U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD for NuScale SMR DESIGN

5.2.5 REACTOR COOLANT PRESSURE BOUNDARY LEAKAGE DETECTION

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of reactor coolant pressure boundary leakage detection.

Secondary - None

I. AREAS OF REVIEW

The reactor coolant pressure boundary (RCPB) leakage detection systems are designed to detect and, to the extent practical, identify the source of reactor coolant leakage. Safety analysis report (SAR) sections concerning system design are reviewed for the systems' capability to meet the requirements of General Design Criteria (GDCs) 2, 14, and 30.

The specific areas of review are as follows:

1. whether the system is safety-related or risk-significant

2. whether the system can identify, to the extent practical, the location of the source of reactor coolant leakage

3. whether the system can separately monitor and collect leakage from both identifiable and unidentifiable sources

4. whether the system has adequate indicators and alarms for each leakage detection system in the main control room and readily permits interpretations of indicators related to leak rates

5. whether the system monitors systems connected to the RCPB for inter-system leakage

6. whether the system has adequate Technical Specifications and operating procedures

7. whether there are sufficient capability, sensitivity, response time, and diversity in the leakage detection system

8. whether the system is used to support reactor coolant system leak-before-break (LBB)

9. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC).

   For 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

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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 SRP 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).

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

Review Interfaces

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

1. SRP Sections 3.2.1 and 3.2.2: review of the acceptability of the safety classification, seismic and quality group classifications for system components

2. SRP Sections 3.9.1, 3.9.2 and 3.9.3: review whether components and piping are designed in accordance with applicable codes and standards

3. SRP Section 3.10: review of the seismic qualification of Category I instrumentation of mechanical and electrical equipment

4. DSRS Section 3.11: review of the environmental capability of system portions to perform their design safety functions in abnormal, accident, and post-accident environments

5. DSRS Section 5.4.2.2: review of steam generator program as it relates to primary-to-secondary leakage and associated Technical Specifications

6. DSRS Section 6.2.4: review of system containment isolation capability

7. DSRS Section 6.6: review of whether inservice inspection requirements are met for system components and review of the compatibility of construction materials with service conditions

8. DSRS Chapter 7: review of the adequacy of the design, installation, testing, and inspection of electrical components (sensing and control) necessary for proper operation

9. DSRS Sections 8.3.1 and 8.3.2: review of the adequacy of the design, installation, testing, and inspection of electrical components (power) necessary for proper operation

10. DSRS Section 11.5: review of radiation monitoring systems

11. SRP Chapter 13: review of the initial test program and operating procedures

12. DSRS Section 14.2 and SRP Section 14.3.7: review of the proposed pre-operational, startup test programs, and ITAAC

13. DSRS Chapter 16: review for technical specifications

14. SRP Chapter 17: review for quality assurance

15. SRP Chapter 19: review of risk classification

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 U.S. Nuclear Regulatory Commission (NRC) regulations:

1. GDC 2, “Design Bases for Protection against Natural Phenomena”

2. GDC 14, “Reactor Coolant Pressure Boundary”

3. GDC 30, “Quality of Reactor Coolant Pressure Boundary”

4. Title 10 of the *Code of Federal Regulations* (10 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 had been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act (AEA), and the NRC’s rules and regulations

5. 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 (for 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 NRC regulations that underlie the DSRS acceptance criteria.

1. For GDC 2, acceptance is based on conformance with the guidelines of Regulatory Guide (RG) 1.29, "Seismic Design Classification," Positions C.1 and C.2, and RG 1.45, "Guidance on Monitoring and Responding to Reactor Coolant System Leakage."

2. For GDC 14, acceptance is based on conformance with guidelines of RG 1.45.

3. For GDC 30, acceptance is based on conformance with guidelines of RG 1.45.

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 be designed to withstand the effects of seismic events and other natural phenomena without losing the capability to perform their intended safety functions. The RCPB leakage detection system detects leakage after an earthquake for an early indication of degradation so that corrective action can be taken before such degradation becomes severe enough to result in a leak rate greater than the capability of the makeup system to replenish the coolant loss. RG 1.29 describes an acceptable method of identifying and classifying system portions that should be designed to withstand the effects of a safe shutdown earthquake. Application of GDC 2 and RG 1.29 to the RCPB leakage detection system ensures that plant operators have the capability to detect and respond to RCPB leakage after an earthquake. The prompt detection of, and response to, RCPB leakage after an earthquake reduces the possibility of a severe loss of coolant accident. Specifically, RG 1.45 describes an acceptable method for RCPB leakage detection systems.

