NUREG-0800
(Formerly NUREG-75/087)

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~~Reactor Systems Branch (~~ASB~~SRXB)[1]

Secondary - ~~None~~Plant Systems Branch (SPLB)[2]

I. AREAS OF REVIEW

The ~~ASB~~SRXB[3] 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~~operational occurrences[4], and prevent or mitigate the consequences of postulated accidents. The ~~ASB~~SRXB[5] review covers the CRDS to assure conformance with the requirements of General Design Criteria 4,[6] 23, 25, 26, 27, 28, and 29 and 10 CFR 50.62(c)(3).[7]

1. ~~ASB~~SRXB[8] reviews the CRDS design for possible single failures.

2. ~~ASB~~SRXB[9] reviews the CRDS to verify that:

   a. Essential portions ~~are isolable~~can be isolated[10] 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.

Review Interfaces:[11]

SRXB also performs the following reviews under the SRP sections indicated:[12]

1. The ~~RSB~~SRXB[13] reviews all transient and accidents in Chapter 15 of the SAR that require reactivity control systems to function. The ~~RSB~~SRXB[14], with the ~~CPB and~~[15] Instrumentation and Controls Branch (HICB)~~ICSB~~[16], 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~~SRXB[17] verifies that no credit has been taken for the Recirculation Flow Control System (RFCS)[18] (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~~SRXB[19] 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~~SRXB[20] 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.

2. As part of its primary review responsibility for SRP Section 4.3, the ~~Core Performance Branch (CPB)~~SRXB[21] verifies the reactivity control requirements.[22]

3. Other reactivity control systems are reviewed by the SRXB as follows:[23] The ~~Auxiliary Systems Branch (ASB)~~SRXB[24] 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)~~SRXB[25] reviews the safety injection system as part of its primary review responsibility for SRP Section 6.3.

In addition, ~~ASB~~SRXB[26] will coordinate other branches'[27] evaluations that interface with the overall review of the control rod system as follows:~~.~~[28]

1. The Instrumentation and Controls~~ Systems~~ Branch (~~ICSB~~HICB)[29] verifies the results of failure modes and effects analyses to assure that a single failure occurring 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.

2. The Mechanical Engineering Branch (EMEB)[30] 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 EMEB[31] 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 EMEB evaluates postulated piping failures inside the containment, including their associated locations and dynamic effects as they relate to the protection of Structures,

Systems, and Components (SSCs) against such effects as part of its primary review responsibility for SRP Section 3.6.2.[32]

3. The ~~Structural~~Civil Engineering and Geosciences Branch (~~SEB~~ECGB)[33] will determine the acceptability of the design and 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.

4. The ~~ICSB~~HICB[34] and ~~Power Systems~~Electrical Engineering Branch (~~PSB~~EELB)[35] 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 ~~ISCB~~HICB[36] and SRP Section 8.3.1 for ~~PSB~~EELB[37].

5. The Plant Systems Branch (SPLB) evaluates potential sources of internal flooding and where applicable, determines that SSCs are adequately protected against the effects of internal flooding, or can otherwise function in the event of such flooding, as part of its primary review responsibility for SRP Section 3.4.1.[38] The SPLB evaluates potential sources of internally-generated missiles, and where applicable, determines that SSCs are adequately protected against the effects of such missiles as part of its primary review responsibility for SRP Sections 3.5.1.1 and 3.5.1.2.[39] The SPLB also verifies the adequacy of specified environments and service conditions for equipment qualification as they relate to the locations of affected equipment and the overall demonstration that systems and components are qualified to perform their function as part of its primary review responsibility for SRP Section 3.11.[40]

6. The review for fire protection, technical specifications, and quality assurance are coordinated and performed by the ~~Chemical Engineering Branch~~(SPLB), ~~Licensing Guidance~~Technical Specifications Branch (TSB), and Quality Assurance and Maintenance Branch (HQMB) as part of their primary review responsibility for SRP Sections 9.5.1, 16.0, and chapter 17~~.0~~, respectively.[41]

7. The ~~Equipment Qualifications Branch (EQB)~~EMEB and SPLB[42] review the seismic qualification of Category I instrumentation and electrical equipment, and the environmental qualification of electrical and mechanical equipment as part of ~~its~~their primary review responsibilities for SRP Sections 3.10 and 3.11, respectively.

