UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

# FINAL SAFETY EVALUATION REPORT

## DOCKET NO. 72-1042
## TN AMERICAS LLC
## CERTIFICATE OF COMPLIANCE NO. 1042
## NUHOMS® EOS SYSTEM
## AMENDMENT NO. 4

**SUMMARY**

This safety evaluation report (SER) documents the U.S. Nuclear Regulatory Commission (NRC) staff's review and evaluation of the request to amend Certificate of Compliance (CoC) No. 1042 for the NUHOMS® EOS system. By letter dated September 29, 2022 (Agencywide Documents Access and Management System (ADAMS) Accession Number ML22272A575), as supplemented in letters dated March 30, 2023 (ML23089A175), June 28, 2023 (ML23179A120), April 22, 2024 (ML24113A307), November 6, 2024 (ML24311A209), and February 12, 2025 (ML25043A122), TN Americas LLC, from here on referred to as the "applicant", requested that the U.S. Nuclear Regulatory Commission amend the Certificate of Compliance (CoC) No. 1042 to include the following changes:

**Change No. 1:**
For the EOS-37PTH, similar to the EOS-89BTH concept submitted under Amendment No. 3 (Change No. 7), incorporate a method to determine new loading patterns based on the maximum allowable heat load per dry shielded canister (DSC), identified as the maximum allowable heat load configuration (MHLC). The MHLC is applicable to the EOS-37PTH transferred in the transfer cask (TC) EOS-TC125 and stored in the EOS-HSM (horizontal storage module). Two new heat load zone configurations (HLZCs) are applicable to this MHLC.

**Change No. 2:**
Introduce a steel-plate composite (SC) option for the EOS HSM. The steel-plate composite option (EOS-HSM-SC) allows for the HSM components to be constructed from concrete-filled integrated steel wall forms. The walls are tied together with tie bars and studs which are welded to the inside of the walls to provide concrete reinforcement. When used without distinction, EOS-HSM-SC refers to both the segmented and one-piece base. The EOS-HSM-SC is used only with the flat plate support structure.

**Change No. 3:**
Introduce the use of MAVRIC software for a confirmatory run of the HSM-MX (NUHOMS® MATRIX HSM) dose rates.

**Change No. 4:**
Technical Specification (TS) changes for consistency among DSC types and terminology clarification.

**Change No. 5:**
Various updated final safety analysis report (UFSAR) editorial corrections for consistency and clarification.

**Change No. 6:**
Add measured exposures from past loading campaigns to highlight that measured exposures are significantly less than calculated exposures.

**Additional Scope Change No. 1:**
Add an additional scope item to allow use of a blended Portland cement that would be certified to the requirements of American Society for Testing and Materials (ASTM) C595. The reason for this change is that the cement supplier will no longer provide cement in accordance with ASTM C150 since the supplier is transitioning to a cement with a smaller carbon footprint that includes 10% limestone. This change supports continued EOS HSM and EOS HSM-MX fabrication activities. In support of this additional scope, revise UFSAR sections 8.2.1.3, EOS HSM Horizontal Storage Module; 8.7, References; A.8.2.1.3, HSM-MX Horizontal Storage Module; and A.8.7, References.

An editorial clarification to UFSAR chapters 8 and A.8 regarding the use of a blended Portland cement that would be certified to the requirements of ASTM C595. The reason for this clarification is that the cement supplier will no longer provide cement in accordance with ASTM C150 since the supplier is transitioning to a cement with a smaller carbon footprint that includes 10% limestone. Although this change for Amendment No. 4 was submitted on March 30, 2023 (ML23089A175), the change was initially submitted as an additional code alternative to American Concrete Institute (ACI) 349-06, appendix E, section E.4, Concrete Temperatures, specifically for Amendments No. 1, 2, and 3. The code alternative application was submitted on August 23, 2023 (ML23235A066). The NRC issued the approval on October 24, 2023 (ML23277A127).

**Additional Scope Change No. 6:**
Add an additional scope item related to the use of the Matrix Loading Crane (MX-LC) for the 61BTH Type 2 DSCs. The reason for this change is that, under Amendment No. 3, TN added detail to demonstrate the single failure proof capability of the MX-LC. That information was provided to demonstrate compliance with CoC No. 1042, Amendment No. 3, Condition 5 for lifts of the DSC and transfer cask (TC) above heights not analyzed for an accidental drop, and to comply with CoC No. 1042, Amendment No. 3, TS 5.2.1 for TC/DSC lifting height limits. However, TN omitted addressing use of the MX-LC for the 61BTH DSCs. This change supports the continued use of the HSM-MX in conjunction with the MX-LC for 61BTH DSCs. In support of this additional scope, revise UFSAR sections B.9.1.6, DSC Transfer to the HSM-MX; B.9.2.1, DSC Retrieval from the HSM-MX; B.9.3, References; B.12.3.1, OS197 Transfer Cask (TC) Drop; and B.12.4, References.

**Additional Scope Change No. 8:**
Add an additional scope item to clarify the scenarios under which the maximum heat loads can be reduced for EOS-37PTH. The reason for this change is to clarify the different site-specific conditions that could result in a reduction in the maximum heat load for existing HLZCs and to also note that one could develop new HLZCs based on the MHLC methodology described in section 2.4.3.1. Add this clarifying language to the fourth paragraph on UFSAR page 2-10 and to page 2-2 of the TS.

The amended CoC, when codified through rulemaking, will be denoted as Amendment No. 4 to CoC No. 1042. This SER documents the staff's review and evaluation of the proposed amendment. The staff followed the guidance of NUREG-2215, "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities," (ML20121A190) when performing technical reviews of spent fuel storage and transportation packaging licensing actions.

The staff's evaluation is based on a review of the applicant's application and whether it meets the applicable requirements of 10 CFR Part 72 for dry storage of spent nuclear fuel. The staff's evaluation focused only on modifications to the CoC, and TS requested in the amendment as supported by the submitted revised UFSAR (see ML22272A575, ML23089A175, ML23179A120, ML24113A307, ML24311A209, and ML25043A122) and did not reassess previous revisions of the UFSAR nor previous amendments to the CoC.

## 1.0 GENERAL INFORMATION

The objective of this chapter is to review the changes requested to CoC No. 1042 for the NUHOMS® EOS system to ensure that the applicant provided an adequate description of the pertinent features of the storage system and the changes requested in the application. The staff finds that the description of the proposed changes requested by the applicant are adequate to allow staff's detailed evaluation as documented in the following SER sections (3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16, and 17). Note that SER sections 2, 13, and 14 are only applicable to site specific license reviews and are not applicable to CoC evaluations.

## 2.0 SITE CHARACTERISTICS FOR DRY STORAGE FACILITIES

This section is not applicable to CoC evaluations.

## 3.0 PRINCIPAL DESIGN CRITERIA EVALUATION

The staff's objective in reviewing the principal design criteria related to the structures, systems and components (SSCs) important to safety (ITS) is to ensure that they comply with the relevant general criteria established in 10 CFR Part 72. The staff reviewed and evaluated the information provided by the applicant and determined that the following changes are applicable to the principal design criteria evaluation:

**Change No. 1:**
For the EOS-37PTH DSC, incorporate a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 TC and stored in the EOS-HSM. Two new HLZCs are applicable to this MHLC.

**Change No. 2:**
Introduce a steel-plate composite option for the EOS-HSM. The steel-plate composite option (EOS-HSM-SC) allows for the HSM components to be constructed from concrete-filled integrated steel wall forms. The EOS-HSM-SC is designed and constructed to American National Standards Institute/American Iron and Steel Institute (ANSI/AISC) N690, ACI 349-13, and ACI 318-08 with the code alternatives identified in the Technical Specifications.

**Additional Scope Change No. 8:**
Clarify the scenarios under which site-specific conditions could result in a reduction in the maximum heat loads for EOS-37PTH DSC.

The NRC staff reviewed the changes to the UFSAR, CoC, and TSs associated with the CoC No. 1042 NUHOMS® EOS Amendment No. 4 application. The staff's review was conducted using the guidance in chapter 3 of NUREG-2215 to ensure adequate materials performance under normal, off-normal, and accident-level conditions. The objective of the principal design criteria review is to determine whether the NUHOMS® EOS system with the proposed amendments continues to meet the regulatory requirements in 10 CFR 72.236.

### 3.1 Change No. 1: Method to Determine New Heat Load Patterns

In Change No. 1, the applicant incorporated a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The applicant specified that the MHLC is applicable to the EOS-37PTH DSC transferred in the EOS-TC125 and stored in the EOS-HSM. The applicant included two new HLZCs that are applicable to this MHLC. The applicant provided the corresponding revision to the following UFSAR Chapters:

Ch. 1. General Information
Ch. 2. Principal Design Criteria
Ch. 4. Thermal Evaluation
Ch. 6. Shielding Evaluation
Ch. 7. Criticality Evaluation
Ch. 8. Materials Evaluation
Ch. 9. Operating Procedures
Ch. 10. Acceptance Tests and Maintenance Program
Ch. 11. Radiation Protection

The applicant included a description of the change in UFSAR chapter 1, "General Information," and stated that the MHLC for the EOS-37PTH is shown in the TS, figure 12, and is similar to that previously added for the EOS-89BTH DSC. The applicant described the new Type 4HA basket type for the EOS-37PTH DSC, which is anodized for improved thermal properties and required when the HLZC with per assembly decay heats greater than 3.5 kW are stored. Corresponding changes to UFSAR table 1-2, "System Configurations for the NUHOMS® EOS System and NUHOMS® MATRIX System," were added to include the Type 4HA basket. The applicant also revised UFSAR section 1.4.1, "EOS-37PTH DSC Contents," to include references to additional tables added to the TS to support this change.

The applicant revised UFSAR section 2.2, "Spent Fuel to Be Stored," to allow a minimum cooling time of 1 year for the EOS-37PTH DSC and revised and added TS tables for the allowed contents. The applicant revised UFSAR section 2.4.3.1, "Methodology for Evaluating Additional HLZCs in EOS-37PTH DSC and EOS-89BTH DSC," to add the EOS-37PTH DSC and describe the qualification process and requirements for new HZLCs.

The applicant also revised TS section 2.1, "Fuel to be Stored in the EOS-37PTH DSC," to include MHLC and decay heat calculations, fuel burnup and minimum cooling times for transfer operations using the EOS TC108/125/135 transfer casks and storage in the EOS-HSMs and HSM-MX. Additionally, the applicant revised TS section 3.1.3, "Time Limit for Completion of DSC Transfer," to include time limits for HLZCs, enveloped by the MHLC shown for the EOS-37PTH DSC in TS figure 12, and allowed for transfer in the EOS-TC125/TC135 and storage in the EOS-HSM. To support this change, the applicant revised TS table 3, "Co-60 Equivalent Activity for CCs Stored in the EOS-37PTH DSC," and table 7B, "EOS-37PTH DSC Fuel Qualification Table for Storage in the HSM-MX," and added table 7C, "EOS-37PTH DSC Fuel Qualification Table for Storage in the EOS-HSM," table 24, "EOS-37PTH DSC Reconstituted

Fuel Limits for Transfer in the EOS-TC125/135 AND Storage in the EOS-HSM," table 25, "EOS-37PTH DSC Reconstituted Fuel Limits for Transfer in the EOS-TC108," and TS figure 13, "Damaged and Failed Fuel Configurations for the EOS-37PTH DSC."

Based on the information provided by the applicant in UFSAR and revisions to the TS, the staff determined that the applicant included an acceptable description and adequately described the principal design criteria and supporting methodology to determine new heat load patterns for the EOS-37PTH DSC. Therefore, the staff determined that the information provided by the applicant meets the regulatory requirements in 10 CFR 72.236(a) and (b). The staff's review of the applicant's evaluation for thermal, shielding, criticality, materials, operating procedures, acceptance tests and maintenance program, and radiation protection to support the methodology to determine new heat load patterns for the EOS-37PTH DSC are provided in the corresponding sections of this SER.

### 3.2 Change No. 2: Steel-Plate Composite HSM Design (EOS-HSM-SC)

In Change No. 2, the applicant added a new steel-plate composite HSM design (EOS-HSM-SC) that is designed in accordance with ANSI/AISC standard N690-18. The applicant provided the corresponding revision to the following UFSAR chapters:

Ch. 1. General Information
Ch. 2. Principal Design Criteria
Ch. 3. Structural Evaluation
Ch. 4. Thermal Evaluation
Ch. 6. Shielding Evaluation
Ch. 8. Materials Evaluation
Ch. 10. Acceptance Tests and Maintenance Program
Ch. 12. Accident Analysis

In UFSAR chapter 1, the applicant provided a description of the EOS-HSM-SC. The applicant included revisions to UFSAR table 1-1, Key Design Parameters of the NUHOMS® EOS System Components, to address the addition of the EOS-HSM-SC. The applicant also included new drawings with component descriptions, quality categories, and material specifications for the EOS-HSM-SC. In UFSAR section 2.1.2, "Horizontal Storage Module (EOS-HSM/EOS-HSMS)," the applicant stated that the EOS-HSM-SC steel-plate composite is designed in accordance with ANSI/AISC N690-18, with UFSAR section 2.4.2.2 specifying the load and resistance factor (LRFD) design method that is employed. UFSAR section 2.3.4 documents that a material damping value of 5 percent is being applied for EOS-HSM-SC structural analyses for seismic loading. Code exceptions are noted in SAR section 3.9.8 and the TS, as described below.

The applicant revised TS section 1.1, "Definitions," to update the definition of the "Horizontal Storage Module (HSM)" to include the steel-plate composite HSM option, and revised TS section 4.2.2, "Storage Pad," to include the SC version of the EOS-HSM. The applicant also revised TS section 4.4, "Codes and Standards," to specify that the steel-plate composite HSM steel faceplate structural system is designed and constructed in accordance with ANSI/AISC N690-18, while the concrete is designed in accordance with ACI 349-13, "Code Requirements for Nuclear Safety Related Concrete Structures," and constructed per ACI 318-08, "Code Requirements for Concrete Structures." Further, the applicant updated TS section 4.4.4, "Alternatives to Codes and Standards," to include the alternatives to ANSI/AISC N690 for the EOS-HSM-SC minimum wall thickness, faceplate yield strength and other code requirements for the EOS-HSM-SC design.

Based on the information provided by the applicant in the UFSAR and revisions to the TS, the staff determined that the applicant has included an acceptable description and adequately described the principal design criteria for the EOS-HSM-SC. Therefore, the staff determined that the information provided by the applicant meets the regulatory requirements in 10 CFR 72.236(b). The staff's review of the applicant's structural, thermal, shielding, materials, and acceptance tests and maintenance program associated with the new EOS-HSM-SC are provided in the corresponding sections of this SER.

### 3.3 Additional Scope Change No. 8: EOS-37PTH DSC Maximum Heat Load for Site Specific Conditions

In Additional Scope Change No. 8, the applicant clarified the scenarios under which site-specific conditions could result in a reduction in the maximum heat loads for the EOS-37PTH DSC. The applicant included changes to UFSAR section 2.2, "Spent fuel to be stored," section 2.2.1, "EOS-37PTH DSC," and TS section 2.1, "Fuel to be Stored in the EOS-37PTH DSC."

In UFSAR section 2.2.1, the applicant stated that new HLZCs may also be developed based on site-specific conditions using the approach presented in UFSAR section 2.4.3.1, and any design changes considered to accommodate the site-specific conditions shall be evaluated as noted in section 2.4.3.1.

In TS section 2.1, the applicant revised the thermal parameters MHLC and decay heat calculations specification to state that the maximum allowable heat loads may be reduced based on the thermal analysis methodology in the UFSAR to accommodate site-specific conditions. The applicant retained the stipulation that the maximum decay heat for each fuel assembly (FA) shall not exceed the values specified in the TS figures showing the HLZC for the EOS-37PTH DSC.

Based on the information provided by the applicant in the UFSAR and revisions to the TS, the staff determined that the applicant included an acceptable description and adequately described the methodology to accommodate site-specific conditions to determine new heat load patterns for the EOS-37PTH DSC. Therefore, the staff determined that the information provided by the applicant meets the regulatory requirements in 10 CFR 72.236(a) and (f). The staff's review of the applicant's evaluation for thermal effects to support the methodology to determine consideration of site-specific conditions in the MHLC and decay heat calculations for the EOS-37PTH DSC are provided in the corresponding sections of this SER.

### 3.4 Evaluation Findings

The staff concludes that the principal design criteria for the NUHOMS® EOS system are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the principal design criteria for compliance with the CFR provides reasonable assurance that the NUHOMS® EOS system will allow safe storage of spent fuel. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices. Some of the key findings from the staff's review of Amendment No. 4 include:

F3.1 The UFSAR and docketed materials adequately identify and characterize the spent nuclear fuel (SNF) to be stored in the dry storage system (DSS) in conformance with the requirements given in 10 CFR 72.236.

F3.2 The UFSAR and docketed materials relating to the design bases and criteria for structures categorized as important to safety meet the requirements given in 10 CFR 72.236.

F3.3 The UFSAR and docketed materials adequately define the bounding conditions under which the DSS is expected to operate in accordance with the requirements of 10 CFR 72.236.

F3.4 The SAR and the docketed materials relating to the design bases and criteria meet the general requirements as given in 10 CFR 72.236(b).

F3.5 The UFSAR and docketed materials meet the regulatory requirements for design bases and criteria for thermal consideration as given in 10 CFR 72.236(f).

## 4.0 STRUCTURAL EVALUATION

The objective of the structural review is to ensure that the applicant has performed adequate structural analyses to demonstrate that the system, as proposed, is acceptable under normal, off-normal operations, and accident conditions, including natural phenomena events. In conducting this evaluation, the staff focused its review on whether the system will maintain confinement, subcriticality, shielding, and retrievability of the fuel, as applicable, under credible loads.

The staff reviewed the information provided by the applicant and found the following changes that required structural evaluation:

**Change No. 2:**
Introduce a steel-plate composite option for the EOS-HSM.

**Change No. 4:**
TS changes for consistency among DSC types and terminology clarification.

**Change No. 5:**
Various UFSAR editorial corrections for consistency and clarification.

**Additional Scope Change No. 1:**
An additional scope item has been added to allow use of a blended Portland cement that would be certified to the requirements of ASTM C595.

**Additional Scope Change No. 6:**
An additional scope item has been added with respect to the use of the MX-LC for the 61BTH Type 2 DSCs.

The NRC staff reviewed the changes to the UFSAR (revision 5), CoC, and TS (revision 5) associated with the CoC No. 1042 NUHOMS® EOS Amendment No. 4 application. The staff's review was conducted using the guidance in chapter 4 of NUREG-2215 to ensure adequate structural performance under normal, off-normal, and accident-level conditions.

The areas of review covered in this SER section are described in NUREG-2215, chapter 4, and included horizontal overpack design and engineering drawings. The staff evaluated the changes in the NUHOMS® EOS Amendment No. 4 application with respect to the 10 CFR Part 72 regulatory requirements identified in section 4.4 and the review procedures identified in section 4.5 of NUREG-2215.

In addition to the guidance in NUREG-2215, the staff evaluated the engineered drawings and the description of the structures, systems, and components included in the NUHOMS® EOS Amendment No. 4 application using the information provided in NUREG/CR-5502, "Engineering Drawings for 10 CFR Part 71 Package Approval" (ML20248L098) and NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety" (ML15127A114).

This section of the SER documents the staff's review and conclusions with respect to structural safety.

## 4.1 Change No. 2: Introduce a steel-plate composite option for the EOS-HSM

### 4.1.1 General Description

In this change, the applicant proposed an alternative version of the EOS HSM that is a steel-plate composite (SC) structural system, labeled the EOS-HSM-SC. The applicant provided the general description of the EOS-HSM-SC in section 1.2.1.3 of the UFSAR, and defined the design criteria in sections 2.1.2, 2.3, and 2.4.2.2. The structural configuration and materials of the EOS-HSM-SC contiguous base unit structure, door, roof, outlet vent cover (OVC), shield walls, bolted connections and their embedments are presented in UFSAR section 1.3.3, on sheets 1 to 17 of drawing EOS01-3300-SAR, revision 0F. UFSAR section 1.3.3 also presents the heat shield plate details and DSC flat-plate support (FPS) structure on sheets 16 to 18 and 32 to 35, respectively, of drawing EOS01-3000-SAR, revision 4. The applicant added section 3.9.8 to the UFSAR to address the structural analysis, design, and stability evaluations for the EOS-HSM-SC and its associated structural components.

In this amendment request, the applicant is only presenting the design for the split-base, medium-length HSM with the DSC supported inside the HSM by the FPS system. Therefore, as reflected in the table in section 1.2.1.3 of the UFSAR, the only EOS-HSM-SC configuration being evaluated in this amendment is more specifically labeled as "EOS-HSMS-FPS-SC." For simplicity's sake, the version of HSM being presented in this amendment will be referred to as the "EOS-HSM-SC" throughout section 4 of the SER.

The dimensions and physical configuration for the EOS-HSM-SC version of the HSM and its components are largely identical to those presented for the previously approved original medium-length reinforced concrete (RC) version of the HSM (i.e., EOS-HSM-RC) in UFSAR section 3.9.4. Similarly, the structural loading effects and stability analysis methodologies for the SC version of the HSM and its components are largely identical to those presented by the applicant for the original medium-length EOS-HSM-RC, as documented in UFSAR sections 3.9.4 and 3.9.7, respectively. The major exceptions are the structural system itself as well as the evaluation for seismic load and tornado missile impact effects. The applicant states that the "EOS-HSM," when used in UFSAR section 3, refers to both the RC and SC version of the HSM, unless explicitly specified.

As is the case for the EOS-HSM-RC version, the modularized SC walls of the EOS-HSM-SC are continuous around their rectangular perimeter but are split into upper and lower sections that are structurally connected with six vertical threaded tie rods that are anchored at the upper wall segment, pass through the upper wall segment, and extend into and anchor into the lower wall segment. The SC roof is supported on the walls by bearing and shear keys but also has four bolted connections at the interior corners. To cover the circular opening in the front wall after the DSC is loaded inside the HSM, an SC door is supported on the front face of the unit by four horizontal tie rod connections, serving primarily a shielding function, and also that of a tornado missile barrier as well.

As a ventilation opening is provided at the roof level of each unit, an SC outlet vent cover is provided as an environmental barrier, spanning across the roofs of adjacent HSM units and anchored to one of the adjacent units with two tie rods in the roof. The applicant states in UFSAR section 3.9.8.10.1 and TS section 4.4.4 that this OVC is considered non-structural and is therefore not credited as performing a tornado missile protection function.

Interior to the EOS-HSM-SC, the FPS system for support of the DSC is largely identical to that provided in and evaluated for the medium-length version of the EOS-HSM-RC. The interior heat shield system and the DSC axial retainer are also identical to those provided for the medium-length EOS-HSM-RC.

