U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD for NuScale SMR DESIGN

3.8.5 FOUNDATIONS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for structural analysis reviews

Secondary - None

I. AREAS OF REVIEW

The review covers areas relating to the foundations of all seismic Category I structures.

The specific areas of review are as follows:

1. Description of the Foundations. The review covers descriptive information, including plans and sections of each foundation, to establish that sufficient information is provided to define the primary structural aspects and elements relied on to perform the foundation function. The review also addresses the relationship between adjacent foundations, including the methods of separation provided if such separation is used to minimize seismic interaction between the buildings. In particular, the review identifies the type of foundation and examines its structural characteristics. Among the types of foundations reviewed are mat foundations and footings, including individual column footings, combined footings supporting more than one column, and wall footings supporting bearing walls, or a single mat foundation for the nuclear island, as applicable.

   Other types of foundations that may be used include pile foundations, drilled caissons, caissons for waterfront structures such as a pumphouse, and rock anchor systems. The review addresses these types of foundations on a case-by-case basis.

   The paragraphs below list major plant seismic Category I foundations that are reviewed, together with associated descriptive information:

   A. Reactor Building Foundation

      The reactor building basemat foundation provides support to the RB, NuScale nuclear plant modules (NPMs) which include the steel containment and reactor pressure vessels (RPVs), and other structures within the RB. The RB foundation is constructed of reinforced concrete.

      The staff reviews the detailed description of the RB mat foundation and its interfaces with the reactor pool, NPMs, and other structures supported by the RB

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foundation. A portion of the RB mat foundation forms the base of the reactor pool which houses and supports up to 12 NPMs. The NPMs are installed in two rows of up to six NPMs in each row. The staff review identifies the types of concrete structures associated with the RB concrete foundation and examines their structural and functional characteristics. Any special features of the RB foundation are also reviewed including modular construction.

The geometry of these structures is reviewed, including sketches showing plan views at various elevations and sections in at least two orthogonal directions. The reviewer examines the arrangement of the RB foundation and the relationship and interaction of the foundation with its surrounding structures and with its interior compartment walls and floors to determine the effect these structures could have on the design boundary conditions and expected structural behavior of the RB foundation when subjected to design loads.

The review encompasses general information related to the RB foundation, including special features such as sump and drain areas, seismic gaps between the RB foundation and adjacent building/structural elements, shear keys, rock anchors, subfoundation drainage system (if applicable), use of waterproofing membrane, and RB settlement monitoring systems.

The review in this Design Specific Review Standard (DSRS) section includes the general arrangement of such foundations, with emphasis on methods of isolating the building foundation from other buildings in a lateral direction when this is preferable to minimize seismic interaction.

The review addresses the general arrangement of the foundation, with particular emphasis on methods of transferring loads from the structure to the foundation media.

B. Other Seismic Category I Foundations

The foundations for other seismic Category I structures (for example, the control building), which may be one or a combination of several foundation types, are reviewed to an extent similar to that of the RB foundation. Among seismic Category I structures with foundations subject to such a review are the control building, intake structures, and cooling towers, if applicable. The review also includes the foundations of structures that may be important to safety, which because of other design provisions are not classified as seismic Category I (e.g., radwaste building).

2. Applicable Codes, Standards, and Specifications. The review addresses information pertaining to design codes, standards, specifications, regulatory guides (RGs), and other industry standards that are applied in the design, fabrication, construction, testing, and surveillance of seismic Category I foundations.

3. Loads and Load Combinations. The review includes information pertaining to the applicable design loads and their various combinations. The loads normally

applicable to seismic Category I foundations are the same as those applicable to the structures that the foundations support. DSRS Section 3.8.4, Subsection I.3, details such loads for seismic Category I foundations. DSRS Section 3.8.2, Subsection I.3, details such loads for NPMs that may impose loads on the RB foundation. These should include loads that are induced by the construction sequence and by the differential settlements of the soil under and to the sides of the structures.

Because the RB mat foundation provides support for up to 12 NPMs over the life of the plant, the loads due to the NPMs and their combinations which are considered in the design are reviewed. The loads reviewed include the loads developed based on the various combinations of NPMs, which should consider the number of NPMs and possible locations of NPMs over the life of the plant.

4. Design and Analysis Procedures. The review assesses design procedures used for seismic Category I foundations, emphasizing the extent of compliance with American Concrete Institute 349, with additional guidance provided by RG 1.142, for concrete structures and the ANSI/AISC N690-1994 including Supplement 2 (2004) specifications for steel structures. The use of more recent codes and standards is reviewed for adequacy on a case-by-case basis. The review includes analysis procedures used for seismic Category I foundations with respect to the applicability of the theories on which these procedures are based.

   Among the areas reviewed are the following:

   A. Assumptions about boundary conditions and the expected behavior of each foundation when subjected to the various design loads.

   B. Methods that transmit lateral loads and forces and overturning moments thereof from the structure to the foundation media. This includes the approach used to analyze and develop loads of the multiple NPMs and their interaction in the reactor pool water. Such forces are generated by environmental and abnormal plant conditions such as earthquakes.