8. Other reactivity control systems are reviewed by other Branches[43] as follows: the ~~ICSB~~HICB[44] reviews the recirculation flow control system as part of its primary review responsibility for SRP Section 7.7. The Materials and Chemical Engineering Branch (~~CEB~~EMCB)[45] reviews the chemical and volume control system as part of its primary review responsibility for SRP Section 9.3.4.

9. For new BWR plant applicants, the Control Rod Drive System (Control Rod Drive Pump) may be included in the systematic assessment of shutdown risks as an alternate feature that can provide core inventory makeup in the event of a loss of normal decay heat removal. The Probabilistic Safety Assessment Branch (SPSB) coordinates and performs the shutdown risk assessment reviews as part of its primary review responsibility for SRP Section 19.1 (proposed).[46]

For those areas of review identified above as being reviewed as part of the primary review ~~the~~ responsibility of other branches, the acceptance criteria and their methods of application are contained in the referenced SRP sections of the corresponding ~~to those~~ primary branch~~es~~.[47]

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 4, "Environmental and dynamic effects design bases," as related to the environmental conditions caused by high or moderate energy pipe breaks during normal plant operation as well as postulated accidents.[48]

2~~1~~. General Design Criterion 23, "Protection System Failure Modes," as related to failing into a safe state.

3~~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.

4~~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 normal operations and anticipated[49] operational occurrences.

5~~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 reliably control reactivity changes to assure the capability to[50] cool the core under accident conditions.

6~~5~~. General Design Criterion 28, "Reactivity Limits," as related to postulated reactivity accidents.

7~~6~~. General Design Criterion 29, "Protection Against Anticipated Operational Occurrences," as related to functioning under anticipated operational occurrences~~events~~[51].

8. 10 CFR 50.62, "Requirements for Reduction of Risk from Anticipated Transients Without Scram (ATWS) Events for Light-Water-Cooled Nuclear Power Plants",

paragraph (c)(3), in regard to those requirements that impact the control rod drive system functional design. Specifically for BWRs the alternate rod injection system must be diverse, independent (from the reactor trip system) and must have redundant scram air header exhaust valves.[52]

Technical Rationale:[53]

1. General Design Criterion 4 requires that SSCs be designed to accommodate the effects of, and to be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, and shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from external events. The CRDS provides a capability to safely shutdown the reactor during normal operations, anticipated operational occurrences, and either prevents or mitigates the consequences associated with postulated accident scenarios. The CRDS needs to be designed such that the ability to perform these safety-related functions are not compromised by adverse environmental conditions. Compliance with GDC 4 assures that the CRDS will remain functional under adverse postulated environmental conditions and provide essential reactor shutdown capabilities.

2. General Design Criterion 23 requires that the protection system be designed to fail into a safe state if adverse conditions or environments are experienced. The control rod drive system provides positive core reactivity control through the use of movable control rods. The movable control rods provide reactivity control for all modes of operation inclusive of all plant conditions from the cold shutdown condition to the full load condition. The control rod drive system, in conjunction with the protection system, must actuate the control rods to effect safety-related functions when necessary to provide core protection during normal operation, anticipated operational occurrences and accidents. Meeting the requirements of General Design Criteria 23 provides assurance that the protection system in conjunction with the control rod drive system will fail in a manner that prevents damage to the fuel cladding by providing positive control and prevention of excessive reactivity changes during a failure.

3. General Design Criterion 25 requires that the protection system be designed to assure that specified acceptable fuel design limits are not exceeded for any single malfunction of the reactivity control systems. The control rod drive system provides the motive force for the moveable control rods providing one functional method for reactivity control. Meeting the requirements of General Design Criteria 25 by designing these systems to withstand single failures, ensures that a single malfunction of the rod control drive system, such as accidental withdrawal, will not prevent proper control of core reactivity and therefore will not result in exceeding acceptable fuel design limits. Maintaining acceptable fuel design limits enhances plant safety by preventing the occurrence of mechanisms that could result in fuel cladding damage such as severe overheating, excessive cladding strain or exceeding the thermal margin limits. Preventing excessive cladding damage ensures that the integrity of the cladding as a fission product barrier will be maintained.

