HOLTEC INTERNATIONAL

Krishna P. Singh Technology Campus, 1 Holtec Blvd., Camden, NJ 08104
Telephone (856) 797-0900
Fax (856) 797-0909

January 6, 2022

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Docket No. 99902086 – Holtec Spent Fuel Pool Heatup Calculation Methodology

Subject: Submittal of U.S. Nuclear Regulatory Commission Draft Safety Evaluation by the Office of Nuclear Reactor Regulation for the Topical Report HI-2200750 Revision 0, "Holtec Spent Fuel Pool Heat Up Calculation Methodology" identifying information proprietary to Holtec International

HDI Spent Fuel Pool Heat Up Calculation Methodology Docket No. 99902086

References:

1. Letter from Holtec to U.S. NRC, "Holtec Spent Fuel Pool Heat Up Calculation Methodology Topical Report," (ADAMS Accession No. ML20280A524) dated September 29, 2020
2. Letter from Holtec to U.S. NRC, "Response to Request for Additional Information-Holtec Spent Fuel Pool Heat Up Calculation Methodology Topical Report," (ADAMS Accession No. ML21148A289) dated May 28, 2021.
3. Letter from Holtec to U.S. NRC, "Revised Response to Request for Additional Information-Holtec Spent Fuel Pool Heat Up Calculation Methodology Topical Report," (ADAMS Accession No. ML 21228A262) dated August 16, 2021.
4. Letter from Holtec to U.S. NRC, "Response to Request for Additional Information 10-Holtec Spent Fuel Pool Heat Up Calculation Methodology Topical Report," (ADAMS Accession No. ML21291A161) dated October 18, 2021.
5. Letter from Holtec to U.S. NRC, Submittal of Topical Report, "Holtec Spent Fuel Pool Heat Up Calculation Methodology Topical Report, Revision 2." Including Site-Specific Calculations for NRC Review (ADAMS Accession No. ML ML21356B704) dated December 22, 2021

Dear Sir or Madam:

In Reference 1, Holtec Decommissioning International, LLC (HDI) submitted a Holtec International Topical Report providing a methodology for calculating Spent Fuel Pool heat up for

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Krishna P. Singh Technology Campus, 1 Holtec Blvd., Camden, NJ 08104
Telephone (856) 797-0900
Fax (856) 797-0909

NRC review and approval. Holtec believes the methodology will enhance safety by reducing the zirconium fire risks in the spent fuel pool.

In References 2, 3 and 4, Holtec provided responses to Requests for Additional Information (RAI) concerning the Topical Report.

In Reference 5, Holtec submitted revision 2 to the Holtec International Topical Report providing a methodology for calculating Spent Fuel Pool heat up for NRC, including site-specific calculations for NRC review.

Enclosure 1 provides a proprietary version of the draft safety evaluation for the Holtec Topical Report, HI-2200750, Revision 0. Enclosure 1 contains information proprietary to Holtec and is therefore supported by an affidavit signed by Holtec which is provided in Enclosure 3. The draft safety evaluation for the Holtec Topical Report, HI-2200750, Revision 0 provided in Enclosure 1 includes appropriate markings identifying those portions that are proprietary. The proprietary information bracketed in Enclosure 1 is requested to be withheld under 10 CFR 2.390 as supported by the affidavit provided in Enclosure 3.

Enclosure 2 provides a non-proprietary, redacted version of the draft safety evaluation.

If you have any questions, please contact me at 856-797-0900 ext. 3578.

Sincerely,

Jean A. Fleming
Digitally signed by Jean A. Fleming
Date: 2022.03.23 14:48:57 -04'00'

Jean A. Fleming
VP, Regulatory and Environmental Affairs
Holtec Decommissioning International

HOLTEC INTERNATIONAL

Krishna P. Singh Technology Campus, 1 Holtec Blvd., Camden, NJ 08104
Telephone (856) 797-0900
Fax (856) 797-0909

Enclosures:

Enclosure 1: Draft Safety Evaluation by the Office of Nuclear Reactor Regulation for the Topical Report HI-2200750 Revision 0, “Holtec Spent Fuel Pool Heat Up Calculation Methodology” (Holtec Proprietary Withhold Information from Public Disclosure pursuant to 10 CFR 2.390)

Enclosure 2: Draft Safety Evaluation by the Office of Nuclear Reactor Regulation for the Topical Report HI-2200750 Revision), “Holtec Spent Fuel Pool Heat Up Calculation Methodology (Non-Proprietary)

Enclosure 3: Affidavit Pursuant to 10 CFR 2.390 to Withhold Information from Public Disclosure

cc: Robert Lucas, NRC, NRR/DORL/LLPB
Dennis Morey, NRC, NRR/DORL/LLPB
Ekaterina Lenning, NRC, NRR/DORL/LLPB
Christopher Regan, NRC, NMSS/DFM
Zahira Cruz Perez, NRC, NMSS/DWUP

HDI-IPEC-22-002

Enclosure 1:

Draft Safety Evaluation by the Office of Nuclear Reactor Regulation for the Topical Report HI-2200750 Revision 0, “Holtec Spent Fuel Pool Heat Up Calculation Methodology”

(Holtec Proprietary Withhold Information from Public Disclosure pursuant to 10 CFR 2.390)

SUBMITTED SEPARATELY

HDI-IPEC-22-002

Enclosure 2:

Draft Safety Evaluation by the Office of Nuclear Reactor Regulation for the Topical Report HI-2200750 Revision 0, “Holtec Spent Fuel Pool Heat Up Calculation Methodology”

(Non-Proprietary)

U. S. NUCLEAR REGULATORY COMMISSION

DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

FOR THE TOPICAL REPORT HI-2200750, REVISION 0,

"HOLTEC SPENT FUEL POOL HEAT UP CALCULATION METHODOLOGY"

HOLTEC DECOMMISSIONING INTERNATIONAL

HOLTEC INTERNATIONAL

DOCKET: 99902086

EPID: L-2020-TOP-0056

Enclosure

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1. INTRODUCTION

On September 29, 2020 (later updated by a submittal on October 30, 2020), Holtec International (HI or Holtec) submitted Topical Report (TR) HI-2200750, Revision 0, "Holtec Spent Fuel Pool Heat Up Calculation Methodology," (Ref. 1) to the U.S. Nuclear Regulatory Commission (NRC). This TR provides the methodology for describing transient heat up of the assemblies in the spent fuel pool (SFP) following a drain down event in a permanently defueled nuclear power plant.

