PRELIMINARY SAFETY EVALUATION REPORT

DOCKET NO. 72-1032
HOLTEC INTERNATIONAL
HI-STORM FLOOD/WIND
MULTIPURPOSE CANISTER STORAGE SYSTEM
CERTIFICATE OF COMPLIANCE NO. 1032
AMENDMENT NO. 6

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UNITED STATES
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SUMMARY

This safety evaluation report (SER) documents the U.S. Nuclear Regulatory Commission (NRC) staff's (staff) review and evaluation of the request to amend Certificate of Compliance (CoC) No. 1032 for the **H**oltec **I**nternational **Stor**age **M**odule (HI-STORM) **F**lood and **W**ind (FW) Multipurpose Canister (MPC) Storage System (hereafter HI-STORM FW system) submitted by Holtec International (Holtec, or applicant) by letter dated October 2, 2019 (Holtec, 2019b), and supplemented on June 30, 2020 (Holtec, 2020a), December 21, 2020 (Holtec, 2020b), August 2, 2021 (Holtec, 2021b), and November 29, 2021 (Holtec, 2021c) (the application,[1] thereafter). Holtec proposed the changes described in table 1 of this SER.[2]

Table 1. Descriptions and reasons for the proposed changes (Holtec, 2019b)

Proposed change No.	Brief description of the change	Reason
1	Add anchored configuration for the HI-STORM FW overpack.	Prevent cask tip over during seismic events at sites where a free-standing overpack would otherwise overturn or slide.
2	Allow use of non-single failure proof lifting equipment during handling of heavy loads within the 10 CFR Part 72 jurisdictional boundary.	Allow use of the HI-STORM FW system at sites without single failure proof lifting equipment.
3	Revise LCO 3.1.2, "SFSC Heat Removal System Operability," to allow an engineering evaluation to be performed in lieu of transferring the MPC into a transfer cask.	Add the option for analysis in lieu of transferring the MPC under LCO 3.1.2, Condition C. Per the applicant, allowing this option eliminates burden on the site using the HI-STORM FW system.
4	Revise the Radioactive Effluent Control Program to no longer require annual submittal of a separate radioactive effluent report [10 CFR 72.44(d)(3)] for the HI-STORM FW system.	Eliminating a separate annual report. Per the applicant, allowing this option eliminates burden on the site using the HI-STORM FW system.
5	Revise the allowable contents for the MPC-37, -89, and -32ML to clarify that fuel debris permitted for storage does not need to meet all of the dimensional requirements and characteristics in tables 2.1-2 and 2.1-3, provided that requirements in table 2.1-1 are met.	Allow fuel debris, currently present at prospective storage sites, to be stored in the HI-STORM FW system.
6	Revise "Design Features the MPC-37, -89, and -32ML basket Design Features to clarify that the minimum cell ID and minimum cell wall thickness are nominal dimensions."	Clarifying that the minimum cell ID and cell wall thickness are nominal dimensions to be consistent with the currently approved testing and acceptance for the basket panels. Per the applicant, this change would also clarify that local deviations from the basket ID and cell wall thickness may be possible.

[1] All the documents listed on the first paragraph above including proposed changes to, as well as different versions of, the final safety analysis report (FSAR) related to this action request are referred as "the application" in this preliminary safety evaluation report (PSER).

[2] This document is known as the PSER when it is issued in the direct final rule package. When the rulemaking process is finalized, this document becomes the FSER. In the text the PSER and FSER are referred as SER for simplification purposes.

The staff evaluated the proposed changes to the CoC and its appendices. This revised CoC, when codified through rulemaking, will be denoted as Amendment No. 6 to CoC No. 1032. This SER documents the staff's review and evaluation of the proposed amendment. The staff followed the guidance in NUREG-2215, "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities – Final Report," April 2020 (NRC, 2020a). The staff's evaluation is based on a review of Holtec's application and supplemental information to determine whether it meets the applicable requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," for dry storage of spent nuclear fuel. The staff's evaluation focused only on modifications requested in the proposed amendment and did not reassess previous revisions of the FSAR[3] nor previous amendments to the CoC that are not impacted by the proposed amendment. The staff also included additional clarifications and editorial and minor changes. These corrections, which are of an administrative or editorial nature, do not change the substantive technical information of the CoC.

1.0 GENERAL INFORMATION EVALUATION

The purpose of the review is to ensure that the applicant has provided in its documentation for the spent fuel storage system a non-proprietary description, or overview, that is adequate to familiarize reviewers and other interested parties with the pertinent features of the system. The HI-STORM FW cask storage system is designed to store spent fuel and allows for the storage of spent nuclear fuel at an independent spent fuel storage installation (ISFSI) under the general license provisions of 10 CFR Part 72. The HI-STORM FW has been previously certified by the NRC under docket number 72-1032 as well as the previous six amendments.

In chapter 1, "General Description," of the application, the applicant proposed adding information related to the proposed anchored cask configuration, HI-STORM FW, Version E, anchored cask. The applicant also proposed adding a definition for "Drop Postulate Exempt (or DPE)" in the "Glossary" section of the application.

The staff finds that the description of the proposed anchored cask configuration, HI-STORM FW, Version E, and changes related to this requested action are adequate to allow staff's detailed evaluation as documented in other sections of this SER.

2.0 PRINCIPAL DESIGN CRITERIA EVALUATION

The objective of evaluating the principal design criteria related to structures, systems, and components (SSCs) important to safety is to ensure that the principal design criteria comply with the relevant general criteria established in the requirements in 10 CFR Part 72.

In addition to chapter 1 of the application, the applicant also proposed to revise chapter 2, "Principal Design Criteria," to add the HI-STORM FW, variant of Version E anchored cask, and supporting information for the analysis of this new configuration. The application also includes applicable criteria related to the proposed changes briefly described in table 1 of this SER.

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[3] When referring to FSARs related to previous amendments of the Model No. HI-STORM FW or other storage systems, the staff uses the term FSAR. The term "FSAR" is also used in section 17.0, "Technical Specifications," of this SER, since technical specifications (TSs) reference specifically the FSAR pertaining the application for amendment 6 of the HI-STORM FW.

The "Version E" overpack is a variant of the standard HI-STORM FW overpack with an alternate design of the thru-wall penetrations at the bottom of the overpack, and this version uses a designated lid ("Version E lid") which is similar to the Version XL lid that was approved in Amendment 5 (NRC, 2020c). The Version E lid of the HI-STORM FW has eight angled inlet ventilation ducts. This differs from the standard HI-STORM FW lid, in which these ducts are straight horizontal channels. The anchored overpack variant differs from the HI-STORM Version E overpack, currently described in the application for the HI-STORM FW, Amendment No. 6, as follows:

1) a baseplate with bolting holes extends from the bottom of the cask and

2) anchorage hardware secures the baseplate to the ISFSI pad.

The applicant evaluated Version E of the HI-STORM FW using the 10 CFR 72.48 process and included it in their biennial 10 CFR 72.48 update dated February 28, 2020 (ML20059K551) [i.e., between Amendment Nos. 5 (NRC, 2020c) and 6 to the CoC of the HI-STORM FW cask system]. Usually, the staff reviews a sample of evaluations performed per 10 CFR 72.48 (72.48, thereafter) using the inspection process. The NRC reviewed the 72.48 evaluation for Version E in an inspection performed in May 2021. The staff documented the inspection results in report No. 72-1014/2021-201 (ML21301A166).

The staff utilized the information available from the Version E overpack to perform an evaluation of the anchored Version E overpack. However, utilization of the information from the Version E overpack does not constitute approval of the Version E overpack, and the review conclusions only apply to the anchored Version E overpack.

Since the staff determines the adequacy of implementing the 72.48 evaluation criteria using the inspection process and the applicant did not submit Version E of the HI-STORM FW overpack for approval, the staff did not review or approve any aspects of the Version E design configuration in this licensing action. Therefore, the staff focused the review on evaluating the anchored configuration of the Version E overpack and other proposed changes described in the application.

3.0 STRUCTURAL EVALUATION

The staff reviewed the proposed changes to the HI-STORM FW spent fuel storage system in the application of the HI-STORM FW, Amendment No. 6, to verify that the applicant performed an acceptable structural evaluation demonstrating that the storage system, as proposed, meets the requirements of 10 CFR Part 72. While the applicant has proposed several changes to the system in this amendment, the staff's structural evaluation focused primarily on the two changes which appreciably impacted the structural performance of the system. These changes are as follows:

1) Proposed change No. 1, Add anchored configuration for the HI-STORM FW overpack.

