U.S NUCLEAR REGULATORY COMMISSION

FINAL SAFETY EVALUATION BY THE

OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS

FOR THE HOLTEC INTERNATIONAL

TOPICAL REPORT HI-2200343, REVISION 2, "TOPICAL REPORT FOR ALLOWANCE OF HEAT LOAD PATTERNS IN HI-STORM 100 AND HI-STORM FW [FLOOD WIND] SYSTEMS"

DOCKET NOS. 721014 AND 721032

1.0 INTRODUCTION

In a letter dated March 19, 2020 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML20101N174), Holtec International (Holtec) submitted Topical Report (TR) HI-2200343, Revision 0, "Topical Report for Allowance of Heat Load Patterns in HI-STORM 100 and HI-STORM FW[Flood Wind] Systems" (Ref. 1), for U.S. Nuclear Regulatory Commission (NRC) review and approval. Subsequently, in a letter dated October 6, 2020, Holtec supplemented the TR (Ref. 2) following a regulatory audit to provide responses to NRC questions (Ref 6), and then, in a letter dated April 2, 2021, further supplemented the TR (Ref. 3) documenting their response to NRC developed open items (Ref. 8).

This safety evaluation (SE) report addresses whether the evaluation of decay heat loading patterns, which include thermal modeling of the cask design and subsequent temperature outputs for cask components, can be achieved for a range of decay heat loading patterns with a generically approved methodology, without NRC review and approval of the specific heat load patterns. This TR (Ref. 3) and SE only consider the thermal evaluation methodology for a range of decay heat loading patterns.

The review for the TR consisted of an acceptance review (ADAMS Accession No. ML20141L621), a technical review, including a technical audit (Ref. 6 and Ref. 7), and development and resolution of open technical issues that remained during the development of the draft safety evaluation (SE).

1.1 General Considerations for the Topical Report Technical Review

This SE documents the technical review and approval of the TR methodology for evaluating a range of decay heat load patterns, which relies, in part, upon previously approved evaluations for fixed heat load patterns. The technical review includes cross-referencing evaluations previously presented in the final safety analysis reports (FSARs) for the HI-STORM 100 and HI-STORM FW systems as well as evaluating any variations not explicitly documented in those previously approved evaluations.

The NRC's review of this TR, in part, included a review of the safety evaluations for previous CoC approvals of alternate heat load patterns. Language in those previous Safety Evaluation Reports (SERs) for the HI-STORM 100 and the HI-STORM FW directly indicated that the technical review relied on previously reviewed and approved evaluations. This technical review approach, namely relying on previously reviewed and approved evaluations, is also consistent across other docket/designs for those CoC amendments that are seeking approval for an alternate heat load pattern.

This TR (Ref. 3) is a stand-alone document which contains the information necessary to fully evaluate a range of decay heat load patterns for both the HI-STORM 100 and the HI-STORM FW. It was asserted by Holtec that each section is the same as the evaluation methodology for the fixed heat load patterns that were presented in the previously reviewed and approved FSARs and subsequent CoCs for the HI-STORM 100 and HI-STORM FW.

2.0 SUMMARY OF CURRENT COC TECHNICAL REVIEW PROCESS FOR ALTERNATE FIXED HEAT LOAD PATTERNS

Specific thermal evaluations from prior SERs for the HI-STORM 100 (Amendment 12 and Amendment 14) and HI-STORM FW (Amendment 5) are excerpted in Section 2.1 of this SE. The purpose for including the specific examples is to show how technical reviews have been performed when changes to heat load patterns are a proposed change in a CoC amendment.

2.1 Summary of Previous NRC CoC Amendments Proposing Alternate Heat Load Patterns

The excerpts below are from previously issued NRC SERs detailing the technical reviews performed for changes to heat loads in the specific spent fuel storage systems noted.

2.1.1 HI-STORM 100 Amendment 12 (Application – ADAMS Accession No. ML16169A363, SER – ADAMS Accession No. ML18355A383)

Application proposed change

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> **]**

SER technical review conclusions

> (1) Section 4.3 (a) of the SER (ML18355A383): "The applicant performed the thermal evaluations using an <u>*ANSYS FLUENT computational fluid dynamics (CFD) model previously used in the HI-STORM 100 FSAR and were reviewed and approved by NRC*</u>.
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> *(2)* Section 4.3 (a) of the SER (ML18355A383): "<u>*The NRC staff concludes that the fuel cladding temperatures will be maintained below the temperature limits in FSAR*</u> Table 4.3.1, i.e., the cladding temperature limit will be 752 °F under normal long-term storage,

