U.S. NUCLEAR REGULATORY COMMISSION
STANDARD REVIEW PLAN
OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 4.6 FUNCTIONAL DESIGN OF REACTIVITY CONTROL SYSTEMS

REVIEW RESPONSIBILITIES

Primary - Reactor Systems Branch (RSB)

Secondary - Core Performance Branch (CPB)
Auxiliary and Power Conversion Systems Branch (APCSB)
Mechanical Engineering Branch (MEB)
Electrical, Instrumentation and Control Systems Branch (EICSB)

I. AREAS OF REVIEW

The RSB reviews the combined functional performance of all the reactivity control systems to confirm that the systems can effect a safe shutdown, respond within acceptable limits during anticipated transients, and prevent or mitigate the consequences of postulated accidents.

The reactivity control systems whose functional performance is reviewed by the RSB include: control rod drive system (CRDS), chemical and volume control system (CVCS) for pressurized water reactors (PWR's), standby liquid control system (SLCS) for boiling water reactors (BWR's) and the recirculation flow control system (RFCS) for BWR's. Other aspects of each of these systems are evaluated by other reviewers as noted below.

The CPB in Standard Review Plan (SRP) 4.3 verifies the reactivity control requirements of the combined reactivity control systems. The negative reactivity available in the reactivity control systems, the allowable reactivity insertion or withdrawal rates, and the values of reactivity parameters throughout plant life are evaluated. Matters relating to steady-state core physics calculations and their integration with power distribution assumptions are considered in the CPB review.

The EICSB reviews in SRP 7.7 the control system for the RFCS. The intent of the EICSB review is to assure that failures of the control system would not impair the protection system capability in any significant manner. The EICSB also assists the RSB in reviewing the time delays for the actuation of each of the reactivity control systems. The EICSB in SRP 7.2 evaluates the results of failure modes and effects analyses to assure that a single failure occurring in the control system, or an operator error, will not result in the loss of capability for safe shutdown.

The APCSB, with the aid of the CPB reviewer, reviews the functional capability of the CVCS (for PWR's) and the SLCS (for BWR's) in SRP 9.3.4 and SRP 9.3.5, respectively, to determine

the adequacy of each system to perform its function of reactivity control for the reactor.

The MEB reviews in SRP 3.9.4 the CRDS to evaluate the adequacy of the system to perform its mechanical function (e.g., rod insertion and withdrawal, scram operation and time) and to maintain the reactor coolant pressure boundary. The pressure-containing components of the CRDS are reviewed by the RSB in SRP 3.2.1 and SRP 3.2.2 to determine that design code requirements, as applicable to the assigned safety class and seismic category, are met.

II. ACCEPTANCE CRITERIA

Acceptability of the information presented in Section 4.6 of the applicant's safety analysis report (SAR), including related sections, is based on meeting the general design criteria (Ref. 1). The acceptance criteria for the areas of review are the following:

1. General Design Criterion 20, "Protection System Functions," as related to the automatic actuation of the reactivity control systems in accident conditions.

2. General Design Criterion 21, "Protection System Reliability and Testability," as related to system design requirements for high functional reliability and capability to meet the single failure criterion.

3. General Design Criterion 23, "Protection System Failure Modes," as related to failing into a safe state.

4. General Design Criterion 25, "Protection System Requirements for Reactivity Control Malfunctions," as related to the functional design of redundant reactivity systems to assure that specified acceptable fuel design limits are not exceeded for malfunction of any reactivity control system.

5. General Design Criterion 26, "Reactivity Control System Redundancy and Capability," as related to the capability of the reactivity control system to regulate the rate of reactivity changes resulting from operational occurrences.

6. General Design Criterion 27, "Combined Reactivity Control Systems Capability," as related to the combined capability of reactivity control systems and emergency core cooling systems to cool the core under accident conditions.

7. General Design Criterion 28, "Reactivity Limits," as related to postulated reactivity accidents.

III. REVIEW PROCEDURES

The RSB reviewer evaluates the capabilities of the combined operation of the reactivity control systems to effect reactor shutdown for all postulated operating conditions.

The review procedures set forth below are used during the construction permit (CP) review to determine that the design criteria and bases and the preliminary design as

forth in the applicant's preliminary safety analysis report (PSAR) meet the acceptance criteria given in Section II of this review plan. During the operating license (OL) review, the reviewer verifies that the initial design criteria and bases have been appropriately implemented in the final design as set forth in the final safety analysis report (FSAR).

1. The RSB reviews the CRDS design with respect to fluid systems and possible single failures. The review of the system description includes piping and instrumentation diagrams (P&IDs), layout drawings, process flow diagrams, and descriptive information on essential supporting systems. The SAR is reviewed to ascertain that failure modes and effects analyses have been completed to determine that the control rod drive system (not the individual drives) is capable of performing its safety-related function following the loss of any active component. The RSB reviewer further confirms, on the basis of previously approved systems or independent failure modes and effects analyses, that the minimum system requirements are met for the failure conditions.

2. The CRDS, P&IDs, layout drawings, and component description and characterictics are reviewed by the RSB to verify that essential portions of the system are correctly identified and are isolable from non-essential portions. The essential portions should be protected from the effects of high or moderate energy line breaks. Layout drawings of the system are reviewed to assure that no high or moderate energy piping systems are close to the CRDS, or that protection is provided from the effects of high or moderate energy pipe breaks.