2) Proposed change No. 2, Allow use of non-single failure proof lifting equipment during handling of heavy loads within the 10 CFR Part 72 jurisdictional boundary.

The following sections are the staff evaluations of proposed change Nos. 1 and 2.

3.1 HI-STORM FW Anchored Configuration

3.1.1 Description of the Structure

The applicant proposed to include a variant of the HI-STORM FW Version E overpack that is anchored to the concrete storage pad of the ISFSI for use in areas with potentially large seismic accelerations. Section 2.0 of this SER includes a brief description of the Version E overpack and the anchored variant of the Version E overpack as well as the main differences between these configurations.

The applicant depicted the details of the anchorage and baseplate of the anchored HI-STORM FW Version E cask in the licensing drawing, Drawing No. 11695, "HI-STORM FW Version E Anchored Cask." The baseplate includes housing for the anchorage hardware, which includes studs imbedded in the concrete of the ISFSI pad and nuts securing the cask to the studs. The applicant categorized the baseplate, the anchorage, and the ISFSI pad as Important to Safety (ITS) Category C for the anchored variant of the Version E cask. The staff verified that the ITS Category C was consistent with the recommendations for a concrete support pad in NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety," (NRC, 1996). The NUREG/CR-6407 is referenced in NUREG-2215 with respect to how QA controls may be applied to the various cask components.

The staff reviewed Drawing No. 11695 of the application and finds that the applicant provided sufficient information to characterize appropriate ITS components. Also, the staff finds acceptable the description of the proposed anchored configuration of the HI-STORM FW Version E overpack provided by the applicant.

3.1.2 Structural Design Criteria

The applicant proposed several changes to the structural design criteria for the anchored variant of the HI-STORM FW Version E storage system. The changes included additions to the structural design criteria concerning the anchorage, the baseplate, and the ISFSI pad in the anchored system, particularly in the earthquake and tornado accident conditions. This section of the SER includes a discussion of the proposed changes to the structural design criteria and the staff's review. Other structural design criteria for the HI-STORM FW remain unchanged and continue to be applicable to the anchored variant of the Version E storage system.

The applicant's proposed changes would require that the Version E cask be installed in the anchored configuration when the seismic hazard of the ISFSI site exceeds the threshold limit for a freestanding HI-STORM FW cask defined in section 3.4.3 of appendix B to the HI-STORM FW CoC. As noted in section 2.2.3(g) of the application, the seismic hazard for a potential site using the anchored HI-STORM FW system is limited by the structural capacity of the system under the earthquake accident conditions. More specifically, the applicant qualified the anchored HI-STORM FW for use with a seismic hazard up to a zero-period acceleration of 1 g in the horizontal direction and a concurrent 0.75 g in the vertical direction.[4] The applicant listed these

[4] The term "g" as used in the seismic evaluation is the acceleration due to gravity. This term is commonly used in seismology to express acceleration as a fraction of gravitational acceleration.

accelerations, along with other key input data for the seismic evaluation in proposed table 3.1.15 of the application. The applicant's proposed changes would require site-specific seismic hazard evaluations for use of the anchored HI-STORM FW system at sites with seismic hazards exceeding the zero period accelerations listed in table 3.1.15 of the application.

The staff reviewed the design criteria for the ISFSI pad described in section 2.0.4 of the HI-STORM FW application including design parameters listed in table 2.2.9. The applicant proposed changes to the principal design criteria of the ISFSI pad to add the anchored storage system. As mentioned in section 3.1.1 of this SER, the applicant designated the ISFSI pad used in the anchored system as ITS Category C, consistent with the safety classification guidance in NUREG/CR-6407. The staff notes that the proposed design criteria require the ISFSI pad for the anchored system to have sufficient structural capacity to hold the embedded anchor studs during the design basis conditions, particularly the earthquake and tornado accident conditions. The applicant included industry concrete codes for the design, evaluation, and construction of the pad in section 2.0.4 of the application. The staff reviewed the load combinations for the ISFSI pad in section 2.0.4.2(b) of the application and noted that the applicant did not change these as part of this amendment. In paragraph 3.4.3(c) of appendix B to the CoC, the applicant proposed a change to require that the embedment of the anchor studs in the concrete ISFSI pad comply with appendix B to ACI 349, "Code Requirements for Nuclear Safety Related Structures" (ACI, 1985). The staff notes that the applicant's proposed changes would require site-specific seismic hazard evaluations for use of the anchored HI-STORM FW system if the effective stiffness of the anchorage, ISFSI pad, and subgrade foundation on-site are lower than the evaluated stiffness derived from the ISFSI pad parameters listed in table 2.2.9 of the application.

The applicant described the design criteria for the anchorage and baseplate in sections 2.0.4(c) and 3.1.2.1(f) of the application:

(1) **Normal conditions of storage.** The applicant required stresses from normal conditions of storage in the anchorage and baseplate, including the preload in the anchorage, to satisfy American Society of Mechanical Engineers (ASME) Boiling and Pressure Vessel (B&PV) Code, Section III, Division 1, Subsection NF Level A allowable stresses (ASME, 2007). The applicant listed the Level A allowable stresses applicable to the anchorage in table 3.1.4 of the application.

(2) **Off-normal storage conditions.** For off-normal storage conditions, the applicant requires stresses in the anchorage and baseplate to satisfy ASME B&PV Code Section III, Division 1, Subsection NF Level B allowable stresses. Table 3.1.5 of the application includes the Level B allowable stresses.

(3) **Accident conditions.** For accident conditions, the applicant limited the stresses in the anchorage and baseplate to ASME B&PV Code Level D allowable stresses from the Nonmandatory appendix F. Table 3.1.6 of the application includes the Level D allowable stresses.

The applicant did not consider the non-mechanistic tip-over to be a credible accident condition for the HI-STORM FW system with an anchored Version E cask. The applicant relied on the non-mechanistic tip-over as a bounding analysis for the unanchored configurations of the HI-STORM FW system. For the anchored HI-STORM FW system, the applicant proposes to rely on the design of the anchorage and ISFSI pad to prevent the tip-over and eliminate the need for the bounding tip-over evaluation.

The staff reviewed the proposed changes to the structural design criteria as well as the industry codes and standards referenced in the proposed design criteria. Based on the description of the design criteria in the application and the staff's consideration of the proposed structural changes, the staff finds that the applicant's proposed design criteria for the anchored variant of the HI-STORM FW Version E storage system are consistent with the applicable industry design codes and standards and the guidance in NUREG-2215, sections 3.4.2.4, "External Conditions," and 3.4.3 "Design Criteria for Safety Protection Systems," (NRC, 2020a) and meets the requirement of 10 CFR 72.236(b).

3.1.3 Structural Evaluation

3.1.3.1 Earthquake Accident Conditions

The applicant described the structural evaluation of the anchored HI-STORM FW Version E storage system for the earthquake accident in section 3.4.4.1.2 of the application with further details in Holtec Report HI-2188720, "Structural Calculation Package for HI-STORM FW Anchor System." The applicant evaluated the anchored storage system for the earthquake accident using calculations and finite element analysis. The applicant listed the input data for the seismic evaluation of the anchored system in proposed table 3.1.15 in the application, including the following:

i. dimensions,

ii. bounding weights, and

iii. design basis accelerations.

The applicant determined the design basis accelerations, which the applicant used in the finite element analysis using the design basis response spectra shown in proposed figures 3.4.47A and 3.4.47B of the application. The applicant developed the response spectra following guidance in Regulatory Guide (RG) 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants" (NRC, 2014)

The applicant performed the finite element analysis using the ANSYS™ finite element software. The ANSYS™ finite element software is widely used in the nuclear industry for this type of analysis. First, the applicant determined the stresses in the anchor studs from the pretension. Then, the applicant applied seismic accelerations based on the design basis response spectra to the pretensioned cask system. The table below summarizes the finite element analysis results, including critical safety factors, associated with the seismic analyses performed by the applicant.

Table 2. Critical safety factors resulting from applicant's finite element analysis for the HI-STORM FW anchored configuration

Component	Proposed Table	Loading Type	Critical Safety Factors Range
anchorage	3.4.19	pretension	1.12 – 1.75
	3.4.20	pretension and seismic	1.37 – 3.10
baseplate	3.4.21	seismic	1.67 – 4.87

The applicant also provided the stress distributions of certain components of the finite element model in proposed figures 3.4.44 through 3.4.46.

