

Draft for Comment

U.S. NUCLEAR REGULATORY COMMISSION



DESIGN-SPECIFIC REVIEW STANDARD FOR NuSCALE SMR DESIGN

3.4.1 INTERNAL FLOOD PROTECTION FOR ONSITE EQUIPMENT FAILURES

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of plant design for protection of structures, systems, and components from internal and external hazards

Secondary - Organization responsible for hydrology reviews

I. AREAS OF REVIEW

The review of the plant internal flood protection includes all structures, systems, and components (SSCs) whose failure could prevent safe shutdown of the plant or result in uncontrolled release of significant radioactivity. The facility design and equipment arrangements presented in the applicant's safety analysis report (SAR) are reviewed with respect to both internal (e.g., pipe break, tank failure) and external (e.g., failure of exterior tanks) causes. The review of external flood protection from natural phenomena (e.g., probable maximum flood, tsunami, etc.) is performed in a separate review as listed in the Review Interfaces subsection of this Design Specific Review Standard (DSRS) section.

The plant internal flood protection should protect SSCs that are either safety-related or classified as regulatory treatment of non-safety systems Category B (RTNSS-B). The NuScale application will provide a list of safety-related SSCs as well as a list of RTNSS-B SSCs. For the purpose of brevity in this section, the "safety-related and RTNSS-B SSCs" that must be reviewed for flood protection will be designated as "SSCs subject to flood protection." SRP 19.3 describes how SSCs are determined to be RTNSS-B.

The specific areas of review are as follows:

1. The safety-related or RTNSS-B SSCs that must be protected against flooding from both external and internal causes.
2. The location of SSCs subject to flood protection relative to the internal flood level in various buildings, rooms, and enclosures that house safety-related or RTNSS-B SSCs.
3. Possible flow paths from interconnected non-safety areas to buildings, rooms, and enclosures that house SSCs subject to flood protection (e.g., leakage through interconnecting doorways).
4. The adequacy of the isolation of systems and equipment subject to flood protection between redundant trains and from non-safety systems that could be sources of internal flooding.
5. Provisions for protection against possible in-leakage sources, such as non-mechanistic cracks in structures and exterior openings and penetrations in structures located at a lower elevation than the internal flood level.

6. SSCs that could be a potential source of internal flooding (e.g., pipe breaks and cracks, tank and vessel failures, backflow through drains).
7. Design features that will be used to mitigate the effects of internal flooding (e.g., adequate drainage, sump pumps, etc.).
8. Any structure subject to flood protection that are protected from below-grade groundwater seepage by means of a permanent dewatering system.
9. 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 SSCs related to this DSRS section in accordance with DSRS 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 DSRS Section 14.3.
10. 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).

or 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 DSRS sections interface with this section as follows:

1. The review of the potential causes of external flooding from natural phenomena and the adequacy of external flood protection is performed under SRP Sections 2.4.1 through 2.4.14.
2. The review of postulated site flooding parameters is performed under SRP Section 2.4 and SRP Section 2.0 for a standard DC application.
3. The review of the acceptability criteria used for the design of structures that should withstand the effects of the design-basis flood is performed under DSRS Section 3.4.2.
4. The review of the adequacy of the technical specifications related to low-water conditions is performed under SRP Section 2.4.14, and the review of the adequacy of overall plant technical specifications is performed under DSRS Section 16.0.
5. The review of the adequacy of the applicant's listing of SSCs, the failure of which could prevent safe shutdown of the plant, is performed under SRP Sections 3.2.1 and 3.2.2.
6. The review of the adequacy of the applicant's plant- and/or site-specific probabilistic risk assessment (PRA), including an internal and external flooding analysis, is performed under SRP Chapter 19.0.
7. The review of the environmental effects of a pipe rupture on safety-related systems is performed under SRP Section 3.6.1.

