U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR NuScale SMR DESIGN

6.1.1 ENGINEERED SAFETY FEATURES MATERIALS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for review of component integrity issues related to engineered safety features

Secondary - None

I. AREAS OF REVIEW

Engineered safety features (ESF) systems are provided in nuclear plants to mitigate the consequences of design-basis or loss-of-coolant accidents (LOCA), even though the occurrence of these accidents is very unlikely. The Commission regulations of Title 10 *Code of Federal Regulations* (10 CFR) Part 50 require that certain systems be provided to serve as ESF systems. The fluids used in ESF systems, when interacting with the reactor coolant pressure boundary (RCPB), should have a low probability of causing abnormal leakage, of rapidly propagating failure, and of gross rupture. ESF systems include those systems that provide emergency core cooling, fission product containment, decay heat removal and containment heat removal. The materials and fluids compatibility for these systems are reviewed in this Design Specific Review Standard (DSRS) section. The General Design Criteria (GDC) establish functional requirements for specific systems. Specific acceptance criteria identified in subsection II of this DSRS section establish the basis for acceptance of materials and fluids compatibility of the ESF systems.

The specific areas of review are as follows:

1. Materials and Fabrication. The review includes the materials and fabrication procedures used in the construction of the ESF systems.. The specific areas of review and review procedures are similar to those in DSRS Section 5.2.3, "Reactor Coolant Pressure Boundary Materials," and DSRS Section 10.3.6, "Steam and Feedwater System Materials." The purpose of the review is to assure compatibility of the materials with the specific fluids to which the materials are subjected. The review is performed to assure compliance with the applicable Commission regulations of 10 CFR Part 50, including the applicable general design criteria; the positions of applicable regulatory guides and branch technical positions, and the applicable provisions of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (hereinafter the Code), including Section II, Parts A, B, C and D, Section III, Division1, and Section IX. Areas that are reviewed include mechanical properties of materials (including fracture toughness), use of cold worked stainless steels, control of ferrite content in austenitic stainless steel welds, and control of ferritic steel welding.

2. Composition and Compatibility of ESF Systems Fluids. The composition of fluids must be controlled to ensure their compatibility with materials in the containment building,

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including the reactor vessel, reactor internals, piping, and structural and insulating materials. The methods and procedures to control the chemical composition of solutions recirculated within the containment after design-basis accidents (DBAs) must be selected (a) to maintain the integrity of the RCPB, by preventing stress corrosion cracking of safety-related components, (b) to insure that adequate solution mixing of ESF fluids will occur, and (c) to prevent evolution of excessive amounts of hydrogen within the containment in the unlikely event of a DBA.

The time-dependent analysis of the pH of the fluids, including the source and quantity of all soluble acids and bases in the containment after a DBA, is reviewed.

The controls on contaminants, such as chlorides, lead, zinc, sulfur, or mercury, in the ESF system fluids are reviewed.

3. Component and Systems Cleaning. The review includes the requirements for the cleaning (in-shop and onsite) of materials and components, cleanliness control, and preoperational system cleaning and the procedures for layup of nuclear plant fluid systems. Requirements for the maintenance of system cleanliness of fluid systems and associated components during the operational phase of the nuclear power plant are also reviewed.

4. Thermal Insulation. The review includes the composition of the nonmetallic insulation and the control of leachable contaminants from the insulation. Nonmetallic thermal insulation that will be exposed to ESF system fluids in DBA environments is evaluated as a potential source of contaminants, such as chlorides, lead, zinc, sulfur, and mercury. The review also includes the use of inhibitors to reduce the probability of stress corrosion cracking of stainless steel components.

5. Combined License Action Items and Certification Requirements and Restrictions. For a design certification (DC) application, the review will also address combined license (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.

6. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For DC and 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.

Review Interfaces

Other SRP and DSRS sections interface with this section as follows:

1. The review of the adequacy of programs for assuring the integrity of bolting and threaded fasteners is performed under DSRS Section 3.13, “Threaded Fasteners-ASME Code Class 1, 2, and 3.”