As the applicant explains in UFSAR section 1.8.1, the loaded HSMs are intended to be arranged in multi-unit arrays, either in a side-to-side and/or back-to-back configuration, as illustrated in UFSAR figures 1-11 to 1-13. However, as the thinnest portions of the end and rear SC walls alone have been determined by the applicant to be structurally insufficient for radiological and tornado missile protection purposes, the DSC-loaded end units of the arrays are outfitted with 3-foot thick, full-height SC shield walls. These shield walls are connected to the roof and exterior faces of the end and rear interior walls with horizontal tie rods. A 3-foot-thick, full-height SC pillar is provided at the corner of the end and rear walls, bolted directly to the end and rear shield walls with horizontal tie rod connections. As the applicant describes in UFSAR sections 1.1 and 1.8.1, there is an alternative installation configuration for providing the required radiation shielding for a DSC-loaded HSM: two empty HSMs may be placed at the end of an array. Note that the applicant states in UFSAR section 3.9.8.10.6 that only a single empty HSM at the end of an array of DSC-loaded HSMs is sufficient as a tornado missile barrier, however, per section 1.8.1, additional shielding mitigation is required for this empty HSM walls and openings. The EOS-HSM-SC, whether outfitted with shield walls or not, is designed as free-standing, with no anchorage to the independent spent fuel storage installation (ISFSI) support pad at its base.

### 4.1.2 Design Criteria

In table 2-1 of UFSAR section 2.1, the applicant identified the following HSM SSCs as ITS, as defined in 10 CFR 72.3: the DSC internal flat-plate support structure and the EOS-HSM-SC structure (i.e., concrete, faceplate, and tie/stud structural system). The specific ITS portions of the EOS-HSM-SC designated as Quality Category B or C, per NUREG/CR-6407, as indicated on the bills of materials on drawings EOS01-3300-SAR, revision 0F or EOS01-3000-SAR, revision 4, are listed below:

- SC structural faceplates, headed anchor studs and tie bars for contiguous HSM structure, including roof, shield walls, and door
- Embedded DSC axial retainer
- Vertical tie rods, nuts, tie plate, and associated concrete embedments
- Shield wall and door attachment horizontal tie rods and nuts and concrete embedments
- DSC FPS support structure, attachment bolts and concrete embedments
- Heat shield plates, attachment bolts and nuts and concrete embedments

Although its materials are labeled as ITS on the licensing drawing, it should be noted that the OVC is indicated by the applicant as having no structural safety function in TS section 4.4.4 and UFSAR section 3.9.8.10.1.

4.1.2.1 Codes and Standards

4.1.2.1.1 Steel-plate composite structural components

The applicant states in UFSAR sections 2.1.2, 2.4.2.2, 3.1.1.2, 3.9.8.3, 8.2.1.3, and 10.1.3.2 that the SC portion of the EOS-HSM-SC structure is designed and constructed in accordance with the ANSI/AISC N690-18, "Specification for Safety-Related Steel Structures for Nuclear Facilities," as modified by the guidance of Regulatory Guide (RG) 1.243, revision 0, "Safety-Related Steel Structures and Steel-Plate Composite Walls for other than Reactor Vessels and Containments," (ML21089A032) with some exceptions taken. The LRFD methodology of appendix N9 is employed for the SC structural design. The applicant described and justified the ANSI/AISC N690-18 code exceptions in UFSAR section 3.9.8.3 and TS section 4.4.4, and the staff addressed the code exceptions in SER section 4.1.2.2.

4.1.2.1.2 Structural steel structural components

The applicant states in UFSAR sections 3.9.8.3 and 3.9.8.10.7 that the following EOS-HSM-SC components are designed to the allowable strength design (ASD) methodology of ANSI/AISC 360-16, "Specification for Structural Steel Buildings": FPS DSC support structure, heat shields, axial retainer, stop plate, and structural tie rods and bolts.

4.1.2.1.3 Concrete embedment structural components

The applicant states in UFSAR sections 2.1.2, 2.4.2.2, and 3.9.8.10.7 that the concrete embedments, including any supplemental reinforcing, are designed in accordance with ACI 349-13, "Code Requirements for Nuclear Safety Related Concrete Structures." Concrete construction is performed in accordance with ACI 318-08, "Code Requirements for Concrete Structures."

4.1.2.2 ANSI/AISC N690 Code Exceptions

SER sections 4.1.2.2.1 to 4.1.2.2.8 address code exceptions taken by the applicant that relate to the EOS-HSM-SC structural design, while SER section 4.1.2.2.9 addresses the code exceptions that relate to its fabrication, inspection, and quality control and assurance. The applicant submitted to the staff, and incorporated into the application by reference, the following proprietary calculation reports prepared by their subcontractor, Ingecid, to provide bases for several of the design-related code exceptions taken below: 00624IT003, "Effect of the Partial Composite Action on the Flexure Stiffness of the SC Sections"; 00624IT004, "Optimized Design of the EOS-HSM Steel-Plate Composite Structure"; 00624IT005, "Structural Assessment of the Laboratory Testing Results."

4.1.2.2.1 SC component minimum thickness requirement

The applicant stated in UFSAR section 3.9.8.3 that the minimum thickness requirements of ANSI/AISC N690-18 section N9.1.1.(a) are not explicitly met for the following SC components of the EOS-HSM-SC structure: several interior walls as well as portions of the door and the OVC.

The applicant provided a justification for this code exception in UFSAR section 3.9.8.3 and TS section 4.4.4.

Section N9.1.1(a) of ANSI/AISC N690-18 specifies minimum thicknesses of 18 inches and 12 inches, respectively, for exterior and interior SC walls. The exterior thickness requirement is not met by two of the exterior sections of the door and the entire length of the OVC. The commentary section for N9.1.1(a) of ANSI/AISC N690-18 describes the basis for those thickness limits. The minimum thickness specified for exterior walls is based on the minimum reinforced concrete wall thickness of 16.9 inches which is determined as being required to resist a tornado missile perforation per table 1 of NUREG-0800, section 3.5.3, "Barrier Design Procedures," (ML070570004) rounded up to 18 inches. The applicant deduced that, since the thinner sections of the door are supported by the front wall of the EOS-HSM-SC during tornado missile impact, the door thickness is appropriate for that particular exterior component, making this an acceptable code exception for these door components. The minimum specified thickness of 12 inches for interior walls is based on the wall thickness needed to satisfy the maximum reinforcement ratio requirement in ANSI/AISC N690-18 section N9.1.1(c) for the minimum faceplate thickness requirement of 0.25 inches, which computes to be 10 inches, but is conservatively rounded up to 12 inches. However, section 3.9.8 of the UFSAR states that the maximum reinforcement ratios for the EOS-HSM-SC meet the maximum reinforcing ratio requirements with only minimal exceedances (of the order of 5%). Refer to SER section 4.1.2.2.2 which addresses these minimal exceedances, and where the staff concludes that they are acceptable given the specified yield stress for the faceplates and concrete strength of those components. Therefore, on the basis of the same material properties and reinforcement ratios, the staff finds the portions of the door that do not meet the specified minimum exterior wall thickness and the walls that do not meet the minimum interior wall thickness code requirements to be acceptable. The staff notes that although the OVC is designed as an SC component, it is not relied upon to protect against tornado missile strikes; the staff finds it acceptable that the OVC thickness does not meet the minimum exterior wall thickness code requirement.

4.1.2.2.2 SC component reinforcement ratio limits

The applicant stated in UFSAR section 3.9.8.3 that the required range of reinforcement ratios, 0.015 to 0.050, cited in ANSI/AISC N690-18 section N9.1.1.(c) is not met by the thinner SC components and the top portion of the front wall of the EOS-HSM-SC. The applicant provided a justification for this code exception in UFSAR section 3.9.8.3 and TS section 4.4.4.

The actual reinforcement ratios reported by the applicant differ minimally from the minimum and maximum reinforcement ratios for the thinner SC components specified in ANSI/AISC N690-18 section N9.1.1.(c). The actual smallest reinforcement ratios reported by the applicant are less than 1% of the minimum while the largest reinforcement ratios are only 5% greater than code-specified maximum. The provision for the minimum reinforcement ratio specified in ANSI/AISC N690-18 section N9.1.1.(c) is intended to address concerns regarding handling strength and stiffness of the fabricated SC modules before concrete casting as well as potential residual stresses from fabrication operations and concrete casting for the large SC walls installed in nuclear power plant structures. Such concerns are not directly applicable to the SC components of the EOS-HSM-SC modules because of the differences in their dimensional proportions as compared to the larger type that would be constructed at nuclear power plants. Additionally, the minimal difference between the actual reinforcement ratio and the specified minimum is not related to an unstable transition: the upper limit of the reinforcement ratio prevents, with margin, the transition of the response mode of the SC walls from yielding of the steel faceplates to failure of the concrete compression strut. For the specified minimum faceplate yield stresses of the EOS-HSM-SC modules where these exceedances occur, which are less than or equal to 60 kips per square inch (ksi), and the minimum specified concrete compressive strength of 5 ksi (per the bill of materials and note 1 of UFSAR drawing EOS01-3300-SAR), the staff finds the minimal exceedance of the maximum reinforcement ratio acceptable. Allowing slight deviations from the minimum and maximum is also supported by the version of section N9.1.1(e) issued for public review on July 1, 2024, prior to the publication of the next edition of ANSI/AISC N690.

4.1.2.2.3 SC component faceplate minimum yield strength requirement

The applicant states in UFSAR section 3.9.8.3 that the required minimum yield strength of faceplates, 50 ksi, cited in ANSI/AISC N690-18 section N9.1.1.(d) is not met for the door and OVC components of the EOS-HSM-SC. The applicant provided a justification for this code exception in UFSAR section 3.9.8.3 and TS section 4.4.4.

ANSI/AISC N690-18 specifies in section N9.1.1(d) that the yield stress of faceplates is to be no less than 50 ksi and no more than 65 ksi. The minimum specified yield stress for the door and OVC steel faceplates are less that the code-specified minimum. The commentary section of N9.1.1(d) ANSI/AISC N690-18 states that the intent of the specified minimum yield strength of steel faceplates is to prevent premature yielding from stresses imposed by concrete casting and thermal stresses. The door and the OVC are free to grow when subjected to thermal volume changes and their concrete heights are low, resulting in pressures during casting that are not significant as compared to those for the taller EOS-HSM-SC walls. Premature yielding of the faceplates might affect the available ductility of the door faceplates to resist tornado missile impact loads under flexure if flexure were the controlling response mode to resist tornado missile impacts. However, the shear response mode instead of the flexure response mode controls the response and capacity of the door to tornado missile impact as shown in UFSAR section 3.9.8.10.6.2, “Global Structural Response.” Therefore, the faceplates of the door do not yield under the tornado missile impact and their ductility demand is less than 1.0, meaning that post-yield response of the faceplates is not involved in the response and capacity of the door to tornado missile impacts. The OVC is not required to resist tornado missile impacts and therefore its available ductility capacity for tornado missile impacts is not relevant. Given the applicant’s assertion that the stresses from thermal loads and from casting concrete pressures are not expected to be significant for the door and OVC, that the door resists tornado missile impacts in shear rather than flexure, that the available ductility for the faceplates is not relevant for the shear capacity, and that the OVC is not required to resist tornado missile impacts, the staff finds the use of a yield stress for the faceplates for the door and OVC that is less than the code-specified minimum is acceptable.

4.1.2.2.4 SC component anchor spacing to achieve composite action

The applicant stated in UFSAR section 3.9.8.3 that a modification of ANSI/AISC N690-18 section N9.1.4b(a) was used to calculate the maximum allowable spacing of steel anchors to develop the yield strength of the faceplates over the development length. The applicant provided a justification for this code modification in UFSAR section 3.9.8.3 and TS section 4.4.4.

Section N9.1.4b(a) of ANSI/AISC N690-18 provides a requirement on the spacing of steel anchors to develop the yield strength of the faceplates over the development length. This requirement is to ensure that sufficient composite action exists between the steel faceplate and concrete of the SC component. The requirement in ANSI/AISC N690-18 considers only the contribution of the available steel anchors (i.e., headed studs) and does not consider the contribution of other available shear connectors such as ties. The applicant states that neglecting the contribution of ties to develop the yield strength of faceplates leads to inefficient designs for SC components such as thin walls for which the density of ties tends to be high. Based on finite element analyses performed by the applicant's contractor, Ingecid, documented in Ingecid document 00624IT003, "Effect of the Partial Composite Action on the Flexure Stiffness of the SC Sections" (also reference [3.9.8-18] in UFSAR section 3.9.8.3), the applicant demonstrated that the ties can be considered in combination with the steel anchors to develop the yield stress of the faceplates over a development length. The staff finds that the finite element analyses provided by the applicant, which are informed by the modeling approaches used to confirm the ANSI/AISC N690-18 provisions in section N9.1.4b(a), are acceptable to demonstrate that the ties also contribute to the development of the faceplates yield strength to achieve composite action. Therefore, the staff finds this code exception, with the alternative approach used by the applicant, which accounts for the contribution of the ties to achieve composite action, to be acceptable. Consideration of ties in addition to steel anchors for the development of the yield stress of the steel plates to ensure composite action is also in agreement with the last version of section N9.1.4b(a) issued for public review on July 1, 2024, prior to the publication of the next edition of ANSI/AISC N690.

4.1.2.2.5 SC component anchor spacing to prevent interfacial shear failure

The applicant stated in UFSAR section 3.9.8.3 that a modification of ANSI/AISC N690-18 section N9.1.4b(b) was used to calculate the maximum allowable spacing of steel anchors required to prevent interfacial shear failure before out-of-plane shear failure for use with thinner walls. The applicant provided a justification for this code exception in UFSAR section 3.9.8.3 and TS section 4.4.4.

Section N9.1.4b(b) of ANSI/AISC N690-18 provides, in equation A-N9-3, the requirement on the spacing of steel anchors to prevent interfacial shear failure before out-of-plane shear failure of the SC section. The applicant purports that this equation is inefficient for increased stud spacing in thinner walls given the requirement for more closely spaced ties. Equation A-N9-3 only considers the contribution of steel anchors to the interfacial shear and does not account for the contribution of tie bars. The applicant uses a modification of the equation in ANSI/AISC N690-18 in section N9.3.6a, equation A-N9-24, for the interaction of out-of-plane shear strength for out-of-plane demands in two planes. The staff notes that Equation A-N9-24 already relates the out-of-plane shear strength to the available combined interfacial shear strength of steel anchors and ties. The applicant then uses Equation A-N9-24 with appropriate modifications for conservatism to determine the required steel anchor spacing considering not only the available shear strength of the section but also the required shear strength. The applicant also validated this approach using interpretation of test data performed by its contractor, Ingecid, and reported in Ingecid document 00624IT005, "Structural Assessment of the Laboratory Testing Results." The staff finds this approach to calculate the spacing of the steel anchors acceptable because it uses a code equation for the acceptable shear strength for the cross section that relates this shear strength to the interfacial shear strength of both steel anchors and ties and is modified to provide additional margin.

4.1.2.2.6 SC modeling and detailing requirements around large openings

The applicant stated in UFSAR section 3.9.8.3 that the detailing requirements to provide a reinforcement plate for a specified distance around a large opening to achieve a fully-developed edge as required in ANSI/AISC N690-18 section N9.1.7 is not practicable for the entire circumference of the circular front wall opening due to the opening being split for HSM modularization as well as geometric constraints. However, for the top portion of the opening and its surrounding structure, the applicant adheres to this code requirement to the maximum practical extent in its analytical modeling and structural detailing. The staff notes that the exterior and interior faceplates of the top portion front wall have been increased to comply with this requirement. The applicant provided a justification for this code exception in UFSAR section 3.9.8.3 and TS section 4.4.4.

Based on the review of the current UFSAR drawing EOS01-3300-SAR, which reflects the changes in the HSM top portion front wall interior and exterior faceplate thicknesses and material, the staff finds that the final design meets the code requirement.

4.1.2.2.7 SC modification of out-of-plane shear force interaction equations

Per UFSAR section 3.9.8.3, the applicant modified ANSI/AISC N690-18 section N9.3.6a equation A-N9-24 for the interaction of out-of-plane shear forces to account for the increased headed anchor stud spacing of the thinner walls of the EOS-HSM-SC, as identified in SER section 4.1.2.2.4 above. The applicant provided a justification for this code exception in UFSAR section 3.9.8.3 and TS section 4.4.4.

The applicant used a modified version of ANSI/AISC N690-18 equation A-N9-24, in section N9.3.6a for the interaction of out-of-plane shear forces with modified coefficients for added margin in determining the required spacing of steel anchors needed to prevent interfacial shear failure prior to shear failure of the thin walls cross-section (UFSAR section 3.9.8.3), which the staff finds acceptable in SER section 4.1.2.2.5. This is an approach that accounts for the contribution of the interfacial shear strength of both the steel anchors and ties as indicated in SER section 4.1.2.2.5. Use of the modified equation A-N9-24 with added margin to calculate the spacing of steel anchors requires, for consistency, that the same equation for the interaction of out-of-plane shear capacity also be used to calculate the shear capacity for the thin walls as the applicant did. Because the modified equation provides added margin, the staff finds it acceptable.

4.1.2.2.8 Use of structural design load combinations

The applicant states in UFSAR section 3.9.8.3 and TS section 4.4.4 that the ANSI/AISC N690-18 section NB2 load combination equations, as modified by RG 1.243, are not employed for the EOS-HSM-SC structural design. Instead, the load combinations from section 6.17.3 of ANSI/American Nuclear Society (ANS) 57.9-84, “Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type),” are employed, as presented in table 2-7 in UFSAR section 2.4.2.2. The use of these load combinations in the design analyses are acceptable to staff, as they yield conservative load demands that bound those that would result from load combinations in the individual codes cited in UFSAR section 3.1.1.2. Furthermore, guidance in NUREG-2215 indicates that the load combinations presented in the cited ANSI/ANS publication are acceptable for use in the analysis of non-confinement components, as reflected in NUREG-2215 table 4-3.

4.1.2.2.9 ANSI/AISC N690 code exceptions relating to fabrication, inspection, and quality control and assurance

The applicant states in UFSAR section 10.1.3.2 that ANSI/AISC N690-18 requirements related to fabrication, inspection, or quality control and assurance for the EOS-HSM-SC will either be modified or excepted, as indicated in TS section 4.4.4. The applicant’s justifications or compensatory measures for each requested exception are documented in TS 4.4.4.

i. NM2.4
The applicant requested an exception to section NM2.4 requirements for welding documentation, as described in the User Note, proposing that the weld documentation requirements of ANSI/AISC 360-16 are sufficient for the non-safety-related EOS-HSM-SC Quality Category B, C, and not-important-to-safety (NITS) components, as defined in UFSAR section 14.2. The staff accepts that the welding documentation and traceability requirements specified in the User Note apply to safety-related welds, whereas the components of the EOS-HSM-SC are categorized as either ITS Quality Category B or C, or NITS; thus, their quality assurance weld documentation requirements are commensurate with those of ANSI/AISC 360-16.

ii. NM2.7.(d).(1) and NM2.7.(d).(3)
The applicant requested a modification to this section's fabrication tolerance requirements for thinner SC plate walls of the EOS-HSM-SC: that the tolerance between faceplate tie locations and free edges be plus or minus the wall thickness divided by 200 or 100, respectively, rounded up to the nearest 1/16 inch. The applicant proposed that for wall thicknesses of less than 24 inches, the tolerance for the distance between fabricated faceplates at tie locations be revised to plus or minus 1/8 inch, and the tolerance for the distance between fabricated faceplates at the free edges of the wall panels be revised to plus or minus 1/4 inch. The applicant explains that due to the SC plate fabrication sequence and free-standing structure of the EOS-HSM-SC, no plate free edges will occur that would require welding with another adjacent free edge, therefore, this magnitude of tolerance is too restrictive on the thinner walls. The staff determined that, for this more compact, modularized SC structural application, the need to splice wall plates should be minimal, thus the tolerances of 1/8 inch between faceplates at tie locations and 1/4 inch between faceplates at free edge locations for walls less than 24 inches in thickness is acceptable.

iii. NM2.7.(2)
The applicant requested an exception from adhering to this section's SC faceplate waviness dimensional limit (i.e., $f_w$ as defined by equation NM2-1) after concrete placement, proposing that the verification of this limit via inspection be waived for the EOS-HSM-SC. The applicant explains that due to the possible installation of multiple EOS-HSM-SC plate fabrications being placed adjacent to each other at licensee sites, many walls would not be accessible to allow for measurement of the faceplate waviness after concrete curing. The applicant has also submitted a finite element model (FEM)-based study (enclosure 7 of ML25043A123) of the hydrostatic concrete pressure effects on the faceplate waviness for various SC components; the results indicate that all faceplates meet the waviness limit. Based primarily on the FEM study results, and also on the limited concrete lift heights afforded by the EOS-HSM-SC geometry coupled with the robust faceplate thicknesses, the staff finds this exception to be acceptable.

iv. NM2.14
The applicant requested an exception to section NM2.14 requirements for commercial grade dedication of materials per American Society of Mechanical Engineers (ASME) NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications," Subpart 2.14 requirements for the EOS-HSM-SC materials, which are Quality Category B, C, and NITS components that, by definition in USFAR section 14.2, do not require commercial grade dedication. The applicant further explains that the HSM is not a "basic component" and therefore, per 10 CFR Part 21, is not subject to commercial grade dedication. The staff determined that, based on their quality categorization of ITS B, C or NITS, it is

acceptable that the HSM and its constituent components are not subject to the commercial grade dedication requirements of ASME NQA-1.

v. NM2.15
The applicant requested an exception to this section's requirement for material traceability of the EOS-HSM-SC materials, which are Quality Category B, C, and NITS components that, by definition in USFAR section 14.2, do not require traceability. The applicant confirms that the remainder of the requirements of section NM2.15, including material identification, are being followed. The staff determined that, based on their quality categorization as ITS B, C or NITS, it is acceptable that the HSM and its constituent components are not subject to the material traceability requirements of this section.

vi. NM3.4
The applicant requested an exception to this section's requirement for the application of a rust-inhibitive coating to machined carbon steel surfaces of the EOS-HSM-SC materials, such as threads and cut edges of rolled shapes and plates. The applicant explains that rust inhibitor is not typically applied to threaded items and cut edges of rolled shapes and plates, or other threaded items used in concrete construction. The staff determined that the commensurate ANSI/AISC 360-16 code requirements for rust-inhibitive coatings are not applicable to the threads and cut edges of rolled shapes and plates of the non-safety-related ITS Quality Category B, C or NITS and therefore finds this exception acceptable.

vii. NN
The applicant requested an exception to this section's requirements for quality control and quality assurance for the EOS-HSM-SC steel elements, but not those of section NN5.5, which addresses the non-destructive examination of welded joints. The applicant explains that the quality control and quality assurance requirements of this section are applicable to safety-related steel elements, whereas the EOS-HSM-SC is, at most, an ITS Quality Category B structure; the applicant proposes that the commensurate requirements of ANSI/AISC 360-16 be applied instead. The staff finds that application of the quality control and quality assurance requirements of ANSI/AISC 360-16 to the EOS-HSM-SC structural steel elements is acceptable based on the EOS-HSM-SC ITS B or lower quality categorization being consistent with relevant NRC guidance in NUREG/CR-6407.