The complete list of correspondence between the NRC and Holtec is provided in Table 1 below. This includes request for additional information (RAI) questions, responses to the RAI questions and any other correspondence relevant to this review.

Table 1: List of Correspondence

Author	Document	Document Date	Reference
Holtec	Initial Submittal	September 29, 2020	N/A
Holtec	Revised Submittal	October 30, 2020	1
NRC	Completeness Determination	December 4, 2020	2
NRC	Proprietary Determination	December 4, 2020	3
NRC	Request for Additional Information – Round 1	March 31, 2021	4
Holtec	RAI Responses	May 28, 2021[1]	5
Holtec	Revised RAI Responses	August 16, 2021	6
NRC	Request for Additional Information – RAI-10	October 1, 2021	17
Holtec	RAI Responses – RAI-10	October 18, 2021	18

In regard to the staff RAI questions, general information for each RAI including its number, its topic, its associated safety evaluation (SE) section, and the reference(s) of its response are given in Table 2 below.

[1] Document placed in ADAMS on June 23, 2021.

Table 2: List of RAI Questions

Question	Subject	Section of SE	Reference of Response
RAI-01	Treatment of near-wall locations	3.1.4	5, 6
RAI-02	Lumped Analysis vs. Pin-by-Pin Analysis	3.3.1.4	5, 6
RAI-03	Radial and Axial Peaking	3.3.1.4	5, 6
RAI-04	Time Step Sensitivity	3.3.5.4	5, 6
RAI-05	Planar Surface Area	3.3.5.1	5, 6
RAI-06	Uncertainty due to emissivity	3.3.5.1	5, 6
RAI-07	Quality Assurance Program	3.3.6.1	5, 6
RAI-08	Comparison to Office of Research (RES) Data	3.3.3.2	5, 6
RAI-09	Variation in Heat Capacity	3.1.4	5, 6
RAI-10	Current NRC Approved Methodology	3.3.1.3	18

2. REGULATORY EVALUATION

2.1. Applicable Regulations

Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," contains regulations that define requirements for SFPs. These requirements are further specified in the general design criteria (GDC) given in Appendix A to Part 50 including: GDC-61, "Fuel Storage and Handling and Radioactivity Control," GDC-2, "Design Bases for Protection Against Natural Phenomena," GDC-4, "Environmental and Dynamic Effects Design Bases," and GDC-63, "Monitoring Fuel and Waste Storage." Holtec's methodology is focused on demonstrating that these regulations are still satisfied following a drain down event in the SFP by demonstrating that the spent fuel temperature remains below a given threshold for a specified time frame.

2.2. Applicable Guidance

NUREG-1738, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants," provides a technical analysis of the SFP accident risk at decommissioning nuclear power plants (Ref. 7). In Appendix 1.B of that report, the NRC provides the background for the proposed acceptance criteria, which vary based on the conditions experienced by the fuel. The acceptance criterion applicable to the Holtec methodology is that the fuel temperature must not exceed 900 °C prior to 10 hours following the drain down event. Satisfying this acceptance criterion will ensure that any significant global fuel damage and substantial release of fission products will be avoided.

To guide the NRC staff in performing its review and assure review quality and uniformity, the NRC created NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP) (Ref. 8). Regulatory guidance for the review of design basis accident evaluation methodologies is provided in Section 15.0.2 of the SRP, "Review of Transient and Accident Analysis Methods" (Ref. 9). Similar guidance is also set forth for the industry in Regulatory Guide 1.203, "Transient and Accident Analysis Methods," dated December 2005 (Ref. 10). While this guidance was specifically developed for reviewing licensing basis accident analysis, it has been noted (Ref. 11) that this guidance is widely applicable to modeling and simulation in general. Therefore, the NRC staff followed the

guidance presented in SRP Section 15.0.2 but has modified that guidance commensurate with the risk-significance of the Holtec simulations.

2.3. Acceptance Criteria

NUREG-1738 provides different acceptance criteria depending on the scenario considered. For the Holtec methodology, the applicable acceptance criterion (as stated in the NUREG and the Holtec submittal) is demonstrating that the spent fuel temperature remains below 900 °C for at least 10 hours following a complete drain down of the SFP. Ensuring this acceptance criterion is satisfied would demonstrate that self-sustained oxidation (that would cause a further increase in the SFP temperatures) will not occur. While Holtec's methodology **[** **]** the NRC staff finds that the acceptance criterion provided in NUREG-1738 remains applicable.

NUREG-1738 does not specify whether or not it is the peak or an averaged fuel temperature which must remain below 900 °C for at least 10 hours. The NRC staff considered understanding the acceptance criterion as average fuel temperature but determined such an understanding was not reasonable because the criterion was based on the cladding temperature that causes self-sustained oxidation. For the average fuel temperature to reach 900 °C, some portion of the fuel must have been above 900 °C for some time period. The portion of the fuel above 900 °C would be hot enough to experience self-sustained oxidation, which would lead to increased fuel temperatures. **[** **]** Because the NRC staff did not understand this acceptance criterion as applying to the average spent fuel temperature as consistent with the goal of the criterion, the staff concluded that the acceptance criterion applied to the peak predicted SFP temperature.

