NUREG-0800

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

15.4.3 CONTROL ROD MISOPERATION (SYSTEM MALFUNCTION OR OPERATOR ERROR)

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of transient and accident analyses for PWRs/BWRs

Secondary - None

I. AREAS OF REVIEW

The specific areas of review are as follows:

1. The types of control rod misoperations that are assumed to occur. For a pressurized water reactor (PWR), this may include one or more rods moving or displaced from normal or allowed control bank positions (such as dropped rods and rods left behind when inserting or withdrawing banks, or single rod withdrawal) and may include the automatic control system attempting to maintain full power.

2. Descriptions of rod position, flux, pressure, and temperature indication systems, and those actions initiated by these systems (e.g., turbine runback, rod withdrawal prohibit, rod block) which can mitigate the effects or prevent the occurrence of various misoperations.

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3. Descriptions of the sequence of events occurring during each anticipated operational occurrence (AOO), e.g., rod drop followed by automatic return to full power with possible power overshoot, including the effect of important feedback mechanisms and trips.

4. Descriptions of the calculational models used and justification of their validity and adequacy.

5. The input to the calculations, including rod worths, power distributions, and feedback coefficients and evidence of the conservatism of the input.

6. Results of the analyses, including, for each of the AOOs considered, plots of the time history of reactor power, reactor vessel pressure, critical heat flux for the limiting fuel rod, and maximum fuel centerline temperature or linear heat generation rate.

7. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

   For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

Review Interfaces

Other SRP sections interface with this section as follows:

1. General information on transient and accident analyses is provided in SRP Section 15.0.

2. Design basis radiological consequence analyses associated with design basis accidents are reviewed under SRP Section 15.0.3.

3. Review of the limiting anomalies for a boiling water reactor (BWR) with current modes of control rod operation is performed under Standard Review Plan (SRP) Sections 15.4.1 and 15.4.2, and no additional areas are considered under SRP Section 15.4.3.

4. Uniform cladding strain (for BWRs) and fuel centerline temperatures (for PWRs) are reviewed under SRP Section 4.2.

5. Reactivity coefficients and control rod worths are reviewed under SRP Section 4.3

6. Thermal margin limits are reviewed under SRP Section 4.4.

7. Safety systems required to prevent misoperations, as required by General Design Criterion 25, as well as the control rod system are reviewed under SRP Sections 7.2 and 7.7. The purpose of the review is to determine the events that are to be included as single error malfunctions (e.g., single rod withdrawal).

The specific acceptance criteria and review procedures are contained in the referenced SRP sections.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. General Design Criterion 10 (GDC 10), which requires that the reactor core and associated coolant, control and protection systems be designed with appropriate margin to assure that specified acceptable fuel design limits are not to be exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

2. General Design Criterion 13 (GDC 13), which requires that the availability of instrumentation to monitor variables and systems over their anticipated ranges to assure adequate safety, and of appropriate controls to maintain these variables and systems within prescribed operating ranges.

3. General Design Criterion 20 (GDC 20), which requires, in part, that the protection system shall be designed to initiate automatically the operation of appropriate systems to ensure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences.

4. General Design Criterion 25 (GDC 25), which requires that the reactor protection system be designed to assure that specified acceptable fuel design limits are not exceeded for any single malfunction of the reactivity control systems, such as accidental withdrawal (not ejection or dropout) of control rods.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for the review described in this SRP section. The SRP is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

The requirements of General Design Criteria 10, 20, and 25 concerning the specified acceptable fuel design limits are assumed to be met for this event when:

1. The thermal margin limits (departure from nucleate boiling ratio for PWRs) as specified in SRP Section 4.4, subsection II.1, are met.

2. Fuel centerline temperatures as specified in SRP Section 4.2, subsection II.A.2(a) and (b), do not exceed the melting point.

