U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

5.4.8 REACTOR WATER CLEANUP SYSTEM (BWR)

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of chemical engineering issues

Secondary - None

I. AREAS OF REVIEW

At the construction permit (CP), standard design certification, or combined license (COL) stage of review, the information in the applicant's safety analysis report (SAR) is reviewed in the following specific areas. At the operating license (OL) or COL stage of review, the review consists of confirming the design accepted at the CP or standard design certification stage and evaluating the adequacy of the applicant's technical specifications.

The specific areas of review are as follows:

1. The design of components, design features that influence system availability and reliability, and interconnections with the reactor primary coolant and radwaste systems are reviewed. Removal of chemical impurities and fission products by the reactor water cleanup system (RWCS) is considered. The means for isolating the RWCS from the reactor system following liquid poison injection, holding filter and demineralizer beds in place if system flow is decreased, straining resins from return flows to the primary system, component venting, and resin transfer are reviewed.

2. The component design parameters for flow, temperature, pressure, heat removal capability, and impurity removal capability are reviewed to ensure the system capacity will meet the reactor coolant specifications.

3. The quality group and seismic design classification are reviewed.

4. The instrumentation and process controls are reviewed to ensure proper system operation and system isolation, when necessary. The review will include instrumentation for (a) automatic system isolation to prevent removal of liquid poison in the event of standby liquid control system actuation and to prevent damage to the filter/demineralizer resins, and (b) monitoring impurity removal (conductivity measurements), differential pressure across pressure-sensitive components, and temperature control prior to demineralization. In addition, the process controls responding to these measurements to maintain operation within the established system parameters are reviewed.

5. 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 SRP 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 SRP 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.

6. 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 sections interface with this section as follows:

1. The material properties and material compatibility requirements for those portions of the RWCS that are within the reactor coolant pressure boundary are reviewed under SRP Section 5.2.3.

2. The in-service inspection requirements for those portions of the RWCS that are within the reactor coolant pressure boundary are reviewed under SRP Section 5.2.4.

3 Compliance of RWCS Class 2 and 3 components with in-service nondestructive examination requirements is verified under SRP Section 6.6.

4. The effects of high- and moderate-energy RWCS piping failures outside the primary containment are evaluated under SRP Section 3.6.1 to ensure that other safety-related systems and equipment will not be made inoperable.

5. The capability of safety-related systems to withstand the effects of internally-generated missiles, both inside and outside the primary containment, is evaluated under SRP Sections 3.5.1.1 and 3.5.1.2.

6. The capability of safety-related systems to withstand the effects of missiles generated by natural phenomena and externally-generated missiles is evaluated under SRP Sections 3.5.1.4 and 3.5.2, respectively.

7. The capability of structures housing the RWCS to withstand external and internal flood conditions is evaluated under SRP Sections 3.4.1 and 9.3.3.

8. The liquid, gaseous, and solid waste management of the RWCS are reviewed under SRP Sections 11.2, 11.3, and 11.4, respectively.

9. The environmental qualification of mechanical and electrical equipment is reviewed under SRP Section 3.11.

10. The instruments and components of the RWCS, with respect to their capabilities, reliability, and conformance to the acceptable criteria are reviewed under SRP Sections 7.1 and 7.6 and related branch technical positions in SRP Chapter 7.

11. The adequacy of the design, installation, inspection, and testing of all electrical systems for the RWCS is evaluated under SRP Section 8.3.1.

12. The process and effluent radiological monitoring aspect of the RWCS are reviewed under SRP Section 11.5.

13. The RWCS, with respect to maintaining occupational radiation exposure as low as reasonably achievable and to provide radiation protection design features, is evaluated under SRP Sections 12.1 and 12.3, respectively.

14. The acceptability of the design analysis, procedures, and criteria used to establish the ability of seismic Category I structures housing the RWCS and the supporting systems to withstand the effects of natural phenomena, such as the safe shutdown earthquake, the probable maximum flood, and tornado missiles, is evaluated under SRP Sections 3.3.1, 3.3.2, 3.4.2, 3.5.3, 3.7.1, 3.7.2, 3.7.3, 3.8.4, and 3.8.5.

15. The seismic qualification of Category I instrumentation and electrical equipment is reviewed under SRP Section 3.10.

16. The acceptability of the seismic and quality group classifications for the RWCS components is determined under SRP Sections 3.2.1 and 3.2.2.

