U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

BRANCH TECHNICAL POSITION 5-4

DESIGN REQUIREMENTS OF THE RESIDUAL HEAT REMOVAL SYSTEM

REVIEW RESPONSIBILITIES

Primary - Organization responsible for review of reactor thermal hydraulic systems in PWRs and BWRs

Secondary - None

A. BACKGROUND

General Design Criterion (GDC) 19 in Appendix A to 10 CFR Part 50 states that, “A control room shall be provided from which actions can be taken to operate the nuclear power unit under normal conditions...”

Normal operating conditions include the shutting down of a reactor; therefore, since the residual heat removal (RHR) system is one of several systems involved in the normal shutdown of all reactors, this system must be operable from the control room.

GDC 34 states that “Suitable redundance...shall be provided to assure that for onsite electrical power system operation (assuming offsite power is not available) and for offsite electrical power system operation (assuming onsite power is not available), the system safety function can be accomplished, assuming a single failure.”

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In most current plant designs, the RHR system has a lower design pressure than the reactor coolant system (RCS), is located outside of containment, and is part of the emergency core cooling system (ECCS). However, it is possible for the RHR system to have different design characteristics. For example, the RHR system might have the same design pressure as the RCS, or be located inside of containment. The staff will review plants that may have RHR systems that deviate from current designs on a case-by-case basis. This position includes the functional, isolation, pressure relief, pump protection, and test requirements for the RHR system.

B. BRANCH TECHNICAL POSITION

1. Functional Requirements

The system(s) that can be used to take the reactor from normal operating conditions to cold shutdown[1] shall satisfy the following functional requirements:

A. The design shall be such that the reactor can be taken from normal operating conditions to cold shutdown using only safety-grade systems. These systems shall satisfy GDC 1 through 5.

B. The system(s) shall have suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities to ensure that for onsite electrical power system operation (assuming offsite power is not available) and offsite electrical power system operation (assuming onsite power is not available) the system function can be accomplished assuming a single failure.

C. The system(s) shall be capable of being operated from the control room (including instrumentation for monitoring and control functions) with either only onsite or offsite power available. In demonstrating that the system can perform its function assuming a single failure, limited operator action outside of the control room would be considered acceptable if suitably justified.

D. The system(s) shall be capable of bringing the reactor to a cold shutdown condition, with only offsite or onsite power available, within a reasonable period of time following shutdown, assuming the most limiting single failure.

2. RHR System Isolation Requirements

The RHR system shall satisfy the following isolation requirements:

A. The following shall be provided in the suction side of the RHR system to isolate it from the RCS:

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[1] Processes involved in cooldown are heat removal, depressurization, flow circulation, and reactivity control. The cold shutdown condition, as described in the Standard Technical Specifications, refers to a subcritical reactor with a reactor coolant temperature no greater than 93.3°C (200°F) for a pressurized-water reactor (PWR) and 100°C (212°F) for a boiling-water reactor.

i. Isolation shall be provided by at least two power-operated valves in series. The valve positions shall be indicated in the control room.

ii. The valves shall have independent diverse interlocks to prevent the valves from being opened unless the RCS pressure is below the RHR system design pressure. Failure of a power supply shall not cause any valve to change position.

iii. The valves should have independent diverse interlocks to protect against one or both valves being open during an RCS increase above the design pressure of the RHR system, to the extent that such interlocks will not degrade high system reliability during shutdown operations (see Generic Letter 88-17).

B. One of the following shall be provided on the discharge side of the RHR system to isolate it from the RCS:

i. The valves, position indicators, and interlocks described in items 1(a) through 1(c) above.

ii. One or more check valves in series with a normally closed power-operated valve. The power-operated valve position shall be indicated in the control room. If the RHR system discharge line is used for an ECCS function, the power-operated valve is to be opened upon receipt of a safety injection signal once the reactor coolant pressure has decreased below the ECCS design pressure.

iii. Three check valves in series.

iv. Two check valves in series, provided that there are design provisions to permit periodic testing of the check valves for leak tightness and the testing is performed at least annually.

3. Pressure Relief Requirements

The RHR system shall satisfy the following pressure relief requirements:

A. To protect the RHR system against accidental over pressurization when it is in operation (not isolated from the RCS), pressure relief in the RHR system shall be provided with relieving capacity in accordance with the American Society of Mechanical Engineers Boiler and Pressure Vessel Code. The most limiting pressure transient during the plant operating condition when the RHR system is not isolated from the RCS shall be considered when selecting the pressure-relieving capacity of the RHR system. For example, during shutdown cooling in a PWR with no steam bubble in the pressurizer, inadvertent operation of an additional charging pump or inadvertent opening of an ECCS accumulator valve should be considered in the selection of the design bases.