3. TECHNICAL EVALUATION

Holtec has submitted a calculational methodology for simulating the temperature following the drain down event of an SFP. SRP Section 15.0.2 directs the reviewer to examine the evaluation model (EM), which is defined as the calculational framework for evaluating the behavior of the SFP and includes the computer programs, mathematical models, assumptions, and procedures on how to treat the input and the output, as well as many other factors. Based on guidance from the SRP, this review is organized into five categories shown in Table 3.

Table 3: General Review Categories

General Review Categories	
3.1	Scenario Identification Process
3.2	Documentation
3.3	Evaluation Model Assessment

3.1. Scenario Identification Process

The scenario identification process is a structured process used to identify the key figures of merit or acceptance criteria for the modeled accident. It is also used to identify and rank the component and physical phenomena modeling requirements based on their: (a) importance to

acceptable modeling of the scenario and (b) impact on the figures of merit for the calculation. Table 4 provides the SRP review criteria topics and the sections providing the NRC staff's review.

<u>Table 4: Review Categories of the Scenario Identification Process</u>

Scenario Identification Process	
3.1.1	Structured Process
3.1.2	Scenario Progression
3.1.3	Phenomena Identification and Ranking
3.1.4	Initial and Boundary Conditions

3.1.1. Structured Process

Structured Process

The process used for scenario identification should be a structured process.

SRP Section 15.0.2, Subsection III.3c

The Holtec submittal is focused on analyzing a single identified scenario, the heat-up resulting from the drain down of an SFP. As the scenario is pre-defined, the NRC staff finds that this criterion has been satisfied.

3.1.2. Scenario Progression

Scenario Progression

The description of each scenario should provide a complete and accurate description of the scenario progression.

SRP Section 15.0.2, Subsection III.3c

Unlike many scenarios, the heat-up following an SFP drain down event is well understood as the fuel heats up without any water to act as a coolant. **[** **]** Because Holtec has described the scenario progression and such progressions are well-understood, the NRC staff finds that this criterion has been satisfied.

3.1.3. Phenomena Identification and Ranking

> **Phenomena Identification and Ranking**
>
> *The dominant physical phenomena influencing the outcome of the scenario should be correctly identified and ranked.*
>
> SRP Section 15.0.2, Subsection III.3c

In the submittal, Holtec identified the dominant physical phenomena and how those phenomena would be modeled. [

] Because these phenomena are the dominant phenomena in the scenario and modeling them would result in an accurate or conservative prediction of reality, the NRC staff finds that this criterion has been satisfied.

3.1.4. Initial and Boundary Conditions

> **Initial and Boundary Conditions**
>
> *The description of each scenario should provide complete and accurate description of the initial and boundary conditions.*
>
> SRP Section 15.0.2, Subsection III.3c

Holtec has provided a description of the initial and boundary conditions of the scenario in its submittal. [

]

The Holtec analysis method is based on [

]

[

]

Because Holtec has defined the initial and boundary conditions consistent with the scenario being modeled, the NRC staff finds that this criterion has been satisfied.

3.2. Documentation

Generally, the documentation for an EM is the focus of seven different review categories. However, the NRC staff did not need such detailed documentation based on two considerations: (1) the simplicity of the Holtec methodology and (2) that Holtec provided sufficient information such that the NRC staff could independently re-create the analysis described in the Holtec methodology. Because the information provided by Holtec was sufficient for the NRC staff to re-create the Holtec analysis, the NRC staff finds that the documentation is sufficient to fully describe the Holtec EM.

3.3. Evaluation Model Assessment

SRP Section 15.0.2, Subsection III.3.b, contains eight review criteria for EMs. The review criteria topics and the subsections that provide the NRC staff's assessments are listed in Table 5.

Table 5: Evaluation Model Assessment Categories

Subsection	
3.3.1	Evaluation Model Applicability
3.3.2	Evaluation Model Verification
3.3.3	Evaluation Model Validation
3.3.4	Evaluation Model - Data Applicability
3.3.5	Evaluation Model – Uncertainty Analysis
3.3.6	Evaluation Model - Quality Assurance Program

3.3.1. Evaluation Model Applicability

3.3.1.1. Previously Reviewed and Accepted Codes and Models

Previously Reviewed and Accepted Codes and Models

It should be determined if the mathematical modeling and computer codes used to analyze the transient or accident should have been previously reviewed and accepted. If so, the reviewer should confirm that any previous conditions and limitations remain satisfied.

SRP Section 15.0.2, Subsection III.3b

The previously approved methods for performing this analysis are addressed in Section 3.3.1.3, "Physical Modeling." Therefore, this criterion is addressed elsewhere.

3.3.1.2. Single Version of the Evaluation Model

Single Version of the Evaluation Model

All assessment cases should be performed with a single version of the evaluation model.

SRP Section 15.0.2, Subsection III.3d

Based on the information provided in the TR, the NRC staff confirmed that all assessment cases were performed with a single version of the EM. The NRC staff concludes that this criterion has been satisfied.

3.3.1.3. Physical Modeling

Physical Modeling

The physical modeling described in the theory manual and contained in the mathematical models should be adequate to calculate the physical phenomena influencing the accident scenario for which the code is used.