   C. Treatment of transient and localized loads.

   D. Treatment of the effects of shrinkage and cracking of the concrete.

   E. Computer programs that are used in the design and analysis of seismic Category I foundations.

   F. Seismic Category I structures design report (see Appendix C to DSRS Section 3.8.4).

   G. A structural audit (see Appendix B to DSRS Section 3.8.4).

   Where applicable, attention is given to bending, shear, and similar factors in the basemat that are attributable to uneven settlement, construction sequence, and mat flexibility. The review also considers the design of the junction of the sidewall and basemat, as well as stiff or soft spots in the underlying soil and soil on the side of the embedded walls. Site-specific soil-bearing capacities are reviewed as part of NUREG-0800 Standard Review Plan (SRP) Section 2.5.4.

5. Structural Acceptance Criteria. The review assesses the foundation for its capability to receive loads from the structure and to transmit loads to the soil media, with appropriate safety margins.

   The review addresses the design limits imposed on the various parameters that serve to quantify the structural behavior of each foundation, emphasizing the extent the allowable limits delineated in Subsection II.5 of this DSRS section are met. The review includes factors of safety against overturning and sliding to ensure adequate safety margins.

6. Materials, Quality Control, and Special Construction Techniques. The review assesses information on the materials used in the construction of seismic Category I foundations. Among the major materials of construction reviewed are the following:

   - concrete ingredients
   - reinforcing bars and mechanical splices
   - structural steel (including steel embedment)
   - rock anchors, including any prestressing system, if applicable

   The review includes the quality control program proposed for the fabrication and construction of seismic Category I foundations, including nondestructive examination of the materials to determine physical properties, placement of concrete, and erection tolerances.

   The review addresses any special construction techniques used on a case-by-case basis.

   In addition, for seismic Category I foundations the following information should be provided:

   A. The extent to which the materials and quality control programs comply with ACI 349, with additional guidance provided by RG 1.142 for concrete and with ANSI/AISC N690-1994 including Supplement 2 (2004) for steel, as applicable.

   B. If welding of reinforcing bars is used, the design should comply with the applicable sections of ASME Boiler and Pressure Vessel Code (hereafter referred as Code), Section III, Division 2. Any exceptions taken should be justified.

   The review of geological and seismological information to establish the free field ground motion is performed as described in SRP Sections 2.5.1 and 2.5.2.

The review of the geotechnical parameters and methods employed in the analysis of free field soil media and soil properties is conducted as described in SRP Sections 2.5.4 and 2.5.5.

7. Testing and Inservice Surveillance Programs. For seismic Category I foundations, the review addresses information on structure monitoring and maintenance requirements.

   It is important for seismic Category I foundations to accommodate inservice inspection (ISI) of critical areas. The review, therefore, assesses any special design provisions (e.g., providing sufficient physical access, furnishing alternative means for identification of conditions in inaccessible areas that can lead to degradation, conducting remote visual monitoring of high-radiation areas) to accommodate ISI of seismic Category I foundations.

   The review of postconstruction testing and inservice surveillance programs for foundations, such as periodic examination of inaccessible areas, monitoring of ground water chemistry, and monitoring of settlements and differential displacements, is on a case-by-case basis.

8. 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) related to this DSRS section in accordance with SRP Section 14.3.2 "Structural and Systems Engineering—Inspections, Tests, Analyses, and Acceptance Criteria" and 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 Sections 14.3 and 14.3.2.

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

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

Review Interfaces

Other SRP and DSRS sections interface with this section as follows:

1. The determination of structures that are subject to a QA program in accordance with the requirements of Appendix B to 10 CFR Part 50 is performed under SRP Sections 3.2.1 and 3.2.2. The review of safety-related structures is performed on that basis.

2. The determination of pressure loads from higher-energy lines located in safety-related structures other than containment, if any, is performed in accordance with SRP Section 3.6.1. The loads thus generated are included in the load combination equations of this DSRS section.

3. The determination of loads generated by pressure under accident conditions is performed in accordance with DSRS Section 6.2.1. The loads thus generated are included in the load combinations in this DSRS section.

4. The organization responsible for QA performs the reviews of design, construction, and operation phase QA programs under the applicable sections of SRP Chapter 17. In addition, while conducting regulatory audits in accordance with Office Instruction NRR-LIC-111 or NRO-REG-108, “Regulatory Audits,” the technical staff may identify quality-related issues. If this occurs, then the technical staff should contact the organization responsible for QA to determine if an inspection should be conducted.

5. The review for foundation settlement, effects of settlement on construction procedures, and modeling of soil stiffness for various loading conditions, as described in DSRS Sections 3.8.5 II.4 H, M, and N, is coordinated with the review under SRP Section 2.5.4. The modeling of soil stiffness for seismic loading is coordinated with the review under DSRS Section 3.7.2.