2. The evaluation of the use and compatibility of ESF system fluids with organic materials (coatings) in containment, including their qualifications, is performed under DSRS Section 6.1.2, Protective Coating Systems (Paints) Organic Materials.”

3. The review of the acceptability of the reactor coolant and reactor pool water inventory chemistry and associated chemistry controls (including additives such as inhibitors) as it relates to corrosion control and compatibility with ESF system materials is performed under DSRS Section 9.3.4, "Chemical and Volume Control system."

4. The review of the adequacy of the design for structural integrity of components and their supports is performed under SRP Section 3.9.3, "ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures."

5. The determination of the adequacy of post-LOCA hydrogen control, including control of the volume of hydrogen gas expected to be generated by metal-water reaction involving the fuel cladding and radiolytic decomposition of the reactor coolant, and corrosion of metals by emergency core cooling is performed under DSRS Section 6.2.5, "Combustible Gas Control in Containment."

6. The review of inservice inspection and testing requirements for Class 2 and 3 ESF system components is performed under DSRS Section 6.6, "Inservice Inspection and Testing of Class 2 and 3 Components."

II. ACCEPTANCE CRITERIA

Requirements

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

1. General Design Criteria (GDC) 1 and 10 CFR 50.55a as they relate to quality standards for design, fabrication, erection, and testing of ESF system components and the identification of applicable codes and standards.

2. GDC 4 as it relates to compatibility of ESF system components with environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs.

3. GDC 14 as it relates to design, fabrication, erection, and testing of the RCPB so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

4. GDC 31 as it relates to designing the RCPB such that the boundary behaves in a nonbrittle manner and there is an extremely low probability of rapidly propagating fracture and of gross rupture of the RCPB.

5. GDC 34 as it relates to the emergancey core cooling system (ECCS) providing passive decay heat removal in non-LOCA design basis accidents at a rate such that specified acceptable fuel design limits and the design conditions of the reactor coolant pressure boundary are not exceeded.

6. GDC 35 as it relates to providing adequate core cooling following a LOCA at such a rate that fuel and clad damage that could inhibit core cooling is prevented and that the clad metal-water reaction is limited to negligible amounts.

7. GDC 41 as it relates to control of the concentration of hydrogen in the containment atmosphere following postulated accidents to assure that containment integrity is maintained.

8. Appendix B to Title 10 of *Code of Federal Regulations* (10 CFR) Part 50, Criteria IX and XIII, as they relate to establishing and controlling work and inspection instructions that prescribe the special cleaning processes and measures necessary to prevent material and equipment damage or deterioration in accordance with applicable codes, standards, specifications, criteria, and other special requirements.

9. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the design certification has been constructed and will be operated in conformity with the design certification, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulatory Commission's (NRC's) regulations.

10. 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 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 (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 the NRC regulations that underlie the DSRS acceptance criteria.

Materials and Fabrication. To meet the requirements of GDC 1 and 10 CFR 50.55a to assure that SSCs important to safety shall are designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed, codes and standards should be identified and records maintained. The materials specified for use in these systems must be as given in Parts A, B, C and D of Section II of the ASME Code and Section III, Division 1 of the Code.

1. Regulatory Guide (RG) 1.84 describes acceptable ASME Code Cases that may be used in conjunction with the above specifications. Fracture toughness of the materials should be as stated in DSRS Section 10.3.6, "Steam and Feedwater System Materials,"for ASME Code Class 2 and 3 systems; DSRS Section 5.2.3 "Reactor Coolant Pressure Boundary Materials," for ASME Code Class 1 components' and DSRS Section 6.2.7 "Fracture Prevention of Containment Pressure Boundary" for ASME Code Class MC components designed to ASME Code Class 1 rules.

