U.S. NUCLEAR REGULATORY COMMISSION

DESIGN SPECIFIC REVIEW STANDARD for NuScale SMR DESIGN

9.1.2 NEW AND SPENT FUEL STORAGE

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of new and spent fuel storage and handling

Secondary - Organization responsible for the review of chemical engineering issues

I. AREAS OF REVIEW

Nuclear reactor plants include facilities to store new and spent fuel assemblies. The safety functions of the new fuel storage vault, new fuel storage racks, spent fuel pool (SFP), and spent fuel storage racks maintain the fuel assemblies in a safe and subcritical array during all credible storage conditions and provide a safe means of loading the spent fuel assemblies into shipping or storage casks.

The NuScale SFP design is different from typical SFPs in that the NuScale's SFP is not isolated from adjacent pools. The SFP is separated by a weir (without gates) from the ultimate heat sink (UHS), but all the volume of water above the weir is in open communication with the UHS. Additionally, the NuScale design does not include a fuel transfer canal. The containment vessel is lifted and moved through the reactor pool UHS while submerged into an area where the containment and reactor vessel are opened and reactor vessel refueled.

Review of the new and spent fuel storage facilities covers the new fuel vault, the new fuel storage racks, spent fuel storage pool, spent fuel storage racks, SFP liner, dry dock, the UHS, and the structure housing these systems for compliance with Title 10 of the *Code of Federal Regulations* (10 CFR) Section 20.1101(b); 10 CFR 50.68, "Criticality Accident Requirements"; and General Design Criteria (GDCs) 2, 4, 5, 61, and 63 of Appendix A to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

This design-specific review standard (DSRS) section addresses the capability of the new and spent fuel storage facilities to maintain the fuel in a safe and subcritical array during all anticipated operating and accident conditions.

The specific areas of review are as follows:

1. the quantity of new and spent fuel to be stored

2. the effects of design loads and forces on the new and spent fuel storage racks, new fuel storage vault, spent fuel storage pool, and pool liner plate

3. the capability to withstand and protect against natural phenomena (e.g., safe shutdown earthquake (SSE), design-basis tornado)

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4. the effectiveness of natural coolant circulation through the spent fuel storage racks and the ability of new fuel racks to drain fluids if the new fuel storage facility is intended for dry storage or to be flooded if the new fuel storage facility is intended for wet storage

5. the ability to detect and contain SFP liner leaks, and the ability to detect and contain UHS liner leak is evaluated in Standard Review Plan (SRP) 9.2.5

6. the configuration of the new fuel vault, the spent fuel storage pool, and their handling areas to prevent accidental falls of heavy objects on the new and spent fuel

7. the ability to provide both radiological shielding for personnel by maintaining adequate water levels in the SFP and adequate shielding for the new fuel if recycled fuel is used

8. using design features to maintain an adequate coolant inventory in the SFP and in the new fuel vault (if wet storage is used) under accident condition (e.g., weirs and gates, absence of unnecessary drains, proper piping penetration levels, etc.); SRP 9.2.5 evaluates the prevention of UHS drain down

9. using appropriate monitoring systems to detect SFP water levels, pool temperature, and building radiation levels; also, dry storage facilities for new fuel are reviewed for appropriate criticality monitors or means to ensure an adequate degree of subcriticality

10. safety implications related to sharing (for multi-module) facilities

11. a secondary review by the organization responsible for chemical engineering issues evaluates the materials of construction in the new and spent fuel storage facilities. This secondary review evaluates the compatibility and chemical stability of the materials wetted by the water in the SFP and, if applicable, in the new fuel vault and evaluates potential mechanisms that alter the dispersion of any strong fixed neutron absorbers.

    A. Compatibility and chemical stability of the materials in the components wetted by water in the SFP and in the new fuel vault. If the possibility for corrosion mechanisms is detected, the existing programs for preventing or minimizing corrosion are reviewed for their applicability to control corrosion.

    B. The reactivity of fuel in the SFP is controlled by plates or inserts attached to spent fuel racks containing neutron poison dispersed in a matrix. In some environments, the matrix may degrade and release the neutron poison, resulting in some reduction of neutron absorbing properties of the panels. The licensee should have a program for monitoring the effectiveness of the neutron poison present in the neutron absorbing panels.