2. GDC 14 requires the RCPB to be designed, fabricated, erected, and tested to have an extremely low probability of abnormal leakage, of rapidly propagating failures, and of gross rupture. RG 1.45 describes acceptable methods for implementing GDC 14 with respect to identifying and eliminating leakage. At least one of the leakage detection systems required by the plant technical specifications should be able to perform its function following any seismic event that does not require a plant shutdown.

3. GDC 30 requires that means be provided for detecting and, to the extent practical, identifying the location of the source of reactor coolant leakage. The RCPB leakage detection system detects and identifies RCPB leakage. RG 1.45 describes acceptable methods for implementing GDC 30 with respect to the selection of RCPB leakage detection systems. Compliance with GDC 30 and the guidance in RG 1.45 ensure that operators have an early indication of RCPB degradation, thus minimizing the likelihood that an RCPB leak may go undetected and result in a severe loss of coolant accident.

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 relevant NRC requirements identified in Subsection II.

RG 1.45 describes methods that are considered acceptable for use in implementing the regulatory requirements with regard to selecting reactor coolant leakage detection systems, monitoring for leakage, and responding to leakage. The guide includes a general discussion of types of leakage, leakage separation, methods for monitoring leakage and identifying its source, monitoring system performance (capability, detector response time, signal correction and calibration, seismic qualification), and leakage management (leakage monitoring of risk-significant areas in the reactor coolant system, capability, operability, and availability of monitoring instruments, trend analysis of leakage data, responding to leakage). The specific review procedures are as follows:

1. Selected Programs and Guidance—In accordance with the guidance in NUREG–0800, "Introduction – Part 2: Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Light-Water Small Modular Reactor Edition" (NUREG-0800, Intro Part 2), as applied to this DSRS Section, the staff will review the information proposed by the applicant to evaluate whether it meets the acceptance criteria described in Subsection II of this DSRS. As noted in NUREG-0800, Intro Part 2, the NRC requirements that must be met by an SSC do not change under the small modular reactor (SMR) framework. Using the graded approach described in NUREG-0800, Intro Part 2, the NRC staff may determine that, for certain SSCs, the applicant's basis for compliance with other selected NRC requirements may help demonstrate satisfaction of the applicable acceptance criteria for that SSC in lieu of detailed independent analyses. The design-basis capabilities of specific SSCs would be verified, where applicable, as part of completing the applicable ITAAC. The use of the selected programs to augment or replace traditional review procedures is shown in Figure 1 of NUREG-0800, Intro Part 2. Examples of such programs that may be relevant to the graded approach for these SSCs include:

    - 10 CFR Part 50, Appendix A, GDC, Overall Requirements, Criteria 1–5
    - 10 CFR Part 50, Appendix B, Quality Assurance (QA) Program
    - 10 CFR 50.49, Environmental Qualification of Electrical Equipment (EQ) Program
    - 10 CFR 50.55a, Code Design, Inservice Inspection, and Inservice Testing (ISI/IST) Programs
    - 10 CFR 50.65, Maintenance Rule requirements
    - Reliability Assurance Program (RAP)
    - 10 CFR 50.36, "Technical Specifications"
    - Availability Controls for SSCs Subject to Regulatory Treatment of Nonsafety Systems (RTNSS)
    - Initial Test Program (ITP)
    - Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)

This list of examples is not intended to be all inclusive. It is the responsibility of the technical reviewers to determine whether the information in the application, including the degree to which the applicant seeks to rely on such selected programs and guidance, demonstrates that all acceptance criteria have been met to support the safety finding for a particular SSC.

2. In accordance with 10 CFR 52.47(a)(8), (21), and (22), and 10 CFR 52.79(a)(17), (20), and (37), for DC or COL applications submitted under 10 CFR Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues which are identified in the version of NUREG-0933, "Resolution of Generic Safety Issues," current on the date up to 6 months before the docket date of the application and which are technically relevant to the design, (2) demonstrate how the operating experience insights have been incorporated into the plant design, and (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v), for a DC application, and except paragraphs (f)(1)(xii), (f)(2)(ix), (f)(2)(xxv), and (f)(3)(v),for a COL application. These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding safety evaluation report (SER) section.