B. Fluid discharged through the RHR system pressure relief valves must be collected and contained such that a stuck open relief valve will not do the following:

i. Result in flooding of any safety-related equipment

ii. Reduce the capability of the ECCS below that needed to mitigate the consequences of a postulated loss-of-coolant accident

iii. Result in a nonisolatable situation in which the water provided to the RCS to maintain the core in a safe condition is discharged outside of the containment

C. If interlocks are provided to automatically close the isolation valves when the RCS pressure exceeds the RHR system design pressure, adequate relief capacity shall be provided during the time period while the valves are closing.

4. Pump Protection Requirements

The design and operating procedures of any RHR system shall have provisions to prevent damage to the RHR system from overheating, cavitation, or loss of adequate pump suction fluid.

5. Test Requirements

The isolation valve operability and interlock circuits must be designed so as to permit online testing when operating in the RHR mode. Testability shall meet the requirements of Institute of Electrical and Electronics Engineers Std 338-1987 and Regulatory Guide 1.22.

The preoperational and initial startup test program shall be in conformance with Regulatory Guide 1.68. The programs for PWRs shall include tests with supporting analysis to (1) confirm that adequate mixing of borated water added before or during cooldown can be achieved under natural circulation conditions and permit estimation of the times required to achieve such mixing, and (2) confirm that cooldown under natural circulation conditions can be achieved within the limits specified in the emergency operating procedures. Comparison with the performance of previously tested plants of similar design may be substituted for these tests.

6. Operational Procedures

The operational procedures for bringing the plant from normal operating power to cold shutdown shall be in conformance with Regulatory Guide 1.33. For PWRs, the operational procedures shall include specific procedures and information required for cooldown under natural circulation conditions. These natural circulation cooldown procedures and analyses should consider the potential for a voiding event in the reactor vessel head and incorporate appropriate controls to address such an occurrence (Generic Letter 92-02).

7. Auxiliary Feedwater Supply

The seismic Category I water supply for the auxiliary feedwater system for a PWR shall have sufficient inventory to permit operation at hot shutdown for at least 4 hours, followed by

cooldown to the conditions permitting operation of the RHR system. The inventory needed for cooldown shall be based on the longest cooldown time needed with either only onsite or only offsite power available with an assumed single failure.

8. Implementation

For the purposes of implementing the requirements for plant heat removal capability to comply with this position, plants are divided into the following three classes:

Class 1 Full compliance with this position for all plant applications that are docketed on or after January 1, 1978. See Table 1 for possible solutions for full compliance.

Class 2 Partial implementation of this position for all plants (custom or standard) for which construction permit or PDA applications are docketed before January 1, 1978, and for which issuance of an operating license is expected on or after January 1, 1979. See Table 1 for recommended implementation for Class 2 plants.

Class 3 The extent to which the implementation guidance in Table 1 will be backfitted for all operating reactors and all other plants (custom or standard) for which issuance of the operating license occurred before January 1, 1979, will be based on the combined I&E and DOR review of related plant features for operating reactors.

C. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 1, “Quality Standards and Records.”

2. 10 CFR Part 50, Appendix A, General Design Criterion 2, “Design Bases for Protection Against Natural Phenomena.”

3. 10 CFR Part 50, Appendix A, General Design Criterion 3, “Fire Protection.”

4. 10 CFR Part 50, Appendix A, General Design Criterion 4, “Environmental and Dynamic Effects Design Bases.”

5. 10 CFR Part 50, Appendix A, General Design Criterion 5, “Sharing of Structures, Systems and Components.”

6. 10 CFR Part 50, Appendix A, General Design Criterion 19, “Control Room.”

7. 10 CFR Part 50, Appendix A, General Design Criterion 34, “Residual Heat Removal.”

8. Regulatory Guide 1.22, “Periodic Testing of Protection System Actuation Functions.”

9. Regulatory Guide 1.33, “Quality Assurance Program Requirements.”

10. Regulatory Guide 1.68, “Initial Test Programs for Water-Cooled Nuclear Power Plants.”

11. Generic Letter 88-17, “Loss of Decay Heat Removal” October 17, 1988.

12. Generic Letter 90-06, “Resolution of Generic Issue 70, ‘Power-Operated Relief-Valve and Block Valve Reliability,’ and Generic Issue 94, ‘Additional Low-Temperature Overpressure Protection for Light-Water Reactors,” June 25, 1990.

