DRAFT for Comment

U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER iPWR 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 and/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 design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the structures, systems, and components (SSCs) related to this DSRS section in accordance with 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).

    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 sections interface with this section as follows:

1. 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. Section 3.6.3: review of LBB leak detection methods.

3. Sections 3.9.1 through 3.9.3: review whether components and piping are designed in accordance with applicable codes and standards.

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

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

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

7. Section 5.4.13: review of isolation condenser system as relates to the valve leakage and leakage reduction program.

8. Section 6.2.4: review of system containment isolation capability.

9. Section 6.6: review of whether in-service inspection requirements are met for system components and review of the compatibility of construction materials with service conditions.

10. Section 7.5: review of the adequacy of the design, installation, testing, and inspection of electrical components (sensing and control) necessary for proper operation.

11. Section 8.3: review of the adequacy of the design, installation, testing, and inspection of electrical components (power) necessary for proper operation.

12. Section 11.5: review of radiation monitoring systems.

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

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

15. Chapter 16: review for technical specifications.

16. Chapter 17: review for quality assurance.

17. 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 Commission regulations:

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

2. GDC 14, as it relates to RCPB being designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

3. GDC 30, as it relates the components which are part of the RCPB being designed, fabricated, erected, and tested to the highest quality standards practical. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of reactor coolant leakage.

4. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed inspections, tests, analyses, and acceptance criteria (ITAAC) that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the design certification had been constructed and will be operated in conformity with the design certification, the provisions of the Atomic Energy Act, and the NRC's 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 combined license, the provisions of the Atomic Energy Act, and the NRC's regulations.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for the review described in this DSRS section. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the DSRS acceptance criteria and evaluate how the proposed alternatives to the DSRS acceptance criteria provide acceptable methods of compliance with the NRC regulations.

1. For GDC 2, acceptance is based on the guidelines of RG 1.29, Positions C.1 and C.2, and RG 1.45.

2. For GDC 14, acceptance is based on meeting the guidelines of RG 1.45.

3. For GDC 30, acceptance is based on meeting the 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 important to safety SSCs be designed to withstand the effects of natural phenomena, including earthquakes, without loss of capability to perform 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 regulatory position describes an acceptable method for RCPB leakage detection systems.

2. GDC 14 requires the RCPB to be designed, fabricated, erected, and tested so as 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.

3. GDC 30 requires that systems 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

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.

For the construction permit review, the review should determine whether the design criteria and bases and the preliminary design as set forth in the preliminary SAR meet the acceptance criteria of subsection II of this DSRS section.

For an operating license review, the review should verify whether the initial design criteria and bases are implemented appropriately in the final design as set forth in the final SAR.

Upon request from the primary reviewer, the coordinating reviewers provide input for the areas of review stated in subsection I of this DSRS section. The primary reviewer uses such input as required to complete the review procedures.

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

2. 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 of the 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 following any seismic event that does not require a plant shutdown.

3. The reviewer verifies whether the provisions for collecting, detecting, and monitoring unidentified leakage are separate from those for identified leakage. The floor drainage system is reviewed for whether such leakage flows readily to the sump or tank for collection and is not held up in any "reservoirs." The containment air coolers are reviewed for whether leakage from "hot" systems flashing into water vapor is condensed readily and whether the condensate flows directly to the sump.

4. 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.

5. The reviewer verifies whether all leakage detection systems have readouts in the control room and alarms. Direct reading systems, like sumps, 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.

6. 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.

7. The reviewer determines whether the radiation monitoring systems have built-in radioactive sources (the FSAR 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 sump level detection system, a method for calibrating the air cooler condensate flow system wherever radiation monitors are used, and a method for calibrating them to RCPB leakage. The frequency of testing and calibration should be justified. The reviewer also determines whether periodic testing of the floor drainage system checks for blockage and ensures operability.

8. 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.

9. 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.

10. If the system is used to support LBB, the reviewer verifies DSRS Section 3.6.3 with respect to leak detection including leakage detection limit for LBB, margin of ten for detector sensitivity and capability. Depending on the application, this consideration may 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, DSRS Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

IV. EVALUATION FINDINGS

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

> The 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.
>
> 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 Position C.1 and C.2, and all positions in RG 1.45.
>
> 2. The applicant has met the applicable GDC 14 and GDC 30 requirements by meeting 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

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The staff will use this DSRS section in performing safety evaluations of DC and COL applications submitted by applicants pursuant to 10 CFR Part 52. The staff will use the method described herein to evaluate conformance with Commission regulations. If the applicant proposes an alternative method for complying with specified portions of the Commission's regulations, the applicant must demonstrate the acceptability of its alternate method.
The provisions of this DSRS section apply to reviews of applications submitted six months or more after the date of issuance of this DSRS section, unless superseded by a later revision.

DRAFT for Comment

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Basis for Protection Against Natural Phenomena."

2. 10 CFR Part 50, Appendix A, General Design Criterion 14, "Reactor Coolant Pressure Boundary."

3. 10 CFR Part 50, Appendix A, General Design Criterion 30, "Quality of Reactor Coolant Pressure Boundary."

4. Regulatory Guide 1.29, "Seismic Design Classification."

5. Regulatory Guide 1.45, “Guidance on Monitoring and Responding to Reactor Coolant System Leakage.”

6. NRC Bulletin 2002-01, “Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity.”

DRAFT for Comment

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

I. In pressurized-water reactors (PWRs):

1. Accumulators
2. Safety Injection Systems (High and Low Pressure)
3. Pressurizer Relief Tank
4. Secondary Side of Steam Generators
5. Residual Heat Removal System (Inlet and Discharge)
6. Secondary Side of Reactor Coolant Pump Thermal Barriers
7. Secondary Side of Residual or Decay Heat Removal Heat Exchangers
8. Secondary Side of Letdown Line Heat Exchangers
9. Secondary Side of Reactor Coolant Pump Seal Water Heat Exchangers
10. ECC Condenser (for iPWR mPower)

II. In boiling-water reactors (BWRs):

1. Safety Injection Systems (High and Low Pressure Core Spray and Coolant Injection Systems, High Pressure Core Flooder System)
2. Residual Heat Removal System (Inlet and Discharge)
3. Reactor Core Isolation Cooling System
4. Steam Side of High Pressure Coolant Injection (BWR-4)
5. Secondary Side of Reactor Water Cleanup System Heat Exchangers
6. Secondary Side of Reactor Coolant Pump Integral Heat Exchangers
7. Secondary Side of Residual Heat Removal Heat Exchangers
8. Isolation Condenser System