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PRELIMINARY SAFETY EVALUATION REPORT

DOCKET NO. 72-1014
HOLTEC INTERNATIONAL
HI-STORM 100
MULTIPURPOSE CANISTER STORAGE SYSTEM
CERTIFICATE OF COMPLIANCE NO. 1014
AMENDMENT NO. 14

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. 1014 for the HI-STORM 100 Multipurpose Canister (MPC) Storage System submitted by Holtec International (Holtec) by letter dated October 31, 2018 (Holtec, 2018a), and supplemented on November 6, 2018 (Holtec, 2018b), February 28, 2019 (Holtec, 2019a), April 5, 2019 (Holtec, 2019b), April 23 (Holtec, 2019c), May 13, 2019 (Holtec, 2019d), and August 8, 2019 (Holtec, 2019e). Holtec proposed the following changes:

1. Add three new regionalized Quarter Symmetric Heat Load (QSHL) loading patterns for the MPC-68M.
2. Reduce the minimum cooling time to 1 year for all fuel types for storage in the MPC-68M.
3. Use a damaged fuel isolator (DFI) for damaged fuel stored in the MPC-68M.
4. Modify the description of the vents in the overpack in the CoC. Remove the word "four" from Section 1.b describing the air inlet and outlet vents.

This amended CoC, when codified through rulemaking, will be denoted as Amendment No. 14 to CoC No. 1014.

This SER documents the staff's review and evaluation of the proposed amendment. The staff followed the guidance in NUREG-1536, Revision 1, "Standard Review Plan for Dry Cask Storage Systems at a General License Facility," July 2010 (NRC, 2010). 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 final safety analysis report (FSAR) nor previous amendments to 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 following proposed changes are applicable to the general information evaluation:

- Proposed Change #1: Add three new regionalized QSHL loading patterns for the MPC-68M.
- Proposed Change #3: Use a DFI for damaged fuel stored in the MPC-68M.

The applicant added the key parameters for the proposed new loading patterns to Table 1.III.1 of the FSAR and described the criteria that would be applied to damage fuel stored using a DFI. The staff determined that the description in the proposed changes to FSAR Chapter 1, "General Information," is adequate to allow the staff's detailed evaluation as documented in the following 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. The following proposed changes are applicable to the principal design criteria evaluation:

- Proposed Change #1: Add three new regionalized QSHL loading patterns for the MPC-68M.
- Proposed Change #2: Reduce the minimum cooling time to 1 year for all fuel types for storage in the MPC-68M.
- Proposed Change #3: Use a DFI for damaged fuel stored in the MPC-68M.

The applicant revised Chapter 2, "Principal Design Criteria," of the FSAR to add the new loading patterns, provide DFI design features, and update Table 2.1.29 for cooling time-depletion coefficients. The staff's evaluation of the principal design criteria for new loading patterns is documented in Section 4.3 of this SER and determines the three new loading patterns acceptable. The staff discusses the principal design criteria of the DFI in Sections 3.1, 4.4, and 8.3 of this SER, and determines the proposed DFI is acceptable for use with the proposed content. The staff evaluates the minimum 1-year cooling time in Section 6 of this SER and determines the proposed shorter cooling time acceptable.

3.0 STRUCTURAL EVALUATION

The staff reviewed the proposed changes to verify that the applicant has performed adequate structural evaluation to demonstrate that the system, as proposed, would be acceptable under normal and off-normal operations, accident conditions, and natural phenomena events. In conducting this evaluation, the staff seeks reasonable assurance that the cask system will maintain confinement, subcriticality, radiation shielding, and retrievability or recovery of the fuel, as applicable, under all credible loads for normal and off-normal conditions accidents, and natural phenomenon events. The following proposed change is applicable to the structural evaluation:

- Proposed Change #3: Use a DFI for damaged fuel stored in the MPC-68M.

3.1 Structural Review

The applicant has made no change to the center of mass, center of gravity, weight, or the thermal or material properties of the existing system as a result of the added loading patterns, the reduced minimum cooling time, or the modified description of vents. Since these changes did not affect the existing structural design basis and acceptance criteria, the staff's review focused primarily on the proposed change of using a DFI to constrain certain partially damaged fuel.

The applicant describes the details and design criteria of the DFI in Figure 2.1.10 and Section 2.1.3.1 of the proposed FSAR. The DFI consists of two stainless steel or nickel alloy caps that will be installed on top of and below a partially damaged fuel assembly in a fuel basket cell of MPC-68M. The DFI caps are designed to satisfy Section III, Division 1, Subsection NF of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC). The applicant has classified the DFI as important to safety class C as described in the applicant's quality assurance program. The staff has previously determined that the applicant's quality assurance program is acceptable, and proper implementation of the program will be assessed during future NRC inspections. The staff has independently assessed the safety class for the DFI and determined that the DFI meets the description of important to safety classification category C as described in NUREG/CR-6407 (NRC, 1996).

The side walls of the DFI caps are a variable length with a minimum length requirement longer than the gap between the top of the fuel basket and the underside of the MPC lid. This minimum length requirement assures that the DFI caps will remain in place within the basket cell in the event that the fuel assembly and DFI move to the top of the MPC during accident conditions. The DFI caps are installed such that the fuel assembly will rest on the horizontal, bottom plate of the bottom DFI cap. The top cap is then pushed into the basket cell until the horizontal, top plate of the DFI top cap contacts the top of the fuel assembly. The side walls of the DFI caps extend into the fuel basket cell and around the fuel assembly. With this positioning of the DFI caps, the weight of the fuel assembly and the inertial loads of the fuel assembly during an accident are ultimately resisted by the base plate and lid of the MPC with the horizontal plates of the DFI caps acting as shims between the fuel assembly and MPC.

Based on the loading configuration and requirements of the design standard, a detailed stress analysis of the DFI is not necessary. The loading configuration primarily results in bearing stresses in the horizontal plates of the DFI caps with no other significant stresses developing under credible conditions. The design standard, ASME BPVC.III.1.NF, does not require these bearing stresses to be evaluated.

3.2 Evaluation Findings

F3.1 Spent nuclear fuel handling, packaging, transfer, and storage systems with the DFI design as proposed in this amendment are designed to ensure subcriticality, in that at least two unlikely, independent, and concurrent or sequential changes must occur before a nuclear criticality accident ensues. The margins of safety of these systems are adequate for the nature of the immediate environment under accident conditions, and therefore meet the requirements in 10 CFR 72.124(a).

F3.2 The DFI is designed to provide favorable geometry, and therefore the application meets the requirements in 10 CFR 72.124(b).

F3.3 Design criteria is provided for the DFI that meets the requirements in 10 CFR 72.236(b).

F3.4 The DFI is designed such that the spent nuclear fuel is maintained in a subcritical condition under credible conditions, and therefore meets the requirement in 10 CFR 72.236(c).

F3.5 The design criteria of the DFI is such that it will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions, and therefore meets the requirements in 10 CFR 72.236(l).

The staff concludes that the applicant's description of the DFI design and design basis is sufficient to demonstrate that the DFIs will constrain fissile material during credible normal operations, off-normal operations, accident conditions, and natural phenomena events. The staff concludes that the structural performance of the structures, systems, and components of the HI-STORM 100 Storage System as proposed in Amendment No. 14 are in compliance with 10 CFR Part 72. The applicant has provided reasonable assurance that the HI-STORM 100 Storage System will allow for the safe storage of spent nuclear fuel and damaged fuel that can be stored in DFIs. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

4.0 THERMAL EVALUATION

The staff reviewed the proposed changes to the HI-STORM 100 storage system to ensure that the applicant had performed an adequate thermal evaluation to demonstrate that the cask and fuel material temperatures will remain within the allowable values or criteria for normal, off-normal, and accident conditions.

The following proposed changes are applicable to the thermal evaluation:

- Proposed Change #1: Add three new regionalized QSHL loading patterns for the MPC-68M.
- Proposed Change #2: Reduce the minimum cooling time to 1 year for all fuel types for storage in the MPC-68M.
- Proposed Change #3: Use a DFI for damaged fuel stored in the MPC-68M for all four regionalized QSHL loading patterns.

