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HI-STORE CTF THERMAL EVALUATION

FOR

GENERIC

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DOCUMENT CATEGORIZATION

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☐ Technical Report (Per HQP 3.2) (Such as a Licensing Report)

☐ Design Criterion Document (Per HQP 3.4)

☐ Design Specification (Per HQP 3.4)

☐ Other (Specify):

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PREFACE

This section contains quality related information on this document in conformance with the provisions in Holtec's Quality Assurance program docketed with the USNRC (Docket # 71-0784).

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- The input information utilized in the work effort is drawn from referenceable sources. Any assumed input data is so identified.
- Significant assumptions are stated or provided by reference to another source.
- The analysis methodology is suitable for the physics of the problem.
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document is to ensure correctness of the technical content rather than the cosmetics of presentation.

Furthermore, this Calculation Package is focused on providing technical results that demonstrate compliance with the applicable safety limits. Informational material that does not bear upon reaching a safety conclusion is minimized in this document to the extent possible. Because of its function as a repository of all analyses performed on the subject of its scope, this document will require a revision only if an error is discovered in the computations or the equipment design is modified. Additional analyses in the future may be added as numbered supplements to this Package. Each time a supplement is added or the existing material is revised, the revision status of this Package is advanced to the next number and the Table of Contents is amended. Calculation Packages are Holtec proprietary documents. They are shared with a client only under strict controls on their use and dissemination. This Calculation Package will be saved as a Permanent Record under the company's QA System.

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Generic Report & ACPL Information	
Generic Report # invoked in this Calc Package, if applicable	HI-2167374
Code(s) name(s) (must be listed in the ACPL)	FLUENT
Code(s) version # (must be approved in the ACPL)	14.5.7
[PROPRIETARY PER 10CFR2.390]	[PROPRIETARY PER 10CFR2.390]
[PROPRIETARY PER 10CFR2.390]	[PROPRIETARY PER 10CFR2.390]

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	Criterion	Response Yes or No
1	Are you qualified per HQP 1.0 to perform the analysis documented in this report?	Yes
2	Are you aware that you must be specifically certified if you use any Category A computer code (as defined in HQP 2.8 in the preparation of this document?	Yes
3	Are you fully conversant with the pertinent sections of the applicable Specification invoked in this report?	Yes
4	Is the input data used in this work fully sourced (i.e., references are provided)?	Yes
5	Are you fully conversant with the user manual and validation manual of the code(s) used in this report, if any?	Yes
6	Is (Are) Category A computer code(s) (if used) listed in the Company's "Approved Computer program list"?	Yes
7	Are the results clearly set down and do they meet the acceptance criteria set down in the governing Specification?	Yes
8	Are you aware that you must observe all internal requirements on needed margins of safety published in Holtec's internal memos, if applicable (which may exceed those in the reference codes and standards or the specification)?	Yes
9	Have you performed numerical convergence checks to ensure that the solution is fully converged?	Yes
10	Is it true that you did not receive more than 10 quality infraction points in the past calendar year or thus far this year?	Yes

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Summary of Revisions

Revision 0: Original Issue

1.0 PURPOSE AND SCOPE

At New Mexico consolidated interim storage facility, the loaded MPCs are transferred from HI-STAR 190 [1] to HI-TRAC CS [2] using Canister Transfer Facility (CTF) [3]. This report documents evaluations to demonstrate compliance of all short-term operations involving HI-STAR 190 to the thermal requirements in Chapter 4 of HI-STORE SAR [4].

Before the HI-STAR 190 cask is placed into the CTF, the impact limiters are removed and the cask cavity is evacuated and backfilled with nitrogen. After the HI-STAR 190 cask is placed into the CTF, the HI-TRAC CS alignment plate is installed on top of the CTF. A thermal evaluation is performed for the thermally limiting short-term operation condition of HI-STAR 190 inside the CTF as described below:

(1) HI-STAR 190 with MPC is placed inside the CTF. The HI-TRAC CS alignment plate is installed on the CTF.
(2) The HI-STAR 190 cask closure lid is in place. The HI-TRAC CS cask is not placed in the stack-up position above the CTF.
(3) The cask cavity is filled with nitrogen.