As depicted in table 2 of this SER, all the safety factors are greater than one. The staff reviewed the seismic evaluation and analyses for the HI-STORM FW Version E anchored configuration per the guidance in section 4.5.4.2 of NUREG-2215. The staff finds that the assumptions and results of the finite element analyses satisfied the applicable sections of the ASME B&PV Code (ASME, 2007) described in section 3.1.2, “Structural Design Criteria,” of this SER for normal, off-normal, and accident conditions.

During a seismic event, the anchor studs sustain a cyclic load and are susceptible to fatigue failure. The applicant evaluated the following possible impacts to the HI-STORM FW storage system due to a seismic event:

i. **fatigue failure**

   Appendix A of Holtec Report HI-2188720, “Structural Calculation Package for HI-STORM FW Anchor System,” includes the evaluation of fatigue failure of the anchorage. The applicant discussed the fatigue evaluation in section 3.1.2.5 of the application. The applicant determined that the anchorage has the capacity to resist fatigue failure from a seismic event.

ii. **thermal loading and thermal fatigue**

   The applicant evaluated the anchorage for thermal loading and thermal fatigue according to ASME Section III, “Rules for Construction of Nuclear Facility Components,” Division 1, “Metallic Components,” Subsection NB, Subparagraph NB-3222.4 and determined that the anchorage was not significantly affected by either condition.

The staff reviewed the evaluation above using the guidance in NUREG-2215, sections 4.5.2, “Design Criteria,” 4.5.3, “Loads,” 4.5.3.3.2, “Earthquake,” 4.5.6, “Accident Conditions,” and appendix 4A, “Computational Modeling Software Technical Review Guidance.” Based on the staff’s review of the applicant’s evaluation described above, the results of the stress analysis, and the factors of safety presented in proposed tables 3.4.19 through 3.4.21 of the application, the staff finds the applicant demonstrated that the anchored HI-STORM FW Version E storage system has adequate structural capacity to withstand the normal, off-normal, and earthquake accident conditions. Therefore, the applicant’s evaluation meets the regulatory requirement in 10 CFR 72.236(l).

3.1.3.2 Tornado Accident Conditions

The applicant described the structural evaluation of the anchored HI-STORM FW Version E storage system for the tornado accident in section 3.4.4.1.3 of the application. The staff reviewed the input data for the tornado winds in table 2.2.4 and the tornado missiles in table 2.2.5 of the application. The design input data for the tornado accident provided in tables 2.2.4 and 2.2.5 is based on the following documents:

i. Regulatory Guide (RG) 1.76, “Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants” (NRC, 2007a);

ii. ANSI/ANS 57.9, “Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)” (ANSI/ANS, 1992);

iii. ASCE 7, “Minimum Design Loads for Buildings and Other Structures” (ASCE, 2010); and

iv. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants” (NRC, 2007b).

The applicant did not change this structural design criteria for the tornado evaluation as part of this amendment. The applicant’s structural analysis considered the combined effects of tornado winds and the controlling large tornado missile. The tornado evaluation focused on three critical components that required analysis for the anchored variant of the HI-STORM FW system:

i. the anchor bolts,

ii. the cask lid, and

iii. the lid bolts.

The staff reviewed the critical stress and the factor of safety calculated for the lid bolts in proposed table 3.4.22 of the application. For the anchor bolts, the staff found that the applicant demonstrated that the loads from the earthquake accident condition bound the tornado accident loads and control the structural analysis of the bolts.

Based on the staff’s review of the applicant’s structural analyses of the anchored HI-STORM FW Version E storage system due to the combined effects of tornado missiles and tornado winds, the staff concludes that the applicant demonstrated that the anchored HI-STORM FW Version E storage system has adequate structural capacity to withstand the tornado accident conditions and meets the regulatory requirement in 10 CFR 72.236(l). Therefore, the staff finds acceptable the applicant’s evaluation of the structural effects of the tornado accident conditions. The evaluation for the tornado accident is consistent with the guidance in sections 3.4.3.2, “Structural,” 4.5.2, “Design Criteria,” 4.5.3, “Loads,” and 4.5.6, “Accident Conditions,” of the NUREG-2215 (NRC, 2020a).

3.2 Allow use of non-single failure proof lifting equipment

3.2.1 Description

The applicant proposed adding paragraph 5.2(c)(4) to the HI-STORM FW lifting requirements in appendix B to the HI-STORM FW CoC. This change to the CoC would allow the use of pre-existing lifting equipment which does not meet the current lifting requirements in section 5.2(c) in appendix A of the CoC if the following conditions are met: (1) the lifting height does not exceed the limits in table 5.1 of appendix B of the CoC and (2) the potential impact surfaces are bounded by the ISFSI pad parameters in table 2.2.9 of the application. Alternatively, a site-specific drop analysis may be performed in accordance with section 3.4.7 of appendix B to CoC to qualify pre-existing lifting equipment. The applicant determined the limits on lifting height in table 5.1 of appendix B of CoC and the bounding parameters for the ISFSI pad in table 2.2.9 of the application by performing drop analyses for handling accident conditions.

As in previous approvals for the HI-STORM FW storage system (Holtec, 2011), the applicant did not consider the handling accident condition to be a credible accident condition when lifting HI-STORM FW casks with newly designed lifting devices that meet the requirements in Paragraphs 5.2(c)(1) through 5.2(c)(3) in appendix A of the CoC. The applicant did not make changes to the previously approved design criteria and analyses for normal and off-normal lifting and handling conditions.

3.2.2 Structural Design Criteria

The applicant described the design criteria for lifting devices in section 2.0.5 and section 2.2.3(a) of the application. Section 2.0.5.1 described the design criteria for newly designed lifting devices intended to satisfy paragraphs 5.2(c)(1) through 5.2(c)(3) in appendix A of the CoC. The applicant described the design criteria for pre-existing lifting equipment intended to satisfy paragraph 5.2(c)(4) in appendix A of the CoC in section 2.0.5.2 of the FSAR, and the applicant provided acceptance criteria for the handling accident condition in section 2.2.3(a) of the application. Section 2.2.3 of the application described the minimum acceptance criteria for evaluating accident conditions include the following:

a) *Confinement Integrity.* The confinement boundary continues to confine the radioactive material.

b) *Shielding Capability.* The system continues to provide adequate shielding.

c) *Retrievability.* The canister can be recovered from the overpack.

d) *Criticality Control.* The fuel basket maintains the configuration of its contents.

The acceptance criteria for the handling accident evaluation also include maintaining the structural design criteria for the fuel basket, listed in table 2.2.11 of the application, to ensure spent nuclear fuel maintains a subcritical arrangement after a drop accident.

The staff reviewed the HI-STORM FW drop analyses including the maximum deceleration values for the fuel rods in a drop accident provided in section 2.1.4 of the application. The applicant based the maximum deceleration values on calculations performed for the HI-STAR 190 FSAR (Holtec, 2018), which the applicant incorporated by reference. The applicant listed the maximum deceleration of fuel assemblies allowed in the drop analysis in table 2.1.9 of the HI-STORM FW application.

In section 3.1.2.1(a) of the application, the applicant notes that the stiffness of the ISFSI pad for the anchored HI-STORM FW variant may be increased to provide structural capacity for the earthquake or tornado accident conditions. If a lifting device that does not meet the requirements in paragraphs 5.2(c)(1) through 5.2(c)(3) of appendix A of the CoC is employed to carry the cask over an ISFSI pad with increased stiffness, a site-specific drop analysis shall be performed to determine the cask carry height.

The staff reviewed the applicant’s proposed method to qualify lifting equipment with a maximum lifting height supported by a drop analysis and found that the applicant’s reliance on a drop analysis was consistent with guidance in NUREG-0612, “Control of Heavy Loads at Nuclear Power Plants” (NRC, 1980) and ANSI N14.6, “Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10,000 pounds (4,500 kg) or More” (ANSI, 1993). Based on the consistency with the guidance and the description of the design criteria accounting for confinement, shielding, retrievability, and criticality in the application, the staff finds that the design criteria for the drop analysis meet the requirement of 10 CFR 72.236(b).

3.2.3 Structural Evaluation

The applicant described the structural evaluation for the handling accident conditions in section 3.4.4.1.9 of the application. The applicant evaluated the handling accident by analyzing the following:

a) an 11-inch free drop of a loaded HI-STORM FW Version E cask, and

b) a loaded HI-TRAC VW transfer cask on to representative targets with bounding stiffness.

