U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR NuScale SMR DESIGN

10.4.1 MAIN CONDENSER

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of power conversion systems

Secondary - None

I. AREAS OF REVIEW

The main condenser system (MC) is designed to condense and deaerate the exhaust steam from the main turbine and provide a heat sink for the turbine bypass system. The exhaust steam is condensed into water, and the water is pumped out of the condenser back to the steam generator. In a pressurized-water reactor (PWR) or integral pressurized water reactor (iPWR), the main condenser may contain radioactive materials in the event of primary to secondary system leakage. The review will be focused on the design features incorporated to control the release of radioactive material to the environment, fire/explosions, and flooding that may affect the ability of safety-related or risk-significant structure, systems, and components (SSCs) to perform their functions.

The specific areas of review are as follows:

1. The design, design objectives, capacity, method of operation, and factors that influence gaseous radioactive material handling, e.g., system interfaces and potential bypass routes. The review may include the system piping and instrumentation diagrams as needed.

2. The means to prevent corrosion and/or erosion of condenser tubes, and detect, control, and facilitate correction of the leakage of cooling water into the condensate.

3. The means to detect radioactive leakage into or out of the system and to preclude accidental releases of radioactive materials to the environment in amounts in excess of established limits.

4. Instrumentation and control features that determine and verify that the MC is operating in a correct mode.

5. The means provided to deal with flooding from a complete failure of the MC and to preclude damage to safety-related or risk-significant equipment from the flooding.

6. The capability of the MC to withstand the blowdown effects of steam from the turbine bypass system.

ADAMS Accession No.ML15127A049

7. If the potential for explosive mixtures exist, design features to preclude the possibility of an explosion which could cause a release of radioactive material to the environment.

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 SSCs related to this design-specific review standard (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 Sections 14.3 and DSRS Section 14.3.7.

9. 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 or standard review plan (SRP) sections interface with this section as follows:

1. Review of the acceptability of the seismic and quality group classifications is performed under DSRS Sections 3.2.1 and 3.2.2.

2. 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 MC is performed under DSRS Section 3.4.1.

3. Review of seismic analyses is performed under DSRS Section 3.7.2.

4. Review of the instrumentation in place to monitor condensate quality and detect MC tube leakage is performed under DSRS Section 9.3.2.

5. Review of fire protection is performed under SRP Section 9.5.1.1.

6. Review of design features to preclude the possibility of an explosion if the potential of hydrogen and oxygen explosive mixtures exist in the system is performed under DSRS Section 11.3.

7. Review of the measures in place to monitor the inventory of radioactive materials in the MC and detect radioactive leakage into or out of the system is performed under DSRS Section 11.5.

8. Review of initial plant test program under DSRS Section 14.2.

9. Review of technical specifications is performed under DSRS Section 16.0.

10. Review of quality assurance is performed under SRP Chapter 17.

11. The review of risk classification is in SRP Section 19.3.

II. ACCEPTANCE CRITERIA

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 3, Fire Protection.

3. GDC 4, Environmental and Dynamic Effects Design Bases.

4. GDC 60, Control of Releases of Radioactive Materials to the Environment.

5. GDC 64, Monitoring Radioactivity Releases.

6. 10 CFR 20.1406, as it relates to facility design and procedures for operation that will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

7. 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;

8. 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 be operated 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. Acceptance of GDC 2 is based in part on meeting the guidance of RG 1.29, for nonsafety-related portions.

2. The applicant demonstrates how it meets the requirements of GDC 3 as they relate to SSCs important to safety being designed and located to minimize the probability and effect of fire and explosion resulting from the explosive mixtures in the MC.

3. The applicant demonstrates how it meets the requirements of GDC 4 as they relate to SSCs important to safety being protected from adverse impacts of flooding associated with MC system failures.

4. The applicant demonstrates how it meets the requirements of GDC 60 as they relate to the MC design includes provisions to prevent excessive releases of radioactivity to the environment which may result from a failure of a structure, system or component in the MC.

