PRELIMINARY SAFETY EVALUATION REPORT

Docket No. 72-1040
HI-STORM UMAX Canister Storage System
Holtec International, Inc.
Certificate of Compliance No. 1040

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1 SUMMARY

By letter dated June 29, 2012, as supplemented July 16, November 20, 2012, and January 30, April 2, April 19, June 21, August 28, December 6, December 31, 2013, and January 13, and 28, 2014, Holtec International (Holtec) submitted an application to the U.S. Nuclear Regulatory Commission (NRC) for the HI-STORM UMAX Canister Storage System, Certificate of Compliance (CoC) No. 1040. The proposed application intends to provide an underground storage option compatible with the Holtec HI-STORM Flood/Wind (FW) System.

This safety evaluation report (SER) documents the review and evaluation of the proposed application. The SER uses the same section-level format provided in NUREG-1536, Revision 1, "Standard Review Plan for Dry Cask Storage Systems," with some differences implemented for clarity and consistency.

The staff's assessment is based on whether Holtec meets the applicable requirements of 10 CFR Part 72 for independent storage of spent fuel and of 10 CFR Part 20 for radiation protection.

1.1 General Description

The objective of the review of the general description of the HI-STORM UMAX Canister Storage System is to ensure that Holtec has provided a description that is adequate to familiarize reviewers and other interested parties with the pertinent features of the system.

1.2 HI-STORM UMAX CANISTER STORAGE System General Description and Operational Features

The HI-STORM (acronym for Holtec International Storage Module) UMAX Canister Storage System is a spent nuclear fuel storage system designed to be in full compliance with the requirements of 10 CFR Part 72. The model designation "UMAX" denotes underground – maximum capacity. The proposed application intends to provide an underground storage option compatible with the Holtec HI-STORM Flood/Wind (FW) System as describe in the HI-STORM FW Final Safety Analysis Report (FSAR). The underground structure system is described in the HI-STORM UMAX Canister Storage System FSAR. Unless designated otherwise in this SER the term "FSAR" denotes the HI-STORM UMAX Canister Storage System FSAR.

The HI-STORM UMAX Canister Storage System stores a hermetically sealed canister containing spent nuclear fuel (SNF) in an in-ground vertical ventilated module (VVM). The HI-STORM UMAX Canister Storage System is designed to provide long-term underground storage of loaded multi-purpose canisters (MPC) previously certified for storage in CoC No. 1032. The HI-STORM UMAX VVM is the underground equivalent of the HI-STORM FW overpack. Although the storage cavity dimensions and the air ventilation system in the HI-STORM UMAX VVM have been selected to enable it to also store all MPCs certified in for storage in the HI-STORM 100 overpack, the proposed CoC No. 1040 does not seek to support their certification at this time. Safety analyses and evaluations of the HI-STORM 100 MPCs under storage in HI-STORM UMAX are nevertheless included in HI-STORM UMAX FSAR, as appropriate, to provide a comparative reference for the licensing-basis analyses of the HI-STORM FW canisters (MPC-37 & MPC-89).

The HI-STORM UMAX Canister Storage System can store either PWR or BWR fuel assemblies, in the MPC-37 or MPC-89, respectively. The MPC is identified by the maximum number of fuel assemblies it can contain in the fuel basket. The MPC external diameters are identical to allow the use of a single overpack design, however the height of the MPC, as well as the overpack and transfer cask, are variable based on the SNF to be loaded.

The HI-STORM UMAX Canister Storage System is autonomous in-as-much as it provides SNF and radioactive material confinement, radiation shielding, criticality control and passive heat removal independent of any other facility, structures, or components at the site. The surveillance and maintenance required by staff is minimized by the HI-STORM UMAX Canister Storage System since it is completely passive and is composed of proven materials. The HI-STORM UMAX Canister Storage System can be used either singly or as an array at an independent spent fuel storage installation (ISFSI). The site for an ISFSI can be located either at a nuclear reactor facility or an away-from a- reactor location.

2 PRINCIPAL DESIGN CRITERIA EVALUATION

The objective of evaluating 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.

2.1 Structures, Systems and Components Important to Safety

HI-STORM UMAX Canister Storage System SSCs important to safety are identified in Chapter 2 of the HI-STORM UMAX Canister Storage System and the HI-STORM FW System FSARs. The safety classifications are based on the guidance in U.S. Nuclear Regulatory Commission, “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” NUREG/CR-6407, INEL-95/0551, February 1996.

2.2 Design Basis for Structures, Systems and Components Important to Safety

The HI-STORM UMAX Canister Storage System design criteria summary includes the allowed range of spent fuel configurations and characteristics, the enveloping conditions of use, and the bounding site characteristics.

2.2.1 Spent Fuel Specifications

The HI-STORM UMAX Canister Storage System is designed to store up to either 37 PWR fuel assemblies or up to 89 BWR fuel assemblies. Detailed specifications for the approved fuel assemblies are provided in the HI-STORM FW FSAR Section 2.1. These include the maximum enrichment, maximum decay heat, maximum fuel assembly average burnup, minimum cooling time, maximum initial uranium mass, and detailed physical fuel assembly parameters. The limiting fuel specifications are based on the fuel parameters considered in the structural, thermal, shielding, criticality and confinement analyses.

2.2.2 External Conditions

The HI-STORM UMAX Canister Storage System FSAR Section 2.2 identifies the bounding site environmental conditions and natural phenomena for which the HI-STORM FW system is analyzed.

2.3 Design Criteria for Safety Protection Systems

The principal design criteria for the HI-STORM UMAX Canister Storage System are identified in the HI-STORM UMAX Canister Storage System and HI-STORM FW System FSARs, Chapter 2.

2.3.1 Decommissioning

The decommissioning considerations of the HI-STORM UMAX Canister Storage System are provided in FSAR Section 2.09.

2.4 Evaluation Findings

Based on the NRC staff's review of information provided in the HI-STORM UMAX Canister Storage System application, the staff finds the following:

F2.1 The staff concludes that the principal design criteria for the HI-STORM UMAX Canister Storage System are acceptable with regard to demonstrating compliance with the regulatory requirements of 10 CFR Part 72. This finding is based on a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices. More detailed evaluations of design criteria and assessments of compliance with those criteria are presented in SER Sections 3 through 8.

3 STRUCTURAL EVALUATION

3.1 Overview

In this portion of the dry storage system (DSS) review, the NRC evaluates aspects of the DSS design and analysis related to structural performance under normal and off-normal operations, accident conditions, and natural phenomena events. In conducting this evaluation, the NRC staff seeks a high degree of assurance that the cask system will maintain confinement, subcriticality, radiation shielding, and retrievability or recovery of the fuel, as applicable, under all credible loads for normal and off-normal conditions accidents, and natural phenomenon events.

The objective of the structural review was to assess the safety analysis of the structural design features, the structural design criteria, and the structural analysis and evaluation criteria used to confirm the structural performance of the HI-STORM UMAX Canister Storage System under normal operations, off-normal operations, accident conditions and natural phenomena events for those ITS SSCs.

The review was conducted utilizing applicable regulations in 10 CFR 72.124 (a), 72.234 (a) and (b), 72.236 (b), (c), (d), (g), (h), and (l) that identify the specific requirements for spent fuel storage cask approval and fabrication.

3.2 Structural Design

3.2.1 Overview

The HI-STORM UMAX Canister Storage System has three major components: MPC-37 and MPC-89, the HI-TRAC VW transfer cask, and the HI-STORM UMAX VVM. The MPCs and the HI-TRAC components used in the HI-STORM UMAX Canister Storage System are identical to those reviewed and approved in the HI-STORM FW System, CoC No. 72-1032. No other approvals were sought for MPC variants for this licensing action.

The structural sub-components of the HI-STORM UMAX VVM include the following items: the steel and concrete closure lid, the steel cavity enclosure container (CEC) shell, the independent spent fuel storage installation (ISFSI) pad, the support foundation pad (SFP), the subgrade, the under-grade, and optional enclosure wall.

All components classified as ITS are designated on the licensing drawings in FSAR section 1.5 of the FSAR.

3.2.1.1 VVM Components and ISFSI Structure

The HI-STORM UMAX VVM serves as a missile and radiation barrier, provides flow paths for natural convection, and provides kinematic stability to the system. The VVM is not a pressure vessel since it is open to the environment. Each subcomponent is summarized below:

CEC – A thick walled open top shell welded to a bottom base plate that defines the storage cavity for the MPCs. The CEC rests on the SFP and is surrounded laterally by an engineered fill or a self-hardening engineered subgrade.

Closure Lid - A steel structure filled with plain concrete that is designed to protect the VVM from the impact of the design basis missiles as well as provide an inlet and outlet for air flow.

ISFSI Pad - A reinforced concrete slab that surrounds the upper portion of the CEC and extends to the underside of the CEC Flange. The ISFSI pad provides robust support for a loaded transporter and to enable rainwater to flow away from the storage array.

SFP - A reinforced concrete provides below grade support to the CEC for loadings due to seismic events and long term settlement.

Subgrade and Under-grade - The soil between the SFP and the ISFSI pad and lateral to the CECs which is replaced with a self-hardening engineered subgrade (SES) is the subgrade. The undisturbed soil in the space below the SFP is referred to as the under-grade.

Enclosure Wall (optional) - The Enclosure Wall was designed to provide a barrier to the engineered fill beneath the ISFSI pad such that each VVM array would be distinct from surrounding soil or other VVM arrays. Another function of the Enclosure Wall is to provide a means of preventing water intrusion beneath the ISFSI pad.

3.2.1.2 Multi-Purpose Canisters

The HI-STORM UMAX system utilizes two MPCs as confinement vessels: the MPC-37 for pressurized water reactor (PWR) fuel and the MPC-89 for boiling water reactor (BWR) fuel. These MPCs have been previously reviewed and approved for storage (CoC No. 1032) and all relevant evaluations are presented in the HI-STORM FW FSAR. Only relevant information necessary to evaluate the interaction between the HI-STORM UMAX VVM and the MPCs was presented in the HI-STORM Canister Storage System application.

3.2.1.3 Transfer cask (HI-TRAC VW)

The HI-STORM UMAX Canister Storage System utilizes the HI-TRAC VW transfer cask to provide a missile and radiation barrier during transport of the MPCs from the fuel pool to the HI-STORM UMAX VVM. The HI-TRAC VW has been previously reviewed and approved for storage (CoC No. 1032) activities and all relevant evaluations are presented in the HI-STORM FW FSAR. Only relevant information necessary to evaluate the interaction between the HI-STORM UMAX VVM and the HI-TRAC was presented in the HI-STORM Canister Storage System application.

3.2.2 Design Criteria and Applicable Loads

Table 2.3.1 summarizes all loads, design criteria, applicable regulations, reference codes and standards for the VVM.

Table 2.3.2 summarizes design data for HI-STORM UMAX Canister Storage System.

3.2.2.1 Applicable Loadings

Loadings applicable to the HI-STORM UMAX Canister Storage System are defined in FSAR Sections 2.4 and 2.5.

3.2.2.2 Design Basis Loads and Load Combinations

Table 2.4.1 contains design basis loads and acceptance criteria applicable to VVM components.

Table 2.4.3 contains load combinations applicable to ISFSI structures.

3.2.2.3 Allowable Stresses

Allowable stresses or performance criteria for ITS components are identified on the design drawings in FSAR Section 1.5,

Allowable stresses and stress intensities for American Society of Mechanical Engineers (ASME) B&PV Code (Code) are identified in Tables 3.1.11 and 3.1.12. Tables 3.1.2 to 3.1.8 contain tabulated values for all VVM and MPC components. Specifically, FSAR Table 3.1.4 contains Level A allowable stresses, FSAR Table 3.1.5 contains Level B allowable stresses, and FSAR Table 3.1.6 contains Level D allowable stresses.

