U.S. NUCLEAR REGULATORY COMMISSION

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

10.4.1 MAIN CONDENSERS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of power conversion systems

Secondary - None

I. AREAS OF REVIEW

The main condenser (MC) system is designed to condense and deaerate the exhaust steam from the main turbine and provide a heat sink for the turbine bypass system. The exhaust steam is condensed into water, and the water is pumped out of the condenser back to the steam generator. In a pressurized-water reactor (PWR) or integral pressurized water reactor (iPWR), the main condenser may contain radioactive materials in the event of primary to secondary system leakage. The review will be focused on the design features incorporated to control the release of radioactive material to the environment, fire/explosions, and flooding that may affect the ability of safety-related or risk-significant structure, systems, and components (SSCs) to perform their functions.

The specific areas of review are as follows:

1. The design, design objectives, capacity, method of operation, and factors that influence gaseous radioactive material handling, e.g., system interfaces and potential bypass routes. The review may include the system piping and instrumentation diagrams as needed.

2. The means to prevent corrosion and/or erosion of condenser tubes, and detect, control and facilitate correction of the leakage of cooling water into the condensate.

3. The means to detect radioactive leakage into or out of the system and to preclude accidental releases of radioactive materials to the environment in amounts in excess of established limits.

4. Instrumentation and control features that determine and verify that the MC is operating in a correct mode.

5. The means provided to deal with flooding from a complete failure of the MC and to preclude damage to safety-related or risk-significant equipment from the flooding.

6. The capability of the MC to withstand the blowdown effects of steam from the turbine bypass system.

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7. If the potential for explosive mixtures exist, design features to preclude the possibility of an explosion which could cause a release of radioactive material to the environment.

8. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the SSCs related to this design-specific review standard (DSRS) section in accordance with DSRS Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this DSRS section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with DSRS Sections 14.3 and 14.3.7.

9. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

   For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

Review Interfaces

Other DSRS or standard review plan (SRP) sections interface with this section as follows:

1. Review of the acceptability of the seismic and quality group classifications is performed under DSRS Sections 3.2.1 and 3.2.2.

2. Review to determine that safety-related or risk-significant systems and structures are protected from the effects of flooding from a complete failure of the MC is performed under DSRS Section 3.4.1.

3. Review of seismic analyses is performed under DSRS Section 3.7.2.

4. Review of the instrumentation in place to monitor condensate quality and detect MC tube leakage is performed under DSRS Section 9.3.2.

5. Review of fire protection is performed under SRP Section 9.5.1.

6. Review of design features to preclude the possibility of an explosion if the potential of hydrogen and oxygen explosive mixtures exist in the system is performed under DSRS Section 11.3.

7. Review of the measures in place to monitor the inventory of radioactive materials in the MC and detect radioactive leakage into or out of the system is performed under DSRS Section 11.5.

8. Review of initial plant test program under DSRS Section 14.2.

9. Review of technical specifications is performed under DSRS Section 16.0.

10. Review of quality assurance is performed under SRP Chapter 17.

11. The review of risk classification is in SRP Section 19.3.

II. ACCEPTANCE CRITERIA

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. General Design Critieron (GDC) 3, as it relates to SSCs important to safety being protected from the effects of fire and explosion and minimize the probability of fire and explosion.

2. GDC 4, as it relates to SSCs important to safety being designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing and postulated accidents, including loss-of-coolant accidents.

3. GDC 60, as it relates to the capability to control releases of radioactive materials to the environment. The design of the MC is acceptable if the integrated design of the system meets the requirements of GDC 60 as related to failures in the design of the system, which do not result in excessive releases of radioactivity to the environment.

4. Title of the *Code of Federal Regulations* (CFR), Section 20.1406 as it relates to facility design and procedures for operation that will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

5. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulatory Commission's (NRC's) regulations;

6. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will be operated in conformity with the COL, the provisions of the AEA, and the NRC's regulations.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are set forth belowas follows for review described in this DSRS section. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required. Identifying the differences between this DSRS section and the design features, analytical techniques, and procedural measures proposed for the facility, and discussing how the proposed alternative provides an acceptable method of complying with the regulations that

underlie the DSRS acceptance criteria, is sufficient to meet the intent of 10 CFR 52.47(a)(9), "Contents of applications; technical information." The same approach may be used to meet the requirements of 10 CFR 52.79(a)(41) for COL applications.