752 °F (HBF) and 1,058 °F (moderate burnup fuel (MBF)) under short-term operations, and 1,058 °F under off-normal and accident conditions. These limits are consistent with Spent Fuel Storage and Transportation (SFST)-Interim Staff Guidance (ISG)-11, Revision 3. *The cask component temperatures will also remain below the design temperature limits listed in FSAR Table 2.2.3. The NRC staff found the reported PCT and component temperatures are acceptable…" (Emphasis added)*

(3) Section 4.3 (b) of the SER (ML18355A383): "The staff reviewed the **[**

] and accepted that the proposed initial helium backfill pressures (≥ 43.5 psig and ≤ 46.5 psig) for MPC-68M under QSHL pattern *are acceptable because the calculated maximum MPC internal pressures and the maximum fuel cladding and cask component temperatures are below the corresponding limits* for under short-term operations and normal, off-normal, and accident-level storage conditions." *(Emphasis added)*

2.1.2 HI-STORM 100 A.14 (Application – ADAMS Accession No. ML18331A056, SER – ADAMS Accession No. ML19295C576)

Application proposed change

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SER technical review conclusions

(1) Section 4.3 of the SER (ML19295C576): "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)" *(Emphasis added)*.

(2) Section 4.3 (a) of the SER (ML19295C576): "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 **[**

] The applicant concluded that the additional QSHL-2, QSHL-3, and QSHL-4 patterns are bounded by the QSHL pattern." (*Emphasis added)*

2.1.3 HI-STORM FW Amendment 5 (Application – ADAMS Accession No. ML18179A100, SER – ADAMS Accession No. ML20163A706)

Application proposed changes

(A) Add new heat load patterns for the MPC-89 and MPC-37 (long, standard, and short length).

(B) Use ANSYS FLUENT analysis model to revise the calculation for evaluating effective fuel conductivities.

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SER technical review conclusions

(1) Section 4.1 of the SER (ML20163A706): "The staff reviewed the applicant's description of the HI-STORM FW system thermal model. Based on the information provided in the application regarding the thermal model, the staff determined that the application is consistent with guidance provided in NUREG-1536, Section 4.4.4, "Analytical Methods, Models, and Calculations." Therefore, the staff concludes that the description of the thermal model is acceptable, as the description is consistent with NUREG-1536, and satisfies the regulatory requirements of 10 CFR 72.236(b), 72.236(f), 72.236(g), and 72.236(h)." *(Emphasis added)*

(2) Section 4.2 of the SER (ML20163A706): **[** **]** *These temperatures bound all heat loading patterns. Therefore, the previously approved licensing basis models continue to be applicable to the new heat load patterns* for either the MPC-37 or MPC-89, and no further evaluation of the new heat load patterns is required." *(Emphasis added)*

2.1.4 Conclusions

As identified in the examples above, the technical review approach and conclusions specifically identify the following:

(a) **[** **]**
(b) There was specific reliance in making the safety determination on the thermal models utilized by the previously approved bounding loading condition with no further investigation of the thermal model with respect to its range of validity.
(c) The basis for accepting the safety analysis relied on the degree of variability of the updated component temperatures and pressures when compared with the bounding case, and subsequently the acceptance criteria.

As such, the NRC determines that within the limits analyzed in this TR, the thermal models used to evaluate fixed alternate heat load patterns for applicable storage conditions within the HI-STORM 100 and the HI-STORM FW FSARs have been previously reviewed and approved by the NRC.

3.0 Thermal Evaluation Methodologies for HI-STORM 100 SYSTEM and HI-STORM FW System Heat Load Patterns

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3.1 General Considerations for Thermal Evaluations of Heat Load Patterns

As stated in SE Section 1.0, Holtec asserted that there is a substantial justification for finding that the previously approved evaluations of alternate decay heat load patterns can provide accurate results supporting a reasonable assurance of adequate protection finding, because the evaluations presented in this TR are unchanged from the evaluations used in the latest versions of the FSARs for both the HI-STORM 100 (Ref. 4) and HI-STORM FW (Ref. 5) systems. Consistent with the discussion in SE Sections 1.1 and 2.1, alternate decay heat load evaluations presented in previous CoC actions for the HI-STORM 100 and HI-STORM FW systems are considered approved methodologies for calculating component temperatures and subsequent system pressures. The NRC noted in the audit plan (Ref. 6) that past SERs may not be explicit on necessary limitations for decay heat. Specifically, defined individual assembly decay heat values and total system decay heat are identified in those previous licensing actions and are part of the approved evaluation as an input to the thermal models. Any deviation from those defined values are changes to inputs to the thermal models requiring an amendment for NRC review and approval.