3.2.3 Stress Analysis Models and Computer Codes

The applicant's finite element analysis was performed with LS-DYNA, which is a commercial explicit dynamics code for dynamic events, and ANSYS which was used for static stress analysis. Some stress analysis was also performed with closed form classical methods.

3.2.3.1 HI-STORM UMAX VVM

The applicant's VVM finite element model was developed for the seismic soil structure interaction (SSI) analysis of a representative 5×5 VVM array loaded with the tallest and heaviest approved MPC.

Key features of the applicant's FEA model included:

- Shell elements were used divider shell and CEC

- Thick shell and solid elements were used for the CEC base plate and MPC pedestals, respectively.

- VVM lid was simplified to a rigid solid body to maximize the contact forces.

- The bounding MPC was modeled in the VVM is a rigid cylinder which yielded bounding stresses in the VVM and bounding loads for the ISFSI structures.

- FEA meshing developed during the licensing process for the HI-STORM 100U (CoC No. 1014) was again utilized to capture the primary stresses.

- The divider shell, CEC baseplate and MPC pedestal, were assumed to behave linear elastically to maximize impact loads.

- The VVM steel components were modeled with nonlinear elastic-plastic true stress-strain relationships

- The key input data of the VVM model is listed in FSAR Table 3.1.13.

3.2.3.2 Multi-Purpose Canister (MPC)

As stated previously, only relevant information necessary to evaluate the interaction between the HI-STORM UMAX VVM and the MPCs was presented in the HI-STORM UMAX Canister Storage System application. A finite element model of the MPC was necessary to demonstrate that any loads imparted on the MPC are within the licensing basis previously approved and to demonstrate that impact of the MPC into the radial guides of the CEC are within the limits of the materials of construction.

Key features of the applicant's FEA model included:

- The contents (fuel assemblies, fuel basket, and basket shims) of the MPC are explicitly modeled to account for the interaction between the MPC shell and the MPC contents.

- A refined finite element mesh at areas of interest in the canister was used to accurately capture the primary membrane and bending stresses as well as secondary stresses.

- The MPC shell and fuel basket were modeled using LS-DYNA thick shell elements.

- MPC lid, baseplate and each fuel assembly were modeled using solid elements.

- The MPC lid weld was explicitly modeled using solid elements.

- The material properties of the MPC components were based on the bounding temperatures under normal storage condition.

- The fuel assembly model, was assumed to be linear elastic

- All other MPC structural members we modeled with their true stress-strain relationships

The key input data of the MPC enclosure vessel model is listed in FSAR Table 3.1.15.

3.2.3.3 HI-TRAC Transfer Cask

The applicant provided no additional analysis on the transfer cask beyond the qualifying analyses presented in the HI-STORM FW Cask System application (CoC No. 1032). The transfer cask was included in analyses for the HI-STORM UMAX Canister Storage System, such as the SSI evaluation for to provide a level of conservatism.

3.3 Weights and Centers of Gravity

FSAR Table 3.2.1 contains bounding weight data of all types of MPCs, HI-TRACs and transporters that may be utilized with the HI-STORM UMAX Canister Storage System.

FSAR Table 3.2.2 contains bounding dimensional data for the MPC types certified for use in the HI-STORM FW Cask System.

3.4 Structural Analysis

The structural analysis for the HI-STORM UMAX Canister Storage System is presented in the FSAR Chapter 3. The HI-STORM UMAX Canister Storage System components are designed to protect the cask contents from significant structural degradation, provide

adequate shielding, and maintain subcriticality and confinement under the design basis normal, off-normal, and accident loads. Individual loads for the three design conditions of normal, off-normal and accident conditions, including natural phenomena, have been addressed in FSAR Sections 2.3.2, 2.3.3 and 2.3.4.

3.4.1 Normal Conditions

The HI-STORM UMAX Canister Storage System is designed to withstand normal conditions of storage, which include dead weight, handling (lifting of loaded MPC, lifting and handling of HI-TRAC VW with loaded MPC, lifting and transfer to ISFSI VVM with loaded MPC), pressure, temperatures, and snow and ice.

3.4.2 Off-Normal Conditions

The HI-STORM UMAX Canister Storage System is designed to withstand off-normal conditions, which include pressure, environmental temperatures, transient event temperatures, leakage of seals, and partial blockage of air inlets.

3.4.3 Accident Conditions

3.4.3.1 Non-Mechanistic Tipover

The applicant stated that the non-mechanistic tipover is not a credible event based on the design features of the HI-STORM UMAX Canister Storage System. The MPCs were evaluated by the applicant for a non-mechanistic tipover in CoC No. 1032.

3.4.3.2 Dead load plus design basis explosion pressure on VVM components

The applicant evaluated the VVM Closure Lid and CEC shell utilizing strength of materials calculations. The applicant demonstrated that the dead load and explosion pressure are bounded by the maximum vertical missile impact force and that the bearing capacity of the engineered fill far exceeds the loading imparted by the design basis explosion.

3.4.3.3 Maximum Temperature and Internal Pressure Under Accident Conditions

The applicant determined that the configuration of the UMAX VVM does not allow internal pressure gradients since it is open to the environment. Maximum temperature and pressures for the MPC-37 and MPC-89 are bounded by the evaluations presented in CoC No.-1032 for the same MPC designs.

3.4.3.4 Design Basis Fire on VVM Closure Lid

The applicant determined that the stresses in the closure lid due to a 10 psi explosion overpressure were extremely small, and the design of the closure lid provides that this loading will be more severe than a design basis fire event. Based on this observation, and that the minimum material properties used for a design basis fire temperature still represent a significant strength reserve, the appicant concluded no collapse of the VVM closure lid due to fire will occur.

3.4.3.5 Design Basis Flood

The staff finds that sliding or other displacement of the stored contents due to moving water is not a credible event due to the specific design and structural restraints inherent in the system.

3.4.3.6 Design Basis Missile Loading

3.4.3.6.1 Tornado Missile Strike on VVM Closure Lid

Due to the design features of the UMAX Canister Storage System, the applicant determined that a missile strike is only credible for a side or top impact of the VVM closure lid. The applicant's strength of materials analysis of a design basis missile strike on the closure lid demonstrated that the lid remained in place and did not collapse. The applicant's result determined that the shielding effectiveness of the closure lid was not reduced.

3.4.3.6.2 Tornado Missile Protection during Construction

The applicant's strength of materials analysis of a design basis missile strike on the exposed engineered fill demonstrated that the CEC and MPC are unaffected. FSAR Table 3.4.8 summarizes the missile impact analysis results and associated safety factors.

3.4.3.7 Design Basis Earthquake

A. Design Basis Seismic Model and SSI Analysis

The applicant's dynamic simulation of the structural response of the buried VVM was performed using the commercial finite element code, LS-DYNA. The seismic input for the transient finite element (FE) SSI analysis was an acceleration-time history set developed using Regulatory Guide (R.G.) 1.60 response spectra. The applicant determined that the acceleration time histories met the bounding spectra and power spectral density requirements of the "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," NUREG-0800, section 3.7.1. The design basis earthquake (DBE) specified a horizontal zero period acceleration (ZPA) of 1.0 g and a vertical ZPA of 0.75g at the ground surface and a horizontal zero period acceleration (ZPA) of 0.93 g and a vertical ZPA of 0.71g at the foundation surface pad per FSAR Table 2.3.2.

The applicant's soil structure model development consisted of a two-step process utilizing SHAKE2000 and LS-DYNA to generate the response spectra at various ISFSI elevations with lower bound soil properties which were intended to bound the soil conditions at most US nuclear power plants. The SHAKE2000 analysis was performed first to generate the average strain compatible shear wave velocities as well as to extract the acceleration time history at the base of the soil column which is subsequently used in the LS-DYNA seismic response analysis (no structure present) and the LS-DYNA SSI analysis. This model also formed the basis for comparison of the site specific seismic and SSI analyses to determine whether site conditions are bounded by the general provisions set forth in the proposed CoC. The analytical approach described above was identical to that used for staff approved amendments 7 and 9 to CoC No. 1014. FSAR Table 3.4.3 lists the peak ISFSI interface loads obtained from the LS-DYNA SSI simulations of the following four loading scenarios:

Scenario 1: All storage locations loaded with maximum weight MPCs, and a loaded VCT is placed at the center of the ISFSI.

Scenario 2: Same as Scenario 1 except that the Young's Modulus of the SFP concrete is reduced to one-half of its nominal value.

Scenario 3: Same as Scenario 1 except that the subgrade adjacent to one side of SES (Space A) is excavated down to the SFP and that the VCT is not considered.

Scenario 4: Same as Scenario 3 except that the Young's Modulus of the SFP concrete is reduced to one-half of its nominal value.

The applicant used the peak interface in the structural qualification of the VVM components and the ISFSI structures.

B. Seismic Qualification of VVM Components

In a seismic event, the loaded MPC in the HI-STORM UMAX VVM could experience impact loading from the MPC guides attached to the divider shell of the VVM.

The MPC enclosure vessel and contents were modeled by the applicant explicitly to correspond to the modeling techniques utilized for the MPC shell in CoC No. 1014, Amendment No. 9 (approved by the staff), to capture the high stress gradient at the impact location. The combination of results obtained from the MPC impact analysis and those the SSI analyses were used to structurally qualify HI-STORM VVM components. FSAR Table 3.4.4 summarizes the seismic qualification analysis results for VVM components.

C. Strength Qualification of the ISFSI Structure

The applicant evaluated the strength qualification of the ISFSI structures under design basis seismic loading is by extracting the peak interface loads obtained from the SSI analyses and applying them to a quasi-static finite element analysis. The applicant determined the actual input loads were larger than the peak loads obtained from the LS-DYNA analyses to provide additional margin of safety. The applicant determined the SFP, TSP, and enclosure wall met the American Concrete Institute (ACI)-318 (2005) strength limits for all load combinations applicable for this design. The quasi-static structural analysis utilized the ANSYS finite element analysis software. The following is a summary of the applicant's model formulation:

- SFP, TSP, Subgrade beneath TSP modeled with elastic SOLID45
- The lateral subgrade adjacent to the ISFSI is included in the FE model
- The element mesh is appropriately refined in areas of load application on the SFP and the TSP.
- Quarter symmetry is utilized
- Simulation Model II, as described below, uses a full FE model since it is non-symmetric

The following is a summary of the VVM loading configurations considered:

- Simulation Model I: all the storage locations in the ISFSI are populated and experience identical bounding peak vertical seismic loading

  Simulation Model II: two rows of VVM locations adjacent to the symmetry line loaded

  Simulation Model III: single middle row of VVM is loaded

  Simulation Model IV: single VVM loaded centered near the periphery of the ISFSI

  Simulation Model V: similar to Model III but with lateral subgrade surrounding the retaining walls removed. Effects of transporter also not considered since loading activities will be suspended during excavations.

  Simulation Models I, II, III and IV, applied the peak bearing load from the LS-DYNA SSI analysis from a single transporter track as a static load to both transporter tracks footprints simultaneously. No credit was taken for the dynamic increase factor of 25% for flexure and 10% for shear permitted by in the strength qualification of reinforced concrete which provided additional conservatism in the analysis.

  Table 3.4.5 of the FSAR illustrates that the ISFSI pad and support foundation pad strength has significant margin over ACI 318 allowable stresses.