12. 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 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.

13. 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/DSRS sections interface with this section as follows:

1. SRP Section 3.10: review of the seismic qualification of Category I instrumentation

2. DSRS Section 3.11: review of equipment qualification

3. SRP Sections 3.2.1 and 3.2.2: review of the acceptability of the seismic and quality group classifications for system components

4. SRP Section 3.4.1: review of flood protection

5. SRP Sections 3.5.1.1, 3.5.1.2, and DSRS 3.5.1.3: review of the protection against internally-generated missiles

6. SRP Sections 3.5.1.4 3.5.1.5, 3.5.1.6, and 3.5.2: review of the protection against externally generated missiles

7. SRP Sections 3.3.1, 3.3.2, 3.4.2, 3.5.3, and 3.7.4, and DSRS 3.7.1 through 3.7.3, 3.8.4, and 3.8.5.: review of the acceptability of the design analyses, procedures, and criteria for the ability of seismic Category I structures housing the system and supporting systems to withstand the effects of such natural phenomena as the SSE, the probable maximum flood, and tornadoes and tornado missiles

8. DSRS Section 6.6: review for whether in-service inspection requirements are met for system components

9. SRP Section 9.1.1: review of the acceptability of the design as to criticality prevention

10. DSRS Section 9.1.3: review of the SFP's water level control, cleanup, and cooling systems

11. SRP Section 9.1.4: review of the spent fuel storage facility's light load handling system

12. SRP Section 9.1.5: review of the spent fuel storage facility's heavy load handling system and the provisions prevent the spent fuel cask from falling into the SFP

13. SRP Section 9.2.5: reviews the UHS pool integrity (adjacent pool that is credited to maintain water level in the SFP)

14. SRP Section 9.5.1: review of fire protection

15. DSRS Sections 12.3 - 12.4: review of the adequacy of the radiation monitoring system

16. DSRS Section 16.0: review of technical specifications

17. SRP Chapter 17: review of quality assurance

The specific acceptance criteria and review procedures are contained in the referenced SRP/DSRS 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. GDC 2, “Design Bases for Protection against Natural Phenomena”

2. GDC 4, “Environmental and Dynamic Effects Design Bases”

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. 10 CFR 20.1101(b), as to radiation doses kept as low as reasonably achievable (ALARA)

7. 10 CFR 50.68, as to criticality monitoring or design to preclude criticality accidents.

8. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act (AEA), and the NRC’s regulations.

9. 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.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria that 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.

1. Acceptance for meeting the relevant aspect of GDC 2 is based on compliance with Positions C.1 and C.2 of Regulatory Guide (RG) 1.13, "Spent Fuel Storage Facility Design Basis," and applicable portions of RG 1.29, "Seismic Design Classification," and RG 1.117, "Tornado Design Classification." For the spent fuel storage facility, additional guidance acceptable for meeting this criterion is found in American Nuclear Society (ANS) 57.2, paragraphs 5.1.1, 5.1.3, 5.1.12.9, and 5.3.2. For the new fuel storage facility, additional guidance acceptable for meeting this criterion is found in ANS 57.3, paragraphs 6.2.1.3(2), 6.2.3.1, 6.3.1.1, 6.3.3.4, and 6.3.4.2.

2. Acceptance for meeting the relevant aspect of GDC 4 is based on Positions C.2 and C.3 of RG 1.13, and RG 1.115, "Protection against Low-Trajectory Turbine Missiles," and 1.117.

3. GDC 5 is met by sharing the SSCs important to safety between the nuclear power units in a manner that does not degrade the performance of their safety functions.

4. Acceptance for meeting the relevant aspect of GDC 61 for the spent fuel storage facility is based on compliance with Positions C.4, C.6, C.10, C.11, and C.12 of RG 1.13 and the appropriate paragraphs of ANS 57.2. Acceptance for meeting this criterion for the new fuel storage facility is based on compliance with the appropriate paragraphs of ANS 57.3. Acceptance is also based on meeting the fuel storage capacity requirements noted in subsection III.1 of this DSRS section. The following design considerations are evaluated:

   A. provisions for periodic inspections of components important to safety

   B. suitable shielding for radiation protection, including adequate water levels

   C. appropriate containment and confinement systems

   D. residual heat removal capability by effective coolant flow through the storage racks for spent fuel assemblies

   E. prevention of reduction in fuel storage coolant inventory under accident conditions

5. Acceptance for meeting the relevant aspect of GDC 63 for spent fuel storage is based on compliance with Position C.7 of RG 1.13 and paragraph 5.4 of ANS 57.2. Acceptance for meeting this criterion for the dry storage of new fuel is based on radiation monitoring pursuant to 10 CFR 70.24, "Criticality Accident Requirements," or acceptable prevention of an increase in effective multiplication factor (K_{eff}) beyond safe limits as described in 10 CFR 50.68.