5. The applicant demonstrates how it meets the requirements of GDC 64 as they relate to the MC design provides means to monitor radioactive materials in the condenser and its water-box drains.

6. The applicant demonstrates how it meets the requirements of 10 CFR 20.1406 as they relate to the design and procedures identifying provisions to detect contamination that may enter MC as in-leakage from other interfacing 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 SSCs important to safety are designed to withstand the effects of postulated local natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of the capability to perform their safety functions.

2. Compliance with GDC 3 provides assurance that SSCs important to safety are designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions, and that SSCs important to safety are protected from the effects of an explosive mixture of hydrogen and oxygen in the MC.

3. Compliance with GDC 4 requires, in part, that SSCs important to safety are appropriately protected from the environmental conditions, including flooding. GDC 4 applies to this DSRS section because flooding resulting from a failure of the MC system can potentially cause a loss of function of safety-related or risk-significant SSCs. Meeting this requirement provides assurance that flooding resulting from a MC system failure will not result in a loss of function of safety related or risk-significant SSCs.

4. Compliance with GDC 60 and GDC 64 requires that provisions be included in the nuclear power unit design to monitor and control suitably the release of radioactive materials during normal operation, including anticipated operational occurrences (AOOs).

Meeting these requirements provides a level of assurance that the release of radioactive materials in gaseous and liquid effluents from the main condensers during normal operation, including AOOs, is kept as low as is reasonably achievable, in accordance with 10 CFR Part 50, Appendix I.

5. The capability to detect and isolate radioactive material in the MC would minimize, to the extent practicable, contamination of the condensate and feedwater systems and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste in accordance with 10 CFR 20.1406.

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: 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. Determine that any allowed MC system degraded operation does not have an adverse effect on the reactor primary system or secondary system to perform its safety related or risk-significant functions.

4. Verify the following:

   A. Means have been provided for controlling and correcting condenser cooling water leakage into the condensate.

   B. Compatibility of the materials of construction with the service conditions and the methods used to reduce the corrosion and/or erosion of MC tubes and components.

5. The reviewer uses engineering judgment and the results of failure modes and effects analyses to determine that:

   A. The safety-related or risk-significant systems and structures are protected from the effects of flooding resulting from a complete failure of the MC. Confirm this is satisfactorily reviewed under DSRS Section 3.4.1, which could have a limiting case from a failure of other systems that is more severe than the MC failure. If not, perform such a review by assuming a failure of the MC.

   B. If there is a potential for explosive mixtures to exist,

      i. Instruments are designed to detect, annunciate, and effect control measures to prevent the buildup of potentially explosive mixtures, as outlined in DSRS Section 11.3 to preclude the occurrence of an explosion, or

      ii. The MC is designed to withstand the effects of an explosion, including the release of radioactive materials to the environment and protection of

surrounding SSCs from performing their safety-related or risk-significant functions.

C. The system, in conjunction with the main steam system, has provisions to detect loss of condenser vacuum and to effect isolation of the steam source. For direct cycle plants, it will be acceptable if the detection system in the MC can actuate the main steam isolation valves to limit the quantity of steam lost to the MC.

D. Design provisions have been incorporated into the MC that will preclude component or tube failures due to steam blowdown from the turbine bypass system.

6. Using the guidance provided in RG 4.21, the applicant should address how they will comply with the requirements of 10 CFR 20.1406.

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 DCD.

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 safety evaluation report. The reviewer also states the bases for those conclusions.

The MC system includes all components and equipment from the turbine exhaust to the connections and interfaces with the main condensate and other systems. The staff concludes that the MC system design is acceptable and meets the following requirements: (1) GDC 3 with respect to minimizing fire/explosion hazards to SSCs important to safety, (2) GDC 4 with respect to flooding of SSCs important to safety, (3) GDC 60 and GDC 64 with respect to monitoring and excessive releases of radioactivity to the environment, and (4) 10 CFR 20.1406, as it relates to facility design and procedures for operation that will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and to minimize, to the extent practicable, the generation of radioactive waste.

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.”