4.1 Regionalized Loading Patterns of QSHL-2, QSHL-3, and QSHL-4 for MPC-68M

The applicant proposed to add three new regionalized QSHL patterns (QSHL-2, QSHL-3, and QSHL-4) to the MPC-68M. The applicant stated in the proposed changes to FSAR Supplement 4.III, "Thermal Evaluation of the MPC-68M," that the additional QSHL patterns allow for the maximum fuel loading flexibility in the MPC-68M. The applicant stated in FSAR Supplement 4.III that the maximum permissible heat load (burnup) in each storage cell is specific to its location within the quadrant and is limited to a unique prescribed value as defined in FSAR Figures 2.III.2, 2.III.3, and 2.III.4, and in CoC Appendix B, Figures 2.4-2, 2.4-3, and 2.4-4. FSAR Section 2.1.9.1.3 indicates that the maximum allowable burnup is a function of fuel assembly cooling time, decay heat, and average enrichment. The applicant provides the equation and corresponding coefficients in FSAR Table 2.1.29 for boiling water reactors. In Section 6.2 of this SER, the staff evaluates the proposed Table 2.1.29 with additional coefficients for 1 to 1.75 years cooling time and determines the proposed Table 2.1.29 is acceptable to account for the fuel that has been cooled for 1 to 1.75 years of cooling.

The design heat load of QSHL-2, QSHL-3, and QSHL-4 patterns is 38.9 kW, which is less than the design heat load of 42.8 kW for the original QSHL pattern. The original QSHL pattern was reviewed and approved by the NRC in Amendment No. 12 to CoC No. 1014.

The applicant performed the thermal analyses for QSHL-2, QSHL-3, and QSHL-4 patterns to ensure that the cask component temperatures and cavity pressure are maintained below the corresponding design temperatures and pressures as shown in FSAR Tables 2.2.3, 2.2.1, and 4.III.2.

The staff reviewed FSAR Supplement 4.III and Holtec proprietary Report No. HI-2043317 Appendix P and finds the description for the new regionalized QSHL patterns appropriate for thermal evaluation.

4.2 Material Properties and Component Specifications

The applicant specified all material design temperatures in FSAR Tables 2.2.3 and 4.3.1 and the design temperatures of fuel basket and basket shim materials in FSAR Table 4.III.2.

The staff reviewed the material design temperature limits and material properties of thermal analysis and finds that they are consistent with those previously approved by the NRC. The staff confirmed that the thermal properties of materials specified in FSAR Section 4.2 and the specifications of components specified in FSAR Section 4.3 are also applicable to the new regionalized QSHL patterns (QSHL-2, QSHL-3, and QSHL-4) for the MPC-68M.

4.3 Thermal Evaluation of New Regionalized QSHL Patterns

The applicant performed thermal analyses, using an ANSYS/FLUENT computational fluid dynamics (CFD) model, for the following regionalized QSHL patterns in the MPC-68M placed inside HI-STORM 100 Casks. The ANSYS/FLUENT CFD modeling approach was previously used for evaluation of the cask design in Amendment No. 7 to CoC No. 1014 and reviewed by the NRC (NRC, 2009).

(i) QSHL-2 with intact fuel assemblies
(ii) QSHL-3 with intact fuel assemblies
(iii) QSHL-2 with damaged fuel assemblies inside DFC
(iv) QSHL-4 with damaged fuel assemblies inside DFC
(v) QSHL-2 with fuel debris inside DFC
(vi) QSHL-2 with damaged fuel in DFI

The staff reviewed FSAR Supplement 4.III and Report No. HI-2043317 Appendix P and confirmed that the information used to describe the new regionalized QSHL patterns is sufficient for the thermal evaluation.

4.3.1 Storage of Intact Fuel Assemblies under Normal, Off-Normal, and Accident Conditions

a. Temperature

The applicant stated in FSAR Supplement 4.III.4.2 that no change was made to the existing thermal model and the selected heat loads in Figures 2.III.2, 2.III.3, and 2.III.4 are suitably limited to ensure that the peak cladding temperatures (PCTs) in the MPC remain below the PCT for the bounding MPC (MPC-32) analyzed in the FSAR under all thermal scenarios. FSAR Table 4.III.3a shows that the PCTs for QSHL-2, QSHL-3, and QSHL-4 patterns are lower than the PCT for the previously analyzed and approved QSHL pattern with a heat load limit of 42.8 kW. The applicant concluded that the additional QSHL-2, QSHL-3, and QSHL-4 patterns are bounded by the QSHL pattern.

The applicant presented in Report No. HI-2043317, Appendix P, Table P.14, the temperature and MPC cavity pressure results for MPC-68M using Patterns QSHL-2 and QSHL-3 containing the intact fuel assemblies under normal long-term storage. The applicant noted that the allowable heat loads in the QSHL-4 pattern is bounded by the QSHL-2 pattern for storage of intact fuel; therefore, no explicit evaluation was performed for the QSHL-4 pattern with intact fuel assemblies. The applicant stated that the PCT and MPC and HI-STORM 100 System component temperatures are within the design limits in FSAR Table 2.2.3 and are bounded by the results shown in Appendix P, Tables P.1 and P.3 for the QSHL pattern. Therefore, the applicant concludes that the safety conclusions for the QSHL pattern under off-normal conditions, short-term operations (e.g., wet transfer, drying, on-site transfer, etc.), and hypothetical accident scenarios, discussed in Report No. HI-2043317 Sections P.5.1 through P.5.12, can be extended to the QSHL-2, QSHL-3 and QSHL-4 patterns containing the intact fuel assemblies.

The staff reviewed Appendix P and finds that for using the QSHL-2, QSHL-3, and QSHL-4 patterns: (1) the PCTs of using these patterns containing the intact fuel assemblies, are maintained below the temperature limits of 752°F as specified in Spent Fuel Storage and Transportation (SFST)-Interim Staff Guidance (ISG)-11, Revision 3 (NRC, 2003a), and FSAR Table 4.3.1 for normal long-term storage and short-term operations; and (2) the temperatures of cask components are below the design temperature limits presented in FSAR Tables 2.2.3 and 4.III.2, and are bounded by those for the QSHL pattern containing the intact fuel assemblies, under normal long-term storage and short-term operations (e.g., drying, helium backfill, and on-site transfer). The QSHL pattern within the MPC-68M was reviewed and approved by the NRC in Amendment No. 12 to CoC No. 1014.

Based on the conditions for normal long-term storage, the staff has reasonable assurance that (1) the bounding correlations of the QSHL pattern can be extended to the QSHL-2, QSHL-3, and QSHL-4 patterns containing the intact fuel assemblies under off-normal conditions and hypothetical accident scenarios; and (2) the PCTs for the QSHL-2, QSHL-3, and QSHL-4 patterns containing the intact fuel assemblies are below the limit of 1,058°F as specified in SFST-ISG-11, Revision 3, and their maximum component temperatures are below the corresponding design temperatures in FSAR Tables 2.2.3 and 4.III.2 for off-normal conditions and hypothetical accident scenarios.

b. Pressures and Initial Helium Backfill Pressures

The applicant defined the initial helium backfill pressures (≥ 45.5 psig and ≤ 48.5 psig) in FSAR Table 1.III.1 and CoC, Appendix A, Table 3-2 for the QSHL-2, QSHL-3, and QSHL-4 patterns. The applicant performed the pressure calculations with the maximum initial helium backfill pressure of 48.5 psig and presented the results in Report No. HI-2043317 Appendix P, Table P.14 for normal, long-term storage. The calculated MPC cavity pressures for the QSHL-2, QSHL-3, and QSHL-4 patterns are bounded by that for the QSHL pattern and are well within the design pressure in FSAR Table 2.2.1 for normal long-term storage.

The staff reviewed the thermal calculations in Appendix P and accepts that the proposed initial helium backfill pressure range (≥ 45.5 psig and ≤ 48.5 psig) for the QSHL-2, QSHL-3, and QSHL-4 patterns containing the intact fuel assemblies is acceptable because the calculated maximum MPC internal pressures are below the design limit and are bounded by that for the QSHL pattern containing the intact fuel assemblies under normal long-term storage.

