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

## 4.6 FUNCTIONAL DESIGN OF CONTROL ROD DRIVE SYSTEM

REVIEW RESPONSIBILITIES

Primary - Auxiliary Systems Branch (ASB)

Secondary - None

## I. AREAS OF REVIEW

The ASB reviews the functional performance of the control rod drive system (CRDS) to confirm that the system can effect a safe shutdown, respond within acceptable limits during anticipated transients, and prevent or mitigate the consequences of postulated accidents. The ASB review covers the CRDS to assure conformance with the requirements of General Design Criteria 23, 25, 26, 27, 28, and 29.

1. ASB reviews the CRDS design for possible single failures.

2. ASB reviews the CRDS to verify that:

   a. Essential portions are isolable from nonessential portions.

   b. The CRDS cooling system meets the design requirements.

   c. The functional tests verify the proper rod insertion, withdrawal, and scram operation times.

   d. Redundant reactivity control systems are not vulnerable to common mode failures.

In addition, ASB will coordinate other branch evaluations that interface with the overall review of the control rod system as follows. As part of its primary review responsibility for SRP Section 4.3, the Core Performance Branch (CPB) verifies the reactivity control requirements. The Instrumentation and Control Systems Branch (ICSB) verifies the results of failure modes and effects analyses to assure that a single failure occuring in the control rod system, or an operator error, will not result in the loss of capability for safe shutdown as part of its primary review responsibility for SRP Section 7.2. The Mechanical Engineering Branch (MEB) verifies the adequacy of the control rod drive mechanisms to perform its mechanical function (e.g., rod insertion and withdrawal, scram operation and time) and to maintain the reactor coolant pressure boundary as part of its primary review responsibility for SRP Section 3.9.4. The MEB verifies that the design and requirements, as applicable to the assigned safety class and seismic category, are met as part of its primary review responsibility for SRP Sections 3.2.1 and 3.2.2. The Structural Engineering Branch (SEB) will determine the acceptability of the design analyses, 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 the tornado missiles, as part of its primary review responsibility for SRP Sections 3.3.1, 3.3.2, 3.5.3, 3.7.1 through 3.7.4, 3.8.4, and 3.8.5. The ICSB and Power Systems Branch (PSB) verify the adequacy of the design, installation, inspection, and testing of all electrical systems (sensing, control, and power) required for proper operation as part of their primary review responsibility for SRP Section 7.1 and Appendix 7-A for ICSB and SRP Section 8.3.1 for PSB. The review for fire protection, technical specifications, and quality assurance are coordinated and performed by the Chemical Engineering Branch, Licensing Guidance Branch, and Quality Assurance Branch as part of their primary review responsibility for SRP Sections 9.5.1, 16.0, and 17.0 respectively.

The Equipment Qualifications Branch (EQB) reviews the seismic qualification of Category I instrumentation and electrical equipment, and the environmental qualification of electrical and mechanical equipment as part of its primary review responsibility for SRP Sections 3.10 and 3.11 respectively.

Other reactivity control systems are reviewed as follows: the ICSB reviews the recirculation flow control system as part of its primary review responsibility for SRP Section 7.7. The Chemical Engineering Branch (CEB) reviews the chemical and volume control system as part of its primary review responsibility for SRP Section 9.3.4. The Auxiliary Systems Branch (ASB) reviews the standby liquid control system (BWRs) as part of its primary review responsibility for SRP Section 9.3.5. The Reactor Systems Branch (RSB) reviews the safety injection system as part of its primary review responsibility for SRP Section 6.3.

The RSB reviews all transients and accidents in Chapter 15 of the SAR that require reactivity control systems to function. The RSB, with the CPB and ICSB, 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 verifies that no credit has been taken for the RFCS (in BWRs) to mitigate any accident. (Although the RFCS controls reactor power level over a limited range, it is not required for shutdown.) In addition, RSB 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 reviews the results of the most limiting transient from a malfunction of the RFCS as part of its primary review responsibility for SRP Section 15.4.5.