3.2 Acceptance Criteria

The resultant temperatures from heat load patterns in this evaluation must remain within the acceptance criteria limits as specified in the TR (Ref. 3) (Tables 2.1 and 2.2, Tables 4.1 and 4.2) and the FSARs for the CoCs. Holtec proposed a normal conditions PCT limit lower than the limits set forth in ISG-11, Revision 3 (now incorporated into NUREG-2215 (Ref. 9)). Similarly, Holtec also proposed a limit on the normal conditions MPC cavity pressure lower than the limit set forth in the latest revisions of the HI-STORM 100 (Ref. 4) and HI-STORM FW (Ref. 5) FSARs.

Holtec asserted that the distribution of decay heat in the MPC and total decay heat are self-limited with the acceptance criteria presented in the TR (Ref. 3) because the acceptance criteria are more conservative than those used for any heat load patterns submitted as part of a CoC review. The NRC notes that the models that predict the calculated temperatures and pressures used to compare with the acceptance criteria must have reasonable accuracy for their intended purpose; specifically, the thermal model should not be used with a decay heat input that is outside of a range of applicability that is valid for the parameters of the thermal model. This is addressed further in section 3.4.3.3 of this SE.

3.3 Elements of the Thermal Evaluation of Heat Load Patterns

3.3.1 HI-STORM 100 Thermal Models, Operational Limits, and Condition Evaluations

3.3.1.1 Design Basis Thermal Models

The design basis thermal models were presented in Section 2.3 of the TR (Ref. 3). These included: a (1) design description and discussion of the material properties to be used, (2) description of HI-STORM 100 thermal model, (3) description of the HI-TRAC transfer cask thermal model, and (4) vacuum drying thermal model. The thermal models presented in this section were identified by Holtec as the same as those presented in the HI-STORM 100 FSAR (Ref. 4). The NRC considered the inclusion of the thermal models in this manner as an incorporation by reference and the staff review consisted of cross-referencing the information presented in the TR (Ref. 3) with the information presented in the HI-STORM 100 FSAR (Ref. 4). This review approach is reasonable because evaluations used in previously approved CoCs are considered reviewed and approved by the NRC. Further, the review approach used in various CoC amendments incorporating alternate heat loads regularly cite prior use of thermal models as reviewed and approved.

3.3.1.2 Operational Limits and Condition Evaluations

Section 2.3 of the TR (Ref. 3) provided helium backfill limits and examples to time to boil calculations as well as descriptions of the various condition evaluations including partial vent blockage, off-normal ambient temperature event, extreme ambient temperature accident, 100 percent vent blockage, burial under debris, loss of water from water jacket, fire, and differential thermal expansion. The NRC cross-referenced these evaluations and found that they are consistent with those presented in the FSAR.

3.3.2 HI-STORM FW Thermal Models, Operational Limits, and Condition Evaluations

3.3.2.1 Design Basis Thermal Models

The design basis thermal models were presented in Section 4.3 of the TR (Ref. 3). These included: (1) design description and discussion of the material properties to be used, (2) description of the HI-STORM FW 3-D thermal model, (3) description of the HI-TRAC VW transfer cask thermal model, and (4) vacuum drying thermal model. The models presented in this section were identified by Holtec as the same as those presented in the HI-STORM FW FSAR (Ref. 5). The NRC considered the inclusion of the thermal models in this manner as an incorporation by reference and the staff review consisted of cross-referencing the information presented in the TR (Ref. 3) with the information presented in the HI-STORM FW FSAR (Ref. 5). This approach was appropriate as the NRC has concluded that evaluations used in previously approved CoCs are considered reviewed and approved by the NRC. Further, the review approach used in various CoC amendments incorporating alternate heat loads regularly cites prior use of the thermal models as reviewed and approved, based on the thermal models remaining the same except for the change in alternate heat load.

3.3.2.2 Operational Limits and Condition Evaluations

Section 4.3 of the TR (Ref. 3) provided helium backfill limits and example time to boil calculations, as well as descriptions of the various condition evaluations including partial vent blockage, off-normal ambient temperature event, extreme ambient temperature accident, 100 percent vent blockage, burial under debris, loss of water from water jacket, fire, and differential thermal expansion. The NRC cross-referenced these evaluations and found that they are consistent with those presented in the FSAR.

The NRC's review of the information summarized above from the TR (Ref. 3) and subsequent cross-referencing with the FSARs, demonstrated that the thermal evaluations for decay heat loading patterns presented in the TR (Ref. 3) were consistent across both FSARs for the HI-STORM 100 (Ref.4) and HI-STORM FW (Ref. 5).