SRP Section 15.0.2, Subsection III.3b

In general, modeling an SFP drain down is simulating the heat up of a spent fuel assembly as well as any heat transfer mechanisms which can reduce the heat of that assembly. Thus, one common method to perform this analysis is to model the heat up of the assembly using the assembly's decay heat, conservatively ignoring all possible physical mechanisms that would transfer heat from that assembly. [

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The NRC staff finds that the physical model and the overall methodology of Holtec's approach would result in a reasonable or conservative estimate of the PCT and is therefore acceptable in determining if the acceptance criteria were satisfied. Further discussion regarding specific aspects of Holtec's assumptions in its heat transfer models [

] are addressed in Section 3.3.1.4, Level of Detail in the Model, of this SE. Because Holtec is conservatively ignoring multiple heat transfer mechanisms between assemblies, is conservatively ignoring multiple heat sinks, and is accurately or conservatively analyzing each bundle in the SFP, the NRC staff finds that this criterion has been satisfied.

3.3.1.4. Level of Detail in the Model

Level of Detail in the Model
The level of detail in the model should be equivalent to or greater than the level of detail required to specify the answer to the problem of interest.
SRP Section 15.0.2, Subsection III.3b

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[

] In view of the foregoing, and particularly considering the conditions and limitations imposed by the staff, the level of detail in the model is adequate to determine if an SFP configuration meets the acceptance criterion, so the NRC staff finds that this criterion has been satisfied.

3.3.1.5. Simplifying and Averaging Assumptions

Simplifying and Averaging Assumptions

The simplifying assumptions and assumptions used in the averaging procedure should be valid for the accident scenario under consideration.

SRP Section 15.0.2, Subsection III.3b

[

]

3.3.1.6. Equations and Derivations

Equations and Derivations
The equations and derivations should be correct.
SRP Section 15.0.2, Subsection III.3b

The main equation used in the Holtec method is the general equation for radiation between two surfaces. Because Holtec is using a form of the equation for radiative heat transfer that is based on first principals and no derivations are necessary, the NRC staff finds that this criterion has been satisfied.

3.3.1.7. Field Equations

Field Equations
The field equations of the evaluation model should be adequate to describe the set of physical phenomena that occur in the accident.
SRP Section 15.0.2, Subsection III.3b

The main equation used in the Holtec method is the general equation for radiation between two surfaces. Because Holtec is using a form of the equation for radiative heat transfer that is based on first principals, the NRC staff finds that this criterion has been satisfied.

3.3.1.8. Code Tuning

Code Tuning
All code options that are to be used in the accident simulation should be appropriate and should not be used merely for code tuning.
SRP Section 15.0.2, Subsection III.3d

Because the NRC did not observe the selection of any options that were chosen merely for code tuning, the NRC staff finds that this criterion has been satisfied.

3.3.2. Evaluation Model Verification

3.3.2.1. Numerical Solution

Numerical Solution
The numerical solution should conserve all important quantities.
SRP Section 15.0.2, Subsection III.3d

[

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Because Holtec performed an analysis demonstrating that the time step size was appropriately chosen, the NRC staff finds that this criterion has been satisfied.

3.3.26. Evaluation Model

3.3.3.1. Validation of the Closure Relationships

> **Validation of the Closure Relationships**
>
> *The range of validity of the closure relationships should be specified and should be adequate to cover the range of conditions encountered in the accident scenario.*
>
> SRP Section 15.0.2, Subsection III.3b

Holtec's methodology models the radiative heat transfer between fuel assemblies. **[** **]** The NRC staff finds that this criterion does not apply.

3.3.3.2. Validation of the Evaluation Model

> **Validation of the Evaluation Model**
>
> *Integral test assessments must properly validate the predictions of the evaluation model for the full-size plant accident scenarios. This validation should cover all of the important code models and the full range of conditions encountered in the accident scenarios.*
>
> SRP Section 15.0.2, Subsection III.3d

[**]**

While validation data of the EM are generally required, there are circumstances where no such data exist, and the NRC staff can still determine that the simulations are credible. One such circumstance is an EM that simulates well-understood phenomena where the uncertainties are fully characterized and can be conservatively treated (one example is given in Ref. 20). Because the phenomena are well understood, because the equation used to model the phenomena accurately describes the physics (i.e., first principles) of radiative heat transfer, because the variables in the equation are known with a high degree of certainty, because it is conservative to ignore the phenomena that are not being modeled, because the assumptions made that reduce the complexity of the model are each conservative in nature, and because of the large number of conservatisms in the methodology, the NRC staff determined that validation data is not required for use of this methodology to calculate PCT in the event of a SFP drain down event. Therefore, the NRC staff finds that this criterion does not apply.

3.3.3.3. Range of Assessment

Range of Assessment
All code closure relationships based in part on experimental data or more detailed calculations should be assessed over the full range of conditions encountered in the accident scenario by means of comparison to separate effects test data.
SRP Section 15.0.2, Subsection III.3d

In general, there are no closure relationships in Holtec's methodology. **[** **]** Because there are no closure relationships used in Holtec's methodology, the NRC staff finds that this criterion does not apply.

3.3.3.4. Compensating Errors

Compensating Errors
The reviewers should ensure that the documentation contains comparisons of all important experimental measurements with the code predictions in order to expose possible cases of compensating errors.
SRP Section 15.0.2, Subsection III.3d

Because there was no comparison to experimental data, the NRC staff finds that this criterion does not apply.

3.3.4. Evaluation Model - Data Applicability

3.3.4.1. Assessment Data

Assessment Data
Published literature should be referred to for sources of assessment data for specific phenomena, accident scenarios, and plant types.
SRP Section 15.0.2, Subsection III.3d

Holtec was able to provide assessment data in comparison to predictions of analysis performed by RES. This analysis is discussed in Section 3.3.3.2, "Validation of the Evaluation Model," of this SE. Additionally, **[** **]** In general, because the NRC staff did not base its acceptance on validation data, the NRC staff finds that this criterion does not apply.

