SAFETY EVALUATION REPORT

DOCKET No. 72-1032
HI-STORM FW Cask System
Holtec International, Inc.
Certificate of Compliance No. 1032
Revision No. 1

1 SUMMARY

By letter dated October 13, 2011, May 23, 2012, January 24, April 18, and July 23, 2013, Holtec International, Inc. (Holtec, the applicant) submitted an application to the U.S. Nuclear Regulatory Commission (NRC) to amend the HI-STORM Flood/Wind (FW) system Certificate of Compliance (CoC) No. 1032 under 10 CFR 72 Subpart K, General License for Storage of Spent Fuel at Power Reactor Sites. The applicant requested the changes to CoC No. 1032.

A. Add a new heat load pattern for the multipurpose canister (MPC)-37,
B. Broaden the backfill pressure range for both MPC-37 and MPC-89, and
C. Update certain definitions related to fuel classification.
D. Provide editorial corrections.

The staff also provided the following editorial correction. The applicant agreed with this correction in correspondence dated January 30, 2014.

E. CoC No. 1032 - The expiration date has been corrected from June 12, 2051, to June 12, 2031. The original CoC was issued incorrectly with a 40-year expiration versus a 20-year expiration as specified in 10 CFR 72.214.

During the review process, the NRC determined that the proposed technical specification (TS) changes would be more applicably implemented as a revision to CoC No. 1032, versus a stand-alone amendment. This safety evaluation report (SER) documents the review and evaluation of the proposed revision. The NRC staff (staff) followed the guidance of NUREG-1536, Revision 1, “Standard Review Plan for Dry Cask Storage Systems,” Interim Staff Guidance (ISG) -11, “Cladding Considerations for the Transportation and Storage of Spent Fuel” and ISG-21, “Use of Computational Modeling Software” in performing its regulatory evaluation.

The staff’s assessment is to determine that CoC No. 1032, as revised, continues to meet the applicable requirements of 10 CFR Part 72 for independent storage of spent fuel and of 10 CFR Part 20 for radiation protection.

2 PRINCIPAL DESIGN CRITERIAL EVALUATION

There were no requested changes requiring evaluating the principal design criteria related to the structures, systems, and components (SSCs) important to safety to ensure compliance with the relevant general criteria established in 10 CFR Part 72.

3 STRUCTURAL EVALUATION

The staff determined that the applicants proposed changes A and B required structural evaluation. The staff reviewed the heat load pattern proposal and finds it will have no negative impact in structural performance, as the temperatures and pressures evaluated by the staff in SER Section 4 remain within the previously analyzed bounds. The staff finds that the backfill pressure range proposal also has no negative impact in the cask's structural performance. These findings are substantiated by the values found in the following tables in the final safety analysis report (FSAR): Table 4.4.5 "SUMMARY OF MPC INTERNAL PRESSURES UNDER LONG-TERM STORAGE", Table 4.4.7 "THEORETICAL LIMITS OF MPC HELIUM BACKFILL PRESSURE", and Table 4.4.8 "MPC HELIUM BACKFILL PRESSURE SPECIFICATIONS"; as compared to the design basis limits set forth in Table 2.2.1 "DESIGN PRESSURES". For all cases, the staff confirmed the maximum pressures remain below the design limits.

The staff also finds that the updated definitions related to fuel classification do not affect structural performance of the cask.

13.1 Evaluation Findings

F3.1 The staff reviewed the heat load pattern and backfill pressure range proposals and finds it will have no negative impact in structural performance, as the temperatures and pressures are within the previously analyzed bounds.

F3.2 The staff also finds that the updated definitions related to fuel classification do not affect structural performance of the cask.

4 HI- STORM FW SYSTEM THERMAL EVALUATION

The staff's thermal review ensures that the cask components and fuel material temperatures of the HI-STORM FW cask system continues to remain within the allowable values or criteria for normal, off-normal, and accident conditions. The staff determined that the applicant's proposed changes A and B required thermal evaluation. The evaluation objectives include confirmation that the fuel cladding temperature will continue to be maintained below allowable 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 NRC and industry accepted analytical techniques and/or testing methods. The review was performed using the documents identified in SER Section 1 and 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 structures, systems, and components important to safety can be assessed under the requirements of 10 CFR 72.236(b). This application was also reviewed to determine whether the HI-STORM FW cask system design fulfills the acceptance criteria listed in Sections 2, 4 and 12 of NUREG-1536, Revision 1, as supplemented by the identified ISGs.

The applicant's proposed revisions require staff thermal evaluation.