4. General Design Criterion 26 requires that two independent reactivity control systems of different design principles be provided, and that each system have the capability of reliably controlling reactivity changes resulting from normal operation. One of the systems shall use control rods and be capable of reliably controlling reactivity changes during anticipated operational occurrences, with appropriate margin for malfunctions such as stuck rods. In addition, one of the systems must be capable of holding the reactor core subcritical under cold conditions. The control rod drive system provides one of the methods for controlling reactivity changes. The control rod drive system is designed to control reactivity during both normal operation and anticipated operational occurrences. The control rod drive system should be capable of rendering a reactor subcritical under conservative conditions with the control rod with the highest rod worth fully withdrawn from the core. The conservative conditions include the highest positive reactivity contributions due to effects such as temperature and power and the lowest negative reactivity contributions from poisons such as Xenon. Meeting the requirements of General Design Criterion 26 ensures that the control rod drive system will be capable of providing sufficient operational control, reliability and safety during reactivity changes, including those during normal operation and anticipated operational occurrences.

5. General Design Criterion 27 requires the reactivity control systems be designed to have a combined capability, in conjunction with poison addition by the emergency core cooling system, of reliably controlling reactivity changes under accident conditions such that the capability to cool the core is maintained. The control rod drive system provides the method for inserting the control rods into the reactor core when monitored plant conditions reach specified safety system setpoints. Insertion of the control rods in conjunction with the poison addition by the emergency core cooling system, provides the means of inserting negative reactivity to rapidly shut the reactor down and ensure core coolability. Coolability, or coolable geometry, implies that the fuel assembly retains its geometry with adequate coolant channels to permit removal of residual heat. Loss of coolability can result from cladding embrittlement, violent expulsion of fuel, generalized cladding melting, structural deformation, and flow blockage due to coplanar fuel rod ballooning. Meeting the requirements of General Design Criterion 27 for the control rod drive systems in conjunction with the emergency core cooling system enhances plant safety by ensuring that the reactor can be shutdown and core coolability will be maintained.

6. General Design Criterion 28 requires that the reactivity control systems be designed with appropriate limits on the potential amount and rate of reactivity increase to prevent the adverse effects of postulated reactivity accidents. A postulated failure of the control rod system such as rod ejection or rod dropout provides the potential for a relatively high rate of positive reactivity insertion which, if large enough, could cause a prompt power excursion. Such a prompt power excursion could cause a fuel element rupture, rapid fragmentation of the fuel cladding and dispersal of fuel and cladding into the coolant. Such an event is accompanied by the conversion of nuclear energy to mechanical energy which if sufficient could breach the reactor coolant pressure boundary or impair the coolability of the core. Meeting the requirements of General Design Criterion 28 for the control rod drive systems enhances plant safety by limiting the effects of postulated

reactivity accidents, thereby mitigating the adverse effects which could result in damage to the reactor coolant pressure boundary or impair the capability to cool the core.

7. General Design Criterion 29 requires that the protection and reactivity control systems be designed to assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences. The control rod drive system is relied upon to function in conjunction with the protection systems under anticipated operational occurrences, including: loss of power to all recirculation pumps, tripping of the turbine generator, isolation of the main condenser, and loss of all offsite power. The control rod drive system provides an adequate means of inserting sufficient negative reactivity to shutdown the reactor and prevent exceeding acceptable fuel design limits during anticipated operational occurrences. Meeting the requirements of General Design Criteria 29 for the control rod drive systems prevents occurrence of mechanisms that could result in fuel cladding damage such as severe overheating, excessive cladding strain or exceeding the thermal margin limits during anticipated operational occurrences. Preventing excessive cladding damage in the event of anticipated transients ensures that the integrity of the cladding as a fission product barrier will be maintained.

8. 10 CFR 50.62(c)(3) requires that each boiling water reactor have an alternate rod injection system that is diverse (from the reactor trip system) from sensor output to the final actuation device. In addition, the alternate rod injection system must have redundant scram air header exhaust valves. There is a potential within all reactor trip system designs for common cause failures of identical or similar components to result in a failure to trip the control rod drive system. The ATWS requirements address this potential and reduces the susceptibility to common mode failures in the scram systems. For BWRs one method of providing diversity in the alternate rod injection system is the use of an "energize to trip" circuit versus a "de-energize to trip" circuit in the output devices of the scram system and by the provision for the redundant scram air header exhaust valves (References 8 and 9). Implementing the requirements of 10 CFR 50.62(c)(3) enhances plant safety by reducing the risk due to an ATWS event at BWR plants, and by providing mitigating capability to permit a safe shutdown of the plant should an ATWS event occur.