3. Uniform cladding strain as specified in SRP Section 4.2, subsection II.A.2(b), does not exceed 1%.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this SRP section is discussed in the following paragraphs:

1. Compliance with GDC 10 requires that the reactor core and associated coolant, control, and protection systems be designed with appropriate margin to ensure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

   GDC 10 is applicable to this section because the reviewer evaluates the effects and consequences of a control rod misoperation due to system malfunction or operator error for a BWR or a PWR to ensure that specified acceptable fuel design limits are not exceeded during normal operation, including the effects of AOOs. This SRP section and SRP Sections 4.2, 4.3, 4.4, 7.2, 7.7, 15.4.1, and 15.4.2 provide guidance for ensuring that instrument setpoints are initially within and remain within the technical specification limits, thereby ensuring that specified acceptable fuel design limits are not exceeded.

   Meeting the requirements of GDC 10 provides reasonable assurance that specified acceptable fuel design limits are not exceeded during either normal operations or AOOs (e.g., control rod misoperation) due to system malfunction or operator error.

2. Compliance with GDC 13 requires the provision of instrumentation that is capable of monitoring variables and systems over their anticipated ranges to assure adequate safety, and of controls that can maintain these variables and systems within prescribed operating ranges.

   GDC 13 applies to this section because the reviewer evaluates the sequence of events, including automatic actuations of projection systems, and manual actions, and determines whether the sequence of events is justified, based upon the expected values of the relevant monitored parameters and instrument indications.

3. Compliance with GDC 20 requires that each reactor protection system be designed (1) to initiate the automatic operation of appropriate systems, including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences, and (2) to sense accident conditions and to initiate the operation of systems and components important to safety.

   GDC 20 is applicable to this section because the reviewer evaluates the effects and consequences of a control rod misoperation due to system malfunction or operator error for a PWR or a BWR to ensure that acceptable fuel design limits are not exceeded as a result of AOOs. The reactor protection system automatically initiates the operation of appropriate systems, including the reactivity control system (RCS), to terminate the AOOs analyzed in this SRP section. AOOs such as those caused by a control rod misoperation are terminated in a timely manner so that acceptable specified fuel design limits are not exceeded for either a PWR or a BWR. This SRP section and SRP Sections 4.2, 4.3, 4.4, 7.2, 7.7, 15.4.1, and 15.4.2 provide guidance for ensuring that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences.

Meeting the requirements of GDC 20 provides reasonable assurance that specified acceptable fuel design limits will not be exceeded when the reactor protection system initiates operation of appropriate systems to terminate AOOs caused by control rod misoperations due to system malfunction or operator error.

4. Compliance with GDC 25 requires that the reactor protection system be designed to assure that specified acceptable fuel design limits are not exceeded for any single malfunction of the reactivity control systems, such as accidental withdrawal (not ejection or dropout) of control rods.

   GDC 25 is applicable to this section because the reviewer evaluates the effects and consequences of a control rod misoperation due to system malfunction or operator error for either a PWR or a BWR at power. One criterion specifies that the reactor protection system be designed to ensure that specific acceptable fuel design limits are not exceeded for either a PWR or a BWR during normal operations or during an AOO, including the event of a single malfunction of the RCS. The reactor protection system operates in a manner that automatically terminates the AOOs analyzed in this SRP section. This SRP section and SRP Sections 4.2, 4.3, 4.4, 7.2, 7.7, 15.4.1, and 15.4.2 provide guidance for ensuring that specified acceptable fuel design limits are not exceeded as a result of AOOs.

   Meeting the requirements of GDC 25 provides reasonable assurance that a single malfunction of the reactivity control system, together with anticipated operational occurrences caused by the initiating event of a control rod misoperation due to system malfunction or operator error during either normal operation or an AOO, will not cause specified acceptable fuel design limits to be exceeded.

III. <u>REVIEW PROCEDURES</u>

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

These review procedures are based on the identified SRP acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

The reviewer, in determining whether the criteria are met, should determine the AOOs to be considered for this event. Generally, the list of errors should include: (1) inadvertently withdrawing one or several rods, (2) leaving one or several rods behind during bank withdrawal, and (3) inserting one or several rods with power compensation in other portions of the core. In addition to these events, the reviewer must also decide, by postulating single failures in equipment or errors in operation, whether additional single rod malfunctions can be created. Once the list of AOOs has been established, the reviewer must determine acceptability in accordance with the criteria of subsection II of this SRP section.

