U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

9.3.4 CHEMICAL AND VOLUME CONTROL SYSTEM (PWR) (INCLUDING BORON RECOVERY SYSTEM)

REVIEW RESPONSIBILITIES

Primary - Chemical Engineering Branch (CMEB)

Secondary - None

I. AREAS OF REVIEW

Pressurized water reactor (PWR) plants include a chemical and volume control system (CVCS) and boron recovery system (BRS). These systems maintain the required water inventory and quality in the reactor coolant system (RCS), provide seal-water flow to the reactor coolant pumps and pressurizer auxiliary spray, control the boron neutron absorber concentration in the reactor coolant, and control the primary water chemistry and reduce coolant radioactivity level. Further, the system provides recycled coolant for demineralized water makeup for normal operation and the design may also provide high pressure injection flow to the emergency core cooling system (ECCS) in the event of postulated accidents. The review is performed to assure conformance with the requirements of General Design Criteria (GDC) 1, 2, 5, 14, 29, 33, 35, 60, and 61.

A. The CMEB reviews the systems from the letdown line of the primary system to the charging lines that provide makeup to the primary system and the reactor coolant pump seal-water system. The system is reviewed to the interfaces with the demineralized water makeup system and radioactive waste system and includes the following considerations:

1. The safety-related functional performance characteristics of CVCS components and the effects of adverse environmental occurrences, abnormal operational requirements, or accident conditions such as those due to a loss-of-coolant accident (LOCA).

2. The determination that a malfunction, a single failure of an active component, or the loss of a cooling source will not reduce the safety-related functional performance capabilities of the system.

3. That quality group and seismic design requirements are met and the effects of failure of equipment or components not designed to withstand seismic events on safety-related functions of the system are evaluated.

4. The system features provided to prevent precipitation of boric acid in components and lines containing boric acid solutions, and the adequacy of the system design to protect personnel from the effects of toxic, irritating, or explosive chemicals that may be used.

5. Provisions for operational testing and the instrumentation and control features that determine and verify that the system is operating in the correct mode.

B. The review for fire protection is performed by CMEB in SRP Section 9.5.1.

Coordinated reviews that interface with the overall review of the CVCS by CMEB are performed by other branches as follows. The Reactor Systems Branch (RSB) reviews the CVCS flow capacity and injection pressure to verify that specified acceptable fuel design limits are not exceeded following a postulated LOCA in evaluating the ECCS function as part of its primary review responsibility for SRP Sections 6.3, 15.6.1, and 15.6.5. RSB also reviews CVCS malfunctions that can result in a decrease in boron concentration in the reactor coolant to assure that fuel damage limits are not exceeded and that adequate time is available to terminate the dilution before the shutdown margin has been eliminated as part of its primary review responsibility for SRP Section 15.4.6. The Core Performance Branch (CPB) evaluates the injection of borated water into the RCS to meet combined reactivity control system redundancy and capability requirements of GDC 26 and 27 as part of its primary review responsibility for SRP Section 4.3. The liquid, solid, and gaseous waste treatment and process and effluent radiological monitoring aspects of the CVCS are reviewed in SRP Sections 11.2, 11.3, 11.4, and 11.5, respectively, by the Effluent Treatment Systems Branch (ETSB) as part of its primary review responsibility for those sections. The Radiation Assessment Branch (RAB), as part of its primary review responsibility for SRP Sections 12.1 and 12.3, reviews the system with respect to maintaining occupational radiation exposure as low as reasonably achievable (ALARA) and to providing radiation protection design features, respectively. The Instrumentation and Control Systems Branch (ICSB) and the Power Systems Branch (PSB) evaluate the adequacy of the design, installation, inspection, and testing of all electrical systems (sensing, control, and power) required to provide the safety-related functions of the CVCS as part of their primary review responsibility for SRP Sections 7.1, 7.6, and Appendix 7A for ICSB and SRP Section 8.3.1 for PSB. The Structural Engineering Branch (SEB) determines the acceptability of the design analysis, procedures, and criteria used to establish the ability of seismic Category I structures housing the system and supporting systems to withstand the effects of natural phenomena, such as the safe shutdown earthquake (SSE), the probable maximum flood (PMF), and tornado missiles as part of its primary review responsibility for 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. The Mechanical Engineering Branch (MEB) determines the acceptability of the seismic and quality group classifications for systems components as part of its primary review responsibility for SRP Sections 3.2.1 and 3.2.2. The MEB also determines that the piping, components, and structures are designed

in accordance with applicable codes and standards as part of its primary review responsibility for SRP Sections 3.9.1, 3.9.2, and 3.9.3. The Auxiliary Systems Branch (ASB), as part of its primary review responsibility for SRP Section 3.6.1, evaluates the effect of high- and moderate-energy CVCS system piping failures outside containment to assure that other safety-related systems will not be made inoperable. The ASB also evaluates the capability of internally generated missiles both inside and outside primary containment as part of its primary review responsibility for SRP Sections 3.5.1.1 and 3.5.1.2. The ASB also evaluates the capability of safety-related systems to withstand the effects of missiles generated by natural phenomena or externally generated missiles as part of its primary review responsibility to SRP Sections 3.5.1.4 and 3.5.2. The ASB also evaluates the capability of the CVCS to withstand external and internal flood conditions as part of its primary review responsibility for SRP Sections 3.4.1 and 9.3.3. The Equipment Qualification Branch (EQB) reviews the seismic qualification of Category I instrumentation and electric equipment and the environmental qualification of mechanical and electrical safety-related equipment as part of its primary review responsibility for SRP Sections 3.10 and 3.11, respectively. The Containment Systems Branch (CSB) reviews the design of isolation provisions of those portions of the CVCS that penetrate primary containment as part of its primary review responsibility for SRP Section 6.2.4. The MEB also reviews the adequacy of the inservice testing program of pumps and valves as part of its primary review responsibility for SRP Section 3.9.6. The Materials Engineering Branch (MTEB) verifies that inservice nondestructive examination requirements are met for system components as part of its primary review responsibility for SRP Sections 5.2.4 and 6.6. The review for technical specifications and quality assurance are coordinated and performed by the Licensing Guidance Branch (LGB) and Quality Assurance Branch (QAB) as part of their primary review responsibility for SRP Sections 16.0, 17.1, and 17.2, respectively.

For those areas of review identified above as being reviewed as part of the primary review responsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP section of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

Acceptability of the CVCS and BRS design, as described in the applicant's safety analysis report (SAR), is based on specific general design criteria and the positions of regulatory guides listed below.

The CMEB acceptance criteria are based on meeting the requirements of the following regulations:

A. General Design Criterion 1, as it relates to system components being assigned quality group classifications and application of quality standards in accordance with the importance of the safety function to be performed. Acceptance is based on meeting the guidance in Regulatory Guide 1.26.

B. General Design Criterion 2, as it relates to structures housing the facility and the system itself being capable of withstanding the effects of earthquakes. Acceptance is based on meeting the guidance of Regulatory Guide 1.29, Position C.1, for safety-related portions of the system and Position C.2 for nonsafety-related portions.

C. General Design Criterion 5, it relates to shared systems and components important to safety being capable of performing required safety functions.

D. General Design Criterion 14, as it relates to assuring reactor coolant pressure boundary material integrity by means of the CVCS being capable of maintaining reactor coolant system water chemistry necessary to meet PWR reactor coolant system water chemistry technical specifications.

E. General Design Criterion 29, as it relates to the reliability of the CVCS to provide negative reactivity to the reactor by supplying borated water to the reactor coolant system in the event of anticipated operational occurrences.