3. For plants containing control rod drive cooling systems (e.g., using air or water as coolant), the description and drawings are reviewed to determine that the systems meet the design requirements. Essential equipment should be delineated in the SAR. The major function of the cooling system in PWR's is to cool the drive mechanism and remove heat from the CRDS motors to preclude motor burnout or damage. Failure of a CRDS motor could result in a rod drop. In BWR's, the major function of the cooling water is to cool the drive mechanism and its seals to preclude damage resulting from long-term exposure to reactor temperatures. The control rod drive hydraulic system includes the cooling function as part of its design. The RSB reviewer confirms by failure modes and effects analysis that the cooling system is capable of maintaining the CRDS temperature below the applicant's maximum temperature criterion. The EICSB reviewer in SRP 7.2 confirms that there are sufficient instrumentation and controls available to the reactor operator to provide information in the control room to monitor the CRDS conditions, including the more significant parameters such as coolant flow, temperature, and pressure and stator temperature.

4. In coordination with the MEB, the RSB reviews the functional tests of the CRDS as related to rod insertion and withdrawal and scram operation and time. The reviewers check the elements of the test program to ensure that all required thermal-hydraulic conditions have been included for all postulated operating conditions. Experimental

verification of system operation where a single failure has been assume_ should be included in the test program, e.g., accumulator leakage for hydraulic CRDS and stuck rod operation.

5. The applicant's proposed preoperational and initial startup test programs are reviewed to determine if they provide reasonable assurance that the CRDS will perform its safety function. This aspect of the review is to verify that sufficient information is provided to identify the test objectives, methods of testing, and test acceptance criteria. If the design is essentially identical and if the proposed test programs are essentially the same as those of previously reviewed plants, the reviewer may conclude that the proposed test programs are adequate. If the proposed CRDS differs from that of prior designs, the impact of the proposed changes on the required preoperational and initial startup testing programs are evaluated.

6. The plant technical specifications are reviewed by the RSB as follows:

   a. For CP's, the reviewer confirms the suitability of the limiting conditions of operation to ensure that the specified operating parameters (scram time, CRDS temperature, operation with inoperable rods) are within the bounds of the analyzed conditions.

   b. For OL's, the reviewer confirms that the content and intent of the technical specifications proposed by the applicant are in agreement with the requirements developed as a result of the staff's review. Where necessary, the review will include requirements for system functional testing, minimum performance, and surveillance requirements.

   c. The reviewer verifies by comparison with other plant reviews that the frequency and scope of periodic surveillance testing is adequate.

7. The reactivity control systems are evaluated to verify that redundant reactivity control systems are not vulnerable to common mode failures. The RSB identifies the common mode failures and the EICSB, MEB, and APCSB assist the RSB reviewer in connection with their responsibilities in SRP 7.4, 3.9.4, and 9.3.4 or 9.3.5, respectively. In addition, the reviewer determines that inadvertent operation of any component or system (e.g., inadvertent scram of axial power shaping rods or inadvertent dilution of boron concentration) would not c use degraded system conditions beyond the capabilities of the safety systems.

8. The RSB reviewer examines all transients and accidents in Chapter 15 of the SAR that require reactivity control systems to function. The RSB reviewer, with the CPB and EICSB reviewers, ascertains that the reactivity and response characteristics of the reactivity control system are conservative with respect to the parameters assumed in the Chapter 15 analyses. In the Chapter 15 review, the RSB reviewer verifies that no credit has been taken for the RFCS (in BWR's) to mitigate any accident. (Although the

RFCS controls reactor power level over a limited range, it is not required for shutdown.) In addition, the reviewer reviews the operation of the RFCS to confirm that a malfunction or failure of the system will not degrade the capabilities of plant safety systems or lead to plant conditions more severe than those considered in the accident analyses (e.g., by determining the effects of a failure of the system following a loss-of-coolant accident or steam line break). The RSB, in SRP 15.4.5, reviews the results of the most limiting transient from a malfunction of the RFCS.

IV. EVALUATIONS FINDINGS

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

"The functional designs of the reactivity control systems for the _____ plant have been reviewed to confirm that the systems have the capability to shut down the reactor with appropriate margin during normal, abnormal and accident conditions. The reactivity control systems reviewed included the CRDS and _____ (CVCS for PWR's or SLCS and RFCS for BWR's). The scope of review included process flow diagrams, layout drawings, piping and instrumentation diagrams, and descriptive information for the systems and for the supporting systems that are essential for operation of the systems. [The applicant's proposed design criteria and design bases for the reactivity control systems and the adequacy of those criteria and bases have been reviewed. (CP)] [The manner in which the design of the reactivity control systems and supporting systems conform to the proposed design criteria and bases has been reviewed. (OL)]

"The basis for staff acceptance has been conformance of the applicant's designs, design criteria, and design bases for the reactivity control systems and their supporting systems to the Commission's regulations as set forth in the general design criteria of 10 CFR Part 50.

"The staff concludes that the designs of the reactivity control systems conform to all applicable regulations and are acceptable."

V. REFERENCES

1. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants."

2. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Revision 2.