#### 4.1.2.3 Design Criteria Conclusion

The staff finds that the design criteria for the EOS-HSM-SC components are consistent with previously approved EOS-HSM-RC design criteria, as appropriate, the applicable portions of the ANSI/AISC N690-18 design code, the guidance of RG 1.243, and the guidance on acceptable design criteria in NUREG-2215. The exceptions taken by the applicant to ANSI/AISC N690-18 appendix N9 requirements for the SC component design and the applicant's justifications are acceptable as documented in SER sections 4.1.2.2.1 to 4.1.2.2.8. The exceptions taken by the applicant to ANSI/AISC N690-18 appendices NM and NN fabrication, inspection and quality requirements for the EOS-HSM-SC and the applicant's justifications are acceptable as documented in SER section 4.1.2.2.9. Therefore, the staff finds that the design of the EOS-HSM-SC meets the requirements of 10 CFR 72.236(b).

### 4.1.3 Drawings

The applicant provided the following drawings to depict the configuration of the EOS-HSM-SC: drawing EOS01-3300-SAR, sheets 1 to 17, "NUHOMS EOS System Horizontal Storage Module Steel-Plate Composite (EOS-HSM-SC) Main Assembly," revision 0F.

The staff reviewed the drawings following the guidance in NUREG-2215 and NUREG/CR-5502 for the recommended content of engineering drawings. In addition, the staff used NUREG/CR-6407 to review the ITS classification of materials identified on the drawing. The staff verified that the drawings include the information described in NUREG-2215 regarding: (1) materials of construction; (2) dimensions and tolerances; (3) codes, standards, or other specifications for materials, fabrication, examination, and testing; (4) welding specifications, including weld locations and non-destructive examination (NDE); (5) coating specifications and other special material treatments that perform a safety function; and (6) specifications and requirements for alternative materials. Based on this review, the staff determined that the EOS-HSM-SC engineering drawings provide the necessary information identified in the NRC guidance documents and the drawings are consistent with the design bases and design criteria for ITS SSCs in accordance with 10 CFR 72.236(b).

### 4.1.4 Material Properties

The applicant identified the specification of materials employed for the EOS-HSM-SC in UFSAR sections 3.9.8.10.7 and 8.2.1.3 and the bills of materials of drawing EOS01-3300-SAR and referenced drawings. The material properties for structural steel components of the EOS-HSM-SC (e.g., axial retainer, stop plate, heat shields, connectors) are specified identically to those for the EOS-HSM-RC, except for the A572, Grade 65 material tabulated in UFSAR table 8-43, which is primarily employed for the FPS DSC support structure. The major material differences relate to the SC components where the faceplate, tie and shear connector materials are unique to the EOS-HSM-SC. The applicant presented the temperature-dependent properties of the SC-specific materials in UFSAR tables 8-37 to 8-43. The staff finds these new materials acceptable for use in the EOS-HSM-SC, as discussed in SER sections 8.5 and 4.1.2.2.3.

### 4.1.5 Load Cases and Load Combinations

The normal, off-normal, and accident load magnitudes and load combinations employed by the applicant for the EOS-HSM-SC structural adequacy and stability analyses are largely identical to those derived for the EOS-HSM-RC as documented in UFSAR sections 2.3, 2.4.2, 3.9.4, and 3.9.7; any differences are noted in the SER sections 4.1.5.1, 4.1.5.2, and 4.1.5.3 below. The applicant states in UFSAR section 3.9.8.5 that the design load combinations specifically for the EOS-HSM-SC are further detailed in table 3.9.4-5 for the SC components, table 3.9.4-16 for the DSC support structure, and table 2-7 for other steel components. SER section 4.1.2.2.8 describes the ANSI/AISC N690-18 code exceptions taken by the applicant for load combinations.

The applicant listed the weights of the DSCs and centers of gravity of the EOS-HSM-SC, empty and loaded with the heaviest DSC, in UFSAR tables 3-6 to 3-8. Footnote 2 of UFSAR table 3-8 states that the DSC weight for the EOS-HSM-SC is 120 kips, corresponding to the medium-length DSC and HSM. As stated in UFSAR section 3.9.8.7, the applicant employed the bounding DSC weight of 125 kips for the EOS-HSM-SC structural analysis FEM input and evaluations, as also stated in section 2.0 of calculation EOS01-0262, revision 2. The staff finds the use of a DSC weight of 125 kips in the finite element structural analysis to be acceptable as it bounds the actual weight of the medium-length DSC of 120 kips used in the EOS-HSM-SC, resulting in over-estimated load demands on the EOS-HSM-SC structure, which is conservative. For the hand-calculated evaluation of the EOS-HSM-SC DSC axial retainer and stop plate, the applicant employs a DSC weight of 124 kips per section 8.4.2 of calculation EOS01-0320, revision 3. The staff finds the use of a DSC weight of 124 kips in the axial retainer and stop plate structural evaluation to be acceptable as it bounds the actual weight of the medium-length DSC of 120 kips used in the EOS-HSM-SC, resulting in over-estimated load demands on the axial retainer and stop plate structures, which is conservative. The applicant employed the same medium-length DSC weight considered for the EOS-HSM-RC stability evaluations of 120 kips for the EOS-HSM-SC stability evaluations, as stated in section 5.1 of calculation EOS01-0268, revision 1. The staff finds the use of a DSC weight of 120 kips in the structural stability evaluation to be acceptable as employing a lower-bound DSC weight results in reduced total system weight and restoring moment to resist the applied forces, which is conservative. As noted in UFSAR section 3.9.8.4, the applicant considered the density of the steel faceplate of the SC structure to be 490 pounds per cubic foot (pcf). The applicant varied the concrete density for the structural evaluations, from 140 pcf to 160 pcf, to create bounding results as described in UFSAR sections 3.9.8.11.1 and 3.9.7.1.3. The staff finds the use of the stated range of concrete densities in the structural evaluations of the EOS-HSM-SC to be acceptable as the applicant conservatively employed the upper or lower bound values in each evaluation in such a manner to produce the most conservative result. Note 1 of drawing EOS01-3300-SAR and UFSAR section 10.1.4.2 require a minimum concrete density of 139 pcf; the use of 140 pcf for analysis purposes is acceptable to staff, as the result of using the higher concrete density would produce no appreciable differences in the evaluation conclusions.

The applicant employed the same code-prescribed ASD and LRFD load combinations for the evaluation of the ITS SSCs as those employed for the design of the EOS-HSM-RC, as tabulated in UFSAR table 2-7 and cited in section 3.9.8.3. The applicant selected these load combinations following section 6.17.3 of ANSI/ANS 57.9-84, “Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type).” The staff finds the use of these load combinations acceptable, as discussed in SER section 4.1.2.2.8.

#### 4.1.5.1 Seismic Load Determination

Although the methodology of static equivalent analysis used by the applicant for seismic load determination is largely identical to that used for the previously approved EOS-HSM-RC design, one difference in the EOS-HSM-SC design is the magnitude of the seismic load demand for the EOS-HSM-SC system design, as presented in UFSAR section 3.9.8.9.

The applicant performed this seismic load determination for all EOS-HSM-SC components using the same methodology presented for the EOS-HSM-RC in UFSAR section 3.9.4, using the response spectra of RG 1.60, revision 1, “Design Response Spectra for Seismic Design of Nuclear Power Plants” (ML003740207) to determine the seismic acceleration corresponding to the structure’s directional modal responses. However, the resulting EOS-HSM-SC design accelerations were amplified from those of the EOS-HSM-RC based on the modal analysis response results specific to the EOS-HSM-SC FEM, which are presented in UFSAR table 3.9.8-1. The staff finds the applicant’s determination of the design seismic accelerations for the EOS-HSM-SC structural evaluations to be acceptable, as it follows a methodology consistent with RG 1.60 and the methodology employed for the structure of the previously approved EOS-HSM-RC.

The applicant states in UFSAR sections 2.3.4 and 3.9.8.9 that a material damping ratio of five percent of critical damping was applied to the SC components of the EOS-HSM-SC in the FEM.

Damping values employed for the DSC FPS and other steel structures remain the same as those for the RC system: three percent and four percent, respectively. The applicant tabulated the resulting seismic accelerations employed for the equivalent static EOS-HSM-SC seismic load application of EOS-HSM-SC components, along with their associated damping values, in UFSAR table 3.9.8-2. The staff finds the applicant's choice of critical material damping values for the EOS-HSM-SC seismic analyses to be acceptable, as the value for the SC components is applied as prescribed by ANSI/AISC N690-18 section N9.2.1(d), and those for the structural steel components agree with the damping values employed and previously accepted for the EOS-HSM-RC analyses.

In order to determine which EOS-HSM-SC configuration produced the bounding seismic load demand, between that of the contiguous EOS-HSM-SC configuration (FEM shown in UFSAR figures 3.9.8-1 and 3.9.8-2) and that of a configuration where the shield walls are attached on one side and the rear faces of the HSM (FEM shown in UFSAR figure 3.9.8-11), the applicant prepared a second FEM that included the shield walls as described in UFSAR section 3.9.8.6.1. The applicant reported that the resulting seismic accelerations for this second FEM are reduced; therefore, the seismic load demand for the original, contiguous HSM FEM configuration with no shield walls produces bounding seismic load demands. The staff finds that the use of seismic load demand results from the FEA of the contiguous EOS-HSM-SC as a basis for the design presented in the UFSAR is acceptable based on the applicant's demonstration that the resulting seismic accelerations are bounding.

The applicant stated in UFSAR section 3.9.8.6.3 that the seismic design load determination for the heat shield panels, connection bolts and concrete embedments was performed using the same methodology and FEM as that presented for the previously approved EOS-HSM-RC in UFSAR section 3.9.4.6.4, which considers that the heat shield system is dynamically uncoupled from the EOS-HSM-SC structure. After performing the modal time-history for the EOS-HSM-SC, the applicant determined in-structure response spectra (ISRS) for the wall and roof heat shield panels, at four percent damping, per RG 1.60, and presented the ISRS in figures 3.9.8-5 to 3.9.8-10. The applicant used the resulting peak accelerations to evaluate the heat shield plates and associated connections. The staff finds the applicant's determination of the design seismic accelerations for the heat shield plate, connection bolts, and embedment structural evaluations to be acceptable, as it follows the same RG 1.60 methodology as employed for the same components of the previously approved EOS-HSM-RC.

The staff finds the applicant's methodology for the determination of the EOS-HSM-SC structure and heat shield modal responses and seismic loading to be consistent with the previously approved EOS-HSM-RC methodology, the applicable sections of the AISC N690 design code, and the guidance in both RG 1.60 and NUREG-2215. Based on these reasons, the staff finds that the determination of seismic design loads for the NUHOMS® EOS-HSM-SC is adequate to meet the requirements of 10 CFR 72.236(l).

4.1.5.2 Tornado Missile Impact Load Determination and Assessment Methodology

The applicant determined the local and global load effects of a tornado missile impact to the various components of the loaded EOS-HSM-SC considered to be missile barriers, as documented in UFSAR section 3.9.8.10.6, using the same missile spectra and evaluation methodology as for the EOS-HSM-RC documented in UFSAR sections 2.3.1, 3.9.4.9.1, and 3.9.4.10.6, with some minor adjustments. As described in UFSAR section 3.9.4.9.1, the tornado wind and missile spectra and parameters that the applicant considered for evaluation conservatively encompass four missiles, consistent with the guidance in revision 0 of RG 1.76, “Design Basis Tornado and Tornado Missiles for Nuclear Power Plants,” (ML003740273) and revision 2 of NUREG-0800 Section 3.5.1.4, “Missiles Generated by Tornado and Extreme Winds,” (ML052340526). The tornado wind parameters employed from revision 0 of RG 1.76 bound the design-basis parameters of revision 1 of RG 1.76 (ML070360253), cited in UFSAR section 2.3.1. Similarly, the tornado missile parameters employed from revision 2 of NUREG-0800 Section 3.5.1.4 bound the design-basis parameters of revision 3 of the same document (ML070380174), cited in UFSAR section 2.3.1. The applicant evaluated the following SC components for local and global missile impacts: the end shield wall, the rear shield wall, the top portion of the front wall (for global effects only), the bottom portion of the front wall, the roof and the shield door. The staff finds the applicant’s choice of design tornado wind and missile parameters for the missile barrier evaluations to be acceptable, as they are conservative from the stated design basis of UFSAR 2.3.1 and follow the same methodology as employed for the same components of the previously approved EOS-HSM-RC.

The applicant also verified the structural adequacy of one empty EOS-HSM-SC module as a tornado missile shield in UFSAR section 3.9.8.10.6.1.1. Local missile effect evaluations consider two separate contiguous base side walls to resist the same missiles as described in 3.9.4.10.6.1, where the SC faceplate contribution is conservatively ignored. The applicant conservatively considered one empty HSM module as a missile barrier, even though a minimum of two empty HSMs are required for radiation shielding purposes, as described in UFSAR section 1.8.1. The staff finds the applicant’s conclusion that one empty EOS-HSM-SC module is effective as a missile shield to be acceptable because ignoring the presence of the steel faceplates of the SC components is conservative.

SER sections 4.1.5.3 and 4.1.6.2.4 address the inclusion of tornado wind and missile effects in stability evaluations.

For the local missile response determinations and assessments, even though some of the failure modes of the more robust SC components are different from those of traditional reinforced concrete components, the applicant employed the same methodology as for the EOS-HSM-RC targets. This methodology follows the American Society of Civil Engineers (ASCE) publication No. 58, “Structural Analysis and Design of Nuclear Plant Facilities” and the modified National Defense Research Committee formulae recommended in NUREG-0800 Section 3.5.3, “Barrier Design Procedures.” The applicant considers this approach to be conservative because it ignores the presence of the SC faceplates in the assessment of the local damage evaluations and compares the missile perforation depth directly to those results determined for the same EOS-HSM-RC components. The staff finds the applicant’s approach for local missile damage assessment to be acceptable as it conservatively ignores the inherent perforation resistance of the faceplates of the SC components.

Likewise, the applicant employed the same methodology for the global missile response determinations and assessments for the EOS-HSM-SC as the EOS-HSM-RC targets. This methodology follows Bechtel Corporation publication entitled “Design Guide Number C-2.45 for Design of Structures for Tornado Missile Impact.” The applicant states in UFSAR section 3.9.8.3 that a deduction (for corrosion/fabrication allowance) from each SC component faceplate is considered in the determination of tornado missile responses and ductility ratios. The material properties of the SC materials employed in the determination of the global response are considered for the normal thermal conditions at 300 °F, per section 4.1 of calculation EOS01-0265, revision 3.

The applicant evaluated the following SC and RC components for global missile impacts: the end shield wall, the rear shield wall, the roof and the shield door. The differences between the EOS-HSM-SC and EOS-HSM-RC global responses methodology include:

- The top and bottom sections of the front wall are considered as separate targets due to their different faceplate thicknesses
- The steel pipe missile considers two different formulations for impact loading
- The roof evaluation considers two different span lengths
- The end shield wall evaluation considers two different span lengths and widths

For the dynamic global response evaluation of all EOS-HSM-SC structural components, the applicant determined the yield resistance and fundamental period of vibration using the SC material properties and configuration. The applicant presents the bounding yield resistance (Ry) and fundamental period of vibration (Tn) of each SC component evaluated in a tabulation in UFSAR section 3.9.8.10.6.2. Dynamic increase factors, per section N9.1.6 of ANSI/AISC N690-18, are included in the determination of the component yield resistance as reported in sections 8.2.3 and 8.3 of calculation EOS01-0265, revision 3. The applicant then determined the resulting ductility ratio of each missile and target pairing following the Bechtel document response charts and compared these to the acceptance criteria of ANSI/AISC N690-18 section N9.1.6, as modified by position 11.1.7 of RG 1.243. The applicant did not combine these missile loadings with other load effects on the SC elements, except the roof, where cumulative loading is considered in the FEA.

The staff finds that the applicant's methodology for the determination for the EOS-HSM-SC tornado wind, missile and target dynamic parameters and those for the associated local and global SC component structural responses to be consistent with the previously approved EOS-HSM-RC methodology, the applicable sections of the ANSI/AISC N690 design code, and the guidance in RG 1.243, RG 1.76, sections 3.5.1.4 and 3.5.3 of NUREG-0800, and portions of NUREG-2215. Based on these reasons, the staff finds that the tornado wind and missile parameter selections and analysis methodologies of the NUHOMS® EOS-HSM-SC are adequate to meet the requirements of 10 CFR 72.236(l).

4.1.5.3 Stability Evaluation Methodology

The applicant presents the stability evaluations in UFSAR section 3.9.8.11, which check for possible overturning or sliding of one loaded EOS-HSM-SC unit, resulting from the natural phenomena accident conditions of tornado wind and missiles, seismic, and flood. These evaluations employ the same methodologies and load combinations as presented in UFSAR section 3.9.7 for the previously approved EOS-HSM-RC, with slight modifications. The primary structural variations are the weight of the EOS-HSM-SC itself, the weight of the DSC, and the assumed coefficient of friction between the structure and the concrete basemat. In UFSAR section 3.9.8.11.1, the applicant states that the weight of the EOS-HSM-SC is varied for the concrete density fluctuation from 306.8 kips to 360.8 kips. The weight of the DSC is conservatively employed as the minimum of 120 kips, as tabulated in the UFSAR section 3.6.2. The loaded EOS-HSM-SC center-of-gravity dimension employed by the applicant for the stability analyses is 126 inches, which is rounded up from the value presented in UFSAR table 3-8. As in the EOS-HSM-RC stability evaluations, the applicant applies the EOS-HSM-SC and DSC weights in the stability analyses to produce the most conservative stability result. For the EOS-HSM-SC sliding evaluations, the applicant reduced the coefficient of friction of the base of the structure from 0.60 to 0.576, to account for the presence of steel faceplates, which comprise a portion of the bottom of the EOS-HSM-SC wall. As stated by the applicant in UFSAR section 3.9.8.11.3, for the flooding scenario, the EOS-HSM-SC evaluation differs from that of the EOS-HSM-RC only in that two side shield walls are considered to be present rather than just one.

The staff finds that the applicant's methodology for the determination for the EOS-HSM-SC sliding and overturning stability evaluations to be conservative and consistent with the previously approved EOS-HSM-RC methodology and the guidance in NUREG-2215. Based on these reasons, the staff finds that the structural stability evaluation methodology of the NUHOMS® EOS-HSM-SC is adequate to meet the requirements of 10 CFR 72.236(l).

### 4.1.6 Structural Analysis and Evaluation

The applicant evaluated the EOS-HSM-SC using both hand calculations and finite element analyses. The applicant submitted to the staff, and incorporated into the application by reference, the following proprietary Orano TN calculation reports to support the structural analyses and results presented in the UFSAR:

EOS01-0262, "Finite Element Model and ANSYS Structural Analysis of the EOS HSM Steel-Plate Composite Structure," revision 2

EOS01-0263, "Design of the EOS-HSM Steel-Plate Composite Structure," revision 3

EOS01-0265, "Tornado Missile Evaluation of EOS-HSM Steel-Plate Composite (EOS-HSM-SC) Structure," revision 3

EOS01-0268, "EOS-HSM-SC Stability Evaluation," revision 1

EOS01-0269, "Steel Composite EOS Horizontal Storage Module (EOS-HSM-SC) Flat Plate DSC Support Structure Reconciliation," revision 1

EOS01-0320, "EOS-HSM-SC Heat Shield, Door, and other Miscellaneous Hardware," revision 3

EOS01-0330, "Connection Bolts and Embedments Evaluation of EOS-HSM-SC," revision 2

#### 4.1.6.1 Finite Element Models and Analyses

The applicant employed several finite element models for the analysis of the EOS-HSM-SC for all load demands, as documented in UFSAR sections 3.9.8.6.1, 3.9.8.6.2, and 3.9.8.6.3: two for the static design load determination for the contiguous base unit and roof, two for the modal analyses for seismic load determination, one for the static design load determination from thermal analyses, and one for the heat shield modal analysis for seismic loading determination. These finite element analyses (FEA) were performed in the same manner as those for the previously approved EOS-HSM-RC. The applicant employed version 2022 R2 of the ANSYS analysis software for all structural analyses. Depictions of the EOS-HSM-SC FEA models are presented in UFSAR figures 3.9.8-1 to 3.9.8-4, and 3.9.8-11.

4.1.6.1.1 HSM finite element models and analyses

The elastic finite element models employed by the applicant to determine the static load demands and modal response of the EOS-HSM-SC contiguous base unit and door presented in UFSAR section 3.9.8.6.1 are geometrically similar to those of the EOS-HSM-RC. UFSAR table 3.9.4-4, as cited in UFSAR section 3.9.8.4, lists the upper-bound concrete density of 160 pcf as being employed in these analyses in order to maximize resulting structural loading demands. UFSAR section 3.9.8.7 states that a DSC weight of 125 kips is employed for the EOS-HSM-SC structural design. Due to the use of the SC structural system, the applicant made many modifications to material inputs and other modeling considerations to comply with the requirements of ANSI/AISC N690-18, section N9.2. These changes as well as any code exceptions taken by the applicant are noted below.

To determine the structural load demands from the majority of load cases, the applicant has explicitly modeled the contiguous base unit walls and roof of the EOS-HSM-SC structure as SC structural elements, whereas only the mass distribution of the door and OVC at their structural connection points are included in the model, as shown in UFSAR figures 3.9.8-1 and 3.9.8-2. The applicant performed two static analyses: one considering the allowance of the SC faceplate thicknesses, and one without. The applicant compared the two sets of results, as described in UFSAR section 3.9.8.3, and confirmed that the use of the FEM with the faceplate thickness reduction produced bounding structural demands, the results of which are reported in the UFSAR.

Per UFSAR section 3.9.8.6.1, the applicant chose the SHELL181 element in ANSYS to represent the various portions of the SC contiguous base unit walls and roof to comply with ANSI/AISC N690-18, section N9.2.1(a); this element type includes the effects of transverse shear deformation. The effective flexural and in-plane shear stiffnesses of the modeled elements were determined in accordance with ANSI/AISC N690-18, section N9.2.2. The composite elements' Poisson's ratios, thermal expansion coefficients, model section thicknesses, material elastic moduli, and material densities were all determined per ANSI/AISC N690-18, section N9.2.3 and included in the model by the applicant. The applicant explains that, as a sensitivity analysis, the thermal analyses of the EOS-HSM-SC using the modified thermal conductivity property were performed and the results were compared to the thermal analyses results from the EOS-HSM-RC analysis, using the concrete-only thermal conductivity value. This comparison indicated the thermal load demand from the EOS-HSM-RC produced bounding results, which the applicant employed in the structural evaluation. This model is constrained in all translational directions at the base of the wall elements in order to maximize the resulting design load demands. The applicant adjusted the concrete, steel faceplate, headed shear connector, and tie bar material properties for expected temperature values: 300 °F for normal thermal conditions and 500 °F for accident thermal conditions. The applicant adjusted the effective in-plane shear stiffnesses of elements for temperature effects to account for concrete section cracking, considering fully cracked concrete for accidental thermal load conditions per ANSI/AISC N690-18, section N9.2(c) and partially cracked concrete, as determined by demands, per ANSI/AISC N690-18, section N9.2.(b).

The applicant described the connection regions of the EOS-HSM-SC in UFSAR section 3.9.8.3.1. As the joint strips identified as part of the connection regions are located at each intersection (e.g., corner) of both the top and bottom portions of the contiguous base structure, they are considered to be rigid for out-of-plane moment transfer. The joint strips of the connection regions are identified in UFSAR table 3.9.8-7, as required per ANSI/AISC N690-18, section N9.4.

