U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD for NuScale SMR DESIGN

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 Design Specific Review Standard (DSRS) 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. Supplementary seismic analysis criteria are presented in this DSRS section for distribution systems, including their supports (e.g., cable trays; conduits; heating, ventilation, and air conditioning (HVAC); and piping) and equipment supports, which are reviewed under NUREG-0800 Standard Review Plan (SRP) Sections 3.9.2, "Dynamic Testing and Analysis of Systems, Structures, and Components," and 3.9.3, "ASME Code Class 1, 2, and 3 Components, and Component Supports, and Core Support Structures." Intervening structural elements between these distribution systems and equipment supports and the building structural steel/concrete are also reviewed under this DSRS section.

The specific areas of review are as follows:

1. Seismic Analysis Methods. The information reviewed is similar to that described in Subsection I.1 of DSRS Section 3.7.2 but as applied to seismic Category I subsystems.

2. Determination of Number of Earthquake Cycles. The staff reviews the 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.

3. Procedures Used for Analytical Modeling. The information reviewed is similar to that described in Subsection I.3 of DSRS Section 3.7.2 but as applied to seismic Category I subsystems.

4. Basis for Selection of Frequencies. As applicable, the staff reviews the criteria or procedures used to separate fundamental frequencies of components and equipment from the forcing frequencies of the support structure.

ADAMS Accession No. ML15355A402

5. Analysis Procedure for Damping. The information reviewed is similar to that described in Subsection I.13 of DSRS Section 3.7.2 but as applied to seismic Category I subsystems.

6. Three Components of Design Ground Motion. The information reviewed is similar to that described in Subsection I.6 of DSRS 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 DSRS Section 3.7.2 but as applied to seismic Category I subsystems.

8. Interaction of Non-Seismic Category I Subsystems with Seismic Category I SSCs. The information reviewed is similar to that described in Subsection I.8 of DSRS Section 3.7.2 but as applied to non-seismic Category I subsystems.

9. Multiply Supported Equipment and Components with Distinct Inputs. The staff reviews the criteria and procedures for seismic analysis of equipment and components supported at different elevations within a building and between buildings with distinct inputs.

10. Use of Equivalent Vertical Static Factors. The information reviewed is similar to that described in Subsection I.10 of DSRS 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 I.11 of DSRS 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 staff reviews the seismic criteria and methods for considering (1) the characteristics of soil media, (2) dynamic pressures, (3) settlement due to earthquake and differential movements at support points, (4) penetrations, and (5) entry points into structures provided with anchors.

13. Methods for Seismic Analysis of Seismic Category I Concrete Dams. The analytical methods and procedures that are used for seismic analysis of seismic Category I concrete dams are reviewed. The staff reviews 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.

14. Methods for Seismic Analysis of Aboveground Tanks. For seismic Category I aboveground tanks, the staff reviews the seismic analysis criteria and methods for considering hydrodynamic forces, tank flexibility, soil-structure interaction (SSI), and other pertinent parameters.

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 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.

16. 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, 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 and DSRS 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 earthquake ground motion (response spectra and time histories) is reviewed under DSRS Section 3.7.1.

4. The seismic system analysis, which includes the seismic SSI analysis, is reviewed under DSRS Section 3.7.2.

5. The design of seismic Category I structures for all applicable load combinations is reviewed under DSRS Sections 3.8.4, and 3.8.5.

6. For DC applications, the staff reviews 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 in accordance with the guidance in SRP Section 2.0, “Site Characteristics and Site Parameters.” For COL applications referencing a DC, the staff reviews the applicant’s site characteristics in COLA final safety analysis report (FSAR) Section 2.0 in accordance with the guidance in SRP Section 2.0.

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. Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, GDC 2—In relevant part, the design basis shall reflect appropriate consideration of the most severe earthquakes 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. Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50, is applicable to applications for a DC or COL pursuant to 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," or a construction permit (CP) or operating license (OL) pursuant to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," on or after January 10, 1997. 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 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 operating basis earthquake (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 peak ground acceleration (PGA) of at least 0.1g.

3. In 10 CFR 52.47(b)(1), the NRC 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 of 1954, as amended (AEA), and the Commission's rules and regulations.

4. In 10 CFR 52.80(a), the NRC 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 AEA, and the Commission's rules and regulations.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the 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. Seismic Analysis Methods. The acceptance criteria provided in DSRS Section 3.7.2, Subsection II.1, are applicable.