3. The reviewer verifies the applicant's determination of whether the system is safety related or risk significant.

4. The reviewer verifies the seismic qualification of the system and components in accordance with the guidance in RG 1.29 Regulatory Position C.1 and C.2, and RG 1.45 Regulatory Position C 2.4. If the system is nonsafety-related and nonrisk-significant, the reviewer verifies whether there is at least one leakage monitoring systems required by the plant technical specifications capable of performing the RCPB leakage detection function following any seismic event that does not require plant shutdown. If a portion of the system is safety related this portion should be designed as Category I. If a portion of the system is nonsafety-related, but risk significant, this portion should be capable of performing the risk-significant leakage detection function after any seismic event that does not require a plant shutdown.

5. The reviewer verifies whether the provisions for collecting, detecting, and monitoring unidentified leakage are separate from those for identified leakage. If separation is not practicable for NuScale, all leakage will be conservatively assumed to be unidentified leakage. The total leakage flow rate will be established and monitored as specified in RG 1.45. If a floor drainage system is not applicable to NuScale, the proposed alternative leakage detection system should be reviewed in sufficient detail according to the guidance in RG 1.45.

6. The reviewer determines whether the applicant identifies all potential inter-system leakage paths and whether the instrumentation for each path is appropriate and adequate for positive indication of inter-system leakage in the affected system and provides adequate monitoring capability so that the limits assumed in the accident analyses are not exceeded. Inter-system leak detection methods include radioactivity, pressure, temperature, flow and pressure relief valve actuation indications, and the water inventory balance method. Table I shows some of the systems that need inter-system leakage monitoring.

7. The reviewer verifies whether all leakage detection systems have readouts in the control room and alarms. Direct reading systems, like traditional sumps or collection reservoirs, normally indicate liters per minute (L/m) or gallon per minute (gpm). Indirect reading systems, like the airborne particulate radioactivity monitoring system, indicate counts per minute. The reviewer determines whether control room operators have a chart or graph that permits rapid conversion of count rate into L/m or gpm, whether conversion procedures account for the isotope monitored and the activity of the primary coolant, and whether the plant maintains a running record of background leakage to factor its effect out from any sudden increases in leak indication, which may be "unidentified" leakage and to accordingly initiate prompt action. If monitoring is computerized, backup procedures should be available to the operator.

8. The reviewer verifies whether the detection system sensitivity and response time are acceptable over the entire range of expected plant operating conditions monitored. The reviewer verifies whether the instrumentation and methodology for determining leak rates are adequate.

9. The reviewer determines whether the radiation monitoring systems have built-in radioactive sources (the final safety analysis report refers to this feature as a "check source") for operability testing and calibration during operation. The reviewer determines whether there are provisions for testing and calibrating the components and instrumentation used for leakage detection consistent with RG 1.45. The frequency of testing and calibration should be justified. If applicable, the reviewer also determines whether periodic testing of the floor drainage system checks for blockage and ensures operability.

10. The operating experiences at Davis Besse (NRC Bulletin 2002-01) indicated that prolonged low-level unidentified reactor coolant leakage inside containment could cause material degradation such that it could potentially compromise the integrity of a system leading to the gross rupture of the reactor coolant pressure boundary. This issue could be addressed by operating procedures including identifying, monitoring, trending, and repairing prolonged low-level leakage. The guidance about developing such procedures for ensuring effective management of leakage, including low-level leakage, is available in RG 1.45. The reviewer verifies whether the applicant has developed such plant procedures for managing the prolonged low-level RCPB leakage or whether there is an acceptable COL information item to address the procedures.

11. The reviewer verifies whether all the positions described in RG 1.45, Section C, "Regulatory Position," are satisfactorily addressed. These positions include general positions, leakage monitoring-related positions, operations-related positions, and technical specification position.

12. If the system is used to support LBB, the reviewer verifies SRP Section 3.6.3 with respect to leak detection including leakage detection limit for LBB, margin of 10 for detector sensitivity and capability. Depending on the application, this consideration could result in a leakage sensitivity and capability that are more limiting than RG 1.45.

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 (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 RCPB leakage detection system reliably monitors reactor coolant leakage from RCPB components by combinations of atmospheric particulate monitors, radio-gas monitors, and level, pressure, humidity, and temperature indicators.

The systems for detecting leakage from RCPB components furnish reasonable assurance that structural degradation, which may develop in pressure retaining RCPB components and result in coolant leakage during service, will be detected promptly and that corrective actions will be made before such degradation becomes severe enough to jeopardize system safety or before the leakage increases to a level beyond the capability of the makeup system to replenish coolant loss. The system is adequate to support the reactor coolant system LBB if it is found acceptable under Review Procedure No. 11. LBB may not apply to NuScale (to be determined by the DC applicant).

