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U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants

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U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 3.9.4 CONTROL ROD DRIVE SYSTEMS

REVIEW RESPONSIBILITIES

Primary - Mechanical Engineering Branch (MEB)

Secondary - None

I. AREAS OF REVIEW

The control rod drive system (CRDS) consists of the control rods and the related mechanical components which provide the means for mechanical movement. General Design Criteria 26 and 27 require that the CRDS provide one of the independent reactivity control systems. The rods and the drive mechanism shall be capable of reliably controlling reactivity changes either under conditions of anticipated normal plant operational occurrences, or under postulated accident conditions. A positive means for inserting the rods shall always be maintained to ensure appropriate margin for malfunction, such as stuck rods. Since the CRDS is a system important to safety and portions of the CRDS are a part of the reactor coolant pressure boundary (RCPB), General Design Criteria 1, 2, 14, and 29 and 10 CFR Part 50,§50.55a, require that the system shall be designed, fabricated, and tested to quality standards commensurate with the safety functions to be performed, so as to assure an extremely high probability of accomplishing the safety functions either in the event of anticipated operational occurrences or in withstanding the effects of postulated accidents and natural phenomena such as earthquakes.

Information in the areas noted below is provided in the applicant's safety analysis report and is reviewed by the MEB in accordance with this SRP section. This information pertains to the CRDS, which is considered to extend to the coupling interface with the reactivity control elements in the reactor pressure vessel. For electromagnetic systems, the review under this SRP section is limited to just the control rod drive mechanism (CRDM) portion of the CRDS. For hydraulic systems, the review covers the CRDM and also the hydraulic control unit, the condensate supply system, and the scram discharge volume. For both types of systems, the CRDM housing should be treated as part of the RCPB; the relevant mechanical engineering information may be presented in this SRP section or by reference to the sections on the RCPB.

If other types of CRDS are proposed or if new features that are not specifically mentioned here are incorporated in CRDS of current types, information should be supplied for the new systems or new features similar to that described below.

1. The descriptive information, including design criteria, testing programs, drawings, and a summary of the method of operation of the control rod drives, is reviewed to permit an evaluation of the adequacy of the system to perform its mechanical function properly.

2. A review is performed of information pertaining to design codes, standards, specifications, and standard practices, as well as to General Design Criteria, regulatory guides, and branch positions that are applied in the design, fabrication, construction, and operation of the CRDS.

   The various criteria, described in general terms above, should be supplied along with the names of the apparatus to which they apply. Pressurized portions of the system which are a part of RCPB are reviewed to determine the extent to which the applicant complies with the Class 1 requirements of Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (hereafter "the Code"). Those portions which are not part of the RCPB are reviewed with other specified parts of Section III, or other sections of the Code. The MEB reviews the non-pressurized portions of the control rod drive system to determine the acceptability of design margins for allowable values of stress, deformation, and fatigue used in the analyses. If an experimental testing program is used in lieu of analysis, the program is reviewed to determine whether it adequately covers the areas of concern in stress, deformation, and fatigue.

3. Information is reviewed which pertains to the applicable design loads and their appropriate combinations, to the corresponding design stress limits, and to the corresponding allowable deformations. The deformations are of interest in the present context only in those instances where a failure of movement could be postulated due to excessive deformation and such movement would be necessary for a safety-related function.

   If the applicant selects an experimental testing option in lieu of establishing a set of stress and deformation allowables, a detailed description of the testing program must be provided for review.
   In the preliminary safety analysis report (PSAR), the load combinations, design stress limits and allowable deformations criteria should be provided for review.

   In the final safety analysis report (FSAR), the actual design should be compared with the design criteria and limits to demonstrate that the criteria and limits have not been exceeded.

   Loadings imposed during normal plant operation and startup and shutdown transients include but are not limited to pressure, deadweight, temperature effects, and anticipated operational occurrences. Loadings associated with specific seismic and other dynamic events are then combined with the above plant-type loads. For BWRs only, the CRDS is reviewed to verify that the system is capable of withstanding adverse dynamic loads such as water hammer. The response to each set of combined loads has a selected stress or deformation limit. The selection of a specific limit is influenced by the probability of the postulated event occurring and the need to assure operation during and after the event.

4. The portion of the SAR is reviewed that describes plans for the conduct of an operability assurance program or that references previous test programs or standard industry procedures for similar apparatus. For example, the life cycle test program for the CRDS is reviewed. The operability assurance program is reviewed to ascertain coverage of the following:

   a. Life cycle test program.

   b. Proper service environment imposed during test, including appropriate anticipated normal operational occurrences, seismic, and postulated accident conditions.

   c. Mechanism functional tests.

   d. Program results.

In addition, the MEB will coordinate other branches' evaluations that interface with the overall review of the CRDS as follows:

The Core Performance Branch (CPB) will verify fuel system design, including effects of the CRDS on fuel behavior in meeting the requirements of the reactor core design under various normal and accident operating conditions in SRP Section 4.2. The Materials Engineering Branch (MTEB) will review the material aspects of CRDS in SRP Section 4.5.1.