2. Determination of Number of Earthquake Cycles. During the plant's 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 that 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 No. ML003708056). The number of earthquake cycles to consider is 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 DSRS Section 3.7.2, Subsection II.3, are applicable.

4. Basis for Selection of Frequencies. To avoid resonance, the fundamental frequencies of components and equipment should preferably be selected to be less than 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 DSRS Section 3.7.2, Subsection II.13, are applicable.

6. Three Components of Design Ground Motion. The acceptance criteria provided in DSRS Section 3.7.2, Subsection II.6, are applicable.

7. Combination of Modal Responses. The acceptance criteria provided in DSRS Section 3.7.2, Subsection II.7, are applicable.

8. Interaction of Non-Seismic Category I Subsystems with Seismic Category I SSCs. To be acceptable, each non-seismic Category I subsystem should be designed to be isolated from any seismic Category I SSCs by either a constraint or barrier, or should be remotely located with regard to the seismic Category I SSCs. If this is not feasible or practical, then adjacent non-seismic Category I subsystems should be analyzed according to the same seismic criteria as applicable to the seismic Category I SSCs. For non-seismic Category I subsystems attached to seismic Category I SSCs, the dynamic effects of the non-seismic Category I subsystems should be simulated in the modeling of the seismic Category I SSCs. The attached non-seismic Category I 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 SSCs.

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 envelops 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, “Report of the U.S. Nuclear Regulatory Commission Piping Review Committee,” Volume 4, Section 2, “Staff Recommendations on Response Combinations.” If the ISM method is utilized, all of the criteria presented in NUREG-1061 related to the ISM method 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 to provide more realistic results than the USM or ISM methods.

10. Use of Equivalent Vertical Static Factors. The acceptance criteria provided in DSRS Section 3.7.2, Subsection II.10, are applicable.

11. Torsional Effects of Eccentric Masses. For seismic Category I subsystems, when the torsional effect of an eccentric mass is judged to be significant, the eccentric mass and its eccentricity should be included in the mathematical model. The criteria for judging the significance will be 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 are considered 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. The definition of the seismic wave field should consider variation over the depth of the embedded structure.

        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, "Recommended Revisions to Nuclear Regulatory Commission Seismic Design Criteria," page 26; in ASCE Standard 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary," Section 3.5.2, "Buried Pipes and Conduits"; 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 takes into consideration the dynamic nature of forces (due to both horizontal and vertical earthquake loadings), the behavior of the dam material under design ground motion loadings, SSI effects, and

nonlinear stress-strain relations for the soil. Analysis of earthen dams is reviewed under SRP Section 2.5.5, “Stability of Slopes.”

14. Methods for Seismic Analysis of Aboveground Tanks. Most aboveground 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 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. 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, “Above-Ground Vertical Tanks.” 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 incorporates at least two horizontal modes of combined fluid-tank vibration and at least one vertical mode of fluid vibration. The horizontal response analysis includes 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 is included in the horizontal analysis.

    B. The fundamental natural horizontal impulsive mode of vibration of the fluid-tank system is 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 are 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 is 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 DSRS Section 3.7.2. The uplift tension resulting from M_o is 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 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 DSRS Section 3.7.2. The maximum hoop forces in the tank wall are 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 is added to the hydrostatic pressure at that level to determine the hoop tension in the tank shell.

G. Either the tank top head is located at an elevation higher than the slosh height above the top of the fluid or else the tank top head should be designed for pressures resulting from fluid sloshing against this head.

H. At the point of attachment, the tank shell is designed to withstand the seismic forces imposed by the attached piping. An appropriate analysis should be performed to verify this design.

I. The tank foundation (see also DSRS Section 3.8.5) is 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, the tank should be designed to not allow buckling of tank walls and roof, failure of connecting piping, and sliding of the tank.

<u>Technical Rationale</u>

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

1. GDC 2 in Appendix A of 10 CFR Part 50 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 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 are provided for the static and dynamic analysis of these subsystems subjected to 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 subsystems, and evaluation of multiply supported equipment.

Meeting these 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 functions. Appendix S to 10 CFR Part 50 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 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 the applicable stress, strain, and deformation limits.

This DSRS section 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 DSRS Section 3.8.2, 3.8.4, and 3.8.5. The criteria in this DSRS section ensure that the effects of SSI and expected duration of the earthquake are appropriately included in the evaluation. In addition, criteria 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 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

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 of this DSRS section.

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. Seismic Analysis Methods. The seismic analysis methods are reviewed to determine whether these are in accordance with the acceptance criteria of DSRS Section 3.7.2, Subsection II.1.