1. The requirements of GDC 3 are met when SSCs important to safety are designed and located to minimize the probability and effect of fire and explosion resulting from the explosive mixtures in the MC.

2. The requirements of GDC 4 are met when SSCs important to safety are protected from adverse impacts of flooding associated with MC system failures.

3. The requirements of GDC 60 are met when the MC design includes provisions to prevent excessive releases of radioactivity to the environment which may result from a failure of a structure, system or component in the MC.

4. The requirements of 10 CFR 20.1406 are met when the design and procedures identify provisions to detect contamination that may enter as in-leakage from other systems, identifies potential collection points such as water treatment systems or system low points, and addresses the long-term control of radioactive material in the system.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this DSRS section is discussed in the following paragraphs:

1. Compliance with GDC 3 provides assurance that the probability of fire/explosion is minimized and that SSCs important to safety are protected from the effects of an explosive mixture of hydrogen and oxygen in the MC.

2. Compliance with GDC 4 requires, in part, that SSCs important to safety are appropriately protected from the environmental conditions, including flooding. GDC 4 applies to this DSRS section because flooding resulting from a failure of the MC system can potentially cause a loss of function of safety-related or risk-significant SSCs. Meeting this requirement provides assurance that flooding resulting from a MC system failure will not result in a loss of function of safety related or risk-significant SSCs.

3. Compliance with GDC 60 requires that provisions be included in the nuclear power unit design to control suitably the release of radioactive materials in gaseous and liquid effluents during normal operation, including anticipated operational occurrences (AOOs).

   In PWRs, radioactive materials may be deposited in the main condensers if there is a primary-to-secondary steam generator tube leak. Measures are taken to prevent uncontrolled release of these radioactive materials to the environment.

   Meeting these requirements provides a level of assurance that the release of radioactive materials in gaseous and liquid effluents from the main condensers during normal operation, including AOOs, is kept as low as is reasonably achievable, in accordance with 10 CFR Part 50, Appendix I.

4. The capability to detect and isolate radioactive material in the MC would minimize, to the extent practicable, contamination of the condensate and feedwater systems and the

environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste in accordance with 10 CFR 20.1406.

III. REVIEW PROCEDURES

The reviewer will select material from the procedures described below, as may be appropriate for a particular case.

These review procedures are based on the identified DSRS acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

1. Programmatic Requirements ─ In accordance with the guidance in NUREG-0800 "Introduction," Part 2 as applied to this DSRS Section, the staff will review the programs proposed by the applicant to satisfy the following programmatic requirements. If any of the proposed programs satisfies the acceptance criteria described in Subsection II, it can be used to augment or replace some of the review procedures. It should be noted that the wording of "to augment or replace" applies to nonsafety-related risk-significant SSCs, but "to replace" applies to nonsafety-related nonrisk-significant SSCs according to the "graded approach" discussion in NUREG-0800 "Introduction," Part 2. Commission regulations and policy mandate programs applicable to SSCs that include:

   A. Maintenance rule, SRP Section 17.6 (DSRS Section 13.4, Table 13.4, Item 17, Regulatory Guide (RG) 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," and RG 1.18, "Assessing and Managing Risk Before Maintenance Activities at Nuclear Power Plants."

   B. Quality Assurance Program, SRP Sections 17.3 and 17.5 (DSRS Section 13.4, Table 13.4, Item 16).

   C. Technical Specifications (DSRS Section 16.0 and SRP Section 16.1) – including brackets value for DC and COL. Brackets are used to identify information or characteristics that are plant specific or are based on preliminary design information.

   D. Reliability Assurance Program (SRP Section 17.4).

   E. Initial Plant Test Program (RG 1.68, "Initial Test Programs for Water-Cooled Nuclear Power Plants," DSRS Section 14.2, and DSRS Section 13.4, Table 13.4, Item 19).