A. Austenitic Stainless Steels. To meet the requirements of GDC 4 relative to compatibility of components with environmental conditions; GDC 14 with respect to fabrication and testing of the RCBP such that there is an extremely low probability of abnormal leakage, rapidly propagating failure, and gross rupture; and the quality assurance requirements of Appendix B of 10 CFR Part 50, the following guidelines should be used:

i. RG 1.44 describes acceptable criteria for preventing intergranular corrosion of stainless steel components in ESF systems. Furnace-sensitized material should not be allowed in ESF systems, and methods described in this guide should be followed for testing the materials prior to fabrication, and for ensuring that no deleterious sensitization occurs during welding.

ii. RG 1.31 describes acceptable criteria for assuring the integrity of welds in austenitic stainless steel ESF system components. The control of delta ferrite content of weld filler metal is specified in this guide, which sets forth an acceptable basis for delta ferrite content of weld filler metal.

iii. The controls for abrasive work on austenitic stainless steel surfaces should, at a minimum, be equivalent to the controls described in ASME NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications," as endorsed in RG 1.28 to prevent contamination, which promotes stress corrosion cracking. Tools that contain materials that could contribute to intergranular or stress corrosion cracking or which, because of previous usage, may have become contaminated with such materials, should not be used on austenitic stainless steel surfaces.

B. Ferritic Steel Welding. To meet the requirements of GDC 1 related to general quality assurance and codes and standards; Appendix B to 10 CFR Part 50, related to control of special processes; and 10 CFR 50.55a, the following acceptance criteria for ferritic steel welding should be used:

i. The amount of minimum specified preheat must be in accordance with the recommendations of the Code, Section III, Appendix D, Article D-1000, and RG 1.50, unless an alternate procedure is justified.

ii. Moisture control on low hydrogen welding materials shall conform to the requirements of the Code, Section III, Articles NB, NC, ND-2000 and 4000, and American Welding Society (AWS) D1.1 "Structural Welding Code - Steel," American Welding Society, unless alternate procedures are justified.

iii. For areas of limited accessibility, the criteria of RG 1.71 apply as discussed in DSRS Section 10.3.6.

2. Composition and Compatibility of ESF System Fluids. In meeting the requirements of GDC 4 and 41 that SSCs important to safety are designed to accommodate the effects of, and to be compatible with environmental conditions associated with normal operation, maintenance, testing, and postulated accident conditions, including LOCAs, and to assure that the concentration of hydrogen in the containment atmosphere following postulated accidents is controlled to maintain containment integrity, hydrogen generation resulting from the corrosion of metals by ESF system fluids during a DBA should be controlled as described in RG 1.7, position C.4.

   A. To meet the requirements of GDC 4, 14, and 41, the composition of cavity flood and core cooling water should be controlled to ensure a minimum pH of 7.0, as addressed in Branch Technical Position (BTP) 6-1,"pH for Emergency Coolant Water for Integral Pressurized Water Reactors (iPWRs)." Experience has shown that maintaining the pH of borated solutions at this level will help to inhibit initiation of stress corrosion cracking of austenitic stainless steel components.

      Hydrogen generation from the corrosion of materials within containment, such as aluminum and zinc, depends upon the corrosion rate, which in turn depends upon such factors as the coolant chemistry, the coolant pH, the metal and coolant temperature, and the surface area exposed to attack by the coolant.

      The assumed corrosion rates of materials in containment should be consistent with standard corrosion rate data.

3. Component and Systems Cleaning. To meet the requirements of Appendix B to 10 CFR Part 50, Criteria IX and XIII, measures should be established to control the cleaning of material and equipment in accordance with work and inspection instructions to prevent damage or deterioration.

   Components and systems should be cleaned in conformance with ASME NQA-1.

4. Thermal Insulation. To meet the requirements of GDC 1, 14, and 31, the RCPB should be designed, fabricated, erected, and tested in conformance with the following guidelines, such that there is an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture:

   A. The composition of nonmetallic thermal insulation on ESF system components should be controlled as described in RG 1.36.