3.3.4.2. Similarity and Scaling

Similarity and Scaling
The similarity criteria and scaling rationales should be based on the important phenomena and processes identified by the accident scenario identification process and appropriate scaling analyses. Scaling analyses should be conducted to ensure that the data and the models will be applicable to the full-scale analysis of the plant transient.
SRP Section 15.0.2, Subsection III.3b

Because there was no comparison to experimental data, the NRC staff finds that this criterion does not apply.

3.3.29. Evaluation Model – Uncertainty

3.3.29 Important Sources of Uncertainty

Important Sources of Uncertainty
The accident scenario identification process should be used in identifying the important sources of uncertainty. Sources of calculation uncertainties should be addressed, including uncertainties in plant model input parameters for plant operating conditions (e.g., accident initial conditions, set points, and boundary conditions). To address these uncertainties, demonstrate that the combined code and application uncertainty should be less than the design margin for the safety parameter of interest in the calculation.
SRP Section 15.0.2, Subsection III.3e

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3.3.30 Experimental Uncertainty

Experimental Uncertainty
The uncertainties in the experimental data base should be addressed. Data sets and correlations with experimental uncertainties that are too large when compared to the requirements for evaluation model assessment should not be used.
SRP Section 15.0.2, Subsection III.3e

Because there was no comparison to experimental data, the NRC staff finds that this criterion does not apply.

3.3.5.3. Calculated and Predicted Results

Calculated and Predicted Results
For separate effects tests and integral effects tests, the differences between calculated results and experimental data for important phenomena should be quantified for bias and deviation.
SRP Section 15.0.2, Subsection III.3e

Because there was no comparison to experimental data, the NRC staff finds that this criterion does not apply.

3.3.5.4. Sensitivity Studies

Sensitivity Studies
Assessments should be performed where applicable {specific test cases for LOCA to meet the requirements of Appendix K to 10 CFR Part 50 and TMI [Three Mile Island] action items for PWR small-break LOCA}.
SRP Section 15.0.2, Subsection III.3d
Appropriate sensitivity studies shall be performed for each evaluation model, to evaluate the effect on the calculated results of variations in noding, phenomena assumed in the calculation to predominate, including pump operation or locking, and values of parameters over their applicable ranges. For items to which results are shown to be sensitive, the choices made shall be justified.
Appendix K to 10 CFR Part 50
A detailed analysis shall be performed of the thermal-mechanical conditions in the reactor vessel during recovery from small breaks with an extended loss of all feedwater.
TMI [Three Mile Island] action items for PWR

In RAI-04, the NRC staff requested Holtec perform a time step sensitivity study to ensure a decrease in time step would not greatly impact its method's results. In its response (Ref. 5, later modified by Ref. 6), Holtec provided results of that sensitivity study demonstrating that a change in time step would not impact the results of its method. Various other sensitivity studies were also requested and provided in connection with other portions of this SE and have been fully addressed elsewhere. Because Holtec has provided all requested sensitivity studies, this criterion has been satisfied.

3.3.6. Evaluation Model - Quality Assurance Program

The Holtec Quality Assurance Program (QAP) covers, in part, the procedures for design control, document control, software configuration control and testing, and error identification and corrective actions used in the development and maintenance of the Holtec EM. The QAP also ensures adequate training of personnel involved with code development and maintenance, as well as those who perform the analyses.

SRP Section 15.0.2, Subsection III.3.f, contains three review criteria for the QAP. The review criteria topics and the subsection providing the NRC staff's reviews are listed in Table 6.

Table 6: Quality Assurance Plan Review Categories

Subsection	
3.3.6.1	Appendix B Quality Assurance Program
3.3.6.2	Quality Assurance Documentation
3.3.6.3	Independent Peer Review

3.3.6.1. Appendix B Quality Assurance Program

Appendix B Quality Assurance Program

The evaluation model should be maintained under a quality assurance program that meets the requirements of Appendix B to 10 CFR Part 50.

SRP Section 15.0.2, Subsection III.3f

In its TR, Holtec made reference to a number of reports (including NRC reports) that contained information important for Holtec's EM (e.g., material properties for UO_2), but which were not generated or maintained under an Appendix B QAP. In response to RAI-07 (Ref. 6), Holtec confirmed that it performed this analysis under its QAP and will also perform any plant specific SFP analysis under the licensee's QAP. Because Holtec has confirmed that the analysis will be maintained under a QAP that satisfies the requirements of 10 CFR Part 50 Appendix B, the NRC staff finds that this criterion has been satisfied.

32 Quality Assurance Documentation

Quality Assurance Documentation

The quality assurance program documentation should include procedures that address all of these areas [design control, document control, software configuration control and testing, and corrective actions].

SRP Section 15.0.2, Subsection III.3f

Due to the simplicity of the Holtec EM, this criterion is addressed under Section 3.3.6.1, "Appendix B Quality Assurance Program," above.

3.3.6.3. Independent Peer Review

Independent Peer Review

Independent peer reviews should be performed at key steps in the evaluation model development process.

SRP Section 15.0.2, Subsection III.3f

Due to the simplicity of the Holtec EM, this criterion is addressed under Section 3.3.6.1, "Appendix B Quality Assurance Program," above.

3.4. Conclusions

The NRC staff has made the following conclusions based on the referenced evaluations provided in this SE:

- Based on the staff's evaluation in Section 3.1, "Scenario Identification Process," the NRC staff has determined that that the accident scenario identification process is a structured process and has been appropriately used to identify the key figures of merit for the SFP drain down event.

