U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER^{TM} iPWR DESIGN

5-4 BRANCH TECHNICAL POSITION (iPWRs)

DESIGN REQUIREMENTS OF THE RESIDUAL HEAT REMOVAL SYSTEM

REVIEW RESPONSIBILITIES

Primary - Organization responsible for review of reactor thermal hydraulic systems

Secondary - None

The mPower^{TM} integral pressurized water reactor (iPWR) designed by Babcock and Wilcox (B&W) makes extensive use of passive systems to meet regulatory requirements. Routine residual heat removal (RHR) for the mPower^{TM} iPWR is provided by the reactor inventory control and purification system (RCI) through the non-regenerative heat exchanger under both high pressure and low pressure conditions. The RCI RHR function is included as a non-safety-related, risk-significant active system for use during normal plant operation, shutdown and to provide defense in depth to the safety-related passive system. RCI is a regulatory treatment of non-safety related system (RNTSS) system. The non-safety-related active system is the first line of defense to reduce challenges to the passive system in the event of transients or plant upsets. The mPower^{TM} iPWR safety-related RHR function is provided by the passive decay heat removal system, an engineered safety feature (ESF) of the mPower^{TM} design, which is evaluated in DSRS Section 6.3.

Branch Technical Position (BTP) 5.4 is written for iPWRs in general; therefore, sections of this procedure are applicable to mPower^{TM} design control document (DCD) Sections 6.3 and 9.3.6.

A. BACKGROUND

General Design Criterion (GDC) 19 in Appendix A to Part 50 of the *Code of Federal Regulations* (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 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.”

In most current pressurized water reactor (PWR) plant designs, the RHR system is an active system with a lower design pressure than the reactor coolant system (RCS), is located outside

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of containment, and is part of the emergency core cooling system (ECCS). However, mPower™ iPWR safety-related RHR systems are typically passive designs with different design characteristics. For example, an iPWR safety-related RHR system might be capable of operating for 72 hours or more without operator intervention; have the same design pressure as the RCS; or be located inside of containment. Additionally, an iPWR design may have a safety-related passive RHR system with an active non-safety-related backup system that operates under normal plant conditions. 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. For iPWRs, the safety-related systems are passive; however, the active back-up systems may be risk significant but nonsafety-related as determined under DSRS Section 19.0 using the selection criteria under Section C.IV.9.3 of Regulatory Guide (RG) 1.206.

B. The passive safety-related 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 passive safety-related and the active risk significant nonsafety-related system(s) shall be capable of being operated or controlled from the control room (including instrumentation for monitoring and control functions) with either only onsite or offsite power available. In demonstrating that the passive safety-related 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 passive safety-related 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.

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[1] Processes involved in cooldown are heat removal, depressurization, flow circulation, and reactivity control. The cold shutdown condition for a PWR, as described in the Standard Technical Specifications (NUREG-1430, Table 1.1-1, MODE 5), refers to a subcritical reactor with a reactor coolant temperature no greater than 93.3°C (200°F). Values for an iPWR design should be similar.

2. <u>RHR System Isolation Requirements</u>

The RHR system shall satisfy the following isolation requirements:

A. The following shall be provided in the high temperature or suction side of the RHR system to isolate it from the RCS if the RHR system has a lower design pressure than the RCS:

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 (GL) 88-17).

B. One of the following shall be provided on the low temperature or 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. <u>Pressure Relief Requirements</u>

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 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 active 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 Standard 338-1987 and RG 1.22.

The preoperational and initial startup test program shall be in conformance with RG 1.68. The programs for iPWRs 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 in iPWR designs where chemical shim is utilized 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 RG 1.33. For iPWRs, 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 (GL 92-02).

7. Auxiliary Feedwater Supply

If an iPWR design utilizes a safety-related auxiliary feedwater (AFW) system, then the seismic Category I water supply for the AFW system 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 passive safety-related or the active risk significant nonsafety-related RHR system. The inventory needed for cooldown shall be based on the longest cooldown time needed using natural circulation or with either only onsite or only offsite power available with an assumed single failure.

8. Implementation

The staff will use this design specific review standard (DSRS) section in performing safety evaluations of mPower™-specific design certification (DC), or combined license (COL), applications submitted by applicants pursuant to 10 CFR Part 52. The staff will use the method described herein to evaluate conformance with Commission regulations.

Because of the numerous design differences between the mPower™ and large light-water nuclear reactor power plants, and in accordance with the direction given by the Commission in Staff Requirements Memorandum SRM- COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010 (ML102510405), to develop risk-informed licensing review plans for each of the small modular reactor reviews including the associated pre-application activities, the staff has developed the content of this DSRS section as an alternative method for mPower™ -specific DC, or COL submitted pursuant to 10 CFR Part 52 to comply with 10 CFR 52.47(a)(9), "Contents of applications; technical information."

This regulation states, in part, that the application must contain "an evaluation of the standard plant design against the Standard Review Plan (SRP) revision in effect six months before the docket date of the application." The content of this DSRS section has been accepted as an alternative method for complying with 10 CFR 52.47(a)(9) as long as the mPower™ DCD final safety analysis report does not deviate significantly from the design assumptions made by the U.S. Nuclear Regulatory Commission staff while preparing this DSRS section. The application must identify and describe all differences between the standard plant design and this DSRS section, and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria. If the design assumptions in the DC application deviate significantly from the DSRS, the staff will use the SRP as specified in 10 CFR 52.47(a)(9). Alternatively, the staff may supplement the DSRS section by adding appropriate criteria in order to address new design assumptions. The same approach may be used to meet the requirements of 10 CFR 52.79(a)(41), and COL applications.

C. REFERENCES

1. 10 CFR Part 50, Appendix A, GDC 1, "Quality Standards and Records."

2. 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena."

3. 10 CFR Part 50, Appendix A, GDC 3, "Fire Protection."

4. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases."

5. 10 CFR Part 50, Appendix A, GDC 5, "Sharing of Structures, Systems and Components."

6. 10 CFR Part 50, Appendix A, GDC 19, "Control Room."

7. 10 CFR Part 50, Appendix A, GDC 34, "Residual Heat Removal."

8. RG 1.22, "Periodic Testing of Protection System Actuation Functions."

9. RG 1.33, "Quality Assurance Program Requirements."

10. RG 1.68, "Initial Test Programs for Water-Cooled Nuclear Power Plants."

11. RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)"

12. GL 88-17, "Loss of Decay Heat Removal" October 17, 1988.

13. GL 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.

14. GL 92-02, "Resolution of Generic Issue 79, 'Unanalyzed Reactor Vessel (PWR) Thermal Stress During Natural Convection Cooldown,'" March 6, 1992.

15. 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."

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