1. For each failure event analyzed, the cases which result in a limiting fuel rod condition should be presented. Initial conditions and parameter values selected for these cases should be justified with a sensitivity analysis or discussion. Conditions of first-order importance for any time in cycle are initial power level and distribution, initial rod

configuration, reactivity addition rate, moderator temperature, fuel temperature, and void reactivity coefficients.

2. For each event, the analytical methods used by the applicant are reviewed. Those steady-state and AOO methods that are primarily based on reactor physics considerations are the responsibility of the organization responsible for reactor systems. Where thermal-hydraulic methods are involved, review assistance may be requested as described in SRP Section 4.4. In either case, the reviewer should determine whether the applicant's evaluation methods are acceptable. This may be done by using one or more of the following procedures:

    A. Determine whether the method has been reviewed and approved previously by considering past safety evaluation reports (SERs) and reports prepared in response to specific technical assistance requests.

    B. Perform an independent review of the method (usually described in a separate licensing topical report and often completed, on a generic basis, outside the scope of the review for a particular facility).

    C. Perform auditing-type calculations with methods available to the staff.

    D. Request additional bounding calculations from the applicant to confirm the validity of those portions of the applicant's analytical method that have not already been fully reviewed and approved.

3. For each event, the results are evaluated. In addition to verifying conformance to the acceptance criteria of subsection II above, the reviewer determines that:

    A. Input conditions (e.g., pressure, temperature, flow rate) are at the adverse end of the range of values specified as the operating range.

    B. Initial power is 102% of licensed core thermal power, unless a lower power level is justified by the applicant.

    C. Output signals (power, temperature, flux perturbation) provide adequate alarm or scram signals.

    D. Nuclear conditions that interact with this event (e.g., Doppler coefficient, void coefficient) have been calculated as described in SRP Section 4.3.

4. For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the final safety analysis report (FSAR) meets the acceptance criteria. DCs have referred to the FSAR as the design control document (DCD). The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an early site permit (ESP) or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

1. The possibilities for single failures of the reactor control system which could result in a movement or misposition of control rods beyond normal limits have been reviewed. The scope of the review has included investigations of possible rod misposition configurations, the course of the resulting AOOs or steady-state conditions, and the instrumentation response to the AOO or power maldistribution. The methods used to determine the peak fuel rod response, and the input to that analysis, such as power distribution changes, rod reactivities, and reactivity feedback effects due to moderator and fuel temperature changes, have been examined. (If audit calculations have been done, they should be summarized.)

   The staff concludes that the requirements of General Design Criteria 10, 13, 20, and 25 have been met. This conclusion is based on the following:

   A. GDC 10, ensuring that the specified acceptable fuel design limits are not exceeded.

   B. GDC 13, ensuring that all credited instrumentation was available, and that actuations of protection systems, automatic and manual, occurred at values of monitored parameters that were within the instruments' prescribed operating ranges.

   C. GDC 20, ensuring that the reactivity control systems are automatically initiated so that specified acceptable fuel design limits are not exceeded.

   D. GDC 25, ensuring that single malfunctions in the reactivity control system will not cause the specified acceptable fuel design limits to be exceeded.

      These requirements have been met by comparing the resulting extreme operating conditions and response for the fuel (i.e., fuel duty) with the acceptance criteria for fuel damage (e.g., critical heat flux, fuel temperatures, and clad strain limits should not be exceeded) to ensure that fuel rod failure will be precluded for this event. The basis for acceptance in the staff review is that maximum configurations and AOOs for single error control rod malfunctions have been analyzed, that the analysis methods and input data are reasonably conservative, and that specified acceptable fuel design limits will not be exceeded.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this SRP section.

V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 10, "Reactor Design."

2. 10 CFR Part 50, Appendix A, General Design Criterion 13, "Instrumentation and Control."

3. 10 CFR Part 50, Appendix A, General Design Criterion 20, "Protection System Functions"

4. 10 CFR Part 50, Appendix A, General Design Criterion 25, "Protection System Requirements for Reactivity Control Malfunctions."