4.1 Spent Fuel Cladding

The applicant adopted certain guidelines of NRC, "Standard Review Plan for Dry Cask Storage Systems," NUREG-1536, and NRC, 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 Chapter 2 of the FSAR and in the CoC for those aspects relevant to the HI-STORM FW design. The applicant demonstrated that CoC No. 1032 continues to comply with the following requirements:

1. The fuel cladding temperature must meet the temperature limit under normal, off-normal, and accident conditions, appropriate to its burnup level and condition of storage or handling set forth in Table 4.3.1 of the FSAR.

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

3. The temperatures of the cask materials shall remain below their allowable limits set forth in Table 2.2.3 of the FSAR, under all scenarios.

4.2 Thermal Properties of Materials

Material property tables for the HI-STORM FW 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 HI-STORM FW storage overpack include carbon steel and concrete. Materials present in the HI-TRAC VW transfer cask include carbon steel, lead, and demineralized water. 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 with some exceptions that were justified by the applicant. The staff finds the material properties used by the applicant in the thermal analyses of HI-STORM FW acceptable.

4.3 Specifications for Components

HI-STORM FW system materials and components designated as "Important to Safety" (ITS) (i.e., required to be maintained within their safe operating temperature ranges to ensure their intended function) are summarized in Table 2.2.3 of the FSAR. For evaluation of HI-STORM FW thermal performance, material temperature limits for long term normal, short-term operations, and off-normal and accident conditions are provided in Table 4.3.1 of the FSAR. Fuel cladding temperature limits included in Table 4.3.1 of the 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.

4.4 HI-STORM FW Cask System

4.4.1 General Description

The HI-STORM FW storage system consists of a sealed metallic MPC contained within an overpack constructed from a combination of steel and concrete. The HI-STORM FW overpack is equipped with thru-wall penetrations at the bottom of the overpack and in its lid to permit natural circulation of air to cool the MPC and the contained spent nuclear fuel (SNF). To maximize the cooling action of the ventilation air stream, the ventilation flow path is optimized to minimize hydraulic resistance. The HI-STORM FW features eight inlet ducts. Each duct is narrow and tall and of an internally refractive contour which minimizes radiation streaming while optimizing the hydraulic resistance of airflow passages. The MPC enclosure vessels are cylindrical weldments with identical (fixed) outside diameters. Each MPC is an assembly consisting of a honeycomb fuel basket, a baseplate, a canister shell, a lid, and a closure ring. The number of spent nuclear fuel storage locations in an MPC depends on the type of fuel assembly (pressurized water reactor (PWR) or boiling water reactor (BWR)) to be stored in it.

The HI-TRAC VW transfer cask is principally made of carbon steel and lead. The cask consists of two major parts, namely (a) a multi-shell cylindrical cask body, and (b) a quick connect/disconnect bottom lid. The cylindrical cask body is made of three concentric shells joined to a solid annular forging (top flange) and a solid annular plate (bottom flange) by circumferentially continuous welds. The innermost and the middle shell are fixed in place by longitudinal connector ribs which serve as radial connectors between the two shells. The radial connectors provide a continuous path for radial heat transfer and render the dual shell configuration into a stiff beam under flexural loadings. The space between these two shells is occupied by lead, which provides the bulk of the transfer cask's gamma radiation shielding capability. Between the middle shell and the outermost shell is the weldment that is referred to as the "water jacket". The water jacket is filled with water (or ethylene glycol fortified water, depending on the host site's environmental conditions) which provides most of the neutron shielding capability to the cask. The water jacket is outfitted with pressure relief devices to prevent over pressurization in the case of an abnormal event that causes the water mass inside of it to boil.

4.4.2 Design Criteria

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

1. The thermal acceptance criteria for spent nuclear fuel (SNF) 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 SNF 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.

The thru-thickness temperature limits for the plain concrete in the overpack for long term and short term temperatures are set identical to those in the HI-STORM 100 FSAR (see FSAR

Table 2.2.3). The allowable temperatures for the structural steel components are based on the maximum temperature for which material properties and allowable stresses are provided in Section II of the American Society of Mechanical Engineers (ASME) Code. The specific allowable temperatures for the structural steel components of the overpack are provided in FSAR Table 2.2.3. The overpack is designed for extreme cold conditions, as discussed in FSAR Subsection 2.2.2. The brittle fracture assessment of structural steel materials used in the storage cask is considered in FSAR Section 3.1. The overpack is designed to dissipate the maximum allowable heat load (shown in Tables 1.2.3 and 1.2.4 of the FSAR) from the MPC.