The closure lid of the HI-STAR 190 cask is then removed. The HI-TRAC CS cask is placed on the alignment plate with its bottom shield gates open. After the MPC is lifted into the HI-TRAC CS cask, the HI-TRAC CS shield gates are closed and the MPC is rested on the shield gates. The HI-TRAC CS cask is then lifted and placed at a location on the floor that is accessible to the VCT.

After the closure lid is removed, the HI-STAR 190 cask cavity is filled with air. The thermal conductivity of nitrogen is slightly lower than that of air. Therefore, the thermal performance of the HI-STAR 190 cask after its closure lid is removed and before the MPC is lifted into the HI-TRAC CS cask is bounded by that under the short-term operation condition described above. Once the MPC is lifted into the HI-TRAC CS cask, the thermal performance is bounded by those evaluated in Ref. [7].

For hypothetical accident, the worst cask transfer building (CTB) collapse scenario is evaluated as described below:

(1) HI-STAR 190 with MPC is placed inside the CTF. The HI-TRAC CS alignment plate is installed on the CTF.
(2) The HI-STAR 190 cask closure lid is in place. The HI-TRAC CS cask is not placed in the stack-up position above the CTF.

(3) The cask cavity is filled with nitrogen.
(4) 90% of the CTF pipe vents and 90% of the CTF cavity top open are blocked by debris [4].

2.0 METHODOLOGY AND ASSUMPTIONS

To accommodate all BWR and all PWR canisters, the HI-STAR 190 cask is available in two discrete lengths: Version SL (standard length) and Version XL (extended length) [1]. The HI-STAR 190 Version XL has a larger external surface for heat dissipation than that of HI-STAR 190 Version SL, and thus the thermal performance of HI-STAR 190 Version XL is bounded by that of HI-STAR 190 Version SL. According to Ref. [8], the bounding configuration of MPC in vertical orientation is MPC-37 loaded with [PROPRIETARY PER 10CFR2.390]. Therefore, the HI-STAR 190 Version SL containing MPC-37 loaded with [PROPRIETARY PER 10CFR2.390] is adopted to yield bounding results. It bounds the configurations below.

(1) Short fuel in MPC-37 within HI-STAR 190 Version SL
(2) Standard fuel in MPC-37 within HI-STAR 190 Version SL
(3) Long fuel in MPC-37 within HI-STAR 190 Version XL
(4) MPC-89 within HI-STAR 190 Version SL

In Appendix F of Ref. [9], HI-STAR 190 Version SL in an open space (without the CTF) containing MPC-37 loaded with [PROPRIETARY PER 10CFR2.390] is evaluated. This model is the same as that provided in Section 3.3 of HI-STAR 190 SAR [5]. The 3D quarter-symmetric model of HI-STAR 190 in Appendix F of Ref. [9] is adopted and modified as follows:

[PROPRIETARY PER 10CFR2.390

].

The HI-STAR 190 Version SL is placed [PROPRIETARY PER 10CFR2.390] inside CTF [3]. The 3D quarter-symmetric model of HI-STAR 190 Version SL inside CTF is illustrated in Figure 2.1 and a 2D cross-section of the CTF cavity is presented in Figure 2.2. The CTF geometry added to the HI-STAR 190 model includes [PROPRIETARY PER 10CFR2.390

] with the following key attributes.

[PROPRIETARY PER 10CFR2.390

].

Following Ref. [8], the thermal evaluations are performed for the bounding heat load pattern, i.e. heat load pattern 1 presented in Table 1.1 of Ref. [8]. The MPC is initially backfilled with helium

in the pressure range specified in Table 1.3 of Ref. [8]. Inside the CTF, the MPC cavity pressure increases with the MPC cavity temperature. Using the minimum backfill pressure specified in Table 1.3 of Ref. [8] and the MPC cavity average temperature predicted in Section 6.0, the minimum MPC cavity pressure under the operation conditions is computed by ideal gas law. The MPC cavity pressure adopted in the simulations is slightly lower than the calculated minimum MPC cavity pressure, which understates the thermo-siphon effect inside the MPC cavity and thereby overestimates the peak cladding temperature.

