U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

9.2.5 ULTIMATE HEAT SINK

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of cooling water systems

Secondary - None

I. AREAS OF REVIEW

The ultimate heat sink (UHS) typically consists of an assured supply of water that is credited for dissipating reactor decay heat and essential station heat loads after a normal reactor shutdown or a shutdown following an accident or transient, including a loss-of-coolant accident (LOCA). Many commercial nuclear power plants also rely upon the atmosphere for performing the UHS function to some extent in conjunction with the assured supply of cooling water, such as in the case of spray ponds and cooling towers; and passive reactor plant designs may rely more exclusively on the atmosphere for dissipating reactor decay heat immediately following plant transient and accident conditions.

This SRP section provides guidance for evaluating the capability of water sources for performing the UHS function in accordance with the requirements specified by General Design Criteria (GDC) 2, 5, 44, 45, and 46. SRP Section 2.4.11, "Cooling Water Supply," provides guidance for evaluating the effects of atmospheric conditions on the inventory and temperature of the UHS water supply, such as for spray ponds and cooling towers; and the capability of passive containment cooling systems to dissipate accident heat loads is evaluated in accordance with the guidance provided in SRP Section 6.2.2, "Containment Heat Removal Systems." These review considerations are not included within the scope of this SRP section.

The water sources that make up the UHS are reviewed to assure that they are capable of performing their safety functions. This review includes the size, type of cooling water supply (e.g., ocean, lake, natural or manmade reservoir, river, or cooling tower), makeup sources to

the ultimate heat sink, and the capability of the heat sink to deliver the required flow of cooling water at appropriate temperatures for normal, accident, or shutdown reactor condition. The UHS is reviewed for whether the design code requirements that are pertinent to this review are met.

The specific areas of review are as follows:

1. The type of cooling water supply.

2. The ability to dissipate the total essential station heat load.

3. The effect of environmental conditions on UHS capability to furnish the required quantities of cooling water at appropriate temperatures and with any required chemical and purification treatment for extended times after shutdown.

4. The effect of earthquakes, tornadoes, missiles, floods, and hurricane winds on the availability of the source water. The UHS is also reviewed for whether adverse environmental conditions including freezing preclude the UHS safety function.

5. Sharing of cooling water sources in multi-unit stations.

6. Applicable design requirements like the high- and low-water levels of the source to determine their compatibility with the service water system.

7. Heat input for the UHS design as to reactor system heat, sensible heat, pump work, and station auxiliary system individual and total heat loads.

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 structures, systems, and components (SSCs) related to this SRP section in accordance with SRP 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 SRP 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 SRP Section 14.3.

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 SRP sections interface with this section as follows:

1. Sections 2.4.1 through 2.4.14: review of UHS water levels, design and inspection of water control structures (e.g., dams, slopes, canals), meteorological and natural phenomena criteria (including ice effects), and transient analysis of the cooling water inventory.

2. Sections 3.2.1 and 3.2.2: review of the acceptability of the seismic and quality group classifications for safety-related SSCs.

3. Sections 3.3.1, 3.3.2, 3.4.2, 3.5.3, 3.7.1 through 3.7.4, 3.8.4, and 3.8.5: review of the acceptability of the design analyses, procedures, and criteria establishing the capability of seismic Category I structures housing the system and supporting systems to withstand the effects of natural phenomena like the safe shutdown earthquake (SSE), the probable maximum flood, and the tornado missiles.

4. Section 3.4.1: review of flood protection.

5. Section 3.5.1.1: review of the protection against internally-generated missiles.

6. Section 3.5.2: review of SSCs to be protected against externally-generated missiles.

7. Section 3.6.1: review of high- and moderate-energy pipe breaks.

8. Section 6.1.1: review of the inservice inspection requirements for system components and the compatibility of materials of construction with service conditions.

9. Section 6.3: review of the heat loads transmitted to the UHS from the reactor coolant and emergency core cooling systems.