The allowable temperatures for the HI-TRAC VW transfer cask structural steel components are based on the maximum temperature for material properties and allowable stress values provided in Section II of the ASME Code. The allowable temperatures for the structural steel and shielding components of the HI-TRAC VW are provided in Table 2.2.3 of the FSAR. The HI-TRAC VW is designed for off-normal environmental cold conditions, as discussed in Subsection 2.2.2 of the FSAR. The HI-TRAC VW is designed and evaluated for the maximum heat load analyzed for storage operations. The maximum allowable temperature of water in the HI-TRAC jacket is a function of the internal pressure. To preclude overpressurization of the water jacket due to boiling of the neutron shield liquid (water), the maximum temperature of the water is restricted to be less than the saturation temperature at the shell design pressure.

4.4.3 Design Features

The design features of the HI-STORM FW components are intended to simplify and reduce the on-site SNF loading and handling work effort, to minimize the burden of in-use monitoring, to provide utmost radiation protection to the plant personnel, and to minimize the site boundary dose. The HI-STORM FW overpack is stored at the ISFSI pad in a vertical orientation, which helps minimize the size of the ISFSI and leads to an effective natural convection cooling flow around the exterior and also in the interior of the MPC. The HI-STORM FW overpack features an inlet and outlet duct configuration engineered to mitigate the sensitivity of wind direction on the thermal performance of the system. More specifically, the HI-STORM FW overpack features a radially symmetric outlet vent (located in its lid) and inlet ducts arranged at 45-degree intervals in the circumferential direction to approximate an axisymmetric opening configuration, to the extent possible. A number of design measures are taken in the HI-STORM FW system to limit the fuel cladding temperature rise under a most adverse flood event (i.e., one that is just high enough to block the inlet duct):

1. The overpack's inlet duct is narrow and configured to block radiation efficiently even if the radiation emanating from the MPC is level (coplanar) with the duct penetration, therefore the MPC is not raised on a pedestal, which will allow floodwater to immediately come in contact with the bottom of the MPC and assist the ventilation air flow in cooling the MPC.

2. The overpack's inlet duct is tall and the MPC stands on the overpack's baseplate, which is welded to the overpack's inner and outer shells. Thus, if the flood water rises high enough to block air flow through the inlet ducts, substantial surface area of the lower region of the MPC will be submerged in the water. Although heat transfer from the exterior of the MPC through air circulation is limited in such a scenario, the reduction is offset by convective cooling through the floodwater itself.

3. The MPCs are equipped with internal thermosiphon capability, which brings the heat emitted by the fuel back to the bottom region of the MPC as the circulating helium flows

along the downcomer space around the fuel basket. This thermosiphon action places the heated helium in close thermal communication with the floodwater, further enhancing convective cooling via the floodwater.

To ensure the permissible peak cladding temperature (PCT) limits are not exceeded, FSAR Subsection 1.2 specifies the maximum allowable decay heat per assembly for each MPC model in the three-region configuration. The following tables summarize the heat load data for MPC-37 and MPC-89.

MPC-37 Heat Load Data – Pattern A1			
Number of Regions: 3			
Number of storage cells: 37			
Maximum Heat Load: 44.05 kW			
Region Number	Decay Heat Limit per Cell, kW	Number of Storage Cells per Region	Decay Heat Limit per Region, kW
1 (inner)	1.05	9	9.45
2 (Middle)	1.70	12	20.40
3 (outer)	0.89	16	14.20

MPC-37 Heat Load Data – Pattern B1			
Number of Regions: 3			
Number of storage cells: 37			
Maximum Heat Load: 45.00 kW			
Region Number	Decay Heat Limit per Cell, kW	Number of Storage Cells per Region	Decay Heat Limit per Region, kW
1 (inner)	1.00	9	9.00
2 (Middle)	1.20	12	14.40
3 (outer)	1.35	16	21.6

MPC-89 Heat Load Data			
Number of Regions: 3			
Number of storage cells: 89			
Maximum Heat Load: 46.36 kW			
Region Number	Decay Heat Limit per Cell, kW	Number of Storage Cells per Region	Decay Heat Limit per Region, kW
1	0.44	9	3.96
2	0.62	40	24.80
3	0.44	40	17.60

The staff finds the description, design criteria, and design features of the HI-STORM FW design as described in the applicant's FSAR acceptable.

4.5 HI-STORM FW System Thermal Model

The applicant used FLUENT program to evaluate the thermal performance of the HI-STORM FW spent fuel 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 has the following key attributes:

1. The Metamic-HT fuel basket is modeled in the same manner as the model described in the HI-STAR 180 FSAR. Fuel storage spaces are modeled as porous media.

2. In the case of a boiling water reactor (BWR) SNF, the fuel bundle and the small surrounding spaces inside the fuel "channel" are replaced by an equivalent porous media having the flow impedance properties computed using a three dimensional (3-D) CFD model. The space between the BWR fuel channel and the storage cell is represented as an open flow annulus. The fuel channel is also explicitly modeled. The channeled space within is also referred to as the "rodded region" that is modeled as a porous medium. The fuel assembly is assumed to be positioned coaxially with respect to its storage cell. In the case of the PWR SNF, the porous medium extends to the entire cross-section of the storage cell. The CFD model for both the BWR and PWR flow resistance calculations is prepared for the design basis fuel defined in Table 2.1.4 of the FSAR in comprehensive detail, which includes grid straps, BWR water rods and PWR guide and instrument tubes (assumed to be plugged for conservatism).

3. Every MPC fuel storage cell is assumed to be occupied by design basis PWR or BWR fuel assemblies specified in Chapter 2 (FSAR Table 2.1.4). The in-plane effective thermal conductivity of the design basis fuel assembly is obtained using ANSYS finite element models of an array of fuel rods enclosed by a square box. Radiation heat transfer from solid surfaces (cladding and box walls) is enabled in these models. Using these models the effective conduction-radiation conductivities are obtained and reported in FSAR Table 4.4.1. For heat transfer in the axial direction an area weighted mean of cladding and helium conductivities are computed. Axial conduction heat transfer in the fuel pellets and radiation heat dissipation in the axial direction are conservatively ignored. Thus, the thermal conductivity of the rodded region, like the porous media simulation for helium flow, is represented by a 3-D continuum having effective planar and axial conductivities.

4. The internals of the MPC, including the basket cross-section, aluminum shims, bottom flow holes, top plenum, and circumferentially irregular downcomer formed by the annulus gap in the aluminum shims are modeled explicitly. For simplicity, the flow holes are modeled as rectangular openings with an understated flow area.

5. The inlet and outlet vents in the HI-STORM FW overpack are modeled explicitly to incorporate any effects of non-axisymmetry of inlet air passages on the system's thermal performance.

6. The air flow in the HI-STORM FW/MPC annulus is simulated by the k-ω turbulence model with the transitional option enabled.

7. A limited number of fuel assemblies (up to 12 in MPC-37 and up to 16 in MPC-89) classified as damaged fuel are permitted to be stored in the MPC inside damaged fuel

containers (DFCs). A DFC can be stored in the outer peripheral locations of both MPC-37 and MPC-89 as shown in FSAR Figures 2.1.1 and 2.1.2, respectively. DFC emplaced fuel assemblies have a higher resistance to helium flow because of the debris screens. However, DFC fuel storage does not affect temperature of hot fuel stored in the core of the basket because DFC storage is limited by TS for placement in the peripheral storage locations away from hot fuel. For this reason the thermal modeling of the fuel basket under the assumption of all storage spaces populated with intact fuel is justified.

8. As shown in HI-STORM FW drawings in FSAR Section 1.5, the HI-STORM FW overpack is equipped with a heat shield to protect the inner shell and concrete from radiation heating by the emplaced MPC. The heat shield, inner and outer shells and concrete are explicitly modeled.

The staff finds the description HI-STORM FW thermal models acceptable because they are consistent with NUREG 1536, Revision 1, ISG-11 and ASME guidelines.

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, 4.4.3 and 4.4.5 provide key thermal and pressure results. From the presented results it can be concluded that that the temperature field in the HI-STORM FW system with a loaded MPC containing heat emitting SNF complies with all regulatory temperature limits (FSAR Table 2.2.3). In other words, the thermal environment in the HI-STORM FW system is in compliance with FSAR Chapter 2 design Criteria. Per FSAR Chapter 3, all HI-STORM FW storage overpack 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 FW 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.

FSAR Table 4.4.4 presents a summary of the MPC free volumes determined for the fixed height MPC-89 and lowerbound height MPC-37 fuel storage scenarios. The applicant calculated the MPC maximum gas pressure for a postulated release of fission product gases from fuel rods into this 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 4.4.5. The maximum computed gas pressures reported in FSAR Table 4.4.5 are all below the MPC internal design pressures for normal, off-normal and accident conditions specified in FSAR Table 2.2.1.

4.7 Thermal Evaluation for Short-Term Operations

Prior to placement in a HI-STORM FW overpack, an MPC must be loaded with fuel, outfitted with closures, dewatered, dried, backfilled with helium and transported to the HI-STORM FW module. If the fuel needs to be returned to the spent fuel pool, these steps must be performed in reverse. Finally, if required, transfer of a loaded MPC between HI-STORM FW overpacks or between a HI-STAR transport overpack and a HI-STORM FW storage overpack must be carried out in a safe manner. All of the above operations are short duration events that would likely occur no more than once or twice for an individual MPC.