Base on the conditions for normal long-term storage, the staff has reasonable assurance that (1) the bounding correlations of the QSHL pattern can be extended to the QSHL-2, QSHL-3, and QSHL-4 patterns containing the intact fuel assemblies under off-normal conditions and hypothetical accident scenarios; and (2) the maximum cavity pressures for the QSHL-2, QSHL-3, and QSHL-4 patterns containing the intact fuel assemblies are below the design pressures in FSAR Table 2.2.1 for off-normal conditions and hypothetical accident scenarios.

4.3.2 Damaged Fuel/Fuel Debris in DFC

The applicant stated in Report No. HI-2043317 Appendix P, Section P.5.13.1 that for intact fuel, the temperatures and pressure for using the QSHL-2 pattern bound those for using the QSHL-3 and QSHL-4 patterns; therefore, the QSHL-2 pattern is adopted for the evaluation of DFCs with damaged fuel assemblies and fuel debris for the three new QSHL loading patterns. For the evaluation of storage of damaged fuel assemblies or fuel debris in the DFCs, the applicant modified the thermal model to have the DFCs in the respective cell locations and have additional features as described in Appendix P, Section P.5.13.1.

The applicant performed the steady-state thermal evaluations for the QSHL-2 and QSHL-4 patterns containing damaged fuel in the DFCs and presented the results in Appendix P, Table P.15 for normal, long-term storage. The applicant stated that for both QSHL-2 and QSHL-4 patterns, (1) the PCTs are below the limits specified in SFST-ISG-11, Revision 3, and (2) the cask component temperatures are below the design temperatures in FSAR Table 2.2.3, and the MPC cavity pressures are all within the design pressure specified in FSAR Table 2.2.1. The applicant noted that the temperatures and pressure using the QSHL-2 pattern bound those using the QSHL-4 pattern; therefore, the QSHL-2 pattern was adopted for the evaluation of the DFC loaded with the fuel debris under all storage scenarios.

The staff reviewed Appendix P, Section P.5.13.1 and the resulting PCT and cask component temperatures in Table P.15 for normal, long-term storage. The staff finds that for the QSHL-2 and QSHL-4 patterns containing damaged fuel in the DFCs (Table P.15), the reported PCTs are below the SFST-ISG-11, Revision 3 limit of 752°F, and the cask component temperatures and the MPC cavity pressures (no rod rupture) are below the design limits in FSAR Tables 2.2.3 and 2.2.1, respectively.

The staff also confirmed that the bounding correlations of QSHL-2 pattern can be extended to the QSHL-3 and QSHL-4 patterns containing damaged fuel in DFCs, based on the bounding correlation of the QSHL-2 pattern on the QSHL-3 and QSHL-4 patterns containing intact fuel assemblies for normal, long-term storage. Therefore, the staff finds that the QSHL-2, QSHL-3, and QSHL-4 patterns are acceptable for storing damaged fuel in DFCs in the MPC-68M.

The applicant performed steady state thermal evaluations for the QSHL-2 pattern containing fuel debris in the DFCs and presented results in Table P.16. The applicant stated that the PCT, cask component temperatures, and the MPC cavity pressure are all within the corresponding design limits specified in SFST-ISG-11, Revision 3, FSAR Table 2.2.3, and FSAR Table 2.2.1, respectively.

The staff reviewed Appendix P, Section P.5.13.1 and the resulting PCT and cask component temperatures in Table P.16 for normal, long-term storage. The staff finds that for the QSHL-2 pattern containing the fuel debris in the DFCs, the reported PCT is below the SFST-ISG-11, Revision 3 limit of 752°F, and the cask component temperatures and the MPC cavity pressure are below their design limits in FSAR Tables 2.2.3 and 2.2.1.

The staff also confirmed that the bounding correlations of the QSHL-2 pattern containing the fuel debris in the DFCs can be extended to the QSHL-3 and QSHL-4 patterns containing the fuel debris in the DFCs, based on the bounding correlations of the QSHL-2 pattern on the QSHL-3 and QSHL-4 patterns for storing the intact fuel assemblies and the damaged fuel. Therefore, the staff finds that the QSHL-2, QSHL-3, and QSHL-4 patterns are acceptable for storing the fuel debris in the DFCs in the MPC-68M.

The applicant also updated the CoC, Appendix A, Table 3-5 to include the new loading patterns. Based on the above evaluation in Section 4.3.1 of the SER that the evaluation of the previously approved bounding QSHL pattern can be extended to the three new loading patterns; therefore, the staff concludes that the inclusion of the new loading patterns QSHL-2, QSHL-3, and QSHL-4 with the original QSHL in Table 3-5 is acceptable.

4.4 Damaged Fuel in DFI

The applicant stated in the application that the MPC-68M basket is also permitted to store damaged fuel assemblies that can be handled by normal means with DFIs. The applicant stated in Report No. HI-2043317 Appendix P Section P.5.13.2 that it only performed thermal analysis for the QSHL-2 pattern with the DFIs because the QSHL-2 pattern bounds both the QSHL-3 and QSHL-4 patterns, based on the results of (a) intact fuel assemblies under normal storage as presented in Table P.14, and (b) damaged fuel placed inside DFCs under normal storage as presented in Table P.15.

The applicant modified the thermal model for the QSHL-2 pattern containing the DFIs in the permitted locations under normal, long-term storage. The staff reviewed the DFI configuration and the DFI thermal model description and verified the applicant's thermal model for the QSHL-2 pattern containing the damaged fuel assemblies in the DFIs is consistent with the description in response to the staff's request for additional information (RAI) (Holtec, 2019a, proprietary attachments). The applicant's description of the DFI configuration states that the bottom DFI opens upward; however, the bottom DFI is modeled upside down for some cell locations and some of the surfaces underneath the fuel region are modelled as a perforated plate with porous jump boundary condition. The staff accepts this approach for modeling the DFIs because the resistance to helium flow through the DFIs is appropriately considered.

As presented in Table P.17, the applicant noted that (1) the computed PCT for the QSHL-2 pattern containing the damaged fuel in the DFIs is below the limit of 752°F as specified in SFST-ISG-11, Revision 3, (2) the MPC cavity pressure is below the design pressure in FSAR Table 2.2.1, and (3) the emplacement of DFIs has an insignificant impact on the PCT and MPC pressure when compared to the intact fuel stored inside the QSHL-2 pattern.

The applicant noted that the PCT, MPC/overpack temperatures and cavity internal pressure for the QSHL-2 pattern containing damaged fuel in DFIs are bounded by those in Tables P.1 and P.3 for the QSHL pattern containing intact fuel under normal, long-term storage. The applicant concludes that the safety conclusions for the QSHL pattern can be extended to the QSHL-2 pattern containing damaged fuel in DFIs for off-normal conditions, short-term operations (e.g., drying and on-site transfer), and hypothetical accident scenarios, which are discussed in Appendix P, Sections P.5.1 through P.5.12.

The staff reviewed Appendix P, Section P.5 and the resulting PCT and MPC cavity pressure tabulated in Table P.17. The staff confirmed that use of the QSHL-2 pattern in the MPC-68M is acceptable for storage of damaged fuel in DFIs under normal, long-term storage; short-term operations; off-normal storage conditions; and hypothetical accident scenarios. The staff also confirmed that the bounding correlations of the QSHL-2 pattern can be further extended to the QSHL-3 and QSHL-4 patterns and, therefore, the QSHL-2, QSHL-3, and QSHL-4 patterns, as described by the applicant for implementation in the MPC-68M, are acceptable for storing damaged fuel in the DFIs under all storage conditions.

Based on the use of the QSHL-2 with intact fuel assemblies (Table P.14) and QSHL-2 with DFIs (Table P.17), the staff also confirmed that the use of the QSHL pattern in the MPC-68M for storage of damaged fuel in DFIs will have the PCTs, maximum component temperatures, and cavity gas pressures below the design limits and close to those for use of the QSHL pattern with intact fuel assemblies. Therefore, the use of the QSHL pattern for storage of damaged fuel in DFIs is also acceptable under normal, long-term storage, short-term operations, off-normal storage conditions, and hypothetical accident scenarios.