  The applicant noted that the structural analysis of the ISFSI considered the peak dynamic loads (unfiltered) from the LS-DYNA SSI analysis and that it is permissible to use equivalent static loads obtained by removing high frequency components using appropriate filters. While the staff does not object to this practice, in theory, any use of numerical filters to alter input data and subsequently output response must be adequately justified, reviewed, and approved by the NRC. Since no information was presented by the applicant regarding the acceptable use of filters nor a definition of what an 'appropriate filter' is, the NRC did not accept the use of filters to establish loadings for the HI-STORM UMAX Canister Storage System in performing its evaluation.

3.5 Staff Evaluation

The staff evaluation of the licensee's structural models and other calculations to support the structural analyses included review of the engineering drawings to verify that adequate geometry dimensions were translated to the analysis models, review of the material properties presented in the FSAR relevant to structural performance to verify that they were used appropriately and properly referenced, confirmation of finite element input values used in the licensee calculation packages, along with a review of design details used to provide parameters in the computer models and other calculations. The staff determined that the proper material properties and boundary conditions were used based on well-established structural engineering methods and analytical techniques. The staff determined that the licensee's selected analytical models, assumptions and other calculations accurately reflected the specific design parameters, and that the assumptions and modeling parameters were consistent with review guidelines in NUREG-1536 and ISG-21, "Use of Computational Software" as well as 10 CFR 72.122, and 10 CFR 72.128. The staff determined that licensee assumptions were adequate for the structural performance characteristics in the HI-STORM UMAX Canister Storage System geometry and analyzed conditions. Finally, the staff determined that the licensee-provided FSAR sections included

accurate information that allowed the staff to make a safety determination on the acceptability of the proposed design.

Therefore the staff finds the HI-STORM UMAX Canister Storage System structural analysis and conclusions acceptable and that the HI-STORM UMAX Canister Storage System will safely store spent nuclear fuel within TS parameters.

3.6 Evaluation Findings

F3.1 The FSAR adequately describes all SSCs that ITS, providing drawings and text in sufficient detail to allow evaluation of their structural performance.

F3.2 The applicant has met the requirements of 10 CFR Part 72.236(b). The SSCs ITS are designed to accommodate the combined loads of normal or off-normal operating conditions and accidents or natural phenomena events with an adequate margin of safety. Stresses at various locations of the cask for various design loads are determined by analysis. Total stresses for the combined loads of normal, off-normal, accident, and natural phenomena events are acceptable and are found to be within limits of applicable codes, standards, and specifications.

F3.3 The applicant has met the requirements of 10 CFR Part 72.236(c), for maintaining subcritical conditions. The structural design and fabrication of the DSS includes structural margins of safety for those SSCs important to nuclear criticality safety. The applicant has demonstrated adequate structural safety for the handling, packaging, transfer, and storage under normal, off-normal, and accident conditions.

F3.4 The applicant has met the requirements of 10 CFR 72.236(l), “Specific Requirements for Spent Fuel Storage Cask Approval.” The design analysis and submitted bases for evaluation acceptably demonstrate that the cask and other systems important to safety will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.

F3.5 The applicant has met the requirements of 10 CFR 72.236 with regard to inclusion of the following provisions in the structural design:

- Design, fabrication, erection, and testing to acceptable quality standards.

- Adequate structural protection against environmental conditions and natural phenomena, fires, and explosions.

- Appropriate inspection, maintenance, and testing.

- Adequate accessibility in emergencies.

- A confinement barrier that acceptably protects the cladding during storage.

- Structures that are compatible with appropriate monitoring

systems.

- Structural designs that are compatible with retrievability of snf.

F3.6 The applicant has met the specific requirements of 10 CFR 72.236(g) and as they apply to the structural design for spent fuel storage cask approval. The cask system structural design acceptably provides for the following required provisions:

- Storage of the spent fuel for a minimum required years.

- Compatibility with wet or dry loading and unloading facilities.

The staff concludes that the structural properties of the SSCs of the HISTORM UMAX Canister Storage System are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the structural properties provides reasonable assurance that the HISTORM UMAX Canister Storage System will allow safe storage of SNF for a licensed (certified) life of 20 years. 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.

4 THERMAL EVALUATION

The staff's thermal review ensures that the cask components and fuel material temperatures of the HI-STORM UMAX Canister Storage System will remain within the allowable values under normal, off-normal, and accident conditions. These objectives include confirmation that the fuel cladding temperature will be maintained below specified limits throughout the storage period to protect the cladding against degradation that could lead to gross ruptures. This portion of the review also confirms that the cask thermal design has been evaluated using acceptable analytical techniques and/or testing methods. The review was conducted against the appropriate regulations as described in 10 CFR 72.236 that identify the specific requirements for spent fuel storage cask approval and fabrication. The unique characteristics of the spent fuel to be stored are identified, as required by 10 CFR 72.236(a), so that the design basis and the design criteria that must be provided for the SSCs ITS can be assessed under the requirements of 10 CFR 72.236(b). This application was also reviewed to determine whether the HI-STORM UMAX Canister Storage System design fulfills the acceptance criteria listed in Sections 2, 4 and 12 of NUREG-1536, Revision 1, as well as applicable interim staff guidance (ISG).

4.1 Spent Fuel Cladding

The applicant adopted certain guidelines of NRC, "Standard Review Plan for Dry Cask Storage Systems," NUREG-1536, Revision No. 1 and ISG-11, Revision 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel", to demonstrate the safe storage of the material content described in FSAR Chapter 2 and in the CoC for those aspects relevant to the HI-STORM UMAX Canister Storage System design. The applicant demonstrated the HI-STORM UMAX Canister Storage System complied with the following requirements:

1. The fuel cladding temperature must meet the temperature limit appropriate to its burnup level and condition of storage or handling set forth in FSAR Table 4.3.1.

2. The maximum internal pressure of the MPC should remain within its design pressures for normal, off-normal, and accident conditions set forth in FSAR Table 2.2.1

3. The temperatures of the cask materials shall remain below their recommended limits set forth in FSAR Table 2.2..

4.2 Thermal Properties of Materials

Material property tables for the HI-STORM UMAX components are included in FSAR Section 4.2. Materials present in the MPCs include Alloy X (defined in the FSAR), Metamic-HT, aluminum, and helium. Materials present in the HISTORM UMAX Canister Storage System underground storage vertical ventilated module (VVM) include carbon steel, concrete, and ambient air. Thermal properties provided in the FSAR include thermal conductivity, density, heat capacity, gas viscosity, and emissivity. The temperature range for the material properties covers the range of temperatures encountered during the thermal analysis. The staff evaluated the applicant's thermal properties used to perform the thermal evaluation of the HI-STORM UMAX Canister Storage System. Based on the information provided in the application regarding thermal properties, the staff determined that the application is consistent with guidance provided in Section 4.5.4.2 (Material Properties) of NUREG-1536 that state the applicant should include thermal properties for all components used in the calculational model and that the thermal properties used in the safety analysis are appropriate. Therefore, the staff concludes that the thermal properties are acceptable because the properties satisfy NUREG-1536 and the requirements in in 10 CFR 72.122(h)(1), 72.122(l), 72.236(b), 72.236(f), 72.236(g), and 72.236(h).

4.3 Specifications for Components

HI-STORM UMAX Canister Storage System materials and components designated as ITS (i.e., required to be maintained within their safe operating temperature ranges to ensure their intended function) are summarized in FSAR Table 2.2.3. For evaluation of HI-STORM UMAX Canister Storage System thermal performance, material temperature limits for long term normal, short-term operations, and off-normal and accident conditions are provided in FSAR Table 4.3.1. Fuel cladding temperature limits included in FSAR Table 4.3.1 FSAR are adopted from ISG-11. These limits are applicable to all fuel types, burnup levels, and cladding materials approved by the NRC for power generation.

The staff reviewed the applicant's specifications for ITS SSCs for the HI-STORM UMAX Canister Storage System. Based on the information provided in the application regarding specifications for components, the staff determines that the application is consistent with guidance provided in Section 4.4.2 (Material and Design Limits) of NUREG-1536 that provides that cask components and fuel materials should be maintained between their minimum and maximum temperature limits for normal, loading, off-normal, and accident-level conditions to enable all components to perform their intended safety function. Therefore, the staff concludes that the specifications for components are acceptable because the material temperature limits satisfy NUREG-1536 and the requirements in in 10 CFR 72.236(b), 72.236(f), 72.236(g), and 72.236(h).

4.1 HI-STORM UMAX Canister Storage System

4.1.1 General Description

As described in FSAR Section 1.2, the HI-STORM UMAX Canister Storage System consists of interchangeable MPCs, which maintain the configuration of the fuel and is the confinement boundary between the stored spent nuclear fuel and the environment; and a storage overpack that provides structural protection and radiation shielding during long-term storage of the MPC. The HI-STORM UMAX VVM provides for storage of the MPC in a vertical configuration inside a subterranean cylindrical cavity entirely below the top-of-grade of an independent spent fuel storage installation. The key constituents of a HI-STORM UMAX VVM are:

1) The Cavity Enclosure Container (CEC)
2) The Closure Lid
3) The ISFSI Pad
4) The Support Foundation Pad
5) The Subgrade and Under-grade
6) The Enclosure Walls (optional)

A detailed description of MPCs and the HI-TRAC transfer cask are provided in Section 1.2 of the HI-STORM UMAX FSAR.

4.1.2 Design Criteria

The thermal design and operation of the MPC in the HI-STORM UMAX system meets the intent of the review guidance contained in NUREG-1536 and ISG-11, Revision 3. Specifically, provisions that are explicitly invoked and satisfied are:

1. The thermal acceptance criteria for all commercial spent fuel (CSF) authorized by the USNRC for operation in a commercial reactor are unified into one set of requirements.

2. The maximum value of the calculated temperature for all CSF under long-term normal conditions of storage must remain below 400ºC (752ºF). For short-term operations, including canister drying, helium backfill, and on-site cask transport operations, the fuel cladding temperature must not exceed 400ºC (752ºF) for high burnup fuel (HBF) and 570ºC (1058ºF) for moderate burnup fuel.

3. The maximum fuel cladding temperature as a result of an off-normal or accident event must not exceed 570ºC (1058ºF).

4. For HBF, operating restrictions are imposed to limit the maximum temperature excursion during short-term operations to 65ºC (117ºF) and the number of excursions to less than 10.

As described in FSAR Section 2.0.3, the HI-STORM UMAX VVM rejects heat from the stored MPCs by delivering cool ambient air to the annular space around the MPC. The ambient air undergoes progressive heating and reduction in density as it rises in the cylindrical space surrounding the MPC through convective heat transfer with the MPC shell, and exits the cell through the vertical flue mounted on the central region of the closure lid. The storage cavities have a constant out flow of air which will tend to retard the deposition of air borne particulates

and debris in the storage space. The accumulated solids can be vacuumed out of the storage cavity by standard means. As shown in FSAR Chapter 4, the VVMs are designed to reject the maximum allowable heat load. The VVM is designed for extreme cold conditions.

4.1.3 Design Features

The HI-STORM UMAX Canister Storage System is designed, with multiple cooling passages and suitably sized flow annuli, which maximize air flow by ensuring a turbulent flow regime at design basis heat loads. Cooling air to each MPC storage cavity is provided by four independent ducts. Thus, there is a significant level of redundancy in the cooling air delivery system for the HI-STORM UMAX Canister Storage System. The air inlet locations are separated from the outlet vent by a significant lateral and vertical distance. This design feature ensures that there is minimal mixing of cold and heated air in the storage system. Calculations summarized in FSAR Chapter 4 show that the heat rejection performance of the system is stable under varying wind speed.

To ensure the permissible PCT limits are not exceeded, FSAR Subsection 2.1.9 specifies the maximum allowable decay heat per assembly for each MPC model in the three-region configuration. FSAR Tables 4.1.1, 4.4.3, 4.4.4, and 4.4.5 summarize the heat load data for MPC-37 and MPC-89.

