviewed on a case-by-case basis. For generated time histories, it should be demonstrated that acceleration, velocity, and displacement are compatible and do not result in baseline drift of the displacement.

For linear structural analyses, the total duration of the ground motion time histories should be long enough such that adequate representation of the Fourier components at low frequency is included in the time history. The corresponding stationary phase strong motion duration should be consistent with the longest duration of strong motion from the earthquakes defined in SRP Section 2.5.2 at low and high frequency and as presented in NUREG/CR-6728. The strong motion duration is defined as the time required for the Arias Intensity to rise from 5 percent to 75 percent. The uniformity of the growth of this Arias Intensity should be reviewed. The minimum acceptable strong motion duration should be 6 seconds. In addition to the duration for site-specific analysis, the ratios V/A and AD/V^2 (A, V, D are PGA, peak ground velocity, and peak ground displacement, respectively) should be consistent with the characteristic values for the magnitude and distance of the appropriate controlling events defining the uniform hazard response spectra (UHRS). These parameters should be consistent with the values determined for the low- and high-frequency events described in Appendix D of RG 1.208.

For nonlinear structural analysis problems, multiple sets of ground motion time histories should be used to represent the design ground motion. Each set of ground motion time histories can be selected from real recorded or artificial time histories. The amplitude of these ground motions may be scaled but the phasing of Fourier components should be maintained. The adequacy of this set of ground motions, including duration estimates, is reviewed on a case-by-case basis.

<u>Option 1: Single Set of Time Histories</u>. To be considered acceptable, the response spectra generated from the design time history to be used as input ground motion in the free field should satisfy the enveloping criteria for either Approach 1 or Approach 2 below:

i. <u>Approach 1</u>. For Approach 1, the spectrum from the design ground motion time history should envelop the free-field design response spectra for all damping values used in the seismic response analysis. When spectral values (e.g., spectral accelerations) are calculated from the design time history, the frequency intervals at which spectral values are determined are to be sufficiently small. Table 3.7.1-1 (below) provides an acceptable set of frequencies at which the response spectra may be calculated.

Each calculated spectrum of the design time history is considered to envelop the design response spectrum when no more than five points fall below, and no points fall more than 10 percent below, the design response spectrum.

Table 3.7.1-1
Suggested Frequency Intervals for Calculation
of Response Spectra

Frequency Range	Increment (hertz)	(hertz)
0.2–3.0		0.10
3.0–3.6		0.15
3.6–5.0		0.20
5.0–8.0		0.25
8.0–15.0		0.50
15.0–18.0		1.0
18.0–22.0		2.0
22.0–highest frequency of interest		3.0

Studies indicate that numerically generated ground acceleration histories produce PSD functions having a quite different appearance from one individual function to another, even when all these time histories are generated so as to closely envelop the same design response spectra. For example, the use of the available techniques of generating acceleration time histories that satisfy enveloping RG 1.60 spectra usually results in PSD functions that fluctuate significantly and randomly as a function of frequency. It is also recognized that the more closely one tries to envelop the specified design response spectra, the more significantly and randomly do the spectral density functions tend to fluctuate and these fluctuations may lead to nonconservative results for the response of SSCs. Therefore, when a single design ground motion time history is used in the design of seismic Category I SSCs, it should satisfy criteria for both enveloping design response spectra as well as adequately matching a target PSD function compatible with the design response spectra. Therefore, in addition to the response spectra enveloping criteria, the use of a single time history should also be justified by demonstrating sufficient energy at the frequencies of interest through the generation of a PSD function that envelops the target PSD function throughout the frequency range of significance.

When RG 1.60 response spectra are used as design response spectra, the criteria for a compatible target PSD are contained in Appendix A to SRP Section 3.7.1. Target PSD functions other than those given in Appendix A to SRP Section 3.7.1 can be used if justified. For design response spectra other than RG 1.60 response spectra, a compatible target PSD should be generated. For generation of target PSD in such cases (e.g., spectra based on NUREG/CR-6728), the guidelines and procedures provided in Appendix B to SRP Section 3.7.1 can be used. These guidelines and procedures are consistent with the approach described in NUREG/CR-5347, "Recommendations for Resolution of Public Comments on USI A-40, 'Seismic Design Criteria,'" dated June 1989. Alternative methods for developing target spectra PSD can be used and are reviewed on a case-by-case basis.