4.6 Evaluation Findings

The staff reviewed the proposed changes and the related thermal evaluations and confirmed that the applicant has met the thermal requirements of 10 CFR 72.236(f):

F4.1 The staff has reasonable assurance that the QSHL-2, QSHL-3, and QSHL-4 patterns loaded in the MPC-68M and the features of the MPC-68M that are important to safety are described in sufficient detail in the application to enable an evaluation of the heat removal effectiveness. The SSCs remain within their operating temperature ranges.

F4.2 The staff has reasonable assurance that the MPC-68M (QSHL-2, QSHL-3, and QSHL-4 patterns with a heat load up to 38.9 kW) continues to be designed with a heat-removal capability having verifiability and reliability consistent with its importance to safety.

F4.3 The staff has reasonable assurance that the fuel cladding of high burnup fuel in the MPC-68M (QSHL-2, QSHL-3, and QSHL-4 patterns with a heat load up to 38.9 kW) continues to be protected against degradation leading to gross ruptures by maintaining the cladding temperatures below 400°C (752°F) for short-term operations and normal conditions of storage and 570°C (1,058°F) for off-normal and accident conditions of storage, and other cask component temperatures continue to be maintained below the allowable limits for the accidents evaluated.

F4.4 The staff has reasonable assurance that the MPC-68M loaded with the QSHL-2, QSHL-3, or QSHL-4 patterns and a design heat load of 38.9 kW is able to sustain the pressures predicted under normal, off-normal, and accident-level conditions. The maximum canister pressures are below the design pressures of 100, 110, and 200 psig for normal, off-normal, and accident conditions of storage, respectively.

F4.5 Based on the evaluations and findings above, the staff has reasonable assurance that the proposed patterns of QSHL-2, QSHL-3, and QSHL-4, each with DFCs and DFIs, as shown in CoC Appendix B Figures 2.4-2, 2.4-3, and 2.4-4, respectively, are acceptable. Based on the evaluations of the QSHL-2 pattern with intact fuel assemblies and with damaged fuel in DFIs, the staff has reasonable assurance that the QSHL pattern with DFIs, as shown in CoC Appendix B Figure 2.4-1 is acceptable.

F4.6 Based on the staff's evaluation of the burnup calculation equation in FSAR Section 2.1.9.1.3 and the proposed additional coefficients in FSAR Table 2.1.29, the staff has reasonable assurance that the MPC-68M basket is acceptable to store fuel that has been cooled for a minimum of 1 year or greater.

The staff concludes that the thermal design of MPC-68M, loaded with QSHL-2, QSHL-3 and QSHL-4 patterns under a design heat load of 38.9 kW, is in compliance with 10 CFR Part 72 and the applicable design and acceptance criteria have been satisfied. The evaluation of the thermal design provides reasonable assurance that the MPC-68M (QSHL-2, QSHL-3, and QSHL-4 patterns) will allow safe storage of spent fuel during the license period. This finding is based on a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

5.0 CONFINEMENT EVALUATION

The applicant did not propose any changes that affect the staff's confinement evaluation provided in the previous SERs for CoC No. 1014, Amendments No. 0 through 13. Therefore, the staff determined that a new evaluation was not required.

6.0 SHIELDING EVALUATION

The staff reviewed the proposed changes in Amendment No. 14 to CoC No. 1014 for the HI-STORM 100 storage system to ensure that the radiation shielding features are sufficient to meet the operational dose requirements of 10 CFR 72.104 and 72.106 in accordance with 10 CFR 72.236(d). The staff evaluated the shielding performance of the dry cask storage system under normal and off-normal operations, accident conditions, and natural phenomena events as they related to the proposed changes below. The system's shielding design bases and acceptance criteria remain unchanged from previous amendments. The staff focused its review on the following proposed changes that are applicable to the shielding evaluation:

- Proposed Change #1: Add three new regionalized QSHL loading patterns for the MPC-68M.
- Proposed Change #2: Reduce the minimum cooling time to 1 year for all fuel types for storage in the MPC-68M.

6.1 Addition of New Loading Patterns for MPC-68M

The applicant requests approval for three new loading patterns: QSHL-2, QSHL-3, and QSHL-4, which are shown in Figures 2.III.2, 2.III.3, and 2.III.4 of the proposed FSAR. The applicant performed source term calculations for each of the three new loading patterns for the MPC-68M using the SCALE 5.1 modeling software. The source terms for the design basis 7x7 fuel, which were calculated using the SCALE 5.1 code as analyzed in Holtec's proprietary Report HI-2146423, "HI-STAR 190 Source Terms and Loading Patterns," are used for this analysis. For dose rate calculations, the applicant used an updated version of MCNP5, Version 1.51. According to NUREG/CR-6802 (NRC, 2003b), "Recommendations for Shielding Evaluations for Transport and Storage Packages," the use of reasonable procedures and well-established computer codes is expected to produce acceptable results. Dose rate calculations performed in previous amendments to CoC No. 1014 for the HI-STORM 100 system were conducted using MCNP4a. The staff found that using the updated version of MCNP is acceptable for this evaluation because the code is a well-established code for shielding evaluations and the update to the code is not expected to impact the results.

The applicant determined the highest dose rate for the new loading patterns. In order to evaluate the high heat load regionalized loading patterns proposed for the MPC-68M, the applicant considered all possible burnup, enrichment, and cooling time combinations of the new loading patterns shown in Table KK-1 of Holtec's proprietary Report HI-2012702. The maximum result among all combinations for each dose rate location from Table KK-1 are reported in Table KK-3 of Report HI-2012702. Table KK-3 provides a comparison of the maximum dose rates at different locations to the approved design basis maximum dose rates based upon the uniform loading pattern. The results show the dose rates for the higher heat load assemblies in the new loading patterns are bounded by the previously approved uniform loading pattern dose rates.

Holtec established and analyzed in Report HI-2012702, as part of the application, that the bounding loading pattern, from a heat load perspective, covers all of the proposed regionalized loading patterns. The staff evaluated Holtec's analysis and concluded that the three new loading patterns will continue meeting the regulatory dose limits in 10 CFR 72.104 and 72.106.

6.2 Reduce the Minimum Cooling Time to 1 Year for All Fuel Types for Storage in the MPC-68M

The applicant proposed to reduce the minimum cooling time from 2 years to 1 year for all fuel types stored in MPC-68M, which would increase heat load. In the previous section, the staff evaluated the proposed addition of three new loading patterns (QSHL-2, QSHL-3, and QSHL-4) to accommodate spent fuel with higher heat load. The evaluation assumes that the MPC-68M is loaded with fuel generating heat at the maximum permissible level under each new QSHL pattern. The burnup equation in FSAR Section 2.1.9.1.3 and CoC Appendix B Section 2.4.3, which was accepted in Amendment No. 2 to CoC No. 1014 (NRC, 2005), is used to estimate the burnup given the decay heat, enrichment, and cooling time as parameters. Once the burnup is estimated, the applicant can choose fuel assemblies acceptable for the loading pattern. In order to accommodate cask users with high heat load spent fuel, i.e., fuel cooled for at least 1 year, the applicant proposes to add coefficients for 1 to 1.75 years cooling time to the correlation approved in Amendment No. 2 of CoC No. 1014. The coefficients for the burnup equation is discussed in Section 2.1.9 of the FSAR. The applicant used the method accepted in Amendment No. 2 to CoC No. 1014 for generating the coefficients. This method was based on curve-fitting to develop a seven-coefficient equation and associated coefficients. The decay heat calculations were performed with the SAS2H/ORIGEN-S and were similar to the calculations performed for the design-basis source terms. The applicant calculated the coefficients and presented them in FSAR Table 2.1.29.

The staff performed confirmatory analysis using ORIGEN-ARP, a depletion code in SCALE 6.1. In order to verify that the added coefficients are acceptable, the staff used the coefficients for given combinations of enrichment, cooling time, and decay heat. Once the estimated burnup is calculated from the burnup equation, the staff used the burnup, enrichment, and cooling time to obtain the decay heat for the specific combination and the neutron and gamma source terms. The staff compared the calculated decay heat and source terms to the applicant's decay heat and source terms. The staff found a close agreement with the applicant's decay heat and source terms values. The staff verified that the applicant used the source terms in the dose rate calculations. The staff concluded that the coefficients for the burnup equation are acceptable to account for fuel that has high heat loads that has been discharged for 1 year or greater.