8. The review of the environmental qualifications of mechanical and electrical equipment is performed under DSRS Section 3.11.
9. The review of possible break locations in high and moderate energy systems during normal plant operation and the dynamic effects (e.g., pipe whip, jet impingement) of pipe breaks is performed under SRP Section 3.6.2.
10. The review of the design of containment internal structures and other safety-related structures is performed under SRP Section 3.8.3 and DSRS Section 3.8.4, respectively.
11. The review of the instrumentation needed for flood protection, including the adequacy of detectors and alarms necessary to detect rising water levels within structures, and the consequences of flooding on other safety-related instrumentation and electrical equipment is performed under DSRS Chapter 7.
12. The review of flooding effects resulting from a failure of a component or piping of the circulating water system is performed under DSRS Section 10.4.5.
13. The review of equipment and floor drainage system is performed under DSRS Section 9.3.3.
14. The review of risk classification is in SRP Sections 17.4 and 19.3.

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

II. ACCEPTANCE CRITERIA

Requirements

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

Acceptability of internal flood protection as described in the applicant's SAR is based on certain requirements of Title 10 of the *Code of Federal Regulations* (CFR), Part 50, Appendix A, General Design Criteria (GDC) and other regulations.

1. The requirements of 10 CFR Part 50, Appendix A, GDC 2 relate to the SSCs important to safety being designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their safety functions. Meeting the requirements of GDC 2 includes evaluating the effects of flooding from full circumferential failures of non-seismic, moderate-energy piping, which is not considered in DSRS Section 3.6.2.
2. The requirements of 10 CFR Part 50, Appendix A, GDC 4 relate to the SSCs important to safety being designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing and postulated accidents, including loss-of-coolant accidents.
3. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulatory Commission's (NRC's) rules

and regulations.

4. 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 NRC'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. Guidance acceptable for meeting the seismic design and classification requirements of GDC 2 is found in Regulatory Guide (RG) 1.29, Position C.1 for safety-related SSCs and Position C.2 for non-safety SSCs.
2. The requirements of GDC 4 are met if SSCs, either safety-related or RTNSS-B, are designed to accommodate the effects of discharged fluid resulting from high and moderate energy line breaks and cracks that are postulated in SRP Sections 3.6.1 and 3.6.2, as well as from postulated failures of non-seismic and non-tornado protected piping, tanks, and vessels.

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 GDC 2 requires that SSCs important to safety 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. Meeting the requirements of GDC 2 is necessary to ensure that flooding due to failures of non-seismic piping does not affect the ability of the plant to shut down safely and remain in safe shutdown condition. The application of GDC 2 to this DSRS section ensures that consideration is given to full-circumferential ruptures of non-seismic moderate energy piping. These ruptures are not considered in SRP Section 3.6.2, which only applies to normal conditions, not seismic events. However, internal flooding caused by seismically-induced full-circumferential ruptures should be considered.
2. Compliance with GDC 4 for flood protection requires that SSCs important to safety being designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing and postulated accidents, including loss-of-coolant accidents. Meeting the requirements of GDC 4 ensures that the SSCs important to safety will be appropriately protected from potential flooding from liquid-carrying components in the plant.

III. REVIEW PROCEDURES

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

These review procedures are based on the identified 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: 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. An evaluation of the SSCs in the SAR and PRA that are either safety-related or RTNSS-B and should be protected against floods or flood conditions.
4. An evaluation using the plant arrangement, layout drawings and any other acceptable methods to assess the adequacy of techniques such as enclosures, pumping systems, drains, internal curbs, penetration seals, and watertight doors used to prevent flooding of SSCs subject to flood protection. The measures for protecting against external flooding are reviewed by and coordinated with the organization responsible for the review of SRP Sections 2.4.1 through 2.4.14.
5. An assessment of the potential flooding of SSCs subject to flood protection due to the operation of the fire protection system and the postulated pipe failures in accordance with SRP Section 3.6.2, as well as postulated failures of non-seismic and non-tornado protected piping, tanks, and vessels. SRP Section 3.6.2 provides guidance for the determination of seismically qualified high energy line breaks or cracks and seismically qualified moderate energy line cracks. For the purposes of flood analysis, the reviewer need only assume, for each analyzed area, the rupture of the single, worst-case pipe (or non-seismic tank/vessel). If the dynamic effects of the worst-case pipe rupture causes additional rupture of the nearby pipes, the resulting pipe rupture needs to be considered as a part of the worse-case.