   B. The use of nonmetallic insulation on nonaustenitic stainless steel components should be controlled as described in RG 1.36. Moisture dripping from wet insulation can affect austenitic stainless steel components at lower elevations.

   C. Concentrations of leachable contaminants and added inhibitors should be controlled as specified in position C.2.b and Figure 1 of RG 1.36 to reduce the probability of stress corrosion cracking of austenitic stainless steel components.

5. 10 CFR 52.47(b)(1) specifies that the application of a DC should contain proposed ITAAC for SSCs necessary and sufficient to assure the plant is built and will operate in accordance with the DC. 10 CFR 52.80(a) specifies that the COL applicant identifies the ITAAC for SSCs necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will be operated in conformity with the COL, the provisions of the Act, and Commission's rules and regulations. SRP 14.3 provides guidance for reviewing the ITAAC. The requirements of 10 CFR 52.47(b)(1) and 10 CFR 52.80(a) will be met, in part, by identifying inspections, tests, analyses, and acceptance criteria of the top-level design features of ECCS materials in the DC application and the COL, respectively.

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 1 and 10 CFR 50.55a require that SSCs be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed. 10 CFR 50.55a also incorporates by reference applicable editions and addenda of the ASME Code. ESF system functions include emergency core cooling, fission product containment, and heat removal to an ultimate heat sink. These functions are provided to establish, maintain, and/or protect barriers against the release of fission products. In addition, ESF systems may interface with the RCPB or protect the RCPB. The RCPB provides a fission product barrier, a confined volume for the inventory of reactor coolant, and flow paths to facilitate core cooling. Application of 10 CFR 50.55a and GDC 1 to the ESF system materials provides assurance that established standard practices of proven or demonstrated effectiveness are used to achieve a high likelihood that these safety functions will be performed.

2. GDC 4 requires that SSCs important to safety be designed to accommodate the effects of, and to be compatible with, the environmental conditions associated with normal operations, maintenance, testing, and postulated accidents, including LOCAs. ESF system functions include emergency core cooling, fission product containment, and heat removal to an ultimate heat sink. These functions are provided to establish, maintain, and/or protect barriers against the release of fission products. In addition, ESF systems interface with the RCPB and protect the RCPB. The RCPB provides a fission product barrier, a confined volume for the inventory of reactor coolant, and flow paths to facilitate core cooling. Application of GDC 4 to the ESF system materials provides assurance that degradation and/or failure of the ESF systems and/or the RCPB resulting from environmental service conditions that could cause substantial reduction in the capabilities of fission product barriers are not likely to occur.

3. GDC 14 requires that the RCPB be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, rapidly propagating failure, and gross rupture. ESF systems, such as emergency core cooling, interface with the RCPB. Application of GDC 14 assures that ESF system materials are selected, fabricated, installed, and tested to provide a low probability of significant degradation and, in the extreme, gross failure of the RCPB that could cause substantial reduction in capability to contain reactor coolant inventory, reduction in capability to confine fission products, or interference with core cooling.

4. GDC 31 requires that the RCPB be designed to assure that when stressed under operating, maintenance, testing, and postulated accident conditions, (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. ESF systems may interface with the RCPB or protect the RCPB. Application of GDC 31 assures that ESF system materials are selected to provide a minimum probability of material degradation leading to rapid failure. The probability of substantial reduction in capability to contain reactor coolant inventory, reduction in capability to confine fission products, and interference with core cooling is thereby minimized.

5. GDC 34 requires that the system safety function shall be to transfer fission product decay heat and other residual heat from the reactor core at a rate such that specified acceptable fuel design limits and the design conditions of the RCPB are not exceeded. During non-LOCA events, this function is provided by the passive ECCS. Appropriate selection of ESF system materials and fluids, including cooling water pH requirements, can enhance the likelihood of achieving design emergency core cooling flow and heat transfer rates following non-LOCA events.. Meeting GDC 34 through proper material selection and fluid chemistry control requirements for the primary coolant and the reactor building pool assures that integrity of fission product barriers is maintained in the event of non-LOCA events.