6. Review of the Probabilistic Risk Assessment is performed under SRP Section 19.

II. ACCEPTANCE CRITERIA

Requirements

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

1. 10 CFR 50.55a and 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 1, as they relate to safety-related structures being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed

2. GDC 2, as it relates to the design of the structures important to safety that are capable of withstanding the most severe natural phenomena such as wind, tornadoes, hurricanes, floods, and earthquakes and the appropriate combination of all loads

3. GDC 4, as it relates to appropriately protecting structures important to safety against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit

4. GDC 5, as it relates to not sharing structures important to safety among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions

5. Appendix B to 10 CFR Part 50, as it relates to the QA criteria for nuclear power plants

6. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAACs 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 design certification has been constructed and will be operated in conformity with the DC, the provisions of the AEA, and the Commission's rules and regulations

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 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. Description of the Foundation. The descriptive information in the FSAR is acceptable if it meets the criteria in Section 3.8.5.1 of RG 1.206.

   New or unique design features that are not specifically covered in RG 1.206 may require a more detailed review. The reviewer determines the additional information that may be needed to accomplish a meaningful review of the structural aspects of such new or unique features.

   RG 1.206 provides the basis for evaluating the description of structures to be included in a DC or a COL application.

2. Applicable Codes, Standards, and Specifications. The design, materials, fabrication, erection, inspection, testing, and surveillance, if any, of seismic Category I foundations are covered by codes, standards, and guides that apply either in their entirety or in part. Subsection II.2 of DSRS Section 3.8.4 includes a list of such documents. The use of more recent codes (e.g., applicable to ACI 349 and ANSI/AISC N690) is reviewed for adequacy on a case-by-case basis.

3. Loads and Load Combinations. The specified loads and load combinations used in the design of seismic Category I foundations are acceptable if found to be in accordance with those combinations described in Subsection II.3 of DSRS Section 3.8.4.

In addition to the load combinations referenced above, the combinations used to check against sliding and overturning attributable to earthquakes, winds, tornadoes, hurricanes, and against flotation because of floods are acceptable if found to be in accordance with the following:

A. D + H + E
B. D + H + W
C. D + H + E′
D. D + H + W_t
E. D + F′

Where D, E (OBE), W, E′ (SSE), and W_t are as referenced in Subsection II.3 of DSRS Section 3.8.4, H is the lateral earth pressure, and F′ is the buoyant force of the design-basis flood. In load combination D, the higher of W_t or hurricane should be used. Justification should be provided for including live loads or portions thereof in these combinations.

As noted in Appendix S to 10 CFR Part 50, the OBE, designated as E above, is associated only with plant shutdown and inspection unless the applicant specifically selects it as a design input. If the OBE is set at one-third or less of the SSE ground motion, an explicit analysis or design is not required. If the OBE is set at a value greater than one-third of the SSE, an analysis and design must be performed to demonstrate that the seismic Category I foundations remain functional and fall within applicable stress, strain, and deformation limits. DSRS Sections 3.7.1, 3.7.2, 3.7.3, and SRP Section 3.7.4 provide additional guidance on OBE use.

4. Design and Analysis Procedures. The design and analysis procedures used for seismic Category I foundations are acceptable if found to be in accordance with the following:

A. The design should consider the soil-structure interaction (SSI), hydrodynamic effect, and dynamic soil pressure.

B. For seismic Category I concrete foundations, the procedures are in accordance with the ACI 349, with additional guidance provided by RG 1.142.

C. After an Emergency Core Cooling System (ECCS) actuation the sudden increase in temperature may produce a localized nonlinear transient temperature gradient across the Reactor Building foundation. The analysis should consider the effects of such loads.

D. The design report is acceptable if it satisfies the guidelines provided in DSRS Section 3.8.4, Appendix C.

E. The structural audit is conducted in accordance with DSRS Section 3.8.4, Appendix B.

F. Methods for determining the sliding forces and overturning moment attributable to an earthquake should be in accordance with the methods described in DSRS Section 3.7.2.

G. Computer programs are acceptable if the validation provided is found to be in accordance with the procedures delineated in Subsection II.4.D of DSRS Section 3.8.4.

In addition to the above, the design and analysis procedures for the following details are reviewed on a case-by-case basis:

A. Appropriateness of the method for determination of the bending moments and shear forces in the mat foundation for seismic loads.

B. During normal operation, a linear temperature gradient across the RB foundation may develop. After a loss-of-coolant accident (LOCA), however, the sudden increase in temperature may produce a nonlinear transient temperature gradient across the RB foundation. In addition, the pressure associated with the LOCA could also potentially affect the RB foundation. The analysis should consider the effects of such loads.

C. The design and analysis methods described in Subsection II.4 of DSRS Section 3.8.4, which are applicable to foundations, also need to be considered. These items include assumptions on boundary conditions, transient and localized loads, shrinkage and cracking of concrete, evaluation of steel embedments and anchors, consideration of the various combinations of multiple NPMs that may occur during the life of the plant and their interaction in the reactor pool water, and pool water loads.

D. Consideration of dynamic lateral soil pressures on the RB foundation (basemat and embedded walls connected to the basemat) is acceptable if the lateral earth pressure loads are evaluated for the governing of the three cases following the guidance in DSRS Section 3.8.4 II.4.H. If the methods identified in DSRS Section 3.8.4 II.4.H are shown to be overly conservative for the cases considered, then any alternative methods proposed will be reviewed on a case-by-case basis.