   F. ITAAC (DSRS Chapter 14).

2. In accordance with 10 CFR 52.47(a)(8),(21), and (22), for new reactor license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues that are identified in the version of NUREG-0933 current on the date 6 months before application and that are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any

technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v). These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding safety evaluation report (SER) section.

3. Determine that any allowed MC system degraded operation does not have an adverse effect on the reactor primary system or secondary system in the case of a PWR to perform its safety related or risk-significant functions.

4. Verify the following:

   A. Means have been provided for controlling and correcting condenser cooling water leakage into the condensate.

   B. Upon request, the MC system is reviewed for the compatibility of the materials of construction with the service conditions and the methods used to reduce the corrosion and/or erosion of MC tubes and components.

5. The reviewer uses engineering judgment and the results of failure modes and effects analyses to determine that:

   A. The safety-related or risk-significant systems and structures are protected from the effects of flooding resulting from a complete failure of the MC. Confirm this is satisfactorily reviewed under DSRS Section 3.4.1, which could have a limiting case from a failure of other systems that is more severe than the MC failure. If not, perform such a review by assuming a failure of the MC.

   B. If there is a potential for explosive mixtures to exist,

      (1) instruments are designed to detect, annunciate, and effect control measures to prevent the buildup of potentially explosive mixtures, as outlined in DSRS Section 11.3 to preclude the occurrence of an explosion, or

      (2) the MC is designed to withstand the effects of an explosion, which include the release of radioactive materials to the environment and protection of surrounding SSCs from performing their safety-related or risk-significant functions.

   C. The system, in conjunction with the main steam system, has provisions to detect loss of condenser vacuum and to effect isolation of the steam source. For direct cycle plants, it will be acceptable if the detection system in the MC can actuate the main steam isolation valves to limit the quantity of steam lost to the MC.

   D. Design provisions have been incorporated into the MC that will preclude component or tube failures due to steam blowdown from the turbine bypass system.

6. Using the guidance provided in RG 4.21, the applicant should address how they will comply with the requirements of 10 CFR 20.1406.

For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the final safety analysis report (FSAR) meets the acceptance criteria. DCs have referred to the FSAR as the design control document (DCD). The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC technical submittal.

For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an early site permit or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

For review of both DC and COL applications, DSRS Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the staff's technical review and analysis, as augmented by the application of programmatic requirements, in accordance with the staff's review approach in the SRP Chapter 0, support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

The MC system includes all components and equipment from the turbine exhaust to the connections and interfaces with the main condensate and other systems. The staff concludes that the MC system design is acceptable and meets the following requirements: (1) GDC 3 with respect to minimizing fire/explosion hazards to SSCs important to safety, (2) GDC 4 with respect to flooding of SSCs important to safety, (3) GDC 60 with respect to excessive releases of radioactivity to the environment, and (4) 10 CFR 20.1406, as it relates to facility design and procedures for operation that will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this DSRS section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

V. IMPLEMENTATION

The staff will use this DSRS section in performing safety evaluations of mPower^{TM}-specific DC, or 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^{TM} and large light-water nuclear reactor power plants, and in accordance with the direction given by the Commission in 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 (Agencywide Documents Access and Management System Accession No. 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 6 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 FSAR does not deviate significantly from the design assumptions made by the NRC staff while preparing this DSRS section. cThe 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) for COL applications.

VI. REFERENCES

1. 10 CFR 20.1406, "Minimization of Contamination."

2. 10 CFR Part 50, Appendix A, GDC 3, "Fire Protection."

3. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases."

4. 10 CFR Part 50, Appendix A, GDC 60, "Control of Releases of Radioactive Materials to the Environment."

5. 10 CFR Part 50, Appendix I, "Numerical Guides For Design Objectives and Limiting Conditions For Operation to Meet the Criterion 'As Low as is Reasonably Achievable' For Radioactive Material in Light Water Cooled Nuclear Power Reactor Effluents."

6. 10 CFR Part 52, "Licenses, Certifications, and Approvals For Nuclear Power Plants."

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

8. RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning."