U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD for NuScale SMR DESIGN

9.1.3 SPENT FUEL POOL COOLING AND CLEANUP SYSTEM

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of cooling water systems

Secondary - Organization responsible for the review of chemical engineering issues
Organization responsible for the review of ultimate heat sink

I. AREAS OF REVIEW

NuScale small modular reactor (SMR) nuclear reactor plants include a spent fuel pool (SFP) for the wet storage of spent fuel assemblies. The SFP is interconnected to the reactor pool and the refueling pool which make up the water volume of the ultimate heat sink (UHS). To ensure water level is maintained in the SFP during a design-basis event, a weir separates the SFP and the UHS to maintain water inventory to cover the nuclear fuel. The safety function of the SFP cooling and cleanup system (SFPCC) is to maintain the spent fuel assemblies cooled and covered with water during all storage conditions. The NuScale design accomplishes this function passively, by designing the SFP with sufficient water volume, such that no active cooling system is needed to cool the stored fuel. Other functions performed by the system but not related to safety include water cleanup for the SFP and the dry dock; and surface skimming to provide clear water in the storage pool.

The review of the SFPCC covers the system from inlet to and exit from the storage pool and pits, the seismic Category I water source and piping used for fuel pool makeup, the cleanup system filter-demineralizers, and the regenerative process to the point of discharge to the radwaste system.

Standard Review Plan (SRP) Section 19.3, "Regulatory Treatment of Nonsafety Systems for Passive Advanced Light-Water Reactors" (passive designs only), provides the process used to identify the structures, systems, and components (SSCs) that are to be treated as regulatory treatment of nonsafety systems (RTNSS). As indicated in SRP Section 19.3, the RTNSS process uses Criteria A through E to determine the SSC functions.

For the passive designs, the UHS emergency makeup water system (which is connected to the SFP) or the SFP makeup water system may be classified as safety-related, RTNSS Criterion B (RTNSS B) or RTNSS Criterion C (RTNSS C), which is defined below:

1. Criterion B—Required to address the function of SSCs relied upon to resolve long-term (post 72 hours) safety and to address seismic events. This criterion pertains to SSCs required after 72 hours of a design-basis accident (DBA) initiation that are key to maintaining core cooling, containment integrity, control room habitability, and

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post-accident monitoring that would require a RTNSS evaluation. RTNSS Criterion B SSCs are nonsafety-related backups to safety-related SSCs.

Note: Long-term safety is defined as the period beginning 72 hours after a design-basis event and lasting the next four days (168 hours) hereafter referred to as the “post-72-hour period.”

2. Criterion C—Required to meet safety goals of core damage frequency (CDF) less than 1.0E-4 and large release frequency (LRF) less than 1.06E-6, each reactor year. This criterion pertains to active nonsafety-related components relied upon to reduce initiating event frequencies, CDF and LRF in the focused probabilistic risk assessment (PRA) sensitivity study, the baseline PRA, or in the assessment of uncertainties that would require a RTNSS evaluation. RTNSS Criterion C SSCs are considered nonsafety-related defense-in-depth backups.

The design-specific review standard (DSRS) includes a list of specific areas of review. Depending on final system safety or risk classifications, these specific areas of review may need to be expanded to include the evaluation of RTNSS system.

The specific areas of review are as follows:

1. The SFP cooling system is not designed to seismic Category I, Quality Group C guidelines, provided that the following systems are designed to seismic Category I, Quality Group C guidelines and are protected against extreme winds: the fuel pool make-up water system and its source; and the fuel pool building, and its ventilation and filtration system.

2. This section addresses the capability of the SFP cooling, makeup, and cleanup systems to provide adequate cooling to the spent fuel during all operating and accident conditions. The review includes the following considerations:

   A. the quantity of fuel to be cooled, including the corresponding requirements for continuous cooling during anticipated operating and accident conditions

   B. the ability of the system to maintain pool water levels

   C. the ability to provide alternate cooling capability and the associated time required for operation

   D. provisions to provide adequate makeup to the pool

   E. provisions to prevent loss of function resulting from failures of nonsafety-related components or systems

   F. the means provided for the detection and isolation of system components that could develop leaks or failures

   G. the instrumentation provided for initiating appropriate safety actions

   H. the ability of the system to maintain uniform pool water temperature conditions

I. the assumed heat up and boil off calculations that need to take into consideration that the SFP is not isolated from other heat sources

    The SFP is interconnected to the reactor pool and refueling pool which form the UHS boundary. The heat loads into the UHS need to be accounted in the assumed heat up calculations.

