U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER™ iPWR DESIGN

6.2.2 CONTAINMENT HEAT REMOVAL SYSTEMS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of containment integrity

Secondary - None

I. AREAS OF REVIEW

Babcock & Wilcox Nuclear Energy mPower™ is an integral pressurized-water reactor with the reactor, steam generator, pressurizer, and control rod drives all located in a single pressure vessel. The mPower™ reactor containment is a free-standing carbon steel structure that is located below grade level.

The review includes the information in the application concerning containment heat removal under post-accident conditions to ensure conformance with the requirements of General Design Criteria (GDCs) 38, 39, and 40 of Appendix A to Title 10 of the *Code of Federal Regulations* (CFR), Part 50 and 10 CFR 50.46(b)(5). The ultimate heat sink (UHS) removes heat from the containment atmosphere.

The mPower™ containment heat removal systems may include the following classifications of equipment:

1. Safety-related and risk-significant equipment

2. Safety-related and nonrisk-significant equipment

3. Nonsafety-related and risk-significant Regulatory Treatment of Nonsafety Systems (RTNSS) equipment

4. Nonsafety-related and nonrisk-significant equipment.

The mPower™ application will include the classification of systems, structures, and components (SSCs), a list of risk-significant SSCs, and a list of RTNSS equipment. Based on this information, the staff will review according to Design-Specific Review Standard (DSRS) Section 3.2, and Standard Review Plan (SRP) Sections 17.4 and 19.3 to confirm the determination of safety-related and risk-significant SSCs.

The specific areas of review are as follows:

1. Analyses of the consequences of single component malfunctions.

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2. The potential for surface fouling on the bottom of the UHS tank on the containment dome and the effect on passive containment heat removal performance.

3. The design provisions and proposed program for periodic inservice inspection and operability testing of each system or component.

4. The design of UHS for containment heat removal.

5. Combined License (COL) Action Items and Certification Requirements and Restrictions. For a design certification (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 SRP and DSRS sections interface with this section as follows:

1. Review of the sensing instrumentation provided for the containment heat removal systems is performed under DSRS Section 7.3.

2. Review of the seismic qualification test program for the containment heat removal system such as [the UHS tank welds, restraints and anchorages] is performed under DSRS Sections 3.7.2 and 3.9.6.

3. Review of fission product control features is performed under SRP Section 6.5.3.

4. Review of the system seismic design and quality group classification of the containment heat removal systems is performed under DSRS Sections 3.2.1 and 3.2.2.

5. Review of the in-containment passive heat sinks provided by the intermediate pressure injection tanks (IPITs) and refueling water storage tanks (RWSTs) is provided in DSRS Section 6.3.

6. Review of the UHS tank functional requirements is performed under DSRS Section 9.2.5.

7. Review of the proposed technical specifications for each system at the operating license stage of review is performed under DSRS Section 16.0.

8. Determination of structures, systems and components risk significance is performed under SRP Chapter 19.

9. Review of containment performance under both large break and small break loss-of-coolant accidents (LOCA) is performed under DSRS Section 15.6.5, for a spectrum of postulated pipe break sizes and locations within the reactor coolant pressure boundary.

II. ACCEPTANCE CRITERIA

Requirements

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

1. GDC 5, as it relates to providing assurance that sharing of SSCs important to safety among nuclear power units will not significantly impair their ability to perform their safety functions.

2. GDC 38, as it relates to the following:

   A. The ability of the containment heat removal system to rapidly reduce the containment pressure and temperature following a LOCA and to maintain these indicators at acceptably low levels.

   B. The ability of the containment heat removal system to perform in a manner consistent with the function of other systems.

   C. The safety-grade design of the containment heat removal system (i.e., suitable redundancy in components and features and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to ensure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished in the event of a single failure).

3. GDC 39, as it relates to the design of the containment heat removal system to permit periodic inspection of components.

4. GDC 40, as it relates to the design of the containment heat removal system to allow periodic testing to ensure system integrity and the operability of the system and active components.