III. REVIEW PROCEDURES

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~~SRXB[54] 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~~SRXB[55] 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~~SRXB[56] 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~~HICB[57] 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 EMEB[58], the ~~ASB~~SRXB[59] 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~~SRXB[60] identifies the common mode failures and the ~~ICSB~~HICB, EMEB, and ~~CMEB~~EMCB[61] assist the ~~ASB~~SRXB[62] reviewer in connection with their responsibilities in SRP Sections 7.4, 3.9.4, and 9.3.4 or 9.3.5, respectively.

6. For BWR plants that have a scram discharge volume (SDV), the SRXB reviews the system capabilities and controls to verify that the design of the SDV and its associated systems satisfy the guidance and criteria contained in the NRC BWR Scram Discharge Safety Evaluation Report (References 10, 11 and 12). For BWR plants without an SDV, the guidance and criteria specific to the SDV portions of the system would not apply, however, one of the issues addressed within the SER is the response of the CRD system

to a slow loss of control air pressure in the scram system. For BWR plants without an SDV, the reviewer should verify that the design incorporates features to prevent the loss or impairment of the scram function due to a slow loss of control air pressure in the system.[63]

7. For BWRs the alternate rod injection systems are evaluated in regard to the rod control drive systems to verify the systems have the capability for automatic insertion of all rods by an independent and diverse method (from the reactor protection system) as necessary for mitigation of an ATWS. The evaluation of the alternate rod injection systems includes verification of the use of redundant scram air header exhaust valves.[64]

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.

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.[65]

IV. EVALUATION~~S~~ FINDINGS[66]

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 operation, anticipated operational occurrences, ~~abnormal,~~ and accident conditions, including single failures.[67] 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 operation, anticipated operational occurrences, and accident conditions, including single failures.[68] The staff concludes that the design of the control rod drive system is acceptable and meets the requirements of the General Design Criteria 4,[69] 23, 25, 26, 27, 28, and 29 and 10 CFR 50.62(c)(3).[70] This conclusion is based on the following:

1. The applicant has met the requirements of GDC 4 with respect to the design of the system against the adverse effects of missiles hazards inside the containment, pipe whipping and jets caused by broken pipes, and adverse environmental conditions

resulting from high and moderate energy pipe breaks during normal plant operations, anticipated operations occurrences, and accident conditions.[71]

2~~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.).

3~~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.

4~~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.

5~~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.

6~~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.

7~~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.

8. The BWR applicant has met the requirements of 10 CFR 50.62(c)(3) by demonstrating that the control rod drive system functions in conjunction with an alternate rod insertion system providing the capability for automatic insertion of all rods by an independent and diverse method (from the reactor protection system). In addition, the BWR applicant demonstrates the use of redundant scram air header exhaust valves.[72]

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.[73]

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.

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.[74] 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.

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.[75]

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."

7. 10 CFR 50.62, "Requirements for Reduction of Risk from Anticipated Transients Without Scram (ATWS) Event for Light-Water-Cooled Nuclear Power Plants," paragraph (c)(3).[76]

8. NUREG-0460, Vols. 1-4, "Anticipated Transients Without Scram for Light Water Reactors," Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission.[77]

9. NUREG-1000, Vols. 1-2, "Generic Implications of ATWS Events at the Salem Nuclear Power Plant," Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission.[78]

10. NRC Letter to All BWR Licensees, "BWR Scram Discharge System (Generic Letter No. 80-107)," December 9, 1980.[79]

11. NRC Letter to All BWR Licensees, "BWR Scram Discharge System; Clarification of Diverse Instrumentation Requirement (Generic Letter No. 81-18)," March 31, 1981.[80]

12. Memorandum for G.C. Lainas, from P.S. Check, "BWR Scram Discharge System Safety Evaluation," dated December 1, 1980.[81]