Note: Because the SFP is interconnected to the UHS, provisions to provide adequate makeup to the pools, provisions to preclude failures of nonsafety related components or systems, means for the detection and isolation of system components that could develop leaks or failures are also described under SRP Section 9.2.5.

3. The staff performs a secondary review of the capability and capacity of the SFP cleanup system to remove corrosion products, radioactive materials, and impurities from the pool water. In addition, at the request of the primary reviewer, an evaluation is performed of the SFP cooling system materials fluid compatibility and potential for metal corrosion degradation and compatibility of the materials of construction with service conditions.

4. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's ITAAC associated with the SSCs related to this DSRS 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 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 SRP Section 14.3.

5. 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 SRP sections interface with this section as follows:

1. Review for flood protection is performed under SRP Section 3.4.1.

2. Review of the protection against internally generated missiles is performed under SRP Section 3.5.1.1.

3. Review of the SSCs to be protected against externally generated missiles is performed under SRP Section 3.5.2.

4. Review of high- and moderate-energy pipe breaks is performed under SRP Section 3.6.1.

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

6. Review of environmental qualification of mechanical and electrical equipment is performed under DSRS Section 3.11.

7. Review to verify that the limits for radioactivity concentrations are not exceeded is performed under DSRS Sections 11.1 and 11.2.

8. Review of the acceptability of the design analyses, procedures, and criteria used to establish the ability of seismic Category I structures housing the system and supporting systems to withstand the effects of natural phenomena such as the safe-shutdown earthquake (SSE), the probable maximum flood (PMF), and extreme wind missiles is performed under DSRS Sections 3.7.1 through 3.7.3, 3.8.4, and 3.8.5; and SRP Section 3.3.1, 3.3.2, 3.5.3, and 3.7.4.

9. Review of whether the components piping and structures are designed in accordance with applicable codes and standards is performed under SRP Sections 3.9.1 through 3.9.3.

10. Review of the acceptability of the seismic and quality group classifications for system components is performed under SRP Sections 3.2.1 and 3.2.2.

11. Review of the adequacy of the inservice testing program of pumps and valves is performed under SRP Section 3.9.6.

12. Review of whether inservice inspection requirements for system components are met is performed under DSRS Section 6.6.

13. Review of the UHS pool integrity (adjacent pool that is credited to maintain water level in the SFP) is performed under SRP Section 9.2.5.

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

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

16. Review of the seismic qualifications of Category I instrumentation and electrical equipment is performed under SRP Section 3.10.

17. Review of the adequacy of the design, installation, inspection and testing of the SFPCC instrumentation and controls important to safety is performed under DSRS Section 7.1 and Appendix 7-A.

18. Review of the adequacy of the design, installation, inspection and testing of onsite ac power systems required for proper operation of the SFPCC is performed under DSRS Section 8.3.1.

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 U.S. Nuclear Regulatory Commission (NRC) regulations:

1. General Design Criterion (GDC) 2, "Design Bases for Protection against Natural Phenomena"

   This criterion does not apply to the cleanup portion of the system or the cooling system, but the fuel pool makeup water system and its source, the fuel pool building and its ventilation and filtration system meet this criterion, and the ventilation and filtration system meets the guidelines of Regulatory Guide (RG) 1.52, "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post-Accident Engineered-Safety-Feature Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants."

   The makeup system should be designed to Quality Group C requirements in accordance with RG 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants"

2. GDC 4, "Environmental and Dynamic Effects Design Bases"

   This criterion does not apply to the cleanup system or the cooling water system, but the makeup system, its source, the building, and its ventilation and filtration system are extreme-wind-protected, and the ventilation and filtration system meets the guidelines of RG 1.52.

3. GDC 5, "Sharing of Structures, Systems, and Components"

4. GDC 61, "Fuel Storage and Handling and Radioactivity Control"

5. GDC 63, "Monitoring Fuel and Waste Storage"

6. Title 10 of the Code of Federal Regulations (10 CFR) Section 20.1101(b), as it relates to radiation doses being kept as low as is reasonably achievable (ALARA). In meeting this regulation, RG 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable," Positions C.2.f(2) and C.2.f(3) can be used as a basis for acceptance.

7. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to reasonably ensure that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the

DC is built and will operate in accordance with the DC, the provisions of the Atomic Energy Act (AEA), and the NRC's regulations.