10. Section 7.1 and Appendix 7-A: review of the adequacy of the design, installation, inspection, and testing of all instrumentation and control systems required for proper operation.

11. Section 8.3.1: review of the adequacy of the design, installation, inspection, and testing of all electrical systems required for proper operation.

12. Section 9.2.1: review of the service water system and review of the program of surveillance and control techniques to detect and control flow blockage problems due to aquatic bivalves and other fouling due to mud, silt, or corrosion products.

13. Section 9.5.1: review of fire protection.

14. Section 16.0: review of technical specifications.

15. Chapter 17: review for quality assurance.

The specific acceptance criteria and review procedures are contained in the referenced SRP sections.

II. ACCEPTANCE CRITERIA

Requirements

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

1. GDC 2 as to capability of structures housing the system and the system itself to withstand the effects of natural phenomena like earthquakes, tornadoes, hurricanes, and floods.

2. GDC 5 as to capability of shared systems and components important to safety to perform required safety functions.

3. GDC 44 as to:

   A. The capability to transfer heat loads from safety-related SSCs to the heat sink under both normal operating and accident conditions.

   B. Suitable component redundancy so that safety functions can be performed assuming a single, active component failure coincident with loss of offsite power.

   C. The capability to isolate components, systems, or piping if required so safety functions are not compromised.

4. GDC 45 as to the design provisions to permit inservice inspection of safety-related components and equipment.

5. GDC 46 as to the design provisions to permit operation functional testing of safety-related systems or components.

6. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed inspections, tests, analyses, and acceptance criteria (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 plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and the NRC's regulations.

7. 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 operate in conformity with the combined license, the provisions of the Atomic Energy Act, and the NRC's regulations.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for review described in this SRP section. The SRP is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

1. Protection Against Natural Phenomena. Information that addresses the requirements of GDC 2 regarding the capability of structures housing the UHS and the UHS itself to withstand the effects of natural phenomena will be considered acceptable if the guidance of Regulatory Guide (RG) 1.27, Positions C.2 and C.3 are appropriately addressed.

2. Sharing of Structures, Systems, and Components. Information that addresses the requirements of GDC 5 regarding the capability of shared systems and components important to safety to perform required safety functions will be considered acceptable if the use of the UHS in multiple-unit plants during an accident in one unit does not significantly affect the capability to conduct a safe and orderly shutdown and cool-down in the other unaffected unit(s).

3. Cooling Water System. Information that addresses the requirements of GDC 44 regarding consideration of the cooling water system will be considered acceptable if the guidance of RG 1.27, Positions C.2 and C.3; RG 1.72, Positions C.1, C.4, C.5, C.6, and C.7.; and American National Standards Institute/American Nuclear Society (ANSI/ANS) 5.1 are applied appropriately.

4 . Cooling Water System Inspection. Information that addresses the requirements of GDC 45 regarding the inspection of cooling water systems will be considered acceptable if the design of the UHS permits inservice inspection of safety-related components and equipment.

5. Cooling Water System Testing. Information that addresses the requirements of GDC 46 regarding the testing of cooling water systems will be considered acceptable if the UHS is designed for testing of safety-related systems or components for structural integrity and leak-tightness, operability, performance of active components, and the capability of the system to function as intended under accident conditions.

Technical Rationale

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

1. GDC 2 requires that nuclear power plant SSCs important to safety be designed to withstand the effects of natural phenomena like earthquake, tornado, hurricane, flood, tsunami, and seiche without loss of capability to perform intended safety functions.

   GDC 2 applies to this SRP section because the reviewer considers UHS capability to withstand natural phenomena. The UHS must be able to provide an adequate supply of cooling water to cool the reactor and its essential support systems under all plausible conditions. RG 1.27 describes methods acceptable to the staff for ensuring UHS capability to withstand the effects of natural phenomena, including earthquakes.