17. The piping, components, and structures of the RWCS are designed in accordance with the applicable codes and standards as determined under SRP Sections 3.9.1, 3.9.2, and 3.9.3.

18. The adequacy of the functional testing programs of the isolation valves in the RWCS is reviewed under SRP Section 3.9.6.

19. The design of the isolation provisions of those portions of the RWCS that penetrate the primary containment is reviewed under SRP Section 6.2.4.

20. The proposed technical specifications are reviewed under SRP Chapter 16.

21. The quality assurance programs are reviewed under SRP Chapter 17.

The specific acceptance criteria and review procedures are contained in the reference SRP sections.

II. ACCEPTANCE CRITERIA

Requirements

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

1. General Design Criterion 1 (GDC 1) as it relates to the design of the RWCS and components to meet standards commensurate with the importance of its safety function.

2. General Design Criterion 2 (GDC 2) as it relates to the RWCS being able to withstand the effects of natural phenomena.

3. General Design Criterion 14 (GDC 14) as it relates to ensuring the reactor coolant pressure boundary integrity.

4. General Design Criterion 60 (GDC 60) as it relates to the capability of the RWCS to control the release of radioactive effluents to the environment.

5. General Design Criterion 61 (GDC 61) as it relates to designing the RWCS with appropriate confinement.

6. 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 plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and the NRC's regulations;

7. 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.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for the review described in this SRP section. The SRP 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 SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

1. The system should be capable of maintaining acceptable reactor water purity in normal operation and during anticipated operational occurrences, e.g., reactor startup, refueling, and condensate demineralizer breakthrough to ensure reactor coolant pressure boundary integrity in accordance with the requirements of GDC 14. The following should be included in the system design:

   A. The system should be designed to maintain reactor water purity within the guidelines provided in the latest version in the Electric Power Research Institute (EPRI) report series, "BWR Water Chemistry Guidelines," and the technical specifications for water chemistry of reactor coolant systems for boiling water reactors. The system should provide demineralization of reactor water through mixed bed resins (beads or powdered) at approximately one percent of the main steam flow rate.

   B. The nonregenerative heat exchangers should be designed to reduce the temperature of cleanup flow to the demineralizer operating temperature when the regenerative heat exchanger cooling capacity is reduced as a result of partially bypassing a portion of the return flow to the main condenser or radwaste system.

   C. The RWCS should have the capability to permit processing excess reactor water during startups, shutdowns, and hot standby conditions. Interconnections between the reactor water cleanup and liquid waste and condensate storage systems to enable sharing of the processing burden are acceptable.

   D. The RWCS should be designed to permit processing reactor water during periods of single active component failures or equipment downtime.

2. The reactor water cleanup system should include the following:

   A. Means for automatically isolating the RWCS from the reactor coolant system in the event the liquid poison system is actuated for reactor shutdown.

   B. Means for automatically isolating the RWCS in the event the nonregenerative heat exchanger effluent temperature exceeds the prescribed resin operating temperature for the cleanup demineralizer resins.

   C. Means for automatically maintaining flow through filter / demineralizer beds to prevent bed loss in the event of low process flow or loss of process flow through the system. The recirculation loop and holding pump subsystem provided for precoating can serve this purpose if it is activated on loss of flow or low flow conditions.

   D. Means of transferring resins. Sight glass provisions (bull's eyes) are acceptable for monitoring resin transfers. Systems should be designed to prevent "resin traps" in sluice lines. Consideration should be given in the design of transfer lines to avoid resin traps; e.g., resin transfer lines may be designed to avoid resins collecting in valves, low points, or stagnant areas.

E. Means for draining and venting RWCS components through a closed system (i.e., not to the immediate atmosphere) in accordance with the requirements of General Design Criteria 60 and 61. The system design should include vent lines that run to a ventilation duct exhausting from the plant for normal system operation when the probability of releases of radiological materials are minimal.

F. Means of resin strainers in return lines to the reactor system or condensate system that are capable of removing resin particles contained in demineralizer effluents.

G. Means to prevent inadvertent opening of the filter / demineralizer backwash valves during normal operation.

3. To meet the requirements of GDC 1 and 2, Regulation Position C.2.c of Regulatory Guide 1.26 and C.1, C.2, C.3, and C.4 of Regulatory Guide 1.29 are applicable so that the portion of the RWCS extending from the reactor vessel and recirculation loops to the outermost drywell isolation valves should be designed to seismic Category I and Quality Group A. The remainder of the system outside the primary containment should be designed to Quality Group C and need not be seismic Category I. The precoating unit for demineralizers need not be designed to Quality Group C and need not be seismic Category I.