8. 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 AEA, and the NRC's regulations.

<u>DSRS Acceptance Criteria</u>

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. As an alternative, and as described in more detail below, an applicant may identify the differences between a DSRS section and the design features (for DC and COL applications only), analytical techniques, and procedural measures proposed in an application and discuss how the proposed alternative provides an acceptable method of complying with NRC regulations that underlie the DSRS acceptance criteria.

<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. Compliance with GDC 2 requires SSCs important to safety to be designed to withstand the effects of expected natural phenomena combined with the appropriate effects of normal and accident conditions without loss of capability to perform their safety functions.

   This DSRS section describes staff positions related to the design of the SFPCC system. It cites RG 1.13, "Spent Fuel Storage Facility Design Basis" to describe the design basis; RG 1.26, to describe quality group classifications; and RG 1.29, "Seismic Design Classification," to describe seismic design classifications. These positions describe the design bases needed to resist expected natural phenomena when combined with the appropriate effects of normal and accident conditions.

   Meeting the requirements of GDC 2 ensures that components of the SFPCC will be designed to withstand the effects of expected natural phenomena and will be capable of performing their intended safety functions.

2. Compliance with GDC 4 requires SSCs important to safety to be designed to accommodate the effects of, and be compatible with, environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents and dynamic effects resulting from pipe whip, missiles, and discharging fluids.

This DSRS section describes staff positions related to the design of the SFPCC and cites RG 1.13 to describe the design basis, including that for protecting the spent fuel storage facility against missiles and heavy loads.

Meeting the requirements of GDC 4 ensures that components of the SFPCC will be designed to accommodate expected environmental conditions and will be capable of performing their intended safety functions.

3. Compliance with GDC 5 requires SSCs important to safety not to be shared among nuclear power units unless it can be shown that such sharing will not impair their ability to perform their safety functions.

   This DSRS section describes staff positions related to the design of the SFPCC, whose safety function is to ensure that no single failure will prevent the system from cooling the spent fuel.

   Meeting the requirements of GDC 5 ensures that components of the SFPCC will be designed to accommodate shared SSCs such that no single failure will prevent the system from performing its safety function.

   Note: Because the SFP is interconnected to the UHS, GDC 5 is also reviewed under SRP Section 9.2.5.

4. Compliance with GDC 61 requires the fuel storage system to be designed to ensure adequate safety under normal and postulated accident conditions. The system shall be designed with: (1) the capability to permit appropriate periodic inspection and testing of components important to safety, (2) suitable shielding for radiation protection, (3) appropriate containment, confinement and filtering capability, (4) residual heat removal that reflects the importance to safety of decay heat and other residual heat removal, and (5) the capability to prevent a significant reduction in fuel storage coolant inventory under accident conditions.

   This DSRS section describes staff positions related to the design of the SFPCC, including provisions for inspection and testing, containment and confinement, residual heat removal, maintenance of an adequate coolant inventory under accident conditions, and shielding and filtration capability to reduce occupational exposure to radiation. Provisions for inspection and testing are satisfied by designing essential portions of the cooling system to Quality Group C criteria. Provisions for containment are satisfied by provisions to collect and isolate leakage. Provisions for residual heat removal that reflect its importance to safety are satisfied by (1) designing essential portions of the cooling system to seismic Category I criteria and with adequate cooling capacity assuming a single active failure, and (2) providing a forced-circulation cooling capability that maintains the pool at temperatures suitable for fuel handling during routine operating conditions, including refueling. Because the NuScale SFP is in communication with the UHS, all heat loads that affect this pool need to be taken into consideration while determining adequate SFP cooling capability. The capability to prevent a significant reduction in fuel storage coolant inventory under accident conditions is satisfied by providing adequate makeup capability and designing the SFPCC such that the coolant can neither be drained nor siphoned below a specified level. Provisions to minimize occupational exposure to radiation are satisfied by providing the capability to remove impurities from the coolant and maintain an adequate water level for shielding of stored fuel. The adequacy of the UHS to prevent SFP draindown is evaluated in SRP Section 9.2.5.

Meeting the requirements of GDC 61 ensures that components of the SFPCC will be inspected, tested, shielded, and provided with containment, confinement, and residual heat removal capability to ensure that the system is capable of performing its intended safety function under normal and postulated accident conditions.