6.3 Evaluation Findings

F6.1 Based on the information provided by the applicant and the fact that the dose rates for the three new loading patterns are bounded by the dose rates of the uniform loading pattern (50,000 MWD/MTU and 3-year cooling), the staff found it acceptable to add the three new loading patterns shown in Figures 2.III.2 through 2.III.4 of the proposed SAR, as approved contents of MPC-68M. The staff has reasonable assurance that the three new loading patterns will meet the regulatory dose limits in 10 CFR 72.104 and 72.106.

F6.2 Based on the staff's independent verification of the burnup equation (Section 2.1.9.1.3) and the updated corresponding coefficients in the FSAR (Table 2.1.29), the staff has reasonable assurance that storage in the MPC-68M of fuel that has been cooled for a minimum of 1 year or greater will meet the regulatory dose limits in 10 CFR 72.104 and 72.106.

The staff concluded that the design of the radiation protection system of the HI-STORM 100 Cask System can be operated in compliance with 10 CFR Parts 72, and the applicable design and acceptance criteria have been satisfied. The evaluation of the radiation protection system design provides reasonable assurance that the HI-STORM 100 Cask System, Amendment No. 14 will provide safe storage of spent fuel. This finding is based on a review that considered appropriate regulatory guides, applicable codes and standards, the applicant's analyses, the staff's confirmatory analyses, and acceptable engineering practices.

7.0 CRITICALITY EVALUATION

The staff reviewed the proposed changes to ensure that the applicant had performed adequate criticality evaluation to demonstrate the system will remain subcritical under all credible normal, off-normal, and accident conditions encountered during handling, packaging, transfer, and storage. The staff's review involved ensuring that the requested changes meet the regulatory requirements of 10 CFR 72.124(a), 72.124(b), 72.236(c), 72.236(g).

The following proposed changes are applicable to the criticality evaluation:

- Proposed Change #1: Add three new regionalized QSHL loading patterns for the MPC-68M.
- Proposed Change #3: Use a DFI for damaged fuel stored in the MPC-68M.

7.1 Description of the Criticality Design

The HI-STORM 100 cask system design is unchanged from previous amendments. The MPC-68M in the HI-STORM 100 system was originally introduced in Appendix X of Holtec proprietary Report HI-2012771 (Holtec, 2018a), and is used as the design basis of the analysis in Appendix AE of that same report to support the proposed addition of DFIs and allow flexibility in damaged fuel and fuel debris loading. DFIs may contain damaged fuel assemblies that may have missing fuel rods or partial fuel rods and/or fuel rods that have cladding defects greater than pinhole leaks or hairline cracks as long as the fuel assembly can be handled by normal means and where structural integrity and geometric reconfiguration of the fuel is not expected. There are no proposed physical changes to the fuel assembly design nor to the physical design of the MPC-68M canister. The cladding, initial enrichment of the fuel, number of fuel rods, fuel length, and all dimensions and tolerances are unchanged; only the three new QSHL loading patterns (QSHL-2, QSHL-3, and QSHL-4) and the addition of DFIs as an allowable content are introduced.

Criticality safety of the HI-STORM 100 with an MPC-68M basket continues to rely on the geometry of the fuel basket design and the use of Metamic-HT as a neutron absorber. From a criticality perspective, the applicant proposed a typical loading pattern configuration of an MPC-68M with undamaged fuel and up to 16 cells around the periphery of the basket containing damaged fuel or fuel debris in basket locations either in DFCs or damaged fuel in DFIs as shown in Figure 6.III.1.1 of the FSAR (for loading patterns QSHL, QSHL-2, and QSHL-3). The applicant proposed an alternate loading pattern in an MPC-68M with four empty cells near the center with eight cells containing either DFCs or DFIs adjacent to each vacant cell as shown in Figure 6.III.1.2 of the FSAR (for loading pattern QSHL-4). The proposed loading patterns QSHL-2 and QSHL-3 are in the typical criticality configuration for the MPC-68M, which was previously evaluated and approved for criticality safety by the staff in Amendment No. 8 to CoC No. 1014. Thus, the staff focuses the criticality review on the alternate criticality configuration used for loading pattern QSHL-4.

The staff evaluated the applicant’s proposed changes to the FSAR for the addition of DFIs in all loading patterns in MPC-68M and the alternate loading patterns against the original contents cited in the FSAR for completeness of information, description of the package design features, parameters, and dimensions, and found them to be sufficient to perform the review.

7.2 Spent Fuel Specification

The applicant provided tables of parameters that specify the limits for spent fuel that are authorized for storage in the HI-STORM 100 cask system (FSAR Tables 2.1.3, 2.1.4, 2.1.12, and 2.1.17 through 2.1.27) and are unchanged by this amendment. However, damaged fuel which can be handled by normal means and stored using DFIs in specific locations was added as an allowable content for this amendment. Damaged fuel stored with DFIs in the MPC-68M canister are loaded into limited basket cell locations with DFIs installed in the upper and lower ends of the specific basket cell location in lieu of using a DFC. These cells may contain damaged fuel assemblies that may have missing fuel rods or partial fuel rods and/or fuel rods that have cladding defects greater than pinhole leaks or hairline cracks as long as the fuel assembly can still be handled by normal means and where the structural integrity of the fuel is maintained and geometric reconfiguration of the fuel is not expected. No fuel debris is allowed in a DFI. Only DFCs may be utilized to store fuel debris in the MPC-68M.

Previous amendments to CoC No. 1014 for the HI-STORM 100 cask system specified a maximum enrichment of 4.0 weight percent (wt.%) ^{235}U for damaged fuel that is loaded into the MPC-68M. For damaged fuel loaded in the proposed QSHL-4 pattern (FSAR Figure 2.III.4), Amendment No. 14 to CoC No. 1014 would allow a maximum enrichment for the damaged fuel of up to 4.5 wt.% ^{235}U to be loaded into the center cell locations specified next to the four vacant basket cells as shown in Table 2.III.2 of the FSAR for 8x8F, 9x9E, and 9x9F assembly types. Similarly, for 10x10G damaged fuel, the NRC has previously approved assembly enrichment up to 4.6 wt.% ^{235}U to be stored in MPC-68M. Amendment No. 14 to CoC No. 1014 would allow loading into the proposed QSHL-4 pattern with the maximum enrichment of 4.5 wt.% ^{235}U as stated in FSAR Table 2.III.3. The staff determined that the enrichment of 4.5 wt.% ^{235}U for fuel loaded into these center locations of the proposed QSHL-4 pattern was allowable based on the overall reduction in reactivity (approximately 4% reduction across all allowable fuel types in the MPC-68M) due to the empty cells directly adjacent to the damaged fuel cells in the loading pattern.

7.3 Model Specification

The applicant performed additional calculations to support this amendment request to address the new QSHL-2, QSHL-3, and QSHL-4 loading patterns using the MCNP5 v1.51 Code with the ENDF/B-VII cross-section library. The applicant's results are presented in Table 6.III.1.5, Table 6.III.4.11, and Table 6.III.4.12 in the FSAR. These results evaluate the maximum k_{eff} of the QSHL-4 pattern containing undamaged fuel, four empty cells, and DFIs/DFCs in 8 cells adjacent to the empty cells, as well as a reactivity comparison between cells loaded with DFIs versus DFCs.

The models utilized in this amendment are similar to those performed for the previously approved MPC-68M basket configurations using MCNP4a with the following differences. The calculations utilized a different number of cycles and histories to ensure convergence while using the updated MCNP5 Code, the updated cross sections from ENDF/B-VII were used, and the benchmarking was adjusted to account for the use of the MCNP5 v1.51 Code with the ENDF/B-VII cross-section library. The staff found these variations and associated justification to be conservative and appropriate for use in the calculations.