For those areas of review identified above 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. <u>ACCEPTANCE CRITERIA</u>

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

1. GDC 1 and and 10 CFR Part 50,§50.55a, as its relates to CRDS, requires that the CRDS be designed to quality standard commensurate with the importance of the safety functions to be performed.

2. GDC 2, as it relates to CRDS, requires that the CRDS be designed to withstand the effects of an earthquake without loss of capability to perform its safety functions.

3. GDC 14, as it relates to CRDS, requires that the RCPB portion of the CRDS be designed, constructed, and tested for the extremely low probability of leakage or gross rupture.

4. GDC 26, as it relates to CRDS, requires that the CRDS be one of the independent reactivity control systems which is designed with appropriate

margin to assure its reactivity control function under anticipated normal operation condition.

5. GDC 27, as it relates to CRDS, requires that the CRDS be designed with appropriate margin, and in conjunction with the emergency core cooling system, be capable of controlling reactivity and cooling the core under postulated accident conditions.

6. GDC 29, as its relates to CRDS, requires that the CRDS, in conjunction with reactor protection systems, be designed to assure an extremely high probability of accomplishing its safety functions in the event of anticipated operational occurrences.

Specific criteria necessary to meet the relevant requirements of the regulations identified above are as follows:

1. The descriptive information is determined to be sufficient provided the minimum requirements for such information meet Section 3.9.4 of Reference 11.

2. Construction (as defined in NCA-1110 of Section III of the ASME Code, Reference 7) should meet the following codes and standards utilized by the nuclear industry which have been reviewed and found acceptable:

   a. <u>Pressurized Portions of Equipment Classified as Quality Group A, B, C (Regulatory Guide 1.26)</u>

      Section III of the ASME Code, Class 1, 2, or 3 as appropriate (Ref. 7).

   b. <u>Pressurized Portions of Equipment Classified as Quality Group D (Regulatory Guide 1.26)</u>

      (1) Section VIII, Division 1 of the ASME Code for vessels and pump casings (Ref. 7).

      (2) Applicable to Piping Systems (American National Standards Institute, ANSI):[1]

B16.5	Steel Pipe Flanges and Flanged Fittings (Ref. 13).
B16.9	Steel Butt Welding Fittings (Ref. 14).
B16.11	Steel Socket Welding Fittings (Ref. 15).
B16.25	Butt Welding Ends (Ref. 16).
B31.1	Piping (Ref. 17).
SP-25	Standards (Ref. 18).
B16.34	Valves (Ref. 19).

   c. <u>Nonpressurized Equipment (Non-ASME Code)</u>

      Design margins presented for allowable stress, deformation, and fatigue should be equal to or greater than those for other plants of

[1]This list can be extended by a staff review and acceptance of other ANSI and MSS standards in the piping system area.

similar design having a period of successful operation. Justification of any decreases should be provided.

3. For the various design and service conditions defined in NB-3113 of Section III of the ASME Code (Ref. 7), load combination sets are as given in Standard Review Plan Section 3.9.3 (Ref. 12). The stress limits applicable to pressurized and nonpressurized portions of the control rod drive systems should be as given in Reference 12 for the response to each loading set. The CRDS design should adequately consider water hammer loads to assure that system safety functions can be achieved.

4. The operability assurance program will be acceptable provided the observed performance as to wear, functioning times, latching, and overcoming a stuck rod meet system design requirements.

III. REVIEW PROCEDURES

The reviewer will select and emphasize material from the procedures described below as may be appropriate for a particular case.

1. The objectives of the review are to determine that design, fabrication, and construction of the control rod drive mechanisms provide structural adequacy and that suitable life cycle testing programs have been utilized to prove operability under service conditions.

   In the construction permit (CP) review, it should be determined that the design criteria utilize proper load combinations, stress and deformation limits, and that operability assurance is provided by reference to a previously accepted testing program or that a commitment is made to perform a testing program which includes the essential elements listed below. In the operating license (OL) review, the results of any testing program not previously reviewed should be evaluated.

2. The design criteria presented should be evaluated for both the internal pressure-containing portions and other portions of the CRDS. These include the CRDM housing, hydraulic control unit, condensate supply system and scram discharge volume, and portions such as the cylinder, tube, piston, and collect assembly.

   Of particular concern are any new and unique features which have not been used in the past. Pressure-containing components are checked to ensure that they meet the design requirements of the codes and criteria which have been accepted by the Mechanical Engineering Branch, and are identified in Standard Review Plan Section 3.2.2. The review of the functional design of reactivity control systems, including control rod drive systems, is the responsibility of the Reactor Systems Branch (RSB) (see SRP Section 4.6). The loading combinations for the various plant operating conditions are checked for consistency with Reference 12; given these loading combinations, the stress limits of the appropriate code should not be exceeded, or the limits in Reference 12 should not be exceeded if not specified in the listed design code. Exceptions taken by the applicant to any of the accepted codes, standards, or NRC criteria must be identified and the basis clearly justified so that evaluation is possible. Engineering judgment, experience, comparisons with earlier cases and design margins, and consultation with supervisors permit the reviewer to reach a decision on the acceptability of any exceptions posed by the applicant.