4. Determination of Number of Earthquake Cycles. Criteria or procedures used to establish the number of earthquake cycles are reviewed to determine whether they are in accordance with the acceptance criteria as given in Subsection II.2 of this DSRS section. Justification for deviating from the acceptance criteria is provided by the applicant.

5. Procedures Used for Analytical Modeling. The criteria and procedures used for modeling for the seismic subsystem analysis are reviewed to determine whether these are in accordance with the acceptance criteria of DSRS Section 3.7.2, Subsection II.3.

6. 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 if the acceptance criteria of Subsection II.4 of this DSRS section are met.

7. 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 whether it is in accordance with the acceptance criteria of DSRS Section 3.7.2, Subsection II.13.

8. Three Components of Design Ground Motion. The procedures by which the three components of design ground motion are considered in determining the seismic response of subsystems are reviewed to determine if the acceptance criteria of DSRS Section 3.7.2, Subsection II.6, are met.

9. Combination of Modal Responses. The procedures for combining modal responses are reviewed to determine if the acceptance criteria of DSRS Section 3.7.2, Subsection II.7, are met.

10. Interaction of Non-Seismic Category I Subsystems with Seismic Category I SSCs. The criteria used to design the interfaces between non-seismic Category I subsystems and seismic Category I SSCs are reviewed to determine if the acceptance criteria of Subsection II.8 of this DSRS section are met.

11. 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 whether the criteria are in accordance with the acceptance criteria of Subsection II.9 of this DSRS section.

12. Use of Equivalent Vertical Static Factors. The procedures for the use of equivalent vertical static factors are reviewed to determine if the acceptance criteria of DSRS Section 3.7.2, Subsection II.10, are met.

13. Torsional Effects of Eccentric Masses. The procedures for seismic analysis of seismic Category I subsystems are reviewed to determine if the acceptance criteria of Subsection II.11 of this DSRS section are met.

14. 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 whether they are in accordance with the acceptance criteria of Subsection II.12 of this DSRS section.

15. 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 if the acceptance criteria of Subsection II.13 of this DSRS section are met.

16. Method for Seismic Analysis of Aboveground Tanks. Methods for seismic analysis of seismic Category I aboveground tanks are reviewed to determine if the acceptance criteria of Subsection II.14 of this DSRS section are met.

17. 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), 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 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.

Evaluation findings for DSRS Section 3.7.3 have been combined with those of DSRS Section 3.7.2 and are given under DSRS Section 3.7.2, 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 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 Phenomenon."

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. American Society of Civil Engineers, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary," ASCE 4-98 (Section 3.5.2 for buried pipes and conduits and Section 3.5.4 for aboveground vertical tanks), 2000.

6. American Society of Civil Engineers, "Seismic Response of Buried Pipes and Structural Components," ASCE Report, 1983.

7. Haroun, M.A. and G.W. Housner, "Seismic Design of Liquid Storage Tanks," *Journal of the Technical Councils*, 107:191–207.

8. Institute of Electrical and Electronics Engineers, 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."

9. U.S. Nuclear Regulatory Commission, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee; Volume 4: Evaluation of Other Loads and Load Combinations," NUREG-1061, December 1984.

10. U.S. Nuclear Regulatory Commission, "Recommended Revisions to Nuclear Regulatory Commission Seismic Design Criteria," NUREG/CR-1161, May 1980.

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

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

13. U.S. Nuclear Regulatory Commission, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," Staff Requirements Memorandum SECY-93-087, July 21, 1993, ADAMS Accession No. ML003708056.

14. U.S. Atomic Energy Commission, “Nuclear Reactors and Earthquakes,” TID-7024, August 1963.

15. A.S. Veletsos, “Seismic Effects in Flexible Liquid Storage Tanks,” *Proceedings of Fifth World Conference on Earthquake Engineering*, Rome, 1974.

16. 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.

17. A.S. Veletsos and J.Y. Yang, “Earthquake Response of Liquid Storage Tanks,” *Advances in Civil Engineering through Engineering Mechanics, Proceedings of the Engineering Mechanics Division Specialty Conference*, pp. 1–24, ASCE, Raleigh, NC, 1977.

18. Veletsos, A.S. and Y. Tang, “The Effects of Soil-Structure Interaction on Laterally Excited Liquid-Storage Tanks,” EPRI Technical Report NP-6500 (Interim Report), Electric Power Research institute, Palo Alto, CA, September 1989.

19. 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.