U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

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

REVIEW RESPONSIBILITIES

Primary - Auxiliary and Power Conversion Systems Branch (APCSB)

Secondary - Core Performance Branch (CPB)
Reactor Systems Branch (RSB)
Structural Engineering Branch (SEB)
Mechanical Engineering Branch (MEB)
Materials Engineering Branch (MTEB)
Effluent Treatment Systems Branch (ETSB)
Electrical, Instrumentation and Control Systems Branch (EICSB)
Radiological Assessment Branch (RAB)

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, control the boron neutron absorber concentration in the reactor coolant, and control the primary water chemistry. Further, the system provides recycled coolant for the demineralized water makeup system for normal operation and high pressure injection flow to the emergency core cooling system in the event of postulated accidents.

1. The APCSB 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.

2. The APCSB reviews the 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).

3. The APCSB reviews the system to determine 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.

4. The system is reviewed with respect to the effects of postulated breaks or leakage cracks in high and moderate energy piping.

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5. The system is reviewed to determine that quality group and seismic design requirements are met. The effects of failure of equipment or components not designed to withstand seismic events on safety-related functions of the system are evaluated.

6. The APCSB reviews the system design with respect to the capability to detect, collect, and control system leakage and to isolate portions of the system in case of excessive leakage or component malfunctions. RAB reviews the system with respect to maintaining occupational radiation exposure as low as practicable.

7. The APCSB reviews 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.

8. Provisions for operational testing are evaluated, as are the instrumentation and control features that determine and verify that the system is operating in the correct mode.

9. The applicant's proposed technical specifications are reviewed for operating license applications as they relate to areas covered in this plan.

Secondary reviews are performed by other branches and the results used by the APCSB to complete overall evaluation of the system. The secondary reviews are as follows. The CPB determines the adequacy of the specified boron concentrations in the primary coolant for normal and accident conditions. The RSB determines that the assigned seismic and quality group classifications for system components are acceptable. The SEB determines the acceptability of the design analyses, procedures, and criteria used to establish the ability of 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 maxium flood (PMF), and tornado missiles. The MEB reviews the seismic qualification of components and confirms that components, piping, and structures are designed in accordance with applicable codes and standards. The MTEB verifies that inservice inspection requirements are met for system components and upon request will verify the compatibility of the materials of construction with service conditions. The EICSB evaluates the controls, instrumentation, and power sources with respect to capability, capacity, and reliability to perform safety-related functions during normal and emergency conditions. The ETSB reviews the CVCS and BRS to determine the source terms for possible radioactive releases and the processing of radioactive effluent from the BRS by the waste management systems. The RAB will verify the system meets radiation protection criteria.

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 regulatory guides. Additional bases for determining the acceptability of the CVCS and BRS include the degree of similarity of the design with that for previously reviewed plants with satisfactory operating experience, and independent calculations by the staff. Listed below are specific criteria related to the CVCS and BRS.

The design of the CVCS and BRS is acceptable if the integrated design of the system is in accordance with the following criteria:

1. General Design Criterion 2, as related to structures housing the facility and the system itself being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods, as established in Chapters 2 and 3 of the SAR.

2. General Design Criterion 4, with respect to structures housing the system and the system itself being capable of withstanding the effects of external missiles and internally generated missiles, pipe whip, and jet impingement forces associated with pipe breaks.

3. General Design Criterion 5, as related to shared systems and components important to safety being capable of performing required safety functions.

4. General Design Criterion 26, as related to the CVCS capability to control the rate of reactivity changes resulting from normal power changes and the capability to maintain the reactor core subcritical under cold conditions.

5. General Design Criterion 27, as related to the CVCS capability to control reactivity changes so that under postulated accident conditions, and with appropriate margin for a stuck control rod, the capability to cool the core is maintained.

6. General Design Criterion 33, as related to the CVCS capability to supply reactor coolant makeup in the event of small breaks or leaks in the reactor coolant pressure boundary so that specified fuel design limits are not exceeded.

7. General Design Criterion 60, as related to the handling of radioactive contaminants.

8. Regulatory Guide 1.26, as related to quality group classifications.

9. Regulatory Guide 1.29, as related to seismic design classifications.

10. Regulatory Guide 8.8 as related to maintaining occupational radiation exposure as low as practicable.

11. Branch Technical Positions APCSB 3-1 and MEB 3-1, as related to breaks in high and moderate energy piping systems outside containment.

II. 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 Section II of this plan. 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.

For the purpose of this review plan, 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 heat exchangers 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 Section II.