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 names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
2.	Current PRB names and abbreviations.	Editorial change made to reflect the current PRB with secondary review responsibility for this SRP section.
3.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
4.	SRP-UDP format item.	Added the words "operational occurrences" to be consistent with the SRP update guidance.
5.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
6.	Integrated Impact #1418.	Added GDC 4.
7.	Integrated Impact #564.	Added 10 CFR 50.62(c)(3) to the list of acceptance criteria and requirements discussed in the areas of review section as being applicable for the reviews performed by the SRXB.
8.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
9.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
10.	Editorial.	Editorial change to replace the non-standard phrase "are isolable" with the phrase "can be isolated."
11.	SRP-UDP format item, Reformat Areas of Review	Added "Review Interfaces" heading to Areas of Review. Reformatted the existing description of review interfaces in a numbered paragraph format to describe how the SRXB coordinates with the other branch evaluations and how other branches support the review. Several review interfaces have been relocated from their original order in the text to accommodate the new SRP-UDP format. In most cases the original text for these relocated review interfaces was maintained as is. Those changes that were required are appropriately marked.
12.	SRP-UDP format item, reformat Areas of Review.	The Reactor Systems Branch SRXB now has the primary review responsibility for the reviews performed under SRP chapter 15 that require reactivity control systems to function. Therefore, the reviews performed by the Reactor Systems Branch under other SRP sections have been moved to the first section of the Review Interfaces.

SRP Draft Section 4.6

Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
13.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section. The acronym for the Reactor Systems Branch is now SRXB.
14.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section. The acronym for the Reactor Systems Branch is now SRXB.
15.	Current PRB names and responsibilities.	The reference made to the Core Performance Branch (CPB) has been deleted because the Reactor Systems Branch (SRXB) is now responsible for the reviews formerly performed by the CPB.
16.	Current PRB names and responsibilities.	The reference to the ICSB has be updated to the Instrumentation and Controls Branch (HICB) that is now responsible for instrumentation and controls issues.
17.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section. The acronym for the Reactor Systems Branch is now SRXB.
18.	Editorial.	The full definition of the acronym RFCS is Recirculation Flow Control System. Because this is the first use of this acronym, its full definition was added to the text.
19.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section. The acronym for the Reactor Systems Branch is now SRXB.
20.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section. The acronym for the Reactor Systems Branch is now SRXB.
21.	Current PRB names and abbreviations.	The SRXB now has primary review responsibility for the reviews performed under SRP section 4.3. Therefore, Core Performance Branch (CPB) was deleted and replaced with SRXB.
22.	SRP-UDP format item, reformat Areas of Review.	This paragraph describes reviews now performed by the Reactor Systems Branch in other SRP sections and was moved to the first subsection of the new Review Interfaces. The only changes in the described reviews involved the current PRB Branch responsibilities for the review performed under SRP section 4.3.

Item	Source	Description
23.	Editorial and SRP-UDP format item, reformat Areas of Review.	This review interface was moved to this subsection of the Review Interfaces from the previous Areas of Review. The changes in PRB branch responsibilities necessitated splitting this review interface up into two sections. The reviews performed by the SRXB were moved to this subsection of the Review Interfaces section. Those reviews performed by other branches remained in the second subsection on other branches that interface with the overall review. The phrase "by the SRXB" was added to make the distinction between the two similar review interfaces.
24.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 9.3.5.
25.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 6.3.
26.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
27.	Editorial.	The plural of branch was used as there are several PRB branches referenced in the review interface section.
28.	Editorial.	Added a colon to introduce the following series of review interfaces.
29.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 7.2.
30.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 3.9.4.
31.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP sections 3.2.1 and 3.2.2.
32.	Integrated Impact #1418.	In response to an identified issue concerning the lack of explicit discussion in the SRP of reviews of the CRDS for compliance with GDC 4 requirements, this review interface was added reflecting one such review relating to protection of the CRDS against dynamic effects in accordance with the requirements of GDC 4.
33.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and 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.
34.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 7.1 and Appendix 7-A.
35.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 8.3.1.