E. Adequacy of the sliding analysis method and the analysis results to account for potential mat foundation liftoff effects. The staff should also review the calculation of the factor of safety against sliding. If sliding resistance is the sum of shear friction along the base mat and contribution of soil lateral pressure up to the full passive pressure capacity induced by embedment effects, the adequacy of the analysis to consider these effects is addressed using a consistent lateral displacement criterion. This involves the use of static versus dynamic coefficient of friction consistent with the use of partial versus full passive pressure. The reviewer should also consider whether the selection of the coefficient of friction used in the sliding stability analysis considers the various sliding interfaces (e.g., soil shear failure, concrete to soil, waterproofing to soil, concrete basemat to concrete mudmat).

Deeply embedded structures would not be expected to have difficulties in satisfying the factors of safety for sliding and overturning; however, that may not be the case for the other structures with shallower embedments.

If the stability evaluation is performed based on a pseudostatic approach, using the maximum seismic demand loads (e.g., maximum forces in the two horizontal directions and one vertical direction), then the factors of safety for sliding and overturning can be determined by the ratio of capacity to demand loads.

However, if a linear time history analysis approach is utilized, then the factor of safety can be calculated at each time step throughout the time history. The minimum value of the factors of safety calculated in this manner should be compared against the acceptance criteria for that load combination. For the pseudostatic and time history analysis methods, all three directional demand forces should be considered to act simultaneously. Therefore, the resultant seismic forces (horizontal resultant force for sliding from the two horizontal forces and similarly the resultant overturning moment for overturning stability) should be considered. In the case of the sliding evaluation, if instead of using the resultant horizontal force with the vertical force, each pair of horizontal force and vertical force is evaluated separately, then the frictional resistance in the horizontal directions should be apportioned considering the existence of the two horizontal forces.

If the stability evaluation is performed using a nonlinear time history analysis that includes foundation sliding and uplift, the analysis should consider the following criteria:

i. The development of the set of time histories should follow the guidance described in DSRS Section 3.7.1. This includes identification of the number of time histories needed to perform the nonlinear time history analyses and the development of each of the individual time histories. In this case, the guidance in DSRS 3.7.1 II.B, Option 2, for multiple sets of time histories is applicable.

ii. To demonstrate an adequate factor of safety, the seismic input time histories should be increased by a factor equal to the factor of safety for the applicable load combination (e.g., increase the seismic input time history amplitudes by a factor of 1.1 for load combination C). No or minimal sliding and no overturning should be demonstrated for each of the time history analyses.

iii. The mathematical model should include the effects of sliding and uplift between the foundation and the soil media using appropriate finite elements that can simulate sliding once the frictional limit is reached and can simulate contact surfaces that can transmit compression but not tension.

iv. The sliding and overturning stability evaluation should consider the various significant parameters that were evaluated in the design-basis seismic SSI analysis (e.g., range of soil profiles, concrete stiffness variation).

v. If the input motion applied at the foundation of the structural model without soil is developed from the response of the linear SSI analysis, justification is needed to demonstrate that any minimal sliding or uplift would not affect the assumed seismic input motion taken from the SSI analysis that does not consider any sliding and uplift. Alternatively, the structural model could be coupled with the soil model and a nonlinear SSI analysis performed.

vi. The mathematical model should adequately represent the dynamic characteristics of the structure and capture the vibration modes important for the sliding and overturning stability analysis.

vii. If some minimal sliding does occur, the justification for incurring a small magnitude of sliding needs to be provided. In this case, the magnitude of sliding should be based on the envelope of the values obtained from the individual time history analyses. In addition, the magnitude of sliding/overturning plus the SSI building displacements need to be evaluated for adequate seismic gaps between structures, and the design adequacy of commodities attached to the structures (e.g., piping and conduit between adjacent structures above grade; buried piping, conduit, and tunnels) needs to be evaluated.

F. Adequacy of the evaluation of the capability of a foundation to transfer shear when waterproofing is used for a range of site conditions (soil sites with shear wave velocity of 1,000 fps to hard rock).

G. Adequacy of the definition of dead load for uplift evaluations (flotation and seismic overturning), including the treatment of the stored volume of water in any pools.

H. Detailed explanation of how settlement is evaluated including potential effects of static or dynamic differential settlement, dependence on time (i.e., short term vs. long term), effect of the soil type (i.e., granular vs. cohesive), and effect of the foundation type and size (e.g., basemats, spread footings).

Evaluation of the effects of settlement on construction procedures.

Evaluation of the allowable settlement (total and differential) that can be accommodated in the foundation/structures.

I. The maximum toe pressure for base mat design under worst-case static and dynamic loads and its justification.

J. The evaluation of stiff and soft spots in the foundation soil to maximize the bending moments used in the design of the mat foundation.

K. Description of the design details of critical locations, such as the junction of sidewall and base mat and the junctions of base mat to sumps.

L. Detail explanation of the load path from all superstructures to the mat foundation to the subgrade.

   Discussion of any unique design features that occur in the load path.

