

Draft for Comment



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

10.4.5 CIRCULATING WATER SYSTEM

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of power conversion systems.

Secondary - None

I. AREAS OF REVIEW

The NuScale small modular reactor (SMR) design includes a circulating water system (CW) that provides a continuous supply of cooling water to the main condenser to remove the heat rejected by the turbine cycle and auxiliary systems, and provides a heat sink to the site cooling water system.

The specific areas of review are as follows:

1. Review of the performance of the CW with respect to its functional requirements and the effects of adverse environmental occurrences, anticipated operational occurrences (AOOs), or accident conditions such as loss of offsite power.
2. Review of the CW and its interfaces with other systems to determine that a malfunction, failure of a component, or failure of a circulating water pipe, including the failure of an expansion joint, do not have unacceptable adverse effects on the functional performance capabilities of safety-related or other risk-significant systems located in the immediate area.
3. Review of the design of the circulating water system with respect to the following:
 - A. The capability to prevent or detect and control flooding of safety-related or other risk-significant areas so that the intended safety function of a safety system or component will not be precluded due to circulating water system leakage.
 - B. Provisions to annunciate abnormal and unsafe operating conditions.
4. 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 Design Specific Review Standard (DSRS) section in accordance with Standard Review Plan (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 DSRS Sections 14.2 and 14.3.7.

5. 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.

Review Interfaces

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

1. Review of high- and moderate-energy pipe breaks is performed under SRP Section 3.6.1. SRP Section 3.6.1 identifies the circulating water system as a moderate-energy system included in the scope of review.
2. Determination of whether liquid-carrying systems could produce flooding and evaluation of the measures taken to protect safety-related equipment from internal flooding is performed under DSRS Section 3.4.1.
3. Review of the compatibility of the methods proposed for control of water chemistry and of long-term corrosion and organic fouling with system components and piping materials, and assurance that agents used for the control of water chemistry, corrosion, and organic fouling are compatible with the materials of the system is performed (upon request from the primary reviewer) by the organization responsible for reviewing the control of water chemistry, long-term corrosion, and organic fouling in system components and piping materials.
4. Review of the classification of systems quality groups is performed under SRP Section 3.2.2.
5. Review of the instrumentation and controls, as they may relate to operations that could affect safety-related systems or components is performed under DSRS Chapter 7.
6. Review of the electrical power systems, as they may relate to operations that could affect safety-related systems or components is performed under DSRS Sections 8.3.1 and 8.3.2.
7. Review of the potential for low water conditions (e.g., those associated with drought) that may affect the CW design is performed under SRP Section 2.4.11.
8. Review of the probabilistic risk assessment performed under SRP Chapter 19.0 for potential risk significant CW elements.

II. ACCEPTANCE CRITERIA

Requirements

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

1. General Design Criterion (GDC) 2, Design Bases for Protection Against Natural Phenomena.
2. GDC 4, Environmental and Dynamic Effects Design Bases.
3. Title 10 of the *Code of Federal Regulations* (CFR), Section 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.
5. 10 CFR 20.1406, as it relates to the minimization of, to the extent practicable, of contamination of the facility and the environment, designs and procedures to facilitate eventual decommissioning, and to minimize, to the extent practicable, the generation of radioactive waste.

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. The applicant demonstrates how it meets the requirements of GDC 2 as they relate to the failure of the CW due to natural phenomena will not adversely affect the functional performance capabilities of safety-related or risk-significant systems or components.
2. The applicant demonstrates how it meets the requirements of GDC 4 as they relate to the circulating water system design including provisions to accommodate the effects of discharging water that may result from a failure of a component or piping in the CW. Acceptance is based on meeting the following:

- A. Means should be provided to prevent or detect and control flooding of safety-related or other risk-significant areas so that the intended safety function of a system or component will not be precluded due to leakage from the CW.
 - B. Malfunction or a failure of a component or piping of the CW, including an expansion joint, should not have unacceptable adverse effects on the functional performance capabilities of safety-related or risk-significant systems or components.
3. The applicant demonstrates how it meets the requirements of 10 CFR 20.1406 as they relate to the interconnections between the CW and other plant systems being designed to preclude CW contamination of connecting systems, or the contamination of the CW by connections with interfacing radioactive systems.

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. GDC 2 requires that the failure of the nonsafety-related system or component due to natural phenomena such as earthquakes, tornadoes, hurricanes, and floods should not adversely affect SSCs important to safety.
- 2. GDC 4 requires that SSCs important to safety shall be designed to accommodate the effects and be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents.
- 3. Although the CW is not safety-related, GDCs 2 and 4 establish CW design limits that will minimize the potential for creating adverse environmental conditions (e.g., flooding of safety-related or risk-significant systems and components).

Meeting the requirements of these criteria provide a level of assurance that safety-related or risk-significant systems and components will perform their intended safety functions.

- 4. The applicant demonstrates how it meets the requirements of 10 CFR 20.1406 as they relate to the interconnections between the CW and other plant systems being designed to preclude CW contamination of connecting systems, or the contamination of CW by connections with interfacing radioactive systems.

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.

Upon request from the reviewer, the interface reviewers will provide input for the areas of review stated in Subsection I. The reviewer obtains and uses such input as required to ensure that this review procedure is complete.

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. Review to determine that safety-related or risk-significant systems and structures are protected from the effects of flooding from a complete failure of the CW is performed under DSRS Section 3.4.1.
4. The reviewer analyzes the CW to verify the capability to detect leaks and to secure the system quickly and effectively.
5. Based on the information contained in the safety analysis report, the reviewer verifies that the applicant's proposed methods for control of water chemistry and of long-term corrosion and organic fouling, and the chemical agents used for these purposes, are compatible with the system materials.

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 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 (ESP) or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

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

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the staff's technical review and analysis support conclusions of the following type to be included in the staff's SER. The reviewer also states the bases for those conclusions.

The circulating water system includes all components and equipment necessary to provide the main condenser with a continuous supply of cooling water. The system is designed to nonsafety-related, Quality Group D, requirements since it is not necessary for safe shutdown, accident prevention, or accident mitigation and performs no risk-significant functions. Based on the review of the applicant's proposed design criteria and bases for the circulating water system, the staff concludes that the design of the circulating water system is acceptable and meets the requirements of GDCs 2 and 4. This conclusion is based on the following:

The applicant has met the requirements of GDCs 2 and 4 with respect to the effects of discharging water that may result from a failure of a component or piping in the CW. Acceptance is based on provisions of the design that prevent flooding of safety-related or other risk-significant areas so that the intended safety function of a system or component will not be precluded due to leakage from the CW; or provisions of the design that detect and control flooding of safety-related or risk-significant areas so that the intended safety function of a system or component will not be precluded due to

leakage from the CW; or provisions of the design such that malfunction of a component or piping of the CW, including an expansion joint, will not have unacceptable adverse effects on the functional performance capabilities of safety-related or risk-significant systems or components. Also, the fact that programmatic requirements will provide assurance that the CW will be designed, installed, and tested as described in the DCD or FSAR.

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 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."