3.0 INPUT DATA

The principal geometric parameters for HI-STAR 190, CTF, MPC-37 and basket are taken from design drawings [1], [3], [12] and [13]. Materials present in the HI-STAR 190 cask include [PROPRIETARY PER 10CFR2.390]. The physical properties of these materials are obtained from HI-STAR 190 SAR [5]. The properties of air are also obtained from HI-STAR 190 SAR [5]. The properties of nitrogen are obtained from Ref. [14] and presented in Table 3.1. It is noted that the temperatures of Holtite-B may be higher than its design temperature limit under the CTB collapse accident. [PROPRIETARY PER 10CFR2.390].

The surface emissivities are obtained from HI-STAR 190 SAR [5]. For the HI-STAR 190 cask cavity surface, the emissivity of carbon steel without paint is assumed for conservatism.

[PROPRIETARY PER 10CFR2.390].

The CTF is inside the cask transfer building and thus there is no insolation. The ambient temperature adopted in the evaluations is 32.8^{o}C (91^{o}F), as specified in HI-STORE SAR [4]. The ambient pressure adopted in the evaluations is [PROPRIETARY PER 10CFR2.390], which is conservatively lower than the actual ambient pressure at the site elevation specified in HI-STORE SAR [4]. The limiting heat load pattern and the corresponding MPC backfill pressure range as descried in Section 2.0 are adopted to yield bounding results.

Table 3.1
Properties of Nitrogen [14]

Temperature °C (°F)	Thermal Conductivity W/m-°C (Btu/ft-hr-°F)	Viscosity 10^{-6} N-s/m (Micropoise)
76.85 (170.33)	0.0293 (0.0169)	20.00 (200.0)
126.85 (260.33)	0.0327 (0.0189)	22.04 (220.4)
226.85 (440.33)	0.0389 (0.0225)	25.77 (257.7)
326.85 (620.33)	0.0446 (0.0258)	29.08 (290.8)
Density kg/m^3 (lbm/ft^3)		(Ideal Gas Law)
Specific Heat J/kg-°C (Btu/lbm-°F)		1041 (0.249)

4.0 ACCEPTANCE CRITERIA

The thermal evaluation acceptance criteria are listed below:

1. The fuel cladding temperature during short-term operations and accident conditions must be below the ISG-11 Revision 3 temperature limit [6].
2. The component temperatures of basket, MPC and HI-STAR 190 must be below their respective design temperature limits specified in Ref. [4] for short-term operations and accident conditions.
3. The MPC cavity pressure (MNOP) must be below the design pressure specified in Ref. [4] for short-term operations and accident conditions.
4. The CTF component temperatures must be below the design temperature limits specified in Ref. [4] for short-term operations and accident conditions.

5.0 COMPUTER CODES AND FILES

The computer code FLUENT Version 14.5 [11] is employed in all thermal calculations involving fluid motion. A list of computer files is provided below.

[PROPRIETARY PER 10CFR2.390

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6.0 RESULTS AND DISCUSSIONS

6.1 Thermal Evaluation of Short-Term Operation

A steady state simulation is performed for the short-term operation scenario described in Section 1.0. The evaluation is performed for most limiting thermal configuration under the bounding heat load pattern, as described in Section 2.0. The predicted fuel temperature and component temperatures are presented in Table 6.1. The fuel temperature and component temperatures are below their limits specified in Section 4.0 for short-term operation.

6.2 Thermal Evaluation of CTB Collapse Accident

A steady state simulation is performed for the worst CTB collapse accident scenario described in Section 1.0. The evaluation is performed for most limiting thermal configuration under the bounding heat load pattern, as described in Section 2.0. The predicted fuel temperature and component temperatures are presented in Table 6.2. The fuel temperature and component temperatures are below their limits specified in Section 4.0 for accident condition.

6.3 Maximum Normal Operation Pressure (MNOP)

For heat load pattern 1 presented in Table 1.1 of Ref. [8], the MPC is initially backfilled with helium in the pressure range specified in Table 1.3 of Ref. [8]. Inside CTF, the MPC cavity pressure increases as the MPC cavity temperature increases. Using the maximum backfill pressure specified in Table 1.3 of Ref. [8] and the MPC cavity average temperatures predicted in Sections 6.1 and 6.2, the maximum MPC cavity pressures are determined by ideal gas law and presented in Table 6.3.