7.4 Criticality Analysis

The staff reviewed the FSAR sections affected by this proposed amendment and the previous criticality analysis performed for the MPC-68M basket type in the HI-STORM 100 cask system. The applicant modeled the QSHL fuel loading configurations to determine the effect on reactivity for the various loading patterns. All the calculations performed are similar to those used to certify fuel assembly types in the MPC-68M basket that had been used in previous amendments. Modeling of the assembly types was the same for undamaged fuel rods. For damaged fuel in a DFC, the applicant utilized the conservative approach of modeling arrays of bare fuel rods since fuel debris is allowed in DFCs. The main difference in modeling the damaged fuel in DFIs is that the applicant used arrays of cladded rods since these rods can be handled by normal means and no fuel debris is allowed in a DFI basket cell.

The applicant analyzed the new DFI loading patterns using the same conservative assumptions as before, including fully flooding the basket, DFCs, DFIs, and the pellet-to-clad gap for undamaged assemblies. For damaged fuel loadings, the applicant used the same approach as used for damaged fuel and fuel debris allowed in the DFCs. As noted above, no fuel debris is allowed in a DFI, only fuel that can be handled by normal means and which retains its structure and geometry. The applicant modeled for all QSHL loading patterns with DFIs either in 16 cells around the periphery of the basket, or with 4 empty cells and 8 DFCs or DFIs loaded as described in Section 7.3 of this SER.

Other parameters that maximize reactivity of the MPC-68M in its various configurations and loading patterns were analyzed, including maximum active fuel length, maximum fuel pellet diameter, maximum fuel rod pitch, minimum cladding outside diameter (OD), maximum cladding inside diameter (ID), minimum guide tube/water rod thickness, maximum channel thickness, and removing part length rods (if present). In all instances, the maximum k_{eff} values show a decrease in reactivity due to the new loading patterns and enrichment restrictions, and the system remains subcritical under the conditions of 10 CFR Part 72.

The staff reviewed the applicant's calculations and assumptions for the QSHL loading patterns and the addition of DFI cells in the basket and found them to be appropriate and conservative in all respects. The staff determined that the net effect of establishing the damaged fuel DFCs/DFIs around the periphery of the basket, and the net effect of locating damaged fuel DFCs/DFIs in the center adjacent to empty cells in the basket as described above were sufficient to lower the overall reactivity of the package in all loaded QSHL configurations, and the staff has reasonable assurance that the proposed changes would continue to allow for the safe storage of spent nuclear fuel under 10 CFR Part 72.

7.5 Burnup Credit

The applicant did not request any changes to burnup credit. Therefore, the previous evaluation continues to be acceptable to the staff and an evaluation is not required.

7.6 Benchmark Evaluations

The applicant provided a benchmark evaluation that compared calculational methods with experimental results to determine appropriate bias and uncertainties for use with the updated MCNP5 v1.51 Code with the ENDF/B-VII cross-section library and found no significant trends when compared to the benchmark evaluation performed with the previous MCNP4a Code. The applicant calculated bias and bias uncertainty and used the more conservative truncated bias of 0.0004 ± 0.0003, instead of the total bias of -0.0024 ± 0.0008, for all k_{eff} results that used the updated MCNP5 v1.51 Code and ENDF/B-VII library. The staff concludes that the method employed continues to be consistent with the acceptance criteria of ANSI/ANS-8.1 and NUREG-1536 for determining the bias.

7.7 Evaluation Findings

F7.1 Structures, systems, and components important to criticality safety are described in sufficient detail in the FSAR to enable an evaluation of their effectiveness.

F7.2 The cask systems are designed to be subcritical under all credible conditions.

F7.3 The criticality design is based on favorable geometry and fixed neutron poisons. The analysis and evaluation of the criticality design and performance have demonstrated that the cask will enable the storage of spent fuel for the term requested in the CoC application.

The staff concludes that the criticality design features for the HI-STORM 100 continue to be in compliance with 10 CFR Part 72 and the applicable design and acceptance criteria have been satisfied. The evaluation of the criticality design provides reasonable assurance that the HI-STORM 100 will continue to allow for the safe storage of spent fuel with the modifications proposed by this amendment. 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.

8.0 MATERIALS EVALUATION

The staff reviewed the proposed changes to the HI-STORM 100 CoC against the appropriate regulations as described in 10 CFR 72.236 to verify that the applicant performed adequate materials evaluation to ensure adequate material performance of components important to safety under normal, off-normal, and accident conditions. The staff's review followed the guidance in Chapter 8 of NUREG-1536, Revision 1, as well as associated ISG documents.

The following proposed changes are applicable to materials evaluation:

- Proposed Change #1: Add three new regionalized QSHL loading patterns for the MPC-68M.
- Proposed Change #2: Reduce the minimum cooling time to 1 year for all fuel types for storage in the MPC-68M.
- Proposed Change #3: Use a DFI for damaged fuel stored in the MPC-68M.

The staff also reviewed the addition of density data of major components as part of the above proposed changes.

8.1 New Heat Loading Patterns

The applicant proposed three new loading patterns and indicated that the heat load of the previously approved QSHL pattern (Figure 2.4-1, heat load of 42.8 kW) bounds QSHL-2, QSHL-3, and QSHL-4 (CoC Appendix B, Figures 2.4-2, 2.4-3 and 2.4-4, all with heat load of 38.9 kW). The applicant proposed to reduce the minimum cooling time to 1 year for the MPC-68M.

The staff reviewed the applicant's analyses of component temperatures in FSAR Table 4.III.3a for the new heat loading pattern. Consistent with the staff's thermal evaluation in Section 4 of this SER, the staff has determined that the applicant's analysis of cladding temperature under normal, off-normal, and accident conditions establishes that cladding temperature will remain within the cladding temperature limits described in NUREG-1536, Revision 1, Section 8.4.17.

8.2 Completion Time for Actions to Restore Spent Fuel Storage Cask Heat Removal System Operable

The applicant included the three new loading patterns in CoC Appendix A, Table 3-5, "Completion Time for Actions to Restore SFSC (spent fuel storage cask) Heat Removal System Operable." The staff evaluated the potential thermal and pressure changes on this inclusion. The staff conducted an independent analysis and determined that, because the temperatures and pressures of the system using the new loading patterns were lower than those for using the previously approved QSHL pattern, the completion times for the previously approved QSHL pattern are applicable for the new QSHL-2, QSHL-3, and QSHL-4 loading patterns. Consistent with the evaluation in Section 4 of this SER, the staff determines that the changes to CoC Appendix A, Table 3-5, for the completion times to restore the operation of the spent fuel storage cask heat removal system are acceptable.

8.3 Addition of the DFI

The applicant proposed to add the DFI which may be used if the damaged fuel assembly can be handled by normal means and its structural integrity is such that geometric rearrangement of fuel is not expected under normal, off normal, and accident conditions. Damaged fuel stored in DFIs may contain (1) missing or partial fuel rods (empty fuel rod locations that are not filled with dummy fuel rods) and/or (2) fuel rods with known or suspected cladding defects greater than hairline cracks or pinhole leaks as long as the fuel assembly can be handles by normal means. The applicant stated that damaged fuel that does not meet the criterion for using DFI must be stored using DFCs. The DFC design and its allowed contents have been previously approved by the NRC. Therefore, the staff determines that the use of DFCs is acceptable for damaged fuel not qualified for the use of DFIs.

The applicant stated that the DFI is a set of specially designed barriers at the top and bottom of a storage cell space used to prevent the migration of fissile material in bulk or coarse particulate form from the nuclear fuel stored in its cellular storage cavity. DFIs are not used to handle the fuel assembly and do not provide assistance in the ability to handle the fuel assembly during normal, off-normal, or accident conditions.

The FSAR notes that the material (corrosion resistant alloy steel, e.g. 304 stainless steel, Monel, etc.) procurement, design, fabrication and inspection of DFI are in compliance with ASME BPVC, Section III Subsection NF. The DFI is made up of two end caps, along with the four cell walls, and comprise the fuel isolation space. The bottom cap is a prismatic box with a flat baseplate which fits inside the storage cell space with a small clearance (for ease of installation). The sidewalls of the bottom cap have perforations or wire mesh to permit transmigration of gases but not fuel fragments or gross particulates and is equipped with a flexible permeable barrier against the storage cell walls for sequestrations of coarse particulate matter. The top cap is anatomically similar to the bottom cap.