For those areas of review identified above as being the responsibility of other branches, the acceptance criteria and their methods of application are contained in the SRP sections corresponding to those branches.

## 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. The acceptance criteria for the areas of review are the following:

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

2. 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.

3. 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.

4. 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.

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

6. General Design Criterion 29, "Protection Against Anticipated Operational Occurrences," as related to functioning under anticipated events.

## III. REVIEW PROCECURES

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 set forth in the applicant's preliminary safety analysis report (PSAR) meet the acceptance criteria given in subsection II of this SRP section. 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 ASB 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.

2. The CRDS, P&IDs, layout drawings, and component description and characteristics are reviewed by the ASB 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 PWRs 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 BWRs, 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 ASB 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 ICSB reviewer in SRP Section 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 ASB 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 assumed should be included in the test program, e.g., accumulator leakage for hydraulic CRDS and stuck rod operation.

5. The reactivity control systems are evaluated to verify that redundant reactivity control systems are not vulnerable to common mode failures. The ASB identifies the common mode failures and the ICSB, MEB, and CMEB assist the ASB reviewer in connection with their responsibilities in SRP Sections 7.4, 3.9.4, and 9.3.4 or 9.3.5, respectively.

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 input as required to assure that this review procedure is complete.

## 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 design of the control rod drive system has been reviewed to confirm that the system has the capability to shut down the reactor with appropriate margin during normal, abnormal, and accident conditions. For PWRs, the CVCS augments the CRDS to maintain safe shutdown. 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 system.

The review has determined the adequacy of the applicant's proposed design criteria, design basis and safety classification of the control rod drive system and the requirements for providing a safe shutdown during normal and accident conditions. The staff concludes that the design of the control rod drive system is acceptable and meets the requirements of the General Design Criteria 23, 25, 26, 27, 28, and 29. This conclusion is based on the following:

1. The applicant has met the requirements of General Design Criterion 23 by demonstrating the ability to insert the control rods upon any failure of the drive mechanism or any induced failure by an outside force (such as loss of electric power, instrumentation air, fire, radiation, extreme heat, pressure, cold, water, steam, etc.).

2. The applicant has met the requirements of General Design Criterion 25 by assuring that no fuel design limits are exceeded for any single malfunction or rod withdrawal accident.

3. The applicant has met the requirement of General Design Criterion 26 by demonstrating the ability to control reactivity changes to assure that, under normal operation and anticipated operational occurrences with the appropriate margin for malfunction (such as stuck rods), no fuel design limits are exceeded and the reactor can be maintained subcritical under cold conditions.

4. The applicant has met the requirements of General Design Criterion 27 by demonstrating the ability to reliably control reactivity changes under accident conditions to assure that no fuel design limits are exceeded and the reactor can be maintained subcritical under cold conditions.

5. The applicant has met the requirements of General Design Criterion 28 by demonstrating the ability to reliably control the amount and rate of reactivity change to assure that no reactivity accident will damage the reactor coolant pressure boundary or disturb the core or the core's appurtenances such as to impair coolant flow. The postulated reactivity accidents include rod ejection, rod drop, steam line rupture, coolant temperature changes, pressure changes, and cold water addition.

6. The applicant has met the requirements of General Design Criterion 29 by demonstrating a high probability of control rod insertion under anticipated operational occurrences.

## V. IMPLEMENTATION

The following is intended to provide guidance to the 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 the specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with the Commission's regulations.

## VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 23, "Protection System Failure Modes."

2. 10 CFR Part 50, Appendix A, General Design Criterion 25, "Protection System Requirements for Reactivity Control Malfunctions."

3. 10 CFR Part 50, Appendix A, General Design Criterion 26, "Reactivity Control System Redundancy and Capability."

4. 10 CFR Part 50, Appendix A, General Design Criterion 27, "Combined Reactivity Control Systems Capability."

5. 10 CFR Part 50, Appendix A, General Design Criterion 28, "Reactivity Limits."

6. 10 CFR Part 50, Appendix A, General Design Criterion 29, "Protection Against Anticipated Operational Occurrences."