   GDC 2 requirements provide assurance that SSCs comprised by the plant's ultimate heat sink have been designed to withstand the most severe natural phenomena likely to occur.

2. GDC 5 requires that SSCs important to safety not be shared by nuclear power units unless such sharing can be shown not to impair their capability to perform intended safety functions.

   RG 1.27 describes staff positions on UHS design for sharing of SSCs. GDC 5 applies to any multi-unit facility in which a UHS portion is shared by two or more units.

   GDC 5 requirements provide assurance that, in an active or a passive failure at a multi-unit site, the sharing of UHS SSCs will not affect the safe shutdown of any unit.

3. GDC 44 requires systems to transfer heat from SSCs important to safety to a UHS. Systems must be able to function under normal and accident conditions, assuming a single failure.

   GDC 44 applies to this SRP section because the reviewer evaluates the UHS design, including assumptions for heat loads, redundancy of components, capability to isolate components, and single failures. RGs 1.27 and 1.72 describe guidance acceptable to the staff for UHS design and fiberglass piping for spray pond applications. In addition, ANSI/ANS-5.1 describes methods acceptable to the staff for calculating residual decay energy.

GDC 44 requirements provide assurance that the UHS will function as designed to transfer heat from SSCs as required under normal and accident conditions, assuming a single failure.

4. GDC 45 requires that the cooling water system be designed to permit appropriate periodic inspection of important components (e.g., heat exchangers and piping) to ensure the integrity and capability of the system.

   Meeting the requirements of GDC 45 provides assurance that components and equipment of the ultimate heat sink can and will be inspected, thereby ensuring that the system will perform its intended safety function.

5. GDC 46 requires that the cooling water system be designed to permit appropriate periodic pressure and functional testing to ensure the leaktight integrity and operability of its components, as well as the operability of the system as a whole, under conditions as close to the design basis as practical.

   Meeting the requirements of GDC 46 provides assurance that components and equipment of the ultimate heat sink can and will be tested, thereby ensuring that the system will perform its intended safety function.

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 SRP 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.

Availability of an adequate supply of water for the UHS is a basic requirement for any nuclear power plant. There are various methods for satisfying the requirement (e.g., a large body of water like an ocean, lake, natural or manmade reservoir, a river, cooling ponds or towers, or such combinations). The UHS design tends to be unique for each nuclear plant, depending upon its geographical location. For purposes of this SRP section, typical procedures are established for identifying UHS essential features. For installations where these general procedures are not completely adequate, the reviewer supplements them as necessary.

1. The safety analysis report (SAR) is reviewed for the overall arrangement and type of UHS proposed. The reviewer verifies that the UHS is designed to maintain system function as required in adverse environmental phenomena including freezing and loss of offsite power. The reviewer evaluates the system for whether:

   A. The heat inputs in the UHS design are conservative. The reviewer makes an independent evaluation of the applicant's calculated heat loads. The UHS heat loads include heat due to decay of radioactive material, sensible heat, pump work, and the heat load from the operation of the station auxiliary systems serving and dependent upon the UHS.

   B. Operational data from plants of similar design confirm, where possible, the heat input values for sensible heat, pump work, and station auxiliary systems.

2. The reviewer verifies whether:

   A. The total essential station heat load and system flow requirements of the service water system are compatible with the UHS heat rejection capability.

   B. The UHS can dissipate the maximum possible total heat load, including that of a LOCA under the worst combination of adverse environmental conditions, even freezing, and can cool the unit (or units, including a LOCA for one unit of a multi-unit station with one heat sink) for a minimum of 30 days without makeup unless acceptable makeup capabilities can be demonstrated. This capability is verified by independent check calculations.

   C. The single failure of any SSCs will not prevent the UHS from performing its safety functions.

3. For plants with UHS cooling towers the reviewer determines, in addition, whether:

   A. The results of failure modes and effects analyses show that the mechanical systems (fans, pumps, and controls) can withstand a single, active failure in any of these systems, including an auxiliary electric power source failure, and deliver water in the quantities and at temperatures required for safe shutdown.