The development of the target PSD and the range of frequencies for the PSD check are reviewed on a case-by-case basis. The PSD criteria are included as a secondary check to prevent potential deficiency of power over the frequency range of interest. It should be noted that the ground motion is still primarily defined by the design response spectrum. The use of PSD criteria alone can yield time histories that may not envelop the design response spectrum.

ii. Approach 2. For Approach 2, the design ground motion time histories that are generated to match or envelop the design response spectra should comply with Steps (1) through (5) below. The general objective is to generate a modified recorded or artificial accelerogram which achieves approximately mean-based fit to the target response spectrum; that is, the average ratio of the spectral acceleration calculated from the accelerogram to the target, where the ratio is calculated frequency by frequency, is only slightly greater than "1." The aim is to achieve an accelerogram that does not have significant gaps in the Fourier amplitude spectrum, but which is not biased high with respect to the target.

(1) The time history should have a sufficiently small time increment and sufficiently long duration. Records should have a Nyquist frequency of at least 50 hertz (Hz), (e.g., a time increment of at most 0.010 seconds) and a total duration of at least 20 seconds. If frequencies higher than 50 Hz are of interest, the time increment of the record should be suitably reduced to provide a Nyquist frequency ($N_f = 1/(2\Delta t)$), where Δt = time increment) above the maximum frequency of interest. The total duration of the record can be increased by zero packing to satisfy these frequency criteria.

(2) Spectral acceleration at 5-percent damping should be computed at a minimum of 100 points per frequency decade, uniformly spaced over the log frequency scale from 0.1 Hz to 50 Hz or the Nyquist frequency. The comparison of the response spectrum obtained from the design ground motion time history with the target response spectrum should be made at each frequency computed in the frequency range of interest.

(3) The computed 5-percent damped response spectrum of the acceleration time history should not fall more than 10 percent below the target response spectrum at any one frequency. To prevent response spectra in large frequency windows from falling below the target response spectrum, the response spectra within a frequency window of no larger than plus or minus 10 percent centered on the frequency should be allowed to fall below the target response spectrum. This corresponds to response spectra at no more than nine adjacent frequency points defined in (2) above falling below the target response spectrum.

(4) The computed 5-percent damped response spectrum of the acceleration time history should not exceed the target response spectrum at any frequency by more than 30 percent (a factor of 1.3) in the frequency range of interest.

(5) In addition, the power spectrum density of the accelerogram needs to be computed and shown to not have significant gaps in energy at any frequency over this frequency range.

If the design ground motion time history, defined in Approach 2 above, is intended to be compatible to a site-specific FIRS, it should have characteristics consistent with characteristic values for the magnitude and distance of the appropriate controlling events defined for the corresponding UHRS.

<u>Option 2: Multiple Sets of Time Histories</u>. As discussed in Section I.1.B and Section II.1.B of this DSRS section, the use of multiple real or artificial time histories for analyses and design of SSCs is acceptable. For linear structural analyses, a minimum of four times histories should be used (NUREG/CR-5347). For nonlinear structural analyses, the number of time histories should be greater than four, and the technical basis for the appropriate number of time histories are reviewed on a case-by-case basis. This review also includes the adequacy of the characteristics of the multiple time histories.

The response spectra calculated for each individual time history need not envelop the design response spectra. However, the multiple time histories are acceptable if the average calculated response spectra generated from these time histories envelop the design response spectra. An acceptable method to demonstrate the adequacy of a set of multiple time histories, in terms of enveloping criteria and having sufficient power over the frequency range of interest, is to follow the procedures described for Approach 2 presented in Subsection II.1.B.ii of this DSRS section. When implementing Approach 2, the criteria in paragraphs (1) and (2) of this approach should be satisfied for each of the time histories. The criteria in paragraphs (3), (4), and (5) of this approach can be satisfied by utilizing the results for the average of the suite of multiple time histories.

When calculating the response of structures (e.g., accelerations, member forces, and displacements) from linear analyses, the average value of the responses from the multiple time histories may be used. When calculating the response of structures from nonlinear analyses (e.g., seismic evaluation of as-built structures), the average value of the responses from the multiple time histories may be used if at least seven nonlinear time history analyses are performed. Otherwise, the maximum value (i.e., envelope) of the individual responses from the multiple time histories should be used.