The applicant used both calculations and finite element analyses in the drop evaluations, which the applicant detailed in Holtec Report HI-2200647 (HI-2200647). The applicant analyzed a vertical drop, which the applicant assessed to be the bounding orientation as described in section 1 of the HI-2200647 report. Table 5.1 of appendix B of CoC defines the lifting height limits as 11 inches based on the drop height analyzed in the analyses. The applicant used bounding dimensions and weights for the loaded HI-STORM FW and HI-TRAC VW transfer casks in the drop analyses, and the applicant used the parameters of an ISFSI pad design documented in table 2.2.9 of the application as the target in the drop analyses. The target ISFSI pad has an upper-bound stiffness, which generates a bounding impact with maximum decelerations for the dropped casks.

The applicant performed finite element analyses using the LS-DYNA finite element software. The applicant created half-symmetry, finite element models of a loaded HI-STORM FW cask and a loaded HI-TRAC VW. The applicant analyzed the models to demonstrate that the casks maintain structural integrity, shielding function, and fuel rod deceleration limits when dropped from a maximum lift height of 11 inches onto the ISFSI pad. The applicant considered strain rate effects for the steel components in the models consistent with the “Atlas of Stress-Strain Curves” by H.E. Boyer (ASM International, Second Edition). The drop analysis primarily focused on four acceptance criteria mentioned in section 2.2.2 of this SER.

3.2.3.1 Determining material properties

The applicant developed the material properties used in the LS-DYNA drop accident model in appendix B of the application with further verification of the methodology in appendix E of HI-2200647. For materials that may experience plastic deformation from the drop accident, the applicant developed true-stress-true-strain curves for elastoplastic analysis in LS-DYNA based on the standard material strength data.

The staff reviewed the applicant’s methodology to determine the material properties for the structural components of the cask are based on developing engineering stress-strain curves from ASME B&PV Code (ASME, 2007) material properties and then converting those to true-stress-true-strain curves needed for finite element modeling. The applicant based their methodology on the journal article, “Numerical Analysis of the Stress-Strain Curve and Fracture Initiation for Ductile Metal,” by K.S. Zhang and Z.H. Li (Zhang and Li, 1994). The methodology used the power law equation to represent the flow curve with empirical factors based on material property test data. The applicant then derived an iterative method to find a convergent solution for each metal, generated true-stress-true-strain curves from the resultant equation, and incorporated the curves into the LS-DYNA model.

The staff reviewed the applicant's derivation of the true-stress-true-strain curves as well as the references such as the journal article by Zhang and Li (Zhang and Li, 1994). The staff notes that, within the range of uniform elongation (i.e., before necking occurs), engineering stress-strain curves can be readily converted to true-stress-true-strain curves. The staff also notes that the results of the drop accident, discussed below, showed that the maximum strains in the cask components were within the range of uniform elongation and well below necking.

The applicant also performed laboratory testing to benchmark the methodology for developing true-stress-true-strain curves. The applicant summarized the benchmarking in Holtec Report HI-2210251, "Benchmarking of Material Stress-Strain Curves in LS-DYNA" (Holtec, 2021a). The applicant originally developed and submitted this benchmarking report to the NRC to support the licensing of the HI-STAR ATB 1T transportation package, which the staff reviewed and approved in an SER in June 2021 (NRC, 2021). The applicant discussed the results of this benchmarking effort in appendix E of HI-2200647 to support the use of the methodology for the analyses of the drop accident in this amendment request. The applicant further supported the methodology with an analysis comparing the true-stress-true-strain curves developed with their methodology to the properties from the "Atlas of Stress Strain Curves" (ASMI, 2002). The applicant concluded that their methodology was conservative in that it underestimated the energy absorbed and overestimated deformation of the materials. The staff reviewed the benchmarking report and the comparative analysis and found that these analyses adequately support the use of the methodology for the HI-STORM FW drop analyses.

Based on the staff's review of the methodology, the referenced literature, and the benchmarking analyses, the staff finds the applicant's methodology of deriving true-stress-true-strain curves and the use of these material curves in the LS-DYNA drop accident model to be acceptable for evaluating the performance of the structures.

3.2.3.2 Drop Analyses

The applicant presented tables of results from the drop analyses of the loaded HI-STORM FW cask and the loaded HI-TRAC VW transfer cask in section 3.4.4.1.9(c) of the application.

(1) <u>MPC</u>

The results of the drop analyses showed that critical strains in the MPC vessel are below plastic strain limits for stainless steel recommended by ASME B&PV Code Section III, Division 1, Subsection NB (ASME, 2007). The stresses in the MPC lid weld were below the allowable stresses for ASME B&PV Code Level D conditions. Therefore, confinement was maintained.

(2) <u>Cask overpack</u>

For the cask overpacks, the drop analyses showed that plastic strains in the overpack were minimal; there was no gross plastic deformation in the overpack baseplate; the stresses in the cask lid closure bolts are below the yield stress; and there was no significant loss of shielding.

(3) HI-TRAC VW

For the HI-TRAC VW drop analysis, the applicant analyzed the potential of lead slump and deformation of the gamma shielding. The results of the evaluation for the HI-TRAC VW drop demonstrated that lead slump did not occur, and the gamma shielding was maintained.

(4) Fuel basket

The evaluation of the fuel basket showed that the plastic strains were negligible and that the total deflection of the basket was less than the maximum deflection limit in table 2.2.11 of the application.

(5) Spent fuel assemblies

The drop analyses show the maximum declarations experienced by the spent fuel assemblies were below the fuel deceleration limits of table 2.1.9 of the application.

As described in appendix B to Holtec Report HI-2200647, the applicant determined the failure strains of materials used in the evaluation of the 11-inch cask drops by generating true-stress-true-strain curves for each structural material used in the finite element models. The applicant evaluated the stresses for the MPC lid weld in appendix C to Holtec Report HI-2200647. The staff finds that the results of the applicant's analyses adequately demonstrate that the loaded HI-STORM FW cask and the loaded HI-TRAC VW transfer cask meet the acceptance criteria for the drop accident in section 2.2.3 of the application because the confinement was maintained, there was no significant loss of shielding, and the maximum decelerations experienced by the fuel rods were below the limiting values in table 2.1.9 of the application.

3.2.3.3 Conclusion

Based on the staff's review described above, the staff finds that the applicant's evaluation of the structural effects of the handling accident condition on the HI-STORM FW storage system is consistent with the guidance in NUREG-2215, chapter 4, "Structural Evaluation," (NRC, 2020a) and is, therefore, acceptable. The staff concludes that the results of the applicant's drop analysis, described above, demonstrate that the design criteria are met in the event of the drop. Thus, the staff finds that the HI-STORM FW storage system has adequate structural capacity to withstand the handling accident conditions and meets the requirement of 10 CFR 72.236(l).

3.3 Evaluation Findings

F3.1 The staff reviewed the structural performance of the ITS SSCs designed to maintain subcriticality and concludes that these SSCs have adequate structural integrity to satisfy the criticality safety requirements of 10 CFR 72.124(a).

F3.2 The staff reviewed the structural performance of the ITS SSCs designed to provide and maintain favorable geometry or permanently fixed neutron-absorbing materials and concludes that these SSCs have adequate structural integrity to satisfy the criticality control requirements of 10 CFR 72.124(b).

F 3.3 The staff reviewed the design bases, design criteria, and structural evaluations information related to proposed change Nos. 1 and 2 to the HI-STORM FW storage cask and its ITS SSCs. The staff concludes the following:

1) The applicant met the requirements of 10 CFR 72.236(b).

2) The applicant conducted appropriate tests and means acceptable to the NRC to demonstrate that the HI-STORM FW will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions and, therefore, meet the requirements of 10 CFR 72.236(l).

F 3.4 The staff reviewed the structural performance of the ITS SSCs designed to maintain the spent nuclear fuel (SNF) in a subcritical condition under normal, off-normal, and accident conditions and concludes that these SSCs have adequate structural integrity to satisfy the subcriticality requirements of 10 CFR 72.236(c).

F 3.5 The staff reviewed the structural performance of the ITS SSCs designed to provide radiation shielding and confinement and concludes that these SSCs have adequate structural integrity to satisfy the radiation shielding and confinement requirements of 10 CFR 72.236(d).

F 3.6 The staff finds the storage cask is designed to provide redundant sealing of confinement systems and, therefore, meets the requirements of 10 CFR 72.236(e).

Based on the analyses performed and the supporting information provided by the applicant, the staff finds that the applicant's evaluation of the structural design demonstrates that the amendment to the CoC of the HI-STORM FW system meets the requirements of 10 CFR Part 72 and provides adequate protection of the public health and safely. The NRC staff reached this finding based on the review described above, which considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

4.0 THERMAL EVALUATION

The thermal review ensures that the cask components and fuel material temperatures will remain within the allowable values under normal, off-normal, and accident conditions. This review includes evaluation whether the fuel cladding temperatures for fuel assemblies stored in the HI-STORM Flood/Wind (FW) system will be maintained below specified limits throughout the storage period in order to protect the cladding against degradation that could lead to gross ruptures. This portion of the review also evaluates whether the cask thermal design has been evaluated using acceptable analytical techniques and/or testing methods.