The choice of structural materials of construction for the CRDS is reviewed by the MTEB in SRP Section 4.5.1.

3. Loading combinations are defined as those loadings associated with plant operations which are expected to occur one or more times during the lifetime of the plant and include but are not limited to loss of power to all recirculation pumps, tripping of the turbine generator set, isolation of the main condenser, and loss of all offsite power, combined with loadings caused by natural or accident events including, for BWRs, water hammer loads. The load combinations which are postulated to occur are specified for each of the design and service conditions as defined in Paragraph NB-3113 of the ASME Code (Ref. 7). These load combinations are defined in Reference 12 and are compared by the reviewer with those provided by the applicant.

   The design stress limits, including fatigue limits, and deformation limits as appropriate to the components of the control rod drive mechanism are compared by the reviewer with those of specified codes, previously designed and successfully operating systems, or with the results of scale model and prototype testing programs.

4. The control rod drive mechanisms of a new design or configuration should be subjected to a life cycle test program to determine the ability of the drives to function during and after normal operating occurrence, seismic, and postulated accident condition over the full range of temperatures, pressures, loadings, and misalignment expected in service. The tests should include functional tests to determine times of rod insertion and withdrawal, latching operation, scram operation and time, system valve operation and scram accumulator leakage for hydraulic CRDS, ability to overcome a stuck rod condition, and wear. Rod travel and number of trips expected during the mechanism operational life should be duplicated in the tests.

   The reviewer checks the elements of the test program to be sure all required parameters have been included and finally reviews the test results to determine acceptability. Excessive wear, malfunction of components, operating times beyond determined limits, scram accumulator leakage, etc., all would be cause for retesting.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided to satisfy the requirements of this SRP section and that his evaluation is sufficiently complete and adequate to support conclusions of the following type, to be included in the staff's safety evaluation report:

> The staff concludes that the design of the control rod drive system is acceptable and meets the requirements of General Design Criteria 1, 2, 14, 26, 27, and 29, and 10 CFR Part 50, §50.55a. This conclusion is based on the following:

1. The applicant has met the requirement of GDC 1 and 10 CFR Part 50, §50.55a, with respect to designing components important to safety to quality standards commensurate with the importance of the safety functions to be performed. The design procedures anu criteria used for the control rod drive system are in conformance with the requirements of appropriate ANSI and ASME Codes.

2. The applicant has met the requirements of GDC 2, 14, and 26 with respect to designing the control rod drive system to withstand effects of earthquakes and anticipated normal operation occurrences with adequate margins to assure its reactivity control function and with extremely low probability of leakage or gross rupture of reactor coolant pressure boundary. The CRDS design capabilities include the ability to accommodate water hammer dynamic loads resulting from rapid opening of the scram insert and withdraw valves and closure of the hydraulic buffer under the worst case loading condition without compromising the safety functions of the system. The specified design transients, design and service loadings, combination of loads, and limiting the stresses and deformations under such loading combinations are in conformance with the requirements of appropriate ANSI and ASME Codes and acceptable regulatory positions specified in SRP Section 3.9.3.

3. The applicant has met the requirements of GDC 27 and 29 with respect to designing the control rod drive system to assure its capability of controlling reactivity and cooling the reactor core with appropriate margin, in conjunction with either the emergency core cooling system or the reactor protection system. The operability assurance program is acceptable with respect to meeting system design requirements in observed performance as to wear, functioning times, latching, and overcoming a stuck rod.

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 and implementation of acceptance criterion associated with water hammer loads in BWRs, subsection II.3, is as follows.

(a) Operating plants and OL applicants need not comply with the provisions of this revision.

(b) CP applicants will be required to comply with the provisions of this revision.

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 14, "Reactor Coolant Pressure Boundary."

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 29, "Protection Against Anticipated Operational Occurrences."

7. ASME Boiler and Pressure Vessel Code, Sections III and VIII, American Society of Mechanical Engineers.

8. Regulatory Guide 1.26, "Quality Group Classifications and Standards."

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

10. Regulatory Guide 1.48, "Design Limits and Loading Combinations for Seismic Category I Fluid System Components."

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

12. Standard Review Plan Section 3.9.3, "ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures."

13. ANSI B 16.5, "Steel Pipe Flanges and Flanged Fittings," American National Standard Institute.

14. ANSI B 16.9, "Wrought Steel Butt Welding Fittings," American National Standard Institute.

15. ANSI B 16.11, "Steel Fittings Steel Welding and Threaded," American National Standard Institute.

16. ANSI B 16.25, "Butt Welding Ends - Pipe, Valves, Flanges, and Fittings," American National Standard Institute.

17. ANSI B 31.1, "Power Piping," American National Standard Institute.

18. MSS-SP-25, "Marking for Valves, Fittings, Flanges, and Unions," Manufacturers Standardization Society.

19. ANSI B 16.34, "Steel Valves with Flanged and Butt Welding Ends," American Society of Mechanical Engineers.