M. Explanation of how loads attributable to construction are evaluated in the design. Some examples of items to be discussed include the excavation sequence and loads from the construction sequence of the mat foundation and walls, as well as the potential for loss of subgrade contact (e.g., because of loss of cement from a mud mat) that may lead to a differential pressure distribution on the mat.

N. An essential aspect of the design and analysis procedures for seismic Category I foundations is the stiffness modeling of the soil material under and to the sides of the structures. Soil stiffness can be represented by means of analytical or numerical (e.g., solid finite elements, distributed springs) formulations that are appropriate for the loading conditions as well as for the soil type, foundation type and size, and time scale being considered.

   In the case of seismic dynamic loads, the soil stiffness parameters should be consistent with the magnitude of soil strains assumed in the SSI analysis described in DSRS Section 3.7.2, which are associated with the relatively short time scale of the seismic input. The distribution of toe bearing pressures used in foundation design should be consistent with the distribution of toe bearing pressures obtained from the SSI analysis.

   In the case of gravity loads and basemat foundations, the soil stiffness parameters should be consistent with (1) dishing or Boussinesq effects (if uncoupled distributed springs are used then it may be necessary for the stiffness to be increased at the edges and reduced at the center of the basemat footprint), (2) basemat size (subgrade modulus could be highly dependent on basemat dimensions), (3) time scale of the loads (i.e., short-term construction loads vs. long-term loads present throughout the life of the structure), and (4) soil type (i.e., granular vs. cohesive soils).

   Appropriate stiffness parameters are particularly important when evaluating loads induced by the construction process and by differential settlements, as described in items H and M above. Additional guidance to consider in the review of DC and COL applications is given below.

i. In the case of a DC application, the staff reviews the following information:

(1) Postulated set of soil stiffness parameters for the construction phase and the technical bases for its selection, for all soils within the zone of influence surrounding the structures. The zone of influence is defined as that region to the side of and below the structure that may induce loads on the structure if induced settlements occur and/or loads are applied within the zone.

(2) Postulated set of soil stiffness parameters for the postconstruction phase and the technical basis for its selection.

(3) Postulated construction sequence and corresponding set of construction loads and the technical basis for its selection.

(4) Analysis methodology for computing soil settlements (total and differential, short term and long term), which should incorporate the postulated soil stiffness and construction sequence, and include potential long-term settlement effects through the life of the structure.

(5) Analysis methodology for computing member forces and moments induced by the settlements and construction sequence, which should then be taken as a separate construction sequence / soil settlement load case, to be included in the structural design of the foundation and superstructure in addition to all other load cases.

(6) Interface considerations between DC and COL applications (e.g., COL action items and appropriate acceptance criteria) that permit verification of the foundation design by a COL applicant. An acceptable interface consideration is to incorporate the settlement profiles computed for a postulated construction sequence (the various stages of construction and postconstruction), which a COL applicant can then use for verification purposes in conjunction with predictive calculations (associated with the actual construction sequence) and a settlement monitoring program. The acceptance criteria for these verifications need to be clearly identified.

(7) Development of a short-term and long-term settlement monitoring program that can detect both vertical and horizontal movements in and around the structures, as well as differential distortion across the foundation footprint, from the beginning of construction at the site, to ensure that the actual settlements are within design allowable.

ii. In the case of a COL application that incorporates a DC application by reference, the staff reviews the following information:

(1) In addition to the geotechnical investigation performed in SRP Section 2.5.4, the staff reviewer for this section should review the site-specific geotechnical investigation program to determine predicted settlements during construction and postconstruction, based on the construction sequence to be used. The investigation program should be carried to sufficient depths to be able to ascertain these properties over the depth considered important to the settlement analyses. The methodology for site-specific settlement analyses should be consistent with the corresponding methodology in the DC application.

(2) Settlement monitoring program to verify whether measured settlements and distortions are consistent with predicted site-specific settlements during construction and postconstruction phases, through the life of the structure.

(3) Verification of the interface considerations between DC and COL applications, which should be based on the information described in the above two bullets.

The above considerations are appropriate for major seismic Category I foundations. Alternative, more simplified, approaches are acceptable for the case of smaller structures if adequate justifications are provided.

In the case of adjacent structures connected by appurtenances (nonflexible commodities, such as piping and conduit), the staff reviews the design criteria for total settlement and for relative settlement between adjacent structures to ensure consistency with the criteria used in the design of the appurtenances.

O. To be acceptable, the design of the foundation should also include design details to prevent and monitor potential leakage from the pool and potential leakage into the RB and control building due to ground water outside the RB and control building.

5. <u>Structural Acceptance Criteria</u>. For the loading combinations referenced in the first paragraph of Subsection II.3 of this DSRS section, the allowable limits that constitute the acceptance criteria are referenced in Subsection II.5 of DSRS Section 3.8.4. In addition, for the five other load combinations in Subsection II.3 of this DSRS section, the factors of safety against overturning, sliding, and flotation are acceptable if found to be in accordance with the following:

Minimum Factors of Safety

For Combination	Overturning	Sliding	Flotation
A	1.5	1.5	—
B	1.5	1.5	—
C	1.1	1.1	—
D	1.1	1.1	—
E	—	—	1.1

6. Materials, Quality Control, and Special Construction Techniques. The materials and quality control programs are acceptable if found to be in accordance with the codes and standards indicated in Subsection I.6 of this DSRS section. Special construction techniques, if any, are treated on a case-by-case basis.