The staff reviewed the applicant’s general description, design criteria, and design features of the HI-STORM UMAX storage system. Based on the information provided in the application regarding these items, the staff determines that the application is consistent with guidance provided in Section 4.4.1 (Decay Heat Removal System) of NUREG-1536 which provides that the applicant should present a detailed description of the proposed cask heat removal system and its passive cooling characteristics. Here, the applicant has provided a detailed description of decay heat removal system and its passive cooling characteristics. Therefore, the staff concludes that the description of the decay heat removal system is acceptable because the description satisfies NUREG-1536 and the requirements in in 10 CFR 72.122(h)(1), 72.122(l), 72.236(b), 72.236(f), 72.236(g), and 72.236(h).

4.2 Thermal Model

The applicant used FLUENT program to evaluate the thermal performance of the HI-STORM UMAX Canister Storage System. FLUENT is a finite volume computational fluid dynamics (CFD) program with capabilities to predict fluid flow and heat transfer phenomena in two and three dimensions. The thermal analysis model developed by the applicant is described below.

The airflow through the cooling passages of the VVM is modeled as turbulent, using the k-co model with transitional option enabled. The underside of the SFP is assumed to be supported on a subgrade at an isothermal surface temperature. A quarter-symmetry model for the VVM assembly seeks to represent the essential geometry details of the physical system as depicted in the Licensing Drawings in FSAR Section 1.5 with the assumptions as summarized below:

1. In FSAR Table 2.1.7, the fuel assemblies loaded in MPC-37 are catalogued as short, standard and long fuel. For each length catalogue, the minimum active fuel length is used in the model. For instance, the active fuel lengths of 128", 144" and 168" are used to model the short, standard and long fuel respectively. This is conservative, because the shorter

active fuel length has the higher heat load density, which results in higher a higher peak cladding temperature (PCT).

2. The soil Subgrade beneath the VVM assembly is assumed to be equal to the design basis soil temperature in FSAR Table 4.1.1.

3. The side surface of VVM is assumed to be insulated.

The applicant stated that that the axial variation of the heat generation rate in the design basis fuel assembly is defined based on the axial burnup distribution and that this distribution is used for analyses only, and do not provide a criteria for fuel assembly acceptability for storage in the HI-TORM UMAX Canister Storage System. The staff questioned this assumption used in the thermal analysis because different distributions may negatively affect the FSAR thermal results and new thermal analysis may be required to demonstrate that thermal limits are not exceeded. To address this issue, the applicant performed the analysis using two axial heat load distributions:

Case1 (flattened axial distribution as depicted in the licensing basis profile in Table 2.1.5 and Figure 2.1.3 of the FSAR) and

Case 2 (axial distribution with peak to average heat generation rate equal to 1.2 in every storage cell. Based on the analysis results the applicant determined a small difference between the two axial profiles. However, the staff questioned if the assumed axial variation would bound other axial distributions during vacuum drying. To address this issue, the applicant performed additional analysis using a center biased heat generation profile. The applicant determined that in order to comply with the permissible peak cladding temperature limit, a reduction in the threshold heat load allowed for vacuum drying was needed, as specified in the FSAR.

The staff reviewed the applicant's description of the HI-STORM UMAX Canister Storage System thermal model. Based on the information provided in the application regarding the thermal model, the staff determines that the application is consistent with guidance provided in Section 4.4.4 (Analytical Methods, Models, and Calculations) of NUREG-1536 that provides that the applicant should present a thermal analysis that clearly demonstrates the storage system's ability to manage design heat loads and have the various materials and components remain within temperature limits. Here, the applicant has provided a detailed description of thermal models used to perform the evaluation of the storage cask. Therefore, the staff concludes that the description of the thermal model is acceptable because the description satisfies NUREG-1536 and the requirements in in 10 CFR 72.122(h)(1), 72.122(l), 72.236(b), 72.236(f), 72.236(g), and 72.236(h).

4.6 Thermal Evaluation for Normal Conditions of Storage

The applicant used the 3-D model described in the previous section to determine temperature distributions under long-term normal storage conditions for both MPC-89 and MPC-37. FSAR Tables 4.4.2, 4.4.7, 4.4.9, and 4.4.10 provide key thermal and pressure results. From the presented results the temperature field in the HI-STORM UMAX Canister Storage System with a loaded MPC containing heat emitting spent nuclear fuel complies with all regulatory temperature limits (FSAR Table 2.3.7). The staff determined the thermal environment in the HI-STORM UMAX Canister Storage System is in compliance with FSAR Chapter 2 Design Criteria. Per FSAR Chapter 3, all HI-STORM UMAX VVM and MPC materials of construction will

satisfactorily perform their intended function in the storage mode under a minimum temperature condition of -40°F.

The storage scenarios described above assumed the HI-STORM UMAX Canister Storage System is located at sea level. However, if an ISFSI is located at an elevation greater than sea level, the effect of altitude on the peak cladding temperature shall be quantified as part of the 10 CFR 72.212 evaluations for the site using the site ambient conditions.

The applicant calculated the MPC maximum gas pressure for a postulated release of fission product gases from fuel rods into the MPC free space. For these scenarios, the amounts of each of the release gas constituents in the MPC cavity are summed and the resulting total pressures determined from the ideal gas law. Based on fission gases release fractions (NUREG 1536 criteria), rods' net free volume and initial fill gas pressure, maximum gas pressures with 1% (normal), 10% (off-normal) and 100% (accident condition) rod rupture are given in FSAR Table 4.4.7. The maximum computed gas pressures reported in FSAR Table 4.4.7 are all below the MPC internal design pressures for normal, off-normal and accident conditions specified in FSAR Table 2.3.

The applicant performed grid sensitivity studies to obtain the discretization error. For this purpose, the applicant generated five different grids. Using the results from these grids, the applicant calculated the grid convergence index (GCI). However, the details of the GCI calculation show that the applicant obtained an apparent order larger than the analytical one. This may indicate the calculations did not follow recommended practices. The applicant recalculated the GCI using a set of three grids. This calculation showed an apparent order smaller than two which is more reasonable. However, as indicated in American Society of Mechanical Engineers (ASME), "Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer," V&V 20-2009, in order to demonstrate that the apparent order is constant for a series of simulations, a minimum of four grids is required. Per V&V 20-2009, three-grid solution for the observed order p may be adequate if some of the values of the variable of interest (for example, peak cladding temperature) predicted on the three grids are in the asymptotic region for the simulation series. The GCI calculation provided by the applicant did not demonstrate that the apparent order was constant nor did it show that the results were in the asymptotic region.

The staff questioned the lack of modeling error in the analysis results. The staff requested the applicant to provide the uncertainty of the analytical results associated with the boundary conditions (e.g., heat transfer coefficient), fuel effective thermal conductivity, and porous media flow resistance factors (used to model the fuel assemblies). The applicant performed additional analyses to obtain the sensitivity of the analytical results to the fuel effective thermal conductivity and porous media flow resistance factors. The calculations included a 10% reduction in the effective thermal conductivity and a porous media flow resistance factor of about one million. The applicant's calculated friction factor used in the PWR fuel assembly porous media model was found to be non-conservative. The staff calculated a higher friction factor based on thermal-hydraulic characterization performed by Sandia National Laboratory (SNL). Staff's thermal analysis of SNL's thermal-hydraulic experiment data, indicated that a fuel assembly viscous resistance factor of about a million would match the thermal-hydraulic experimental data obtained by SNL. In order to ensure that the fuel, MPC, and cask components remain below their respective temperature limits, the applicant lowered the allowable heat loads originally requested, as indicated in the FSAR.

For wind studies, the applicant developed a separate model to obtain the effect of wind and the effect of air mixing. The staff questioned the applicant's approach to treating wind as an off-normal occurrence since, based on observations and measurements (from National Oceanic and Atmospheric Administration data), low speed wind is a normal environmental variable. The applicant stated that wind should be treated as an off-normal occurrence but provided no additional justification. Per ANSI/ANS-57.9, off-normal operations are those conditions which, although not occurring regularly, are expected to occur no more than once a year. However, it appears that low wind speed (e.g. 7 mph wind) in any given direction would occur much more frequently, and, therefore, should be treated as a normal condition. Treating low speed wind as a normal occurrence requires the use of the long term storage recommended temperature limit (752°F or 400°C.) Therefore, the staff concluded wind should be treated as a normal environmental variable and should be included in the analysis, especially since it has an effect on the predicted peak cladding temperature as compared to the quiescent conditions.

The applicant stated that in order to include the effect of wind in the inlet temperature, the increase in the inlet temperature (obtained from analysis which considers a one by eight array model, as described in the FSAR) is added to the peak cladding temperature predicted by the thermal model developed for wind studies. The applicant predicted a PCT that was below, but very close to the ISG-11 recommended limit.

Chapter 4 (Thermal Evaluation) of NUREG-1536 provides the need to assess modeling details such as simulation options, simplifications, and accuracy of results. It also states that for any computational modeling software to demonstrate that a particular cask design satisfies regulatory requirements, adequate validation of that computational modeling software must be demonstrated by the applicant. As defined in NUREG-1536, validation is a demonstration of the validity of a computer code for use in a general area of application by comparison of the code's calculational results with the measured results (data) from a variety of experiments spanning the area of intended applications. The applicant performed the analysis but the application did not include any validation data to determine the accuracy of the analytical results. Therefore, without adequate validation of the analytical models, the staff is unable to determine the accuracy of the calculations and claimed thermal margins. If the staff can't determine the accuracy of the calculations, assessment against thermal limits is not possible and therefore, the staff is unable to determine compliance with regulations that require that spent fuel cladding must be protected against degradation and that the spent fuel is ready retrievable at any time. The staff requested the applicant to provide adequate validation. The applicant stated that a HI-STORM UMAX thermal test would be added to the CoC to address the staff's concern. The applicant's proposed test would require the user to perform an in-situ thermal acceptance test in accordance with the provisions provided in FSAR Section 10.3 on the first loaded MPC type whose aggregate heat load is equal to 80% of the design basis heat load. The applicant would use the measured thermal parameters (specifically air mass flow rate) to validate the analytical thermal models described in FSAR Chapter 4. The staff found the applicant's approach unacceptable because the proposed thermal test does not address the staff's concern on validation of analytical methods. This approach postpones the validation of the analytical methods after the CoC is issued. This practice put into question the validity of the design since the applicant should fully demonstrate and document in the safety analysis report the adequacy of the design so the staff can make a safety determination to issue the CoC. The staff recognizes that, at this time, the applicant does not have experimental data obtained from a geometry that resembles the HI-STORM UMAX Canister Storage System design. In order to compensate for the lack of validation of the thermal models and uncertainty of the calculations, the applicant reduced the total heat load by 20%. Without this reduction in heat load, the staff

was unable to make a determination on the adequacy of the design because of the unique characteristics of the HI-STORM UMAX Canister Storage System thermal-hydraulic design (specifically the nature of the underground design where air needs to flow downwards before it reaches the heated MPC shell), small thermal margin obtained by the applicant, and lack of validation of analytical methods. The staff performed additional calculations to determine the additional margin that would exist with a 20% reduction in the total heat load. The staff's results were consistent with the FSAR, which includes a calculation at 80% of design basis heat load. Based on these calculations the staff determined that the 20% reduction would provide sufficient margin against the recommended peak cladding temperature limit. The staff determined that this margin against the recommended limit was sufficient to provide reasonable assurance because it would compensate for uncertainties associated with the modeling and application errors.