- Based on the staff's evaluation in Section 3.2, "Documentation," the NRC staff has determined that the documentation provided was sufficient to adequately describe Holtec's methodology for performing the analysis of the SFP drain down event.

- Based on the staff's evaluation in Section 3.3, "Evaluation Model Assessment," the NRC staff has determined that:
    - the EM generated is applicable to the scenario,
    - Holtec has performed adequate verification analysis for the model,
    - based on the staff's engineering judgment the model does not need additional validation analysis,
    - the model has had adequate uncertainty analysis performed, and
    - the QAP covers all relevant actions in the development and maintenance of the EM.

The NRC staff identified the following major uncertainties in the Holtec methodology:

- There is no experimental data to confirm the credibility of the simulations.

- There is limited data on the decay heat radial and axial peaking factors of the fuel in the SFP.

- It has not been mathematically proven that Holtec's method will always result in analyzing the most limiting configuration.

- There is limited data on the applicability of **[ ]** at the temperatures of interest.

However, as discussed in this SE, the NRC staff concludes these uncertainties are more than offset by the following:

- Holtec is conservatively ignoring any heat transfer from the fuel assemblies to other structures in the SFP. This ensures that the modeled heat in the spent fuel assemblies will be conservatively higher than expected. This includes ignoring convection, conduction, and radiation to the plates separating the fuel assemblies, the SFP walls, and ultimately to the environment.

- Holtec is conservatively ignoring any natural convection from the air or steam that would be expected to flow through assemblies following an SFP drain down event. This ensures that the heat in the spent fuel assemblies will be conservatively higher than expected.

- Holtec is conservatively treating the fuel pellet and fuel cladding as a single material. This will result in a conservatively high cladding temperature, as there would normally be a temperature distribution in the fuel pin that would have its peak in the pellet and would decrease as the heat is transferred through the pellet, through the gap, and through the cladding. Holtec's method ignores this temperature gradient and calculates a single lumped clad/fuel temperature that represents the average temperature of the fuel pin and will always be higher than the cladding surface temperature where the acceptance criterion is applied.

- Holtec is conservatively ignoring the neutron absorbing material, which would act as a heat sink and reduce the temperature in the assembly.

- Holtec's analysis methodology is based on radiative heat transfer, which is well understood. Further, the NRC staff has concluded that as the temperatures increase, the method's predictions would become more conservative due to ignoring the impacts of an increasing surface emissivity.

- Holtec's analysis methodology has been confirmed using higher fidelity models.

- Holtec's **[ ]** methodology generally results in a conversative limiting decay heat power for fuel assemblies **[ ]**

Based on the above conclusions, the NRC staff finds that there is reasonable assurance that Holtec's EM (described in Ref. 1, with modifications provided by Refs. 5 and 6) along with the staff's conditions and limitations, conservatively or accurately predicts the PCT following an SFP drain down event, and use of the method is acceptable for ensuring that the acceptance criteria of 900 °C is satisfied.

3.4.1. Conditions and Limitations

1) The Holtec methodology is approved with the limitation that the decay heat values - including axial peaking factors - of all assemblies are analyzed in order to determine the most limiting case. **[** **]**

The following three conditions and limitations only apply in situations **[** **]**

2) The Holtec methodology is approved with the condition that the modified form of Equation (26) - as stated in response to RAI-02 and given in Equation (1) in this SE - is used to determine the PCT after applying the method described in Chapter 3 of the TR to determine the average fuel temperature. **[** **]**

3) The Holtec methodology is approved with the condition that a **[** **]** must be applied to the PCT.

4) The Holtec methodology is approved with the condition that **[** **]**

4. <u>REFERENCES</u>

1. Holtec, HI-2200750 Revision 0, "Holtec Spent Fuel Pool Heat Up Calculation Methodology," September 29, 2020 – initial submittal (October 30, 2020 – resubmittal) (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML20280A525 (Non-Publicly Available) and ML20280A524 (Publicly Available)).

2. Lenning, E., NRC, email to A. Sterdis, Holtec Decommissioning International (HDI), HI, "Completeness determination for Holtec Decommissioning International Topical Report HI-2200750 Revision 0, 'Holtec Spent Fuel Pool Heat Up Calculation Methodology'," December 4, 2020 (ADAMS Accession No. ML20329A373 (Transmittal Email), ML20329A368 (Completeness Determination)).

3. Lenning, E., NRC, email to A. Sterdis, HDI, HI "U. S. NRC Proprietary information withholding determination form for the Holtec Decommissioning International Topical Report HI-2200750 Revision 0, 'Holtec Spent Fuel Pool Heat Up Calculation

Methodology’,” December 4, 2020 (ADAMS Accession No. ML20329A360 (Transmittal Email), ML20329A364 (Completeness Determination)).

4. Lenning, E., NRC, email to A. Sterdis, HDI, HI “Formal Transmittal of the U.S. Nuclear Regulatory Commission Requests for Additional Information for Holtec Topical Report HI-2200750 Revision 0, ‘Holtec Spent Fuel Pool Heat Up Calculation Methodology’,” March 31, 2021 (ADAMS Accession No. ML21077A102 (Transmittal Email/Publicly Available), ML21077A098 (Non-Publicly Available).

5. Sterdis, A., HDI, HI to E. Lenning, NRC, “Response to Request for Additional Information - Holtec Spent Fuel Pool Heat Up Calculation Methodology Topical Report,” May 28, 2021, (ADAMS Accession No. ML21148A289 (Non-Proprietary/Publicly Available), ML21174A041 (Proprietary/Non-Publicly Available)).