4.7.1 Drying

4.7.1.1 Vacuum

The vacuum drying option is evaluated for the two limiting scenarios defined in FSAR Section 4.5.2.2 to address moderate burnup fuel under design basis heat load and high burnup fuel under threshold heat load defined in FSAR Table 4.5.1. The principle objective of the analysis is to ensure compliance with ISG-11 temperature limits. For this purpose the applicant developed 3-D FLUENT thermal models of the MPC-37 and MPC-89 canisters, as described in FSAR Section 4.5.2.2 and bounding steady state temperatures computed. The results are tabulated in FSAR Tables 4.5.6 and 4.5.7. The results show that the cladding temperatures comply with the ISG-11 limits for moderate and high burnup fuel in FSAR Table 4.3.1 by adequate margins.

4.7.1.2 Forced Helium Dehydration

The Forced Helium Dehydration (FHD) system provides concurrent fuel cooling during the moisture removal process through forced convective heat transfer. The attendant forced convection-aided heat transfer occurring during operation of the FHD system ensures that the fuel cladding temperature will remain below the applicable peak cladding temperature limit in FSAR Table 2.2.3.

4.7.2 On-Site Transfer

The applicant evaluated an MPC-37 situated inside a HI-TRAC VW under the design heat load defined in FSAR Section 1.2. The MPC-37 is evaluated because it yields the highest fuel and cask temperatures (per FSAR Table 4.4.2). This scenario is analyzed using the same 3-D FLUENT model of the MPC-37 described in FSAR Section 4.4 for normal storage inside the HI-TRAC VW transfer cask. The applicant's approach is to assume steady state maximum temperatures are reached. The results of thermal analyses tabulated in FSAR Table 4.5.2 show that the cladding temperatures are below the ISG-11 temperature limits of High and Moderate Burnup Fuel (FSAR Table 4.3.1). Under HI-TRAC VW operations, the bulk temperature of water in the water jacket surrounding the HI-TRAC VW body remains below the temperature limit specified in FSAR Table 2.2.3.

4.8 Off-Normal and Accident Events

4.8.1 Off-Normal Events

The applicant considered three off-normal events: off-normal pressure, off-normal environmental temperature, and partial blockage of air inlets. The MPC off-normal pressures are reported in FSAR Table 4.6.7. The result is below the off-normal design pressure (FSAR Table 2.2.1). The off-normal temperature results are provided in FSAR Table 4.6.1. The results are below the off-normal condition temperature and pressure limits (FSAR Tables 2.2.3 and 2.2.1). 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 4.6.7. The staff the applicant's results to be below the temperature and pressure limits (FSAR Table 2.2.3 and 2.2.1) for off-normal conditions and, therefore, finds this acceptable.

4.8.2 Accident Events

The applicant considered five accident events: fire, jacket water loss, extreme environmental temperatures, 100% blockage of air ducts, and burial under debris. Accident analyses results are provided in FSAR Tables 4.6.2, 4.6.3, 4.6.4, 4.6.5, 4.6.6, and 4.6.7. All predicted maximum temperatures and pressures remain below the accident limits defined in FSAR Table 2.2.1 (accident design pressure) and Table 2.2.3 (accident temperature limit).

The staff finds the description, assumptions, and analysis results of normal, off-normal and accident events acceptable since the applicant followed the guidelines of NUREG-1536, Revision 1, as supplement by the previously referenced ISGs.

4.9 Thermal Tests

HI-STORM FW thermal tests are described in FSAR Chapter 9. Per Condition No. 8 of the CoC, the first user of a specific canister will perform an annular air flow thermal test to measure and confirm the mass flow rate predictions obtained by applying FSAR Chapter 4 thermal models. Also, as described in FSAR Chapter 10, the first manufactured HI-STORM FW MPC will be thermally tested to confirm the thermal models described in FSAR Chapter 4 to provide additional confirmation of the applicant's thermal model results and conclusions.

The staff found description of the thermal tests acceptable as they provided additional assurance of the thermal performance of the HI-STORM FW cask system predicted by CFD analyses.

4.10 Confirmatory Analyses

The staff reviewed the applicant's models and calculation options to determine the adequacy of the HI-STORM FW thermal design. Additionally, the staff performed selected confirmatory analyses using the FLUENT finite volume CFD code, as an independent evaluation of the thermal analysis and modeling options presented in the applicant's FSAR. 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 the thermal-hydraulic experiment data indicates that a fuel assembly viscous resistance factor of about a million would match the thermal-hydraulic experimental data obtained by SNL. In order to comply with the thermal limits and show adequate margin, the applicant performed the CFD analysis for transfer and storage conditions using the higher flow resistance factor. Heat load limits provided in SER Section 4.4.3 were determined by the applicant to be the maximum heat load permitted during storage and transfer operations.