In addition, if the extent of the nonlinear response is found to be significant or if the nonlinear response due to one or several time histories is found to be substantially different from the other results, then additional time histories should be considered. If there is a particular ground motion or time history analysis that dominates the response values, it should not be replaced with another motion or analysis to reduce the responses. Also, if a ratcheting effect is noted (e.g., increasing deformation with subsequent cycling of earthquake motion), then the system characteristics should be reviewed to ensure that they have been conservatively considered or the design should be revised to eliminate this behavior.

2. Percentage of Critical Damping Values. The specific percentage of critical damping values used in the analyses of seismic Category I SSCs is considered to be acceptable if they are in accordance with RG 1.61. Damping values different from those listed in RG 1.61 (e.g., higher damping values) may be used in a dynamic seismic analysis if test data are provided to support them. These damping values are reviewed and accepted by the staff on a case-by-case basis.

   In addition, a demonstration of the correlation between stress levels and damping values is necessary and reviewed to determine if the applicable regulatory position in RG 1.61 is met. If other methods for correlation of damping values with stress level are used, they will need to be reviewed and accepted on a case-by-case basis.

   The material soil damping for foundation soils should be based upon validated values or other pertinent laboratory data, considering variation in soil properties and strains within the soil, and should include an evaluation of dissipation from pore pressure effects as well as material damping for saturated site conditions. The maximum soil damping value acceptable to the staff is 15 percent.

3. Supporting Media for Seismic Category I Structures. To be acceptable, the description of supporting media for each seismic Category I structure should include foundation embedment depth, depth of soil over bedrock, soil layering characteristics, design groundwater elevation, dimensions of the structural foundation, total structural height, and soil properties (such as shear wave velocity, shear modulus, material damping including strain-dependent effect as well as Poisson’s ratios, and density as a function of depth). If the minimum shear wave velocity of the supporting foundation material is less than 1,000 fps, additional studies need to be performed which consider the average shear wave velocity, and its degree of variability addressing potential impact of soft soil on the SSI analyses, potential settlements, and design of foundation elements.

4. Review Considerations for DC and COL Applications

A. COL Application Referencing an ESP and DC

i. Site-specific FIRS and PBRS are reviewed separately under this DSRS section for adequacy. For a COL application referencing an ESP and DC, the FIRS and PBRS are included in the application. The COL review should include a determination of the PBRS at the surface and intermediate depth(s) and the associated deterministically defined soil columns needed for determining the adequacy of the PBRS using the guidance in DC/COL-ISG-017. For sites that have relatively uniform variation of shear wave velocity with depth, it is anticipated that PBRS are developed at the surface and at a central depth between the surface and foundation level. For sites that have unusual velocity characteristics with depth such as those containing significant inversions in the layer profiles, additional depths should be selected at which PBRS are developed to adequately reflect the effect of these inversions on the facility's seismic response. The process for selecting the number and locations of these intermediate depths is reviewed on a case-by-case basis. The FIRS with the consistent soil columns together form the design basis that is used for the seismic analysis of the facilities.

ii. Confirm that the criterion for the minimum required response spectrum (in accordance with Subsection II.1.A.ii of this DSRS section) has been satisfied.

iii. Confirm that COL action items contained in the DC have been adequately addressed. Determine whether the seismic site characteristics fall within the seismic design parameters such as soil layering assumptions used in the certified design, range of soil parameters, shear wave velocity values, and minimum soil bearing capacity. A technical justification for all deviations from the range of values used in the standard plant design should be provided.

iv. Confirm that the ESP conditions have been met or review the COL applicant's approach to address any deviations.