6. In meeting the requirements of 10 CFR 20.1101(b), Positions C.2.f(2) and C.2.f(6) of RG 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable," are the bases for acceptance with respect to provisions for decontamination. For spent fuel storage, paragraph 5.1.5 of ANS 57.2 and appropriate positions of RG 1.13 are the bases for

acceptance. For new fuel storage, paragraphs 6.3.3.7 and 6.3.4 of ANS 57.3 are the bases for acceptance.

7. 10 CFR 50.68 allows the applicant to follow the guidelines of 10 CFR 70.24 for criticality monitors or the guidelines described therein for significant margins of subcriticality.

Technical Rationale

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

1. GDC 2 requires that nuclear power plant SSCs important to safety be designed to withstand the effects of such natural phenomena as earthquake, tornado, hurricane, flood, tsunami, and seiche without loss of capability to perform their safety functions. The design of these SSCs also must reflect appropriate combinations of the effects of accidents and natural phenomena.

   The functions of the new and spent fuel storage facilities are to maintain new and spent fuel in a safe and subcritical array during all anticipated operating and accident conditions and to limit offsite exposures in the event of significant release of radioactive materials from the fuel. The spent fuel storage facility also must keep spent fuel assemblies adequately cooled during all anticipated operating and accident conditions. GDC 2 requirements verify whether SSCs of the new and spent fuel storage facilities (e.g., the SFP, new and spent fuel storage racks, and pool liner) will withstand the effects of natural phenomena that might occur at the plant site. Because of the large size of the pools, the applicant needs to address seismic-induced pool water sloshing and determine that sloshing will not result in substantial coolant loss, or that the resulting internal flooding will not harm safety-related SSCs. Designing the storage pool, and fuel storage racks to meet seismic Category I requirements provides reasonable assurance that earthquakes will not cause a substantial coolant loss, a reduction in margin to criticality, or damage to the fuel assemblies.

   GDC 2 requirements provide assurance that natural phenomena will not prevent maintenance of a subcritical configuration and adequate cooling of the stored fuel.

2. GDC 4 requires that SSCs important to safety be designed to accommodate the effects of, and be compatible with, the environmental conditions of anticipated operating and accident conditions. This requirement includes protection against dynamic effects, including those of missiles, pipe whipping, and discharging fluids caused by equipment failures and from events and conditions outside the nuclear power unit.

   GDC 4 requires for new and spent fuel storage facilities a controlled and protected environment for the new and spent fuel and all SSCs necessary for safety. The SFP liner, the new and spent fuel assemblies, and the fuel storage racks must be protected from dynamic effects, including turbine and tornado missiles. Adequately thick SFP walls and adequate water levels usually provide the necessary protection from dynamic effects for SSCs within the pool. The new fuel and its storage racks also must be protected from dynamic effects to provide reasonable assurance that a substantial margin to criticality is maintained. SRP Section 9.2.5 evaluates the UHS protections from dynamic effects.

GDC 4 requirements provide assurance that the new and spent fuel storage facilities will contain radioactive materials and maintain a subcritical configuration that can be cooled adequately in all environmental conditions, even after exposure to dynamic effects like missiles.

3. GDC 5 requires that SSCs important to safety not be shared among nuclear power units (one nuclear power unit is equal to one NuScale reactor module and its associated equipment necessary for electric power generation) unless such sharing can be shown not to significantly impair their ability to perform safety functions, including, in an accident in one unit, an orderly shutdown and cooldown of the remaining units.