6. GDC 35 requires that a system be provided to transfer heat from the reactor core following any loss of reactor coolant. Appropriate selection of ESF system materials and fluids, can enhance the likelihood of achieving design emergency core cooling flow and heat transfer rates following a loss of reactor coolant, thereby minimizing fuel damage. Meeting GDC 35 through proper material selection assures that integrity of fission product barriers is maintained in the event of a LOCA.

7. GDC 41 requires that systems be provided to control the concentration of hydrogen in the containment atmosphere following postulated accidents to assure that containment integrity is maintained. If hydrogen gas were to accumulate in explosive concentrations inside the reactor containment, ignition or detonation of the gas could threaten or breach this fission product barrier. Containment atmosphere cleanup is an ESF system function. Appropriate selection of ESF system materials and fluids can limit the quantity of hydrogen gas generated following postulated accidents. Application of GDC 41 thus assures that following postulated accidents, hydrogen gas will not accumulate in concentrations that could threaten or breach the containment fission product barrier.

8. Criterion IX of Appendix B to 10 CFR Part 50 requires that measures be established to assure that special processes, including welding, heat treating, and nondestructive testing, are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements. ESF system functions include emergency core cooling, fission product containment, and heat removal to an ultimate heat sink. These functions are provided to establish, maintain, and/or protect barriers against the release of fission products. Application of special process control requirements provides assurance that implementation of special processes will not introduce conditions adverse to quality in ESF systems, including, but not limited to, damage or deterioration of ESF system and/or RCPB materials and pressure boundaries, alteration of critical material properties, acceleration of effects associated with aging, flow blockages in ESF systems, or increases in the susceptibility to failure mechanisms such as stress corrosion

cracking. This reduces the likelihood of degradation and/or failure of the ESF systems that could cause substantial reduction in the capabilities of fission product barriers.

Criterion XIII of Appendix B to 10 CFR Part 50 requires that measures be established to control the cleaning of material and equipment to prevent damage or deterioration. Application of cleaning requirements to the ESF system materials provides assurance that contaminants to which they could be exposed will not damage or deteriorate the materials, alter their properties, accelerate effects associated with aging, or increase the susceptibility to failure mechanisms such as stress corrosion cracking. This reduces the likelihood of degradation and/or failure of the ESF systems that could cause substantial reduction in the capabilities of fission product barriers.

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.

2. 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: Integral Pressurized Water 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 SMR framework. Using the graded approach described in NUREG-0800 Intro Part 2, the NRC staff may determine that, for certain structures, systems, and components (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 completion of the applicable ITAAC. The use of the selected programs to augment or replace traditional review procedures is described in Figure 1 of NUREG-0800, Introduction - Part 2. Examples of such programs that may be relevant to the graded approach for these SSCs include:

    - 10 CFR Part 50, Appendix A, General Design Criteria (GDC), Overall Requirements, Criteria 1 through 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 Non-Safety 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.

3. In accordance with 10 CFR 52.47(a)(8),(21), and (22), and 10 CFR 52.79(a)(17), (20) and (37), for design certification or combined license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues which are identified in the version of NUREG-0933 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 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.

4. Materials and Fabrication

    A. Material Specifications. The reviewer verifies that the materials proposed for the ESF systems are in conformance with Parts A, B, C and D of Section II of the Code, Section III, Division 1, and/or with acceptable material ASME Code Cases as identified in RG 1.84.

    B. Nickel-Chromium-Iron Alloys. Operating experience has indicated that certain nickel-chromium-iron alloys (e.g., Inconel) are susceptible to cracking due to corrosion. Inconel Alloy 690 has improved corrosion resistance in comparison to Inconel Alloy 600 previously used in reactor applications. Where nickel-chromium-iron alloys are proposed for use as ESF system materials, the reviewer verifies that an acceptable technical basis is either identified (based upon demonstrated satisfactory use in similar applications) or presented by the applicant to support use of the material under the expected environmental conditions (e.g., exposure to the reactor coolant). Particular review emphasis is placed upon the corrosion resistance and stress corrosion cracking resistance properties of the proposed nickel-chromium-iron alloy(s).