3.4 Implementation of the Thermal Evaluation Methodology for Decay Heat Loading Patterns

3.4.1 General

Sections 2.3 and 4.3 of the TR (Ref. 3) outline the process for evaluating the normal long-term storage condition for a heat load pattern using the approved thermal models. The thermal evaluation specifies that all component temperatures and the cavity pressure shall remain below the limits specified in the TR (Ref. 3) (Tables 2.1 and 2.2, Tables 4.1 and 4.2) for the pattern to be considered acceptable. **[**

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Sections 2.3.18, [

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To support this proposal, Holtec provided initial justification [

] The results of this evaluation demonstrated that the PCT over time was lower for the accident condition using the TR example decay heat pattern even though the allowable per cell decay heat for the example pattern was higher than the design basis per cell limiting decay heat. [

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In response to questions raised during discussions of the proposed screening evaluation during the regulatory audit (Ref. 6 and Ref. 7), Holtec provided additional justification submitted in Revision 2 of the TR (Ref. 3). The additional information included the three CoC amendment examples summarized in Section 2.2 of this SE (HI-STORM 100 amendment 12, HI-STORM 100 Amendment 14, and HI-STORM FW Amendment 5). These examples demonstrate that in cases where the value of Q/I exceeded the design basis value, all transient or conditions of storage events were subsequently evaluated and, in the cases, where Q/I was bounded by the design basis value, only the long-term storage condition was evaluated.

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The NRC concludes that this approach is acceptable based on the evaluation provided by Holtec in the TR (Ref. 3) which demonstrates that the long-term storage condition with a candidate heat load pattern is a bounding condition. Additionally, this approach is consistent with the technical approach presented by Holtec for the CoC amendment examples described in Section 2.1 of this SE.

3.4.3 Decay Heat Loading Evaluation

3.4.3.1 Decay Heat Load Excursions – Individual Fuel Assemblies

As an outcome of the regulatory audit (Ref. 7), Holtec provided examples (HI-STORM 100 Amendment 14, HI-STORM FW Amendment 5) which demonstrated that there have been alternate heat load patterns submitted to the NRC for review and approval with individual fuel assembly decay heats that exceeded what had been previously approved by the NRC. A review of these examples showed no deviation in the technical review process followed by the NRC and that those same technical review processes were consistent with cases where the proposed individual assembly decay heats were less than what was previously reviewed and approved.

3.4.3.2 Decay Heat Load Excursions – Total Decay Heat

As identified in Section 3.1 of this SE regarding enhancement to the evaluation methodology discussion, heat load patterns which exceed the total decay heat previously approved in a CoC needed additional justification to demonstrate that the thermal models are still valid for those increases in total decay heat.

As an outcome of the regulatory audit (Ref. 7), Holtec provided examples (HI-STORM 100 Amendment 14, HI-STORM FW Amendment 5) which demonstrated that there have been alternate heat load patterns submitted to the NRC for review and approval with total decay heats that exceeded what had been previously approved by the NRC. A review of these examples showed no deviation in the technical review process followed by the NRC and that those same technical review processes were consistent with cases where the proposed total decay heat was less than what was previously reviewed and approved. As another outcome of the regulatory audit (Ref. 7), Holtec also provided supplemental justification demonstrating that the validity of the thermal modeling approach is not dependent on the magnitude of the decay heat either on an individual fuel assembly basis or a total system basis. This justification is evaluated further in Section 3.4.3.3 of this SE.

3.4.3.3 Thermal Model Range of Applicability

As noted in Section 3.1 as well as Sections 3.4.3.1 and 3.4.3.2 of this SE and an outcome of the regulatory audit (Ref. 7), Holtec made certain enhancements to the evaluation methodology justification to demonstrate the loading scenarios described above would not result in proposed decay heat load patterns in which the thermal models and subsequent evaluations would produce invalid temperature results. Holtec submitted additional information in the revised TR (Ref. 3)
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The staff concludes that the justification is reasonable for determining whether the evaluation remains valid for alternate heat load patterns with decay heat above previously approved design basis values (Section 3.4.3.1 and 3.4.3.2 of this SE), because it demonstrates that the physics underpinning the evaluation is invariant or self-limiting with respect to decay heat. If a thermal model with a proposed heat load pattern does not align with these justifications, then the pattern is not suitable for use because the thermal models producing component temperature outputs have not been evaluated for acceptability beyond the justifications presented above.