13. Generic Letter 92-02, “Resolution of Generic Issue 79, ‘Unanalyzed Reactor Vessel (PWR) Thermal Stress During Natural Convection Cooldown,’” March 6, 1992.

14. NUREG-1316, “Technical Findings and Regulatory Analysis Related to Generic Issue 70—Evaluation of Power- Operated Relief Valve and Block Valve Reliability in PWR Nuclear Power Plants.”

15. Institute of Electrical and Electronics Engineers Std 338-1987, “Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems.”

TABLE 1
POSSIBLE SOLUTION FOR FULL COMPLIANCE WITH BTP 5-4
AND RECOMMENDED IMPLEMENTATION FOR CLASS 2 PLANTS

Design Requirements of BTP 5-4	Process and [System or Component]	Possible Solution for Full Compliance	Recommended Implementation for Class 2 Plants (see Note 1)
I. Functional requirement for taking to cold shutdown: a. Capability using only Safety-grade systems. b. Capability with either only onsite or only offsite power and with a single failure (limited action outside control room to meet the single failure criterion). c. Reasonable time for cooldown assuming most limiting single failure and only offsite or only onsite power.	Long-term cooling [RHR drop line].	Provide double drop line (or valves in parallel) to prevent single valve failure from stopping RHR cooling function. (Note: This requirement in conjunction with meeting the effects of a single failure for long-term cooling and isolation requirements involve increased number of independent power supplies and possibly more than four valves.)	Compliance will not be required if it can be shown that correction for single failure by manual actions inside or outside of containment or return to hot standby until manual actions (or repairs) are found to be acceptable for the individual plant.

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	Heat removal and RCS circulation during cooldown to cold shutdown. (Note: Need steam generator cooling to maintain RCS circulation even after RHR in operation when under natural circulation [steam dump valves].)	Provide safety-grade dump valves, operators, power supply, and other equipment so that manual action should not be required after SSE except to meet the single failure criterion.	Compliance required.
	Depressurization (pressurizer auxiliary spray or PORVs).	Provide upgrading and additional valves to ensure operation of auxiliary pressurizer spray using only safety-grade subsystem meeting failure criterion. Possible alternative may involve using pressurizer PORVs that have been upgraded (see Generic Letter 90-06, NUREG-1316, and SRP Section 3.2.2). Meet SSE and single failure criteria without manual operation inside containment.	Compliance will not be required if (1) dependence on manual actions inside containment after an SSE or single failure or (2) remaining at hot standby until manual actions or repairs are complete are found to be acceptable for the individual plant.

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	Boration for cold shutdown [CVCS and boron sampling]	Provide procedure and upgrading where necessary such that boration to cold shutdown concentration meets the requirements of I. Solution could range from (1) upgrading and adding valves to have both letdown and charging paths at safety grade and meet the single failure criterion to (2) using backup procedures involving less cost. For example, boration without letdown may be acceptable and eliminate the need for upgrading the letdown path. Use of ECCS for injection of borated water may also be acceptable. Need surveillance of boron concentration (boronometer and/or sampling). Limited operator action inside or outside of containment if justified.	Same as above.

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II. RHR isolation	RHR system	Comply with one of the allowable arrangements given.	Compliance required. (Plants normally meet the requirement under existing SRP Section 5.4.7.)
III. RHR pressure relief Collect and contain relief discharge.	RHR system	Determine piping and other equipment needed to meet requirement to provide RHR pressure relief in design.	Compliance will not be required if it is shown that adequate alternate methods of disposing of discharge are available.
V. Test requirement Meet Regulatory Guide 1.68. For PWRs, test plus analysis for cooldown under natural circulation to confirm adequate mixing and cooldown within limits specified in EOP.		Run tests confirming analysis to meet requirement.	Compliance required.
VI. Operational procedure Meet Regulatory Guide 1.33. For PWRs include specific procedures and information for cooldown under natural circulation.		Develop procedures and information from tests and analysis.	Compliance required.

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VII. Auxiliary feedwater supply Seismic Category I supply for auxiliary feedwater for at least 4 hours at hot shutdown plus cooldown to RHR cut-in based on longest time for only onsite or only offsite power and assumed single failure.	Emergency feedwater supply	From tests and analysis obtain conservative estimate of auxiliary feedwater supply to meet requirement and provide seismic Category I supply.	Compliance will not be required if it is shown that an adequate alternate seismic Category I source is available.

Note 1: The implementation for Class 2 plants does not result in a major impact while providing additional capability to go to cold shutdown. The major impact results from the requirement for safety-grade steam dump valves.