This review was conducted under the regulations described in 10 CFR 72.236, which identify the specific requirements for the regulatory approval, fabrication, and operation of spent fuel storage cask designs.

The following proposed change is applicable to the thermal evaluation:

<u>Proposed change No. 3</u>, Revise limiting conditions for operation (LCO) 3.1.2 to allow an engineering evaluation to be performed in lieu of transferring the multi-purpose canister (MPC) into a transfer cask.

The staff evaluated the proposed change in section 4.1 of this SER.

4.1 Revise LCO 3.1.2 to Allow for an Engineering Evaluation

The HI-STORM FW appendix A of the CoC technical specification (TS) 3.1.2, “SFSC Heat Removal System,” proposed required action C.2.3 describes the performance of an engineering evaluation using the models and methods from the HI-STORM FW application in order to demonstrate the following:

1) all component and content temperatures remain below allowable accident condition temperature limits,

2) the MPC internal pressure remains below the accident condition limit, and

3) the completion time for proposed required action C.2.3 is 24 hours.

The staff finds this to be acceptable because the HI-STORM FW appendix A of the CoC, TS 3.1.2 proposed required action C.2.3 describes using models and methods from the HI-STORM FW application. These models and methods from the HI-STORM FW application have been previously reviewed by the NRC staff and evaluated in chapter 4 of the HI-STORM FW SERs (NRC, 2015, 2016a, 2016c, 2020b, and 2020c), and have not changed in this amendment request, to demonstrate that all components and contents remain below the allowable accident condition temperature and pressure limits. The proposed required action C.2.3 does not impact the staff’s conclusion.

The applicant also described in the HI-STORM FW technical specification bases B 3.1.2, “SFSC Heat Removal System,” proposed action C.2.3, on page 13.A-22 of the application that efforts must continue to restore the spent fuel storage cask (SFSC) heat removal system to operable status by removing the air flow obstruction(s). The staff finds this approach to be necessary to ensure that the HI-STORM FW spent fuel storage cask heat removal system is not in an inoperable condition for an extended period of time due to partially or fully blocked vents. The staff has determined that the efforts to continue to restore the SFSC heat removal system to operable status by removing the air flow obstruction(s) are captured in the HI-STORM FW appendix A of the CoC, TS 3.1.2, surveillance requirement (SR) 3.1.2. The latter specifies verifying every 24 hours that all overpack inlets and outlets are free of blockage from solid debris or floodwater, or (for overpacks with installed temperature monitoring equipment) that the difference between the average overpack air outlet temperature and independent spent fuel storage installation (ISFSI) ambient temperature meets the criteria in SR 3.1.2.

The applicant described in bases B 3.1.2, proposed action C.2.3, on page 13.A-22 of the application that an engineering evaluation may be performed to demonstrate the following:

1) all component and content temperatures remain below the accident condition temperature limits in table 2.2.3, “Temperature Limits,” of the application; and

2) the MPC internal pressure remains below the accident condition pressure limit in table 2.2.1, “Pressure Limits,” of the FSAR (Holtec, 2019a).

The staff reviewed the bases B 3.1.2, proposed action C.2.3, and based on the staff's review, the staff finds this description to be consistent with the temperature limits described in the HI-STORM FW appendix A of the CoC, TS 3.1.2 proposed required action C.2.3. The applicant described in bases B 3.1.2, proposed action C.2.3, of the application (in general) how the engineering evaluation is performed either by:

1) performing a new evaluation using the cask thermal model described in chapter 4 of the application, or

2) making a comparison to a previously evaluated similar condition for a bounding blockage event.

Based on the staff's review of the applicant's general engineering evaluation, the staff finds acceptable the applicant's additional specification in bases B.3.1.2, proposed action C.2.3, that only the model inputs would be modified to reflect actual or bounding expected site conditions. The actual or bounding expected site conditions would include the bounding expected amount of blockage, actual decay heat load, and actual or expected ambient temperature. Also, based on the staff's review, making a comparison to a previously evaluated similar condition is also acceptable because the previously evaluated similar condition is for a bounding blockage event.

The applicant also described in bases B 3.1.2, proposed action C.2.3, of the application that if none of the components exceed the temperatures limits in table 2.2.3 of the application), the MPC can remain in the overpack. While this portion of the applicant's description does not explicitly describe the contents in addition to the components, the staff finds this description to be consistent with the temperature limits described in the HI-STORM FW appendix A of the CoC, TS 3.1.2 proposed required action C.2.3. The HI-STORM FW appendix A of the CoC TS 3.1.2 proposed required action C.2.3 explicitly describes the contents. The applicant also described in bases B 3.1.2 proposed action C.2.3 of the application that once the air flow obstructions have been cleared, the SFSC heat removal system is declared operable, and compliance with the LCO 3.1.2 is then restored; the staff finds this acceptable. The applicant described in bases B 3.1.2, proposed action C.2.3 of the application, that if the HI-STORM FW appendix A of the CoC TS 3.1.2 proposed required action C.2.3 cannot be performed within the stipulated completion time of 24 hours, the HI-STORM FW appendix A of the CoC TS 3.1.2 required action C.2.1 to restore the SFSC heat removal system to operable status, or the HI-STORM FW appendix A of the CoC TS 3.1.2 required action C.2.2 to transfer the MPC into a transfer cask must be performed; the staff finds this acceptable because of the inclusion of the aforementioned required actions C.2.1 and C.2.2.

In the applicant's response to request for additional information (RAI) 4-1 (Holtec, 2021c), the applicant described that no vent blockage (0%) is the normal condition, greater than 0% and up to and including 50% vent blockage is the off-normal condition, and greater than 50% and up to 100% vent blockage is the accident condition. This is consistent with TS 3.1.2 that describes that the SFSC heat removal system is operable when partially (≤50%) blocked, and inoperable during other blockage conditions. However, NUREG-2215, section 3.5.2.4.2, "Off-Normal Conditions," describes that off-normal conditions includes partial blockage of air vents, and section 3.5.2.4.3, "Accident Conditions," includes blockage of air inlets and outlets as an accident condition (NRC, 2020a). Therefore, the applicant is conservatively including greater than 50% blockage and less than 100% blockage as an accident condition.

The staff reviewed the off-normal and accident temperature and pressure limits in tables 2.2.3 and 2.2.1, respectively, of the application. The staff finds that the off-normal and accident conditions temperature limits are numerically the same for both off-normal and accident conditions. However, the pressure limit is higher for accident conditions (200 psig), as compared to off-normal conditions (120 psig). In table 4.6.7, "Off-normal and accident condition maximum pressures," of the application, the applicant calculated that the maximum pressure for off-normal conditions partial blockage of inlet ducts is 99.9 psig, and the maximum pressure for accident conditions of 100% blockage of air inlets is 116.4 psig. Therefore, the applicant's calculated accident conditions 100% blockage of air inlets (i.e., 116.4 psig) is less than both the off-normal (i.e., 120 psig) and accident conditions (i.e., 200 psig) pressure limits that are specified in table 2.2.1 of the application. However, if the applicant increases the temperature or pressure limits in tables 2.2.3 and 2.2.1 of the application in the future, or if the applicant increases the decay heat such that the applicant calculated accident conditions 100% blockage of air inlets pressure in table 4.6.7 is no longer bounding, the applicant should provide justification that the use of the accident limits only are appropriate for the TS 3.1.2 proposed required action C.2.3, or use the lower off-normal limits for that acceptance criteria.

4.2 Evaluation Findings

F5.1 Storage container SSCs important to safety remain within their operating temperature ranges in accordance with 10 CFR 72.236(a) and 10 CFR 72.236(b).

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

The staff concludes that the thermal design of the HI-STORM FW is in compliance with 10 CFR Part 72, and that the applicable thermal design and acceptance criteria have been satisfied. The evaluation of the thermal design provides reasonable assurance that the HI-STORM FW will allow safe storage of spent fuel for its licensed life. 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.

6.0 SHIELDING EVALUATION

The shielding review evaluates the ability of the proposed shielding features to provide adequate protection against direct radiation from the dry storage system contents. The shielding features must limit the dose to the workers and members of the public so that the dose remains within regulatory requirements during normal operating, off-normal, and design-basis accident conditions.

