NUREG-0800
(Formerly NUREG-75/087)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

15.4.2 UNCONTROLLED CONTROL ROD ASSEMBLY WITHDRAWAL AT POWER

REVIEW RESPONSIBILITIES

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

Secondary - None

I. AREAS OF REVIEW

The ~~CPB~~SRXB[2] evaluates the effects and consequences of an uncontrolled control rod assembly withdrawal (a bank for a pressurized water reactor, PWR;~~and~~[3] a single rod with current control modes for a boiling water reactor, BWR)[4] at power to ~~assure~~ensure[5] conformance with the requirements of General Design Criteria 10, 17,[6] 20, and 25 under this Standard Review Plan (SRP)[7] section. The review under this SRP section covers the description of the causes of the ~~transient~~anticipated operational occurrence (AOO)[8] and of the ~~transient~~AOO itself, the initial conditions, the reactor parameters used in the analysis, the analytical methods and computer codes used, and the consequences of the ~~transients~~AOOs as compared with the acceptance criteria. ~~The reactivity coefficients and control rod assembly worths involved are reviewed by the CPB under SRP Section 4.3.~~[9]

Review Interfaces[10]

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

a. Fuel centerline temperatures (for PWRs) are reviewed by the SRXB under SRP Section 4.2, subsections II.A.2(a) and (b).[11]

b. Uniform cladding strain (for BWRs) are reviewed by the SRXB under SRP Section 4.2, subsection II.A.2(b).[12]

c. The reactivity coefficients and control rod assembly worths involved are reviewed by the ~~CPB~~SRXB[13] under SRP Section 4.3.

d. The thermal margin limits (departure from nucleate boiling ratio (DNBR) for PWRs and minimum critical power ratio (MCPR) for BWRs) are reviewed by the SRXB under SRP Section 4.4, subsection II.1.[14]

II. <u>ACCEPTANCE CRITERIA</u>

1. The following General Design Criteria apply:

a. General Design Criterion 10 (GDC 10),[15] which requires that specified acceptable fuel design limits are not to be exceeded during normal operation, including the effects of ~~anticipated operational occurrences~~AOOs.

b. General Design Criterion 17 (GDC 17), which requires that an onsite electric power system and an offsite electric power system be provided to permit functioning of structures, systems, and components important to safety.[16]

~~b.~~c. General Design Criterion 20 (GDC 20),[17] which requires that the protection system initiate automatically appropriate systems to ~~assure~~ensure[18] that specified acceptable fuel design limits are not exceeded as a result of ~~anticipated operational occurrences~~AOOs.

~~c.~~d. General Design Criterion 25 (GDC 25)[19], which requires that the reactor protection system be designed to ~~assure~~ensure[20] 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[21] 10, 17,[22] 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 for PWRs and MCPR for BWRs) as specified in SRP Section 4.4, subsection II.1, are met.

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

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

Technical Rationale[23]

The technical rationale for application of these acceptance criteria to reviewing the uncontrolled control rod assembly withdrawal at power is discussed in the following paragraphs:[24]

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 an uncontrolled control rod assembly withdrawal (a bank for a PWR; a single rod with current control modes for a BWR) at power to ensure that specified acceptable fuel design limits are not exceeded during normal operation, including the effects of AOOs. SRP Section 15.4.2 as well as SRP Sections 4.2, 4.3, and 4.4 provide guidance for ensuring that instrument setpoints are initially within and remain within the technical specification limits.

   Meeting the requirements of GDC 10 provides assurance that specified acceptable fuel design limits are not exceeded for AOOs caused by an uncontrolled control rod assembly withdrawal at power.[25]

2. Compliance with GDC 17 requires (in part) that an onsite and an offsite electric power system be provided to permit functioning of structures, systems, and components important to safety. The safety function for each system (assuming the other system is not functioning) shall be to provide sufficient capacity and capability to ensure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of AOOs and (2) the core is cooled and containment and other vital functions are maintained.

   GDC 17 is applicable to SRP Section 15.4.2 because this section reviews an anticipated operational occurrence to which the GDC should be applied.

   Meeting the requirements of GDC 17 provides assurance that an uncontrolled control rod assembly withdrawal at power, in combination with a LOOP will not result in a reactor transient that could cause the reactor coolant pressure boundary design conditions or the fuel design limits to be exceeded.[26]

3. Compliance with GDC 20 requires that the protection system be designed (1) to initiate automatically the operation of appropriate systems, including the reactivity control systems, to ensure 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 an uncontrolled control rod assembly withdrawal at power (i.e., a bank for a PWR; a single rod with current control modes for a BWR). The reactor protection system (RPS) automatically initiates the operation of appropriate systems, including the reactivity control system (RCS), to terminate the AOOs analyzed in this SRP section. The AOOs are terminated in a timely manner so that acceptable specified fuel design limits are not exceeded for either a PWR or a BWR. SRP Section 15.4.2 as well as SRP Sections 4.2, 4.3, and 4.4 provide guidance for ensuring that specified acceptable fuel design limits are not exceeded as a result of AOOs.