The staff concludes that the RCPB leakage detection system design is acceptable and meets GDC 2 with respect to withstanding the effects of natural phenomena without loss of capability to perform its safety functions, GDC 14, with respect to RCPB having an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture, and GDC 30 with respect to the detection and identification of the location of sources of reactor coolant leakage. This conclusion is based on the following findings:

1. The applicant has met GDC 2 requirements by meeting applicable regulatory positions described in RG 1.29, Positions C.1 and C.2, and appropriately addressing the positions in RG 1.45.

2. The applicant has met the applicable GDC 14 and GDC 30 requirements by appropriately addressing the positions in RG 1.45.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this DSRS section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

V. IMPLEMENTATION

The regulations in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), and 10 CFR 52.79(a)(41) establish requirements for applications for ESPs, DCs, and COLs, respectively. These regulations require the application to include an evaluation of the site (ESP), standard plant design (DC), or facility (COL) against the SRP revision in effect 6 months before the docket date of the application. While the SRP provides generic guidance, the staff developed the SRP guidance based on the staff's experience in reviewing applications for construction permits and operating licenses for large light-water nuclear power reactors. The proposed SMR designs, however, differ significantly from large light-water nuclear power plant designs.

In view of the differences between the designs of SMRs and the designs of large light-water power reactors, the Commission issued Staff Requirements Memorandum (SRM)-COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights To Enhance Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010. In the SRM, the Commission directed the staff to develop risk-informed licensing review plans for each of the SMR design reviews, including plans for the associated preapplication activities. Accordingly, the staff has developed the content of the DSRS as an alternative method for evaluating a NuScale-specific application submitted pursuant to 10 CFR Part 52, and the staff has determined that each application may address the DSRS in lieu of addressing the SRP, with specified exceptions. These exceptions include particular review areas in which the DSRS directs reviewers to consult the SRP and others in which the SRP is used for the review. If an applicant chooses to address the DSRS, the application should identify and describe all differences between the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and the guidance of the applicable DSRS section (or SRP section, as specified in the DSRS), and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria.

The staff has accepted the content of the DSRS as an alternative method for evaluating whether an application complies with NRC regulations for NuScale SMR applications, provided that the application does not deviate significantly from the design and siting assumptions made by the NRC staff while preparing the DSRS. If the design or siting assumptions in a NuScale application deviate significantly from the design and siting assumptions the staff used in preparing the DSRS, the staff will use the more general guidance in the SRP, as specified in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), or 10 CFR 52.79(a)(41), depending on the type of application. Alternatively, the staff may supplement the DSRS section by adding appropriate criteria to address new design or siting assumptions.

VI. REFERENCES

1. *U.S. Code of Federal Regulations,* "Design Basis for Protection against Natural Phenomena," General Design Criterion (GDC) 2, Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants."

2. *U.S. Code of Federal Regulations,* "Reactor Coolant Pressure Boundary," GDC 14, Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants."

3. *U.S. Code of Federal Regulations,* "Quality of Reactor Coolant Pressure Boundary," GDC 30, Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants."

4. U.S. Nuclear Regulatory Commission, "Seismic Design Classification," Regulatory Guide (RG) 1.29, Revision 4, March 2007, Agencywide Documents Access and Management System (ADAMS) Accession No. ML070310052.

5. U.S. Nuclear Regulatory Commission, "Guidance on Monitoring and Responding to Reactor Coolant System Leakage," RG 1.45, Revision 1, May 2008, ADAMS Accession No. ML073200271.

6. U.S. Nuclear Regulatory Commission, "Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity," NRC Bulletin 2002-01, March 18, 2002, ADAMS Accession No. ML020770497.

Table I. Systems and Components Connected to Reactor Coolant System and Needing Inter-system Leakage Monitoring

I. In typical pressurized-water reactors (PWRs):

1. Accumulators (not applicable to NuScale)

2. Safety Injection Systems (High and Low Pressure) (not applicable to NuScale)

3. Pressurizer Relief Tank (not applicable to NuScale)

4. Secondary Side of Steam Generators

5. Residual Heat Removal System (Inlet and Discharge) (NuScale has a Decay Heat Removal System)

6. Secondary Side of Reactor Coolant Pump Thermal Barriers (not applicable to NuScale)

7. Secondary Side of Residual or Decay Heat Removal Heat Exchangers (NuScale has a Decay Heat Removal System)

8. Secondary Side of Letdown Line Heat Exchangers (not applicable to NuScale),

9. Secondary Side of Reactor Coolant Pump Seal Water Heat Exchangers (not applicable to NuScale)

10. ECC Condenser (not applicable to NuScale)