As described by the applicant in table 3.9.4-4, the same load cases that were applied to the EOS-HSM-RC static FEM are applied to this FEM for the EOS-HSM-SC: dead load from self-weight of composite walls and FPS, roof and door, live load on roof and from DSC and normal wind, off-normal handling condition of DSC, and accident conditions of seismic, flooding pressure, and tornado.

The applicant employed the same model described above for the modal and time-history analyses of the EOS-HSM-SC for seismic load determination.

To determine the structural load demands from the normal and accident thermal conditions, the applicant employed the same model as described above, and excluded the door and FPS which is consistent with previously approved analysis for EOS-HSM-RC. Also, the boundary conditions at the base of the wall elements were revised to allow for thermal expansion of the structure. The same thermal loading conditions as described in UFSAR sections 3.9.4.6.2, 3.9.4.7.4, and 3.9.4.8.2 as derived from UFSAR section 4, were employed by the applicant to determine the structural thermal loading demands on the wall and roof elements. The applicant depicted the temperature results from the normal and accident thermal analyses in UFSAR figures 3.9.8-3 and 3.9.8-4, respectively.

The staff finds the applicant’s methodology for the FEA performed for the EOS-HSM-SC, subjected to the normal, off-normal, and accident conditions to be consistent with the previously approved methodology for the EOS-HSM-RC, the requirements of appendix N9 of ANSI/AISC N690-18 code (as excepted), and the guidance on FEA in NUREG-2215. Therefore, the staff finds the results sufficient to provide bounding load demands that form the basis of the structural adequacy evaluations, thus satisfying the requirements of 10 CFR 72.236(l).

4.1.6.1.2 Heat shield finite element model and analysis

The finite element model employed by the applicant to determine the dead load demand on the internal heat shield plates and connections and their modal response is the same model as that for the EOS-HSM-RC, as described in UFSAR section 3.9.4.6.4. The EOS-HSM-SC time-history responses, shown in UFSAR figures 3.9.8-5 to 3.9.8-11 for a four-percent material damping value, are then applied by the applicant as static equivalent loads to determine the design loading of the EOS-HSM-SC heat shield plates and their connections to the EOS-HSM-SC walls and roof.

The staff finds the applicant’s methodology for the heat shield seismic load determination performed for the EOS-HSM-SC to be consistent with the previously approved methodology for the EOS-HSM-RC. The staff finds that the applicant described and implemented the FEMs cited above consistent with the guidance on FEMs in appendix 4A of NUREG-2215. Therefore, the staff finds the FEMs adequately represent the EOS-HSM-SC structural components and provide bounding loading demands that form the basis of the structural adequacy evaluations, thus satisfying the requirements of 10 CFR 72.236(l).

4.1.6.2 Structural Adequacy Evaluation

The structural demands from each applicable load combination for each EOS-HSM-SC ITS component is determined by the applicant and is then checked against the criteria set forth by the codes and standards, less any exceptions, as discussed in SER section 4.1.2.2 above.

4.1.6.2.1 EOS-HSM-SC SC components and joint connection regions

The applicant first checked each SC component of the EOS-HSM-SC structure for compliance with the requirements of ANSI/AISC N690-18, N9.1.1 for minimum total thicknesses, minimum and maximum faceplate thicknesses, minimum and maximum reinforcement ratios, minimum yield stress value of faceplates, and minimum compressive strength of concrete with some cited exceptions. The applicant also checked SC components for several additional N9.1.1 requirements: nonslender faceplates, composite action assurance, faceplate ties, minimum effective rupture strength, faceplate pairing requirements, and welding or bolting requirements at faceplate connections. These checks are presented for the contiguous SC components and roof in tables 1 to 4 of calculation EOS01-0262, revision 2, as well as tables 3 to 10 of calculation EOS01-0263, revision 3.

The applicant determined the structural capacity of each SC component using the equations in ANSI/AISC N690-18 section N9.3, with the exception of the combined out-of-plane shear force capacity for thinner walls, as noted in UFSAR section 3.9.8.3. The equations employed to determine SC component structural capacities are also noted in UFSAR section 3.9.8.3. As explained by the applicant in UFSAR section 3.9.8.10.1, for those load combinations that include accident thermal loading the applicant limits the out-of-plane thermal strength of each component to the value required per ANSI/AISC N690-18 section N9.2.4.

4.1.6.2.1.1 Walls and roof

The applicant determined the bounding load demands of the contiguous base unit walls and roof by the combination of the elastic FEA results and tabulated them in UFSAR table 3.9.8-3. The structural capacities determined per ANSI/AISC N690-18 appendix N9 are presented by the applicant in calculation EOS01-0263, revision 3, tables 11 to 15. Along with the structural load demands for each SC component, being presented in UFSAR table 3.9.8-3, the associated demand-to-capacity (D/C) ratio are included. The applicant reports a maximum D/C ratio of less than 1.0 for the roof due to out-of-plane shear, indicating the roof is sufficient to resist the out-of-plane shear load.

Although the structural demands and capacities are not explicitly tabulated in the UFSAR, the shear key portions of the wall and roof components are evaluated by the applicant in section 8.8 of calculation EOS01-0263, revision 3, for the bounding load from a seismic event, as determined by hand calculations.

The roof and the top and bottom portions of the front wall are also evaluated by the applicant for tornado missile strikes, as described in SER section 4.1.6.2.1.4. Calculation EOS01-0265, revision 3, table 11 summarizes the component-missile interaction ratios of the walls and roof for each of the assessed missile types. Since the failure mode of these elements are determined to be shear-controlled, the ductility ratio limit is determined to be 1.0. A ductility ratio is defined as a ratio of the actual displacement of the structural element due to the impact of the missile to the calculated element displacement at its yield point, which is considered its elastic limit. Table 11 indicates that the resulting ductility ratios for the walls and roof are less than 1.0.

The staff finds the structural adequacy of the walls and roof, including shear keys, to be acceptable as the determined structural load demands are less than the calculated structural capacities. Based on these results, the staff finds that the structural design of the EOS-HSM-SC roof and walls are adequate to meet the requirements of 10 CFR 72.236(l) under the normal, off-normal, and accident loadings.

4.1.6.2.1.2 Door, OVC, and shield walls

The applicant determined the bounding load demands on the door and OVC by hand calculations in sections 8.2 and 8.3, respectively, of calculation EOS01-0320, revision 3. Tables 13 through 19 and 22 through 28 of this calculation, for door and OVC, respectively, show whether ANSI/AISC N690-18 appendix N9 provisions for SC components were satisfied. Tables 20, 21, and 29 through 32 also indicate the structural capacities of these SC components determined by the applicant per ANSI/AISC N690-18, as described in UFSAR section 4.6.4.1.1.

The applicant determined the bounding load demands on the shield walls by hand calculations to be from tornado missile strikes as presented in sections 8.2 and 8.3 of calculation EOS01-0265, revision 3. Tables 2 to 7 of this calculation show whether ANSI/AISC N690-18 appendix N9 provisions for SC components were satisfied, while tables 8 to 12 indicate the structural capacities of the shield walls determined by the applicant per ANSI/AISC N690-18, as described in UFSAR section 4.6.4.1.1. The shield walls are evaluated by the applicant for tornado missile strikes, as described in SER section 4.1.6.2.1.4. Calculation EOS01-0265, revision 3, table 11 summarizes the component-missile interaction ratios of the shield walls for each of the assessed missile types. Since the shear wall failures are determined to be shear-controlled, the ductility ratio limit is 1.0. Table 11 indicates that the resulting ductility ratios for the shield walls are less than 1.0.

The door is also evaluated by the applicant for tornado missile strikes, as described in SER section 4.1.6.2.1.4. Calculation EOS01-0320, revision 3, table 34 summarizes the component-missile interaction ratios of the door for each of the assessed missile types. Since the door failure is determined to be shear-controlled, the ductility ratio limit is 1.0. Table 34 indicates that the resulting ductility ratios for the door are less than 1.0.

In table 33 of calculation EOS01-0320, revision 3, the applicant summarizes the structural load demands and presents the D/C ratios for the door and OVC, reporting a maximum D/C ratio of less than 1.0 for the door due to punching shear from tornado missile impact, and a maximum D/C ratio of less than 1.0 for the OVC from seismic vertical shear. Table 34 of calculation EOS01-0320, revision 3, summarizes the component-missile interaction ratios for the door determined by the applicant for each of the assessed missile types, resulting in ductility ratio values less than 1.0. Similarly, table 11 of calculation EOS01-0265, revision 3, summarizes the component-missile interaction ratios of the shield walls, resulting in all ductility ratio values less than 1.0.

Based on these results, the staff finds that the structural design of the EOS-HSM-SC door, OVC, and shield walls are adequate to meet the requirements of 10 CFR 72.236(l) under the normal, off-normal, and accident loadings.

4.1.6.2.1.3 Connection regions

The applicant described the connection regions of the EOS-HSM-SC in UFSAR section 3.9.8.3.1. As the joint strips identified as part of the connection regions are located at each intersection (e.g., corner) of both the top and bottom portions of the contiguous base structure, they are considered to be rigid for out-of-plane moment transfer. As required by section N9.2.5 of ANSI/AISC N690-18, the structural force demands for each identified joint strip of the connection regions are determined by the applicant by averaging the demand over panel sections and widths, as described in UFSAR section 3.9.8.3.1. Additionally, the applicant employed the overstrength connection design philosophy, as recommended in section N9.4.2 of ANSI/AISC N690-18, where the required connection strength is determined as 200% of the required strength due to seismic loads plus 100% of the required strength due to non-seismic loads. The structural load demands for each joint strip region of each connection region are presented in UFSAR table 3.9.8-7.

The applicant determined the connection region structural steel load capacities using the following sections of ANSI/AISC 360-16, “Specification for Structural Steel Buildings”: section I8.3 for headed anchor studs both inside and outside the joint strip regions, and chapter J for welds.

The required and provided number of headed anchor studs, inside and outside the connection region, are presented by the applicant in UFSAR table 3.9.8-9, as are the required and provided weld sizes and types in table 3.9.8-8. Structural shear capacities of the connection regions are determined by the applicant per ACI 349 and ACI 352R, “Recommendations for Design of Beam-Column Connections in Monolithic Reinforced Concrete Structures,” and are presented in UFSAR table 3.9.8-10.

The applicant followed the provisions in ANSI/AISC N690-18 sections N.9.4, “Design of SC Wall Connections.” Specifically, the applicant followed the requirements in section N.9.4.1 to address connections between walls as rigid and the requirement in section N.9.4.2(b) for the required strength of the connections, presenting results in UFSAR tables 3.9.8-7, 3.9.8-8, and 3.9.8-10 to demonstrate that the requirements in section N9.4.3 are met.

Based on these results, the staff finds the design of the connection regions is acceptable. Based on using the ANSI/AISC N690-18 provisions in N9.4 and these results, the staff finds that the structural design of the EOS-HSM-SC connection regions are adequate to meet the requirements of 10 CFR 72.236(l) under the normal, off-normal, and accident loadings.

4.1.6.2.1.4 Local and global effects from tornado missile loading

The methodology employed by the applicant for the determination of local and global structural responses of SC components to tornado missile impact is discussed in SER section 4.1.5.2.

For the local structural damage evaluation, in UFSAR section 3.9.8.10.6.1, the applicant conservatively compares the total thicknesses of SC components to the minimum thickness of 18.5 inches required to prevent tornado missile penetration or perforation for a reinforced concrete component, as determined for the EOS-HSM-RC in UFSAR section 3.9.4.10.6.1. As reported in UFSAR section 3.9.8.10.6.1, the applicant concludes from this comparison that no through-perforation of the SC components results from tornado missile impacts.

The ductility ratios determined for the global missile impact effects on the SC components are reported by the applicant in UFSAR section 3.9.8.10.6.2 as being controlled by shear failures. Therefore, the components' global response ductility ratios, which are less than 1.0, satisfy the RG 1.243 position 11.1.7 guidance limits of a) 1.0 for components with shear reinforcement spaced at greater than half of the section thickness, or b) 1.3 for components with shear reinforcement spaced at not greater than half of the section thickness.

The structural adequacy of a single, empty EOS-HSM-SC module to suffice as a missile barrier to prevent the postulated tornado missiles from reaching an adjacent loaded EOS-HSM-SC module is confirmed by the applicant for the considered missile spectra, as described in UFSAR section 3.9.8.10.6.1.1.

Based on the results of the local and global missile barrier analyses demonstrating that no through-perforation occurs and that resulting ductility ratios remain below those required by ANSI/AISC N690-18, as modified by RG 1.243, the staff finds that the EOS-HSM-SC components have sufficient structural integrity to maintain their radiation shielding function under accident conditions and meet the requirements in 10 CFR 72.236(d) and 10 CFR 72.236(l).

4.1.6.2.2 EOS-HSM-SC structural steel components, and connections

4.1.6.2.2.1 Heat shields, connection bolts, and embedments

The applicant determined the bounding load demands of the roof and wall heat shield plates by combining the elastic FEA results to be less than the plate structural capacities as stated in UFSAR section 3.9.8.10.4. The interaction ratios of axial load and bending moment of the heat shield connection bolts are also determined to be less than 1.0 in this section of the UFSAR. The concrete embedment D/C ratios for the heat shield connectors, determined by the applicant as described in UFSAR section 3.9.8.10.7 and shown in table 3.9.8-5, are less than the code allowable. The staff finds the structural adequacy of the heat shields, connection bolts, and embedments to be acceptable as the determined structural load demands are less than the structural capacities determined by code. Based on these results, the staff finds that the structural design of the EOS-HSM-SC heat shields, connection bolts, and embedments are adequate to meet the requirements of 10 CFR 72.236(l) under the normal, off-normal, and accident loadings.

4.1.6.2.2.2 FPS DSC support structure

The applicant determined the bounding load demands of the FPS DSC support structure and connections to be identical to those for the previously approved EOS-HSM-RC presented in UFSAR section 3.9.4 from the combination of the FEA results, with the exception of the DSC stop plate and rail bolts. Additionally, the use of the temperature-dependent material properties in UFSAR table 8-43 required the applicant to re-evaluate the FPS structure, as described in UFSAR section 3.9.8.10.2. The applicant notes in UFSAR sections 3.9.8.10.2, 8.2.1.3, and 8.2.5.6 that a material thickness allowance is conservatively considered for all ITS exposed steel components when determining the structural capacities of the DSC support structure components, as described in UFSAR section 3.9.4.10.2. The applicant determined that the structural capacities of the stop plate and rail bolts, which are affected by the higher seismic acceleration of the EOS-HSM-SC, are greater than the load demands, as reported in UFSAR section 3.9.8.10.2 and section 8.5 of calculation EOS01-0320, revision 3. Additionally, the re-evaluation of the FPS structure for the updated material properties required the modification of some components. The resulting structural demands and capacities of the various FPS components are presented in UFSAR tables 3.9.8-11 to 3.9.8-13, and section 8.0 of calculation EOS01-0269, revision 1.

The staff finds the structural adequacy of the DSC FPS support structure and stop plate to be acceptable as the determined structural load demands are less than the structural capacities determined by code. Based on these results, the staff finds that the structural design of the EOS-HSM-SC FPS DSC support structure and stop plate are adequate to meet the requirements of 10 CFR 72.236(l) under the normal, off-normal, and accident loadings.

4.1.6.2.2.3 DSC axial retainer

As stated in UFSAR section 3.9.8.10.5, the applicant determined the bounding load demands of the embedded DSC axial retainer by hand calculations using the previously approved EOS-HSM-RC methodology. The resulting design loads are determined by the applicant to be less than the axial restraint shear and moment structural capacities. The staff finds the structural adequacy of the axial retainer to be acceptable as the determined structural load demands are less than the structural capacities determined by code. Based on these results, the staff finds that the structural design of the EOS-HSM-SC DSC axial retainer is adequate to meet the requirements of 10 CFR 72.236(l) under the normal, off-normal, and accident loadings.

4.1.6.2.3 SC component tie rods and embedments

The structural load demands for the SC component threaded tie rods are determined by hand calculations by the applicant in sections 8.1 to 8.6 and 8.9 of calculation EOS01-0330, revision 2. The load demands are then compared to the structural capacities determined in the same sections of calculation EOS01-0330 using the ANSI/AISC 360-16 code, as described in SER section 4.1.2.1.2. The applicant states in section 4.1.3 of calculation EOS01-0330 that for tie rod load capacity determination purposes, the material properties are considered to be at 250 °F, and a material corrosion allowance on the tie rod is also considered by the applicant.

In UFSAR table 3.9.8-6, the applicant presents the load demands, structural capacities, and D/C and interaction ratios for the structural steel tie rods between various SC components and the concrete embedments. All D/C ratios and interaction ratios, as applicable, are less than one.

The applicant determined the structural load demands for the concrete embedments in sections 8.1 to 8.9 of calculation EOS01-0330, revision 2. The load demands are then compared to the structural capacities determined in the same sections of calculation EOS01-0330 using appendix D of the ACI 349 code, as described in SER section 4.1.2.1.3. In some cases, supplemental reinforcement is provided by the applicant to provide the required structural capacity.

In UFSAR table 3.9.8-5, the applicant presents the load demands, structural capacities, and D/C and interaction ratios for the embedded concrete connections for the tie rods between various SC components as well as the heat shield plate connections to the EOS-HSM-SC walls and roof. All D/C ratios are less than one and interaction ratios, as applicable are less than 1.2.

All EOS-HSM-SC ITS structural components listed in SER sections 4.1.6.2.1 to 4.1.6.2.3 above are acceptable to staff for use as they have been structurally evaluated per the cited codes and standards, with any noted exceptions being accepted, and the resulting D/C ratios for all normal, off-normal, and accident conditions are less than the prescribed allowable code limits, thus meeting the requirements of 10 CFR 72.236(l).

4.1.6.2.4 Stability evaluations

The methodology and input parameters employed by the applicant for the determination of stability evaluations from extreme natural phenomena are discussed in SER section 4.1.5.3.

UFSAR table 3.9.8-4 presents the results of the applicant's EOS-HSM-SC stability analyses, which, in most cases, have improved performance from those of the previously approved medium length EOS-HSM-FPS-RC presented in UFSAR table 3.9.7-4. The applicant determined factors of safety for each scenario, which are a ratio of the structural resistance over the applied load, for EOS-HSM-SC stability during flooding conditions to be greater than 1.0, while some sliding and uplift rotation of the loaded module occurs during tornado events. The applicant determined that sliding and rotation of the EOS-HSM-SC during seismic events does not occur at the maximum acceptable acceleration values of 0.45 g and 0.30 g, respectively, where 'g' refers to the ratio of applied acceleration to the acceleration of gravity.

Based on the finding in SER section 4.1.5.3 for methodology, and the resulting factors of safety greater than 1.0 in the determination of EOS-HSM-SC sliding and overturning stability evaluation, the staff finds the results acceptable and consistent with NUREG-2215.

4.1.7 Conclusion

Based on the structural performance evidence presented in SER section 4.1 above, the staff concludes that the steel-plate composite HSM option introduced by the applicant, the EOS-HSM-SC and its associated structural components, complies with 10 CFR Part 72.

## 4.2 Change No. 4: TS Changes for Consistency Among DSC Types and Terminology Clarification

In this change the applicant introduces several editorial revisions and code exceptions to the TS. The structurally-related editorial changes involve clarifying language throughout the TS to distinguish between the EOS-HSM-RC, the EOS-HSM-SC, and the HSM-MX, such as the revision to the definition of "HSM" in TS section 1.1. The code exceptions introduced in TS section 4.4.4 address those aspects of the EOS-HSM-SC design that deviate from the requirements of the ANSI/AISC N690-18 design code and provide justifications for these exceptions. The staff finds these TS additions and corrections to be acceptable, while the acceptability of the code exceptions is addressed in SER section 4.1.2.2.

## 4.3 Change No. 5: Various UFSAR Editorial Corrections for Consistency and Clarification

The applicant introduces several editorial corrections and additions to the UFSAR in Change No. 5. The primary structurally-related editorial change, introduced in UFSAR section 3.9.4.9.2, reiterates the need that the user site-specific response at the top of the ISFSI pad be bounded by the response spectra considered in the development of the input time-history, and cautions that a soil-structure interaction analysis of the ISFSI foundation may be needed to capture the site-specific, foundation-related parameters and configuration. The staff determines that this UFSAR addition and all other corrections and additions are acceptable.

### 4.4 Additional Scope Change No. 1: An Additional Scope Item Has Been Added to Allow Use of a Blended Portland Cement That Would Be Certified to The Requirements of ASTM C595

In UFSAR section 8.2.1.3, the applicant introduces the use of blended hydraulic cement per ASTM C595 as an alternative to Portland cement per ASTM C150 for use in the structural concrete employed for all EOS-HSMs. Cement supplied per ASTM C595 is an acceptable substitution to Portland cement, as discussed in section 8.3.3.1 of this SER.

### 4.5 Additional Scope Change No. 6: An Additional Scope Item Has Been Added with Respect to the Use of the MX-LC for the 61BTH Type 2 DSCs

In Additional Scope Change No. 6, the applicant proposed several changes in appendix B of the UFSAR to include procedures for handling the 61BTH Type 2 DSCs. These changes address the installation of wheel chocks and make the appendix B procedures consistent with procedures in UFSAR appendix A.9 for the MX-LC. The staff previously approved the MX-LC and the appendix A procedure in Amendment No. 3 to the NUHOMS® EOS system in the SER (ML23137A413). In that report, the staff also noted the need for the applicant to change the appendix B procedures to address the wheel chock installation. Based on the similarity with the previously approved procedures, the staff finds this change acceptable.

### 4.6 Evaluation Findings

The staff concludes that the structural performance of the NUHOMS® EOS-HSM-SC and its associated structural components, as discussed in section 4 of this SER, is in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria in section 4, “Structural Evaluation,” of NUREG-2215 have been satisfied. The applicant’s evaluation of structural performance provides reasonable assurance that the EOS-HSM-SC system will allow for the safe storage of spent nuclear fuel for the licensed period. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, standard review plans, applicable codes and standards, and accepted engineering practices.

Some of the key findings from the staff’s review of Amendment No. 4 include:

F4.1 The staff reviewed the design bases and design criteria of the ITS SSCs of the EOS-HSM-SC and concludes that they meet the requirements of 10 CFR 72.236(b).

F4.2 The staff reviewed the structural performance of the ITS SSCs of the EOS-HSM-SC designed to provide radiation shielding and concludes that these SSCs have adequate structural integrity to satisfy the radiation shielding requirements of 10 CFR 72.236(d).

F4.3 The staff reviewed the structural performance of the ITS SSCs of the EOS-HSM-SC and concludes that these SSCs have adequate structural integrity to store the spent fuel safely for the term proposed in the application and satisfy the requirements of 10 CFR 72.236(g).

F4.4 The staff reviewed the structural performance of the ITS SSCs of the EOS-HSM-SC and concludes that these SSCs have adequate structural integrity to maintain confinement under normal, off-normal, and credible accident conditions and satisfy the requirements of 10 CFR 72.236(l).

## 5.0 THERMAL EVALUATION

The staff reviewed the information provided by the applicant and the following four changes are applicable to the thermal evaluation:

**Change No. 1:**
Incorporate a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 and stored in the EOS-HSM. Two new HLZCs are applicable to this MHLC.