5. 10 CFR 50.46(b)(5), as it relates to requirements for long-term cooling.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are set forth below. 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 containment heat removal systems should meet the redundancy and power source requirements for an engineered safety feature (i.e., the results of failure modes and

effects analyses of each system should ensure that the system is capable of withstanding a single failure without loss of function). This conforms to the requirements of GDC 38.

2. In evaluating the heat removal capability of the containment heat removal system to satisfy GDC 38, the analyses of its heat removal capability should account for the potential for surface fouling of the UHS tank floor by the stored cooling water over the life of the plant and the effect of surface fouling on the heat removal capacity of the UHS tank. The application should discuss the results of the analysis. The results will be acceptable if they demonstrate that provisions such as closed cooling water systems are provided to prevent surface fouling or that surface fouling has been taken into account in the establishment of the heat removal capability of the heat exchangers.

   mPower™ plans to remove the core decay heat via natural circulation inside the containment and the UHS tank, such that no residual heat removal heat exchanger and fan cooler are used. The analysis should involve natural-circulation based decay heat removal. This would potentially need a test program and simulation models to demonstrate the performance capabilities and transient response of the containment and UHS tank under natural circulation conditions. mPower™ design specific single-phase and two-phase heat transfer correlations may be needed to handle natural circulation conditions within the containment and the UHS tank. Condensation calculations should also account for the effect of non-condensable gases. The impact of any surface coatings used has to be assessed on boiling/condensation heat transfer from the surface. These activities would also involve validation and verification of the computer codes, as well as the scaling and uncertainty analyses of any experimental data.

3. In meeting the requirements of GDCs 39 and 40 regarding inspection and testing, the design of the containment heat removal systems should provide for periodic inspection and operability testing of the systems and system components.

4. To satisfy the system design requirements of GDC 38, instrumentation should be provided to monitor the performance of the containment heat removal system and its components under normal and accident conditions. The instrumentation should determine whether a system is performing its intended function or whether a system train or component is malfunctioning and should be isolated. The containment heat removal system for normal operation is the nonsafety-related annulus ventilation system, and the systems for accident conditions are the combined capacities of the IPITs, RWSTs, and the UHS tank on the containment dome serving as passive heat dumps.

<u>Technical Rationale</u>

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. GDC 5, as it relates to providing assurance that sharing of SSCs important to safety among nuclear power units will not significantly impair their ability to perform their safety functions.

   GDC 5 applies to this DSRS section because the dual reactors with dual containments share structures, and may share systems or components important to safety.

2. Compliance with GDC 38 requires that systems be provided to remove heat from the reactor containment. The system safety function is to rapidly reduce containment pressure and temperature after any LOCA and to maintain these indicators at acceptably low levels.

   Meeting the requirements of GDC 38 regarding the characteristics and designs of containment heat removal systems provides assurance that containment pressure and temperature will be reduced to and maintained at acceptably low levels after any LOCA, thereby protecting the safety function of the containment as an engineered safety feature.

3. Compliance with GDC 39 requires that the designs of containment heat removal systems allow for appropriate periodic inspection of important components, such as the passive in-containment heat dumps provided by the in-containment steel and concrete structures, IPITs, and RWSTs, and the UHS tank on the containment dome to ensure the integrity and capability of these systems. The ECCS passive heat dumps provided by the IPITs and RWSTs are reviewed under GDC 36 as described in DSRS Section 6.3.

   This DSRS section describes staff positions related to the inspection of containment heat removal systems, indicating that provisions should be made for periodic inspection of system components.

   Meeting the requirements of GDC 39 with regard to periodic inspection of containment heat removal systems provides assurance that containment pressure and temperature will be reduced to and maintained at acceptably low levels after any LOCA, thereby protecting the safety function of the containment as an engineered safety feature.

4. Compliance with GDC 40 requires that the design of containment heat removal systems permits periodic pressure and functional testing to ensure leaktight integrity of components, such as passive heat dumps provided by IPITs, RWSTs, and the UHS tank, as well as overall system availability and functionality for passive performance of safety-related functions. The periodic pressure and functional testing of IPITs and RWSTs is performed under GDC 37 as described in DSRS Section 6.3.