F. General Design Criteria 33 and 35 as they relate to the CVCS capability to supply reactor coolant makeup in the event of small breaks or leaks in the reactor coolant pressure boundary, to function as part of ECCS assuming a single active failure coincident with the loss of offsite power, and to meet ECCS technical specifications.

G. General Design Criteria 60 and 61 as they relate to CVCS components having provisions for venting and draining through closed systems.

Other specific criteria used to review the CVCS and BRS design follows.

1. The CVCS should include provisions for monitoring:

   a. temperature upstream of the demineralizer to assure that resin temperature limits are not exceeded, and

   b. filter demineralizer differential pressure to assure that pressure differential limits are not exceeded.

2. The CVCS should have provision for automatically diverting or isolating the CVCS flow to the demineralizer in the event the demineralizer influent temperature exceeds the resin temperature limit.

3. A program is implemented to leakage from the makeup and letdown lines in accordance with Item III.D.1.1 of NUREG-0737 for OL applications and III.D.1.1 of NUREG-0718 for CP applications.

III. REVIEW PROCEDURES

The procedures below are used during the construction permit (CP) review to determine that the design criteria and bases and the preliminary design as set forth in the preliminary safety analysis report meet the acceptance criteria given in subsection II. For the review of operating license (OL) applications, the procedures are utilized to verify that the initial design criteria and bases have been appropriately implemented in the final design as set forth in the final safety analysis report.

The procedures for OL applications include a determination that the content and intent of the technical specifications prepared by the applicant are in agreement with the requirements for system testing, minimum performance, and surveillance developed as a result of the staff's review.

Upon request from the primary reviewer, the coordinated review branches will provide input for the areas of review stated in subsection I. The primary reviewer obtains and uses such inputs as required to assure that this review procedure is complete.

For the purpose of this SRP section, a typical system is assumed for use as a guide since the design of the CVCS will vary with each reactor plant supplier. It is assumed that the typical system consists of a regenerative heat exchanger to cool the letdown flow from the RCS before processing through the demineralizers and to reheat it prior to reinjection into the RCS, demineralizers, and filters for removal of suspended and dissolved impurities, high pressure charging pumps to inject makeup flow into the RCS, a volume control tank for system surge capacity and makeup volume, a boron makeup and storage system to provide neutron absorber to the RCS as needed, evaporators and tanks for boron recovery and demineralized water makeup, and a boron thermal regeneration subsystem to minimize the quantity of waste water and allow reactivity control by varying the temperature of demineralizers so as to remove or add boron to the CVCS. For cases where there are variations from this system, the reviewer would adjust the review procedures given below. However, the system design would be required to meet the acceptance criteria given in subsection II.

A. The SAR is reviewed to determine that the system description and piping and instrumentation diagrams (P&IDs) show the CVCS equipment that is used for normal operation, and the minimum system heat transfer and flow requirements for normal plant operation. The system performance requirements will also be reviewed to determine that it limits expected component operational degradation (e.g., pump leakage, heat exchanger scaling, resin deterioration) and describes the procedures that will be followed to detect and correct these conditions when they become excessive. The reviewer, using the results of failure modes and effects analyses, comparisons with previously approved systems, or independent calculations, as appropriate, determines that the system can sustain the loss of any active component and meet the minimum system requirements for plant shutdown or accident mitigation. The system P&IDs, layout drawings, and component descriptions and characteristics are then reviewed for the following points:

   1. Essential portions of the CVCS are correctly identified and are verified to be isolable from the nonessential portions of the system and from interfacing systems such as demineralized water makeup and radioactive waste systems. The P&IDs will be reviewed to verify that they clearly indicate physical divisions between such portions and indicate design classification changes. Systems drawings are also reviewed to see that they show the means for accomplishing isolation and the system description is reviewed to identify minimum performance requirements for the isolation valves.