The staff reviewed the applicant's thermal evaluation of the HI-STORM UMAX Canister Storage System during normal conditions of storage. Based on the information provided in the application regarding the thermal model and evaluation, the staff determines that the application is consistent with guidance provided in Section 4.4.4 (Analytical Methods, Models, and Calculations) of NUREG-1536 which provides that the applicant should present a thermal analysis that clearly demonstrates the storage system's ability to manage design heat loads and have the various materials and components remain within temperature limits. Here, the applicant has provided a thermal evaluation used to show that calculated maximum temperatures remain below the recommended limits described in the application. However, the applicant did not provide evidence that analytical models have been validated, as required by NUREG-1536. To compensate for the lack of validation and uncertainty determination, the applicant reduced the total heat load by 20%. The staff determined that a 20% reduction in the total heat load would be sufficient to provide additional margin against the recommended cladding temperature limit. The staff concluded that this additional margin would compensate for the uncertainty in the applicant's thermal models.

4.3 Thermal Evaluation for Short-Term Operations

The applicant incorporated by reference all short-term operations involving the HI-TRAC VW transfer cask.

4.4 Off-Normal and Accident Events

4.7.1 Off-Normal Events

The applicant considered five off-normal events: off-normal pressure, off-normal environmental temperature, partial blockage of air inlets, off-normal, malfunction of forced helium dehydrator (incorporated by reference to HI-STORM FW, and sustained wind. The current staff's position is that sustained winds from 0 to 10 miles per hour (mph) are normal occurrence and should apply the normal temperature limit. The MPC off-normal pressures are reported in FSAR Table 4.6.5. The results are below the off-normal design pressure (FSAR Table 2.3.5). The off-normal temperature results are provided in FSAR Table 4.6.1. The results are below the off-normal condition temperature (FSAR Tables 2.3.7). The computed temperatures for the partial blockage of air inlets are reported in FSAR Table 4.6.1 and the corresponding MPC internal pressure in FSAR Table 4.6.5. The results are confirmed to be below the temperature and pressure limits (FSAR Table 2.3.7 and 2.3.5) for off-normal conditions.

The staff reviewed the applicant's thermal evaluation during off-normal conditions and verified the maximum cladding temperatures predicted by the applicant would remain below ISG-11 Rev. 3 recommended limit of 570°C for all postulated off-normal events. Based on the information provided in the application regarding off-normal events, the staff determines that the application is consistent with guidance provided in Section 4.4.4 (Analytical Methods, Models, and Calculations) of NUREG-1536 which provides that the applicant should present a thermal analysis that clearly demonstrates the storage system's ability to manage design heat loads and have the various materials and components remain within temperature limits. Here, the applicant has demonstrated this ability by performing the calculations and demonstrating that the analysis results are lower than the recommended limit of 570°C. Therefore, the staff concludes that the thermal evaluation during off-normal events is acceptable because the thermal evaluation satisfies NUREG-1536 and the requirements in in 10 CFR 72.122(h)(1), 72.122(l), 72.236(b), 72.236(f), 72.236(g), and 72.236(h).

4.7.2 Accident Events

The applicant considered six accident events: fire, jacket water loss, extreme environmental temperatures, 100% blockage of air ducts, burial under debris, and flood. Accident analyses results are provided in FSAR Tables 4.6.6, 4.6.7, 4.6.9, and 4.6.10. All predicted maximum temperatures and pressures remain below the accident limits defined in FSAR Table 2.3.5 (accident design pressure) and Table 2.3.7 (accident temperature limit).

The staff reviewed the applicant's thermal evaluation during accident conditions and verified the maximum cladding temperatures predicted by the applicant would remain below ISG-11 Rev. 3 recommended limit of 570°C for all postulated accident events. Based on the information provided in the application regarding accident events, the staff determines that the application is consistent with guidance provided in NUREG-1536, Section 4.4.4 (Analytical Methods, Models, and Calculations) that provides that the applicant should present a thermal analysis that clearly demonstrates the storage system's ability to manage design heat loads and have the various materials and components remain within temperature limits. Here, the applicant has demonstrated this ability by performing the calculations and demonstrating that the analysis results are lower than the recommended limit of 570°C. Therefore, the staff concludes that the thermal evaluation during accident events is acceptable because the thermal evaluation satisfies NUREG-1536 and the requirements in in 10 CFR 72.122(h)(1), 72.122(l), 72.236(b), 72.236(f), 72.236(g), and 72.236(h).

4.8 Confirmatory Analysis

The staff reviewed the applicant's thermal models used in the analyses. The staff checked the code input in the calculation packages 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 flow and heart transfer characteristics prevailing in the HI-STORM UMAX Canister Storage System geometry and analyzed conditions. The engineering drawings were also consulted to verify that adequate geometry dimensions were translated to the analysis models. The material properties presented in the FSAR were reviewed to verify that they were appropriately referenced and used. The staff assured that the applicant performed appropriate sensitivity analysis calculations to obtain mesh-independent results that would provide bounding predictions for all analyzed conditions during normal fuel transfer and accidents. Finally, through request for additional information (RAI) the staff made sure the applicant provided an FSAR that included complete and accurate information for the staff to

make a safety determination on the adequacy of HI-STORM UMAX Canister Storage System thermal design.

To verify the applicant's model used to analyze for wind conditions, the staff modified the applicant's FLUENT model to extend the location of the boundary to make sure it does not affect the applicant's predicted results. Using the confirmatory analysis, the staff verified the applicant's developed model is adequate to represent wind conditions.

4.9 Evaluation Findings

F4.1 FSAR Chapter 2 describes SSCs important to safety to enable an evaluation of their thermal effectiveness. Cask SSCs important to safety remain within their operating temperature ranges.

F4.2 The HI-STORM UMAX Canister Storage System is designed with a heat-removal capability having verifiability and reliability consistent with its importance to safety. The cask is designed to provide adequate heat removal capacity without active cooling systems.

F4.3 The spent fuel cladding is protected against degradation leading to gross ruptures under long-term storage by maintaining cladding temperatures below 752°F (400°C). Protection of the cladding against degradation is expected to allow ready retrieval of spent fuel for further processing or disposal.

F4.4 The spent fuel cladding is protected against degradation leading to gross ruptures under off-normal and accident conditions by maintaining cladding temperatures below 1058°F (570°C). Protection of the cladding against degradation is expected to allow ready retrieval of spent fuel for further processing or disposal.

F4.5 The staff finds that the thermal design of the HI-STORM UMAX Canister Storage System 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 cask 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.

5 CONFINEMENT EVALUATION

In the confinement review, the NRC evaluated the confinement features and capabilities of the proposed cask system. In conducting this evaluation, the NRC staff seeks to ensure that radiological releases to the environment will be within the limits established by the regulations and that the spent fuel cladding and fuel assemblies will be sufficiently protected during storage against degradation that might otherwise lead to gross ruptures.

The HI-STORM Canister Storage System is similar in design to the HI-STORM 100U system approved by the NRC in CoC No. 1014, Amendment No. 7. The major differences between are that the HI-STORM UMAX Vertical Ventilated Module (VVM) Cavity is larger in diameter and the UMAX closure lid features a modified outlet ventilation duct system than the HI-STORM 100 VVM. Given that (1) the HI-STORM UMAX Canister Storage System confinement vessel is the MPC that is similar to that evaluated in CoC No. 1014, Amendment No. 7 and (2) there is only a

minor change in confinement system design between the HI-STORM UMAX Canister Storage System and the HI-STORM 100U the confinement review was focused on evaluating the effects of the differences in design.

5.1 Confinement System

The confinement boundary is defined by the MPC shell, MPC baseplate, MPC lid, port cover plates, closure ring, and associated welds (the HI-STORM UMAX VVM does not serve a confinement function). There are no bolted closures or mechanical seals in the MPC confinement boundary.

Helium Leak Testing

All the confinement components (including the confinement welds and the base metals) of the HI-STORM UMAX are required for helium leak testing except the lid-to-shell weld since the weld meets the criteria of ISG-18. The confinement boundary of the HI-STORM UMAX is helium leakage tested to be leak-tight (1.0×10^{-7} ref-cm^3/sec) in accordance with the leakage test methods and procedures of ANSI N14.5-1997.

5.1 Staff Evaluation

The staff reviewed the description of HI-STORM UMAX Canister Storage System confinement system and assures that (1) confinement of all radioactive materials in the HI-STORM UMAX system is provided by the MPC which remains unchanged from those used HI-STROM 100U which was approved and licensed; (2) the material of construction (austenitic stainless steel) for HI-STORM UMAX confinement vessel is known from extensive industrial experience to lend to high integrity, high ductility and high fracture strength welds, as well as the MPC enclosure vessel welds provide a secure barrier against leakage; and (3) all the confinement components (including the confinement welds and the base metals) of the HI-STORM UMAX are required for helium leak testing except the lid-to-shell weld since the weld meets the criteria of ISG-18.

After reviewing the descriptions of the confinement system in FSAR and referencing to HI-STORM FW, the staff agrees that leakage from the confinement boundary is not credible.

5.2 Evaluation Findings

F5.1 The FSAR sufficiently describes confinement structures, systems, and components important to safety.

F5.2 The HI-STORM UMAX Canister Storage System design adequately protects the spent fuel cladding against degradation that might lead to gross ruptures.

F5.3 The HI-STORM UMAX Canister Storage System provides redundant sealing of the confinement system. There are no bolted closures or mechanical seals in the MPC confinement boundary.

F5.4 The cask confinement system was evaluated to demonstrate that it will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.

F5.5 All the confinement components (including the confinement welds and the base metals) of the HI-STORM UMAX Canister Storage System are required for helium leak testing except the lid-to-shell weld since the weld meets the criteria of ISG-18.

6 SHIELDING AND RADIATION PROTECTION EVALUATION

The shielding and radiation protection review evaluates the ability of the proposed shielding features to provide adequate protection against direct radiation from the DSS contents. The shielding features should limit the dose to the operating staff and members of the public so that the dose remains within regulatory requirements during normal operating, off-normal, and design-basis accident (DBA) conditions. The review seeks to ensure that the shielding design is sufficient and reasonably capable of meeting the operational dose requirements of 10 CFR 72.104 and 72.106 in accordance with 10 CFR 72.236(d).

6.1 Introduction

The staff's review considered the acceptance criteria specified in Section 6 of NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems." The staff's review was performed based on information provided in the HI-STORM UMAX Canister Storage System FSAR.

The HI-STORM stores a sealed canister containing spent nuclear fuel in an in-ground Vertical Ventilated Module (VVM). The HI-STORM UMAX VVM is the underground equivalent of the HI-STORM FW overpack certified in CoC No. 72-1032. The HI-STORM UMAX Canister Storage System is also similar to the HI-STORM 100U VVM approved in CoC No. 1014, Amendment No. 7. The main differences between the HI-STORM UMAX VVM and HI-STORM 100 VVM are that the HI-STORM UMAX VVM cavity is larger in diameter and has a modified outlet ventilation duct system for the closure lid

6.2 Design Criteria

The objective of shielding is to assure that radiation dose rates at key locations are as low as practical in order to maintain occupational doses to operating personnel as low as reasonably achievable (ALARA) and to meet the requirements of 10 CFR 72.104 (a) to a maximum of 25 mrem/year whole body, 75 mrem/year thyroid, and 25 mrem/year for other critical organs, including contributions from all nuclear fuel cycle operations for a real individual beyond the controlled area boundary and 10 CFR 72.106 for dose at the controlled area boundary

The applicant stated that the three locations are of particular interest in the storage mode:
1. Immediate vicinity of the cask
2. Restricted area boundary
3. Controlled area (site) boundary

Dose rates in the immediate vicinity of the loaded VVM are important in consideration of occupational exposure.

The applicant stated since these limits are dependent on plant operations as well as site specific conditions, the determination and comparison of ISFSI doses to this limit are necessarily site-specific. The determination of site-specific ISFSI dose rates at the site boundary and demonstration of compliance with regulatory limits is to be performed by the licensee in accordance with 10 CFR 72.212.