The purpose of the review is 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). While the applicant has proposed several changes to the system in this amendment, the staff's shielding evaluation focused primarily on the two changes that appreciably impacted the shielding performance of the system. The following proposed changes are applicable to the shielding evaluation:

1) Proposed change No. 1, Add anchored configuration for the HI-STORM FW overpack.

2) Proposed change No. 4, Radioactive Effluent Control Program to no longer require annual submittal of a separate radioactive effluent report [10 CFR 72.44(d)(3)] for the HI-STORM FW system.

6.1 HI-STORM FW Anchored Configuration

The staff's shielding review evaluated the proposed change requested in this revision in conjunction with the findings from HI-STORM FW, Amendment 5 (NRC, 2020c) to determine whether, with the requested changes, the system continues to provide adequate protection from the radioactive contents of the fuel within the system. This review evaluated the methods and calculations employed by the applicant to determine the expected gamma and neutron radiation at locations near the cask surface and at specific distances away from the cask for the anchored Version E of the HI-STORM FW overpack.

The Version E lid of the HI-STORM FW has eight angled inlet ventilation ducts. This differs from the standard HI-STORM FW lid, in which these ducts are straight horizontal channels.

The angled design reduces the streaming radiation. This version of the MPC rests on thin stainless-steel lines that are welded to the baseplate so the MPC is not in direct connection with the carbon steel baseplate. The applicant provided a bounding shielding analysis in appendix T of HI-2094431(HI-STORM FW and HI-TRAC VW Shielding Analysis).

The anchored Version E has a radially extended baseplate with bolting holes so it can be anchored to the pad. Otherwise, it is the same as the unanchored HI-STORM FW Version E. The occupational dose of the anchored configuration will be increased due to the time required to anchor the loaded HI-STORM FW Version E to the pad.

The staff examined surface dose rates from the shielding evaluation for the Version E design configuration in table T.1 of HI-2094431. The applicant compares the dose rates for Version E to the standard version of the HI-STORM FW in that table. The applicant used the same fuel assembly and source term as the standard HI-STORM FW in its evaluation of the dose rates of the Version E. The shielding analyses were performed with the MCNP5 Monte Carlo particle transport code developed by Los Alamos National Laboratory (LANL). The source terms for the design basis fuels were calculated with the SAS2H and ORIGEN-S sequences from the SCALE 5 system. A detailed description of the MCNP models and the source term calculations are presented in sections 5.3 and 5.2 of the application, respectively (Holtec Report No. HI-2114830). The MCNP5 model used for the evaluation of Version E accounts for the different location of the inlets and different lid design as compared to the standard HI-STORM FW system. The dose rates for the overpack with a concrete density of 2.4 grams per cubic centimeter (g/cm^3) and 2.75 g/cm^3 for Version E are lower than or comparable to the standard version of the HI-STORM FW system. Concrete density of 2.4 g/cm^3 is used for the standard HI-STORM FW dose rate evaluation.

The dose rates for the standard version of the HI-STORM FW system are higher or comparable to the Version E of the HI-STORM FW system. Therefore, the dose rates calculated for the HI-STORM FW system bound those for the Version E configuration. The dose rates for the anchored configuration will be higher than the Version E, but still below of the standard version of the HI-STORM FW system. The staff reviewed the bounding dose rates provided by the applicant and determined that these met the 10 CFR Part 72 radiation protection requirements. Since the dose rates for Version E of the HI-STORM FW are lower than for the standard HI-STORM FW, the site boundary dose is bounded by the standard HI-STORM FW system.

6.2 Evaluation Findings

F6.1 The staff reviewed the sections 1, 2, and 6. These sections describe the SSCs important to shielding safety in sufficient detail to allow evaluation of their effectiveness and concludes that these SSCs have adequate structural integrity to satisfy the radiological protection requirements of 10 CFR 72.126(a).

F6.2 The staff reviewed the sections 1, 2, and 6. These sections provide reasonable assurance that the radiation shielding features are 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 reviewed the Operational restrictions to meet dose and ALARA requirements in 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106, which are the responsibility of the site licensee. The HISTORM FW system shielding features are designed to assist in meeting these requirements.

The evaluation of the shielding system design provides reasonable assurance that the HI-STORM FW system Amendment No. 6 will allow safe storage of spent fuel in accordance with 10 CFR 72.236(d). This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, accepted engineering practices, and the statements and representations in the application.

7.0 CRITICALITY EVALUATION

The objective of this review is to ensure that the applicant has performed an adequate criticality safety evaluation to demonstrate that the HI-STORM FW cask system will be maintained in a subcritical configuration under all credible normal, off-normal, and accident conditions during all handling, packaging, transfer, and storage operations. This review consisted of the staff's evaluation of the application to determine whether it meet the regulatory requirements of 10 CFR 72.124(a), 72.124(b), and 72.236(c).

The following proposed changes are applicable to the criticality evaluation:

1) Proposed change No. 1, Add anchored configuration for the HI-STORM FW overpack.

2) Proposed change No. 2, Allow use of non-single failure proof lifting equipment during handling of heavy loads within the 10 CFR Part 72 jurisdictional boundary.

3) Proposed change No. 5, Revise the allowable contents for the MPC-37, -89, and -32ML to clarify that fuel debris permitted for storage does not need to meet all of the dimensional requirements and characteristics in tables 2.1-2 and 2.1-3, provided that requirements in table 2.1-1 are met.

4) Proposed change No. 6, Revise “Design Features the MPC-37, -89, and -32ML basket to clarify that the minimum cell ID and minimum cell wall thickness are nominal dimensions.”

In reviewing these changes on the HI-STORM FW system’s criticality safety design, the staff followed the guidance in chapter 7 of NUREG-2215 (NRC, 2020a) in performing this review.

7.1 HI-STORM FW anchored configuration

The HI-STORM FW cask system consists of a welded metallic multi-purpose canister (MPC) that is contained in a concrete and steel overpack. The applicant proposed adding a variation of Version E of the HI-STORM FW, which consists of an anchored configuration of the storage system. The staff evaluated this change to the structure of the storage system in section 3 of this SER. The staff found that this proposed change provides adequate structural integrity to satisfy the criticality control requirements of 10 CFR 72.124(b).

7.2 Allow use of non-single failure proof lifting equipment

The HI-STORM FW system continues to utilize the HI-TRAC VW transfer cask in three configurations, which are unchanged in this amendment. In terms of criticality safety, the HI-TRAC relies on a minimum level of soluble boron in the MPC for PWR fuels as listed in the TS for criticality safety control during loading and unloading operations and remain the same as previously approved. Thus, the use of non-single failure proof lifting equipment does not affect criticality safety.

7.3 Revise Design Features the MPC-37, -89, and -32ML basket

Criticality controls in place within the HI-STORM FW cask include controlling the allowed contents, favorable geometry within the MPC, neutron poison loading of the poison plates, and soluble boron. The MPC is constructed of borated Metamic-HT plates to form a basket within the steel cylinder of the canister and is unchanged in this amendment. Damaged fuel may be stored in the HI-STORM FW using damaged fuel cans (DFCs) and damaged fuel isolators (DFIs) that have been previously approved for use by the NRC in prior amendments and remains unchanged for this amendment, including handling the fuel by normal means within a DFI. The applicant noted that fuel unable to be handled by normal means must be placed in a DFC.

7.4 Clarify the allowable contents for the MPC-37, -89, and -32ML

The previously NRC approved MPCs allowed in the HI-STORM FW are unchanged from the previous amendment, and include the MPC-37, MPC-89, and MPC-32ML. Also, the NRC notes that all of the allowable fuels eligible to be stored in the HI-STORM FW cask system have been previously approved by the NRC and are unchanged by this amendment. The applicant did propose a clarification regarding fuel debris as part of this amendment, specifically that fuel debris would not need to meet all of the dimensional requirements and characteristics listed in table 2.1-2 and table 2.1-3 in the application as long as they met the overarching requirements of table 2.1-1 in the application. Burnup credit of fuels is not used in the HI-STORM FW cask system.

7.4.1 Non-fuel Hardware

No changes to the allowable non-fuel hardware were proposed by this amendment.

7.4.2 Fuel Condition

This amendment did not propose any changes to the allowable fuel conditions of fuels stored in the HI-STORM FW cask system for the previously approved contents of intact fuel assemblies, damaged fuel assemblies in DFCs, and damaged fuel assemblies that are able to be handled by normal means in a DFI. The applicant proposed a clarification regarding fuel debris as part of this amendment, specifically that fuel debris would not need to meet all of the dimensional requirements and characteristics listed in table 2.1-2 and table 2.1-3 in the application as long as they met the overarching requirements of table 2.1-1 in the application. The staff reviewed the applicant’s analysis of fuel debris and notes that the applicant used very conservative assumptions, including modeling the fuel as bare pellets. Since this approach neglects the absorption in the cladding and the structural material, in addition to having a physical limit on the mass of fuel debris and the maximum active length in a DFC or DFI in each basket position, the staff finds that relying on the requirements specified in table 2.1-1 of the application is bounding and conservative for fuel debris and is acceptable.