1. The SAR is reviewed to determine that the system description section 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 section 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 site shutdown or accident mitigation. The system P&IDs, layout drawings, and component descriptions and characteristics are then reviewed for the following points:

    a. Essential portions of the CVCS are correctly identified and are verified to be isolable from the non-essential portions of the system. The P&IDs will be reviewed to verify that they clearly indicate physical divisions between such portions and indicate design classification changes. System 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.

    b. Essential portions of the CVCS, including the isolation valves separating essential portions from non-essential portions, are classified Quality Group C or higher and seismic Category I. Component and 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.

    c. Design provisions have been made that permit appropriate inservice inspection and functional testing of system components important to safety. It will be acceptable if the SAR information delineates a testing and inspection program and if the system drawings show the connections and special piping and equipment required by this program.

d. 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. It is further ascertained from a review of the P&IDs that makeup to the RSC can be accomplished via two redundant appropriately designed flow paths.

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

   (1) Boration of the reactor coolant system is accomplished through either of two flow paths and from either of two boric acid sources. This is verified from the review of P&IDs and system description.

   (2) 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 from a review of the SAR.

   (3) The CVCS is capable of counteracting the inadvertent positive reactivity insertion caused by the maximum boron dilution accident.

f. 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.

g. 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.

h. 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.

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

j. 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.

2. 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 judgement, failure modes and effects analyses, and the results of reviews performed under other review plans, as applicable, to determine the following:

a. 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 non-seismic 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. 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)

b. The essential portions of the CVCS are protected from the effects of floods, hurricanes, tornadoes, and internally or externally generated missiles. Flood protection and missile protection criteria are discussed and evaluated in detail under the standard review plans for Chapter 3 of the SAR. The location and the design of the system, structures, and pump rooms (cubicles) are reviewed to determine that the degree of protection provided is adequate. A statement to the effect that the system is located in a seismic Category I structure that is tornado missile and flood protected, or that components of the system will be located in individual cubicles or rooms that will withstand the effects of both flooding and missiles is acceptable.

c. Essential portions of the system are protected from the effects of high energy line breaks and moderate energy line cracks. Layout drawings of the system are reviewed to assure that no high or moderate energy piping systems are close to essential portions of the CVCS, or that protection from the effects of failure will be provided. The means of providing such protection will be given in Section 3.6 of the SAR and procedures for reviewing the information presented are given in the corresponding review plans.

d. 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 an acceptable verification of system functional reliability.

3. 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.

4. 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 non-seismic Category I design, the results of analyses which postulate the rupture of tanks are reviewed to verify that the accident releases are in accordance with safe limits. The facility design, including P&IDs, are reviewed to assure that safety-related equipment will not be adversely affected by flooding.

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. The scope of review of the chemical and volume control system for the ___________ plant included process flow diagrams, layout drawings, piping and instrumentation diagrams, and descriptive information for the system and for the supporting systems that are essential to its operation. [The review has determined the adequacy of the applicant's proposed design criteria and design bases for the chemical and volume control system, and the requirements for system performance of necessary functions during normal, abnormal, and accident conditions. (CP)] [The review has determined that the design of the chemical and volume control system and supporting systems is in conformance with the design criteria and design bases. (OL)]

"The basis for acceptance in the staff review has been conformance of the applicant's designs, design criteria, and design bases for the chemical and volume control system and its supporting systems to the Commission's regulations as set forth in the general design criteria, and to applicable regulatory guides, staff technical positions, and industry standards.

"The staff concludes that the design of the chemical and volume control system conforms to all applicable regulations, guides, staff positions, and industry standards, and is acceptable."

V. REFERENCES

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

2. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Missile Design Bases."

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 26, "Reactivity Control System Redundancy and Capability."

5. 10 CFR Part 50, Appendix A, General Design Criterion 27, "Combined Reactivity Control Systems Capability."

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

7. 10 CFR Part 50, Appendix A, General Design Criterion 60, "Control of Releases of Radioactive Materials to the Environment."

8. Regulatory Guide 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive Waste Containing Components of Nuclear Power Plants," Revision 1.

9. Regulatory Guide 1.29, "Seismic Design Classification," Revision 1.

10. Regulatory Guide 8.8 "Information Relevant to Maintaining Occupational Radiation Exposure As Low As Practicable (Nuclear Reactors)."

11. Branch Technical Positions APCSB 3-1, "Protection Against Postulated Piping Failures in Fluid Systems OUtside Containment," attached to Standard Review Plan 3.6.1, and MEB 3-1, "Postulated Break and Leakage Locations in Fluid System Piping Outside Containment," attached to Standard Review Plan 3.6.2.

SRP 9.3.5