The overpack is designed to limit the calculated surface dose rates on the cask for all MPC designs. The storage overpack provides structural protection and radiation shielding during long-term storage of the MPC. In addition, the HI-TRAC transfer cask provides the structural and radiation protection of an MPC during its loading, unloading, and transfer to the storage overpack is approved by the USNRC in CoC No. 1032. The overpack is also designed to maintain occupational exposures ALARA during MPC transfer operations, in accordance with 10 CFR Part 20.

6.3 Shielding Design Feature

The HI-STORM UMAX System Canister Storage System shielding design is described in the FSAR, Section 1.2. The details of design are described in the licensing drawings in FSAR, Section 1.5. The HI-STORM UMAX VVM differs from above ground HISTORM overpacks approved in CoC Nos. 72-1014 and 1032 in that the used fuel is stored below the ISFSI's top of grade (TOG). HI-STORM UMAX VVM, however, is comparable with the HI-STORM FW overpack model in that it can store the certified MPC-37 and MPC-89 in the FW system. Furthermore, the HI-TRAC VW transfer cask used to transfer and install the MPCs in the storage system is identical to that used in the HI-STORM FW system. The MPC's content, conditions and the loading operations up to the time the loaded MPC's transfer cask enters at the ISFSI are identical to the HI-STORM FW system.

The HI-TRAC VW transfer cask shielding safety analyses are already provided in NRC-approved CoC No. 1032.

The HI-STORM UMAX VVM is considered an overpack and consists of a set of vertically disposed thick-walled steel containers founded on a thick reinforced concrete pad and located over 20 feet below top of grade (TOP) embedded in a SES. The top region of the steel container is reinforced by a thick plate-type flange that rests on a reinforced concrete pad represents as the overpack pad.

The top opening in the container is the only location of access into the cavity and potential path of emission of radiation to the environment. The closure lid, made as an over-40 inch thick steel filled with concrete, provides a barrier in the path of the radiation emanating from the fuel.

The top of an MPC is equipped with a 9" thick lid and about 2 feet below the bottom of the VVM closure lid for shielding purpose.

Source Specification:

The applicant's design-basis source specifications for bounding calculations are identical to those used and evaluated by the staff in CoC No. 1032. The gamma source, neutron source and non-fuel hardware are the same as the sources described in HI-STORM FW FSAR.

6.4 Staff Evaluation

The staff performed shielding and source term calculations using SCALE6 to compare photon and neutron sources and concludes that the design of the shielding system for the HI-STORM UMAX VVM system applicable design and acceptance criteria is in compliance with 10 CFR Part 72 and acceptance criteria have been satisfied. The evaluation of the shielding system provides reasonable assurance that the HI-STORM UMAX VVM system will provide safe storage of spent fuel. This finding is based on a review of the specifications provided in the SAR, the regulations, appropriate regulatory guides, staff confirmatory calculations and modeling analysis, and accepted engineering practices

6.5 Shielding Analysis

The applicant used the MCNP-5 code for all of the shielding analyses. FSAR Figure 5.1.1 or Figure 1 and Figure 2 of HI-212519 identify the locations of the dose points that are shown in FSAR Tables 5.1.1 and 5.1.2 or Tables 1 and 2 of HI-212519 loaded with MPC-32 and MPC-37, on the surface and 1 meter from the surfaces respectively. Dose point #1 represents the side of the closure lid shell on top of the inlet plenum. The maximum dose rate is reported for the side surface of the lid shell, while the dose rate value reported at 1.6 meter was taken at the middle of the lid shell. Dose point #2 is the location of the surface of the outlet duct. Dose point #3 is positioned on the closure lid cover plate. Dose points # 4 and #5 are the locations of the outlet and inlet vents (top surface), respectively. Dose point #6 is located over a tube that would be required for the impressed current cathodic protection system (ICCPS) test station if an ICCPS is used. Dose point #7 is located over an empty VVM located adjacent to a loaded VVM. The annual dose at 100 meters from a Single HI-STORM UMAX VVM is provided in FSAR Table 3.

Dose rates profile across the lid and the ISFSI pad are provided in FSAR Table 4

6.5.1 Off-Normal Condition

The potential off-normal conditions and their effect on the HI-STORM UMAX Canister Storage System are provided in the Chapter 12 of HI-STORM FW FSAR. None of the off-normal conditions as defined in accordance with ANSI/ANS-57.9 and listed in Chapter 12 of SAR as defined in Section 2.3 of SAR have any impact on the shielding analysis. Therefore for the purpose of shielding evaluation both off-normal and normal conditions are treated identically

6.5.2 Occupational Exposures

The applicant states that the HI-TRAC VW transfer cask provides shielding to maintain occupational exposures ALARA in accordance with 10 CFR Part 20, while also maintaining the maximum load on the plant's crane hook to below the rated capacity of the crane. The HI-TRAC VW calculated dose rates for a set of reference conditions are provided in the HI-STORM FW FSAR, Section 5.1 and evaluated by the staff in CoC No. 1032.

6.5.3 Off-Site Dose Calculation

The off-site dose for normal operating conditions to a real individual beyond the controlled area boundary is limited by 10 CFR 72.104(a) to a maximum of 25 mrem/year whole body, 75 mrem/year thyroid, and 25 mrem/year for other critical organs, including contributions from all

nuclear fuel cycle operations. According to the applicant, since these limits are dependent on plant operations as well as site specific conditions, the determination and comparison of ISFSI doses to this limit are necessarily site-specific. Dose rates for a single cask and a range of typical ISFSIs using the HI-STORM UMAX Canister Storage System are provided in the FSAR , Tables 5.1.1, and 5.1.2. The determination of site-specific ISFSI dose rates at the site boundary and demonstration of compliance with regulatory limits is performed by the general licensee in accordance with 10 CFR 72.212.

FSAR Table 5.1.4 presents the dose for the accident condition caused by an impact of tornado borne missile on the radiation protection space boundary.

Dose rates were also calculated at a distance of 100 m from the VVM. This would indicate what portion of the dose rate results from direct radiation through the concrete and soil of the ISFSI pad as opposed to radiation from the streaming from the air inlet and outlet. The dose locations for the profile are shown in FSAR Figure 5.3.2, and are labeled alphabetically (A through X). The calculated dose rates are listed in FSAR Tables 5.4.2 and 5.4.3 for MPC-32 and MPC-37, respectively.

6.6 Staff Evaluation

The staff performed confirmatory analyses of selected dose rates using the MAVRIC sequence of the SCALE 6 code system, with the Monaco three dimensional Monte Carlo shielding analysis code. The staff based its evaluation on the design features and model specifications presented in the drawings shown in SAR. Limiting fuel characteristics, and the burnup and cooling time, are included in the TS, as are the dose rates profile across the HI-STORM UMAX lid and surrounding ISFSI pad. The staff's calculated dose rates were in reasonable agreement with the SAR values or were generally lower due to the applicant's conservative loading assumptions. The staff found that the SAR has adequately demonstrated that the HI-STORM UMAX is designed to meet the criteria of 10 CFR 72.104(a) and 72.106. Each general licensee is responsible to verify compliance with 10 CFR 72.104(a) in accordance with 10 CFR 72.212. In addition, a general licensee will also have an established radiation protection program as required by 10 CFR Part 20, Subpart B and will demonstrate compliance with dose limits to individual members of the public and workers including for excavation activities, as required, by evaluation and measurements. The staff notes that the system contents result in relatively significant direct radiation dose rates, which is a concern primarily for operations involving the transfer cask such as, loading, unloading, and transport for the UMAX system. Thus, each user may be required to take additional ALARA precautions to minimize doses to personnel and to make additional use of realistic fuel characteristics and distances to demonstrate compliance with public dose limits in 10 CFR Part 20 and 10 CFR Part 72. The staff reviewed the accident evaluation and found it acceptable for the design changes requested in the application. The staff has reasonable assurance that the direct radiation from the UMAX satisfies 10 CFR 72.106(b) at or beyond a controlled boundary of 100 meters from the design-basis accidents.

6.7 Evaluation Findings

Based on the NRC staff's review of information provided for the HI-STORM UMAX Canister: Storage System application, the staff finds the following:

F6.1 The FSAR sufficiently describes shielding design features and design criteria for the structures, systems, and components important to safety.

F6.2 Radiation shielding features of the HI-STORM UMAX Canister Storage System are sufficient to meet the radiation protection requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106.

F6.3 Operational restrictions to meet dose and ALARA requirements in 10 CFR Part 20, 10 CFR 72.104 and 72.106 are the responsibility of each general licensee. The HI-STORM UMAX Canister Storage System shielding features are designed to satisfy these requirements.

F6.4 The staff finds the design addresses construction activities involving excavation (for ISFSI expansion) adjacent to the (operating) HI STORM UMAX Canister Storage System sufficient to ensure that the shielding features will continue to be sufficient to meet the radiation protection requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106.

The staff concludes that the design of the radiation protection system of the HI-STORM UMAX Canister Storage System can be operated in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the radiation protection system design provides reasonable assurance that the HI-STORM UMAX Canister Storage System will provide safe storage of spent fuel. This finding is based on a review that considered the regulation itself, the appropriate regulatory guides, applicable codes and standards, the applicant's analyses, the staff's confirmatory analyses, and acceptable engineering practices.

7 CRITICALITY EVALUATION

The criticality review and evaluation ensures that SNF to be placed into the DSS remains subcritical under normal, off-normal, and accident conditions involving handling, packaging, transfer, and storage. The criticality review is designed to fulfill the strategic outcome of no inadvertent criticality events, part of the strategic goal of safety described in the NRC's strategic plan (NUREG-1614).

For the staff's criticality evaluation, the staff determined that the HI-STORM UMAX Canister Storage System design is identical to the NRC approved HI-STORM FW System in CoC No. 1032. Criticality safety was demonstrated during the CoC No. 1032 review, and there are no substantive differences applicable to the criticality evaluation between the two systems except for the overpack configuration, which is now below ground.

As part of the review, the staff asked the applicant whether flooding of the MPC is a plausible scenario. The applicant identified two unlikely independent events that would need to be overcome before a criticality event could be possible. These were a flooding of the CEC and a failure of the MPC confinement boundary. Under normal conditions, the interior of the MPC is dry and the inside of the CEC is dry. Since during storage conditions the HI-STORM UMAX Canister Storage System is dry within the MPC, the maximum k_{eff} is significantly below the limiting maximum k_{eff} of 0.95 as demonstrated in the CoC No. 1032 evaluation.

The applicant identified several scenarios that could lead to accumulation of water in the CEC, including underground sources of water and precipitation, and described the defense-in-depth of each scenario in their response to request for information (RAI) 6-1. The applicant also

addressed the potential for water to leak into the MPC assuming the failure of the CEC to remain dry in this RAI response, and indicated that the welding procedure to ensure the inert atmosphere (i.e., helium) remains in the MPC; the materials, manufacturing processes, closure procedure, and long term integrity of the MPC under storage conditions; and the physical protection of the MPC due to the underground configuration of the HI-STORM UMAX Canister Storage System, combined to make the potential for the MPC to allow an ingress of water to be highly unlikely. The staff finds that failure of the MPC as identified by the applicant is highly unlikely at this point, but is continuing to evaluate the potential for flooding due to recent industry events. This may also become an issue for above ground storage systems, and the NRC will continue to investigate this issue via the generic issue process as additional information becomes available.