v. The PBRS are generated using the soil profiles for which the performance-based FIRS are generated. The properties of the individual realizations of the soil column consist of at least 60 or more randomized sets of soil profiles similar to those used in the probabilistic seismic hazard analysis process and reviewed under SRP Section 2.5.2 and as described in DC/COL-ISG-017. From this set of randomized columns, three individual soil columns are generated with individual layer properties (shear wave velocity and iterated hysteretic damping) selected at the best estimate (BE), lower bound at minus one-sigma (LB), and upper bound at plus one-sigma (UB) values. For SSI analyses, the LB and UB profiles may need to be modified to ensure that they satisfy the criteria of coefficient of variance in velocity properties as described in DSRS Section 3.7.2. These individual soil columns are to be used in deterministic site response and SSI analyses described in DSRS Section 3.7.2. Free-field response spectra are then generated at the ground surface and intermediate depth(s) from the FIRS input at the foundation level for each of these three deterministic soil profiles. The envelope of these three spectra (BE, LB, and UB) should equal or exceed the corresponding performance-based PBRS at the ground surface and intermediate depth(s). If the envelope spectra do not exceed the PBRS, additional soil profiles can be developed for which SSI analyses are to be performed, or the input time histories may be modified in accordance with DC/COL-ISG-017, Section 5.2, “Position on Site-Consistent Seismic Input and Soil Profiles Properties for the SSI Analysis.”

vi. When the site-specific FIRS and the CSDRS are calculated at the same elevation, confirm that the CSDRS envelop the FIRS as indicated in DC/COL-ISG-017, provided that the site-specific soil profile is captured within the range of profiles considered in the development of the CSDRS. For this case, the standard design is acceptable for that site, assuming no other issue is identified during the review process. If the CSDRS do not envelop the site-specific FIRS, then proceed to Step vii.

vii. When the site-specific FIRS and the CSDRS are determined at different elevations, the CSDRS-consistent spectra need to be calculated at the foundations of each seismic Category I structure. For each seismic Category I structure foundation, if the CSDRS-consistent spectra at the foundation level envelop the site-specific FIRS at the foundation level, the standard design is acceptable for that site, provided that the potential effects of the variation in ground motion over the depth of the facilities are defined and incorporated into the analysis and assuming no other issue is identified during the review process. If not, then proceed to Step viii.

viii. Perform an analysis of the seismic response of the facilities using the site-specific FIRS as input and an appropriate seismic analytical technique (e.g., a method that considers the effects of ground motion variation with depth and, if necessary, incoherent ground motion). When such analytical methods are utilized, the detailed technical justification will be reviewed on a case-by-case basis. Further discussion on consideration of the effects of incoherent ground motion is provided in Subsection II.4.C (under the heading “Input Ground Motion, Specific Guidelines for SSI Analysis”) in DSRS Section 3.7.2. The in-structure responses in terms of floor response spectra, building member forces, and deformations at key locations in the structure should be obtained using seismic analysis methods provided in Subsection II of this DSRS section. The key locations proposed by the licensee for calculating the in-structure responses need to be evaluated to ensure that they are sufficient to represent the various locations throughout the building. Locations should include responses at peripheral locations to detect rocking and torsion, and should include responses to check overturning, torsional, and sliding stability of the structures. The dynamic models and analysis techniques need to be sufficiently refined to be able to capture the response of the structures throughout the frequency range of interest, including the high frequency responses, typically expected in the central and eastern United States (CEUS) regions. The SSI analysis should also consider the site-specific soil variability (i.e., best estimate, lower bound estimate, and upper bound estimate of site properties) as described in Item v above.

Compare these responses at the key locations in the structure to the standard design in-structure responses. If the computed responses from the CSDRS envelop the corresponding in-structure responses from the individual deterministic soil columns, the standard design is acceptable, assuming no other issue is identified during the review process. If the responses are not enveloped, additional analyses are required to demonstrate the acceptability of the design, or the design might need to be modified. If further analyses are utilized, then the analyses should consider the potentially higher responses at all locations, not only those at the key locations described above.

B. COL Application Referencing a DC. Follow the same steps described above under A, "COL Application Referencing an ESP and DC," except that Step iv does not apply to this case.

Technical Rationale

The technical rationale for application of these criteria to reviewing this DSRS section is discussed in the following paragraphs:

1. 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 of 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.

   This DSRS section describes acceptance criteria for developing seismic design parameters to assure that they are appropriate and contain sufficient margin such that seismic analyses (reviewed under other DSRS sections) accurately and/or conservatively represent the behavior of SSCs during postulated seismic events. Criteria are provided for developing the seismic design ground motion, percentage of critical damping, supporting media, and the technical interface requirements for ESP, DC, and/or COL applications, as well as for making the site acceptability determination. RGs 1.60 and 1.208 provide procedures that are acceptable to the staff for defining seismic GMRS for input into the seismic design analysis of nuclear power plant SSCs.