5. Compliance with GDC 63 requires appropriate systems to be provided in the fuel storage area to detect conditions that may result in the loss of residual heat removal capability or excessive radiation levels, and initiate appropriate safety actions.

    This DSRS section describes staff positions related to the design of the SFPCC, including provisions for monitoring and detection systems.

    Meeting the requirements of GDC 63 ensures that components of the SFPCC will be provided with monitoring and detection capabilities to ensure that the system is capable of performing its intended safety function.

6. Compliance with 10 CFR 20.1101(b) requires that the licensee use, to the extent practicable, procedures and engineering controls based on sound radiation protection principles to achieve occupational doses and doses to members of the public that are ALARA.

    This DSRS section describes staff positions related to the design of the SFPCC, including positions to achieve radiation doses in conformance with the ALARA principle. Positions in RG 8.8 regarding methods for preventing the generation and spread of contamination are provided.

    Meeting the requirements of 10 CFR 20.1101(b) ensures that components of the SFPCC will result in radiation doses that comply with the ALARA standard.

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 or DSRS acceptance criteria. For deviations from these specific acceptance criteria, including review of unique designs, the staff should review the applicant’s evaluation of how the proposed alternatives provide an acceptable method of complying with relevant NRC requirements identified in Subsection II.

Upon request from the primary reviewer, the interfacing review branches will provide input for the areas of review stated in Subsection I of this DSRS section. The secondary review branch will provide input on a routine basis for those areas of review indicated in this DSRS section. The primary reviewer obtains and uses such input as necessary to ensure that this review procedure is complete.

In the review, the staff evaluates SFPCC and its makeup system with respect to their capability to perform the necessary functions during all conditions, including normal operation, refueling, and accident conditions.

1. Selected Programs and Guidance—In accordance with the guidance in NUREG–0800, “Introduction – Part 2: Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Light-Water Small Modular Reactor Edition” (NUREG-0800, Intro Part 2), as applied to this DSRS Section, the staff will review the information proposed by the applicant to evaluate whether it meets the acceptance criteria described in Subsection II of this DSRS. As noted in NUREG-0800, Intro Part 2, the NRC requirements that must be met by an SSC do not change under the small modular reactor (SMR) framework. Using the graded approach described in NUREG-0800, Intro Part 2, the NRC staff may determine that, for certain SSCs, the applicant’s basis for compliance with other selected NRC requirements may help demonstrate satisfaction of the applicable acceptance criteria for that SSC in lieu of detailed independent analyses. The design-basis capabilities of specific SSCs would be verified, where applicable, as part of completing the applicable ITAAC. The use of the selected programs to augment or replace traditional review procedures is shown in Figure 1 of NUREG-0800, Intro Part 2. Examples of such programs that may be relevant to the graded approach for these SSCs include:

    - 10 CFR Part 50, Appendix A, GDC, Overall Requirements, Criteria 1–5
    - 10 CFR Part 50, Appendix B, Quality Assurance (QA) Program
    - 10 CFR 50.49, Environmental Qualification of Electrical Equipment (EQ) Program
    - 10 CFR 50.55a, Code Design, Inservice Inspection, and Inservice Testing (ISI/IST) Programs
    - 10 CFR 50.65, Maintenance Rule requirements
    - Reliability Assurance Program (RAP)
    - 10 CFR 50.36, “Technical Specifications”
    - Availability Controls for SSCs Subject to Regulatory Treatment of Nonsafety Systems (RTNSS)
    - Initial Test Program (ITP)
    - Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)

    This list of examples is not intended to be all inclusive. It is the responsibility of the technical reviewers to determine whether the information in the application, including the degree to which the applicant seeks to rely on such selected programs and guidance, demonstrates that all acceptance criteria have been met to support the safety finding for a particular SSC.

2. In accordance with 10 CFR 52.47(a)(8), (21), and (22), and 10 CFR 52.79(a)(17), (20), and (37), for DC or COL applications submitted under 10 CFR 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 which are identified in the version of NUREG-0933, "Resolution of Generic Safety Issues," current on the date up to 6 months before the docket date of the application and which 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), for a DC application, and except paragraphs (f)(1)(xii), (f)(2)(ix), (f)(2)(xxv), and (f)(3)(v),for a COL application. 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. The reviewer will identify the safety function of the system for refueling and normal operations by reviewing the information provided in the application pertaining to the design bases and criteria and the safety evaluation section. The application section describing the system functional performance requirements is also reviewed to determine that it describes the minimum system heat transfer and system flow requirements for normal plant operation, component operational degradation requirements (i.e., pump leakage, etc.) and describes the procedures that will be followed to detect and correct these conditions should degradation become excessive. The reviewer, using failure modes and effects analyses, determines that the system is capable of sustaining the loss of any active component and evaluates, on the basis of previously approved systems or independent calculations, that the minimum system requirements (cooling load and flow) are met for these failure conditions. Because the NuScale SFP is not isolated from the UHS, the heat loads assumed in the different accident scenarios need to consider the heat load added to the pool by the reactors. The reviewer will evaluate the system drawings and component descriptions for the following points:

    A. Essential portions of the system are correctly identified and are isolable from the nonessential portions of the system. The reviewer verifies that the drawings clearly indicate the physical division between each portion and indicate classification changes. The reviewer also ensures that system drawings show the means for accomplishing isolation and that the system description identifies minimum performance requirements for the isolation valves. The reviewer examines drawings and reviews descriptions to verify that adequate isolation valves separate nonessential portions and components from the essential portions.

    B. The cooling loop can be constructed to nonseismic Category I requirements, provided the SFP water makeup system and the building ventilation and filtration system are 1) designed to Quality Group C and seismic Category I requirements, 2) are protected from the effects of extreme winds, and 3) meet the single-failure requirements. The ventilation system provides the capability to vent steam and moisture to the atmosphere to protect safety-related components from the effects of boiling in the SFP. If necessary to limit the offsite dose consequences of SFP boiling, the ventilation and filtration system should also meet the guidelines of RG 1.52. The review for seismic design and seismic and quality group classification is performed under DSRS Sections 3.7.1 through 3.7.3, and SRP Sections 3.7.4, 3.2.1, and 3.2.2.

C. The stated quantity of fuel to be cooled by the spent fuel cooling system is consistent with the quantity of fuel stored.

D. The cooling system retains at least half of its full heat removal capacity. This minimum heat removal capacity shall provide reasonable assurance that the pool temperature will remain within design bounds for the structure during full core discharges to the SFP when the forced-circulation cooling system is in operation, and ensures that significant heat removal capacity will remain available.

E. The SFP and cooling systems have been designed so that in the event of failure of inlets, outlets, piping, or drains, the pool level will not be inadvertently drained below the minimum safety water level. Pipes or external lines extending into the pool that are equipped with siphon breakers, check valves, or other devices to prevent drainage are acceptable as a means of implementing this requirement.

Note: Because the SPF is interconnected to the UHS, SRP Section 9.2.5 will address these same requirements to the entire UHS boundary.

F. A seismic Category I, Quality Group C makeup system and an appropriate backup method to add coolant to the SFP are provided. The backup system should also be permanently installed, physically separated and independent from the primary makeup system, and designed to seismic Category I, Quality Group C standards. The minimum makeup capacity for each system exceeds the larger of the pool leakage rate assuming SFP liner perforation resulting from a dropped fuel assembly or the maximum evaporation rate. The design permits initiation of makeup water flow through either system from locations remote from the operating floor surrounding the pool surface. Engineering judgments are used to determine that the time necessary to align systems and connect makeup systems not permanently installed is consistent with heatup times or expected leakage from structural damage.

G. Design provisions have been made that permit appropriate inservice inspection and functional testing of system components important to safety. A statement that essential portions of the SFP cooling and makeup systems are included in the inservice inspection program per DSRS Section 6.6 and the inservice testing program of SRP Section 3.9.6 is acceptable.

H. The system design provides adequate SFP cooling capacity for routine operations, including refueling. The staff reviews either a bounding evaluation of potential refueling conditions or a method of performing outage-specific evaluations described in the safety analysis report (SAR). The largest heat load placed on the SFPCC heat exchangers is imposed by refueling offloads, which are deliberate, planned evolutions. As a result, if necessary for adequate cooling of the fuel, factors that increase heat load (e.g., power increases, decay time reductions, or storage capacity increases) may be offset by operational factors that reduce heat load (e.g., longer decay times or transfer of fewer fuel assemblies to the SFP) or that increase heat removal capability (e.g., scheduling offloads for periods of reduced UHS temperature or optimizing cooling system performance).