Moderate energy piping that is not seismically supported should be considered for full circumferential ruptures, not just cracks.

This assessment should consider ways to mitigate the consequences of potential internal flooding to SSCs subject to flood protection, such as drains and sump pumps. If a postulated break is in a non-seismically supported system, then only seismically-qualified systems should be assumed to be available to mitigate the effects of the analyzed break (since a seismic event may have caused the failure).

The environmental effects of piping failures are assessed in accordance with DSRS Section 3.6.1, and the determination of mechanistic rupture locations and the resulting dynamic effects are evaluated in accordance with SRP Section 3.6.2.

6. A review of the applicant's risk assessment of external and internal flooding should be performed in consultation with the organization responsible for the review of the PRA to identify potentially significant vulnerabilities to flooding, including an analysis of flooding during shutdown conditions. A failure modes and effects analysis may be performed to determine that the flooding consequences resulting from failures of such liquid-carrying

systems close to essential equipment will not preclude required functions of safety systems.

7. A review of the SAR to ascertain if SSCs subject to flood protection are capable of normal function while completely or partially flooded.
8. A review of plant arrangement and layout drawings to determine if equipment or components subject to flood protection are located within individual compartments or cubicles which act as positive barriers against possible means of flooding, and if barriers or other means of physical separation are utilized between redundant safety-related trains. The review also will identify possible flow paths from interconnected nonsafety-related areas to rooms that house SSCs subject to flood protection (e.g., leakage through interconnecting doorways).
9. A review of the design features that will be used to mitigate the effects of internal flooding (e.g., adequate drainage, sump pumps, etc.), if these features are safety-related or RTNSS-B to ensure adequate time to perform a safe shutdown. Only seismically-qualified systems should be assumed to be available to mitigate the effects of the flooding from non-seismic systems.
10. A review of plant structure design drawings to determine if the flood protection of any structure subject to flood protection, such as below-grade groundwater seepage, depends on a permanent dewatering system. If so, the dewatering system should be designed as a safety-related system, and should meet the single failure criterion requirements. In addition, a review of the accidental release of radioactive liquid effluents into the groundwater should be performed in accordance with SRP Section 2.4.13. Onsite external tank failure should be reviewed for the flood protection of any SSCs subject to flood protection by looking into site grading, sealing of the affected building openings and penetrations, and hydrodynamic loading on building structures.
11. 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. DCs have referred to the FSAR as the design control document (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 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 SER. The reviewer also states the bases for those conclusions.

The internal flood protection review includes all safety-related and RTNSS "B" SSCs. Based on the review of the applicant's proposed design criteria, design bases, and safety classifications for

safety-related and RTNSS “B” SSCs, the staff concludes that the design of the facility for flood protection conforms to the requirements as set forth in 10 CFR Part 50, Appendix A, GDC 2 and GDC 4. This conclusion is based on the applicant having met these requirements with respect to protection of SSCs subject to flood protection from the effects of external and internal flooding by:

1. Identifying all possible sources of internal flooding, including all pipe breaks or cracks postulated in SRP Sections 3.6.1 and 3.6.2 for seismically qualified high energy and moderate energy lines, full circumferential breaks of non-seismic moderate energy piping, failures of non-seismic internal and external tanks and vessels, backflow through drains, and operation of the fire protection system. The application also considers possible flow paths from non-safety related areas into areas containing SSCs subject to flood protection.
2. Using a method that has been reviewed and found acceptable by the staff to protect safety-related and RTNSS-B SSCs from flooding by external and internal causes. The design includes the separation of redundant trains of safety-related and RTNSS-B SSCs, the use of protective barriers and enclosures wherever necessary, the placement of safety-related and RTNSS-B SSCs above internal flood levels, and an analysis that shows that any safety-related and RTNSS-B SSCs subject to flooding will retain their safety function if submerged.
3. Using a safety-related dewatering system that meets single-failure criteria if safety-related SSCs depend on its operation to maintain their safety function.

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 DSRS 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 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena."
2. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases."
3. RG 1.29, "Seismic Design Classification."