   GDC 5 requires that the fuel storage facility at multiple-unit sites either not be shared among the units or that shared SSCs be designed so an accident at one facility will not significantly impair the ability of the remaining facility to protect new and spent fuel. The NuScale reactor modules are designed with only one UHS and one SFP that will provide service for up to 12 modules.

   GDC 5 requirements provide assurance that SSC sharing will not impair the safety functions of the new and spent fuel storage facilities.

4. GDC 61 requires that the fuel storage system be designed for adequate safety under anticipated operating and accident conditions. The system must be designed with (1) the capability for 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 safety importance 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.

   GDC 61 requires that the new and spent fuel storage facilities provide for inspection of the facilities, protection of the new and spent fuel, cooling for the spent fuel, shielding for the workers, and containment of the radioactivity. Provisions for inspection and testing are necessary to verify that there is no corrosion of the SFP liner or new and spent fuel storage racks, no buildup of crud or debris that may obstruct coolant flow in wet storage facilities, and no degradation of any strong fixed neutron absorbers. Containment is provided by the SFP liner, liner leakage collection, and appropriate floor sumps. SRP Section 9.2.5 will evaluate how the applicable protections are included into the UHS design.

   Provisions for removing decay heat from the spent fuel are by (1) design of spent fuel storage racks for adequate coolant flow, (2) maintenance of adequate SFP water levels, and (3) design of the SFP and storage racks to seismic Category I criteria. Prevention of significant reduction in SFP coolant inventory under accident conditions is by elimination of pool penetrations below coolant levels necessary for shielding and by anti-syphon devices and check valves on piping that could be a source of coolant draining. Furthermore, gates and weirs should separate the spent fuel storage pool from adjacent fuel-handling areas. Suitable shielding from spent fuel is provided by water levels at least 3 meters (10 feet) above the top of the stored fuel assemblies. There must also be appropriate shielding in the new fuel storage facility if recycled fuels are used.

GDC 61 requirements for the new and spent fuel storage facilities provide assurance of adequate cooling of stored fuel, appropriate confinement of radioactive materials, and adequate radiation shielding for personnel.

5. GDC 63 requires appropriate systems in fuel storage and radioactive waste systems and handling areas to detect conditions that may cause loss of residual heat removal capability and excessive radiation levels and to initiate appropriate safety actions.

   GDC 63 for spent fuel storage facilities requires SFP water level, pool temperature, and pool building radiation monitoring to protect personnel, to prevent significant offsite radiation doses, and to detect conditions that could cause loss of decay heat removal capabilities. For the dry storage of new fuel, either criticality accident monitors pursuant to 10 CFR 70.24 or an acceptable method of preventing an increase in K_{eff} beyond safe limits may be used pursuant to 10 CFR 50.68.

   Because the NuScale SFP water inventory is open and in communication with the UHS, any thermal loading that the different scenarios (normal operation or accident scenarios) impose on the UHS pool will affect the SFP thermal evaluation. These heat loads, in conjunction with the maximum SFP heat loads are determined in DSRS Section 9.1.3, to properly identify conditions that could cause loss of minimum decay heat removal capabilities.

   In addition, alarms and communications systems must alert personnel and provide for communications between fuel handling machines and the control room. If necessary to limit offsite dose consequences from a fuel handling accident or pool boiling, instrumentation should automatically place the spent fuel facility ventilation system in a mode to reduce the offsite release of radioactive material.

   GDC 63 requirements provide assurance that loss of residual heat removal capability and high radiation levels will be detected and that the release of radioactive materials to the environment will be prevented.

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

   This DSRS section describes staff positions and ANS guidance for the new fuel storage vault, new fuel storage racks, SFP, spent fuel storage racks, and the containing facility meant to achieve radiation doses in compliance with the ALARA principle. Controlled drainage for the SFP limits the spread of contamination from leakage of the pool liner. Smooth and non-porous surfaces for all components in contact with contaminated coolant (e.g., SFP liner and storage racks) avoid unnecessary buildup of radioactive material. Appropriate shielding of spent fuel and new recycled fuels also ensures compliance with the ALARA principle.

   10 CFR 20.1101(b) requirements provide assurance that components of the new and spent fuel storage facilities will generate radiation doses that comply with the ALARA standard.

7. 10 CFR 50.68 requires provisions either to monitor for criticality accidents pursuant to 10 CFR 70.24 or to follow its guidelines to ensure K_{eff} will not increase beyond safe limits.