7.5 Model Specification

No new models were specified for criticality safety as part of this amendment. As noted in section 7.4.2 above the fuel debris change was adequately covered by the previous NRC approved amendment analysis.

7.6 Criticality Safety Analysis

No new criticality safety analysis was submitted as part of this amendment.

7.7 Evaluation Findings

Based on the staff evaluation described above, the staff finds the following with respect to the criticality safety of the HI-STORM FW cask system with the proposed changes of this amendment:

F7.1 The structures, systems, and components important to criticality safety are described in sufficient detail in the HI-STORM FW application to enable an evaluation of their effectiveness.

F7.2 The HI-STORM FW storage cask and the associated spent fuel transfer systems continue to meet the requirements of 10 CFR 72.236(c), and that the systems remain subcritical under all expected normal, off-normal, and accident conditions.

F7.3 The criticality safety design is based on favorable geometry, fixed neutron poisons, and soluble boron poison. The evaluated fixed neutron poison demonstrates that it will remain effective and there is no credible means for the poisons to significantly degrade for the design basis life of the cask, and therefore are not subject to the verification of continued efficacy under 10 CFR 72.124(b).

F7.4 The analyses and evaluation of the criticality design and performance continue to demonstrate that the HI-STORM FW cask system will be adequate to allow the storage of spent fuel for the term specified in the CoC.

The staff concludes, based on the review of the proposed amendment, that the criticality design features for the HI-STORM FW cask, as amended, are in compliance with regulatory requirements in 10 CFR 72.124(a) and (b) and 10 CFR 72.236(c). The design evaluation provides reasonable assurance that the HI-STORM FW will continue to allow for the safe storage of spent nuclear fuel. These findings were reached based on the evaluation of the applicant's design changes and review of the applicable application sections, the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, accepted engineering practices, and the statements and representations in the application.

8.0 MATERIALS EVALUATION

The staff reviewed the proposed changes to the HI-STORM FW CoC Amendment No. 6 against the appropriate regulations as described in 10 CFR 72.236 to verify that the applicant adequately evaluated the material performance of components important to safety under normal, off-normal, and accident conditions. The staff's review followed the guidance in section 8 of NUREG-2215 (NRC, 2020a).

The following proposed change is applicable to the materials evaluation:

Proposed change No. 1, Add anchored configuration for the HI-STORM FW overpack.

The remaining proposed revisions to the CoC do not introduce any additional changes to the materials design, fabrication, and examination criteria, nor do the proposed revisions impact the materials performance of those aspects of the storage system that remain unchanged.

8.1 HI-STORM FW Anchored Configuration

The HI-STORM FW Version E overpack may be anchored to the ISFSI pad using hardened steel fasteners (also referred as anchored variant of Version E). Using that option, the carbon steel overpack baseplate is thickened to enhance its rigidity. The baseplate is also radially extended and equipped with holes for bolted installation to the ISFSI pad.

8.1.1 Drawings

The staff reviewed the licensing drawings and verified that the applicant provided an adequate description of the following items associated with the new and revised components of the anchored overpack:

a) component safety functions,

b) materials of construction,

c) fabrication instructions, and

d) dimensions.

The steels used in the fabrication of the HI-STORM FW Version E anchored overpack are specified in the bill of materials, and the welding details are defined in the drawings' welding symbols and the drawings' reference to the application description of welding criteria. The staff reviewed the drawing content with respect to the guidance in NUREG/CR-5502, "Engineering Drawings for 10 CFR Part 71 Package Approvals," and confirmed that the drawings provide an adequate description of the materials and fabrication requirements, and, therefore, the staff finds them to be acceptable.

8.1.2 Codes and Standards

The applicant did not propose any changes to the applicable design code for the metallic structural components of the overpack. Similar to the existing Version E overpack, the anchored variant cites specific paragraphs of ASME B&PV Code, Section III, Subsection NF, and Appendix F (ASME, 2007) for design for normal, off-normal, and accident events.

For those overpack components that are new or altered to accommodate the anchors, the materials of construction are in accordance with the ASME B&PV Code. The overpack plates are constructed of SA-516 Grade 70 carbon steel, and the hardened alloy steel anchor studs and nuts are constructed of SA-193 Grade B7 and SA-194 Grade 2H, respectively. The anchor stud and nut materials are identical to the stud and nut materials used in the lid of the existing Version E overpack. Based on the staff's verification that the materials codes are consistent with the overpack design standard, the staff finds the codes to be acceptable.

8.1.3 Weld Design and Specification

The applicant made no changes to the weld design and specifications used in the design and fabrication of the HI-STORM FW Version E anchored overpack.

8.1.4 Mechanical Properties

The applicant made no changes to the mechanical properties used in the structural analysis of the HI-STORM FW Version E anchored overpack, as the new components associated with the anchorage are constructed of steel grades that were previously employed in the storage system design.

8.1.5 Corrosion Reactions

The applicant made no changes to the materials or operating conditions used in the design and fabrication of the anchored variant of the HI-STORM FW Version E overpack. Therefore, the amendment does not introduce any potential corrosion reactions that were not previously evaluated.

8.1.6 Bolt Applications

The applicant addressed the brittle fracture performance of the anchor studs by following ASME BP&V Code, Subsection NF, NF-2311 (ASME, 2007), which states that the SA-193 Grade B7 stud material is exempt from impact testing requirements because the lowest service temperature is equal to or above the exemption threshold defined in the ASME B&PV Code. The staff reviewed the applicant's brittle fracture analysis and verified that applicant is appropriately following the code requirements to ensure adequate fracture performance.

In application section 8.6, the applicant also stated that potential overloading of bolts due to differential thermal expansion is precluded by matching the thermal expansion of the bolts to that of the parts being fastened together. The staff notes that the ASME B&PV Code, Section II, Part D, "Properties," identifies the same thermal expansion coefficients for the SA-193 Grade B7 carbon steel anchor studs and the SA-516 Grade 70 carbon steel base plate. Therefore, the applicant's materials selection is considered to adequately address potential overloading of the bolts.

Therefore, based on the staff's verification that the applicant appropriately considered the brittle fracture performance and differential thermal expansion effects on the anchor studs in a manner consistent with the ASME B&PV Code, the staff finds the bolting materials to be acceptable.

8.1.7 Concrete ISFSI Pad: Anchorage

The applicant noted in the proposed revision to section 2.0.4.1 of the application that the ISFSI pad is an ITS structure when the HI-STORM FW Version E overpack is used in the anchored configuration. The applicant also noted in the proposed revision to section 2.0.4.2 of the application that the embedment design for the anchored overpack is the responsibility of the ISFSI owner and shall comply with appendix B of American Concrete Institute (ACI) 349-85, "Code Requirements for Nuclear Safety-Related Concrete Structures" (ACI, 1985). The staff notes that ACI 349 provides design requirements for anchoring systems to ensure that they are capable of sustaining applied loads. The ACI 349 methodology includes consideration for the strength of the steel embedments, strength of the concrete, and interactions between the two materials (e.g., pullout strength).

Based on the staff's review of the anchor design standard, which is consistent with the applicable ACI code for load-bearing embedments, the staff finds the materials controls for the concrete anchorages to be acceptable.

8.2 Evaluation Findings

F8.1 The applicant has met the requirements in 10 CFR 72.236(b). The applicant described the materials design criteria for the anchored variant of HI-STORM FW storage system SSCs that are ITS in sufficient detail to support a safety finding.

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

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

The staff concludes that the HI-STORM FW Amendment 6 design adequately considers material properties, environmental degradation, and material quality controls such that the design is in compliance with 10 CFR Part 72. The evaluation of these materials considerations provides reasonable assurance that Amendment 6 to the CoC for the HI-STORM FW will allow safe storage of SNF for a certified life of 20 years. This finding is reached on the basis of a review that considered the regulation, itself, appropriate regulatory guides, the standard review plan, applicable codes and standards, and accepted engineering practices.

9.0 OPERATING PROCEDURES EVALUATION

The objective of the operating procedures evaluation is to ensure that the application includes acceptable operating sequences, guidance, and generic procedures for the key operations. The review also ensures that the application incorporates and is compatible with the applicable operating control limits in the TSs.