Considering the preceding measures to manage the heat load relative to cooling capability, the staff evaluates the following criteria:

i. the SAR describes a method of performing decay heat load calculations using a conservative model that evaluates multiple fission product groups and considers offload size, decay time, power history, and inventory of previously discharged assemblies.

ii. the SAR describes a method of calculating heat removal capability for a bulk SFP temperature of 60 degrees Celsius (C) (140 degrees Fahrenheit (F)) and considering UHS temperature, cooling system flow rates, and heat exchanger performance (i.e., fouling and tube plugging margin).

iii. the SAR describes appropriate administrative controls in the SAR to ensure that the full heat removal capability at a SFP temperature of 60 degrees C (140 degrees F) will exceed the calculated decay heat load at all times during the refueling offload.

Note: Because the SFP is interconnected to the UHS, the heat load calculations are also addressed under DSRS Section 9.2.5.

4. The reviewer verifies that the system has been designed so that system functions will be maintained, as required, in the event of adverse natural phenomena, such as earthquakes, extreme winds, hurricanes, and floods. The reviewer evaluates the system, using engineering judgment and the results of failure modes and effects analyses to determine the following:

A. The failure of portions of the system, or of other systems not designed to seismic Category I standards and close to essential portions of the system, or of nonseismic Category I structures that house, support, or are close to essential portions of the pool and cooling system, will not prevent essential functions. Statements that the above conditions are met are acceptable. Reference to site features, the general arrangement and layout drawings, and the seismic design classifications for structures and systems included with the application will be necessary.

B. The essential portions (i.e. pool connections) of the SFP cooling system are protected from the effects of floods, hurricanes, extreme winds, and internally or externally generated missiles. Flood protection and missile protection criteria are discussed in detail in the respective SRP or DSRS sections.

The reviewer uses the procedures identified in these plans to ensure that the analyses presented are valid. A statement that the system is in a seismic Category I structure that is extreme wind missile and flood protected, or that components of the system will be in individual cubicles or rooms that will withstand the effects of both flooding and missiles is acceptable. The staff reviews the location and design of the system, structures, and pump rooms (cubicles) to determine that the degree of protection provided is adequate.

5. The reviewer analyzes the system design information and drawings to ensure that features to contain radioactivity will be incorporated. A statement that these features will be included in the design by the following means is a basis for acceptance:

   A. A leakage detection system is provided to detect component or system leakage. An adequate means for implementing this requirement is to provide sumps or drains with adequate capacity and appropriate alarms in the immediate area of the system.

   B. Components and headers of the system are designed to provide individual isolation capabilities to ensure system function, control system leakage, and allow system maintenance.

   C. Design provisions are made to ensure the capability to detect leakage of radioactivity from one system to another. Radioactivity monitors and conductivity monitors located in the system discharge lines are acceptable means for implementing this requirement.

      Note: Because the SFP is interconnected to the UHS, the leak detection system is also addressed under SRP Section 9.2.5.

6. Descriptive information, drawings, and system analyses are reviewed to ensure that essential portions of the system will function after design-basis accidents, assuming a concurrent single active component failure. The reviewer evaluates failure mode and effects analyses presented in the SAR to ensure the function of required components, trace the availability of these components on system drawings, and check that minimum system flow, makeup, and heat transfer requirements are met for each degraded situation over the required time spans. For each case, the design will be acceptable if alarms are provided to notify operators of the degraded condition and essential functions can credibly be restored.

7. The SFP cleanup system and various auxiliary systems are designated as nonsafety-related systems and are designed accordingly (nonseismic Category I). The reviewer evaluates these systems to ensure that their failure cannot affect the functional performance of any safety-related system or component. The relationship and proximity between the nonsafety-related system and safety-related systems or components are determined by reviewing the integrated structure and component layout diagrams. Independent analyses, engineering judgment, and comparisons with previously approved systems are used to verify that where a nonsafety-related system

interconnects or interfaces with the cooling system, its failure by any event or malfunction will not preclude adequate functional performance of the cooling system.

8. The staff also reviews the cleanup system to ensure that it has been designed with the capability to maintain acceptable pool water conditions. The staff reviews the descriptive information and drawings provided in the application to verify the following:

   A. the cleanup system to verify it has the capacity and capability to remove corrosion products, maintain boron concentrations (if required), radioactive materials, and impurities so that water clarity and quality will enable safe operating conditions in the pool

      i. This includes instrumentation and sampling to monitor the water purity and need for demineralizer resin replacement, including the chemical and radiochemical limits such as conductivity, gross gamma and iodine activity, demineralizer differential pressure, pH, and crud level, which are used to initiate corrective action.