Item	Source	Description
36.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 7.1 and Appendix 7-A.
37.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 8.3.1.
38.	Integrated Impact #1418.	In response to an identified issue concerning the lack of explicit discussion in the SRP of reviews of the CRDS for compliance with GDC 4 requirements, this review interface was added reflecting a review relating to CRDS functionality in the event the CRDS is subject to flooding effects due to equipment/pipe failures in accordance with the requirements of GDC 4.
39.	Integrated Impact #1418.	In response to an identified issue concerning the lack of explicit discussion in the SRP of reviews of the CRDS for compliance with GDC 4 requirements, this review interface was added reflecting reviews relating to protection of the CRDS against internally-generated missiles in accordance with the requirements of GDC 4.
40.	Integrated Impact #1418.	In response to an identified issue concerning the lack of explicit discussion in the SRP of reviews of the CRDS for compliance with GDC 4 requirements, this review interface was added reflecting reviews relating to design of the CRDS to accommodate accident environmental effects in accordance with the requirements of GDC 4.
41.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP sections 9.5.1, 16.0 and 17.0.
42.	Current PRB names and abbreviations and editorial.	Editorial change made to reflect current PRB name and responsibility for SRP sections 3.10 and 3.11. In addition, an editorial change to replace "its" with "their" was made in this review interface to indicate that the reviews are now done by two branches rather than one.
43.	Editorial.	The changes in PRB branch responsibilities necessitated splitting this review interface up into two sections. The reviews performed by the SRXB were moved to the first subsection of the Review Interfaces section. Those reviews performed by other branches remained in this subsection. The phrase "by other Branches" was added to make the distinction between the two similar review interfaces.
44.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 7.7.

SRP Draft Section 4.6

Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
45.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 9.3.4.
46.	Added Review Interface with Section 19.1, PI #25877.	This review interface identifies reviews conducted to satisfy ABWR FSER and SECY 93-087 guidance on Shutdown and Low Power Operations. The staff requested that design certification applicants complete an assessment of shutdown and low-power risk. The shutdown and low-power risk assessment must identify design-specific vulnerabilities and weaknesses and document consideration and incorporation of design features that minimize such vulnerabilities. The Control Rod Drive system (Control Rod Drive Pumps) were included in the ABWR FSER risk assessment as a system that can provide alternative core inventory capability in the event of the loss of normal decay heat removal. Consideration of this system in the shutdown and low-power risk assessment is the responsibility of the SPSB and will be included in the proposed SRP Section 19.1 on risk assessments.
47.	SRP-UDP format item, editorial	This is an editorial change to modify the concluding statement of the Review Interfaces section so that it is consistent with the format of the SRP-UDP program.
48.	Integrated Impact #1418.	Added GDC 4 as acceptance criteria to support review procedure item III.2 which describes a review verifying that the control rod drive systems is protected against the effects of postulated pipe break accidents.
49.	SRP-UDP format item.	Added normal operations to be consistent with GDC 26. Added the word "anticipated" to be consistent with the SRP update guidance.
50.	Editorial.	This is an editorial change to add the phrase "reliably control reactivity changes to assure the capability to" to the description of General Design Criteria 27. This more fully describes the capability of the reactivity control systems and emergency core cooling systems and is consistent with the wording in Appendix A to 10 CFR 50.
51.	SRP-UDP format item.	Replaced the word "events" with "operational occurrences" to be consistent with the SRP update guidance.
52.	Integrated Impact #564.	10 CFR 50.62 was added to the acceptance criteria to address the requirements for the reduction of risk from anticipated transients without scram events for light water nuclear reactors. The application of this requirement to this SRP section is limited only to those aspects that have a direct impact on the functional design of the control rod drive systems.

Item	Source	Description
53.	SRP-UDP format item, develop Technical Rationales.	Added Technical Rationale for GDC 23, 25, 26, 27, 28, 29 and 10 CFR Part 50.62. Technical Rationale is a new SRP-UDP format item.
54.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
55.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
56.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
57.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP section 7.2.
58.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for the Mechanical Engineering Branch.
59.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
60.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
61.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for SRP sections 7.4, 3.9.4, 9.3.4, and 9.3.5.
62.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB name and responsibility for this SRP section.
63.	Integrated Impact #565.	Added a review procedure to address the staff guidance and criteria contained in the SER and its supplement disseminated by Generic Letters 80-107, and 81-18 respectively. The guidance in the referenced Generic Letters detail acceptable actions and methods for addressing the proper design and modification of the SDV and its associated systems. The criteria and guidance ensures that the SDV is properly designed to prevent the failure of a scram due to insufficient capacity to accept the exhaust flow from the control rod drive mechanisms. In addition, the guidance and criteria that would be applicable to BWRs without an SDV including evolutionary BWRs was clarified. This guidance is consistent with the NRC staff positions on this issue as described in the ABWR FSER.

