Table I.4.2.1: Thermal Properties of 24PT1-DSC Pressure Boundary Note 1

	@70°F	@200°F	@400°F	@600°F	@800°F
SA-240 Conductivity (Btu/ft-hr-°F)	7.7	8.4	9.5	10.5	11.5
SA-537 Conductivity (Btu/ft-hr-°F)	23.6	24.4	24.2	23.1	-
SA-240 Thermal Diffusivity (ft^2/hr)	0.134	0.141	0.151	0.162	0.173
SA-537 Thermal Diffusivity (ft^2/hr)	0.454	0.422	0.386	0.346	-
SA-240 Density (lbm/in^3)	0.285				
SA-537 Density (lbm/in^3)	0.284				
Emissivity	0.40 – Stainless Steel 0.587 – 24PT1 DSC Shell Surface				
Note 1: Properties obtained from Section 4.2 of NUHOMS FSAR [I.1.2.1].					

I.4.4 THERMAL EVALUATION UNDER NORMAL CONDITIONS OF STORAGE

24PT1-DSC storage in the UMAX VVM is evaluated using a suitably calibrated thermal model of the canister that conservatively represents the temperatures in its licensed configuration as articulated in the NUHOMS FSAR [I.1.2.1]. The canister model is then incorporated in the UMAX thermal model as articulated in the main body of the FSAR and evaluated under the licensing basis scenarios in this Supplement. All analyses including model calibration use the approved and benchmarked FLUENT Computational Fluid Dynamics program [4.4.3] utilized in all Holtec cask dockets.

I.4.4.1 Analysis Approach

(a) Input data

The following information on the canister's thermal performance under storage in the AHSM module is available from the canister's native docket [I.1.2.1]:

- i) The inlet and outlet temp of air (t and T)
- ii) Air flow rate ,W††
- iii) Insolation heat, S
- iv) Corresponding peak cladding temperature in the stored fuel, C
- v) Canister heat load, Q

As shown in the following the above data is adequate for proper thermal characterization of the canister.

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†† Ascertained from the canister heat load and co-incident outlet air temperature rise.

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(c) NUHOMS AHSM Model

The NUHOMS AHSM is a horizontal concrete storage cask engineered with inlets and outlets to facilitate ventilation cooling as articulated in the NUHOMS FSAR [I.1.2.1]. The NUHOMS AHSM description is incorporated in this chapter by reference (See Table I.4.0.1). Principal construction data relevant to supporting NUHOMS AHSM thermal modeling is tabulated in Table I.4.4.8.

The FLUENT model of NUHOMS AHSM with 24PT1-DSC situated in it has the same features as the NUHOMS FSAR thermal model. The principal features are as follows:

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A 3D rendering of the FLUENT thermal model is depicted in Figure I.4.4.1.

(d) Model Calibration

The necessary NUHOMS thermal inputs as defined in this section are tabulated in Table I.4.4.1. [

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The results confirm the adequacy of the homogenized model as a conservative method for thermal evaluation of canisters loaded with spent nuclear fuel. The calibrated parameters thus obtained are tabulated in Table I.4.4.3 and adopted to evaluate 24PT1-DSC in the "UMAX" system.

I.4.4.2 UMAX Thermal Model

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I.4.4.6 Maximum Internal Pressure in the DSC

As is standard practice, the 24PT1-DSC is helium filled prior to storage. During normal storage, the gas temperature within the 24PT1-DSC rises to its maximum operating basis temperature. The gas pressure inside the MPC will also increase with rising ambient temperature which can be determined using the ideal gas law. The 24PT1-DSC is also subject to pressure rise under hypothetical release of gases as evaluated in the NUHOMS FSAR [I.4.0.3]. The gas release quantities are tabulated in Table I.2.2.1. Based on fission gases release fractions (NUREG 1536 criteria [I.4.0.1]) the maximum gas pressures with 1% (normal), 10% (off-normal) and 100% (accident condition) rod rupture are computed and tabulated in Table I.4.4.6. The computed pressures comply with 24PT1-DSC design pressures (NUHOMS FSAR Table 3.1-6 [I.1.2.1]) pressure limits.

I.4.4.7 Engineered Clearances to Eliminate Thermal Interferences

The NUHOMS FSAR addresses 24PT1-DSC thermal interferences under temperatures reached in the NUHOMS storage system [I.1.2.1]. As the operating temperatures under UMAX storage are lower the co-incident thermal expansions are lesser.

I.4.4.8 Effect of Elevation

Storage of 24PT1-DSC in the UMAX VVM is evaluated under standard 1 atm. pressure conditions. If conditions at a site are substantially different then site-specific evaluation should be performed to ensure safety compliance.

I.4.4.9 Burnup Effects on Fuel Conductivity

See Chapter 4, Section 4.4.8.

I.4.4.10 Evaluation of Sustained Wind

As evaluated in main body of the report wind has a second order effect on the performance of UMAX structures. Under a worst case scenario wherein wind is postulated as a sustained condition of a certain magnitude and direction to maximize its effects temperature increments on the order of ~30^{o}F are obtained. As 24PT1-DSC thermal margins are an order of magnitude greater (~200-250^{o}F) this condition does not challenge the safety of stored fuel.