10 CFR 50.68, as to the dry storage of fuel ensures an adequate degree of subcriticality or adequate criticality monitors. The applicant may provide radioactivity monitors as specified in 10 CFR 70.24, administrative controls or design features to prevent flooding of the dry storage area, or analysis to show that K_{eff} does not exceed 0.95 if the storage area is flooded with unborated water and that K_{eff} does not exceed 0.98 if the storage area is filled with an optimum moderator (e.g., fire extinguishing foam), assuming fuel of the maximum reactivity. SRP Section 9.1.1 provides the guidance necessary for criticality evaluation in the new and spent fuel storage areas.

10 CFR 50.68 requirements ensure that criticality accidents will not endanger the safety of personnel.

III. REVIEW PROCEDURES

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

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

Upon request from the primary reviewer, the interfacing review branches provide input for the areas of review stated in Subsection I of this DSRS section. The secondary review branch provides an input routinely for areas of review of this DSRS section. The primary reviewer uses such input as required to complete this review procedure.

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 SAR is reviewed to determine whether the design bases and facility description section indicate the storage capacity of the design.

   The minimum storage capacity in the spent fuel storage pool should equal or exceed the amount of spent fuel from five years of operation at full power plus one full-core discharge from each reactor module sharing the pool. Because of insufficient away-from-reactor storage capacity, the industry trend has been to use high-density storage racks. The reviewer evaluates high-density storage case by case. Low-density storage should be used, at a minimum, for the most recently discharged fuel to enhance the capability to cool it.

4. The SAR information on the facility design criteria, safety evaluation, system description, and layout drawings for the new fuel vault, SFP, the containing building, and the new and spent fuel storage racks is reviewed to verify whether:

A. The new fuel vault, new fuel storage racks, spent fuel storage racks, pools, and pool liners are capable of withstanding all design loads. This review is coordinated, as necessary, with the primary reviewer for DSRS Sections 3.8.4 and SRP 9.2.5.

B. The new and spent fuel storage racks are designed so a fuel assembly can be inserted only in a design location. The design also should prevent placement of fuel assemblies in the adjacent regions external to the racks.

C. Nonsafety-related SSCs not designed to seismic Category I standards located in the vicinity of the new and spent fuel storage facilities are reviewed for whether their failure would cause an increase in K_{eff} to more than the maximum allowable. The SAR description section, the general arrangement and layout drawings, and the tabulation of seismic design classifications for structures and systems are reviewed for whether this condition is met. A SAR statement establishing this condition as a design criterion is acceptable at the construction permit (CP) review stage.

D. Design calculations should show that the new and spent fuel storage racks and any anchorages can withstand the maximum fuel handling equipment uplift forces without an increase in K_{eff} or damage to the watertight integrity of the SFP liner. An SAR statement that excessive forces cannot be applied because of the design of the fuel handling equipment is acceptable with justification. The evaluation procedures of SRP Sections 9.1.4 and 9.1.5 validate this statement.

E. The load handled by the light load handling system, as addressed in SRP Section 9.1.4, with the potential to cause the greatest damage to stored fuel should be used in the fuel handling accident evaluation.

The provisions for protecting the new fuel storage area from loads dropped by the heavy load handling system are covered under SRP Section 9.1.5.

F. Sharing of storage facilities will not decrease the ability to remove decay heat from the spent fuel or maintain new and spent fuel in a subcritical array.

G. The materials wetted in the SFP, (e.g., spent fuel racks, fixed neutron poison, and the SFP liner) and, if applicable, the new fuel vault, are chemically compatible and stable. The review also verifies whether there are potential mechanisms to alter the dispersion of any strong fixed neutron absorbers. The secondary reviewer provides input for this review.

H. The SFP coolant water level can be maintained at a safe level for cooling and shielding. The design should include:

i. Weirs and gates separating the spent fuel storage areas from handling areas to prevent the accidental draining of the coolant to levels inadequate for fuel cooling or radiation shielding. The bottoms of any gates should be above the top of the fuel assemblies, and the adjacent pool should be designed to prevent leakage that would reduce the coolant inventory below the minimum safety limit.

ii. Absence of drains, permanently connected mechanical or hydraulic systems, and other features that by failure or improper operation could reduce coolant levels to inadequacy for cooling the spent fuel and all piping penetration locations above minimum shielding depth. DSRS Section 9.2.5 evaluates the design features that prevent failure or improper operation of the UHS and its associated piping connections from reducing the coolant levels to inadequacy for cooling the spent fuel.