7. Testing and Inservice Surveillance Requirements. For seismic Category I foundations, structure monitoring and maintenance requirements are acceptable if found to be in accordance with 10 CFR 50.65 and RG 1.160.

   For water control structures (if applicable), ISI programs are acceptable if found to be in accordance with RG 1.127. Water control structures covered by this program include concrete structures, embankment structures, spillway structures and outlet works, reservoirs, cooling water channels and canals, as well as intake and discharge structures, and safety and performance instrumentation.

   For seismic Category I foundations, it is important to accommodate ISI of critical areas. The staff considers monitoring and maintaining the condition of seismic Category I foundations as essential for plant safety. It is also important that a foundation monitoring program include monitoring of settlements (both differential and total) during construction and postconstruction to ensure that the foundation continues to perform as designed.

   Any special design provisions (e.g., providing sufficient physical access, supplying a means for identification of conditions in inaccessible areas that can lead to degradation, performing remote visual monitoring of high-radiation areas) to accommodate ISI of seismic Category I foundations are reviewed on a case-by-case basis.

   For plants with nonaggressive ground water / soil (i.e., pH>5.5, chlorides<500 ppm, sulfates<1,500 ppm), an acceptable program for normally inaccessible below-grade concrete walls and foundations is to (1) examine the exposed portions of below-grade concrete for signs of degradation, when excavated for any reason, and (2) conduct periodic site monitoring of ground water chemistry to confirm that the ground water remains nonaggressive.

   For plants with aggressive ground water / soil (i.e., exceeding any of the limits noted above), an acceptable approach is to implement a periodic surveillance program to monitor the condition of normally inaccessible below-grade concrete for signs of degradation.

Technical Rationale

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. Compliance with 10 CFR 50.55a requires that SSCs be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety functions to be performed.

   This DSRS section refers to a list of acceptable documents in DSRS Section 3.8.4 that provide guidance regarding construction, quality control, tests, and inspections. ACI 349, with additional guidance provided by RG 1.142 and ANSI/AISC N690-1994 including Supplement 2 (2004), contain basic specifications for concrete and steel structures, respectively. These guides and specifications impose specific restrictions to ensure that the foundations of structures will perform their intended safety function.

   Meeting these requirements and criteria provides additional assurance that the foundations of structures described in this section will perform their intended safety function and limit the release of radioactive materials.

2. Compliance with GDC 1 requires that (1) SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of their safety function, (2) a QA program be established and implemented, and (3) sufficient and appropriate records be maintained. If generally recognized codes and standards are used, they should be identified and evaluated to determine their applicability, adequacy, and sufficiency and supplemented or modified as necessary to assure a quality product in keeping with the required safety function.

   This DSRS section, which also refers to DSRS Section 3.8.4, describes acceptable criteria related to static and dynamic loadings and evaluation programs for structures. It also describes acceptable materials, design methodology, quality control procedures, construction methods, and ISIs, as well as documentation criteria for design and construction controls.

   This DSRS section, which also refers to DSRS Section 3.8.4, cites ACI 349, ANSI/AISC N690-1994 including Supplement 2 (2004), and RGs to provide guidance describing design methodology, materials testing, and construction techniques that are commensurate with the importance of the safety function to be performed. Conformance with these requirements imposes specific restrictions to ensure that the foundations will perform acceptably, commensurate with their intended safety function, when designed in accordance with the above standards.

   Meeting these requirements and criteria provides assurance that the foundations of structures described in this section will perform their intended safety function.

3. Compliance with GDC 2 requires that the design of SSCs important to safety withstand the effects of expected natural phenomena, such as earthquakes, tornadoes, hurricanes,

floods, tsunami, and seiches, without losing the capability to perform their safety functions. The design bases for these SSCs shall reflect appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.

To ensure that the design of structures of a nuclear power plant will withstand natural phenomena, it is necessary to consider the most severe natural phenomena that have been historically reported, allowing sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. These data should be used to specify the design requirements of nuclear power plant components to be evaluated as part of COL and early site permit (ESP reviews, or for site parameter envelopes in the case of DCs, thereby ensuring that components important to safety will function in a manner that will maintain the plant in a safe condition.

This DSRS section, which also refers to DSRS Section 3.8.4, provides detailed acceptance criteria and cites appropriate regulatory guidance for design methodology, materials testing, and construction techniques that are acceptable to the staff. GDC 2 requires that the design of structures be able to withstand the effects of natural phenomena combined with the effects of normal and accident conditions without losing the capability to perform their safety functions. The primary function of a foundation is to transmit the loads imposed by the superstructure to the foundation material, bedrock, and/or soil supporting the structure. Foundations need to be designed to interact with the structures they support. Consequently, it is necessary to specify the most severe natural phenomena (e.g., earthquakes) likely to occur as a function of their frequency of occurrence. The load combinations and specifications cited in these DSRS sections provide acceptable engineering criteria to accomplish that function.