I.4.4.11 Evaluation of System Performance for Normal Conditions of Storage

The HI-STORM UMAX System thermal analysis is based on a detailed 3-D heat transfer model that conservatively accounts the principal modes of heat transfer in the canister and overpack. The thermal model incorporates conservative assumptions that render the computed temperature results for long-term storage to be conservative. The computed temperatures in "UMAX" under design basis heat load comply with the licensing limits as summarized below:

a. The peak cladding temperature is below the ISG-11 Rev 3 limit.
b. The temperatures of structural members in the VVM and 24PT1-DSC are below their allowable values set down in the Chapter 2 (presented in Table 2.3.7) and Supplement 2.I (Table I.2.2.1) with positive margins.
c. The temperature of shielding concrete and insulation (both non-structural members) are well within stipulated limits set forth in Table 2.3.7.

The modest metal temperatures reached in "UMAX" insure that the components of the system will not suffer long term degradation from elevated temperature effects such as creep, alloy phase transformation, recrystallization of the materials' grain structure, and the like. Therefore, safety of long term storage from the thermal standpoint is assured.

I.4.4.12 Homogenized Canister Methodology Benchmarking

The homogenized canister methodology articulated in Section I.4.4.1 is benchmarked with the aid of 3D CFD models of spent fuel storage casks. [

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Table I.4.4.1: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.2: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.3: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.4: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.5: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

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Table I.4.4.10: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.11: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.12: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.13: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

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Table I.4.4.15: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

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Table I.4.4.17: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.18: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Figure I.4.4.2: **PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390**

Figure I.4.4.3: **PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390**

Figure I.4.4.4: **PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390**

Table I.4.5.1: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

I.4.6.2 Accident Events

I.4.6.2.1 Fire Accident

(a) HI-STORM UMAX Fire

Under design basis fire accident the UMAX VVM exposed surfaces are subject to intense heating under the incident fire flux. Thermal calculations in the main body of the FSAR show that the large mass of concrete protects loaded canister from the brunt of direct heating. The fuel temperatures are essentially unchanged (~1^{o}F temperature rise computed) and shell temperatures are unaffected by fire accident (~4^{o}F temperature rise). These evaluations support the safety case that 24PT1-DSC storage in UMAX VVM is not challenged by fire accident.

(b) Transfer Cask Fire

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I.4.6.2.2 Extreme Environmental Temperatures

As justified in Chapter 4, Section 4.6 the UMAX System temperature elevation under off-normal ambient condition is suitably obtained by the difference $\delta = 45^{o}F$ ambient temperature under extreme ambient ($125^{o}F$) and normal ($80^{o}F$) temperatures. Inspection of the normal ambient UMAX temperatures evaluated in Table I.4.4.4 support the observation that margins to off-normal temperature limits are well in excess of δ. This supports the safety conclusion that safe operating temperatures under extreme ambient condition are below the regulatory limit. The canister pressure under the increased temperature is computed in accordance with Ideal Gas Law and tabulated in Table I.4.6.5. The pressure complies with NUHOMS FSAR accident limits [I.1.2.1, Chapter 3, Table 3.1-6].

4.6.2.3 100% Blockage of Air Inlets

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I.4.6.2.4 Burial under Debris

Burial of the HI-STORM UMAX system under debris is not a credible accident. During storage at an ISFSI there are no structures that loom over the casks whose collapse could completely bury the casks in debris. Minimum regulatory distances from the ISFSI to the nearest ISFSI security fence precludes close proximity of substantial amount of vegetation. There is no credible

Table I.4.6.1: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.6.2: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.6.3: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.6.4: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.6.5: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

I.4.8 REFERENCES

[I.4.4.1] Holtec International, "Thermal Evaluation of HI-STORM UMAX System Loaded with 24PT1-DSC," HI-2167272, Rev. 2.

[I.4.4.2] HI-STORM 100 FSAR, Holtec Report HI-2002444, Rev. 15.

[I.4.4.3] "Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer", ASME V&V 20-2009.

[I.4.4.4] "Absolute Measurement of the Thermal Conductivity of Helium and Hydrogen", Mustafa M., Ross R. D., Trengove W., A. Wakeham, M. Zalaf, Physica A: Statistical Mechanics and its Applications, Vol. 141, Issue 1, February 1987.

[I.4.4.5] "Thermal Conductivity of Gases", Huber, Marcia L. and Allan H. Harvey, CRC Handbook of Chemistry and Physics 92 (2011).

[I.4.4.6] ASME Codes and Standards 2011, BPVC Section II, Part D.

[I.4.4.7] "MATPRO-Version 11: A Handbook of Materials Properties for Use in the Analysis of Light Water Reactor Fuel Rod Behavior", Hagrman, D. L., Reymann, G. A., NUREG/CR-0497.

[I.4.4.8] Kern, D.Q., "Process Heat Transfer", McGraw Hill Kogakusha (1950).
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