**Change No. 2:**
Introduce a steel-plate composite option for the EOS-HSM, the EOS-HSM-SC.

**Change No. 4:**
TS changes for consistency among DSC types and terminology clarification.

**Additional Scope Change No. 8:**
UFSAR clarifications for the scenarios under which the maximum heat loads can be reduced for the EOS-37PTH.

This section of the SER documents the staff's review and conclusions with respect to thermal safety.

### 5.1 Change No. 1: Incorporate a Method to Determine New Loading Patterns Based on the Maximum Allowable Heat Load per DSC, Identified as the MHLC, Applicable to the EOS-37PTH Transferred in the EOS-TC125 and Stored in the EOS-HSM

In a prior NRC review and approval of the NUHOMS® EOS System Amendment No. 3 (ML23137A413), the staff approved changes similar to the proposed Change No. 1 in this application. In section 4.5 of the SER for Amendment No. 3, the staff discussed, in significant depth, the acceptability of a method for determining new loading patterns based on the maximum allowable heat load per EOS-89BTH DSC.

In the previous SER, the staff reviewed numerous facets of the applicant's methodology including a thorough review of the computational fluid dynamics (CFD) analysis models used to support three distinct HLZCs. Specifically, the staff evaluated HLZCs 4 – 6 in section 4.1 of the Amendment No. 3 SER and found it acceptable. The staff's review included an assessment of the various operating conditions for the EOS-89BTH DSC including normal and off-normal storage, normal and off-normal transfer operations, as well as accident conditions. The staff's detailed review of this methodology is found in Amendment No. 3 SER section 4.5.2.1, paragraphs 1 – 9.

The staff's review of the changes requested in this amendment are completed in light of the previous NRC staff approval of the analysis methodology described above and is detailed in the following sections.

### 5.1.1 Overview of Request of HLZCs 12 and 13 for the EOS-37PTH DSC

The applicant's UFSAR, in appendix 4.9.9, presents the thermal evaluation for the EOS-37PTH with basket assembly 4HA with HLZCs 12 and 13 when transferred in the EOS-TC-125/TC135 and stored in the EOS-HSM. UFSAR section 4.9.9.1 provides a description of HLZCs 12 and 13, which does not allow for the storage of WE 14x14 fuel assemblies. A representation of the proposed HLZCs is provided in chapter 2 of the UFSAR, specifically figures 2-3l and 2-3m (on pages 2-74 and 2-75, respectively, of the UFSAR). As discussed below, the applicant examined two specific “subsets” for HLZCs 12 and 13 to address the bounding configurations for both transfer (section 5.1.2) and storage (section 5.1.3).

The figures mentioned above provide specific loading patterns comprised of nine different zones. The zones 1-9 are arranged from the lowest to the highest heat loads per fuel assembly, with Zone 9 (in HLZC 12) having a maximum of 4.3 kW per fuel assembly, the highest decay heat for a single fuel assembly allowed in the EOS-37PTH DSC. Zones 6 thru 8 all have heat loads above 2.0 kW (for both HLZCs 12 and 13). In general, for both HLZCs 12 and 13, the hottest fuel assemblies are placed in the outermost compartments of the DSC. The applicant notes, in UFSAR section 2.4.3, that the total heat load for the proposed HLZCs 12 and 13 is limited to 50 kW; therefore, all fuel assembly loading combinations, following the decay heat values specified by figures 2-3l and 2-3m, will not exceed 50 kW for any loaded DSC.

As described by the applicant in UFSAR section 4.9.9.1, HLZCs 12 and 13 may accommodate up to six damaged fuel assemblies, or up to two failed fuel assemblies, in any basket loading, with the balance being intact fuel assemblies. The applicant has specified that damaged and failed fuel assemblies may not be loaded together in the same basket. For failed fuel assemblies, the maximum allowable heat load is 0.8 kW per assembly.

### 5.1.2 Transfer Evaluation for HLZCs 12 and 13

In section 4.9.9.2 of the UFSAR, the applicant described the analysis of EOS-37PTH DSCs loaded using the HLZCs 12 and 13 under transfer operations in the EOS-TC125/TC135 for normal, off-normal, and accident conditions.

The applicant, in UFSAR section 4, table 4-23 provides ten load cases (LCs) for the transfer in the EOS-TC125, which would be applicable to transfer of the EOS-37PTH DSC with HLZCs 12 and 13. The bounding LCs for normal, off-normal, and accident conditions of transfer were LC 1, LC 3, and LC 5, respectively. The applicant completed transient thermal analyses for each of these bounding LCs in order to evaluate the performance of the EOS-TC125 for these transfer conditions. The applicant's thermal analysis included WE 17x17 fuel assemblies, as these are considered to be the bounding fuel assemblies for HLZCs 12 and 13.

#### 5.1.2.1 Normal and Off-Normal Conditions of Transfer

In order to bound the temperatures calculated by the applicant, the applicant examined an NRC previously approved analysis of the EOS-37PTH DSC with HLZC 1 during transfer, found in section 4.5 of the UFSAR. The results of the applicant's analysis of the normal and off-normal transfer conditions are provided in UFSAR tables 4.9.9-2 and 4.9.9-3, respectively, and a comparison is provided between the calculated temperatures for HLZCs 12 and 13 and the bounding temperatures calculated for HLZC 1. Further, as indicated in table 4.9.9-2 of the

UFSAR, the applicant demonstrates that HLZC 12 bounds HLZC 13 for the transfer evaluation.

5.1.2.2 Transfer Time Limits

The applicant, as described in section 4.9.9.2.3.1 of the UFSAR, has evaluated the time limits for normal/off-normal transfer operations, as shown in UFSAR tables 4.9.9-2 and 4.9.9-3, respectively, for the EOS-37PTH DSC with HLZCs 12 and 13, and determined that the transfer time limit should be reduced from 10 hours to 8 hours. This makes the total duration for transfer operations in the EOS-37PTH DSC 13 hours, which includes the 8-hour transfer limit plus a 5-hour recovery time. The applicant's finding for transfer time limits is based on the comparisons of temperatures to those calculated for HLZC 1 which, as mentioned above, provides bounding results when compared to HLZCs 12 and 13. This reduction in the transfer time limit is provided in the TS under Limiting Condition for Operation (LCO) 3.1.3. The staff has reviewed and approved similar changes previously, as discussed in section 4.4 of the EOS Amendment No. 3 SER (ML23137A413).

5.1.2.3 Accident Conditions of Transfer

For accident conditions of transfer, the applicant evaluated a loss of neutron shield and loss of air circulation using a bounding heat load configuration which is defined as a "hot" ambient temperature condition (117 °F), loss of liquid neutron shield, and no air circulation (designated LC 5 and as mentioned above). Table 4.9.9-4 of the UFSAR provides the maximum cladding temperatures calculated and demonstrates that these temperatures are below allowable limits.

5.1.2.4 EOS-37PTH DSC Internal Pressure during Transfer

The applicant, in section 4.9.9.2.3.3 of the UFSAR, provides a brief discussion of how the internal pressure during transfer operations involving the EOS-37PTH DSC with basket type 4HA in an EOS-TC125/TC135 with intact fuel for HLZCs 12 or 13 is bounded by previously submitted calculations in section 4.7 of the UFSAR, as summarized in table 4-45 of the UFSAR. The internal pressures calculated based on these internal helium temperatures remain bounding for the normal, off-normal, and accident transfer conditions.

5.1.3 Storage Evaluation (Intact Fuel) for HLZCs 12 and 13 in the EOS-37PTH DSC

In section 4.9.9.3 of the UFSAR, the applicant evaluates the thermal performance of the EOS-HSM loaded with the EOS-37PTH DSC for HLZCs 12 and 13 with intact fuel during normal, off-normal, and accident conditions.

As in the case of transfer, described in the previous section of this SER, the applicant evaluated the HLZC 1 (50 kW), described in UFSAR section 4.9.5 and presented as LC 1 in UFSAR tables 4.9.5-1 and 4.9.5-2, as a bounding case, with a predicted peak cladding temperature of 716 °F. This case takes into account a wind deflector and models the presence of a "side wind" for the evaluation of the DSC in the EOS-HSM. The deployment of the wind deflectors on the EOS-HSM is depicted in figure 4.9.4-7 of the UFSAR. This loading case is then applied to evaluate the thermal performance of the HLZCs 12 and 13 for the EOS-37PTH DSC.

As described in UFSAR section 4.9.9.1, the applicant evaluated two specific load conditions for HLZC 12, as HLZC 12 bounds HLZC 13. In UFSAR section 4.9.9.3.2, the applicant describes the CFD analysis models used to evaluate the storage conditions described above, including the thermal model, the application of heat generation in the model, the solver controls, and the convergence criteria. The applicant used the CFD model described in UFSAR section 4.9.5.2, which was previously reviewed by the NRC staff, with specific changes to the heat generation rates, based on the HLZC 12, and the fuel assembly $K_{eff}$ properties based on the WE 17x17 fuel assemblies that would be stored in the EOS 37PTH-DSC.

The staff reviewed the CFD model provided by the applicant and found that it was acceptable.

The applicant provides a discussion of the thermal analysis results and their conclusions in UFSAR section 4.9.9.3.3. Component temperatures calculated for the EOS storage system are listed in UFSAR table 4.9.9-8 and compared (in that table) to the thermal analysis results for HLZC 1. The component temperatures listed are within all applicable limits.

The applicant maintains that, given the bounding nature of the HLZC 1 temperature values for the EOS-37PTH DSC for normal storage conditions, the prior analyses completed for HLZC 1 under off-normal and accident conditions remains bounding, and additional analyses in the current amendment request for the EOS-37PTH DSC was not warranted. The staff agrees with the position taken by the applicant and, therefore, finds it acceptable.

5.1.3.1 EOS-37PTH DSC Internal Pressure during Storage

The applicant, in section 4.9.9.3.3.2 of the UFSAR, provides a brief discussion of how the internal pressure during storage of the EOS-37PTH DSC with basket type 4HA in an EOS-TC125/TC135 with intact fuel for HLZCs 12 or 13 is bounded by previously submitted calculations of internal pressure described in section 4.7 of the UFSAR, the results of which are summarized in table 4-45 of the UFSAR. The internal pressures calculated based on these internal helium temperatures remain bounding for the normal, off-normal, and accident storage conditions.

5.1.4 Storage Evaluation (Damaged/Failed Fuel) for HLZCs 12 and 13 in the EOS-37PTH DSC

In UFSAR section 4.9.9.4, the applicant states that:

> *HLZCs 12 and 13 can accommodate a combination of intact FAs along with damaged FAs, or intact FAs along with failed FAs. HLZCs 12 and 13 can be loaded with up to six damaged FAs or up to two failed FAs, but not both, as noted in Figure 2-3l and Figure 2-3m, respectively.*

The applicant presents the thermal evaluation of the EOS-37PTH DSC with basket type 4HA for HLZCs 12 and 13 with damaged FAs (along with intact FAs) in UFSAR section 4.9.9.4.1 and failed FAs (along with intact FAs) in UFSAR section 4.9.9.4.2 for both storage and transfer conditions. A summary of the applicant's findings for damaged and failed FAs is provided below.

5.1.4.1 Damaged FAs

The applicant describes in UFSAR section 4.9.9.4.1 that the damaged FAs have the following characteristics, when compared to intact FAs:

- Damaged FAs maintain structural integrity during normal and off-normal storage as well as on-site transfer (UFSAR chapter 3, section 3.9.6.7), ensuring no reconfiguration of the fuel.
- The effective thermal conductivity of the damaged FAs is equivalent to the intact FAs during normal and off-normal conditions, as calculated in section 4.9.1.4 of the UFSAR.
- Thermal evaluations presented in UFSAR section 4.9.9.2.3 for normal and off-normal transfer and section 4.9.9.3.3 for normal and off-normal storage are applicable for up to six damaged FAs.
- For accident conditions, the thermal evaluations in UFSAR sections 4.9.9.2.3 and 4.9.9.3.3 will apply to damaged FAs if they maintain their physical configuration during accident conditions.
- There are no credible accident scenarios that would alter the physical configuration of the damaged FAs during storage operations.
- Cladding of high burnup damaged FAs could potentially experience further damage during a drop scenario, resulting in rubblization of the fuel in the bottom of the DSC.

The applicant, also in UFSAR section 4.9.9.4.1, evaluates the placement of up to 6 damaged FAs in the EOS-37PTH DSC. The applicant compares the HLZCs 12 and 13 with damaged FAs to the evaluation of HLZC 10 (for LC 5) with damaged FAs as described in UFSAR section 4.9.7.3 (which was previously reviewed and approved by NRC). The applicant further notes that for HLZC 10, the accident transfer case evaluated showed an increase of only 7 °F in the maximum fuel cladding temperature when compared to the accident transfer case with intact FAs (as reported in UFSAR tables 4.9.7-5 and 4.9.7-7 when comparing the fuel cladding temperatures). The applicant maintains that damaged FAs in HLZCs 12 and 13 would have a similar small increase.

The applicant points to UFSAR table 4.9.9-4 which indicates that the bounding HLZC 12 with intact fuel is 17 °F below the design basis accident transfer condition LC 5 as indicated in UFSAR table 4-29. The applicant maintains that even with a 7 °F increase, the maximum fuel cladding temperature for the bounding HLZC 12 with damaged FAs will remain bounded by the design basis accident transfer condition, therefore the thermal evaluation for the accident transfer case, as presented in UFSAR section 4.9.9.2.3, remains applicable. The staff finds this reasoning applicable to damaged FAs in the EOS-37PTH DSC with fuel loaded under HLZCs 12 and 13.

5.1.4.2 Failed FAs

The applicant, in UFSAR section 4.9.9.4.2, provides a description of failed FAs, similar to the discussion of damaged FAs described above.

In the case of failed FAs, the applicant evaluates the placement of up to 2 failed FAs in the EOS-37PTH DSC. The applicant compares the HLZCs 12 and 13 with failed FAs to the evaluation of HLZC 10 with failed FAs as described in UFSAR section 4.9.7.4 (which was previously reviewed and approved by NRC), noting that for that particular HLZC, the normal transfer case evaluated indicated a decrease of 9 °F in the maximum fuel cladding temperature (as demonstrated in UFSAR table 4.9.7-8) when compared to the normal transfer case with intact FAs. The applicant maintains that failed FAs in HLZCs 12 and 13 would have a similar decrease in cladding temperature. The staff finds this reasoning applicable to failed FAs in the EOS-37PTH DSC loaded with HLZCs 12 and 13.

5.1.4.3 Conclusions

Based on the staff's review of the applicant's evaluation of the storage and transfer operations, as discussed above, the staff finds that the applicant has demonstrated that all the temperature criteria along with the internal pressure criteria are satisfied for storage and transfer operations of intact and damaged, or intact and failed FAs in the EOS-37PTH DSC loaded in accordance with HLZCs 12 or 13.

5.1.5 Evaluation of Analysis Models for Storage and Transfer

In UFSAR section 4.9.9.3.2, the applicant describes the CFD analysis models used to evaluate the storage conditions described above, including the thermal model, the application of heat generation in the model, the solver controls, and the convergence criteria. The applicant used the CFD model described in UFSAR section 4.9.5.2, which was previously reviewed by the NRC staff, with specific changes to the heat generation rates, based on the HLZC 12, and the fuel assembly $K_{eff}$ properties based on the WE 17x17 fuel assemblies that would be stored in the EOS 37PTH-DSC.

In UFSAR section 4.9.9.5, the applicant described CFD analysis models that were developed for the evaluation of asymmetric HLZCs, which are permitted in the EOS-37PTH DSC. These "full" models include an entire EOS-37PTH DSC basket in order to evaluate either storage in the EOS-HSM or transfer in the EOS-TC125. The applicant compared the model design and applied storage boundary conditions of the "full" models to those of the "symmetrical" basis models (which were described in UFSAR sections 4.9.5.2 and 4.5.2, for evaluating storage and transfer, respectively). The applicant, in UFSAR section 4.9.9.5.1, highlights the main differences between the "full" and "symmetric" models and includes a description of how the storage boundary conditions found in UFSAR section 4.9.9.3.2 are placed on the "full" models.

The applicant reported that the component temperatures predicted by the "full" models were very similar to those reported in the "symmetrical" models, and therefore the average helium temperatures and maximum internal pressures of the DSC as well as the maximum HSM concrete temperatures were generally the same or only slightly elevated in the "full" models, therefore all temperatures and pressures calculated were within the existing limits. The "full" models were provided to the NRC staff, and those models were audited by the staff as described below.

5.1.5.1 Thermal Model Audit

As part of the staff's thermal model audit of the applicant's CFD models that are associated with this amendment request, the staff reviewed the applicant's thermal models used in the analyses and confirmed that the proper material properties and boundary conditions were used. The staff verified that the applicant's selected code, models, and assumptions were adequate for the prevailing flow and heat transfer characteristics in the EOS geometry and analyzed conditions. The staff also verified adequate convergence levels were reached for the heat transfer and mass flow rate to assure predicted temperatures were below allowable limits, as described in the UFSAR.

### 5.1.6 Conclusion

As discussed above, the staff finds the method proposed by the applicant for Change No. 1 is acceptable and may be used for determining new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC, to the EOS-37PTH transferred in the EOS-TC125 and stored in the EOS-HSM.

## 5.2 Change No. 2: Introduce a steel-plate composite option for the EOS-HSM, the EOS-HSM-SC

The applicant provided a new UFSAR section 4.4.12, titled, "Thermal Evaluation of EOS-HSM-SC." The EOS-HSM-SC is constructed of a steel-plate composite with concrete, the design of which is discussed in UFSAR section 1.2.1.3. Further discussion of the EOS-HSM-SC may be found in section 3.1 of this SER. The applicant provided Drawing EOS01-3300-SAR to provide specific details on this new EOS-HSM-SC design.

The applicant reviewed the thermal performance of the proposed EOS-HSM-SC in this new UFSAR section and produced a comparison of the effective thermal conductivity of the new steel-plate composite design to the current reinforced concrete HSM design, specifically for the front wall of the HSM. The applicant reported the conductivity values in a table in section 4.4.12 of the UFSAR (page 4-77) that indicated the EOS-HSM-SC wall that was considered has higher conductivity values, in both the across and parallel directions, than the current HSM wall design with reinforced concrete.

The applicant maintains that this comparison demonstrates that the steel-plate composite design for the HSM does not negatively impact thermal performance.

The majority of the heat generated by fuel stored in the EOS-HSM storage system is dissipated through air that flows over and around the surfaces of the DSC housed in the HSM. The applicant indicated that the impact on the heat removed from the EOS-HSM-SC through air flow driven convection heat transfer would be minimal due to the vent sizes in the EOS-HSM-SC being identical to the standard EOS-HSM. To further examine the potential impacts that the more "conductive" HSM walls of the EOS-HSM-SC could have on the removal of heat from the DSC through natural convection, the applicant performed a thermal analysis of the entire system with an increased concrete conductivity to "mimic" the higher conductivity of the steel-plate composite HSM walls. The analysis results, provided in a table in UFSAR section 4.4.12, demonstrated that the reinforced concrete EOS-HSM is indeed bounding, and that temperature of the DSC shell and maximum concrete temperature were slightly less for the EOS-HSM system with the increased concrete conductivity. The applicant also points out that removal of the optional dose reduction hardware (DRH), which is not needed for the EOS-HSM-SC storage system, will also act to reduce the overall system temperatures.

The staff reviewed the applicant's assertions and conclusion for the introduction of a steel-plate composite option for the EOS-HSM and finds the thermal performance of the EOS-HSM-SC storage system adequate.

## 5.3 Change No. 4: TS Changes for Consistency Among DSC Types and Terminology Clarification

The applicant, in the addition of figure 12 to the proposed TS for the EOS System Amendment No. 4, provides the MHLC 1 for the EOS-37PTH DSC, designated as MHLC-37-1, which provides the maximum heat loads allowed in six zones in the EOS 37PTH DSC. This figure is advisory and not directly intended to be used for loading but may be used to develop HLZCs. As such, there is no need for figure 12 to provide specific instructions to adjust the payload to maintain the total canister heat load limit, as is done in UFSAR figures 2-3l and 2-3m for HLZCs 12 and 13.

The applicant also proposed to add figure 13 to the TS which depicts the allowable configurations for damaged and failed fuel in the EOS 37PTH-DSC.

In section 2.1, "THERMAL PARAMETERS," of the TS, the applicant changed the first section heading to, "Maximum Heat Load Configuration (MHLC) and Decay Heat Calculations," and then added the appropriate information related to the additions of figure 12 and the HLZCs enveloped by the MHLC.

In section 3.1, "DSC Fuel Integrity," subsection 3.1.3, "Time Limit for Completion of DSC Transfer," in LCO 3.1.3 which is: "The time to transfer the DSC to the HSM shall be within the limits," the applicant added a LCO for HLZCs per the new figure 12 (mentioned above), with a time limit for transfer of 8 hours.

The applicant also proposed other changes, including the addition of, and revisions to, tables and figures in the TSs to accommodate the changes introduced under proposed Change No. 1, as described in section 5.1 of this SER.

The staff finds, based on its review of the thermal TS changes as discussed in this section, that the thermal TS changes are acceptable.

### 5.4 Additional Scope Change No. 8: UFSAR Clarifications for the Scenarios Under Which the Maximum Heat Loads Can Be Reduced for the EOS-37PTH

In a response to staff's request for supplement information dated March 30, 2023 (ML23089A175), the applicant provided additional change requests to the proposed Amendment No. 4 changes.

The applicant added an additional scope change to clarify the different site-specific conditions that could result in a reduction in the maximum heat load of the EOS-37PTH for existing HLZCs. The applicant also noted that new HLZCs could be developed based on the MHLC methodology, as described in UFSAR section 2.4.3.1. The applicant specifically added clarifying language to the fourth paragraph on UFSAR section 2.2.1 (page 2-10) and to TS section 2.1 (page 2-2).

The staff reviewed the changes proposed and found them to be acceptable.

### 5.5 Evaluation Findings

The staff concludes that the thermal design of the EOS-HSM and EOS-HSM-SC is in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the thermal design provides reasonable assurance that the EOS-HSM and EOS-HSM-SC will allow safe storage of spent fuel for a certified life of 20 years. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, and accepted engineering practices. Some of the key findings from the staff's review of Amendment No. 4 include:

F5.1 SSCs important to safety are described in sufficient detail in the UFSAR to enable an evaluation of their thermal effectiveness in accordance with 10 CFR 72.236(f) and 10 CFR 72.236(h). Storage container SSCs important to safety remain within their operating temperature ranges in accordance with 10 CFR 72.236(a) and 10 CFR 72.236(b).

F5.2 The EOS-HSM and EOS-HSM-SC are designed with a heat-removal capability, verifiably and reliably consistent with its importance to safety. The storage container is designed to provide adequate heat removal capacity without active cooling systems in accordance with 10 CFR 72.236(f).

F5.3 The SNF cladding is protected against degradation leading to gross ruptures under normal conditions by maintaining the cladding temperature for 20 years below 400 °C (752 °F) in a helium environment. Protection of the cladding against degradation is expected to allow ready retrieval of the SNF for further processing or disposal in accordance with 10 CFR 72.236(g), 10 CFR 72.236(l), and 10 CFR 72.236(m).