6.4 Differential Thermal Expansion

In this section, thermal expansion of components inside HI-STAR 190 in the radial and axial directions is computed. The calculations address the following thermal expansions:

a) Basket-to-MPC Radial Growth
b) Basket-to-MPC Axial Growth
c) Fuel-to-MPC Axial Growth
d) MPC-to-Cask Radial Growth
e) MPC-to-Cask Axial Growth

(a) Basket-to-MPC Radial Growth

The radial growth of the fuel basket relative to MPC cavity upon heating from a 21^{o}C (70^{o}F) reference temperature (T_o) to hot operation temperatures is computed as follows:

[PROPRIETARY PER 10CFR2.390] (Eq. 6.1)

[PROPRIETARY PER 10CFR2.390

].

(b) Basket-to-MPC Axial Growth

The axial growth of the fuel basket relative to MPC cavity upon heating from a 21^{o}C (70^{o}F) reference temperature to hot operation temperatures is computed as follows:

[PROPRIETARY PER 10CFR2.390] (Eq. 6.2)

[PROPRIETARY PER 10CFR2.390

].

(c) Fuel Axial Growth

The axial growth of the fuel relative to MPC cavity upon heating from a 21^{o}C (70^{o}F) reference temperature to hot operation temperatures is computed as follows:

[PROPRIETARY PER 10CFR2.390] (Eq. 6.3)

[PROPRIETARY PER 10CFR2.390

].

(d) MPC-to-Cask Radial Growth

The radial growth of MPC relative to HI-STAR 190 cask cavity upon heating from a 21^{o}C (70^{o}F) reference temperature to hot operation temperatures is computed as follows:

[PROPRIETARY PER 10CFR2.390] (Eq. 6.4)

[PROPRIETARY PER 10CFR2.390

].

(e) MPC-to-Cask Axial Growth

The axial growth of MPC relative to HI-STAR 190 cask cavity upon heating from a 21^{o}C (70^{o}F) reference temperature to hot operation temperatures is computed as follows:

[PROPRIETARY PER 10CFR2.390] (Eq. 6.5)

[PROPRIETARY PER 10CFR2.390

].

6.5 Discussion and Conclusion

Based on the results presented in Sections 6.1 thru 6.4, the following conclusions are drawn:

1. During short-term operation inside CTF, the fuel cladding temperature and the MPC and cask component temperatures remain below their short-term temperature limits indefinitely. The MPC cavity pressure also remains below its short-term pressure limit.
2. Under CTB collapse accident event, the fuel cladding temperature and the MPC and cask component temperatures remain below their accident temperature limits. The MPC cavity pressure also remains below its accident pressure limit.
3. Free thermal expansion is ensured for fuel, basket and MPC for both short-term operation and CTB collapse accident event.

Thermal evaluations in Section 3.3.5 of HI-STAR 190 SAR [5] demonstrate that the predicted temperatures and cavity pressures under sub-design basis heat loads is bounded by design maximum heat load scenario. Therefore, the above conclusions remain applicable to sub-design basis heat loads also.

Table 6.1
Maximum Temperatures of HI-STAR 190 and MPC-37 during Short-Term Operation inside CTF

Material/Components	**Temperature ºC (°F)**
Fuel Cladding	380 (716)
Fuel Basket	353 (667)
Basket Shims	292 (558)
MPC Shell	262 (504)
MPC Baseplate (Section Average)	202 (396)
MPC Lid (Section Average)	257 (495)
Containment Shell	196 (385)
Lead Shield	194 (381)
Intermediate Shell	192 (378)
Holtite-B Shield	191 (376)
Enclosure Shell	169 (336)
Bottom Forging (Maximum)	199 (390)
Bottom Forging (Volumetric Average)	160 (320)
Bottom Forging Lead Shield	197 (387)
Bottom Forging Holtite-B Shield	157 (315)
Bottom Forging Cover Plate	154 (309)
Bottom Holtite-B Shield	196 (385)
Top Forging (Maximum)	144 (291)
Top Forging (Volumetric Average)	129 (264)
Top Forging Holtite-B Shield	142 (288)
Spacer Ring	208 (406)
Closure Lid Spacer	148 (298)
Closure Lid (Maximum)	128 (262)
Closure Lid (Section Average)	122 (252)
CTF Structures	147 (297)