4. The RWCS should include equipment for monitoring:

   A. System effluent to ensure the conductivity is below the threshold for immediate reactor shutdown. Instrumentation should have sufficient range to measure conductivities up to the value requiring immediate shutdown of the reactor.

   B. Temperature upstream of the demineralizer, to ensure the ion exchange resin temperature limits are not exceeded.

   C. Differential pressure, to ensure the design limits on filter/ demineralizer septums and resin strainers are not exceeded.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this SRP section is discussed in the following paragraphs:

1. Compliance with GDC 1 requires that structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.

   GDC 1 applies to the RWCS because the system is connected directly to the reactor coolant system and contains reactor coolant and radioactive demineralizer resins. Failure of a component of the system could result in a loss-of-coolant accident, release of reactor coolant outside the containment structure, and/or release of demineralizer resins. For this reason, the portion of the RWCS extending from the reactor vessel and

recirculation loops to the outermost drywell isolation valves should be designed to seismic Category I and Quality Group A. The remainder of the system need not be seismic Category I and should be designed to Quality Group C. The precoating unit for demineralizers need not be designed to Quality Group C and need not be seismic Category I.

Meeting the requirements of GDC 1 minimizes the probability that a failure of the RWCS will occur, thus reducing the potential for a loss-of-coolant accident or release of radioactive materials outside the containment structure.

2. Compliance with GDC 2 requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, and seiche without loss of capability to perform their safety functions.

   GDC 2 applies to the RWCS because the system carries reactor water outside the containment structure and contains radioactive material. Failure of a system component as the result of a natural phenomenon could result in release of reactor water until the containment isolation valves close and in release of radioactive materials outside the containment structure.

   Meeting the requirements of GDC 2 minimizes the probablity that a failure of the RWCS will occur, thus decreasing the potential for release of reactor coolant or other radioactive materials outside the containment structure.

3. Compliance with GDC 14 requires that the reactor coolant pressure boundary shall be designed, fabricated, erected, and tested to ensure extremely low probability of abnormal leakage, rapidly propagating failure, and gross rupture.

   GDC 14 applies because the RWCS is used to maintain reactor cooling water chemistry. Thus, reactor cooling water chemistry and levels of impurities must be monitored to avoid deterioration of the reactor coolant pressure boundary by general corrosion or by intergranular stress corrosion cracking (IGSCC). IGSCC results from the simultaneous occurrence of aggressive water environment, susceptible material, and tensile stress conditions. Should general corrosion or IGSCC occur, leakage, failure, or gross rupture could result. The RWCS provides a means of controlling reactor cooling water chemistry and levels of impurities. In addition, parts of the RWCS connected directly to the reactor coolant system must be fabricated to the same standards as the reactor coolant system.

   Meeting the requirements of GDC 14 minimizes the probability of failure of the reactor coolant pressure boundary as a result of general corrosion or IGSCC, thus decreasing the potential for a loss-of-coolant accident.

4. Compliance with GDC 60 requires that the nuclear power unit design shall include a suitable means to control the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences.

GDC 60 applies because the RWCS is used to purify the reactor coolant. As such, gaseous, liquid, and solid radioactive materials will be accumulated within the system and will have the potential for discharge to the environment unless gaseous effluents, spent demineralizer resins, and liquid effluents are collected in closed systems and discharged to the radwaste system for processing and disposal.

Meeting the requirements of GDC 60 minimizes the probability that releases of radioactive materials during normal operation or anticipated operational occurrences would result in onsite radiation doses exceeding the limits specified in 10 CFR Part 50, Appendix I, or offsite radiation doses exceeding those specified in 10 CFR Part 20.

5. Compliance with GDC 61 requires that the fuel storage and handling, radioactive waste, and other systems that may contain radioactivity shall be designed to ensure adequate safety under normal and postulated accident conditions.

   GDC 61 applies because the RWCS is used to purify the reactor coolant. As such, gaseous, liquid, and solid radioactive materials will be accumulated within the system and will have the potential for discharge to the environment.

   Meeting the requirements of GDC 61 minimizes the probability that releases of radioactive materials during normal operation or anticipated operational occurrences would result in radiation doses exceeding the limits specified in 10 CFR Part 20. In addition, meeting the GDC 61 requirements minimizes the probability that the system would fail under postulated accident conditions.