6. Sterdis, A., HDI, HI to E. Lenning, NRC, “Revised Response to Request for Additional Information - Holtec Spent Fuel Pool Heat Up Calculation Methodology Topical Report,” August 16, 2021, (ADAMS Accession No. ML21228A262 (Non-Proprietary/Publicly Available), ML21228A263 (Proprietary/ Non-Publicly Available)).

7. “NUREG-1738 Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants (ADAMS Accession No. ML010430066),” 2001.

8. NRC, NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants,” June 1987.

9. NRC, NUREG-0800, Section 15.0.2, “Review of Transient and Accident Analysis Methods,” December 2005 (ADAMS Accession No. ML053550265).

10. NRC, Regulatory Guide 1.203, “Transient and Accident Analysis Methods,” December 2005 (ADAMS Accession No. ML053500170).

11. Kaizer, J. S., Heller, A. K., and Oberkampf, W. L., “Scientific computer simulation review,” Reliability Engineering and System Safety 138: 210-218, 2015.

12. Manteufel, R.D. and N.E. Todreas, “Effective Thermal Conductivity and Edge Configuration Model for Spent Fuel Assembly,” Nuclear Technology, Vol. 105, pp. 421–440, March 1994.

13. Manteufel, R.D., “Heat Transfer in an Enclosed Rod Array,” Submitted to the Department of Mechanical Engineering in partial fulfillment of the requirements for the degree of Doctor of Philosophy, Massachusetts Institute of Technology, May 1991.

14. American Nuclear Society, “Decay Heat Power in Light Water Reactors,” ANSI/ANS 5.1-1979, La Grange Park, IL.

15. NRC, “Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses,” NUREG/CR-6801, March 2003 (ADAMS Accession No. ML031110292).

16. NRC, “Axial Moderator Density Distributions, Control Blade Usage, and Axial Burnup Distributions for Extended BWR Burnup Credit,” NUREG/CR-7224, August 2016 (ADAMS Accession No. ML16237A100).

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18. Sterdis, A., HDI, HI, to E. Lenning, NRC, “Response to Request for Additional Information 10 - Holtec Spent Fuel Pool Heat Up Calculation Methodology Topical Report,” October 18, 2021 (ADAMS Accession No. ML21291A161 (Non-Proprietary/Publicly Available), ML21291A165 (Proprietary/Non-Publicly Available)).

19. Wengert, T.J., NRC, to David Heacock, Dominion Energy Kewaunee, “Kewaunee Power Station – Exemptions from certain emergency planning requirements and related safety evaluation (TAC NO. MF2567)," October 27, 2014 (ADAMS Accession No. ML14261A223).

20. Kaizer, J. S., and Anzalone R., “In-Vessel Thermal-Hydraulic Analysis Associated with License Amendment for a Risk-Informed Approach to Address Generic Safety Issue 191 and Generic Letter 2004-02,” 2017 (ADAMS Accession No. ML17019A003).

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Principal Contributors: J.S. Kaizer
Adam Rau
John Grasso

Date: December 16, 2021

Appendix A Description of Confirmatory Calculations

The purpose of this appendix is to describe the confirmatory calculations that were performed by the NRC staff in support of the review of Holtec International (HI) HI-2200750, Revision 0, (Hereafter referred to as HI-2200750). Two sets of calculations were performed. The first set of calculations was a direct re-creation of the calculational method described in HI-2200750. These calculations were initially performed to confirm NRC staff's understanding of the method. **[** **]** These calculations are described in A.1 Recreation of HI-2200750 Method. The second set of calculations were **[** **]** These calculations are described in A.2 Pin by Pin Simulation.

A.1Re-creation of HI-2200750 Method

Initially, this model was developed to reproduce Holtec's method in order to verify completeness of description within the TR and facilitate reviewer understanding of the method. To that end, the equations and properties employed are effectively identical to that described in the TR. **[**

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A.2 Pin by Pin Simulation

These simulations were performed to **[**

] using ANSYS Fluent. **[**

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] Gambit was used to generate the geometry and the mesh. **[**

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Parameters provided in HI-2200750 were used to facilitate comparison with Holtec's calculations. **[** **]** were taken from the publicly available DOE/RW-0184 Vol. 3 (Ref. 1).

[

] Homogenized density and specific heat capacity were calculated using the following equations

$$\rho_{homogenized} = (m_{UO_2} + \rho_{zircaloy} V_{zircaloy})/(V_{UO_2} + V_{zircaloy})$$

$$c_{p,homogenized} = (m_{UO_2} c_{p,UO_2} + \rho_{zircaloy} V_{zircaloy} c_{p,zircaloy})/(m_{UO_2} + \rho_{zircaloy} V_{zircaloy})$$

Where ρ, c_p, V, and m represent density, specific heat capacity, volume in an assembly, or mass in an assembly, respectively, of the material named in the subscript. Zircaloy density was taken from Table 5.2, UO_2 mass from Table 5.3, and UO_2 specific heat from Appendix A of HI-2200750. Zircaloy specific heat capacity was calculated using equation 3-14 with the values listed in Table 5.1 of HI-2200750. Volumes were calculated using the dimensions in Table 5.3. Specific heat capacity of the homogenized material was calculated at the same temperature intervals used in Appendix A of HI-2200750 and linearly interpolated between these intervals. Material density, dimensions, and **[** **]** were modeled as constant with respect to temperature.