The staff determines the use of the ASME BPVC Section III Subsection NF is acceptable. The staff notes that SFST-ISG-1, Revision 2, considers gross breach of fuel cladding as any cladding breach greater than 1 millimeter. Gross breaches of fuel cladding may permit the release of fuel particulates. The DFI design specifies that the cap walls shall have perforation with a maximum size of 1 millimeter. This keeps any gross particulate fissile material inside the basket cell. The staff determines that the design of the DFI is acceptable because the perforation size of 1 millimeter allows the fuel to be dried and is sufficient to retain fuel particulates released from the basket cell with the damaged fuel.

The applicant identified the allowed locations for using DFIs. DFI storage locations are limited to the same locations allowed for the DFC in the MPC-68M. For damaged fuel assemblies that can be handled by normal means and whose structural integrity is such that geometric rearrangement of fuel is not expected, the use of DFIs can be substituted for the use of the DFC for storage in allowed locations. The staff determines that substituting DFIs for DFCs is an acceptable alternative for storing damaged fuel as described in NUREG-1536, Revision 1, Section 8.6.C, because the use of DFIs is limited to fuel that (1) can be handled by normal means and (2) will not undergo geometric rearrangement under normal, off-normal, and accident conditions. The staff determined that the use of the DFIs is consistent with the regulatory requirement of 10 CFR 72.122(h)(1) which states that the fuel must be confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage.

8.4 Density Data of Holtite-A

The applicant presented density data for Holtite-A, the applicant's proprietary neutron shield material, in FSAR Table 6.III.3.5. The applicant states that the density of Holtite-A is 1.612 g/cm^3. The applicant states that the specific gravity of Holtite-A is 1.68 g/cm^3 in FSAR Appendix 1.B. As noted in FSAR Section 1.2.1.3.2, the applicant reduced the density by 4% to 1.61 g/cm^3 to conservatively bound any potential weight loss at the design temperature and any inability to reach the theoretical density. The applicant also used the 1.61 g/cm^3 density for shielding analysis. The staff determines the use of this density value to be acceptable because the lower density of 1.61 g/cm^3 is conservative.

8.5 Evaluation Findings

F.8.1. The applicant has met the requirements of 10 CFR 72.236(b). The applicant provided the design basis and design criteria for structures, systems, and components important to safety in sufficient detail in the FSAR. The materials properties comply with ASME BPVC.

F.8.2. The applicant has met the requirements of 10 CFR 72.122(h)(1) and 72.236(h). The design of the dry cask storage system and selection of materials adequately protect the spent fuel cladding against degradation that might otherwise lead to gross rupture of the cladding. The temperature limits are met.

F.8.3. The applicant has met the requirements of 10 CFR 72.236(h) and 236(m). The material of construction for SSCs important to safety will be maintained during normal, off-normal, and accident conditions of operation so the spent fuel can be readily retrieved without posing operational safety problems. The staff has reasonable assurance of the readily safe retrievability of the spent fuel, as supported by F.8.2.

F.8.4. The applicant has met the requirements of 10 CFR 72.236(g). The materials of construction for SCCs important to safety will be maintained during all conditions of operation so the spent fuel can be stored for a minimum of 20 years and maintenance can be conducted as required. The staff has reasonable assurance that such conditions will be maintained with the new heat loading patterns and the reduced minimum cooling time, and within the completion time to restore the spent fuel storage cask heat removal system to operation.

F.8.5. The applicant has met the requirements of 10 CFR 72.236(h). The HI-STORM 100 Storage System employs materials compatible with wet and dry spent fuel loading and unloading operations and facilities. These materials should not degrade over time or react with one another during any conditions of storage. The staff has reasonable assurance that the strength of DFI materials are adequate for their use and the material will not produce any adverse chemical reaction.

The staff concludes that the material properties of the structures, systems, and components of the HI-STORM 100 Cask System remain in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the material properties provides reasonable assurance that the cask will allow safe storage of spent nuclear fuel for the licensed life. This finding is reached based on a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

9.0 OPERATING PROCEDURES EVALUATION

The applicant proposed additional operating procedures for Proposed Change #3, the use of a DFI for damaged fuel stored in the MPC-68M. The applicant added additional steps in FSAR Chapter 8.1.3, 8.1.4, and 8.3.4 for loading and unloading the DFI.

The applicant stated that the DFI may only be used for a fuel assembly that can be handled by normal means. Fuel will not undergo geometric rearrangement under normal, off-normal, and accident conditions. The applicant stated in its response to the staff's RAI (Holtec, 2019a) that the bottom DFI cap is installed in the empty fuel basket location prior to the fuel assembly being loaded. After the fuel assembly is loaded, then the top DFI cap is installed into the fuel basket cell location. The staff determined that the additional steps in FSAR Chapter 8 are adequate for loading and unloading the DFI.

10.0 ACCEPTANCE TESTS AND MAINTANANCE PROGRAM EVALUATION

The applicant did not propose any changes that affect the staff's acceptance tests and maintenance program evaluation provided in the previous SERs for CoC No. 1014, Amendments No. 0 through 13. Therefore, the staff determined that a new evaluation was not required.

11.0 RADIATION PROTECTION EVALUATION

The applicant did not propose any changes that affect the staff's radiation protection evaluation provided in the previous SERs for CoC No. 1014, Amendments No. 0 through 13. Therefore, the staff determined that a new evaluation was not required.

12.0 ACCIDENT ANALYSES EVALUATION

The applicant did not propose any changes to the principal design criteria related to the SSCs important to safety. For this reason, the staff finds the applicant complied with the relevant general criteria established in 10 CFR Part 72 and does not require an accident analysis evaluation of the principal design criteria. Internal pressure changes were investigated as part of the thermal evaluation and found to be either bounding, or non-safety significant for all cases. Therefore, no further confinement evaluation was necessary for accident conditions.

13.0 TECHNICAL SPECIFICATIONS AND OPERATING CONTROL AND LIMITS EVALUATION

The staff reviewed the proposed amendment to determine that applicable changes made to the conditions in the CoC, and to the technical specifications for CoC No. 1014, Amendment No. 14 would be in accordance with the requirements of 10 CFR Part 72. The staff reviewed the proposed changes to the CoC and Technical Specifications to confirm the changes were properly evaluated and supported in the applicant's revised safety analysis report. Specifically, the staff reviewed the following proposed change:

- Proposed Change #4: Modify the description of the vents in the overpack in the CoC. Remove the word “four” from Section 1.b describing the air inlet and outlet vents.

Currently, the CoC states that the “overpack has four air inlets at the bottom and four air outlets at the top to allow air to circulate naturally through the cavity to cool the MPC inside.” The applicant proposed to remove the specific number of air inlets and outlets identified in the CoC. The staff reviewed the latest FSAR, Revision 15 (Holtec, 2018c), and recognized that the proprietary overpack drawings in Chapter 1 show four air inlets at the bottom and four air outlets at the top to allow air to flow through the annulus to cool the MPC inside. The staff’s evaluation and approval for Amendment No. 0 was based on the applicant’s analysis with four air inlets and four air outlets (NRC, 2000). The staff notes that any reduction in the number of air inlets and outlets on the overpack would change the licensing safety basis and would require additional safety analysis. Based on these reasons, the staff determines that there is reasonable assurance that the current FSAR for HI-STORM 100 storage system contains sufficient information in the cask and overpack design to maintain adequate heat removal capability. As such, the removal of the specific languages on the number of overpack air inlet and outlet is acceptable.

