

Draft for Comment



U.S. NUCLEAR REGULATORY COMMISSION DESIGN-SPECIFIC REVIEW STANDARD FOR NuScale SMR DESIGN

3.4.2 PROTECTION OF STRUCTURES AGAINST FLOOD FROM EXTERNAL SOURCES

REVIEW RESPONSIBILITIES

Primary - Organization responsible for structural analysis reviews

Secondary - None

I. AREAS OF REVIEW

The following areas are related to the design of seismic Category I structures to withstand the effects of the highest flood level from external sources including tsunamis and other sources (e.g., dam breaks, storm surges, etc.) and groundwater level specified for the plant. These areas are reviewed to ensure conformance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, General Design Criterion (GDC) 2.

The specific areas of review are as follows:

1. The data of the highest flood, tsunami and groundwater levels. Appropriate loading to account for flood, tsunami and groundwater on seismic Category I structures are established. Further, for plants where the flood level is higher than the proposed grade around the plant structures, the dynamic phenomena associated with flooding and tsunami such as currents, flood waves, and their hydrodynamic effects are considered. The bases for these parameters are reviewed by organization responsible for review of hydrology related issues in conformance with relevant subsections of Standard Review Plan (SRP) Section 2.4.
2. The analysis procedures that are utilized to transform the static and dynamic effects of the highest flood level, probable maximum tsunami, and highest groundwater level into effective loads applied to seismic Category I structures are reviewed.
3. 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, "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.
4. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address 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.

An applicant for a standard design certification may postulate values for site parameters that are representative of a reasonable number of sites that have been or may be considered for a COL application as the basis for plant design.

Review Interfaces

Other SRP and Design-Specific Review Standards (DSRS) sections interface with this section as follows.

1. The flood related data to determine the design basis external flood and the dynamic effects on structures of the flood where it is above the plant grade is reviewed in accordance with SRP Sections 2.4.2, 2.4.3, 2.4.4, and 2.4.5.
2. The probable maximum tsunami data to determine the design basis tsunamigenic sources, tsunami wave propagations, static and dynamic hydraulic forces, debris and water-borne projectiles, and other site-related effects (e.g., site specific terrain and topography) on structures is reviewed in accordance with SRP Section 2.4.6.
3. The data related to groundwater to determine the highest groundwater level is reviewed in accordance with SRP Section 2.4.12.
4. The coordination and the review of site parameters postulated for design in a standard design certification application are conducted in accordance with SRP Section 2.0.
5. Review of the description and results of the Probabilistic Risk Assessment is performed under SRP 19.0.
6. Review of consideration of the applicable external flood load for all seismic Category I structures and other safety-related and risk significant structures discussed under DSRS Section 3.8

The specific acceptance criteria and review procedures are contained in the referenced SRP and DSRS sections.

II. ACCEPTANCE CRITERIA

Requirements

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

1. GDC 2 requires that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions as it relates to natural phenomena. 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.

2. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the design certification has been constructed and will operate in conformity with the design certification, the provisions of the Atomic Energy Act (AEA), and the Commission's rules and regulations.
3. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the combined license, the provisions of the AEA, and the NRC's 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.

The design of a structure that must withstand the effects of the highest flood, maximum probable tsunami, and highest groundwater levels is acceptable if the relevant requirements of GDC 2, "Design Bases for Protection against Natural Phenomena," are complied with. The criteria necessary to meet the relevant requirements of GDC 2 are as follows:

1. The highest flood, maximum probable tsunami, and highest groundwater levels and the associated static and dynamic effects, if any, used in the design shall be the most severe ones 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.
2. In most situations, the highest flood level is below the proposed plant grade and only its hydrostatic effects should be addressed. If drainage or pumping systems are not included around the foundations of structures to reduce the hydrostatic head associated with the highest flood and groundwater levels, hydrostatic pressure should be included as a structural load on basement walls and the foundation slab of a structure. In consideration of any uplifting or floating of a structure, the total buoyancy force may be based on the highest flood level or the highest groundwater level excluding wave action. However, if the highest flood level or the highest groundwater level is above the proposed plant grade, wave action should be included in the calculation for lateral and overturning movements of a structure.
3. For sites where the flood level is above the proposed plant grade, the COL applicant should include the dynamic loads of wave action. Procedures for determining such dynamic loads are acceptable if they are in accordance with or equivalent to those

delineated in the U.S. Army Coastal Engineering Research Center, "Shore Protection Manual" (Vol. I, June 2002, reprinted from 1973 edition and Vol. II, June 2002, reprinted from 1973 edition), in EM 1110-2-1100, Coastal Engineering Manual, Part II, Chapter 1, "Water Wave Mechanics," U.S. Army Corps of Engineers, April 30, 2002, or in FEMA 55, "Coastal Construction Manual," Federal Emergency Management Agency, Jessup, MD, 2005, as applicable.

Any other methods proposed should be provided with adequate justification and are reviewed on a case by case basis.

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:

GDC 2 requires that structures important to safety shall be designed to withstand the effects of natural phenomena such as floods, tsunamis, and seiches without loss of capability to perform their safety function. GDC 2 also requires that the design basis for these SSCs shall reflect appropriate consideration of the most severe of the natural phenomena that has been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy. This includes that the effects of the highest groundwater condition need to be considered.

This DSRS guides the review of analysis procedures for the determination of static and dynamic loadings due to natural flooding phenomena. These loadings are to be used in the design of safety-related SSCs and RTNSS-B SSCs to ensure their capability to withstand flood effects without loss of their safety functions.

Meeting this requirement provides a level of assurance that plant structures are constructed in such a manner as to withstand stresses resulting from the most severe flooding condition they may experience.