   B. the capability for processing the UHS

   C. provisions to prevent the inadvertent transfer of spent filter and demineralized media to any place other than the radwaste facility have been provided

9. For reviews under 10 CFR Part 50, the procedures set forth above are used during the construction permit (CP) application review to determine that the design criteria and bases and the preliminary design as set forth in the preliminary SAR meet the acceptance criteria given in Subsection II of this DSRS section. For the review of operating license (OL) applications, the review procedures are used to determine that the acceptance criteria and bases have been appropriately implemented in the final design as set forth in the final SAR. The review procedures for OL applications include a determination that the content and intent of the technical specifications prepared by the applicant are in agreement with the requirements for system testing, minimum performance, and surveillance developed because of the staff's review.

10. 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.

11. 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).

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 basis for those conclusions.

The SFPCC includes all components and piping of the system from inlet to and exit from the storage pool and pits, the seismic Category I water source and piping used for fuel pool makeup, the cleanup system filter-demineralizers and the regenerative process to the point of discharge to the radwaste system. The scope of review of the SFPCC includes layout drawings, process flow diagrams, piping and instrumentation diagrams, and descriptive information for the system and the supporting systems that are essential to safe operation. The portions of systems essential for adequate cooling and maintenance of an adequate fuel storage coolant inventory have been identified and are designed to seismic Category I, Quality Group C standards because they are necessary to remove decay heat from the spent fuel and to prevent fuel damage that could lead to unacceptable releases of radioactivity.

Accordingly, the staff concludes that the design of the SFPCC and its makeup system meets the requirements of GDC 2, 4, 5, 61, and 63. This conclusion is based on the following:

1. The applicant has met the requirements of GDC 2 with respect to safety-related portions of the system being protected against natural phenomena. Acceptance is based on having met the guidelines of RG 1.13, which include (1) Position C.1, recommending a seismic Category I design for necessary portions of the spent fuel storage facility, (2) Position C.2, regarding protection against winds and wind generated missiles, (3) Position C.6, as it relates to the system being capable of withstanding earthquakes without loss of coolant that would uncover the fuel, and (4) Position C.8, recommending a seismic Category I makeup system with appropriate redundancy or a backup from a Category I water source. Acceptance is also based on having met the seismic design requirements of RG 1.29, Position C.1, for safety-related portions of the system necessary for adequate cooling to prevent excessive radioactivity releases (Position C.1.p of RG 1.29) and Position C.2 as it relates to the failure of nonsafety-related portions of the system.

2. The design meets the requirements of GDC 4 with regard to protection against the effects of externally generated missiles; it is in accordance with Position C.2 of RG 1.13 because no loss of watertight integrity or fuel damage occurs in the event of extreme wind missiles.

3. The design meets the requirements of GDC 5 regarding the sharing of safety-related structures, systems, and components because no single failure will prevent the system from performing its safety-related function, which is cooling the spent fuel.

   Note: Because the SFP is interconnected to the UHS, GDC 5 is also reviewed under SRP Section 9.2.5.

4. The system is designed in accordance with the requirements of GDC 61 as it relates to the system design for fuel storage because the system has the following design capabilities: the system has the capability for periodic testing of components important to safety; the system has the capability to remove decay heat from the spent fuel under both normal operating and accident conditions; the system has redundancy so that decay heat can be removed assuming a single active failure; the system is designed to provide suitable shielding by maintaining a minimum water level above the fuel; the system provides appropriate containment of radioactivity by collecting and providing a means for detecting leakage; and the system is designed to prevent reduction in fuel storage coolant inventory under accident conditions in accordance with Position C.6 of RG 1.13. The SFP cleanup portion of the system (1) provides the capability and capacity of removing radioactive materials, corrosion products, and impurities from the pool water and thus meets the requirements of Criterion 61 as it relates to appropriate filtering systems for fuel cooling and storage, (2) reduces occupational exposure to radiation by removing radioactive materials from the pool water and thus meets the requirements of 10 CFR 20.1101(b) as it relates to maintaining radiation exposures ALARA and, (3) retains radioactive materials and crud in the pool water in the demineralizer and filters and thus meets Positions C.2.f(2) and C.2.f(3) of RG 8.8.