4.11 Evaluation Findings

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

F4.2 The CoC No. 1032 continues to be 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 continues to be 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 continues to be 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 CoC No. 1032 remains 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 CoC No. 1032 will continue to provide safe storage of spent nuclear 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

The applicant did not propose any changes that affect the staff's confinement evaluation provided in the SER supporting the staff's CoC No. 1032 issued June 13, 2011. Therefore, the staff determined that a new evaluation was not required.

6 SHIELDING EVALUATION

The objective of the shielding review is to evaluate the effect of the three proposed changes to the shielding design and TS affected by the revision request to ensure the HI-STORM FW Cask System continues to meet regulatory requirements of 10 CFR Part 72 for external radiation during normal operations, off-normal, and design-basis accident (DBA) conditions.

This change to the CoC is proposed to allow more flexibility to users of the HI-STORM FW Cask System. As part of the previous revision, the MPC-37 was authorized to have up to 37 PWR assemblies loaded into a cask where higher decay heat assemblies were restricted to the two innermost zones of the MPC (Pattern A). This restricted the placement of higher decay heat assemblies into the periphery positions of the cask; taking credit for the self-shielding provided by the lower decay heat assemblies. However, this proposed revision allows storage of higher decay heat PWR assemblies into periphery locations (Pattern B).

Changes were also made to extend "undamaged fuel" to include low enriched and channeled BWR with potential cladding defects larger than pinhole leaks or hairline cracks but without gross breaches, and to clarify that repaired or reconstituted assemblies are also covered by the undamaged fuel definition.

To support the proposed changes as part of this revision, changes were made to the definitions and operational portions of TS and to portions of the CoC.

6.1 Description of Shielding Design

The HI-STORM FW MPC Storage System consists of an interchangeable multipurpose canister containing fuel, a storage overpack (HI-STORM FW) which contains the MPC during storage, and a transfer cask (HI-TRAC VW) which contains the MPC during loading, unloading, and transfer operations.

The MPC is a welded, cylindrical canister with a honeycombed fuel basket. The MPC utilizes a three-region loading configuration for the storage of fuel and is designed to provide confinement for the fuel while in storage. The MPC-37 and MPC-89 contain a maximum of 37 PWR and 89 BWR assemblies, respectively. The MPC-37 is currently authorized to store fuel using a "Pattern A" loading configuration, which restricts higher decay heat assemblies to the two innermost regions of the MPC. This allows the applicant to credit self-shielding provided by the lower decay heat assemblies located in the periphery positions in the outermost region of the MPC-37. However, as part of this revision request, the applicant proposed an additional "Pattern B" loading configuration for the MPC-37 that would allow the higher decay heat assemblies to be stored in the periphery locations (outermost region) of the MPC-37. The changes in the loading pattern proposed in this revision only impact PWR fuel placed in the MPC-37.

The HI-TRAC VW is a transfer cask used to provide shielding and structural protection during loading, unloading, and transfer operations. The HI-TRAC VW is a carbon steel/lead/carbon steel multi-walled cylindrical vessel with a neutron shield jacket attached to the exterior surface.

The HI-STORM FW overpack consists of a storage unit used to provide shielding and structural protection for the MPC while in storage. The outer wall of the overpack consists of un-reinforced concrete placed between carbon steel shells.

6.2 Source Specification

The methodology used to determine the design basis source specifications for bounding calculations, as presented in Section 5.2 of the FSAR were not changed as a result of this revision. The neutron and gamma source terms, decay heat values, and quantities of radionuclides available for release were calculated with the SAS2H and ORIGEN-S modules of the SCALE5 system.

Section 5.1 of the FSAR identifies that Pattern B, having the higher decay heat assemblies in the periphery locations, would yield the highest dose rates on the surface of the cask.

The methodology used to determine the design basis fuel assemblies used in the evaluation is discussed in detail in Subsection 5.2.5 of the FSAR. In performing the SAS2H and ORIGEN-S calculations, a single full power cycle was used to achieve the desired burnup. This assumption, in conjunction with the above-average specific powers listed in Table 5.2.1 ensures that source term calculations used by the applicant are conservative since using average powers would result in a lower source term.