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Manteufel discussed a similar consideration in Appendix A of his dissertation. Specifically, he evaluated a modified Biot number to determine whether the effect of conduction within a fuel pin needed to be considered. The Biot number Bi is the ratio of the thermal resistance to conduction within the body of an object to the thermal resistance to convection at its surface.

$$Bi = hL_c/k$$

Where h is the convective heat transfer coefficient, L_c is a characteristic length, and k is the thermal conductivity of the material. Smaller Biot numbers indicate that the thermal resistance due to conduction within the body is smaller, and the assumption of uniform temperature within the object is better. In Manteufel's application, the relevant comparison was between conduction heat transfer and radiative heat transfer, so Manteufel substituted the convective heat transfer coefficient with an approximated heat transfer coefficient due to radiation.

$$h_r = 4\sigma\epsilon T^3$$

For PWR applications, Manteufel calculated a Biot number of approximately 0.02 using the worst-case emissivity and thermal conductivity, indicating that the assumption of isothermal rods would not have a significant impact on the solution. However, the maximum temperature considered in his application was 300 °C. In the present application, temperatures can reach 900 °C, so more energy will be transferred through radiation, and temperature gradients within the pin will have a greater impact on the solution. Biot numbers between 0.01 and 0.15 were calculated assuming a cladding temperature of 900 °C, depending on whether cladding or fuel properties and dimensions are used. The exact relationship between the magnitude of the Biot number and the **[ ]** is not clear, but generally a Biot number of less than 0.1 has been used to justify the isothermal temperature assumption. For

the majority of the transient, the temperature will be lower than 900 °C, so the Biot number will be less limiting. Because the Biot number for this application remains relatively small, conduction within each pin was not simulated.

Simulated cases are shown in Table 7. In each case, the power density in each pin is determined by dividing the nominal assembly power by total volume of the fuel pins **[**

] Cases 7, 8, and 9 were run to confirm that the method Holtec proposed in response to RAI-02 would result in a conservative **[**

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Results for all cases are plotted in Figures 17 through 22 and Figures 24 through 26. Simulations were run for a fixed period of 20 hours to ensure that PCTs exceeded the limit during the simulation time. The limiting temperature, 1173.15 K, is plotted as a black dotted line. [

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A.3 References

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Enclosure 3:

Affidavit Pursuant to 10 CFR 2.390 to Withhold Information from Public Disclosure

AFFIDAVIT PURSUANT TO 10 CFR 2.390

I, Jean A. Fleming, being duly sworn, depose and state as follows:

1) I have reviewed the information provided in U.S. Nuclear Regulatory Commission Draft Safety Evaluation by the Office of Nuclear Reactor Regulation for the Topical Report HI-2200750 Revision 0, "Holtec Spent Fuel Pool Heat Up Calculation Methodology" which is sought to be withheld and I am authorized to apply for its withholding.

2) The information sought to be withheld is in Enclosure 1 to this letter, "U.S. Nuclear Regulatory Commission Draft Safety Evaluation by the Office of Nuclear Reactor Regulation for the Topical Report HI-2200750 Revision 0, Holtec Spent Fuel Pool Heat Up Calculation Methodology." and is proprietary to Holtec International.

3) In making this application for withholding of proprietary information of which it is the owner, Holtec International relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4) and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR Part 9.17(a)(4), 2.390(a)(4), and 2.390(b)(1) for "trade secrets and commercial or financial information obtained from a person and privileged or confidential" (Exemption 4). The material for which exemption from disclosure is here sought is all "confidential commercial information", and some portions also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

4) Some examples of categories of information which fit into the definition of proprietary information are:

   a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by Holtec's competitors without license from Holtec International constitutes a competitive economic advantage over other companies;

AFFIDAVIT PURSUANT TO 10 CFR 2.390

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

c. Information which reveals cost or price information, production, capacities, budget levels, or commercial strategies of Holtec International, its customers or its suppliers;

d. Information which reveals aspects of past, present, or future Holtec International customer-funded development plans and programs of potential commercial value to Holtec International;

e. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs 4.a and 4.b, and 4.c above.

5) The information sought to be withheld is being submitted to the NRC in confidence. The information (including that compiled from many sources) is of a sort customarily held in confidence by Holtec International, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by Holtec International. No public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access

AFFIDAVIT PURSUANT TO 10 CFR 2.390

to such documents within Holtec International is limited on a "need to know" basis.

7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his designee), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside Holtec International are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

8) The information classified as proprietary was developed and compiled by Holtec International at a significant cost to Holtec International. This information is classified as proprietary because it contains detailed descriptions of analytical approaches and methodologies not available elsewhere. This information would provide other parties, including competitors, with information from Holtec International's technical database and the results of evaluations performed by Holtec International. A substantial effort has been expended by Holtec International to develop this information. Release of this information would improve a competitor's position because it would enable Holtec's competitor to copy our technology and offer it for sale in competition with our company, causing us financial injury.

9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to Holtec International's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of Holtec International's comprehensive decommissioning and spent fuel storage technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology, and includes development of the expertise to determine and apply the appropriate evaluation process.

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The research, development, engineering, and analytical costs comprise a substantial investment of time and money by Holtec International.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

Holtec International's competitive advantage will be lost if its competitors are able to use the results of the Holtec International experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to Holtec International would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake similar expenditure of resources would unfairly provide competitors with a windfall, and deprive Holtec International of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

AFFIDAVIT PURSUANT TO 10 CFR 2.390

STATE OF NEW JERSEY)
) ss:
COUNTY OF CAMDEN)

Jean A. Fleming, being duly sworn, deposes and says:

That she has read the foregoing affidavit and the matters stated therein are true and correct to the best of her knowledge, information, and belief.

Executed at Camden, New Jersey, this 6th day of January 2022.

Jean A. Fleming

Jean A. Fleming
Holtec Decommissioning International
Holtec International
VP, Regulatory & Environmental Affairs

Subscribed and sworn before me this 6th day of January, 2022

Sharon Y. Page

SHARON Y. PAGE
NOTARY PUBLIC OF NEW JERSEY
My Commission Expires 01/15/2026