Meeting these requirements and criteria provides added assurance that the design of foundations of structures will withstand the effects of natural phenomena and will perform their intended safety functions.

4. Compliance with GDC 4 requires that the design of nuclear power plant SSCs important to safety (1) accommodate the effects of, and be compatible with, environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs, and (2) appropriately protect against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

   This DSRS section, which also refers to DSRS Section 3.8.4, provides acceptable methods including load combinations, acceptance criteria, standards, and codes to ensure compliance with GDC 4. Meeting this criterion provides assurance that the foundations of structures will withstand loads from internal events, such as those described above, and from external sources, such as explosive hazards in proximity to the site, potential aircraft crashes (nonterrorist-related incidents), and missiles generated from activities of nearby military installations or turbine failures, thus decreasing the probability that these events would damage structures and cause release of radioactive material.

Meeting these requirements and criteria provides assurance that the foundations of structures will not fail to function as designed, thus protecting against loss of their structural integrity.

5. Compliance with GDC 5 prohibits the sharing of structures important to safety among nuclear power units unless it can be shown that such sharing will not significantly impair the ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units.

   The requirements of GDC 5 ensure that the use of common structures in multiunit plants will not significantly affect orderly and safe shutdown and cooldown in one plant in the event of an accident in another. The load-combination equations combine loads from normal operation and from design-basis accidents so that the resulting structural designs provide for mutual independence of shared structures.

   Meeting this requirement provides additional assurance that the foundations are capable of performing their required safety functions even if they are shared by multiple nuclear power units.

6. Compliance with 10 CFR Part 50, Appendix B, requires that applicants establish and maintain a QA program for the design, construction, and operation of SSCs.

   This DSRS section, which also refers to DSRS Section 3.8.4, provides guidance specifically related to the design, construction, testing, and inservice surveillance of structural concrete and steel used in nuclear power plants. Subsection II.2 of DSRS Section 3.8.4 cites ACI 349, with additional guidance provided by RG 1.142, ANSI/AISC N690-1994 including Supplement 2 (2004), and RGs 1.127 and 1.160, to satisfy the requirements of Appendix B to 10 CFR Part 50.

   Meeting these requirements and criteria provides additional assurance that the foundations of structures covered in this DSRS section will meet the requirements of Appendix B to 10 CFR Part 50 and thus perform their intended safety functions.

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. Description of the Foundations. After the type of foundation and its structural characteristics are identified, the staff obtains information on similar foundations previously licensed for reference. Such information, which is available in FSARs and amendments to previous license applications, enables the identification of differences for the case under review. These differences require additional scrutiny and evaluation. New and unique features that have not been used in the past are examined in greater detail.

   The reviewer evaluates the information furnished in the FSAR for completeness in accordance with RG 1.206 for a DC or a COL (for application submitted in accordance with 10 CFR Part 52).

4. Applicable Codes, Standards, and Specifications. The reviewer compares the list of codes, standards, guides, and specifications with the list referenced in Subsection II.2 of this DSRS section. The reviewer verifies that the appropriate code or guide is used and that the applicable edition and stated effective addenda are acceptable.

5. Loads and Load Combinations. The reviewer verifies that the loads and load combinations are as conservative as those referenced and specified in Subsection II.3 of this DSRS section. The reviewer identifies any deviations from the acceptance criteria for loads and load combinations that have not been adequately justified as unacceptable and transmits these findings to the applicant.

6. Design and Analysis Procedures. The reviewer verifies that, for the design and analysis procedures, the applicant has used the procedures in the applicable code as delineated in Subsection II.4 of this DSRS section.

   The reviewer verifies that the provisions of Subsection II.4 of this DSRS section are met.

7. Structural Acceptance Criteria. The reviewer compares the limits on allowable stresses and strains in the concrete, reinforcement, and structural steel and on factors of safety for overturning, sliding, and flotation with the corresponding allowable values specified in Subsection II.5 of this DSRS section. If the applicant proposes to deviate from these limits, it should be supported with adequate justification and evaluation.

8. Materials, Quality Control, and Special Construction Techniques. The reviewer compares the materials, quality control procedures, and any special construction techniques with those referenced in Subsection II.6 of this DSRS section. If a new material not used in previously licensed cases is employed, the reviewer asks the applicant to provide sufficient test and user data to establish the acceptability of such a

material. Similarly, the reviewer evaluates any new quality control procedures or construction techniques in detail to ensure that there will be no degradation of quality that might affect the structural integrity of the foundation.

9. Testing and Inservice Surveillance Programs. For seismic Category I foundations, the reviewer verifies that structure monitoring and maintenance requirements are in accordance with 10 CFR 50.65 and RGs 1.127 and 1.160.

   Any special design provisions (e.g., providing sufficient physical access, supplying alternative means for identification of conditions in inaccessible areas that can lead to degradation, performing remote visual monitoring of high-radiation areas) to accommodate ISI of seismic Category I foundations are reviewed on a case-by-case basis.