III. REVIEW PROCEDURES

The reviewer will select and emphasize material from the procedures described below, as may be appropriate for a particular case.

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.

The site-related and hydrodynamic parameters described in subsection II.1 of this DSRS section are reviewed by staff in accordance with SRP Sections 2.4.2, 2.4.3, 2.4.6 and 2.4.12.

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: Integral Pressurized Water 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 SMR framework. Using the graded approach described in NUREG-0800 Intro Part 2, the NRC staff may determine that, for certain structures, systems, and components (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 completion of the applicable ITAAC. The use of the selected programs to augment or replace traditional review procedures is described in Figure 1 of NUREG-0800, Introduction - Part 2. Examples of such programs that may be relevant to the graded approach for these SSCs include:

- 10 CFR Part 50, Appendix A, General Design Criteria (GDC), Overall Requirements, Criteria 1 through 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 Non-Safety 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 design certification or combined license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues which are identified in the version of NUREG-0933 current on the date up to 6 months before the docket date of the application and which are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v) 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. After the acceptability of the site-related and hydrodynamic parameters is established, the reviewer proceeds with the review of the structural aspects of the design for flood, tsunami or groundwater. The procedures used by the applicant to determine effective flood and groundwater loads are reviewed by staff responsible for the review of

structures in accordance with subsection II of this DSRS section.

4. 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 final safety analysis report (FSAR) meets the acceptance criteria. 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 early site permit or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

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

IV. EVALUATION FINDINGS

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

The staff concludes that the plant design is acceptable and meets the requirements of GDC 2. This conclusion is based on the following:

The applicant has met the requirements of GDC 2 with respect to the structures' capability to withstand the effects of the highest flood, probable maximum tsunami and highest groundwater levels so that their design reflects:

1. appropriate consideration for the most severe flood recorded for the site with an appropriate margin,
2. appropriate combination of the effects of normal and accident conditions with the effect of the natural phenomena, and
3. the importance of the safety functions to be performed.

The applicant has designed the plant structures with sufficient margin to prevent structural damage for the most severe flood and groundwater levels for the site and used appropriate dynamic effects for structural design, in accordance with U.S. Army Coastal Engineering Research Center, "Shore Protection Manual" (Vol. I, June 2002, reprinted from 1973 edition and Vol. II, June 2002, reprinted from 1973 edition) or in EM 1110-2-1100, Coastal Engineering Manual, Part II, Chapter 1, "Water Wave Mechanics," U.S. Army Corps of Engineers, April 30, 2002 or in FEMA 55, "Coastal Construction Manual," Federal Emergency Management Agency, Jessup, MD, 2005, as applicable, so that the requirements of Item 1 listed above are met. In addition, the design of seismic Category I structures, as required by Item 2 listed above, has included load combinations of the most severe flood or groundwater-related loads and the loads resulting from normal and accident conditions.

The procedures used to determine the loadings on seismic Category I structures induced by the highest design flood, probable maximum tsunami or highest groundwater levels specified for the plant site are acceptable since these procedures have been used in the design of conventional structures and proven to provide an adequate basis which together with other engineering design considerations assures that the structures will withstand such environmental forces.

The use of these procedures provides reasonable assurance that, in the event of floods, tsunami or high groundwater, the structural integrity of the plant seismic Category I structures will not be impaired and, in consequence, safety related and RTNSS-B systems and components located within these structures will be adequately protected and expected to perform necessary safety functions, as required, thus satisfying the requirement of item 3 listed above

For an application referencing a certified plant design, the reviewer's finding should include a concluding statement similar to the following:

Historical data for the proposed site are consistent with the flood level identified in the site parameter envelope specified in the certified plant design documents.

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 Standard Review Plan (SRP) revision in effect six 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 small modular reactor (SMR) designs, however, differ significantly from large light-water nuclear reactor 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 SRM- COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010 (ML102510405) (SRM). 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 pre-application activities. Accordingly, the staff has developed the content of the DSRS as an alternative method for the evaluation of 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 in order to address new design or siting assumptions.

VI. REFERENCES

1. 10 CFR Part 20, "Standards for Protection Against Radiation."
2. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."
3. 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."
4. GDC 61, "Fuel Storage and Handling and Radioactivity Control."
5. GDC 19, "Control Room."
6. GDC 4, "Environmental and Dynamic Effects Design Bases."
7. RG 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident."
8. RG 1.112, "Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors."
9. RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors."
10. ANSI/ANS Standard 18.1-1999, "Source Term Specification," American National Standards Institute/American Nuclear Society."
11. NUREG-0737, "Clarification of TMI Action Plan Requirements."
12. 40 CFR Part 190, "Environmental Radiation Protection Standards For Nuclear Power Operations."

13. RG 1.89, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants."
14. RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants."
15. RG 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants."
16. RG 1.29, "Seismic Design Classification."
17. RG 1.117, "Tornado Design Classification."
18. RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."
19. EPRI, "Pressurized Water Reactor Primary Water Chemistry Guidelines."
20. EPRI, "Pressurized Water Reactor Primary Water Zinc Application Guidelines."
21. EPRI, "Advanced Light Water Reactor Utility Requirements Document, Volume III, ALWR Passive Plant."
22. NUREG-1242, "NRC Review of Electric Power Research Institute's Advanced Light Water Reactor Utility Requirements Document, Passive Plant Designs" Volume 3, Part 1 and Volume 3, Part 2 (ADAMS Accession Nos. ML070600372 and ML070600373).
23. EPRI, "Cobalt Reduction Guidelines."
24. RG 8.8, "Information Relevant to Assuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as is Reasonably Achievable."