F5.4 The SNF cladding is protected against degradation leading to gross ruptures under off-normal and accident conditions by maintaining the cladding temperature below 570 °C (1,058 °F) in a helium environment. Protection of the cladding against degradation is expected to allow ready retrieval of spent fuel for further processing or disposal in accordance with 10 CFR 72.236(g), 10 CFR 72.236(l), and 10 CFR 72.236(m).

The staff concludes that the thermal design of the EOS-HSM and EOS-HSM-SC is in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the thermal design provides reasonable assurance that the EOS-HSM and EOS-HSM-SC will allow safe storage of SNF for a licensed (certified) life of 20 years. This conclusion is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

## 6.0 SHIELDING EVALUATION

The staff reviewed the information provided by the applicant and the following changes are applicable to the shielding design:

**Change No. 1:**
For the EOS-37PTH DSC, incorporate a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 TC and stored in the EOS-HSM. Two new HLZCs are applicable to this MHLC.

**Change No. 3:**
Introduce the use of MAVRIC software for a confirmatory run of the HSM-MX dose rates.

**Change No. 4:**
TS changes for consistency among DSC types and terminology clarification.

**Change No. 6:**
Measured exposures from past loading campaigns are added to highlight that measured exposures are significantly less than calculated exposures.

This section of the SER documents the staff's review and conclusions with respect to the shielding design of the NUHOMS® EOS system with the proposed amendments.
The objective of the shielding review is to determine whether the NUHOMS® EOS system with the proposed amendments continues to meet the regulatory requirements of 10 CFR 72.234(a) and 10 CFR 72.236(d).

### 6.1 Change No. 1: For the EOS-37PTH DSC, Incorporate a Method to Determine New Loading Patterns Based on the Maximum Allowable Heat Load per DSC, Identified as the MHLC

In the proposed Change No. 1, the applicant requested to add two new HLZCs to the EOS-37PTH DSC. These two new HLZCs 12 and 13 are shown in figures 2-3l and 2-3m of the UFSAR. Figure 12 of the TS is used to establish the limits on the total decay heat load of the DSC and the maximum heat load in each fuel compartment to qualify the various HLZCs. There is no change to the EOS-HSM structural design which was previously approved in Amendment Nos. 0 and 1 for the NUHOMS® EOS system.

The applicant used the source term inputs to rank the burnup/enrichment/cooling time (BECT) combinations based on the total masses provided in tables 6-5 and 6-6 of the UFSAR for pressurized water reactor (PWR) and boiling water reactor (BWR) fuel, respectively and, therefore, includes the entire FA source. The computed decay heat represents the entire fuel assembly decay heat and is used to determine the minimum cooling times for the burnups of interest. Fifty-one BECT combinations were examined for the PWR source terms, and 16 BECT combinations are examined for the BWR source terms. These candidate source terms are listed in tables 6-8 and 6-9 of the UFSAR for PWR and BWR fuel, respectively.

These new HLZCs allow for heat load up to 4.3 kW per assembly. With the two new HLZCs, the EOS-37PTH DSC will have 13 HLZCs available for loading in the cask. The new HLZCs are defined in figures 2-3l, and 2-3m of the revised UFSAR for the EOS-HSM system design. The EOS-37PTH DSC also have MHLCs that bound the HLZCs. The MHLCs are provided in the TS, although the individual HLZCs may be provided in the TS. When source terms are developed based on a MHLC rather than individual HLZCs, all HLZCs bounded by the MHLC are also bounded by the shielding analysis. Systems for which the MHLC concept has been employed in source term development are summarized in table 6-1 of the UFSAR.

As approved in Amendment No. 1 for the NUHOMS® EOS system, the EOS-HSM system is using the standard overpack configurations. The two new proposed HLZCs (i.e., 12 and 13) for the EOS-37PTH DSC are designed for the EOS-HSM. The applicant developed the source terms for the fuel to be loaded in each loading zone of the two new HLZCs based on the MHLC per figure 12 of the TS. The applicant developed the bounding gamma and neutron source terms using the ORIGEN-ARP module of the ORNL Scale 6.0 code. The B&W 15x15 FA was selected as the design basis PWR because of its higher uranium content than other fuel types. The staff finds using B&W 15x15 FAs as design basis is acceptable because it is well known that these FAs contain high uranium loadings, therefore have the higher gamma and neutron source terms which result in higher dose rates than other FAs.

Section 6.2.2.4 of the UFSAR presents the overall methodology in calculating the source terms for the EOS-37PTH DSC transferred within the EOS-TC125/135 transfer cask and stored in the EOS-HSM using "Method 2." In contrast with "Method 1" where the applicant used only a few BECT combinations, "Method 2" uses a comprehensive set of BECT combinations, approximately 100 BECT combinations, in the source terms calculation. The applicant describes the approach for determining the bounding source term in the UFSAR sections 6.2.2.2 and 6.2.2.3. FAs reconstituted with 10 stainless steel rods are addressed in the baseline analysis which give less dose rate for the standard FAs (without irradiated stainless steel rods). Response functions from Monte Carlo N-Particle (MCNP) code for EOS-HSM and EOS-TC125/135 analyses are provided in tables 6-65 and 6-66 of the UFSAR, respectively. The EOS-TC125/135 response functions are based on the maximum lead thickness design, and the nominal lead thickness for the EOSTC125/135 design varies from 3.12 inches to 3.56 inches. The bounding BECT combinations, response function results, Co-60 activities, and neutron sources are summarized in UFSAR tables 6-8a and 6-8b for standard and reconstituted fuel, respectively. The staff found that the dose rates presented in tables 6-8a and 6-8b are in compliance with 10 CFR 72.104.

The applicant developed the EOS-37PTH DSC shielding HLZC to bound the HLZCs 12 and 13 using the same method that was previously approved in EOS Amendment No. 3 for EOS-37PTH DSC transferred by EOS-TC125 and stored in overpack EOS-HSM.

The dose rates effect of reconstituted fuel assemblies containing irradiated stainless-steel rods is addressed in section 6.2.6.3 of the UFSAR for the EOS-37PTH DSC transferred by the EOS-TC125/135 to the EOS-HSM overpack using shielding HLZC bounding source term.

According to the applicant, each basket location in the “shielding HLZC” configuration bounds the corresponding heat load at the same location allowed in HLZCs 12 and 13. The shielding HLZC for the EOS-89BTH is provided in figure 6-18 of the UFSAR and it is identical to the MHLC as shown in figure 12 of the TS. The staff found that the “shielding HLZC” is conservative for dose rate analysis because the “shielding HLZC” is identical to MHLC and thus provides the maximum dose rates within the entire DSC and have the maximum source terms. The minimum cooling time of 1 year was used in the “shielding HLZC” shielding calculations. The staff found the applicant’s bounding source to be conservative to calculate the dose rates for the two new HLZCs 12 and 13 because they are bounded by the MHLC, which showed to have the maximum dose rates among the HLZCs. Therefore, the staff found the source term calculations to be acceptable.

In section 6.2.2.4 of the UFSAR, the applicant described development of the fuel qualification tables (FQTs), which are the combinations of BECTs. The applicant stated that the candidate source terms over a range of BECT combinations were generated to match the decay heat of each zone of the EOS-37PTH DSC shielding HLZC in figure 6-19 of the UFSAR. A comprehensive set of 100 burnup and enrichment combinations were considered for the EOS-37PTH DSC shielding HLZC. The burnup and enrichment combinations considered correspond to the FQT provided in TS table 7C which is used to control the source terms for shielding calculations. The applicant used MCNP compute code to generate the response functions for the side of the EOS-TC125 and outlet vent opening of the EOS-HSM. The response functions when multiplied by a source term generate a dose rate. These dose rates were used to rank the source terms and select bounding BECT combinations in the active fuel region. As an added conservatism, the applicant selected the bounding BECT of the hardware regions, consisting of the bottom nozzle, plenum, and top nozzle, which are due almost entirely to Co-60, to optimize Co-60 activation and to differ from the bounding BECT of the active fuel region.

Decay heat cannot uniquely define the allowable spent fuel contents for the purpose of shielding design since there are many different BECT combinations that can produce the same decay heat but different source terms. For this reason, the applicant developed a list of BECTs that can produce the decay heat and source terms. In this way, the allowable spent fuel contents are uniquely defined for both the decay heat limit and source term limits. The decay heat limit is used for thermal analyses and the BECT defines the source terms used for the shielding analyses.

The applicant demonstrated that the system will be able to meet the dose limit prescribed in 10 CFR 72.236(d) assuming that accident recovery is within eight hours. Consistent with 72.212(b)(6), the user is required to review the UFSAR and, therefore, should be aware of the assumptions described in the UFSAR for the development of the radiation protection plan based on site-specific characteristics and operation procedures. Because the staff has accepted this assumption in the review of Amendment No. 0 for the NUHOMS® EOS system, and there is no change in the assumption, the staff does not need to re-review the validity of this assumption.

#### 6.1.1 Source Terms Confirmatory Calculations

The staff reviewed the applicant's source term calculation and performed confirmatory analysis. The staff calculated the source terms for the new spent fuel to be stored in the EOS-37PTH DSC using the ORIGEN-ARP module of the SCALE 6.0 code package (ORNL, 2009). The staff used the design basis assembly and the BECTs in the TS to ensure that the source terms are clearly defined by these spent fuel parameters. The staff found that the BECTs specified in the TS provide data that are sufficient for calculating the sources of the spent fuel to be stored in the cask. The SCALE computer code and the ENDF/B-VII cross section library are one of the computer codes and cross section libraries recommended by NUREG-2215 and this code has been used and accepted by the staff in the review of the previously approved Amendment No. 3 for the NUHOMS® EOS system. On these bases, the staff found that the computer code and cross section library are appropriate and acceptable.

The staff also reviewed the applicant's shielding calculation for the system under accident conditions and found that the assumptions and the methodology are similar to those used in the previously approved accident conditions for Amendment No. 3 for the NUHOMS® EOS system. For this reason, the staff finds that the applicant's shielding analyses for Change No. 1 are acceptable and that there is reasonable assurance that the shielding design for the EOS-HSM system, as amended, will continue to meet the regulatory requirements of 10 CFR 72.236(d).

### 6.2 Change No. 3: Introduce the Use of MAVRIC Software for a Confirmatory Run of the HSM-MX Dose Rates

In section A.6.5.3 of the UFSAR, the applicant provides a comparison between MCNP computer code and MAVRIC software included in SCALE 6.2 to demonstrate the acceptability of MAVRIC as a computational tool. MAVRIC is a Monte Carlo radiation transport program that can perform most of the functions of MCNP5.

For the comparison, the applicant used the HSM-MX "triple reflection" MCNP5 dose rate on the surface and compare it to an equivalent MAVRIC calculation. The MAVRIC source terms inputs were consistent with the EOS-37PTH DSC HLZC 10, as provided in tables 6-19a through 6-19c of the UFSAR. The hardware source terms inputs were consistent with a Co-60 spectrum in MAVRIC since the hardware source terms are essentially due to Co-60. The control component source is also included in the MAVRIC analysis, consistent with table 6-37 of the UFSAR. Lastly, the MAVRIC model is constructed using the same geometry and materials as equivalent to MCNP models. Front and roof dose rates are computed in separate models to optimize the important map used to transport particles to the tallies.

The comparison between MAVRIC and MCNP5 generated results shows that they produce similar dose rate results. The MAVRIC dose rates were provided in the upper portion of UFSAR table A.6-15, and the equivalent MCNP5 dose rates provided in table A.6-2a. A comparison between MCNP5 and MAVRIC is provided in the lower portion of table A.6-15. The total dose rate for the two programs agrees within 5%. For the upper compartment outlet vent, the MCNP5 result is approximately 30% larger than the equivalent MAVRIC result. The applicant explained that this difference is likely due to geometry differences in the modeling. As indicated in figure A.6-6, reflective boundaries in the x-direction are applied in the MCNP5 models, although the HSM-MX roof is not symmetric in the x-direction.

The staff reviewed the applicant's comparison between MAVRIC and MCNP5 and found that the applicant demonstrated the acceptability of MAVRIC as a computational tool because the total dose rate for the two programs agrees within 5%, which is an excellent agreement. For this reason, the staff finds that the applicant's comparison between MAVRIC and MCNP5 dose rates calculations is acceptable and that there is reasonable assurance that the dose rates performed using MAVRIC software for the EOS systems, as amended, will continue to meet the regulatory requirements of 10 CFR 72.236(d).

### 6.3 Change No. 4: TS Changes for Consistency Among DSC Types and Terminology Clarification

The applicant revised the TS for the NUHOMS® EOS system to reflect revised contents supported by the shielding analyses described in the preceding sections of this SER. The primary changes to the TS due to changes in the shielding analysis are:

- add two new HLZCs for the EOS-37PTH for higher heat load 4.3 kW/assembly,
- reduces the minimum cooling time to one year and increases the heat load capacity of the EOS-37PTH to 45.05 kW, and
- add a lead thickness of 3.51 in EOS-TC125 for transfer with the EOS-37PTH DSC.

The staff reviewed the proposed TS changes for the NUHOMS® EOS system and finds that the proposed changes are consistent with the results of the applicant's shielding analysis. The proposed TS will ensure that the NUHOMS® EOS system dose rates are as required by 10 CFR 72.124(a) and 72.236(c).

### 6.4 Change No. 6: Measured Exposures from Past Loading Campaigns are Added to Highlight that Measured Exposures are Significantly Less Than Calculated Exposures

In UFSAR section 11.2.1, "EOS-DSC Loading, Transfer, and Storage Operations", the applicant describes that the estimated occupational exposures to ISFSI personnel during loading, transfer, and storage operations using the EOS-TC125/135 (time and number of workers may vary depending on individual ISFSI practices). The estimated occupational exposures are provided in table 11-4 for the EOS-37PTH DSC. The task, duration, number of personnel, and total doses are listed in the table. The total exposure result for EOS-TC125/135 with EOS-37PTH DSC is 5,393 person-mrem (5.4 person-rem).

The staff reviewed the estimated occupational exposure and found that those are bounding estimates. Measured exposures from typical NUHOMS® System loading campaigns have been

0.6 person-rem or lower per canister for normal operations, and exposures for the NUHOMS® EOS System are expected to be similar. Measured occupational exposure data for three EOS-HSM loading campaigns using the EOS-37PTH DSC are provided in table 11-5a. The average measured occupational exposures range from 0.16 person-rem to 0.75 person-rem and are significantly lower than the computed value of 5.4 person-rem.

The staff reviewed the proposed Change No. 6 for the NUHOMS® EOS system and finds that the proposed change is consistent with the results of the applicant's shielding and radiation protection analysis. The proposed Change No. 6 will ensure that the NUHOMS® EOS system dose rates are as required by 10 CFR 72.124(a) and 72.236(c).

### 6.5 Evaluation Findings

F6.1 The UFSAR provides specifications of the spent fuel contents to be stored in the EOS Storage System in sufficient detail that adequately defines the allowed contents and allows evaluation of the DSS shielding design for the proposed contents. The UFSAR includes analyses that are adequately bounding for the radiation source terms associated with the proposed contents' specifications.

F6.2 The UFSAR describes the SSCs important to safety that are relied on for shielding in sufficient detail to allow evaluation of their effectiveness for the proposed term of storage.

F6.3 The UFSAR provides reasonable and appropriate information and analyses, including dose rates, to allow evaluation of the EOS Storage System compliance with 10 CFR 72.236(d).

F6.4 The UFSAR continues to provide reasonable and appropriate information and analyses, including dose rates, to allow evaluation of consideration of ALARA in the EOS Storage System design and evaluation of occupational doses.

The staff concludes that the NUHOMS® EOS dry storage system adequately considers the design features relied on for shielding during normal, off-normal, and accident conditions. The evaluation of the shielding design provides reasonable assurance that the NUHOMS® EOS dry storage system will allow safe storage of SNF. The staff reached this finding on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, accepted engineering practices.

## 7.0 CRITICALITY EVALUATION

The staff reviewed the information provided by the applicant and found that none of the proposed changes affect criticality safety of the NUHOMS® EOS system. The applicant made some conforming changes to the UFSAR chapter 7, Criticality Evaluation, to update references to TS related to the addition of two heat load patterns (Change No. 1).

The staff concludes that the criticality design features for Amendment No. 4 of the NUHOMS® EOS system are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the criticality design provides reasonable assurance that the NUHOMS® EOS system will allow safe storage of spent fuel. This finding is reached on the basis of a review that considered the regulatory requirements, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

## 8.0 MATERIALS EVALUATION

The staff reviewed and evaluated the information provided by the applicant requested in Amendment No. 4. The specific changes evaluated in this section include:

**Change No. 1**:
For the EOS-37PTH DSC, incorporate a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 TC and stored in the EOS-HSM.

**Change No. 2:**
Introduce a steel-plate composite option for the EOS-HSM. The steel-plate composite option, EOS-HSM-SC, allows for the HSM components to be constructed from concrete-filled integrated steel wall forms.

**Change No. 4:**
TS changes for consistency among DSC types and terminology.

**Change No. 5:**
Various UFSAR editorial corrections for consistency and clarification.

**Additional Scope Change No. 1:**
Allow use of a blended Portland cement that would be certified to the requirements of ASTM C595.

**Additional Scope Change No. 6:**
Use of the MX-LC for the 61BTH Type 2 DSCs.

**Additional Scope Change No. 8:**
Clarify the different site-specific conditions that could result in a reduction in the maximum heat load for existing HLZCs for EOS-37PTH.

The NRC staff reviewed the changes to the UFSAR, CoC, and TSs associated with the CoC No. 1042 NUHOMS® EOS Amendment No. 4 application. The staff's review was conducted using the guidance in chapter 8 of NUREG-2215 to ensure adequate materials performance under normal, off-normal, and accident-level conditions.

The areas of review covered in this SER section are described in NUREG-2215, chapter 8, and included system design, engineering drawings, material selection and material properties, environmental conditions and material compatibility, cladding integrity, and fuel condition. The staff evaluated the changes in the NUHOMS® EOS Amendment No. 4 application with respect to the 10 CFR Part 72 regulatory requirements identified in section 8.4 and the review procedures identified in section 8.5 of NUREG-2215.

In addition to the guidance in NUREG-2215, the staff evaluated the engineered drawing, and the description of the structures systems and components included in the NUHOMS® EOS Amendment No. 4 application using the information provided in NUREG/CR-5502 and NUREG/CR-6407.

### 8.1 Change No. 1: EOS-37PTH Maximum Allowable Heat Load Configuration

The applicant stated that this change was similar to the EOS-89BTH concept submitted under Amendment No. 3 and incorporated a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 and stored in the EOS-HSM. The applicant described two new HLZCs applicable to this MHLC.

The applicant also added a new basket type (4HA) which was described as a subset of the 4H basket where the aluminum basket plates are anodized. The applicant stated that anodizing is required when HLZCs with decay heats greater than 3.5 kW are stored in the basket and included the basket type 4HA in UFSAR table 1-2. This information was also included in SAR drawing EOS01-1010-SAR, with a note that indicates that anodizing is required for the A4HA and B4HA baskets and required for HLZCs with a maximum decay heat greater than 3.5 KW per assembly. The applicant also specified the Boron content of the A4HA and B4HA baskets in UFSAR section 1.1. The applicant included the emissivity requirements for the anodized coating in UFSAR section 4.9.9 and identified the anodized coating as an important to safety category C item in the UFSAR drawing EOS01-1010-SAR.

The applicant updated the TS figures and tables that identify the approved contents of the EOS-37PTH including fuel assembly burnup, maximum heat load, transfer time limits, minimum cooling times, and the maximum number of irradiated stainless steel rods per DSC and per reconstituted fuel assembly.

The applicant provided the component temperatures for normal, off-normal, and accident conditions during transfer operations for the EOS-37PTH with the EOS-TC-125 in UFSAR tables 4.9.9-1 to 4.9.9-3 for the two new HLZCs. The applicant showed that the maximum component temperatures for the new HZLCs were below the maximum allowed temperatures. Time limits for the EOS-37PTH with the new HZLCs for a transfer operation with the EOS-TC-125 with a maximum heat load of 50 kW and different load cases are included in UFSAR table 4.9.9-5.

The staff reviewed the information provided by the applicant in the UFSAR and TS to support this change. The staff determined that the new Type 4HA basket design was acceptable because the basket is the same as the Type 4H basket that was previously approved but with the addition of an anodized coating to promote heat transfer. The staff determined that the applicant has adequately specified the anodized coating requirements because the applicant provided a required emissivity value as well as testing requirements to verify the adequacy of the anodized coating.

The staff reviewed the revisions to the approved contents and the increased maximum allowable heat load for the EOS-37PTH. The staff determined that these changes were acceptable because the applicant specified the maximum DSC and fuel assembly burnup, maximum heat load, transfer time limits, and minimum cooling times. In addition, the applicant included an analysis for the new HLZCs that shows the component temperatures for the EOS-37PTH DSC and the EOS-TC-125 do not exceed their maximum temperature limits under normal, off-normal, and accident conditions.

## 8.2 Change No. 2: New Steel-Plate Composite Option For The EOS-HSM

The applicant stated that the steel-plate composite option allows for the HSM components to be constructed from concrete-filled integrated steel wall forms. The applicant referred to this design option as the steel composite EOS-HSM or EOS-HSM-SC. The applicant used EOS-HSM-RC to distinguish the previously approved reinforced concrete from the EOS-HSM-SC included in the EOS Amendment 4 application.

### 8.2.1 Drawings for the EOS-HSM-SC

The applicant described the EOS-HSM-SC design as being composed of welded steel plate outer and inner walls that are tied together with tie bars and studs are welded to the inside of the walls. The gap between the steel walls is then filled with concrete and the tie bars and studs provide concrete reinforcement. The applicant provided drawings for the EOS-HSM-SC which included a list of components, materials specifications, component quality category, and dimensions tolerances.

The staff reviewed the drawings using the guidance in NUREG-2215 and NUREG/CR-5502 for the recommended content of engineering drawings. In addition, the staff used NUREG/CR-6407. The staff verified that the drawings include the information described in NUREG-2215 on the (1) materials of construction; (2) dimensions and tolerances; (3) codes, standards, or other specifications for materials, fabrication, examination, and testing; (4) welding specifications, including location and NDE; (5) coating specifications and other special material treatments that perform a safety function; and (6) specifications and requirements for alternative materials. The staff determined that the drawings for the package provide the necessary information identified in the NRC guidance documents and the engineering drawings provided by the applicant are consistent with the design bases and design for SSCs important to safety in accordance with 10 CFR 72.236(b). Therefore, the staff determined that the drawings provided by the applicant for the EOS-HSM-SC are acceptable.

### 8.2.2 Codes and Standards for the EOS-HSM-SC

In UFSAR section 8.2.1.3, “EOS-HSM Horizontal Storage Module,” the applicant stated that the applicable codes for EOS-HSM-SC are as follows:

- Steel-plate composite design and construction per ANSI/AISC-N690-18, “Specification for Safety-Related Steel Structures for Nuclear Facilities.”
- Concrete components are designed in accordance with ACI 349-13, “Code Requirements for Nuclear Safety-Related Concrete Structures,” and constructed per ACI-318-08, “Building Code Requirements for Structural Plain Concrete and Commentary.”
- DSC support structure design per AISC Manual of Steel Construction.