6.2.1 Gamma Source

The applicant specifies that the gamma source term was comprised of three distinct sources. The first was a gamma source term from the active fuel region due to decay of fission products. The second source term was due to the Co^{60} activity of the stainless steel structural material in the fuel element above and below the active fuel region. The third source was from (n,γ) reactions described below. Table 5.2.1 of the FSAR provides a description of the design basis fuel used for the source term calculations.

The gamma source in MeV/s and photons/s as calculated with SAS2H and ORIGEN-S for the design basis Zircaloy clad fuel at the burnups and cooling times used for normal and accident conditions were provided in FSAR Tables 5.2.2 through 5.2.5. All photons with energies in the range of 0.45 to 3.0 MeV were included in the shielding calculations. In FSAR Section 5.2.1 the applicant referenced previous analyses that were performed for the HI-STORM 100 system to justify the determination of gamma contributions as a function of energy. In these analyses it was determined that due to the magnitude of the gamma sources at lower energies, photons with energies as low as 0.45 MeV must be included in the shielding analysis, but photons with energies below 0.45 MeV are too weak to penetrate the HI-STORM overpack or HI-TRAC. The effect of gammas with energies above 3.0 MeV, on the other hand, was found to be insignificant. This is due to the fact that the source of gammas in this range is extremely low.

6.2.2 Neutron Source

In order to obtain conservative source terms, the applicant used low initial fuel enrichments of 3.2 wt% and 3.6 wt%, as shown in FSAR Table 5.0.1, for the BWR and PWR design basis fuel assemblies under normal conditions, respectively. For the accident conditions, a fuel enrichment of 4.8 wt% was chosen to accommodate the higher burnups of the selected source terms, as shown in FSAR Table 5.0.2. The neutron source calculated for the design basis fuel assemblies for the MPCs and the design basis fuel are listed in Tables 5.2.11 through 5.2.14 in neutrons/s for the selected burnup and cooling times used in the shielding evaluations for normal and accident conditions. The neutron spectrum was generated using ORIGEN-S.

Staff reviewed the source term analyses described in the FSAR and determined the methodology used to be acceptable. Sample input files for SAS2H and ORIGEN-S were provided in Appendix 5.A of the FSAR.

6.3 Shielding Model Specifications

The shielding analysis of the HI-STORM FW system was performed with MCNP5. The HI-STORM FW shielding and source configuration is described in FSAR Sections 5.3 and 5.4. The shielding evaluation described in the previous application for the HI-STORM FW system was used in the same manner for this revision with the following exception. The “Pattern B” loading configuration was determined to be the most reactive configuration, and was thus used in place of the “Pattern A” configuration for the normal and accident conditions of the shielding evaluation. FSAR Section 5.4 specifies that although the bounding configuration (Pattern B) allows higher decay heat assemblies in the periphery positions, that a uniform loading pattern is modeled in the shielding analyses. Staff determined that the assumption of a uniform loading configuration in the model based on assemblies with higher decay heat values (Pattern B) is conservative. A sample ORIGEN-S input file used for the source strength corresponding to the bounding configuration (Pattern B) at a 4.5 year cooling time was provided in Appendix 5.A of the FSAR.

6.4 Staff Evaluation

Staff reviewed the source term analyses and the methodology for assuring that the design basis fuel was, in fact, bounding, as discussed in Section 5 of the FSAR. The applicant’s analyses were performed utilizing NUREG 1536, Revision 1, guidance as supplemented by ISGs. Staff also reviewed the methodology used in the shielding evaluation of the HI-STORM FW overpack and the HI-TRAC VW transfer cask. Staff determined that dose calculations corresponding to normal and accident conditions were acceptable as they remained below 10 CFR Part 20 limits. Staff has reasonable assurance that compliance with 10 CFR Part 20 and 10 CFR 72.104(a) from direct radiation can be achieved by general licensee users. The actual doses to individuals beyond the controlled area boundary depend on several site specific conditions such as fuel characteristics, cask-array configurations, topography, demographics, and distances. In addition, 10 CFR 72.104(a) includes doses from other fuel cycle activities, such as reactor operations. 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 (i.e., loading, unloading, and transport) for the FW system. Thus, each user may be required to take additional as low as reasonably achievable (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 72.26. Staff also reviewed the accident evaluation and determined it to be acceptable for the proposed loading configurations requested in the application.

6.5 Evaluation Findings

Based on the NRC staff's review of information provided for the HI-STORM FW 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 FW continue to be sufficient to meet the radiation protection requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106.

F6.3 The staff finds the design acceptably addresses construction activities involving excavation (for ISFSI expansion) adjacent to the (operating) FW 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.

F6.4 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 FW shielding features are designed to satisfy these requirements.