Meeting the requirements of GDC 20 provides assurance that specified acceptable fuel design limits are not exceeded by ensuring that the RPS initiates the operation of appropriate systems in a timely manner to terminate AOOs caused by an uncontrolled control rod assembly withdrawal at power.[27]

4. Compliance with GDC 25 requires that protection systems 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, based on accepted criteria, the reviewer evaluates the effects and consequences of an uncontrolled control rod assembly withdrawal at power (i.e., a bank for a PWR; a single rod with current control modes for a BWR). One criterion specifies that the RPS be designed to ensure that acceptable fuel design limits are not exceeded for either a PWR or a BWR during normal operation or AOOs, including in the event of a single malfunction of the RCS. The RPS operates in a timely manner to initiate automatic termination of the AOOs analyzed in this SRP section. SRP Section 15.4.2 as well as SRP Sections 4.2, 4.3 and 4.4 provide guidance for ensuring that specified acceptable fuel design limits are not exceeded as a result of operation or AOOs.

   Meeting the requirements of GDC 25 provides assurance that a single malfunction of the reactivity control system, together with AOOs caused by the initiating event of an uncontrolled control rod assembly withdrawal at power, will not cause specified acceptable fuel design limits to be exceeded.[28]

III. REVIEW PROCEDURES

1. The review process and the areas examined differ somewhat, depending on whether a BWR or PWR is being reviewed. For both systems, the review covers the entire power range from low to full power and the allowed extreme range of reactor conditions during the operating (fuel) cycle, including rod configurations, power distribution, and associated reactivity feedback components. The continuous withdrawal of normal configurations of rods should be assumed for the initial conditions in the ~~transient~~AOO calculation. For a PWR, this is one or two control banks; for a BWR with current modes of control, it is a single control rod (future modifications under consideration may change this to group movement). The review covers a full range of rod or bank withdrawals, up to maximum rod or bank worths and rates of reactivity addition.

The exact analysis of the ~~transient~~AOO would ideally involve a three-dimensional, coupled neutron kinetics, thermal-hydraulics calculation. However, acceptable results may be obtained with suitable approximate calculations. The problem examined and the approximations used differ for a PWR and a BWR.

2. For a BWR, past analyses and reviews have shown that at maximum rod worths and rates of reactivity addition, the reactor power increases slowly and the total increase is relatively small, so that the ~~transient~~AOO may be approximated by steady-state analyses. Because of changes in local power distribution attributable to rod motion and strong void feedback effects on the power distribution, three-dimensional, steady-state, coupled neutron distribution, thermal-hydraulics calculations that take account of these effects are required. The ~~transient~~AOO is halted by action of a rod block system, which should block rod withdrawal before fuel safety limits are reached.

   The review process for a BWR, while recognizing the inherent ~~transient~~AOO nature of the problem, is concentrated on the steady-state aspects of the ~~transient~~AOO to ~~assure~~ensure[29] that initial and subsequent power distributions are maximized, that the reactor conditions produce minimum critical power ratio, CPR, and that the response of the rod block system is conservatively calculated considering minimum operation of the associated local power range monitoring system.

3. A PWR analysis, on the other hand, generally involves larger power changes and requires ~~transient~~AOO calculations. Because power distributions in the course of the ~~transient~~AOO can frequently be predicted conservatively using design-limit peaking factors, point kinetics may be used for the nuclear ~~transient~~AOO. The nuclear ~~transient~~AOO is coupled, however, to core and system thermal-hydraulic response to the power changes (fuel and moderator thermal feedback and system instrumentation response).

   For a PWR, the reviewer ascertains that a full range of ~~transient~~AOO conditions are explored; that the ~~transient~~AOO calculation models are adequate; and that scram response of the flux, temperature, or pressure instrumentation is correctly calculated. The range of parameters to be considered includes:

   a. Initial power levels from low to full power.

   b. Reactivity insertion rates from very low to maximum possible for the control system, including allowance for uncertainties.

   c. Fuel and moderator feedback reactivity coefficients covering the range expected throughout the cycle, including allowance for uncertainties.

   d. Power peaking factors at design limits for the initial power level conditions.

4. For both types of reactors, the reviewer determines whether the applicant's analytical methods and models are acceptable, including steady-state, ~~transient~~AOO, system

response, and fuel response models. 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 technical assistance requests.

b. Perform a de novo review of the method (usually described in a separate licensing topical report and frequently 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 cover portions of the applicant's analytical methods that are not fully reviewed or approved.

5. For new application reviews, the analysis must consider a loss of offsite power in conjunction with the limiting single active failure when assessing the consequences of the anticipated operational occurrence. (This position is based upon interpretation of GDC 17, as documented in the Final Safety Evaluation Report for the ABB-CE System 80+ design certification.)[30]

6~~5~~. The significant results of the analysis should be presented and should include maximum power levels reached for the reactor and the peak fuel rod, scram or rod block actions that occur, reactor temperatures and pressures, maximum heat flux levels, and the related fuel duty (operating conditions and performance). The latter are compared with the acceptance criteria in subsection II of this SRP section.[31]

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.[32]

IV. EVALUATION FINDINGS

If on completion of the review the staff finds the applicant's analysis acceptable, conclusions of the following type should be included in the staff's safety evaluation report:

1.[33] The possibilities for single failures of the reactor control system which could result in uncontrolled withdrawal of control rods beyond normal limits under power operation conditions have been reviewed.