   2. CMEB coordinates with MEB to assure that essential portions of the CVCS, including the isolation valves separating essential portions from nonessential portions, are classified Quality Group A, B, or C and seismic Category I in accordance with the guidelines of Regulatory Guides 1.26 and 1.29; also, system descriptions in the SAR are reviewed to verify that the above seismic and safety classifications have been included, and that the P&IDs indicate any points of change in piping quality group classification.

3. The failure of portions of the system or of other systems not designed to seismic Category I standards and located close to essential portions of the system, or of nonseismic Category I structures that house, support, or are close to essential portions of the CVCS, will not preclude operation of the essential portions of the CVCS (Position C.2 of Regulatory Guide 1.29). Reference to SAR sections describing site features and the general arrangement and layout drawings will be necessary, as well as the SAR tabulation of seismic design classifications for structures and systems. Statements in the SAR that verify that the above conditions are met are acceptable (CP).

4. Using the results of evaluations performed by CPB, the CMEB verifies the adequacy of the system for reactivity control in the following areas:

   a. Boration of the reactor coolant system is accomplished through either of two flow paths and from either of two boric acid sources, and CVCS meets PWR boration technical specifications. This is verified from the review of P&IDs and system description.

   b. The amount of boric acid stored in the CVCS exceeds the amount required to borate the reactor coolant system to cold shutdown concentration, assuming that the control assembly with the highest reactivity worth is held in the fully withdrawn position, and to compensate for subsequent xenon decay during any part of core life. This is verified by coordinating with the CPB.

5. The adequacy of the CVCS for control of water chemistry is verified by examination of the information provided in the SAR, i.e., the allowable ranges for primary coolant activity, total dissolved solids, pH, and maximum allowable oxygen and halide concentrations and verification that CVCS can meet PWR reactor coolant system water chemistry technical specifications.

6. The adequacy of resin overtemperature protection is verified by reviewing the system description and drawings to determine that temperature sensors are provided that will actuate the demineralizer bypass or isolation valves. Also, verify that instrumentation is available to monitor filter demineralizer differential pressure.

7. The boron thermal regeneration subsystem is reviewed to determine the maximum change in primary coolant boron concentration due to equipment or control errors as determined from failure modes and effects analyses.

8. The operating procedures and controls for boron addition and primary coolant dilution are reviewed for adequacy.

9. The system P&IDs are examined to determine that all components and piping that can contain boric acid will either be heat traced or will be located within heated rooms to prevent precipitation of boric acid.

10. The application is reviewed with respect to establishing a leak reduction program in accordance with NUREG-0737 (OL applications) or NUREG-0718 (CP applications).

B. The reviewer verifies that the safety function of the system will be maintained as required in the event of adverse environmental phenomena such as earthquakes, tornadoes, hurricanes, and floods, or in the event of certain pipe breaks or loss of offsite power. The reviewer uses engineering judgment, failure modes and effects analyses, and the results of reviews performed under other SRP sections, as applicable, to determine the following:

1. The system description and drawings are reviewed in conjunction with the reactor coolant system to determine that the CVCS has sufficient pumping capacity to maintain the RCS water inventory within the allowable pressurizer level range for all normal modes of operation, including startup from cold shutdown, full power operation, and plant cooldown. Verify that CVCS can supply reactor coolant makeup in the event of small pipe breaks and can function as part of the ECCS, assuming a single active failure coincident with the loss of offsite power. It is further ascertained from a review of the P&IDs that makeup to the RCS can be accomplished via two redundant appropriately designed flow paths.

2. Essential components and subsystems (i.e., those necessary for safe shutdown) can function as required in the event of loss of offsite power. The system design will be acceptable if the CVCS meets minimum system requirements as stated in the SAR assuming a failure of a single active component, within the system or in the auxiliary electric power source, which supplies the system. The SAR is reviewed to verify that for each CVCS component or subsystem affected by the loss of offsite power, boric acid addition and coolant charging capabilities meet or exceed minimum requirements. Statements in the SAR and the results of failure modes and effect analyses are considered in assuring that the system meets these requirements. This will be acceptable verification of system functional reliability.