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 SRP 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. The system description and piping and instrumentation diagrams (P&IDs) are reviewed to determine the processing sequence, interconnections with other systems, and similarity to systems previously evaluated. This review also verifies that the following are considered in the applicant's design:

   A. Provisions to automatically terminate flow to the RWCS following liquid poison injection into the reactor water.

   B. Provisions to automatically terminate flow to the cleanup demineralizers if the nonregenerative heat exchanger effluent temperature exceeds the resin operating temperature limits.

   C. Provisions for automatically maintaining flow through filter / demineralizer units in the event system flow decreases to a point where the bed may drop from the septum.

D. Provisions for monitoring resin transfers to ensure transfers are complete and design considerations are incorporated to eliminate resin traps.

E. Provisions for venting cleanup system components during drain, fill, and air-mixing operations.

F. Provisions for removing resin particles from cleanup system product water to prevent resins from entering the reactor system.

2. The system capacity and processing flexibility are reviewed and the following items are considered:

A. The process equipment, resin types, bed volumes, and RWCS capability are compared to those of similar reactors.

B. The design flows and temperatures through the system to ensure that criteria for outlet temperature relative to resin temperature are met.

C. The RWCS capability to process surplus refueling water prior to storage in the refueling water storage tanks or the condensate storage tanks.

D. Redundant or parallel components which will permit cleanup, if required, during periods of equipment downtime or single active component failure.

3. The quality group and seismic design classification of the system are reviewed to compare the design to the guidelines of Regulatory Guides 1.26 and 1.29 to ensure conformance with Acceptance Criterion II.3, above.

4. The instrumentation and controls for the reactor water cleanup system are reviewed to ensure that monitors are provided for:

A. Conductivity of demineralizer effluent.

B. Temperature and conductivity of demineralizer influent.

C. Differential pressure across the demineralizer and across the resin strainers.

5. The system controls are reviewed to ensure they are responsive to the monitor indications to maintain the required temperature and flow and that conductivity meters cover the entire range up to mandatory shutdown as delineated in the plant technical specifications in the final safety analysis report (FSAR).

6. 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 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 reactor water cleanup system (RWCS) will be used to aid in maintaining the reactor water purity and to reduce the reactor water inventory as required by plant operations. The staff's review has included piping and instrumentation diagrams and process diagrams along with descriptive information concerning the system design and operation.

The staff concludes that the proposed design of RWCS is acceptable and meets the relevant requirements of General Design Criteria 1, 2, 14, 60 and 61 of Appendix A to 10 CFR Part 50. This conclusion is based on the following:

1. The applicant has met the requirements of General Design Criterion 1 by designing the portion of the RWCS extending from the reactor vessel and recirculation loops to the outermost primary containment isolation valves to Quality Group A, in accordance with the guidelines of Regulatory Guide 1.26, and by designing the remainder of the RWCS outside the primary containment (excluding the precoating unit) to Quality Group C, in accordance with position C.2.c of Regulatory Guide 1.26.

2. The applicant has met the requirements of General Design Criterion 2 by designing the portion of the RWCS extending from the reactor vessel and recirculation loops to the outermost primary containment isolation valves to seismic Category I, in accordance with positions C.1, C.2, C.3 and C.4 of Regulatory Guide 1.29.

3. The applicant has met the requirements of General Design Criterion 14 by maintaining reactor water purity and material compatibility to reduce corrosion probabilities, thus reducing the probability of reactor coolant pressure boundary failure.

4. The applicant has met the requirements of General Design Criteria 60 and 61 by incorporating confinement into the design of the radioactivity-containing RWCS and by venting and collecting drainage from the RWCS components through closed systems.

   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 SRP 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 staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision.

VI. REFERENCES

1. 10 CFR Part 20, "Standards for Protection Against Radiation."

2. 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."

3. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

4. 10 CFR Part 50, Appendix A, General Design Criterion 14, "Reactor Coolant Pressure Boundary."

5. 10 CFR Part 50, Appendix A, General Design Criterion 60, "Control of Releases of Radioactive Materials to the Environment."

6. 10 CFR Part 50, Appendix A, General Design Criterion 61, "Fuel Storage and Handling and Radioactivity Control."

7. 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as is Reasonably Achievable' for Radioactive Material in Light-Water Cooled Nuclear Power Reactor Effluents."

8. Regulatory Guide 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants."

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

10. Electric Power Research Institute (EPRI) Report Series, "BWR Water Chemistry Guidelines."