In addition, RG 1.61 is referenced for guidance of acceptable damping values to be used in performing dynamic analyses of SSCs.

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

2. 10 CFR Part 50, Appendix S, is applicable to applications for a DC or COL pursuant 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 associated with the SSE 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 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 remain functional and within applicable stress, strain, and deformation limits. Appendix S also requires that the horizontal component of the SSE ground motion in the free field at the foundation level of the structures must be an appropriate response spectrum with a PGA of at least 0.1g.

   This DSRS section describes acceptance criteria for developing the required design ground motion loadings consisting of the SSE and OBE (if applicable) and other seismic design parameters needed to perform an SSI analysis. This DSRS section indicates that an explicit analysis for the OBE, in addition to the SSE, should be performed unless the magnitude of the OBE is set at one-third or less of the SSE. Criteria for the required characteristics of the earthquake motion are presented, which include the duration of the seismic ground motion. This DSRS section also specifies that the horizontal free-field SSE ground motion at the foundation level should be represented by an appropriate response spectrum, such as that defined in RG 1.60, with a minimum PGA of 0.1g. The criteria presented in this DSRS section provide the design ground motion loadings and seismic design parameters so that the SSI analysis can determine the response of the SSCs in terms of stresses, strains, and deformations. In addition, the use of these criteria allows the SSI analysis to calculate the floor response spectra for use in qualification of equipment.

   Meeting these criteria provides assurance that appropriate methods will be used to determine the required OBE and SSE loadings and the response of SSCs, which will ensure that they will remain functional within applicable acceptance limits.

III. REVIEW PROCEDURES

These review procedures are based on the identified DSRS 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 Subsection II.

1. Selected Programs and Guidance—In accordance with the guidance in NUREG–0800, “Introduction – Part 2: Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Light-Water Small Modular Reactor Edition” (NUREG-0800, Intro Part 2), as applied to this DSRS Section, the staff will review the information proposed by the applicant to evaluate whether it meets the acceptance criteria described in Subsection II of this DSRS. As noted in NUREG-0800, Intro Part 2, the NRC requirements that must be met by an SSC do not change under the small modular reactor (SMR) framework. Using the graded approach described in NUREG-0800, Intro Part 2, the NRC staff may determine that, for certain SSCs, the applicant’s basis for compliance with other selected NRC requirements may help demonstrate satisfaction of the applicable acceptance criteria for that SSC in lieu of detailed independent analyses. The design-basis capabilities of specific SSCs would be verified, where applicable, as part of completing the applicable ITAAC. The use of the selected programs to augment or replace traditional review procedures is shown in Figure 1 of NUREG-0800, Intro Part 2. Examples of such programs that may be relevant to the graded approach for these SSCs include:

   - 10 CFR Part 50, Appendix A, GDC, Overall Requirements, Criteria 1–5
   - 10 CFR Part 50, Appendix B, Quality Assurance (QA) Program
   - 10 CFR 50.49, Environmental Qualification of Electrical Equipment (EQ) Program
   - 10 CFR 50.55a, Code Design, Inservice Inspection, and Inservice Testing (ISI/IST) Programs
   - 10 CFR 50.65, Maintenance Rule requirements
   - Reliability Assurance Program (RAP)
   - 10 CFR 50.36, “Technical Specifications”
   - Availability Controls for SSCs Subject to Regulatory Treatment of Nonsafety Systems (RTNSS)
   - Initial Test Program (ITP)
   - Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)

   This list of examples is not intended to be all inclusive. It is the responsibility of the technical reviewers to determine whether the information in the application, including the degree to which the applicant seeks to rely on such selected programs and guidance, demonstrates that all acceptance criteria have been met to support the safety finding for a particular SSC.

2. In accordance with 10 CFR 52.47(a)(8), (21), and (22), and 10 CFR 52.79(a)(17), (20), and (37), for DC or COL 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, "Resolution of Generic Safety Issues," 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), for a DC application, and except paragraphs (f)(1)(xii), (f)(2)(ix), (f)(2)(xxv), and (f)(3)(v),for a COL application. 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.