The staff reviewed the codes and standards identified by the applicant for the EOS-HSM-SC. The staff determined that the codes and standards for the construction of the EOS-HSM-SC are appropriate. The staff noted the NRC endorsement of ANSI/AISC-N690-18 is documented in RG 1.243. The staff’s structural review of the EOS-HSM-SC utilizing ANSI/AISC-N690-18 is documented in this SER section 4.1.

The NRC has previously accepted concrete construction in accordance with ACI-318 as described in NUREG-2215, section 8.5.8, "Concrete and Reinforcing Steel." In addition, the NRC has previously reviewed the use of the AISC Manual of Steel Construction for EOS HSM components in the SER for EOS Amendment No. 1 (ML20136A052). The staff determined that the codes and standards identified by the applicant are sufficient for the design of structures, systems, and components important to safety in accordance with 10 CFR 72.236(b). Therefore, the staff determined that the codes and standards identified by the applicant for the EOS-HSM-SC are acceptable.

The applicant included code alternatives to the EOS-HSM-SC in TS section 4.0, "Design Features," which include alternatives for the minimum section thickness for the EOS-HSM-SC walls and the minimum yield stress for the faceplates to withstand tornado missile impacts. The staff's evaluation of the structural integrity of the EOS-HSM-SC to withstand tornado missile impacts are documented in this SER section 4.

#### 8.2.3 EOS-HSM-SC Welding

The applicant stated that the EOS-HSM-SC faceplates, constructed from either ASTM A572 Grade 60 steel or ASTM A36 steel, are designed in accordance with ANSI/AISC N690-18, and faceplate and corner joint welds are full penetration welds. In addition, the applicant stated that the steel tie bars that connect the faceplates are either ASTM A706 Grade 60 when using rebar ties, or ASTM A449 Type 1 when using threaded rod. The steel headed stud anchors that attach the concrete to the faceplate are ASTM A29, Grades 1010-1020. The applicant stated that all welds, including faceplates, studs and tie bars of the EOS-HSM-SC are made in accordance with American Welding Society (AWS) D1.1.

The staff reviewed the codes and standards identified by the applicant for the EOS-HSM-SC. The staff determined that the codes and standards for the construction of the EOS-HSM-SC are consistent with the guidance in NUREG-2215, section 8.5.3, "Welding," and adequately describe the design bases and design criteria that must be provided for SSCs important to safety in accordance with the regulatory requirements in 10 CFR 72.236(b). Therefore, the staff determined that the welding requirements identified by the applicant for the EOS-HSM-SC are acceptable.

#### 8.2.4 EOS-HSM-SC Materials Properties

The applicant stated that the concrete used in the EOS-HSM-SC is identical to that of the EOS-HSM-RC and that the concrete properties are already included in UFSAR table 8-23. The applicant stated that the EOS-HSM-SC faceplates are constructed from either ASTM A572 Grade 60 steel or ASTM A36 steel. Steel tie bars that connect the faceplates are either ASTM A706 Grade 60 when using rebar ties, or ASTM A449 Type 1 when using threaded rod. The steel headed stud anchors that attach the concrete to the faceplate are ASTM A29, Grades 1010-1020. The applicant stated that the EOS-DSC support structure is fabricated from ASTM A913 Grade 70 or ASTM A572 Grade 65 for the FPS option.

The applicant included temperature dependent material properties for the faceplates, studs, and tie bars for the EOS-HSM-SC in tables 8-37 through 8-41 in chapter 8 of the UFSAR. The applicant stated that the material properties of the ASTM A913 Grade 70 steel used for the W beam option DSC support structure are provided in table 8-15. The properties for the ASTM A572 Grade 65 steel used for the FPS option DSC support structure are provided in table 8-43.

The staff reviewed the material properties and determined that the applicant provided temperature dependent properties including modulus of elasticity, yield strength, tensile strength, and density for the EOS-HSM-SC and the EOS-DSC FPS. The staff confirmed that the temperature dependent mechanical properties conservatively bound the upper temperature limits for the EOS-HSM-SC and the EOS-DSC FPS components. Based on a review of the information provided by the applicant, staff determined that the material properties included in chapter 8 of the UFSAR for the EOS-HSM-SC and the EOS-DSC FPS components are sufficient for the design of SSCs important to safety in accordance with 10 CFR 72.236(b). Therefore, the staff determined that the material properties for the the EOS-HSM-SC and the EOS-DSC FPS components are acceptable.

8.2.5 EOS-HSM-SC Coatings

The applicant included a note in the EOS-HSM-SC drawing stating that the exterior faceplates are coated with either an inorganic or organic zinc-rich primer and epoxy finish coating which is NITS. In UFSAR section 10.3.2, “HSM Repair, Replacement, and Maintenance,” the applicant stated that a corrosion allowance of 1/8-inch provides significant margin for any defects that may occur over the lifetime of the EOS-HSM-SC.

In USFAR section 8.2.1.3, “EOS-HSM Horizontal Storage Module,” the applicant stated that the EOS-DSC support structure is fabricated from ASTM A913 Grade 70 or ASTM A572 Grade 65 for the FPS option. The applicant stated that both DSC support structure designs are coated with an inorganic zinc rich primer and a high build epoxy enamel finish that is NITS and a corrosion allowance of 1/16 inch is used in the design calculations.

The staff reviewed the information provided by the applicant on the protective coatings and the corrosion allowance for the EOS-HSM-SC and the EOS-DSC FPS option. The staff determined that the application of a zinc rich primer and epoxy finish coating for corrosion protection of the carbon steel components is acceptable as such coatings are widely used in commercial application including spent fuel storage and radioactive materials transportation systems. Because the coatings are categorized as NITS, staff reviewed the corrosion allowance for the carbon steel components by comparing the values provided by the applicant to measured and predicted long-term atmospheric corrosion rates in a range of environments published by McCuen and Albrecht (1994). Staff determined that the corrosion allowance for the EOS-HSM-SC and the EOS-DSC FPS are sufficient for at least 60 years of operation. Therefore, the staff determined that the coating specifications and corrosion allowance for the the EOS-HSM-SC and the EOS-DSC FPS are acceptable.

McCuen, R. H. and Albrecht, P., "Composite Modeling of Atmospheric Corrosion Penetration Data," Application of Accelerated Corrosion Tests to Service Life Prediction of Materials, ASTM STP 1194 Gustavo Cragnolino and Narasi Sridhar, Eds., American Society for Testing and Materials, Philadelphia, pp. 65-102, 1994.

**8.3 Change No. 4: TS Changes for Consistency Among DSC Types and Terminology**

The applicant provided updated TS to support the amendment request with minor changes to the terminology for consistency. The changes included minor edits to the definitions and to improve the consistency of the terminology in some TS sections. The applicant also included TS revisions that were aligned with the changes in this amendment application. The TS changes relevant to the materials evaluate include the following:

2.1, “Fuel to be Stored in the EOS-37PTH DSC”
2.2, “Fuel to be Stored in the EOS-89BTH DSC”
2.3, “Fuel to be stored in the 61BTH Type 2 DSC”
3.1.3, “Time Limit for Completion of DSC Transfer”
4.4, ”Codes and Standards”
5.3, “Concrete Testing”

The staff reviewed the TS changes provide by the applicant. The staff determined that the edits to TS sections 2.2, 2.3, and 5.3 did not affect any previously evaluated functional or operating limits or administrative controls and meet the regulatory requirements in 10 CFR 72.236(a) and (b). Therefore, the staff determined that the TS changes for consistency among DSC types and terminology identified by the applicant are acceptable. Staff’s review of the remaining TS changes relevant to the materials evaluation is documented in the following subsections.

8.3.1 Changes to TS 2.1, “Fuel to be Stored in the EOS-37PTH DSC”

The applicant provided changes to TS 2.1 that were associated with application Change No. 1 which documented the changes to the maximum heat load and fuel to be stored in the EOS-37PTH DSC. These TS changes included the addition of new TS tables and TS figures described in the revised TS 2.1.

Staff reviewed the changes to TS 2.1 and determined that the changes to the TS, including the addition of the new figures and tables associated with application Change No. 1, adequately addressed the materials to be stored in the EOS-37PTH DSC. Therefore, the staff determined that the applicant’s changes to TS 2.1 associated with application Change No. 1 are acceptable. The staff’s review of Change No. 1 with respect to principal design criteria evaluation, thermal evaluation, and shielding evaluation associated with this TS change are documented in SER sections 3, 5, and 6, respectively.

8.3.2 Changes to TS 3.1.3, “Time Limit for Completion of DSC Transfer”

The applicant provided changes to TS 3.1.3 that were associated with application Change No. 1 which documented the changes to the maximum heat load and fuel to be stored in the EOS-37PTH DSC. This TS change revised the transfer time limits for the EOS-37PTH DSC.

Staff reviewed the changes to TS 3.1.3 and determined that this change to the Time Limit for Completion of DSC Transfer associated with application Change No. 1 adequately addressed the necessary revision to the transfer times for the EOS-37PTH DSC. Therefore, the staff determined that the applicant’s changes to TS 3.1.3 associated with application Change No. 1 were acceptable. The staff’s review of Change No. 1 with respect to principal design criteria evaluation and thermal evaluation associated with this TS change are documented in SER sections 3 and 5, respectively.

8.3.3 Changes to TS 4.4,” Codes and Standards”

The applicant provided changes to TS 4.4 that were associated with application Change No. 2 regarding the construction of the steel composite HSM (EOS-HSM-SC) components and code alternatives to the HSM concrete and code alternatives for the for EOS-HSM-SC construction. The applicant included tables in the TS that summarized the code requirements and a description of the justification and compensatory measures for the proposed code alternatives.

Staff reviewed the changes to TS 4.4 and determined that the only proposed code alternatives that required a materials evaluation were changes to the concrete codes and standards identified in ACI 349 appendix E, section E.4-Concrete Temperatures, paragraphs E4.1 and E.4.3. The staff's review of the applicant's proposed TS changes for ACI 349 paragraph E4.1 are included in the following section 8.3.3.1 which addresses Additional Scope Change No. 1, the use of blended hydraulic cement. The staff's review of the applicant's proposed TS changes for ACI 349 paragraph E4.3 are documented in SER section 8.3.3.2.

8.3.3.1 Additional Scope Change No. 1: Allow Use of a Blended Portland Cement and TS 4.4 Code Alternative to ACI 349 Paragraph E4.1

ACI 349 paragraph E.4.1 specifies that the concrete temperatures for normal operations shall not exceed 150 °F except for local areas such as around penetrations, which are allowed to have increased temperatures not to exceed 200 °F.

The concrete temperature limit criteria in NUREG-1536, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility" (ML101040620), section 8.4.14.2, "Concrete Temperature Limits," which are applicable to normal and off-normal conditions, specifically calls out the use of ASTM C150 Type II cement. The applicant proposed the alternative to use blended cement per ASTM C595 in lieu of ASTM C150 Type II Portland cement. In its justification, the applicant stated that the cement supplier, as of January 2023, will no longer provide cement in accordance with ASTM C150 because the concrete industry is transitioning to a cement with a smaller carbon footprint that includes 10% limestone. The applicant also stated that ACI 349-06/-13 identifies several ASTM specifications for cement that are acceptable per the code requirements. ASTM C150 and ASTM C595 are two of the acceptable cement specifications identified in section 3.2 of ACI 349-06/-13. In addition, the applicant stated that thermal compatibility tests conducted on concrete mixes using the two cement types show comparable strength results with no signs of degradation due to exposure to elevated temperatures.

The staff reviewed the information provided by the applicant and determined that this proposed code alternative is consistent with a previously approved code alternative applicable to CoC No. 1042, NUHOMS® EOS, Amendment Nos. 1, 2, and 3. The NRC staff's review is documented in ML23277A127. Based on the prior NRC review, the staff determined that the proposed alternative is acceptable.

8.3.3.2 Changes to TS 4.4, ACI 349 Paragraph E4.3 Regarding Concrete Testing

The applicant proposed an alternative to the concrete testing requirements in ACI 349 paragraph E4.3 which are applicable to concrete used at elevated temperatures. Specifically, ACI 349 paragraph E.4.3 requires testing of concrete for temperatures higher than those given in paragraph E.4.1 where the concrete temperature limit is 150 °F except for local areas, such as around penetrations, which are allowed to have increased temperatures not to exceed 200 °F. ACI 349 states that this limit is permitted to be increased to 180 °F for general surface area and 230 °F for local surface area if the tested concrete strength (for example, measured compressive strength at 28 days or more) is equal to or greater than 115% of the specified 28-day compressive design strength.

The applicant cited the concrete temperature limits guidance in NUREG-1536, revision 1, section 8.4.14.2. In addition, the applicant cited the commentary in ACI 349-13 appendix E which states if a reinforced concrete structural member is required to maintain its functional and performance requirements at temperatures in excess of code limits, or at moderately elevated temperatures for extended periods of time, techniques for optimizing the design of structural members to resist these exposures should be investigated. ACI 349 further states that the performance of the concrete materials can be improved by a number of means including to design the concrete mixture for higher strength so that any losses in properties resulting from long-term thermal exposure will still provide adequate design (safety) margins. The applicant stated that the specified compressive strength, which may be tested up to 56 days, is increased to 7,000 pounds per square inch (psi) for HSM fabrication so that any losses in properties (e.g., compressive strength) resulting from long-term thermal exposure will not affect the safety margins based on the specified 5,000 psi compressive strength used in the design calculations. The applicant determined that the safety margin on compressive strength is 40% for a concrete temperature limit of 300 °F during normal and off-normal conditions.

The staff reviewed the applicant's proposed code alternative and determined that the applicant's justification properly incorporated the NRC staff guidance, the recommendations included in the ACI 349 commentary, and were consistent with a previously approved code alternative for NUHOMS® EOS Amendment No. 1 documented in a 2020 NRC staff review (ML20262H086). Therefore, the staff determined that the applicant's proposed alternative to ACI 349 paragraph E3 is acceptable.

### 8.4 Change No. 5: UFSAR Editorial Corrections

The applicant included corrections and edits to the UFSAR for consistency and clarification. These revisions are identified in following UFSAR chapters:

Chapter 1, "General Information"
Chapter 2, "Principal Design Criteria"
Chapter 3, "Structural Evaluation"
Chapter 6, "Shielding Evaluation"
Chapter 8, "Materials Evaluation"
Chapter 12, "Accident Analysis"

The staff reviewed the changes and determined that the edits to these UFSAR sections did not affect any previous conclusions or findings for the materials evaluation. Therefore, the staff determined that the included corrections and edits to the UFSAR for consistency and clarification identified by the applicant are acceptable.

### 8.5 Additional Scope Change No. 6: Use of the MX-LC for the 61BTH Type 2 DSCs

The applicant included revisions to UFSAR appendix B, chapter B.9, "Operating Procedures," and chapter B.12, "Accident Analysis," for use of the MX-LC for the inclusion of the NUHOMS® 61BTH Type 2 DSC in the NUHOMS® EOS dry storage system. Specifically, the applicant revised the following UFSAR sections:

Section B.9.1.6, "DSC Transfer to the HSM-MX"
Section B.9.2.1, "DSC Retrieval from the HSM-MX"
Section B.9.3, "References"
Section B.12.3.1, "OS197 Transfer Cask (TC) Drop"
Section B.12.4, "References"

The staff reviewed the changes and determined that the edits to these UFSAR sections did not affect any previous conclusions or findings for the materials evaluation. Therefore, the staff determined that the included corrections and edits to the UFSAR for consistency and clarification identified by the applicant are acceptable.

The staff's review of these changes with respect to the operating procedures and accident analysis are documented in SER sections 11 and 16, respectively.

### 8.6 Additional Scope Change No. 8: Clarification on Site-Specific Conditions That Could Result in A Reduction in The Maximum Heat Load for Existing HLZCs for EOS-37PTH

The applicant included revisions to TS section 2.1, "Fuel to be Stored in the EOS-37PTH DSC," and UFSAR section 2.2.1, "EOS-37PTH DSC," to clarify the scenarios under which the maximum heat loads can be reduced for EOS-37PTH. The applicant stated that the reason for this change is to address the different site-specific conditions that could result in a reduction in the maximum heat load for existing HLZCs and to also note that new HLZCs could be developed based on the MHLC methodology described in UFSAR section 2.4.3.1.

The staff reviewed and determined that the TS changes are descriptive of the additional scope change and did not affect any previously evaluated functional or operating limits or administrative controls and meet the regulatory requirements in 10 CFR 72.236(a) and (b). Therefore, the staff determined that the TS changes necessary for this additional scope change identified by the applicant are acceptable.

The staff reviewed and determined that the UFSAR changes in these UFSAR sections did not affect any previous conclusions or findings for the materials evaluation. Therefore, the staff determined that the included corrections and edits to the UFSAR for consistency and clarification identified by the applicant are acceptable.

### 8.7 Evaluation Findings

F8.1 The applicant has met the requirements in 10 CFR 72.236(b). The applicant described the materials design criteria for SSCs important to safety in sufficient detail to support a safety finding.

F8.2 The applicant has met the requirements in 10 CFR 72.236(g). The properties of the materials in the storage system design have been demonstrated to support the safe storage of SNF.

F8.3 The applicant has met the requirements in 10 CFR 72.236(h). The materials of the SNF storage container are compatible with their operating environment such that there are no adverse degradation or significant chemical or other reactions.

F8.4 The applicant has met the requirements in 10 CFR 72.236(a) and 10 CFR 72.236(m). SNF specifications have been provided, and adequate consideration has been given to compatibility with retrieval of stored fuel for ultimate disposal.

F8.5 The applicant has met the requirements in 10 CFR 72.234(b). Quality assurance programs and control of special processes are demonstrated to be adequate to ensure that the design, testing, fabrication, and maintenance of materials support SSC intended functions.

The staff concludes that the NUHOMS® EOS dry storage system design adequately considers material properties, environmental degradation and other reactions, fuel clad integrity, content retrievability, and material quality controls such that the design is in compliance with 10 CFR Part 72. The evaluation of these materials considerations provides reasonable assurance that the NUHOMS® EOS dry storage system will allow safe storage of SNF. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

## 9.0 CONFINEMENT EVALUATION

There were no changes to the applicant's confinement section of the UFSAR requested in the amendment application.

## 10.0 RADIATION PROTECTION EVALUATION

The objectives of the radiation protection evaluation are to determine whether the design features and proposed operations meet the following criteria:

1. The radiation protection features with the proposed changes to the DSC design meet the NRC design criteria for protecting the general public and occupational workers from direct radiation.

2. The applicant has proposed engineering features and operating procedures for the DSC that will ensure occupational exposures will remain as low as reasonably achievable (ALARA).

3. The radiation doses to the general public will meet regulatory standards during normal conditions, anticipated operational occurrences, and accidents.

For the CoC No. 1042 Amendment No. 4 application, the applicant provided the estimated occupational exposures to ISFSI personnel during loading, transfer, and storage operations using the EOS-TC108 (time and number of workers may vary depending on individual ISFSI practices) in tables 11-2 and 11-3 for the EOS-37PTH DSC and EOS-89BTH DSC, respectively. Similar operations for the EOS-TC125/135 are provided in tables 11-4 and 11-5 of the UFSAR. These tables include task times, number of personnel required, and total doses. The total exposure results are as follows:

- EOS-TC125/135 with EOS-37PTH DSC: 5,393 person-mrem (5.4 person-rem)
- EOS-TC125 with EOS-89BTH DSC: 6,980 person-mrem (~7.0 person-rem)

The applicant states that for equivalent sources, the EOS-TC108 results in larger exposures than the EOS-TC125/135 because it is a lighter cask and provides less shielding. The exposure due to a crane hang-up off-normal event is also considered. The additional dose due to a crane hang-up event is provided in the footnotes of tables 11-2 through 11-5 of the UFSAR.

The applicant also states that the EOS-TC125/135 may utilize an optional aluminum top cover plate that is exchanged for a steel top cover plate after down ending. For the EOS-TC135, this option is applicable only to the EOS-TC135 with the EOS-37PTH DSC. If the aluminum top cover plate option is used, the total exposure will increase by approximately 220 person-mrem and 130 person-mrem for the EOS-37PTH DSC and EOS-89BTH DSC, respectively. Use of a minimum 74.0-inch diameter shield plug for the EOS-37PTH DSC when transferred in the EOS-TC108 results in a negligible increase in occupational exposure (< 5%). The effect of the 74.0-inch diameter shield plug is included in the EOS-TC125/135 exposures provided in table 11-4 of the UFSAR.

The staff found the estimated occupational exposures to ISFSI personnel acceptable based on the facts that the exposures provided by the applicant above are bounding estimates. Measured exposures from typical NUHOMS® System loading campaigns have been 0.6 person-rem or lower per canister for normal operations, and exposures for the NUHOMS® EOS System are expected to be similar. Measured occupational exposure data for three EOS-HSM loading campaigns using the EOS-37PTH DSC are provided in table 11-5a of the UFSAR. The average measured occupational exposures range from 0.16 person-rem to 0.75 person-rem and are significantly lower than the computed value of 5.4 person-rem.

In terms of hypothetical accident conditions, per 10 CFR 72.106, the exposure to an individual at the site boundary due to an accident is limited to 5 rem. The computed average EOS-HSM roof dose rates and surface fluxes in an accident are provided in UFSAR chapter 6, tables 6-56 through 6-58 for the EOS-89BTH DSC and tables 6-58a through 6-58c for the EOS-37PTH DSC. Under accident conditions, the roof dose rate for the EOS-89BTH DSC is larger than the roof dose rate for the EOS-37PTH DSC (18,800 mrem/hr vs. 12,400 mrem/hr). Therefore, accident dose rates are reported only for the EOS-89BTH DSC.

The bounding dose rate as a function of distance from a 2x10 back-to-back array of EOS-HSMs for the accident configuration described above is shown in Table 11-10. These dose rates are calculated assuming that the outlet vent covers and wind deflectors (if required) for the entire array are lost.

The total annual exposure estimates are based on 100% occupancy for 365 days. At large distances, the annual exposure from the 2x10 back-to-back array is similar to the two 1x10 front-to-front array (two rows of 1x10 array) configurations. Per 10 CFR 72.104, the annual whole-body dose to an individual at the site boundary is limited to 25 mrem. Based on the data shown in table 11-6, the offsite dose rate drops below 25 mrem at a distance of approximately 450 m from the ISFSI.

The applicant used MCNP code inputs for a 2x10 ISFSI accident configuration using the same method as described for the normal condition models. At a distance of 200 m and 450 m from the ISFSI, the accident dose rate is approximately 2.6 mrem/hr and 0.1 mrem/hr, respectively. It is assumed that the recovery time for this accident is five days (120 hours). Therefore, the total exposures to an individual at a distance of 200 m and 450 m are 312 mrem and 12 mrem respectively. This is significantly less than the 10 CFR 72.106 limit of 5 rem.

The staff reviewed the operating procedures, the estimated time for completing each step of the operation, and the estimated dose for loading and unloading an EOS-89BTH DSC loaded with authorized contents and provided the results in tables 11-4 and 11-5 of the UFSAR, “Occupational Exposure, EOS-TC125/135 with EOS-89BTH DSC and EOS-TC125/135 with EOS-37PTH DSC.” A crane hang-up off-normal event adds 976 person-mrem. Contact doses for the EOS-HSM are designed to be ALARA.