   B. Adequate net positive suction head can be provided to all essential pumps with water level variations in the basins. This determination is verified by independent calculations.

   C. The towers can provide the design cooling water temperature under the worst combination of adverse environmental conditions, even freezing, and the basins can supply water for 30-day cooling at the required temperature without makeup unless acceptable makeup capabilities can be demonstrated. This determination is verified by independent calculations.

4. Reactor sites that utilize large natural or manmade water sources, which for all practical purposes have an infinite supply of water, are reviewed as described in subsections III.1 and III.2 of this SRP section, and in addition the reviewer determines:

   A. By reviewing the SAR preliminary site and plant arrangement sketches (construction permit) and site drawings and plant arrangement drawings (operating license) whether the intake and outlet conduits (open or closed type) are properly separated to prevent recirculation or water temperature stratification.

   B. Whether manmade earth dam, dike, or other SAR structure design bases include requirements for withstanding the design basis natural phenomena or combinations of such phenomena at historically recorded intensities. In a failure of a dam, dike, or other structure not designed to withstand the design basis natural phenomena (particularly the SSE), sufficient water must remain in the source pool for a 30-day minimum cooling water supply with adequate cooling capability so that the required service water system inlet cooling water temperature is not exceeded.

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 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 FSAR.

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 (ESP) or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

6. For review of both DC and COL applications, SRP 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 review and calculations (if applicable) 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 UHS review included the size, type of cooling supply (e.g., large body of water, ocean, lake, natural or manmade reservoir, river, pond, or cooling tower), and makeup sources. The review has determined the adequacy of the applicant's proposed UHS design criteria, design bases, and safety classification and the requirements for cooling water delivery for a safe shutdown during normal and accident conditions. The UHS and its supporting systems meet seismic Category I, Quality Group C requirements. The staff concludes that the UHS design is acceptable and meets the requirements of GDCs 2, 5, 44, 45, and 46. This conclusion is based on the following findings:

1. The applicant meets GDC 2 requirements for capability to withstand the effects of natural phenomena like earthquakes, tornadoes, tornado missiles, hurricanes, and floods. Acceptance is based on RG 1.27, Positions C.2 and C.3.

2. The applicant meets GDC 5 requirements for sharing of SSCs by demonstrating that such sharing does not affect the safe shutdown of any unit in an active or passive failure.

3. The applicant meets GDC 44 UHS requirements. Acceptance is based on RG 1.27, Positions C.2 and C.3; RG 1.72, Positions C.1, C.4, C.5, C.6, and C.7; and ANSI/ANS 5.1.

4. The applicant meets GDC 45 requirements for inservice inspection of the safety-related components and equipment by demonstrating the accessibility of the UHS system for periodic inspections.

5. The applicant meets GDC 46 requirements for periodic pressure and functional testing to ensure structural and leaktight integrity, operability, and performance of its active components, and operability of the system as a whole by demonstrating the capability to operate the system at full capacity during normal startup or shutdown procedures or during normal operation without degrading the system to provide for a safe shutdown or to mitigate the consequences of an accident.

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 SRP 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 SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena."

2. 10 CFR Part 50, Appendix A, GDC 5, "Sharing of Structures, Systems, and Components."

3. 10 CFR Part 50, Appendix A, GDC 44, "Cooling Water."

4. 10 CFR Part 50, Appendix A, GDC 45, "Inspection of Cooling Water System."

5. 10 CFR Part 50, Appendix A, GDC 46, "Testing of Cooling Water System."

6. RG 1.27, "Ultimate Heat Sink for Nuclear Power Plants."

7. RG 1.72, "Spray Pond Piping made from Fiberglass-Reinforced Thermosetting Resin."

8. ANS 5.1, "Decay Heat Power for Light Water Reactors," October 1979.