3. Design Ground Motion

   A. Design Response Spectra. For the DC, the CSDRS for the OBE and SSE for applicable damping values are checked to ensure that the CSDRS are in accordance with the acceptance criteria as given in Subsection II.1.A.ii of this DSRS section. Any deviations from the acceptance criteria applicable to the development of the design response spectra or CSDRS that have not been adequately justified are identified, and the applicant is informed of the need for additional technical justification.

   B. Design Time History. Methods of defining the design ground motion time histories are reviewed to confirm that the acceptance criteria of Subsection II.1.B of this DSRS section are met.

4. Percentage of Critical Damping Values. The specific percentage of critical damping values for the OBE and SSE (CSDRS for DC Applications) used in the analyses of seismic Category I SSCs, are checked to ensure that the damping values are in accordance with the acceptance criteria as given in Subsection II.2 of this DSRS section. Any differences in damping values that have not been adequately justified are identified, and the applicant is informed of the need for additional technical justification.

5. Supporting Media for Seismic Category I Structures. The description of the supporting media is reviewed to verify that sufficient information, as specified in the acceptance criteria of Subsection II.3 of this DSRS section, is included.

6. Review Considerations for DC and COL Applications. The information provided by the applicant to address the review considerations in the DSRS acceptance criteria of Subsection II.4 of this DSRS section is reviewed. The review should verify that the CSDRS envelop the site-specific FIRS for a COL application that references a DC. In addition, the review should verify that the applicant addressed the identified COL action

items. If these acceptance criteria are not met, then the technical basis for alternative methods needs to be provided by the applicant for review and approval.

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), set forth in the FSAR meets the acceptance criteria. DCs have referred to the FSAR as the DCD. The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure that 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 SER. The reviewer also states the bases for those conclusions.

The staff concludes that the seismic design parameters used in the design of plant SSCs are acceptable and meet the applicable requirements of 10 CFR Part 50, Appendix A, GDC 2, and 10 CFR Part 50, Appendix S. This conclusion is based on the following.

The applicant has met the relevant requirements of GDC 2 and 10 CFR Part 50, Appendix S, by appropriate consideration of the most severe earthquake recorded for the site with an appropriate margin and appropriate consideration of the SSE and OBE. The applicant has met these requirements by the use of the methods and procedures as follows:

For a standard plant design, the seismic design response spectra applied in the design of seismic Category I SSCs are developed based on smooth-shaped broadband spectra consistent with the site conditions postulated for the standard design. For a COL application, the FIRS and PBRS are developed in accordance with the method described in DC/COL-ISG-017 and are consistent with the GMRS developed in accordance with the guidance in SRP Section 2.5.2. For the plant subject to Appendix S of 10 CFR Part 50, the horizontal component of the SSE ground motion in the free field at the foundation level of the structures is based on an appropriate response spectrum with a PGA of at least 0.1g. The appropriate response spectrum associated with this minimum PGA should be a smooth broadband response spectrum (e.g., RG 1.60, or other appropriate shaped spectra, if justified). The percentage of critical damping values used in the seismic analysis of seismic Category I SSCs is in conformance with RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants." The design time history used for seismic design of seismic Category I plant SSCs is adjusted in amplitude and frequency content to obtain response spectra that envelop the design response spectra specified for the site and also exhibits sufficient energy in the frequency range of interest. Conformance with the recommendations of SRP Section 2.5.2 and RG 1.61 ensures that the seismic inputs to the analysis of seismic Category I SSCs are adequately defined so as to form a conservative basis for the design of such SSCs to withstand seismic loadings.

The CSDRS used in the certified design of seismic Category I SSCs meet the requirements of Appendix S to 10 CFR Part 50 by either (1) demonstrating that the CSDRS meet or exceed the site-specific FIRS reviewed and approved in accordance with the guidance in SRP Section 2.5.2 and DC/COL-ISG-017 and meet or exceed the minimum required response spectrum specified in 10 CFR Part 50, Appendix S, or (2) showing that the design resulting from application of the CSDRS is still adequate to resist design demands resulting from the analysis conducted using the site-specific FIRS.