Below is the list of applicant’s proposed changes to the CoC and Technical Specifications:

Table 13-1 – Conforming Changes to the Certificate of Compliance and Technical Specifications

Page Number	**Reference**	**Description**	**Proposed Change**
CoC 2	Section 1.b	Modify the description of the vents in the overpack by removing the word “four” describing the number of air inlet and outlet vents.	4
Appendix A 1.1-2	Section 1.1	Add the definition for DFI.	3
Appendix A 3.4-1	Table 3-1	Modify Note 7 to add reference to Figures 2.4-2 through 2.4-4.	1
Appendix A 3.4-4	Table 3-2	Under MPC-68M, add three new loading patterns and associated helium backfill limits.	1
Appendix A 3.4-6	Table 3-5	Add three new loading patterns for MPC-68M.	1
Appendix B 2-33, 2-34, 2-36	Table 2.1-1, Section VI, A.2, A.2.h, B.1	Add conditions for using DFI, including allowable contents, fuel assembly weight, and quantity per MPC.	3
Appendix B 2-33	Table 2.1-1, Section VI, A.2.d.ii	Change the minimum cooling time to 1 year.	2

Table 13-1 – Conforming Changes to the Certificate of Compliance and Technical Specifications			
Appendix B 2-45 through 2-47	Table 2.1-3	(1) Change the note for 10x10G maximum planar average initial enrichment from Note 15 to Note 21. (2) Revised Note15 to add conditions of fuel assembly for using the loading pattern in Figure 2.4-4. (3) Add Note 21 to provide conditions of fuel assembly for using the loading pattern in Figure 2.4-4.	1
Appendix B 2-50	Section 2.4.2	Editorial changes to (1) remove "(Intact or Undamaged Fuel only)" and (2) add "or undamaged" to the first sentence. The first change reflects that Section 2.4.2 also refers to damaged fuel and fuel debris. The second change clarifies that the equations only apply to intact or undamaged fuel assemblies.	N/A
Appendix B 2-50	Section 2.4.2	Add reference to the new loading patterns in Figures 2.4-2 through 2.4-4 for MPC-68M.	1
Appendix B 2-51	Table 2.4-2	In the Note, add reference to the new loading patterns in Figures 2.4-2 through 2.4-4 for MPC-68M.	1
Appendix B 2-51	Table 2.4-5	(1) Clarify the use of DFC, (2) add reference to the new loading patterns in Figures 2.4-2 through 2.4-4 for MPC-68M, and (3) provide the conditions for using DFI.	1, 3
Appendix B 2-62 through 2-71	Table 2.4-4	Update the cooling time-dependent coefficient to including cooling time for 1, 1.25, 1.5, and 1.75 years.	2
Appendix B 2-72 through 2-75	Figures 2.4-1 through 2.4-4	Update the figure with DFI information and add three new loading patterns.	1, 3

The staff finds that the proposed changes to the CoC and Technical Specifications for the HI-STORM 100 MPC Storage System conform to the changes requested in the amendment application and do not affect the ability of the cask system to meet the requirements of 10 CFR Part 72. The proposed changes provide reasonable assurance that the HI-STORM 100 MPC Storage System will continue to allow safe storage of spent nuclear fuel.

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. 1014, Amendments No. 0 through 13. Therefore, the staff determined that a new evaluation was not required.

15.0 CONCLUSIONS

The staff has performed a comprehensive review of the amendment application, during which the following requested changes to the HI-STORM 100 MPC Storage System were considered:

1. Add three new loading patterns for the MPC-68M.
2. Reduce the minimum cooling time to 1 year for all fuel types for storage in the MPC-68M.
3. Use a DFI for damaged fuel stored in the MPC-68M.
4. Modify the description of the vents in the overpack in the CoC. Remove the word "four" from Section 1.b describing the air inlet and outlet vents.

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 100 MPC Storage System do not affect the ability of the cask system to meet the requirements of 10 CFR Part 72. Amendment No. 14 for the HI-STORM 100 MPC Storage System should be approved.

Issued with Certificate of Compliance No. 1014, Amendment No. 14
on ________________________.

References

American Society of Mechanical Engineers, “ASME Boiler and Pressure Vessel Code,” Section III, “Rules for Construction of Nuclear Power Plant Components,” 2010 Edition through 2011 Addenda.

ANSI/ANS-8.1, “Nuclear Criticality Safety in Operations with Fissile Material Outside Reactors,” American Nuclear Society.

Holtec, 2018a. Letter from Holtec International to NRC, “Holtec International HI-STORM 100 Multipurpose Canister Storage System Amendment Request 1014-14.” October 31, 2018. This package contains 13 attachments, and Attachments 6 through 12 are Proprietary Information and Not Publicly Available. Agencywide Document Access and Management System (ADAMS) Accession No. ML18331A056.

Holtec, 2018b. Letter from Holtec International to NRC, “Holtec International HI-STORM 100 Multipurpose Canister Storage System Amendment Request 1014-14.” November 6, 2018. ADAMS Accession No. ML18324A577.

Holtec, 2018c. Final Safety Analysis Report for the HI-STORM 100 Dry Spent Fuel Storage System, Revision 15. April 27, 2018. ADAMS Accession No. ML18130A139.

Holtec, 2019a. Letter from Holtec International to NRC, “Submittal of Responses to NRC's 1st Round RAIs for HI-STORM 100 Amendment Number 14,” February 28, 2019. This package contains five attachments, and Attachment 1 is Proprietary Information and Not Publicly Available. ADAMS Accession No. ML19065A076.

Holtec, 2019b. Letter from Holtec International to NRC, “Submittal of Responses to Clarification Questions for Holtec’s Response to NRC's 1st Round RAIs for HI-STORM 100 Amendment Number 14,” April 5, 2019. ADAMS Accession No. ML19101A335.

Holtec, 2019c. Letter from Holtec International to NRC, “Submittal of Responses to Clarification Questions for Holtec's Response to NRC's 1st Round RAIs for HI-STORM 100 Amendment Number 14,” April 23, 2019. ADAMS Accession No. ML19121A283.

Holtec, 2019d. Letter from Holtec International to NRC, “Submittal of Responses to Clarification Questions for Holtec's Response to NRC's 1st Round RAIs for HI-STORM 100 Amendment Number 14,” May 13, 2019. ADAMS Accession No. ML19140A285.

Holtec, 2019e. Email from Holtec International to NRC, “small change to HI-STORM 100 Amd 14 CoC appendix B,” August 8, 2019. ADAMS Accession No. ML19224A393.

NRC, 1996. “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” NUREG/CR-6407, U.S. Nuclear Regulatory Commission, February 1996. ADAMS Accession No. ML15127A114.

NRC, 2000. Safety Evaluation Report for Holtec International’s HI-STORM 100 Cask System, U.S. Nuclear Regulatory Commission, May 4, 2000. ADAMS Accession No. ML003711865.

NRC, 2003a. “Cladding Considerations for the Transportation and Storage of Spent Fuel,” SFST-ISG-11, Revision 3, U.S. Nuclear Regulatory Commission, November 17, 2003. ADAMS Accession No. ML033230335.

NRC, 2003b. “Recommendations for Shielding Evaluations for Transport and Storage Packages,” NUREG/CR-6802, U.S. Nuclear Regulatory Commission, May 2003. ADAMS Accession No. ML031330514.

NRC, 2005. U.S. Nuclear Regulatory Commission, Safety Evaluation Report, Docket No. 72-1014, Holtec International, HI-STORM 100 Cask System, Certificate of Compliance No. 1014, Amendment No. 2,” June 7, 2005. ADAMS Accession No. ML051580522.

NRC, 2007. “Damaged Fuel,” SFST-ISG-1, Revision 2, U.S. Nuclear Regulatory Commission, May 11, 2007. ADAMS Accession No. ML071420268.

NRC, 2009. U.S. Nuclear Regulatory Commission, Safety Evaluation Report, Docket No. 72-1014, Holtec International, HI-STORM 100 Cask System, Certificate of Compliance No. 1014, Amendment No. 7,” December 28, 2009. ADAMS Accession No. ML093620075.

NRC, 2010. “Standard Review Plan for Spent Fuel Dry Cask Storage Systems at a General License Facility,” NUREG-1536, Revision 1, U.S. Nuclear Regulatory Commission, July 2010. ADAMS Accession No. ML101040620.

SUBJECT: PRELIMINARY SAFETY EVALUATION REPORT, DOCKET NO. 72-1014, HOLTEC INTERNATIONAL HI-STORM 100 MULTIPURPOSE CANISTER STORAGE SYSTEM CERTIFICATE OF COMPLIANCE NO. 1014, AMENDMENT NO. 14

DOCUMENT DATE: ___________________

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