   This DSRS section describes staff positions related to the testing of containment heat removal systems, indicating that provisions should be made for startup and periodic operability testing of these systems and their components.

   Meeting the requirements of GDC 40 with regard to testing of containment heat removal systems provides assurance that containment pressure and temperature are reduced to and maintained at acceptably low levels after any LOCA, thereby protecting the safety function of the containment as an engineered safety feature.

III. REVIEW PROCEDURES

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.

The procedures described below provide guidance for the review of containment heat removal systems. The reviewer selects and emphasizes material from the review procedures as may be appropriate for a particular case.

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 1.182, "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. Upon request from the primary review organization, the review organizations with review interface responsibilities, as noted in Subsection I, will provide input for the areas of review, as stated in Subsection I of this DSRS section. The input obtained will ensure that the review is complete. The primary review organization ensures that the design

and functional capability of the containment heat removal system conforms to the requirements of 10 CFR 50.46(b)(5) and GDCs 38, 39, and 40.

4. The acceptability of the containment heat removal system design is determined by reviewing the system to ensure the following:

   A. All potential single failures have been identified in accordance with GDC 38, and no single failure could incapacitate the entire system.

   B. Engineered safety feature design standards have been applied.

   C. The system design provisions for periodic inservice inspection and operability testing ensure that the system and components are accessible for inspection and all active components can be tested.

   D. The capability exists to monitor system performance from the control room.

5. 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 design control document. 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 design control document.

   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).

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable), as augmented by the application of programmatic requirements in accordance with the staff's technical review approach in the DSRS Introduction, support conclusions of the following type to be included in the staff's SER. The reviewer also states the bases for those conclusions.

1. Containment Heat Removal Systems

The containment heat removal systems include the safety-related UHS tank plus the safety-related IPITs and RWSTs that serve as in-containment heat sinks.

The scope of review of the containment heat removal systems for the (plant name) included system drawings and descriptive information. The review included the applicant's proposed design bases for the containment heat removal systems and analyses of the functional capability of the systems.

The staff concludes that the design of the containment heat removal system is acceptable and meets the requirements of 10 CFR 50.46(b)(5) and GDCs 38, 39, and 40.

The conclusion is based on the following:

A. The staff's review indicates that the applicant complied with GDC 38 by providing containment heat removal systems consisting of (list systems). The staff's review indicates that the systems will be capable of performing their intended safety function, which is to rapidly reduce containment pressure and temperature and to maintain these indicators at acceptably low levels after any LOCA. Suitable redundancy in components and features and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to ensure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished in the event of a single failure.

B. The staff's review indicates that the applicant complied with GDC 39 by designing the containment heat removal system to permit appropriate periodic inspection of risk-significant components of the system such as the UHS, IPITS, and RWSTs. (Other or additional examples may be appropriate.)

C. The staff's review indicates that the applicant complied with GDC 40 by designing the containment heat removal systems to permit appropriate periodic pressure and functional testing to ensure the structural and leaktight integrity of their components; the operability and performance of the components of the systems such as UHS, IPITS, and RWSTs; and the operability of the systems as a whole. Testing will be conducted to ensure the performance of the full operational sequence that brings the systems into operation under conditions as close to design as practical, including operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of associated systems.

D. The staff's review indicates that the applicant has demonstrated adequate long-term core cooling in accordance with 10 CFR 50.46(b)(5).

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.

V. IMPLEMENTATION

The staff will use this DSRS section in performing safety evaluations of mPower™-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™ 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. 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) for COL applications.

VI. REFERENCES

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

2. RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."

3. RG 1.174, Revision 1, An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant Specific Changes to the Licensing Basis, U.S. Nuclear Regulatory Commission, November 2002.

4. RG 1.182, "Assessing and Managing Risk before Maintenance Activities at Nuclear Power Plants."

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

6. RG 1.215, "Guidance for ITAAC Closure Under 10 CFR Part 52."