    C. Austenitic Stainless Steels. The reviewer verifies that cold-worked austenitic stainless steels used in fabrication of the ESF systems and associated controls for fabrication are in conformance with the criteria specified in subsection II.1.A of this DSRS section.

    The methods of controlling sensitized stainless steel in the ESF systems are examined by the reviewer who verifies that the methods are in conformance with RG 1.44. This applies especially to the verification of nonsensitization of the materials, and to the qualification of welding procedures using ASTM A-262. If

alternative methods of testing the qualification welds for degree of sensitization are proposed by the applicant, the reviewer determines if these are satisfactory, based on the degree to which the alternate methods provide the needed results. An alternate method of testing for degree of sensitization that has previously been accepted is described in DSRS Section 5.2.3, subsection II.4.A.

D. Corrosion Allowances. The reviewer determines that corrosion allowances are specified for ESF system materials to be exposed to process fluids and that specified allowances are supported by adequate technical bases. The reviewer verifies that specified corrosion allowances are adequate for the proposed design life of affected components and piping.

E. Fabrication Controls. The reviewer examines the methods for controlling the amount of delta ferrite in stainless steel weld deposits in accordance with RG 1.31.

The reviewer verifies the applicant's description of abrasive work controls for austenitic stainless steel surfaces is adequate to minimize the cold-working of surfaces and the introduction of contaminants through stress corrosion cracking.

The reviewer verifies that the controls of ferritic steel welding are in conformance with subsection II.1.B of this DSRS section. The reviewer verifies that the fracture toughness of the materials is in accordance with the requirements of the Code.

5. Composition and Compatibility of ESF System Fluids.

The reviewer examines the information on the compatibility of the ESF system materials of construction with the ESF system fluids to verify that all materials used are compatible.

A. The reviewer determines that the coolant fluids will have a minimum pH of 7.0 and reviews the methods of ascertaining that the pH will remain above this minimum during operation.

The reviewer examines the methods of storing the ESF system fluids to determine whether deterioration will occur either by chemical instability or by corrosive attack on the storage vessel. The reviewer determines what effects such deterioration could have on the compatibility of these ESF system fluids with both the ESF system materials of construction and the other materials within the containment.

The reviewer further verifies that hydrogen release due to corrosion of metals by emergency core cooling fluids is controlled in accordance with RG 1.7, position C.4.

The reviewer also compares the assigned corrosion rates of materials in containment, as stated in the applicant's technical submittal, with standard corrosion rate data. In accordance with the procedures in SRP Section 6.5.2, the reviewer examines the paths that the solutions would follow in the containment from ECCS to the sump, for both injection and recirculation phases to verify that no areas accumulate very high or low pH solutions.

6. Component and Systems Cleaning. The reviewer verifies that components and systems are cleaned in accordance with ASME NQA-1.

7. Thermal Insulation. The reviewer determines whether non-metallic thermal insulation will be used on components of the ESF systems. If so, the reviewer verifies that the amount of leachable impurities in the specified insulation will be within the acceptable analysis area of Figure 1 of RG 1.36, as discussed in subsection II.4 of this DSRS section.

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 design control document (DCD), meets the acceptance criteria. 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 DCD.

   For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an 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 (SER). The reviewer also states the bases for those conclusions.

1. GDC 1, 14, and 31, and 10 CFR 50.55a have been met with respect to assuring an extremely low probability of leakage, of rapidly propagating failure, and of gross rupture. This is demonstrated by the selection of materials for the ESF systems that satisfy Parts A, B, C and D of Section II of the ASME Code and Section III, Division 1 of the Code. The fracture toughness of ferritic materials selected for the ESF systems meets Code requirements.