   The reviewer evaluates any other testing and inservice surveillance programs for seismic Category I foundations on a case-by-case basis.

10. Design Certification / Combined License Application Reviews. 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 14.3.2 and 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 design of the seismic Category I foundations is acceptable and meets the relevant requirements of 10 CFR 50.55a, 10 CFR Part 50, Appendix B, and GDCs 1, 2, 4, and 5. This conclusion is based on the following:

1. The applicant has met the requirements of 10 CFR 50.55a and GDC 1 with respect to ensuring that the seismic Category I foundations are designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the safety

functions to be performed. The staff used the guidelines of RGs and industry standards indicated below in making this determination.

2. The applicant has met the requirements of GDC 2 by designing the seismic Category I foundation described in this section to withstand the effects of natural phenomena, reflecting appropriate consideration of the most severe earthquake that has been established for the site with sufficient margin and also the combinations of the effects of normal and accident conditions with the effects of environmental loadings such as earthquakes and other natural phenomena.

3. The applicant has met the requirements of GDC 4 by ensuring that the designs of seismic Category I foundations are appropriately protected against dynamic effects associated with missiles, pipe whipping, and discharging fluids.

4. The applicant has met the requirements of GDC 5 by demonstrating that SSCs are not shared between units or that, if shared, the applicant has demonstrated that sharing will not impair their ability to perform their intended safety functions.

5. The applicant has met the requirements of 10 CFR Part 50, Appendix B, because the QA program provides adequate measures for implementing guidelines relating to structural design audits.

6. The criteria used in the analysis, design, and construction of all plant seismic Category I foundations to account for anticipated loadings and postulated conditions that may be imposed upon each foundation during its service lifetime are in conformance with established criteria, codes, standards, and specifications acceptable to the NRC staff. These include meeting the positions of RG and industry standards listed in Subsection II.2 of DSRS Section 3.8.4 for other seismic Category I foundations.

7. The use of these criteria as defined by applicable codes, standards, and specifications; the loads and loading combinations; the design and analysis procedures; the structural acceptance criteria; the materials, quality control, and special construction techniques; and the testing and inservice surveillance requirements provide reasonable assurance that, in the event of winds, tornadoes, hurricanes, earthquakes, and various postulated events, seismic Category I foundations will withstand the specified design conditions without impairment of structural integrity and stability or the performance of required safety functions.

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*, "Standards for Protection against Radiation," Part 20, Chapter I, Title 10, "Energy."

2. *U.S. Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter I, Title 10, "Energy."

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

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

5. GDC 61, "Fuel Storage and Handling and Radioactivity Control."

6. GDC 19, "Control Room."

7. GDC 4, "Environmental and Dynamic Effects Design Bases."

8. U.S. Nuclear Regulatory Commission, "Control of Combustible Gas Concentrations in Containment," Regulatory Guide 1.7, ADAMS Accession No. ML070290080.

9. U.S. Nuclear Regulatory Commission, "Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," Regulatory Guide 1.112, ADAMS Accession No. ML070320241.

10. U.S. Nuclear Regulatory Commission, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," Regulatory Guide 1.183, ADAMS Accession No. ML003716792.

11. American National Standards Institute/American Nuclear Society, "Radioactive Source Term for Normal Operation of Light Water Reactors," ANSI/ANS 18.1-1999, La Grange Park, IL.

12. U.S. Nuclear Regulatory Commission, "Clarification of TMI Action Plan Requirements," NUREG-0737, November 1980, ADAMS Accession No. ML051400209.

13. *U.S. Code of Federal Regulations*, "Environmental Radiation Protection Standards for Nuclear Power Operations," Part 190, Chapter I, Title 40, "Protection of Environment."

14. U.S. Nuclear Regulatory Commission, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants," Regulatory Guide 1.89, ADAMS Accession No. ML003740271.

15. U.S. Nuclear Regulatory Commission, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," Regulatory Guide 1.143.

16. U.S. Nuclear Regulatory Commission, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," Regulatory Guide 1.26.

17. U.S. Nuclear Regulatory Commission, "Seismic Design Classification," Regulatory Guide 1.29.

18. U.S. Nuclear Regulatory Commission, "Tornado Design Classification," Regulatory Guide 1.117, ADAMS Accession No. ML003739346.

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

20. Electric Power Research Institute, "Pressurized Water Reactor Primary Water Chemistry Guidelines."

21. Electric Power Research Institute, "Pressurized Water Reactor Primary Water Zinc Application Guidelines."

22. Electric Power Research Institute, "Advanced Light Water Reactor Utility Requirements Document, Volume III, ALWR Passive Plant."

23. U.S. Nuclear Regulatory Commission, "NRC Review of Electric Power Research Institute's Advanced Light Water Reactor Utility Requirements Document, Passive Plant Designs," NUREG-1242, Volume 3, Parts 1 and 2 (ADAMS Accession Nos. ML070600372 and ML070600373).

24. Electric Power Research Institute, "Cobalt Reduction Guidelines."

25. U.S. Nuclear Regulatory Commission, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable," Regulatory Guide 8.8, ADAMS Accession No. ML003739549.