4.0 LIMITATIONS ON THE EVALUATION METHODOLOGY

L4.1 The approval for use of the evaluations in the TR (Ref. 3) is not intended to provide a generic approval for the use of those evaluations, including supporting thermal models, beyond selecting alternate heat load patterns for the HI-STORM 100 and HI-STORM FW systems.

L4.2 The previously approved thermal models for the design configurations listed in Appendix 1 of this SE were identified as invariant, which means that no changes to the models, modeling choices, boundary conditions, other inputs, or thermal model manipulations are allowed if used with the TR (Ref. 3). The only exceptions to altering the thermal models are: (1) the use of mirror symmetry of the existing model formulation, and (2) changes to the per cell decay heat values identified for a given candidate heat load pattern.

L4.3 The thermal models that predict the calculated temperatures, and subsequently system pressures, used to compare with the acceptance criteria must have reasonable accuracy for their intended purpose; therefore, the thermal models cannot be used with decay heat inputs that may render the thermal models as outside their range of applicability.

L4.4 Acceptability of cask and fuel assembly heat loads are solely determined by safety evaluations performed by the user of this TR and the established temperature and pressure acceptance criteria. Any heat load pattern that does not comply with all applicable safety limits under any design basis condition (normal, off-normal, accident or short-term operations) is not a qualified heat load pattern.

5.0 CONCLUSIONS

Based upon the review of the TR (Refs. 1 to 3) and confirmation of the docketed information in the regulatory audit (Ref. 7), the NRC concludes that Holtec's general methodology to evaluate alternate candidate heat load patterns is acceptable as a means to calculate component temperatures and pressures and to evaluate those results against the appropriate acceptance criteria. When implementing TR HI-2200343, Revision 2, the user must ensure compliance with the limitations listed in Section 4.0 of this SE.

7.0 REFERENCES

1. "Submittal of Topical Report for Allowance of Heat Load Patterns in HI-STORM 100 and HI-STORM FW Systems," HI-2200343 Revision 0, April 2020 (ADAMS Package Accession No. ML20101N174).

2. "Submittal of Updated Thermal Topical Report for Allowance of Heat Load Patterns in HI-STORM 100 and HI-STORM FW Systems," HI-2200343 Revision 1, 2020 (ADAMS Package Accession No. ML20280A773).

3. "Submittal of Topical Report for Allowance of Heat Load Patterns in HI-STORM 100 and HI-STORM FW Systems," HI-2200343 Revision 2, 2021 (ADAMS Package Accession No. ML21092A162).

4. "Final Safety Analysis Report for the Holtec International Storage and Transfer Operation Reinforced Module Cask System (HI-STORM 100 Cask System)," USNRC Docket No. 72-1014, Holtec Report HI-2002444, Revision 20, 2020.

5. "Final Safety Analysis Report on the HI-STORM FW MPC Storage System," USNRC Docket No. 72-1032, Holtec Report HI-2114830, Revision 6, 2019.

6. Letter from M. Diaz, NRC, to K. Manzione, Holtec International, "September 9, 2020 - Regulatory Audit Plan for Holtec International (Holtec) Topical Report for Allowance of Heat Load Patterns in HI-STORM 100 and HI-STORM FW Systems," (ADAMS Accession No. ML20244A023).

7. "Audit Report Regarding the September 9, 2020, Regulatory Audit for Holtec International Topical Report for Allowance of Heat Load Patterns in HI-STORM 100 and HI-STORM FW Systems," November 2020, USNRC (ADAMS Package Accession No. ML20282A525).

8. Letter from D. Mitra-Majumdar, Holtec International, to L. Perkins, NRC, “Submittal of Holtec Proprietary Information Review and Response to Open Items on the Thermal Topical Report on the HI-STORM 100 and HI-STORM FW Systems,” April 2021 (ADAMS Accession No. ML21092A162).

9. NUREG-2215, “Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities – Final Report,” April 2020 (ADAMS Accession No. ML20121A190).

10. Regulatory Guide 3.72, Revision 1, “Guidance for Implementation of 10 CFR 72.48, ‘Changes, Tests, and Experiments’,” dated October 2020 (ADAMS Accession No. ML20211L879).

APPENDIX 1

The methodology in this report is considered applicable to and limited according to L4.2 to the following design variants for the HI-STORM 100 and HI-STORM FW:

MPCs - 24/24E/24EF
MPCs - 32/32F
MPCs - 68/68F/68FF/68M
MPC - 37
MPC - 89

HI-TRAC Transfer casks 100/125/100D/125D/100G/VW/VW Version P

HI-STORM 100 overpacks 100/100S/100S Version B/100A

HI-STORM FW overpacks FW/Version XL/Version E

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