U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

15.4.3 CONTROL ROD MISOPERATION (SYSTEM MALFUNCTION OR OPERATOR ERROR)

REVIEW RESPONSIBILITIES

Primary - ~~Core Performance Branch (CPB)~~Reactor Systems Branch (SRXB)[1]

Secondary - None

I. AREAS OF REVIEW

~~CPB~~SRXB[2] reviews the following:

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. ~~For a boiling water reactor (BWR) with current modes of control rod operation, limiting anomalies are reviewed under SRP Sections 15.4.1 and 15.4.2, and no additional areas are considered here.~~[3]

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.

   ~~Those safety systems required to prevent misoperations, as required by General Design Criterion 25, as well as the control rod system are reviewed in SRP Sections 7.2 and 7.7.~~

~~The purpose of the review is to determine what events are to be included as single error malfunctions (e.g., examine single rod withdrawal).~~[4]

3. Descriptions of the sequence of events occurring during each ~~transient~~anticipated operational occurrence (AOO),[5] 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 includ~~ing~~e,[6] for each of the ~~transients~~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.

Review Interfaces[7]

1. SRXB also performs the following reviews under the SRP sections indicated:

   a. 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.[8]

   b. Review of uniform cladding strain and fuel centerline temperatures are performed under SRP Section 4.2.

   c. Review of Doppler and void coefficients are performed under SRP Section 4.3.

   d. Review of thermal margin limits are performed under SRP Section 4.4.[9]

2. The SRXB will coordinate other branches' evaluations that interface with the overall review of the system, as follows:

   The Instrumentation and Controls Branch (HICB) reviews those safety systems required to prevent misoperations, as required by General Design Criterion 25, as well as the control rod system. The purpose of the review is to determine what events are to be included as single error malfunctions (e.g., single rod withdrawal). The HICB performs these reviews as part of its primary review responsibility under SRP Sections 7.2 and 7.7.[10]

For those areas of review identified above as part of the primary responsibility of other branches, the acceptance criteria and methods of application are contained in the referenced SRP section.[11]

II. ACCEPTANCE CRITERIA

1. The following General Design Criteria ~~(Ref. 1)~~[12] apply:

   a. General Design Criterion 10 (GDC 10),[13] which requires that specified acceptable fuel design limits are not to be exceeded during normal operation, including the effects of anticipated operational occurrences.

   b. General Design Criterion 20 (GDC 20),[14] which requires that the protection system initiate automatically appropriate systems to ensure~~assure~~[15] that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences.

   c. General Design Criterion 25 (GDC 25),[16] which requires that the reactor protection system be designed to ensure~~assure~~ that specified acceptable fuel design limits are not exceeded in the event of a single malfunction of the reactivity control system.

2. The requirements of ~~GDC~~General Design Criteria[17] 10, 20, and 25 concerning the specified acceptable fuel design limits are assumed to be met for this event when:

   a. The thermal margin limits (~~DNBR~~departure from nucleate boiling ratio[18] for PWRs) as specified in SRP Section 4.4, subsection II.1, are met.

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

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

Technical Rationale[19]

The technical rationale for application of these acceptance criteria to reviewing control rod misoperation (i.e., system malfunction or operator error) is discussed in the following paragraphs:[20]

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 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.[21]

2. 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, thereby ensuring 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 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.[22]

3. Compliance with GDC 25 requires that each reactor protection system be designed to ensure that specified acceptable fuel design limits are not exceeded for any single malfunction of the reactivity control system 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 acceptance criterion requires 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 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.[23]

III. REVIEW PROCEDURES

The reviewer, in determining whether the criteria are met, must determine the ~~transients~~AOOs that should 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 ~~transients~~AOOs has been established, the reviewer must determine acceptability in accordance with the criteria of subsection II of this SRP section.[24]

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 ~~transient~~AOO methods that are primarily based on reactor physics considerations are the responsibility of ~~CPB~~SRXB.[25] Where thermal-hydraulic methods are involved, review assistance may be requested as described in SRP Section 4.4. In either case, the reviewer must 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 a de novo review of the method (usually described in a separate licensing topical report and often handled outside the scope of the review for a particular facility).