   The controls on the use and fabrication of austenitic stainless steel in ESF systems satisfy the positions of RG 1.31, "Control of Ferrite Content of Stainless Steel Weld Metal," and RG 1.44, "Control of the Use of Sensitized Stainless Steel." Fabrication and heat treatment practices performed in accordance with these positions provide added assurance that the probability of stress corrosion cracking will be reduced during the postulated accident time interval.

   Conformance with the Codes and RGs and with the staff positions mentioned above constitutes an acceptable basis for meeting the requirements of GDC 1, 4, 14, 34, 35, 41 and Appendix B to 10 CFR Part 50; and 10 CFR 50.55a, in which the systems are to be designed, fabricated, and erected so that the systems can perform their function as required.

2. GDC 1, 14, and 31 and Appendix B to 10 CFR Part 50 have been met with respect to assuring that the RCPB and associated auxiliary systems have an extremely low probability of leakage, of rapidly propagating failures, and of gross rupture. The controls placed on concentrations of leachable impurities in non-metallic thermal insulation used on engineered safety features components are in accordance with the positions of RG 1.36, "Nonmetallic Thermal Insulation for Austenitic Stainless Steels." Compliance with the positions of RG 1.36 is the basis for meeting the requirements of GDC 1, 14, and 31.

3. The requirements of GDC 4, 34, 35, 41, and Appendix B, 10 CFR Part 50 have been met with respect to compatibility of ESF system components with environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs, since the controls on pH and chemistry of emergency core cooling water following a LOCA or DBA are adequate to reduce the probability of stress corrosion cracking of the austenitic stainless steel components and welds of the ESF systems in containment throughout the duration of the postulated accident to completion of cleanup.

   Also, the control of the pH of cooling water, in conjunction with controls on selection of containment materials, is in accordance with RG 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident," and provides assurance that the cooling water will not give rise to excessive hydrogen gas evolution resulting from corrosion of containment metal or cause serious deterioration of the materials in containment.

   The controls placed upon component and system cleaning are in accordance with ASME NQA-1 and provide a basis for the finding that the components and systems have been protected against damage or deterioration by contaminants as stated in the cleaning requirements of 10 CFR Part 50, Appendix B.

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. <u>IMPLEMENTATION</u>

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 Standard Review Plan (SRP) revision in effect six 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 small modular reactor (SMR) designs, however, differ significantly from large light-water nuclear reactor 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 SRM- COMGBJ-10-0004/COMGEA-10-0001, “Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews,” dated August 31, 2010 (ML102510405) (SRM). 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 pre-application activities. Accordingly, the staff has developed the content of the DSRS as an alternative method for the evaluation of 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 in order to address new design or siting assumptions.

VI. REFERENCES

1. 10 CFR Part 20, “Standards for Protection Against Radiation.”

2. 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities.”

3. 10 CFR Part 52, “Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants.”

4. GDC 61, “Fuel Storage and Handling and Radioactivity Control.”

5. GDC 19, “Control Room.”

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

7. RG 1.7, “Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident.”

8. RG 1.112, “Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors.”

9. RG 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors.”

10. ANSI/ANS Standard 18.1-1999, “Source Term Specification,” American National

Standards Institute/American Nuclear Society."

11. NUREG-0737, "Clarification of TMI Action Plan Requirements."

12. 40 CFR Part 190, "Environmental Radiation Protection Standards For Nuclear Power Operations."

13. RG 1.89, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants."

14. RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants."

15. RG 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants."

16. RG 1.29, "Seismic Design Classification."

17. RG 1.117, "Tornado Design Classification."

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

19. EPRI, "Pressurized Water Reactor Primary Water Chemistry Guidelines."

20. EPRI, "Pressurized Water Reactor Primary Water Zinc Application Guidelines."

21. EPRI, "Advanced Light Water Reactor Utility Requirements Document, Volume III, ALWR Passive Plant."

22. 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).

23. EPRI, "Cobalt Reduction Guidelines."

24. RG 8.8, "Information Relevant to Assuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as is Reasonably Achievable."