5. The system design meets the requirements of GDC 63 because it has provisions to detect the loss of heat removal function through the use of loss of flow and temperature alarms, and to detect conditions that would result in excessive radiation through the use of coolant low level alarms and radiation monitoring alarms. The above alarms provide adequate notification of abnormal conditions for operators to initiate timely actions to ensure the safety functions are satisfied because of the large coolant inventory within the storage pool.

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 regulations in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), and 10 CFR 52.79(a)(41) establish requirements for applications for ESPs, DCs, and COLs, respectively. These regulations require the application to include an evaluation of the site (ESP), standard plant design (DC), or facility (COL) against the SRP revision in effect 6 months before the docket date of the application. While the SRP provides generic guidance, the staff developed the SRP guidance based on the staff's experience in reviewing applications for construction permits and operating licenses for large light-water nuclear power reactors. The proposed SMR designs, however, differ significantly from large light-water nuclear power plant designs.

In view of the differences between the designs of SMRs and the designs of large light-water power reactors, the Commission issued Staff Requirements Memorandum

(SRM)-COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights To Enhance Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010. In the SRM, the Commission directed the staff to develop risk-informed licensing review plans for each of the SMR design reviews, including plans for the associated preapplication activities. Accordingly, the staff has developed the content of the DSRS as an alternative method for evaluating a NuScale-specific application submitted pursuant to 10 CFR Part 52, and the staff has determined that each application may address the DSRS in lieu of addressing the SRP, with specified exceptions. These exceptions include particular review areas in which the DSRS directs reviewers to consult the SRP and others in which the SRP is used for the review. If an applicant chooses to address the DSRS, the application should identify and describe all differences between the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and the guidance of the applicable DSRS section (or SRP section, as specified in the DSRS), and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria.

The staff has accepted the content of the DSRS as an alternative method for evaluating whether an application complies with NRC regulations for NuScale SMR applications, provided that the application does not deviate significantly from the design and siting assumptions made by the NRC staff while preparing the DSRS. If the design or siting assumptions in a NuScale application deviate significantly from the design and siting assumptions the staff used in preparing the DSRS, the staff will use the more general guidance in the SRP, as specified in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), or 10 CFR 52.79(a)(41), depending on the type of application. Alternatively, the staff may supplement the DSRS section by adding appropriate criteria to address new design or siting assumptions.

VI. REFERENCES

1. *U.S. Code of Federal Regulations*, "Radiation Protection Programs," Section 20.1101(b), Part 20, Subpart B, Title 10, "Energy."

2. *U.S. Code of Federal Regulations,* "Domestic Licensing of Production and Utilization Facilities," Part 50, Title 10, "Energy," Appendix A, General Design Criterion (GDC) 2, "Design Bases for Protection against Natural Phenomena."

3. *U.S. Code of Federal Regulations,* "Domestic Licensing of Production and Utilization Facilities," Part 50, Title 10, "Energy," Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases."

4. *U.S. Code of Federal Regulations,* "Domestic Licensing of Production and Utilization Facilities," Part 50, Title 10, "Energy," Appendix A, GDC 5, "Sharing of Structures, Systems and Components."

5. *U.S. Code of Federal Regulations,* "Domestic Licensing of Production and Utilization Facilities," Part 50, Title 10, "Energy," Appendix A, GDC 61, "Fuel Storage and Handling and Radioactivity Control."

6. *U.S. Code of Federal Regulations,* “Domestic Licensing of Production and Utilization Facilities,” Part 50, Title 10, “Energy,” Appendix A, GDC 63, “Monitoring Fuel and Waste Storage.”

7. U.S. Nuclear Regulatory Commission, “Spent Fuel Storage Facility Design Basis,” Regulatory Guide (RG) 1.13, Revision 2, March 2007, Agencywide Documents Access and Management System (ADAMS) Accession No. ML070310035.

8. U.S. Nuclear Regulatory Commission, “Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants,” RG 1.26, Revision 4, March 2007, ADAMS Accession No. ML070290283.

9. U.S. Nuclear Regulatory Commission, “Seismic Design Classification,” RG 1.29, Revision 4, March 2007, ADAMS Accession No. ML070310052.

10. U.S. Nuclear Regulatory Commission, “Design, Testing, and Maintenance Criteria for Engineered-Safety-Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants,” RG 1.52, Revision 4, September 2012, ADAMS Accession No. ML12159A013.

11. U.S. Nuclear Regulatory Commission, “Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable,” RG 8.8, Revision 3, June 1978, ADAMS Accession No. ML003739549.