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

    d. Require additional bounding calculations by 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) provided 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.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.[26]

IV. EVALUATION FINDINGS

If the reviewer's evaluation shows that the applicant's analyses are acceptable, the following kinds of statements should be included in the staff's safety evaluation report:

> The possibilities for single failures of the reactor control system which could result in a movement or malposition of control rods beyond normal limits have been reviewed. The scope of the review has included investigations of possible rod malposition configurations, the course of the resulting ~~transients~~AOOs or steady-state conditions, and the instrumentation response to the ~~transient~~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, 20, and 25 have been met. This conclusion is based on the following:
>
> The applicant has met the requirements of GDC 10 that the specified acceptable fuel design limits are not exceeded, GDC 20 that the reactivity control systems are automatically initiated so that specified acceptable fuel design limits are not exceeded, and GDC 25 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~~assure~~ that fuel rod failure will be precluded for this event. The basis for acceptance in the staff review is that maximum configurations and ~~transients~~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 design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.[27]

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.[8] 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.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.[29]

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 10, "Reactor Design~~,~~." ~~General Design Criterion 20, "Protection System Functions," and General Design Criterion 25, "Protection System Requirements for Reactivity Control Malfunctions."~~

2. 10 CFR Part 50, Appendix A, General Design Criterion 20, "Protection System Functions"

3. 10 CFR Part 50, Appendix A, General Design Criterion 25, "Protection System Requirements for Reactivity Control Malfunctions."[30]

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SRP Draft Section 15.4.3

Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current PRB name and abbreviation	Changed PRB to Reactor Systems Branch (SRXB).
2.	Current PRB abbreviation	Changed PRB to SRXB.
3.	SRP-UDP format item	Relocated to "Review Interfaces" as item 1.a.
4.	SRP-UDP format item	Relocated to "Review Interfaces" as item 2.a.
5.	SRP-UDP format item	Replaced the word "transient" with "anticipated operational occurrence (AOO)" in 8 places to accommodate Generic Issue B-3.
6.	Editorial	Corrected from "including" to "include."
7.	SRP-UDP format item	Added "Review Interfaces" to AREAS OF REVIEW and organized in numbered paragraph form to describe how SRXB reviews aspects of the control rod misoperation under other SRP sections and how other branches support the review. Rearranged wording but preserved contents of material.
8.	Editorial	Moved from subsection I.1, with minor editorial changes. (See item 3 above.)
9.	SRP-UDP format item	Excerpted items b and d from subsections II.2.a, b, and c. Excerpted item c from subsection III.3.d.
10.	Current PRB name and abbreviation	Moved from subsection I.2, with minor editorial changes. (See item 4 above.) Added review interface branch, Instrumentation and Controls Branch (HICB), for SRP Sections 7.2 and 7.4.
11.	Editorial	Added "For areas of review...." to be consistent with SRP Section 15.4.4.
12.	Editorial	Deleted unnecessary reference callout, "(Ref. 1)."
13.	Editorial	Added "General Design" to "Criterion 10" to provide consistency with other SRP sections, and provided "GDC 10" as initialism for "General Design Criterion 10."
14.	Editorial	Added "General Design" to "Criterion 20" to provide consistency with other SRP sections, and provided "GDC 20" as initialism for "General Design Criterion 20."
15.	Editorial	Changed "assure" to "ensure" (global change for this SRP section).

SRP Draft Section 15.4.3

Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
16.	Editorial	Added "General Design" to "Criterion 25" to provide consistency with other SRP sections, and provided "GDC 25" as initialism for "General Design Criterion 25."
17.	Editorial	Defined "GDC" as "General Design Criteria" to accommodate plural usage.
18.	Editorial	Spelled out "DNBR" as "departure from nucleate boiling ratio."
19.	SRP-UDP format item	"Technical Rationale" added to ACCEPTANCE CRITERIA and organized in numbered paragraph form to describe the bases for referencing the General Design Criteria.
20.	SRP-UDP format item	Added lead-in sentence for "Technical Rationale."
21.	SRP-UDP format item	Added technical rationale for GDC 10.
22.	SRP-UDP format item	Added technical rationale for GDC 20.
23.	SRP-UDP format item	Added technical rationale for GDC 25.
24.	Editorial	Provided numbered format to paragraph, and made minor editorial changes for clarity.
25.	Current PRB abbreviation	Changed PRB to SRXB.
26.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
27.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items.
28.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
29.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
30.	SRP-UDP format item	Reorganized references as separate items.

Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
	No Integrated Impacts were incorporated in this SRP Section.	