I. The thermal-hydraulic analysis of the flow through the spent fuel racks is adequate for decay heat removal from the spent fuel assemblies during all anticipated operating and accident conditions. Furthermore, the analysis should show adequate natural circulation of the coolant during all anticipated operating conditions, including full core-offloads during refueling, to prevent nucleate boiling for all fuel assemblies.

J. The new fuel storage racks include openings at the bottom to facilitate drainage if intended for dry storage or flooding if intended for wet storage.

K. Detection and collection of SFP liner leaks incorporated into the design with capability to collect pool liner leaks (e.g. drains and sumps) to prevent uncontrolled releases of radioactive material to the environment and to keep radiation exposure as low as reasonably achievable for personnel.

L. If new fuel is intended to be stored dry, adequate drainage for the new fuel storage vault to prevent accumulation of any liquid moderators. The drain system should be sized to handle the maximum flow from the rupture of the largest water pipe in the area. Backflow into the vault through the drain system should be prevented.

M. If necessary to limit offsite dose consequences from a fuel-handling accident or from SFP boiling, an air filtration system designed to meet the requirements of 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.”

N. If the spent fuel storage facility is designed to allow boiling during accident conditions the SFP liner and containing structure should withstand the high temperatures and pressure of the boiling coolant.

O. Appropriate monitoring systems included in the design. For spent fuel storage, monitoring systems should detect pool water levels, pool temperatures, and pool building radiation levels. Alarms should be both local and in a continuously manned location. Guidance acceptable to the staff for spent fuel monitoring requirements is in position C.7 of RG 1.13. For dry storage of new fuel assemblies, the dry fuel storage facility should have one of the following under 10 CFR 50.68:

i. criticality monitors as specified in 10 CFR 70.24

ii. administrative controls and/or design features to prevent flooding

iii. K_{eff} not more than 0.95 if the storage area is flooded with unborated water and not more than 0.98 if the storage area is filled with an optimum moderator (e.g., fire extinguishing foam), assuming fuel of the maximum reactivity. SRP Section 9.1.1 provides the necessary guidance for criticality evaluation in the new and spent fuel storage areas

Criticality monitors are not required for the underwater storage of fuel pursuant to 10 CFR 70.24, but there should be area radiation monitoring equipment for spent fuel storage pursuant to GDC 63.

P. Appropriate monitoring and controls for ground water intrusion into the SFP concrete should exist.

5. The reviewer determines whether the safety function of the facility will be maintained, as required, if the facility is subjected to adverse natural phenomena of earthquakes, tornadoes, hurricanes, and floods. In this determination, the reviewer considers the following points:

A. The facility design basis and criteria and the component classification tables are reviewed for whether the new and spent fuel storage facilities including the new fuel storage vault, spent fuel storage pool, pool liner, and new and spent fuel racks are classified and designed to seismic Category I requirements.

B. If the SFP liner plate is not designed and constructed to seismic Category I requirements, the SFP liner plate is reviewed for whether a failure of the liner plate because of an SSE will not cause any of the following:

i. significant releases of radioactivity because of mechanical damage to the fuel

ii. significant loss of water from the pool that could uncover the fuel and lead to release of radioactivity because of heat-up

iii. loss of ability to cool the fuel because of flow blockage caused by a complete section or portion of the liner plate falling on the fuel racks

iv. damage to safety-related equipment because of pool leakage

v. uncontrolled release of significant quantities or radioactive fluids to the environs

C. The essential portions of the new and spent fuel storage facilities are reviewed for protection from the effects of floods, hurricanes, tornadoes, and internally- or externally-generated missiles. Flood protection and missile protection criteria are addressed in the SRP and DSRS Chapter 3 sections listed in the Review Interfaces subsection of this DSRS section. The reviewer utilizes the information in those SRP/DSRS sections, as appropriate, to validate the analyses presented. The reviewer accepts a statement to the effect that the storage facility is located in a seismic Category I structure that is missile-and flood-protected.