The staff reviewed the applicant's criticality safety analyses and determined that their assessment on system criticality safety is consistent with the new review guidance of NUREG-1536. Based on its review, the staff finds that the criticality safety assessment acceptable and there is reasonable assurance that the HI-STORM UMAX Canister Storage System meets the regulatory requirements of 10 CFR Part 72 and the acceptance criteria specified for both intact and damaged fuel. In summary, the staff finds the following:

F7.1 Structures, systems, and components ITS are described in sufficient detail in Chapters 1, 2 and 6 of the HI-STORM UMAX Canister Storage System and HI-STORM FW Cask System FSARs to enable an evaluation of their effectiveness.

F7.2 The staff determined the cask and its spent fuel transfer systems are designed to be subcritical under all credible conditions.

F7.3 The staff determined the criticality design is based on favorable geometry, and fixed neutron poisons. An appraisal of the fixed neutron poisons has shown that they will remain effective for the term requested in the application. The staff determined there is no credible way for the fixed neutron poisons to significantly degrade during the requested term in the application; therefore, there is no need to provide a positive means to verify their continued efficacy as required by 10 CFR 72.124(b).

F7.4 The staff determined the applicant's analysis and evaluation of the criticality design and performance have demonstrated that the cask will enable the safe storage of spent fuel with respect to criticality safety for the term requested in the application.

The staff concludes that the criticality design features for the HI-STORM UMAX Canister Storage 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 HI-STORM UMAX Canister Storage System will allow safe storage of spent fuel. These findings are reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

8 MATERIALS EVALUATION

The materials review ensures adequate material performance of components ITS of a DSS, including the spent fuel canister or cask, under normal, off-normal, and accident-level

conditions. To ensure an adequate margin of safety in the design basis of the DSS, the review determined reasonable assurance that:
The physical, chemical, and mechanical properties of materials for components ITS meet their service requirements including normal, off normal and accident-level conditions, and that the mechanical properties are code accepted values.

Materials for components ITS have sufficient requirements to control the quality of the production, fabrication, and test activities.

Materials for ITS components are selected to accommodate the effects of, and to be compatible with, the ISFSI site characteristics, environmental conditions, and duration of the license period.

The SNF cladding is protected from gross rupture and from conditions that could lead to fuel redistribution.

The DSS is designed to maintain the spent fuel in a readily retrievable condition.

Other materials which support or protect ITS components (such as coatings) are suitable for the application.

The HI-STORM UMAX Canister Storage System incorporates one new material not previously evaluated by the staff for SNF storage applications, and that is the use of Metamic HT for the fuel basket structure. The remaining materials used in the fabrication of the HI-STORM UMAX Canister Storage System have been used in previously staff-reviewed storage system designs. No changes to the various other materials used to fabricate the HI-STORM UMAX Canister Storage System, therefore evaluation is primarily provided for the HI-STORM UMAX VVM. The HI-STORM UMAX Canister Storage System VVM is similar to the HI-STORM 100U VVM approved in CoC No. 72-1014. The major differences between the HI-STORM UMAX and HI-STORM 100U VVM are that the HI-STORM UMAX VVM cavity is larger in diameter and the HI-STORM UMAX closure lid features a modified outlet ventilation duct system. In addition, the HI-STORM UMAX VVM is essentially the underground equivalent of the HI-STORM FW over pack approved in CoC No. 72-1032.

8.1 HI-STORM UMAX Canister Storage System Materials

8.1.1 Metamic HT Spent Fuel Basket

Metamic HT is a Holtec proprietary aluminum-based material intended for dual purpose use in the HI-STORM UMAX spent fuel basket. Metamic HT is designed to be both a neutron poison for criticality control and a load-bearing structural material. Metamic-HT is a powder metallurgy material composed of aluminum combined with aluminum oxide and boron carbide (Holtec uses the terminology metal matrix composite (MMC) to generically describe Metamic HT). The aluminum oxide is a finely dispersed second-phase which provides enhanced room temperature and elevated temperature (creep) strength. The boron carbide is the neutron poison used for criticality control. The neutronic properties of Metamic HT are essentially identical to previously reviewed classical Metamic. The staff finds the composition and properties of Metamic HT to be unique; however the applicants test program was comprehensive in scope and supported the wide variety of property data for characterizing Metamic HT. Using the guidance of ASME Section II, Appendix 5, Holtec determined mechanical properties at room temperature and also

at several temperatures. The staff found this to in accordance with the ASME guidelines and is therefore acceptable.

CORROSION RESISTANCE:

Metamic HT was tested for compatibility with borated water, as would be typical for cask loading and unloading conditions. Aluminum alloys are very slightly corroded by borated water and Metamic HT performed similar to other aluminum-based materials in immersion tests. The applicant concluded that Metamic HT has more than adequate corrosion resistance for the intended service. The staff finds that Metamic HT is not susceptible to significant chemical or galvanic reactions and will perform adequately in accordance with 10 CFR 72.120(d).

The staff finds that the applicant has met the requirements of 10 CFR 72.124. Materials used for criticality control are adequately designed and specified to perform their intended function.

8.1.2 Cavity Enclosure Container (CEC) Portion Of The Vertical Ventilation Module (VVM)

The VVM is an ITS buried structure. As a buried structure, it is susceptible to different corrosion conditions as comparable to above-ground steel structure. In order to provide reasonable assurance that the VVM will meet its intended design life and perform its intended safety functions, the potentially degrading effects of soil corrosion must be mitigated.

Although the CEC portion of the VVM is not part of the MPC containment boundary, it should not corrode to the extent where localized in-leakage of groundwater occurs or where gross general corrosion prevents the CEC from performing its primary safety function. In addition, the foundation anchor housings (which are the only parts which cannot be inspected after installation) shall be protected from degradation over time.

Corrosion mitigation of the exterior of the CEC warrants special consideration for the following reasons, inaccessibility of the exterior coated surface after installation, potential for a highly corrosive soil environment at certain sites, and potential for a high radiation field. Since the buried configuration will not allow for the inspection and re-application of surface preservative, corrosion mitigation measures shall be determined after evaluation of the soil's corrosivity at the general licensee's ISFSI site.

To evaluate soil corrosivity, a "10 point" soil-test evaluation procedure, in accordance with the guidelines of Appendix A of ANSI standard for Polyethylene Encasement for Ductile-Iron Pipe Systems", ANSI/AWWA C105/A21, is utilized. The classical soil evaluation criteria in this standard focuses on parameters such as: resistivity, pH, redox (oxidation-reduction) potential, sulfides, moisture content, potential stray current, and experience with existing installations in the area. ISFSI soil environment corrosivity is categorized as either "mild" for a soil test evaluation resulting in 9 points or less or "aggressive" for a soil test evaluation resulting in 10 points or greater. The specific mitigation measures that shall be implemented based upon soil environment corrosivity, for example, for mild corrosivity an exterior coating with either concrete encasement or cathodic protection or both will be used and for aggressive corrosivity an exterior coating with cathodic protection will be used, concrete encasement optional.

8.1.3 Coating

In addition to a corrosion allowance for the CEC structural steel itself, the CEC shall be coated with a radiation resistant surface preservative designed for below-grade and/or immersion service. Inorganic and/or metallic coatings are sufficiently radiation resistant for this application; therefore radiation testing is not required for inorganic or metallic coatings. Organic coatings such as epoxy, however, must have proven radiation resistance or must be tested without failure to at least 10^7 Rads. Radiation resistance to lower radiation levels is acceptable on a site-specific basis.

Radiation testing shall be performed in accordance with ASTM D 4082, "Standard Test Method for Effects of Gamma Radiation on Coatings for Use in Light Water Nuclear Power Plants", or equivalent. The coating should be conservatively treated as a service Level II coating as described in USNRC Regulatory Guide 1.54. As such, the coating shall be subjected to appropriate quality assurance in accordance with the applicable guidance provided by ASTM D 3843-00, "Standard Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities".

The coating should preferably be shop applied in accordance with manufacturer instructions and, if appropriate, applicable guidance from ANSI C 210-03, "Standard Practice for Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines." A Keeler & Long polyamide-epoxy coating, according to the manufacturer's product data sheet, is pre-tested to radiation levels up to 1x10E9 Rad without failure.

Alternative coatings may be selected by Holtec on the basis of pre-established criteria which are provided in FSAR Chapter 8. These criteria include consideration of various environmental conditions along with a ranking of their relative importance. The Keeler & Long epoxy meets all the criteria and is the standard coating for use.

8.1.4 Concrete Encasement

The applicant stated that the CEC concrete encasement shall provide a minimum of 5 inches of cover to provide a pH buffering effect for additional corrosion mitigation. This concrete thickness has been selected to provide a 100-year service life based upon data provided in in the FSAR. A claim of 100 year service life provides some degree of uncertainty. However, this design provides for a conservative assumptions which the staff finds acceptable. The thickness specified for the concrete is greater than that specified by several recognized codes or references that are based upon a 20 year minimum design life. Thus, a working life of significantly greater than 20 years is reasonably assured. Additionally, an inspection of the interior surface of the CEC, along with a thickness survey of the CEC wall, will be performed once every 20 years to verify the continued efficacy of the corrosion protection measures.

It is recognized by the industry and staff that shrinkage cracks occur in concrete. Such cracks may create a path for water to intrude to the steel portions of the CEC that are being protected from corrosion by the concrete. To control the inevitable shrinkage cracks that form in concrete, the applicant has specified the addition of wire or fiber reinforcement to the concrete. The reinforcement materials will be corrosion and radiation resistant.

The staff notes that the use of reinforcement is a departure from normal practice by this applicant. Normally, reinforcement is avoided in structures where the primary purpose is radiation shielding. This is because the presence of reinforcement bar can create unintended voids in the concrete, leading to a deficient radiation shield. However, in the case of the CEC,

the primary shielding is accomplished by the earthen backfill. The purpose of the HI-STORM UMAX concrete encasement is to mitigate any corrosive effects from the soil, not provide for radiation shielding. Thus, use of reinforcement will enhance the corrosion prevention performance of the concrete and not affect the shielding.

8.1.5 Impressed Current Cathodic Protection System (ICCPS)

Where required by soil conditions, an ICCPS will be employed. The initial start-up of the ICCPS must occur within one year after installation of the VVM to ensure timely corrosion mitigation. In addition, the ICCPS should be maintained operable at all times after initial start-up except for system shutdowns due to power outages, repair or preventive maintenance and testing, or system modifications. Because there are a multitude of ISFSI variables that will bear upon the design of the ICCPS for a particular site, the essential criteria for its performance and operational characteristics are established in the FSAR, which the detailed design work for each ISFSI site must follow as required by 10 CFR 72.212(b)(2)(ii)(3).

Finally, the surface preservative used to coat the CEC must meet the requirements described in the FSAR for resistance to environmental conditions and also be compatible with cathodic protection and resistant to the alkaline conditions created by cathodic protection and/or concrete encasement. Organic coatings, such as the Keeler & Long epoxy coating previously specified are inherently compatible with these conditions.

The ICCPS provides reasonable assurance that the aggressive corrosion conditions of some soils will not cause degradation of the CEC (including the bottom plate) to the extent that the CEC structural integrity is challenged, or, allow in-leakage of ground water into the storage cavity. Normally, the ICCPS must remain operational at all times to the extent practicable. Consequently, a monthly surveillance of the ICCPS operation is required (Section B, Bases). Since the cathodic protection system is an active system, consideration of system outages for maintenance or other reasons must be made.

For ICCPS outages, regardless of cause, a limiting condition of operation (LCO) is established which provides a maximum allowable time limit (of 6 months) for a non-functioning ICCPS. Because corrosion in this case is an intrinsically slow process, there is sufficient time available to perform repairs and other corrective actions. In the event that the LCO period is exceeded, the user may opt to demonstrate continued integrity of the affected CEC components by means of an engineering evaluation, including tests. A time period of one year from the initiation of the ICCPS outage is allowed under this option. Other LCO's are imposed by the TS to address other situations regarding the amount of time the ICCPS has been intermittently inoperable over a period of time.