2. The scope of the review has included investigations of possible initial conditions and the range of reactivity insertions, the course of the resulting ~~transient~~AOO, and the instrumentation response to the ~~transient~~AOO.

3. The methods used to determine the peak fuel rod response, and the input into that analysis, such as power distributions, rod reactivities, and reactivity feedback effects of 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, 17,[34] 20, and 25 have been met. This conclusion is based on the following:

The applicant has met the following requirements ~~of~~:

a. GDC 10 and GDC 17, ensuring that the specified acceptable fuel design limits are not exceeded;

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

c. GDC 25, ensuring[35] 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 ~~assure~~ensure[36] that fuel rod failure will be precluded for this event. The basis for acceptance in the staff review is that the applicant's analysis of maximum ~~transients~~AOOs for single error control rod malfunctions have been confirmed, that the analytical 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.[37]

V. <u>IMPLEMENTATION</u>

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.[38] 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.[39]

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~~."[40]

2. 10 CFR Part 50, Appendix A, General Design Criterion 17, "Electric Power Systems."[41]

3. 10 CFR Part 50, Appendix A, General Design Criterion 20, "Protection System Functions."[42]

4. 10 CFR Part 50, Appendix A, General Design Criterion 25, "Protection System Requirements for Reactivity Control Malfunctions."[43]

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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.	Editorial	Provided "PWR" as initialism for "pressurized water reactor."
4.	Editorial	Provided "BWR" as initialism for "boiling water reactor."
5.	Editorial	Changed "assure" to "ensure."
6.	Integrated Impact No. 1356.	Added requirement for GDC 17 (LOOP).
7.	Editorial	Defined "SRP" as "Standard Review Plan."
8.	SRP-UDP format item	Replaced the word "transient" with "anticipated operational occurrence (AOO)" throughout this SRP section to accommodate Generic Issue B-3.
9.	SRP-UDP format item	Relocated to "Review Interfaces" as item c.
10.	SRP-UDP format item	Added "Review Interfaces."
11.	SRP-UDP format item	Added item a to "Review Interface" since SRXB also reviews SRP Section 4.2.
12.	SRP-UDP format item	Added item b to "Review Interface" since SRXB also reviews SRP Section 4.2.
13.	Current PRB abbreviation	Changed PRB to SRXB.
14.	SRP-UDP format item	Added item d to "Review Interface" since SRXB also reviews SRP Section 4.4.
15.	Editorial	Added "General Design" to "Criterion 10" to provide consistency between SRP sections, and provided "GDC 10" as the corresponding initialism.
16.	Integrated Impact No. 1356.	Added requirement for GDC 17 (LOOP).
17.	Editorial	Added "General Design" to "Criterion 20" to provide consistency between SRP sections, and provided "GDC 20" as the corresponding initialism.
18.	Editorial	Changed "assure" to "ensure."
19.	Editorial	Added "General Design" to "Criterion 25" to provide consistency between SRP sections, and provided "GDC 25" as the corresponding initialism.
20.	Editorial	Changed "assure" to "ensure."
21.	Editorial	Changed "GDC" to "General Design Criterion" to accommodate plural usage.

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Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
22.	Integrated Impact No. 1356.	Added requirement for GDC 17 (LOOP).
23.	SRP-UDP format item	"Technical Rationale" added to Acceptance Criteria and formatted as numbered paragraphs describing the bases for referencing the GDC.
24.	SRP-UDP format item	Added lead-in sentence for "Technical Rationale."
25.	SRP-UDP format item	Added technical rationale for GDC 10.
26.	SRP-UDP format item	Added technical rationale for GDC 17.
27.	SRP-UDP format item	Added technical rationale for GDC 20.
28.	SRP-UDP format item	Added technical rationale for GDC 25.
29.	Editorial	Changed "assure" to "ensure."
30.	**Integrated Impact No. 1356.**	Incorporated new staff position related to LOOP and single failure as a new Review Procedure.
31.	Editorial	Added "section" to complete intent of sentence.
32.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
33.	SRP-UDP format item	Reformatted evaluation findings in numbered form.
34.	Integrated Impact No. 1356.	Added requirement for GDC 17 (LOOP).
35.	Integrated Impact No. 1356.	Reformatted sample finding to improve clarity, including minor editorial revisions and addition of requirement for GDC 17 (LOOP).
36.	Editorial	Changed "assure" to "ensure."
37.	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.
38.	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.
39.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
40.	SRP-UDP format item	Revised reference including three General Design Criteria into separate items.
41.	Integrated Impact No. 1356.	Added GDC 17 as a reference.
42.	Editorial	Revised reference for GDC 20 as a separate item to be consistent with other sections.

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Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
43.	Editorial	Revised reference for GDC 25 as a separate item to be consistent with other sections.

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Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
1356	Added requirements of GDC 17 (LOOP).	Subsections I, II, III, IV, & VI