6. The safe handling of spent fuel assemblies necessitates the underwater transfer of spent fuel between plant areas including the spent fuel cask loading area. The SAR is

reviewed for a statement in the design basis and facility description section that a separate spent fuel shipping cask loading area is adjacent to the SFP. The reviewer verifies whether the loading area is designed to maintain the safety function of the SFP during accident conditions and natural phenomena. In addition, the reviewer verifies whether the design includes the following:

A. The cask-loading area should be capable of isolation from the fuel pool by gates and weirs. A SAR statement that the design includes these features is acceptable. The reviewer uses engineering judgment to verify whether the means provided meet the stated intent.

B. As to the handling of heavy loads (e.g., the spent fuel shipping cask) in the vicinity of the spent fuel storage pool, the reviewer must establish and verify in SRP Section 9.1.5 that one of the alternative approaches described in Section 5 of NUREG-0612 has been satisfied. If Sections 5.1.1 and 5.1.6 of NUREG-0612 have not been met, the SAR safety evaluations, results of design calculations, and the general arrangement and layout drawings should show that the spent fuel cask loading area is designed to withstand the loads from falling heavy objects, including the shipping cask, is not part of the storage pool floor, and, if breached by a falling object, would not cause loss of fuel pool water to an unacceptable level.

C. Because of the unique fuel design to be used at the NuScale reactors, the reviewer needs to verify that an NRC-licensed cask can be lowered into the dry dock and used to offload spent fuel, or, that the applicant has proposed a COL Action Item to require the COL applicant to demonstrate that an NRC-licensed cask can be lowered into the dry dock and used to offload spent fuel.

7. For reviews under 10 CFR Part 50, the procedures for CP application review for whether the design criteria and bases and the preliminary design meet the acceptance criteria of Subsection II of this DSRS section. For the review of the operating license application, the review procedures and acceptance criteria verify whether the initial design criteria and bases are implemented appropriately in the final design. The operating license review verifies whether the content and intent of the technical specifications prepared by the applicant agree with requirements for system testing, minimum performance, and surveillance developed from the staff's review.

8. 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).

9. 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 new and spent fuel storage facilities include the new and spent fuel storage racks, the spent fuel storage pool, the new fuel storage vault, and equipment storage pits. After review of the applicant's proposed DC, design bases, and safety classification for the new and spent fuel storage facilities and the provisions necessary to maintain a subcritical array and prevent uncontrolled releases of radiation, the staff concludes that the design of the spent fuel storage facility and supporting systems complies with NRC regulations in 10 CFR 20.1101(b), 10 CFR 50.68, and GDCs 2, 4, 5, 61, and 63.

This conclusion is based on the following findings:

1. The applicant has met the requirements of GDC 2 by compliance with Positions C.1 and C.2 of RG 1.13 and with applicable portions of RGs 1.29 and 1.117. For the spent fuel storage facility, acceptance is also based on compliance with ANS 57.2, paragraphs 5.1.1, 5.1.3, 5.1.12.9, and 5.3.2. For the new fuel storage facility, acceptance is also based on compliance with ANS 57.3, paragraphs 6.2.1.3(2), 6.2.3.1, 6.3.1.1, 6.3.3.4, and 6.3.4.2.

2. The applicant has met the requirements of GDC 4 for environmental and missile protection design basis by compliance with Positions C.2 and C.3 of RG 1.13 and the applicable portions of RGs 1.115 and 1.117.

3. The applicant has met the requirements of GDC 5 because the failure of any portion of the shared new and spent fuel storage facilities will not impair the ability of plant systems to perform safety functions.

4. The applicant has met the requirements of GDC 61 for new and spent fuel provisions for inspections, shielding, containment, residual heat removal, coolant flow through wet storage racks, and prevention of loss of coolant by compliance with Positions C.4, C.6, C.10, C.11, and C.12 of RG 1.13, the appropriate paragraphs of ANS 57.2, and the appropriate paragraphs of ANS 57.3.

5. The applicant has met the requirements of GDC 63 for monitoring the status of the stored spent fuel by compliance with Position C.7 of RG 1.13 and paragraph 5.4 of ANS 57.2. Monitoring systems can detect the loss of decay heat removal capabilities or excessive radiation levels and initiate appropriate safety actions.