The staff finds that the surveillance and maintenance programs outlined are acceptable for establishing the continued integrity of the CEC, and that appropriate LCO's have been established for the ICCPS.

8.1.6 Other Materials of Construction

The balance of the HI-STORM UMAX Canister Storage System is fabricated from materials which have all been previously evaluated by the staff for their suitability in storage applications. The bill of materials in FSAR drawings and FSAR Chapter 8 provide details of each material type and specification. Since all the materials have been previously reviewed and employed for

staff approved 10 CFR Part 71 transportation CoCs, a brief discussion of materials related findings are summarized below.

8.1.7 Confinement Boundary

The fuel canister confinement is fabricated from one of several ASME grades of austenitic stainless steel, referred to by the applicant as “Alloy X”. Alloy X assumes the least favorable property characteristics from among the several materials grades specified. These properties are use for all design calculations. The purpose is to allow for free interchange of the several grades of stainless steel. This provides the applicant with procurement flexibility while complying with all required design properties. This method of allowing for material substitution has been previously reviewed by the staff and found to be acceptable. The use of austenitic stainless steel also means that the fuel canister is immune to brittle fracture issues.

8.1.8 Gamma and Neutron Shield

The radiation shield (concrete over pack) is composed primarily of un-reinforced concrete with a carbon steel liner plate on the inside. Since the overpack has no structural role, the lack of reinforcing steel is not a detriment. The lack of reinforcing steel is a deliberate exclusion in order to avoid the possibility of interior voids in the concrete which would degrade the shielding performance. This type of construction has been approved by the staff previously and found to be entirely satisfactory in service at numerous installations. For the design service conditions, there are no conditions which will result in a degradation of the materials performance for the duration of the license period. Experience has shown that the materials should easily achieve 40 years of service with no loss of performance or adverse degradation.

8.1.9 Weld Material

All weld filler materials utilized in the welding of the confinement boundary comply with the provisions of the appropriate Code subsection. All non-code welds (e.g. not important to safety) will be made using weld procedures that meet the Code Section IX, AWS D1.1, D.1.2 or equivalent. All non-destructive examinations will comply with Section V of the Code, with acceptance criteria as specified by the code of construction for the specific component.

8.1.10 Chemical, Galvanic, or Other Reactions

The applicant has stated that the MPC is dried and helium backfilled to eliminate any credible corrosion from moisture and oxidizing gasses. Therefore, chemical, galvanic or other reactions involving the cask materials are minimal or unlikely. The staff finds that the applicant has met the requirements of 10CFR 72.236(h). The HI-STORM UMAX MPCs employ materials that are compatible with wet and dry SNF loading and unloading operations and facilities. The staff confirmed the designed features and concluded that these materials will not degrade over time or react with one another during environmental conditions of storage.

8.2 CORROSION MITIGATION

The corrosion mitigation methods described in the FSAR have a support role to an ITS system (the CEC portion of the VVM) and are required as a result of the unique design features and corrosion environment associated with underground structures. Since the ITS portions of the CEC are not normally accessible for routine inspection, certain parameters of the cathodic

protection system are incorporated into the technical specifications. This ensures, through operational monitoring, that the cathodic protection system is performing as designed and thus no degradation of the CEC is occurring. Operational history becomes the alternative to direct inspection, hence the requirement for technical specification control of an otherwise not-safety-related system. In the event of unforeseen questions about the efficacy of the cathodic protection system (or other component of the corrosion mitigation measures) the CEC structure may be examined by means of ultrasonic inspection (UT) from the inside of a CEC cell where there is no fuel canister yet installed, by remote means in a cell where a spent fuel canister is installed, or, a cell from which the canister has been removed to allow inspection.

The staff finds that the applicant has specified in sufficient detail the design and operational parameters for an effective corrosion mitigation program for a range of potential environments. Additionally, operation and control of a cathodic protection system is placed into the technical specifications to ensure reliable operation of this system in the place of a routine inspection of the protected ITS components of the CEC.

8.3 CONCLUSION: (OTHER MATERIALS OF CONSTRUCTION)

Since the materials of construction for the balance of the storage canister have all been previously reviewed for acceptability, and since the conditions of use are unchanged, the staff finds that the materials are acceptable for their specified uses.

The HI-STORM UMAX Canister Storage System and HI-STORM FW Cask System FSARs, Chapter 8, adequately describes the materials used for SSCs ITS and the suitability of those materials for their intended functions is sufficient detail to evaluate their effectiveness.

The applicant has met the requirements of 10 CFR 72.122(a). The material properties of SSCs important to safety conform to quality standards commensurate with their safety function.

The applicant has met the requirements of 10 CFR 72.122(h)(1) and 72.236(h). The design of the DSS and the selection of materials adequately protect the SNF cladding against degradation that might otherwise lead to damaged fuel.

The applicant has met the requirements of 10 CFR 72.236(h) and 72.236(m). The material properties of SSCs ITS will be maintained during normal, off-normal, and accident conditions of operation so the SNF can be readily retrieved without posing operational safety problems.

The applicant has met the requirements of 10 CFR 72.236(g). The material properties of SSCs ITS will be maintained during all conditions of operation so the SNF can be safely stored for the minimum required years and maintenance can be conducted as required.

8.4 EVALUATION FINDINGS

F8.1 The staff concludes the material properties of the structures, systems, and components of the HI-STORM UMAX Canister Storage System are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the material properties provides reasonable assurance the cask 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 code requirements and standards, and accepted engineering practices.

9 OPERATING PROCEDURES EVALUATION

The operating procedures review ensures that the applicant's FSAR presents acceptable operating sequences, guidance, and generic procedures for identified key operations. The review also ensures that the FSARs incorporate and are compatible with the applicable operating control limits in the TS.

9.1 Areas of Review

The HI-STORM UMAX HI-STORM FW FSARs were reviewed and the following operations were acceptably addressed:

Loading Operations

Fuel Specifications
Damaged Fuel
Subcriticality Features
ALARA
Offsite Releases
Draining and Drying
Filling and Pressurization
Welding and Sealing
Administrative Programs

Cask Handling and Storage Operations

Cask Unloading

Damaged Fuel
Cooling, Venting, and Reflooding
Fuel Crud
ALARA
Offsite Release

9.2 Staff Evaluation

The staff concludes that the generic procedures and guidance for operation of the HI-STORM UMAX Canister Storage System are in compliance with 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The evaluation of the operating procedure descriptions provided in the FSARs offer reasonable assurance that the system will enable safe storage of spent fuel. This finding is based on a review that considered the regulations, appropriate regulatory guides, applicable codes and standards, and acceptable practices.

9.3 Evaluation Findings

F9.1 The HI-STORM UMAX Canister Storage System can be wet loaded and unloaded. General procedure descriptions for these operations are summarized in Chapter 9 of the HI-STORM UMAX Canister Storage System and HI-STORM FW Cask System FSARs. Detailed procedures are developed and evaluated by general licensees on a site-specific basis.

F9.2 The bolted closure plate of the overpack and welded MPC allow for ready retrieval of the spent fuel for further processing or disposal as required.

F9.3 The general operating procedures are designed to prevent contamination of the MPCs and facilitate decontamination of the overpack. Routine decontamination will be necessary after the cask is removed from the spent fuel pool.

F9.4 No significant radioactive effluents are produced during storage. Any radioactive effluents generated during the cask loading and unloading will be governed by the 10 CFR Part 50 license conditions.

F9.5 The general operating procedures described in the FSARs are adequate to protect health and minimize danger to life and property. Detailed procedures are developed and evaluated by general licensees at their sites.

F9.6 Section 11 of the SER assesses the operational restrictions to meet the limits of 10 CFR Part 20. Additional site-specific restrictions may also be established by the site licensee.

F9.7 The staff concludes that the generic procedures and guidance for the operation of the UMAX Canister Storage System are in compliance with 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The evaluation of the operating procedure descriptions provided in the FSARs offers reasonable assurance that the cask will enable safe storage of spent fuel. This finding is based on a review that considered the regulations, appropriate regulatory guides, applicable codes and standards, and accepted practices.

10 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The specific discipline acceptance tests and maintenance programs are evaluated by specific disciplines in sections 3 through 8 of this SER. The results of the evaluation are captured in their applicable sections.

11 ACCIDENT ANALYSIS EVALUATION

The specific discipline accident analyses are evaluated in sections 3 through 9 and 11 of this SER. The results of the evaluation are captured in their applicable sections.

12 TECHNICAL SPECIFICATION S AND OPERATING CONTROLS AND LIMITS EVALUATION

12.1 Objective

The technical specifications and operating controls and limits review ensures that the operating controls and limits of the TS, including their bases and justification, meet the requirements of 10 CFR Part 72. The evaluation is based on information provided by the applicant in the HI-STORM Canister Storage System and HI-STORM FW Cask System FSARs Chapter 13 as well as accepted practices and any commitments discussed in other chapters of the FSARs.

12.2 Evaluation Findings

F.12.1 The staff concludes that the conditions for use of the HI-STORM Canister Storage System identify necessary TS to satisfy 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The TS provide reasonable assurance that the cask will provide for 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 practices.

13 QUALITY ASSURANCE EVALUATION

The purpose of this review and evaluation is to determine whether Holtec has a quality assurance (QA) program that complies with the requirements of 10 CFR Part 72, Subpart G. Holtec's QA program has been previously evaluated in the review of the HI-STORM 100 Cask system, CoC No. 1014, and HI-STORM FW System, CoC No. 1032, applications and subsequent amendments.

13.1 Areas Reviewed

QA Organization
QA Program
Design Control
Procurement Document Control
Instructions, Procedures, and Drawings
Document Control
Control of Purchased Material, Equipment, and Services
Identification and Control of Materials, Parts, and Components
Control of Special Processes
Licensee Inspection
Test Control
Control of Measuring and Test Equipment
Handling, Storage, and Shipping Control
Inspection, Test, and Operating Status
Nonconforming Materials, Parts, or Components
Corrective Action
QA Records
Audits

NUREG-1536, Revision 1 provides the criteria for evaluating the above 18 areas. In a number of cases, the description of, or actions to be taken by, personnel involved in quality activities were incorporated by reference to the applicable sections of the Holtec's Quality Assurance Manual (HQAM). It was therefore necessary to review such referenced sections in the HQAM to determine whether the QA program, as submitted, met the requirements of 10 CFR Part 72, Subpart G. While this evaluation determined that the QA program is acceptable, proper implementation of the QA program will be assessed during future NRC inspections.

13.2 Evaluation Findings

F13.1 The QA program describes the requirements, procedures, and controls that, when properly implemented, comply with the requirements of 10 CFR Part 72, Subpart G, and 10 CFR Part 21, Reporting of Defects and Noncompliance.

F13.2 The structure of the organization and assignment of responsibility for each activity ensure that designated parties will perform the work to achieve and maintain specified quality requirements.

F13.3 Conformance to established requirements will be verified by qualified personnel and groups not directly responsible for the activity being performed. These personnel and groups report through a management hierarchy which grants the necessary authority and organizational freedom and provides sufficient independence from economic and scheduling influences.

14 CONCLUSIONS

Based on its review of the application and supporting FSARs, the staff has determined that there is reasonable assurance that: (i) the activities authorized by the HI-STORM Canister Storage System, CoC No. 1040 can be conducted without endangering the health and safety of the public and (ii) these activities will be conducted in compliance with the applicable regulations of 10 CFR Part 72. The staff has further determined that the issuance of the amendment will not be inimical to the common defense and security. Therefore, CoC No. 1040 should be approved.

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