Item	Source	Description
64.	Integrated Impact #564.	Review Procedures specific to BWRs were added to address the review of the rod control drive system functional requirements in regard to the ATWS requirements contained in 10 CFR 50.62(c)(3). The review procedure addresses the requirements for an alternate rod injection system including redundant scram air header exhaust valves.
65.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
66.	SRP-UDP format change, editorial	This is an editorial change to the title for the Evaluation Findings section. This change was made so that the title is consistent with the SRP-UDP format.
67.	Editorial and GSI B-3 resolution.	Added the phrase "anticipated operational occurrences" so the terminology used in the Evaluation Findings is consistent with the Acceptance Criteria and with items 3 and 6 of the Evaluation Findings. This terminology is also consistent with the findings documented in section 4.6 of the ABWR FSER.
68.	Editorial and GSI B-3 resolution.	Added the phrase "anticipated operational occurrences" so the terminology used in the Evaluation Findings is consistent with the Acceptance Criteria and with items 3 and 6 of the Evaluation Findings. This terminology is also consistent with the findings documented in section 4.6 of the ABWR FSER.
69.	Integrated Impact #1418.	Added GDC 4 to the evaluation findings.
70.	Integrated Impact #564.	Added 10 CFR 50.62(c)(3) to the list of acceptance criteria and requirements discussed in the evaluation findings as being applicable to the findings for the reviews completed by the SRXB.
71.	Integrated Impact #1418.	Added evaluation findings to support compliance with GDC 4.
72.	Integrated Impact #564.	An evaluation finding specific to BWR applicants was added to address the findings in regard to the requirements contained in 10 CFR 50.62(c)(3). The evaluation finding addresses each of the requirements contained in 10 CFR 50.62(c)(3) and is consistent with the editorial style of the existing evaluation findings.
73.	10 CFR 52 applicability issue.	A standard paragraph addressing design certification issues and reviews was appended to the evaluation findings. This paragraph is consistent with the SRP-UDP format regarding design certification reviews.

Item	Source	Description
74.	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.
75.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
76.	Integrated Impact #564.	Added a reference to 10 CFR 50.62(c)(3), "Requirements for Reduction of Risk from Anticipated Transients Without Scram (ATWS) Event for Light-Water-Cooled Nuclear Power Plants".
77.	Integrated Impact #564.	Added a reference to NUREG-0460 which contains relevant documentation and reference material on the staff's resolution of the ATWS issue.
78.	Integrated Impact #564.	Added a reference to NUREG-1000 which contains relevant documentation and reference material on the staff's resolution of the ATWS issue.
79.	Integrated Impact #565.	Added a reference to NRC Generic Letter 80-107. This generic letter contains relevant information and guidance addressing the ability of BWR scram discharge volume systems to operate properly during a scram.
80.	Integrated Impact #565.	Added a reference to NRC Generic Letter 81-18. This generic letter contains relevant information and guidance addressing the ability of BWR scram discharge volume systems to operate properly during a scram.
81.	Integrated Impact #565.	Added a reference to the NRC memorandum that detailed the BWR scram discharge system safety evaluation.

Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
564	Add 10 CFR Part 50.62(c)(3) to the Acceptance Criteria and associated Review Procedures to address the requirements in regard to ATWS for light water nuclear reactors. The application of this requirement was limited only to those aspects that have a direct impact on the functional design of the control rod drive systems.	Areas of Review: First paragraph. Acceptance Criteria: Added item 7. Review Procedures: Added new step 7. Evaluation Findings: Revised last sentence of the third paragraph. Added new conclusion item 7. References: Added new references 7,8 and 9.
565	Add a Review Procedure to address the guidance and criteria contained in Generic Letters 80-107, and 81-18. This issue concerns the capability of the scram discharge volume and associated systems to receive exhaust water from the control rod drive mechanisms in BWRs during a scram.	Review Procedures: Added new step 6. References: Added new references 10, 11, and 12.
1418	Added GDC 4 as acceptance criteria to support review procedure III.2. Developed corresponding evaluation findings. And modified review interface to include other reviews that demonstrate compliance of the CRDS with GDC 4 requirements.	I, II, and IV