   The applicant has also met, by either radiation monitoring under 10 CFR 70.24 or an analysis the staff has found acceptable, the requirements of GDC 63 for monitoring the status of the dry storage of new fuel to prevent an increase in K_{eff} beyond safe limits from flooding of the dry fuel storage area as pursuant to 10 CFR 50.68.

6. The applicant has met the requirements of 10 CFR 20.1101(b) as to ALARA radiation exposures by compliance with positions C.2.f(2) and C.2.f(6) of RG 8.8 and paragraphs 5.1.5 and 5.1.7.1 of ANS 57.2.

7. The applicant has met the requirements of 10 CFR 50.68 for the dry storage of new fuel by appropriate criticality monitoring, by administrative controls or design features that prevent flooding, or by an analysis that shows that the dry storage facility will maintain the degree of subcriticality specified in 10 CFR 50.68 even if flooded.

For DC and COL reviews, the findings will also summarize the staff's evaluation of the 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*, "Standards for Protection against Radiation," Part 20, Title 10, "Energy."

2. *U.S. Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities," Part 50, Title 10, "Energy."

3. 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection against Natural Phenomena."

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

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

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

7. 10 CFR Part 50, Appendix A, GDC 61, "Fuel Storage and Handling and Radioactivity Control."

8. 10 CFR Part 50, Appendix A, GDC 63, "Monitoring Fuel and Waste Storage."

9. *U.S. Code of Federal Regulations*, "Early Site Permits," Subpart A; "Standard Design Certifications," Subpart B; and "Combined Licenses for Nuclear Power Plants," Subpart C; "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Title 10, "Energy."

10. U.S. Nuclear Regulatory Commission, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident," Regulatory Guide (RG) 1.7, Revision 3, March 2007, Agencywide Documents Access and Management System (ADAMS) Accession No. ML070290080.

11. U.S. Nuclear Regulatory Commission, "Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," RG 1.112, Revision 1, March 2007, ADAMS Accession No. ML070320241.

12. U.S. Nuclear Regulatory Commission, "Alternative Radiological Source Terms for Evaluating Design-Basis Accidents at Nuclear Power Reactors," RG 1.183, July 2000, ADAMS Accession No. ML003716792.

13. American National Standards Institute/American Nuclear Society (ANSI/ANS), "Source Term Specification," Standard 18.1-1999" (withdrawn 2009).

14. U.S. Nuclear Regulatory Commission, "Clarification of TMI Action Plan Requirements," NUREG-0737, November 1980, ADAMS Accession No. ML051400209.

15. *U.S. Code of Federal Regulations*, “Environmental Radiation Protection Standards for Nuclear Power Operations,” Part 190, Title 40, “Protection of the Environment.”

16. U.S. Nuclear Regulatory Commission, “Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants,” RG 1.89, Revision 1, June 1984, ADAMS Accession No. ML003740271.

17. U.S. Nuclear Regulatory Commission, “Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants,” RG 1.143, Revision 2, November 2001, ADAMS Accession No. ML013100305.

18. 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.

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

20. U.S. Nuclear Regulatory Commission, Tornado Design Classification,” RG 1.117, Revision 1, April 1978, ADAMS Accession No. ML003739346.

21. U.S. Nuclear Regulatory Commission, “Combined License Applications for Nuclear Power Plants (LWR Edition),” RG 1.206.

22. Electric Power Research Institute (EPRI), “Pressurized Water Reactor Primary Water Chemistry Guidelines,” ADAMS Accession Nos. ML081230449 and ML081230448.

23. Electric Power Research Institute (EPRI), “Pressurized Water Reactor Primary Water Zinc Application Guidelines.”

24. Electric Power Research Institute (EPRI), “Advanced Light Water Reactor Utility Requirements Document, Volume III, ALWR Passive Plant.”

25. U.S. Nuclear Regulatory Commission, NUREG-1242, “NRC Review of Electric Power Research Institute’s Advanced Light Water Reactor Utility Requirements Document, Passive Plant Designs” Volume 3, Part 1 and Volume 3, Part 2, ADAMS Accession Nos. ML070600372 and ML070600373.

26. Electric Power Research Institute (EPRI), “Cobalt Reduction Guidelines.”

27. 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.