C. The descriptive information, P&IDs, layout drawings, and failure modes and effects analyses in the SAR are reviewed to assure that essential portions of the system will function following design basis accidents assuming a single active component failure. The reviewer evaluates the analyses presented in the SAR to assure function of required components, traces the availability of these components on system drawings, and checks that the SAR contains verification that minimum system flow and heat transfer requirements are met for each accident situation for the required time spans. For each case, the design will be acceptable if minimum system requirements are met.

D. The boron recovery system is not required for safe shutdown, or for the prevention or mitigation of postulated accidents. The BRS will be reviewed for the following: if the system tankage is of nonseismic Category I design, the results of analyses which postulate the rupture of tanks are reviewed by AEB to verify that the accident releases are in accordance with safe limits.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided and his review supports conclusions of the following type, to be included in the staff's safety evaluation report:

The chemical and volume control system (including boron recovery system) includes components and piping associated with the system from the letdown line of the primary system to the charging lines that provide makeup to the primary system and the reactor coolant pump seal water system. Based on the review of the applicant's proposed design criteria, design bases, and safety classification for the chemical and volume control system, and the requirements for system performance of necessary functions during normal, abnormal, and accident conditions, the staff concludes that the design of the chemical and volume control system and supporting system is acceptable and meets the requirements of General Design Criteria 1, 2, 5, 14, 29, 33, 35, 60, and 61. This conclusion is based on the following: the applicant's design of the chemical and volume control system meets (1) the requirements of General Design Criterion 1 and the guidelines of Regulatory Guide 1.26 by assigning quality group classifications to system components in accordance with the importance of the safety function to be performed; (2) the requirements of General Design Criterion 2 and the guidelines of Regulatory Guide 1.29 by designing safety-related portions of the system to seismic Category I requirements; (3) the requirements of General Design Criterion 5 by designing the CVCS so that components important to safety are not shared between nuclear power units unless such sharing will not significantly impair the ability of the CVCS to perform its safety functions in the event of an accident in one unit and an orderly shutdown and cooldown of the remaining units; (4) the requirements of General Design Criterion 14 by maintaining reactor coolant purity and material compatibility to reduce corrosion and thus reduce the probability of abnormal leakage, rapid propagating failure, or gross rupture of the reactor coolant pressure boundary; (5) the requirements of General Design Criterion 29 as related to the reliability of the CVCS to provide negative reactivity to the reactor by supplying borated water to the reactor coolant system in the event of anticipated operational occurrences; (6) the requirements of General Design Criteria 33 and 35 by designing the CVCS with the capability to supply reactor coolant makeup in the event of small breaks or leaks in the reactor coolant pressure boundary and to function as part of ECCS assuming a single failure coincident with loss of offsite power; (7) the requirements of General Design Criteria 60 and 61 with respect to confining radioactivity by venting and collecting drainage from the CVCS components through closed systems; and (8) the provisions of III.D.1.1 of NUREG-0737 (OL) or NUREG-0718 (CP) as it relates to establishing a leak reduction program.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

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

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

3. 10 CFR Part 50, Appendix A, General Design Criterion 5, "Sharing of Structures, Systems, and Components."

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 29, "Protection Against Anticipated Operational Occurrences."

6. 10 CFR Part 50, Appendix A, General Design Criterion 33, "Reactor Coolant Makeup."

7. 10 CFR Part 50, Appendix A, General Design Criterion 35, "Emergency Core Cooling."

8. 10 CFR Part 50, Appendix A, General Design Criterion 60, "Control of Release of Radioactive Material to the Environment."

9. 10 CFR Part 50, Appendix A, General Design Criterion 61, "Fuel Storage and Handling and Radioactivity Control."

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

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

12. NUREG-0737, "Clarification of TMI Action Plan Requirements.

13. NUREG-0718, "Licensing Requirements for Pending Applications for Construction Permits and Manufacturing Licenses."