The staff reviewed the revised dose estimates for completing these operations and determined that the applicant has adequately calculated the expected dose for completing the necessary operating procedures.

The staff reviewed the updated radiation protection evaluation for the EOS dry cask spent fuel storage system with these requested changes. The staff finds that the applicant has provided an adequate estimate of the occupational doses rates in table 11-1 of the UFSAR for the system operations and the staff finds the estimated dose to be appropriate. The radiation protection evaluation outlined in the UFSAR includes cautions and reminders of the use of optional supplemental shielding, when practical, to further reduce the operator's exposure to radiation. Based on its review, the staff has reasonable assurance that the design and operating procedures of the EOS-HSM DSS provide acceptable means for controlling and limiting occupational radiation exposures within the limits given in 10 CFR Part 20 and for meeting the ALARA objective with respect to exposures, consistent with 10 CFR 20.1101(b). The EOS-HSM DSS is adequately designed to facilitate decontamination in accordance with 10 CFR 72.236(i) and includes, to the extent practical and appropriate, adequate features, operating procedures, and controls that are designed to assist a general licensee to meet the radiological protection criteria in 10 CFR 72.126(a) and 10 CFR 72.126(d).

### 10.1 Evaluation Findings

F10.1 The TC and storage module of the EOS-HSM DSS consist of neutron shields and gamma shields to provide sufficient shielding for protecting the general public and occupational workers and meets the requirements of 10 CFR 72.236(d).

## 11.0 OPERATING PROCEDURES EVALUATION

The staff reviewed the information provided by the applicant and the following changes are applicable to the operating procedures evaluation:

**Change No. 1:**
Incorporate a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 and stored in the EOS-HSM. Two new HLZCs are applicable to this MHLC.

**Change No. 2:**
Introduce a steel-plate composite option for the EOS HSM.

**Change No. 4:**
TS changes for consistency among DSC types and terminology clarification.

**Change No. 5:**
Various UFSAR editorial corrections for consistency and clarification.

**Additional Scope Change No. 1:**
An additional scope item has been added to allow use of a blended Portland cement that would be certified to the requirements of ASTM C595.

**Additional Scope Change No. 6:**
An additional scope item has been added with respect to the use of the MX-LC for the 61BTH Type 2 DSCs.

## 11.1 Change No. 1: Incorporate a Method to Determine New Loading Patterns Based on the Maximum Allowable Heat Load per DSC to EOS-37PTH

The EOS-37PTH DSC, incorporates a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 TC and stored in the EOS-HSM. Two new HLZCs are applicable to this MHLC. In support of Change No. 1, a change was made to UFSAR chapter 9 that added planned DSC heat load zone configurations per figure 2-3a, 3b, and 3d through 3m in UFSAR chapter 2. There were no changes in the assembly and operational verification of the air circulation system within 7 days prior to initiating transfer operations per TS LCO 3.1.3 (similar to previously noted in figures 2-2a, 2b, and 2d through 2f). The change is in support of the staff's review of the applicant's materials evaluation associated with Change No. 1 in section 8.1 of this SER. In support of Change No. 1, no changes were made to UFSAR chapter 9.0.

## 11.2 Change No. 2: Introduce a Steel-Plate Composite Option for the EOS HSM

The applicant stated that the steel-plate composite option allows for the HSM components to be constructed from concrete-filled integrated steel wall forms. The applicant referred to this design option as the steel composite EOS-HSM or EOS-HSM-SC. The applicant used EOS-HSM-RC to distinguish the previously approved reinforced concrete from the EOS-HSM-SC included in the EOS Amendment No. 4 application.

The staff determined that the corrosion allowance for the EOS-HSM-SC and the EOS-DSC FPS are sufficient for at least 60 years of operation. Therefore, the staff determined that the coating specifications and corrosion allowance for the EOS-HSM-SC and the EOS-DSC FPS are acceptable. The change is in support of the staff's review of the applicant's materials evaluation associated with Change No. 2 in section 8.2 of this SER. In support of Change No. 2, no changes were made to UFSAR chapter 9.0.

## 11.3 Change No. 4: TS Changes for Consistency Among DSC Types and Terminology Clarification

With respect to TS changes for consistency among DSC types and terminology clarification, staff noted improvements to the quality and consistency of the TS. No changes were made to UFSAR chapter 9.0

The applicant provided updated TS to support the amendment request with minor changes to the terminology for consistency. These changes included minor edits to the following TS sections:

2.1, "Fuel to be Stored in the EOS-37PTH DSC"
2.2, "Fuel to be Stored in the EOS-89BTH DSC"
2.3, "Fuel to be stored in the 61BTH Type 2 DSC"
5.1.3.2, "HSM-MX Thermal Monitoring Program"
5.3, "Concrete Testing"

The staff reviewed the TS changes for consistency among DSC types and terminology clarification and determined that the edits to these TS sections did not affect any previous conclusions or findings for the operating procedures evaluation. This is consistent with the staff's review of the applicant's materials evaluation associated with Change No. 4 in section 8.3 where the staff determined that the TS changes for consistency among DSC types and terminology identified by the applicant are acceptable. Staff noted that no changes were made to UFSAR chapter 9.0.

## 11.4 Change No. 5: Various UFSAR Editorial Corrections for Consistency and Clarification

The applicant included corrections and edits to the UFSAR for consistency and clarification. These revisions are identified in following UFSAR Chapters:

Chapter 1, "General Information"
Chapter 2, "Principal Design Criteria"
Chapter 3, "Structural Evaluation"
Chapter 6, "Shielding Evaluation"
Chapter 8, "Materials Evaluation"
Chapter 12, "Accident Analysis"

The staff reviewed the changes and determined that the edits to these UFSAR sections did not affect any previous conclusions or findings for the operating procedures evaluation. This is consistent with the staff's review of the applicant's materials evaluation associated with Change No. 5 in section 8.4 of this SER where the staff determined that the included corrections and edits to the UFSAR for consistency and clarification identified by the applicant are acceptable. Staff noted that no changes were made to UFSAR chapter 9.0.

## 11.5 Additional Scope Change No. 1: Allow Use of a Blended Portland Cement

The applicant introduces use of a blended Portland cement that would be certified to the requirements of ASTM C595. The reason for this change is that the cement supplier will no longer provide cement in accordance with ASTM C150 since the supplier is transitioning to a cement with a smaller carbon footprint that includes 10% limestone. This change supports continued EOS HSM and EOS HSM-MX fabrication activities. In support of this additional scope, changes have been made to UFSAR sections 8.2.1.3, EOS HSM Horizontal Storage Module; 8.7, References; A.8.2.1.3, HSM-MX Horizontal Storage Module; and A.8.7, References. This is consistent with the changes, as well as the staff's review of the applicant's structural evaluation associated with Additional Scope Change No. 1 in section 8.3.3.1 of this SER. The staff reviewed the information provided by the applicant and found that the changes are acceptable.

Although this change for Amendment No. 4 was submitted on March 30, 2023 (ML23089A175), the change was initially submitted as an additional code alternative to ACI 349-06, appendix E, section E.4, "Concrete Temperatures," specifically for Amendment Nos. 1, 2, and 3. The code alternative application was submitted on August 23, 2023 (ML23235A066), and the NRC approved it on October 24, 2023 (ML23277A127).

## 11.6 Additional Scope Change No. 6: Use of the MX-LC for the 61BTH Type 2 DSCs

The applicant introduces the use of the MX-LC for the 61BTH Type 2 DSCs. The reason for this change is that, in Amendment No. 3, TN addressed detail to demonstrate the single failure proof capability of the MX-LC. That information was provided to demonstrate compliance with CoC No. 1042 Amendment No. 3 Condition 5 for lifts of the DSC and TC above heights not analyzed for an accidental drop, and to comply with CoC No. 1042 Amendment No. 3 TS 5.2.1 for TC/DSC lifting height limits. However, TN omitted addressing use of the MX-LC for the 61BTH DSCs. This change supports the continued use of the HSM-MX in conjunction with the MX-LC for 61BTH DSCs. In support of this additional scope, changes have been made to UFSAR sections B.9.1.6, DSC Transfer to the HSM-MX; and B.9.2.1, DSC Retrieval from the HSM-MX. The operating procedures for the NUHOMS® 61BTH Type 2 DSC and the OS197 TC are provided in UFSAR chapter B.9. The staff reviewed the information provided by the applicant and found that the changes are acceptable.

## 11.7 Evaluation Findings

The staff concludes that the operating procedures evaluation for the NUHOMS® EOS system is in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of description of operations provides reasonable assurance that the NUHOMS® EOS system will allow safe storage of spent fuel. This finding is reached based on a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices. The key finding from the staff's review of Amendment No. 4 includes:

F11.1 The NUHOMS® EOS system is compatible with dry loading and unloading in compliance with 10 CFR 72.236(h). General procedure descriptions for these operations are summarized in chapter 8 of the applicant's UFSAR. Detailed procedures will need to be developed and evaluated on a site-specific basis.

## 12.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM EVALUATION

The staff's objective in reviewing the acceptance tests and maintenance program is to ensure that the NUHOMS® EOS SSCs are fabricated and maintained in accordance with the design described in the UFSAR. The staff reviewed and evaluated the information provided by the applicant and determined that the following changes are applicable to the acceptance tests and maintenance program evaluation:

**Change No. 1:**
For the EOS-37PTH DSC, incorporate a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 TC and stored in the EOS-HSM.

**Change No. 2:**
Introduce a steel-plate composite option for the EOS-HSM. The steel-plate composite option allows for the HSM components to be constructed from concrete-filled integrated steel wall forms.

The NRC staff reviewed the changes to the UFSAR, CoC and TSs associated with the CoC No. 1042 NUHOMS® EOS Amendment No. 4 application. The staff's review was conducted using the guidance in chapter 12 of NUREG-2215 to determine whether the NUHOMS® EOS SSCs will be designed, fabricated tested and maintained such that the ITS functions of the system are assured under normal, off-normal, and accident-level conditions.

## 12.1 EOS-37PTH Maximum Allowable Heat Load Configuration

The applicant stated that this change was similar to the EOS-89BTH concept submitted under Amendment No. 3 and incorporated a method to determine new loading patterns based on the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 and stored in the EOS-HSM. The applicant described two new HLZCs that are applicable to this MHLC.

In the UFSAR chapter 1, “General Information,” the applicant stated that the 4HA basket type is a subset of the 4H basket where the aluminum basket plates are anodized. This anodizing is required when HLZCs with decay heats greater than 3.5 kW are stored in the basket. In UFSAR chapter 10, “Acceptance Tests and Maintenance Program,” the applicant provided acceptance criteria for the anodized coating necessary to load fuel assemblies with decay heats greater than 3.5 kW.

The staff reviewed the applicant’s anodized coating specifications and determined that the specifications are appropriate for a coating designed to enhance heat transfer. In addition, the staff reviewed the applicant’s verification methodology for the anodized coating specifications and determined that the codes and standards cited are appropriate for verifying the anodized coating properties. Therefore, the staff determined that the applicant’s anodized coating specifications and verification testing methodology are acceptable.

## 12.2 New Steel-Plate Composite Option for the EOS-HSM

The applicant stated that the steel-plate composite option allows for the HSM components to be constructed from concrete-filled integrated steel wall forms. The applicant referred to this design option as the steel composite EOS-HSM or EOS-HSM-SC. The applicant used EOS-HSM-RC to distinguish the previously approved reinforced concrete from the EOS-HSM-SC included in the EOS Amendment No. 4 application.

In UFSAR section 10.1, “Acceptance Tests,” the applicant stated that for the EOS-HSM-SC, the minimum concrete compressive strength is 5,000 psi and testing of the specimens are to be performed at a temperature of 500 °F. The applicant stated that the HSM concrete is tested in accordance with ASTM C138 to verify a minimum density of 139 pcf for the EOS-HSM-SC. The applicant also stated in UFSAR section 10.1.1.2 that the concrete construction, placement and testing are performed in accordance with ACI 318. In UFSAR section 10.1.3.2, the applicant stated that the EOS-HSM-SC is inspected in accordance with ANSI/AISC N690 with alternatives identified in the TS.
The applicant stated that the EOS-HSM-SC faceplate, studs, and tie bar materials are procured as ASTM materials and are tested for their mechanical properties in accordance with their respective specifications. Weld procedures and welders for the faceplates, studs, and tie bars for the EOS-HSM-SC, and the DSC support structure for all EOS-HSMs are qualified in accordance with ASME code section IX or AWS D1.1. The shielding capability of the faceplates of the EOS-HSM-SC is verified by its material certifications and dimensional inspections and no further testing is required.

In UFSAR section 10.3.2, “HSM Repair, Replacement, and Maintenance,” the applicant stated that examples of typical exterior surface repairs for the EOS-HSM-SC include:

- Coating scratching or damage - Evaluate extent of damage and determine if coating repair is required. Coat affected area with coating or sealant to mitigate rusting or additional coating damage.

The applicant stated that the steel faceplate is much less susceptible to environmental conditions than the reinforced concrete, and a corrosion allowance, as accounted for in UFSAR section 3.9.8, provides significant margin for any defects that may occur over the lifetime of the EOS-HSM-SC.

The staff reviewed the information provided by the applicant for the acceptance tests and maintenance program for the EOS-HSM-SC and determined that the program is acceptable because the applicant has (1) specified appropriate values for the EOS-HSM-SC concrete density, test temperature specifications, and testing methods; (2) identified material specifications for the steel components of the EOS-HSM-SC that include material property specifications; (3) identified the codes employed for the construction and inspection of the SC components of the EOS-HSM-SC; and (4) identified repair methods for the metal components of the EOS-HSM-SC. Therefore, the staff determined that the acceptance tests and maintenance program provided by the applicant are acceptable.

### 12.3 Evaluation Findings

F12.1 SSCs important to safety will be designed, fabricated, erected, tested, and maintained to quality standards commensurate with the importance to safety of the function(s) they are intended to perform.

F12.2 The applicant or licensee, as appropriate, will examine and test, as needed, the NUMOMS® EOS DSS SSCs and features to ensure they do not exhibit any defects that could significantly reduce their confinement effectiveness.

The staff concludes that the acceptance tests and maintenance programs for the NUHOMS® EOS DSS are in compliance with 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The evaluation of the conduct of operations program provides reasonable assurance that the DSS will allow for the safe storage of SNF throughout its licensed or certified period of storage. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

## 13.0 WASTE MANAGEMENT EVALUATION

This section is not applicable to CoC evaluations.

## 14.0 DECOMMISSIONING EVALUATION

This section is not applicable to CoC evaluations.

## 15.0 QUALITY ASSURANCE EVALUATION

There were no changes to the applicant's quality assurance program requested in the amendment application.

## 16.0 ACCIDENT ANALYSIS EVALUATION

The applicant provided a revised accident analysis for the NUHOMS® EOS system in UFSAR chapter 12. The staff reviewed the information provided by the applicant and found the following changes in the application are applicable to the accident analysis evaluation:

**Change No. 2:**
Introduce a steel-plate composite option for the EOS-HSM: the EOS-HSM-SC. The steel-plate composite option allows for the HSM components to be constructed from concrete-filled integrated steel wall forms.

**Change No. 5:**
Various updated UFSAR editorial corrections for consistency and clarification.

**Additional Scope Change No. 6:**
This change supports the continued use of the HSM-MX in conjunction with the MX-LC for 61BTH Type 2 DSCs

### 16.1 Change No. 2: Introduce a Steel-Plate Composite Option, EOS-HSM-SC

The applicant made editorial changes to the following UFSAR sections to address the addition of the EOS-HSM-SC design: 12.3.2, 12.3.3, and 12.3.7. In section 12.3.2, “Earthquake,” the applicant added the modal frequencies and corresponding orthogonal seismic accelerations determined for the designs of both the EOS-HSM-SC exterior structure and DSC FPS internal structure, and updated the table of ITS components to refer to appendix 3.9.8 for the EOS-HSM-SC. Similarly, in UFSAR section 12.3.3, “Tornado Wind and Tornado Missiles Effect on EOS-HSM,” the applicant updated the “Accident” section to refer to UFSAR appendix 3.9.8 section 3.9.8.10.6, which addresses the tornado wind and missile evaluations for the EOS-HSM-SC. The applicant updated UFSAR section 12.3.7, “Lightning,” to state that the EOS-HSM-SC faceplates receive the current discharge from lightning strikes.

For each accident condition, the applicant evaluated the dose consequences and, if applicable, provided a description of the corrective actions. The applicant’s evaluation determined that there were no dose consequences, and no corrective actions required for the earthquake and lightning strike evaluation.

For the tornado wind and tornado missiles evaluation, the applicant corrected the analysis as described in Change No. 5 below. The applicant determined that the dose consequences were unchanged and no changes to the corrective actions were necessary.

The staff reviewed the changes to the UFSAR accident analysis chapter associated with the addition of the EOS-HSM-SC design. The staff determined that the accident analyses provided by the applicant were acceptable because the applicant considered a reasonable time for corrective actions to be implemented, when necessary, and showed that the accident dose rate for an individual at the site boundary was well below the regulatory limit.

### 16.2 Change No. 5: Editorial Corrections in UFSAR for Consistency and Clarification

The applicant revised the reported dose rate on the HSM roof for a tornado and tornado missile accident to be consistent with the existing analysis in the USFAR chapter 6, “Shielding Evaluation,” and chapter 11, “Radiation Protection.” The applicant did not alter the analysis of the damage and stated that the tornado wind and tornado missiles do not breach the EOS-HSM such that the DSC confinement boundary is compromised but localized scabbing of the end shield wall of an EOS-HSM array may be possible. The EOS-HSM outlet vent covers, and wind deflectors (if required) may be lost due to a tornado or tornado missile event, therefore, only the dose rates on the roof are affected, and the front, rear, and side dose rates remain the same. The applicant assumed that the recovery time for this accident is five days (120 hours). Therefore, the total exposure to an individual at distances of 200 m and 450 m is 312 mrem and 12 mrem, respectively. The applicant stated that both values are significantly less than the 10 CFR 72.106 limit of 5 rem. The applicant provided a description of the corrective actions which include removal of debris, inspection of the HSM for damage and repair of the HSM.

The staff reviewed the tornado missile accident analysis provided by the applicant. The staff determined that the applicant's analyses were acceptable because they are consistent with the analysis previously submitted and approved in Amendment No. 3 and described in USFAR chapter 6, "Shielding Evaluation," and chapter 11,"Radiation Protection." The staff confirmed that the applicant considered a reasonable time for corrective actions to be implemented and showed that the accident dose rate for an individual at the site boundary was well below the regulatory limit in 10 CFR 72.106.

### 16.3 Additional Scope Change No. 6: Continued Use of the HSM-MX in Conjunction with the MX-LC for 61BTH Type 2 DSCs

The applicant provided revisions to UFSAR section B.12 to address using the MX-LC to assist in loading the DSC into the HSM. The applicant stated that the MX-LC is designed, fabricated, installed, tested, inspected, and qualified in accordance with the applicable portions of ASME NOG-1 as a Type I gantry type of crane, per the guidance provided in NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants: Resolution of Generic Technical Activity A-36" (ML070250180). The applicant stated that for CoC No. 1042 Amendment No. 3, the applicant inadvertently omitted addressing use of the MX-LC for the 61BTH DSCs. The applicant added additional information to UFSAR section B.12 to describe administrative controls for lifting operations. Specifically, the applicant stated that ASME NOG-1 prohibits the use of a Type I gantry crane under extreme weather conditions (i.e., tornado wind and missile conditions, and high winds), and imposes administrative controls to place the crane in a secured position in advance of impending extreme weather conditions involving wind gusts that are expected to exceed the operating wind limit of the ISFSI equipment. The applicant stated that this change supports the continued use of the HSM-MX horizontal storage module in conjunction with the MX-LC for 61BTH DSCs.

The staff reviewed the changes to the UFSAR provided in the application as well as the applicant's justification for the change to UFSAR section B.12. The staff determined that the changes to the UFSAR section B.12 for the use of the MX-LC with the 61BTH DSC are consistent with similar changes made to UFSAR section A.12 for movement of either an EOS-37PTH or EOS-89BTH DSC and approved in EOS Amendment No. 3. Therefore, the staff determined that the changes in UFSAR section B.12 that describe the administrative controls for lifting operations using the MX-LC with the 61BTH DSC are acceptable.

### 16.4 Evaluation Findings

The staff reviewed the applicant's revised accident analysis conditions for the proposed amendment application. The staff determined that the applicant's analyses of postulated accidents are acceptable because the applicant considered a reasonable time for corrective actions and showed that the consequences of accident conditions are below the regulatory dose limits of 10 CFR 72.106. Findings from the staff's review of Amendment No. 4 include:

F16.1 The analyses of off-normal and accident events and conditions and reasonable combinations of these and normal conditions show that the design of the DSS will acceptably meet the requirements in 10 CFR 72.236(d) regarding criteria for radiological protection.

## 17.0 CONDITIONS OF CASK USE - TECHNICAL SPECIFICATIONS

The staff reviewed the proposed amendment to determine that applicable changes made to the conditions in the CoC and to the TS for CoC No. 1042, Amendment No. 4, would be in accordance with the requirements of 10 CFR Part 72. The staff reviewed the proposed changes to confirm that the changes were properly evaluated and supported in the applicant's revised UFSAR. These modifications were found acceptable based on the staff's findings for the structural, thermal, shielding, criticality, materials, operating procedures, acceptance test and maintenance program, radiation protection, and accident analysis evaluation sections of this SER.

The staff finds that the proposed changes to the TS for the NUHOMS® EOS system conform to the changes requested in the amendment application and do not affect the ability of the cask system to meet the requirements of 10 CFR Part 72. The proposed changes provide reasonable assurance that the NUHOMS® EOS system will continue to allow safe storage of spent nuclear fuel.

## 18.0 CONCLUSIONS

The staff has performed a comprehensive review of the amendment application, during which the following requested changes to the NUHOMS® EOS system were considered:

**Change No. 1:**
Incorporate a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the MHLC. The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 and stored in the EOS-HSM. Two new HLZCs are applicable to this MHLC.

**Change No. 2:**
Introduce a steel-plate composite option for the EOS HSM.

**Change No. 3:**
Introduce the use of MAVRIC software for a confirmatory run of the HSM-MX dose rates.

**Change No. 4:**
TS changes for consistency among DSC types and terminology clarification.

**Change No. 5:**
Various UFSAR editorial corrections for consistency and clarification.

**Change No. 6:**
Add measured exposures from past loading campaigns to highlight that measured exposures are significantly less than calculated exposures.

**Additional Scope Change No. 1:**
Add an additional scope item to allow use of a blended Portland cement that would be certified to the requirements of ASTM C595.

**Additional Scope Change No. 6:**
Add an additional scope item related to the use of the MX-LC for the 61BTH Type 2 DSCs.

**Additional Scope Change No. 8:**
Add an additional scope item to clarify the scenarios under which the maximum heat loads can be reduced for EOS-37PTH.

Based on the statements and representations provided by the applicant in its amendment application, as supplemented, the staff concludes that the changes described above to the NUHOMS® EOS system do not affect the ability of the cask system to meet the requirements of 10 CFR Part 72. Therefore, Amendment No. 4 to CoC No. 1042 for the NUHOMS® EOS system should be approved.

Issued with Certificate of Compliance No. 1042, Amendment No. 4
on September 3, 2025.