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 DSRS section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

V. IMPLEMENTATION

The regulations in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), and 10 CFR 52.79(a)(41) establish requirements for applications for ESPs, DCs, and COLs, respectively. These regulations require the application to include an evaluation of the site (ESP), standard plant design (DC), or facility (COL) against the SRP revision in effect 6 months before the docket date of the application. While the SRP provides generic guidance, the staff developed the SRP guidance based on the staff's experience in reviewing applications for construction permits and operating licenses for large light-water nuclear power reactors. The proposed SMR designs, however, differ significantly from large light-water nuclear power plant designs.

In view of the differences between the designs of SMRs and the designs of large light-water power reactors, the Commission issued Staff Requirements Memorandum (SRM)-COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights To Enhance Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010. In the SRM, the Commission directed the staff to develop risk-informed licensing review plans for each of the SMR design reviews, including plans for the associated preapplication activities. Accordingly, the staff has developed the content of the DSRS as an alternative method for evaluating a NuScale-specific application submitted pursuant to 10 CFR Part 52, and the staff has determined that each application may address the DSRS in lieu of addressing the SRP, with specified exceptions. These exceptions include particular review areas in which the DSRS directs reviewers to consult the SRP and others in which the SRP is used for the review. If an applicant chooses to address the DSRS, the application should identify and describe all differences between the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and the guidance of the applicable DSRS section (or SRP section, as specified in the DSRS), and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria.

The staff has accepted the content of the DSRS as an alternative method for evaluating whether an application complies with NRC regulations for NuScale SMR applications, provided that the application does not deviate significantly from the design and siting assumptions made by the NRC staff while preparing the DSRS. If the design or siting assumptions in a NuScale application deviate significantly from the design and siting assumptions the staff used in preparing the DSRS, the staff will use the more general guidance in the SRP, as specified in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), or 10 CFR 52.79(a)(41), depending on the type of application. Alternatively, the staff may supplement the DSRS section by adding appropriate criteria to address new design or siting assumptions.

VI. REFERENCES

1. *U.S. Code of Federal Regulations*, "General Design Criteria for Nuclear Power Plants," Appendix A, Part 50, Chapter I, Title 10, "Energy."

2. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

3. *U.S. Code of Federal Regulations*, "Earthquake Engineering Criteria for Nuclear Power Plants," Appendix S, Part 50, Chapter I, Title 10, "Energy."

4. *U.S. Code of Federal Regulations*, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter I, Title 10, "Energy."

5. U.S. Nuclear Regulatory Commission, "Design Response Spectra for Seismic Design of Nuclear Power Plants," RG 1.60, ADAMS Accession No. ML13210A432.

6. U.S. Nuclear Regulatory Commission, "Damping Values for Seismic Design of Nuclear Power Plants," RG 1.61.

7. U.S. Nuclear Regulatory Commission, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," RG 1.70, ADAMS Accession No. ML011340072.

8. U.S. Nuclear Regulatory Commission, "Combined License Applications for Nuclear Power Plants (LWR Edition)," RG 1.206.

9. U.S. Nuclear Regulatory Commission, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," RG 1.208.

10. U.S. Nuclear Regulatory Commission, "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications," DC/COL-ISG-01, June 12, 2009, ADAMS Accession No. ML081400293.

11. U.S. Nuclear Regulatory Commission, “Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses,” DC/COL-ISG-017, April 15, 2010, ADAMS Accession No. ML100570203.

12. U.S. Nuclear Regulatory Commission, “Interim Staff Guidance on Implementation of a Probabilistic Risk Assessment-Based Seismic Margin Analysis for New Reactors,” DC/COL-ISG-020, March 15, 2010, ADAMS Accession No. ML100491233.

13. U.S. Nuclear Regulatory Commission, “Recommendations for Resolution of Public Comments on USI A-40, ‘Seismic Design Criteria,’” NUREG/CR-5347, June 1989.

14. U.S. Nuclear Regulatory Commission, “Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines,” NUREG/CR-6728, October 2001.

15. Pacific Earthquake Engineering Research Center Headquarters at the University of California, Berkeley, “Spectral Damping Scaling Factors for Shallow Crustal Earthquakes in Active Tectonic Regions,” PEER Report 2012/01, July 2012.

16. Houston, T.W., et al., “Investigation of the Impact of Seed Record Selection on Structural Response,” *Proceedings of the 2010 ASME PVP Conference, Division K, Paper 25919, Bellevue, Washington, July 18–22, 2010*.