F6.5 The staff concludes that the design of the radiation protection system ensures the revised HI-STORM FW cask system can continue to be operated in compliance with 10 CFR Part 20 and 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied.

7 CRITICALITY EVALUATION

As part of the current revision, the applicant is proposing an additional loading configuration (Pattern B) to be stored in the HI-STORM FW cask storage system. The criticality evaluation does not credit any of the different heat load combinations, and thus is not impacted as a result of the proposed revision. The criticality evaluation approved as part of the previous application remains valid for this revision.

8 MATERIALS EVALUATION

The staff has reviewed the proposed definition changes and or additions for UNDAMAGED FUEL ASSEMBLY, GROSSLY BREACHED FUEL SPENT FUEL ROD, AND REPAIRED/RECONSITUTED FUEL ASSEMBLY and found them to be acceptable. The staff determined that they were consistent with NUREG 1536, Revision 1, guidance.

9 OPERATING PROCEDURES EVALUATION

The applicant did not propose any changes that affect the staff's operating procedures evaluation provided in the SER supporting the staff's CoC No. 1032 issued June 13, 2011. Therefore, the staff determined that a new evaluation was not required.

10 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The applicant did not propose any changes that affect the staff's acceptance tests and maintenance program evaluation provided in the SER supporting the staff's CoC No. 1032 issued June 13, 2011. Therefore, the staff determined that a new evaluation was not required.

11 RADIATION PROTECTION

The objective of the radiation protection review is to evaluate the effect of the three proposed changes to the shielding design and TS affected by the revision request to ensure the HI-STORM FW Cask System continues to meet regulatory requirements. The description of system designs and requirements utilized to ensure ALARA were outlined in Section 11.1 and 11.2 of the SAR. Staff reviewed the estimated exposures for certain surveillance and maintenance activities. Staff determined that the methodology used in the previous version of the application was not impacted as a result of the proposed changes in this revision. However, the applicant did revise Table 11.3.2 to include the exposure effects considering a Pattern B loading configuration.

11.1 Evaluation Findings

Based on the staff's review of information provided for the HI-STORM FW revision application, the staff finds the following:

F11.1 The HI-STORM FW provides radiation shielding and confinement features that are sufficient to meet the requirements of 10 CFR 72.104 and 72.106.

F11.2 The design and operating procedures of the HI-STORM FW provide acceptable means for controlling and limiting occupational radiation exposures within the limits given in 10 CFR Part 20 and for meeting the objective of maintaining exposures ALARA.

12 ACCIDENT ANALYSIS EVALUATION

The applicant did not propose any changes that affect the staff's accident analysis evaluation provided in the SER supporting the staff's CoC No. 1032 issued June 13, 2011. Therefore, the staff determined that a new evaluation was not required.

13 TECHNICAL SPECIFICATIONS AND OPERATING CONTROLS AND LIMITS EVALUATION

13.1 Objective

The TS 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 FW FSAR Chapter 13 as well as accepted practices and any commitments discussed in other chapters of the FSAR or other subsequent correspondence.

The applicant proposed TS revisions are:

1. Appendix A, Table 3-2; updated to reflect the backfill requirements for MPC-37 Pattern B. (Proposed Changes A and B)

2. Appendix B, Section 2.3; MPC-37 "Pattern B" decay heat limits for the cells/regions/total MPC are added to Table 2.3-1. (Proposed Change A)

3. Appendix A; Modify definition of UNDAMAGED FUEL ASSEMBLY. Add definition of GROSSLY BREACH SPENT FUEL ROD and REPAIRED/RECONSTITUTED FUEL ASSEMBLY. This is to extend undamaged fuel to include low enriched and channeled BWR with potential cladding defects larger than pinhole leaks or hairline cracks but without gross breaches, and to clarify that repaired or reconstituted assemblies are also covered by the undamaged fuel definition. (Proposed change C)

4. Appendix B, Table 2.1-3; Note 14 is added. (Proposed change C)

The staff reviewed the proposed TS revisions against the applicant's proposed changes and determined that they are consistent and acceptably reflect the proposed revisions.

13.2 Evaluation Findings

F.13.1 The staff concludes that the conditions for use of the HI-STORM FW 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.

14 QUALITY ASSURANCE EVALUATION

The applicant did not propose any changes that affect the staff's quality assurance evaluation provided in the SER supporting the staff's CoC No. 1032 issued June 13, 2011. Therefore, the staff determined that a new evaluation was not required.

15 CONCLUSION

Based on its review of revision request No. 1 to CoC No. 1032, the staff has determined that there is reasonable assurance that: (i) the activities authorized by the revised certificate 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 revision will not be inimical to the common defense and security. Therefore, the revision should be approved.

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