9.1 HI-STORM FW anchored configuration

The applicant revised chapter 9, "Operating Procedures," of the application to address the following proposed change:

> Proposed change No. 1, Add the allowance for the HI-STORM FW Version E overpack to be deployed in an anchored configuration

The applicant made minor changes to chapter 9, "Operating Procedures," which now includes the option for general licensee sites with high seismic conditions to use the anchored variant of the HI-STORM FW Version E. This variant is anchored to the ISFSI pad using concrete embedded anchor bolt receptacles and threaded anchor bolts.

Other changes to chapter 9 include the addition of an operational procedure to inspect the anchorage components for general condition and replace worn or damaged components with new ones if the anchored variant of HI-STORM FW Version E is used. Generic procedures were also added for inspecting anchor stud receptacles in the ISFSI concrete pad, aligning the FW anchored variant overpack over the embedded anchor locations, and installing the anchor connecting hardware. In addition, an ALARA warning was added to address the possible need for supplemental shielding around the anchored FW overpack to reduce personnel dose during anchor installation.

9.2 Evaluation Findings

The HI-STORM FW Version E anchored variant will be used at sites with high seismic conditions. General procedure descriptions for anchorage operations are summarized in chapter 9 of the application. In addition, the general operating procedures are adequate to protect health and minimize damage to life. Detailed procedures will need to be developed by the licensee. The staff evaluates those procedures on a site-specific basis during the site's 72.212 review through the NRC's oversight process.

The staff concludes that the generic procedures and guidance for the operation of the HI-STORM FW Version E are in compliance with 10 CFR Part 72 and that the applicable acceptance criteria provided in chapter 11 of SRP NUREG-2215 have been satisfied. Adequate generic operating details have been provided for the HI-STORM FW Version E anchored variant. The evaluation of the operating procedure descriptions provided in the application 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.

14.0 QUALITY ASSURANCE EVALUATION

The applicant did not propose any changes that affect the staff's quality assurance evaluation provided in the previous SERs for CoC No. 1032, Amendments Nos. 0 through 5. Therefore, the staff determined that a new evaluation was not required. The staff evaluated the adequacy of categorizing ITS components related to this amendment in the appropriate technical evaluations in this SER.

17.0 TECHNICAL SPECIFICATIONS

Besides the changes described in this section, the staff made editorial changes to the TSs. Editorial changes were not marked with change bars to highlight the changes relevant to this amendment request and did not change the outcome of the staff's evaluation.[5]

17.1 Changes to the Certificate of Compliance

Revised the end of the last paragraph of the "DESCRIPTION:" section as follows:

> "The HI-STORM FW storage overpack can be arrayed in a free-standing or anchored configuration (required when the seismic event for an ISFSI site exceeds the threshold limit for the free-standing configuration). If the seismic loads for a given ISFSI site exceed the threshold limit for a free-standing configuration of the HI-STORM FW set forth in the CoC, then the cask must be installed in an anchored configuration.""

17.2 Changes to Technical Specifications in Appendix A

17.2.1 Technical specification 3.1.2, "SFSC Heat Removal System"

a) Revised TS 3.1.2, LCO 3.1.2, "The SFSC Heat Removal System shall be operable," was revised as follows:

(1) specify under "CONDITION" A. that the SFSC Heat Removal System is considered operable, but partially (≤50%) blocked, and

(2) add the following "REQUIRED ACTION" under "CONDITION" C.:

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[5] The final safety analysis report or FSAR in one of the documents submitted as part of the application. In this safety evaluation report. The TSs refer to the FSAR.

<u>OR</u> C.2.3 Perform an engineering evaluation to demonstrate, using the models and methods from the HI-STORM FW FSAR, that all component and content temperatures remain below allowable temperature limits and the MPC internal pressure remains below the accident condition pressure limit.	24 hours

17.2.2 Technical specification 5.1, "Radioactive Effluent Control Program"

The applicant requested to remove TS 5.1 c. related to the "Radioactive Effluent Control Program" which requires an "annual submittal of a separate radioactive effluent report [10 CFR 72.44(d)(3)] for the HI-STORM FW system." The 10 CFR 72.44(d)(3) regulation applies to licensees and not to certificate holders. Therefore, TS 5.1 c. was removed from the TSs in appendix A. Nevertheless, licensees are still responsible for submitting a radioactive effluent report and complying with 10 CFR 72.44(d)(3).

17.2.3 Technical specification 5.2, "Transport Evaluation Program"

Added TS No. 4, which reads as follows:

"For existing handling equipment which does not meet the above criteria:

a. lift heights shall not exceed the limits in Table 5-1, provided the impact surface is bounded by the ISFSI pad parameters in Table 2.2.9 of the HI-STORM FW FSAR.

b. if lift heights exceed the limits in Table 5-1, a site-specific drop analysis shall be performed in accordance with Section 3.4, item No. 7. of Appendix B to demonstrate the safe operation of the system."

17.2.4 Table 5-1, "TRANSFER CASK and OVERPACK Lifting Requirements."

Added table 5-1, "TRANSFER CASK and OVERPACK Lifting Requirements."

17.3 Changes to Technical Specifications in Appendix B of the CoC

17.3.1 Technical specification 2.3, "Decay Heat Limits"

(1) Deleted the phrase "Changes in blue are due to RAI response" from the title.

(2) Added subsection 2.3.2, "Maximum fuel storage location decay heat limits."

17.3.2 Table 2.1-1, "Fuel Assembly Limits"

MPC Models MPC-32ML changes to reference tables in the TSs in appendix B of the CoC of the HI-STORM FW.

17.3.3 Technical specification 3.2, "Design Features Important for Criticality Control"

Revised TS section 3.2, "Design Features Important for Criticality Control," to clarify that the MPCs minimum basket cell internal diameter and minimum cell wall thickness are nominal values.

17.3.4 Technical specification 3.4, "Site-Specific Parameters and Analyses,"

TS section 3.4, "Site-Specific Parameters and Analyses," was updated as follows:

a) Revise condition Nos. 3.a. and b. to specify that these are applicable to the storage overpack in "free standing" position.

b) Add condition 3.c. for the anchored configuration of the HI-STORM FW overpack, which states the following:

> "For those ISFSI sites with design basis seismic acceleration values that may overturn or cause excessive sliding of free-standing casks, the anchored HI-STORM FW OVERPACK shall be utilized. Each OVERPACK shall be anchored with studs and nuts fabricated with material(s) compatible with the environment of the expected location of the ISFSI. The embedment design shall comply with Appendix B of ACI-349-97. A later edition of this Code may be used, provided a written reconciliation is performed."

c) Revise TS No. 7.a. as follows:

> "For a storage cask in a freestanding OVERPACK, the user shall demonstrate that the ISFSI pad parameters used in the non-mechanistic tipover and drop analyses are bounding for the site or a site specific non-mechanistic tipover and drop analyses to demonstrate that the acceptance criteria set forth in the HI-STORM FW FSAR are met shall be performed using the dynamic model described in FSAR section 3.4. The maximum total deflection, d, in the active fuel region of the basket panels shall be limited by the following inequality: $d \le 0.005\,\ell$, where ℓ is basket cell inside dimension. The site-specific analyses shall be performed using methodologies consistent with those described in the HI-STORM FW FSAR."

d) Add TS No. 7.b., which states the following:

> "For storage in an anchored OVERPACK, a tipover event is not credible. However, the ISFSI pad shall be designed to meet requirements of the anchored design. In addition, the user shall demonstrate that the ISFSI

pad parameters used in the drop analysis are bounding for the site or a site-specific drop analysis to demonstrate that the acceptance criteria set forth in the HI-STORM FW FSAR are met shall be performed using the dynamic model described in FSAR section 3.4. The maximum total deflection, d, in the active fuel region of the basket panels shall be limited by the following inequality: $d \leq 0.005\ \ell$, where ℓ is basket cell inside dimension. The site-specific drop analysis shall be performed using methodologies consistent with those described in the HI-STORM FW FSAR."

CONCLUSIONS

The staff has performed a comprehensive review of the amendment application. Table 1 of this SER includes a brief description of the proposed changes related to this amendment.

Based on the statements and representations provided by the applicant in its amendment application, as supplemented, the staff concludes that the changes described above to the HI-STORM FW MPC Storage System Amendment No. 6 will meet the requirements of 10 CFR Part 72. Amendment No. 6 for the HI-STORM FW MPC Storage System should be approved.

Issued with Certificate of Compliance No. 1032, Amendment No. 6
on _____________.

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