Table 6.2
Maximum Temperatures of HI-STAR 190 and MPC-37 under CTB Collapse Accident inside CTF

Material/Components	Temperature ºC (°F)
Fuel Cladding	461 (862)
Fuel Basket	434 (813)
Basket Shims	376 (709)
MPC Shell	351 (664)
MPC Baseplate (Section Average)	277 (531)
MPC Lid (Section Average)	332 (630)
Containment Shell	311 (592)
Lead Shield	309 (588)
Intermediate Shell	307 (585)
Enclosure Shell	288 (550)
Bottom Forging (Maximum)	273 (523)
Bottom Forging (Volumetric Average)	228 (442)
Bottom Forging Lead Shield	271 (520)
Bottom Forging Cover Plate	210 (410)
Top Forging (Maximum)	264 (507)
Top Forging (Volumetric Average)	250 (482)
Spacer Ring	299 (570)
Closure Lid Spacer	266 (511)
Closure Lid (Maximum)	253 (487)
Closure Lid (Section Average)	246 (475)
CTF Structures	276 (529)
Note: The temperature of Holtite is above its design temperature limit and is therefore replaced with air in the thermal model.	

Table 6.3
MNOP of Helium in MPC and HI-STAR 190 inside CTF

Condition	Gauge Pressure kPa (psig)	Cavity Average Temperature ^{o}C (^{o}F)
Short-term Operation	705.3 (102.3)	294 (561)
CTB Collapse Accident	817.7 (118.6)	373 (703)

Table 6.4
[PROPRIETARY PER 10CFR2.390]

7.0 REFERENCES

[1] “HI-STAR 190 Cask Assembly,” Holtec Drawing 9841, Revision 0.

[2] “HI-TRAC CS,” Holtec Drawing 10868, Revision 0.

[3] “Canister Transfer Facility (CTF),” Holtec Drawing 10895, Revision 0.

[4] “Licensing Report on the HI-STORE CIS Facility,” Holtec Report HI-2167374, Revision 0.

[5] “Safety Analysis Report on the HI-STAR 190 Package,” Holtec Report HI-2146214, Latest Revision.

[6] “Cladding considerations for the Transportation and Storage of Spent Fuel,” Interim Staff Guidance-11, Revision 3, USNRC, Washington, DC

[7] “Thermal Analysis for HI-TRAC CS Transfer Cask,” Holtec Report HI-2177553, Revision 0.

[8] “Thermal Evaluations of HI-STORM UMAX at HI-STORE CIS Facility,” Holtec Report HI-2177591, Revision 0.

[9] “Thermal Evaluations of HI-STAR 190 System,” Holtec Report HI-2146286, Revision 3.

[10] “Flow of Fluids through Valves, Fittings, and Pipe,” Crane Co., 1988.

[11] FLUENT Computational Fluid Dynamics Software, ANSYS Inc.

[12] “MPC 37 Enclosure Vessel,” Holtec Drawing 6505, Revision 17.

[13] “Assembly, MPC 37 Fuel Basket,” Holtec Drawing 6506, Revision 12.

[14] F. P. Incropera and D. P. DeWitt, “Fundamentals of Heat and Mass Transfer,” 4th edition, John Wiley & Sons, New York, 1996

[15] “Final Safety Analysis Report on the HI-STORM FW MPC Storage System,” Holtec Report HI-2114830, Latest Revision.

[16] “Final Safety Analysis Report on the HI-STORM UMAX Canister Storage System,” Holtec Report HI-2115090, Latest Revision.

[17] “Effective Thermal Properties of PWR Fuel to Support Thermal Evaluation of HI-STORM FW,” Holtec Report HI-2094356, Revision 5.

[PROPRIETARY PER 10CFR2.390]

[PROPRIETARY PER 10CFR2.390]