SUPPLEMENT I.4: THERMAL EVALUATION OF 24PT1-DSC CANISTER

I.4.0 OVERVIEW

In this Supplement the thermal evaluation of the NUHOMS 24PT1-DSC [I.1.2.1] canister for vertical storage in the UMAX VVM is documented. As shown in this supplement, cooling of the canister by ventilation action is increased when it is arrayed vertically in "UMAX" because of the increase in the "chimney height" of the air column. As a result the 24PT1-DSC temperatures are lower than those that will obtain in the horizontal configuration in the NUHOMS module.

Supplement I adds the 24PT1-DSC canister to the HI-STORM UMAX system [I.1.2.1]. Only those design features of "UMAX" that are revised or added to incorporate the 24PT1-DSC canister are described in this chapter. This chapter also references to the main body of the FSAR where existing safety analyses are bounding, as applicable. The material in this supplement is organized to mirror the corresponding material in the main body of the FSAR with the letter I. inserted before each chapter/section/subsection/paragraph number. Thus the numeric sequence I.m.n.p.r indicates that the material belongs to Supplement I, Chapter #m, Section #n , sub-section# p and paragraph # r. (m, n, p and r are numeric values). Thus, the numbering of the material in the supplement is readily distinguished from the main FSAR's while the content correspondence is maintained.

The 24PT1-DSC canister is approved by the NRC for storage under Part 72, Docket No. 72-1029. The safety analysis information applicable to thermal analysis is incorporated by reference to the NUHOMS FSAR [I.1.2.1]. A roadmap of the referenced information is tabulated in Table I.4.0.1.

As described in the main body of this report the HI-STORM UMAX is an underground vertical ventilated module (VVM) with openings for air ingress and egress and internal air flow passages for ventilation cooling of the stored canisters. The main body of the FSAR evaluates storage of Holtec's MPC-37 and MPC-89 canisters. In Supplement I the 24PT1-DSC canister is evaluated for storage in the "UMAX" VVM.

Supplement I.1 provides a general description of the 24PT1-DSC. In this chapter, thermal evaluation under storage of this canister in HI-STORM UMAX system using 3-D thermal models is performed. The analyses consider passive rejection of decay heat from the stored SNF assemblies to the environment under normal, off-normal, and accident conditions of storage. In particular, the thermal margins of safety under long-term storage of moderate burnup fuel‡ (up to 45,000 MWD/MTU) are quantified. The HI-STORM UMAX deploys the same HI-TRAC VW transfer casks that are used in HI-STORM FW vertical ventilated system (USNRC Docket 72-1032) [I.1.2.3]. Safe thermal performance of 24PT1-DSC placed in HI-TRAC VW during short-

‡ High Burnup Fuel is not authorized for storage in the 24PT1-DSC.

term operations defined in Supplement I.9 is also evaluated. The cases of normal, off-normal and accident conditions of storage, enumerated in Supplement I.2 are also evaluated to establish an acceptable safety case for long term storage in the HI-STORM UMAX VVMs.

The thermal evaluation of HI-STORM UMAX follows the guidelines of NUREG-1536 [4.0.1] and ISG-11 [4.0.2] and the acceptance criteria set forth in Design Criteria Chapter 2 and Supplement I.2. These guidelines provide specific limits on the permissible maximum cladding temperature in the stored commercial spent fuel (CSF)[§] and other Confinement Boundary components, and on the maximum permissible pressure in the confinement space under certain operating scenarios. Specifically, the requirements are:

1. The fuel cladding temperature must meet the temperature limit appropriate to its burnup level and condition of storage / handling set forth in ISG-11 [4.0.2].

2. The maximum internal pressure of the 24PT1-DSC should remain within its design pressures for normal, off-normal, and accident conditions defined in NUHOMS FSAR Table 3.1-6 [I.1.2.1].

3. The temperatures of the cask and canister materials shall remain below their allowable limits set forth in Tables 2.3.7 and I.2.2.1 under all scenarios.

Section I.2.5 of this FSAR lists all thermally challenging scenarios that warrant analysis. Table I.2.1.2 in Supplement I.2 specifies the 24PT1-DSC Design Basis heat loads. As evaluated in this Supplement, the HI-STORM UMAX system is designed to comply with Supplement 2.I thermal criteria.

Sections I.4.1 through I.4.3 define the thermal input data that are common to all conditions of storage, handling and on-site transfer operations. All required thermal analyses to evaluate normal conditions of storage in a HI-STORM UMAX storage module are described in Section I.4.4. The thermal performance of the system is also evaluated under sustained wind conditions in Section I.4.4. Thermal analyses of on-site transfer in a HI-TRAC transfer cask are evaluated in Section I.4.5 and evaluation under off-normal and accident conditions are addressed in Section I.4.6.

To evaluate the storage of 24PT1-DSC in the UMAX VVM with the exception of 24PT1-DSC modeling[**] the same methodology defined in the main body of the FSAR for modeling the VVM and the ventilation cooling of the heater canister is adopted.

§ Defined as nuclear fuel that is used to produce energy in a commercial nuclear reactor (See Glossary).
** 24PT1-DSC modeling addressed in Section 4.4.

Table I.4.0.1: Material Incorporated by Reference

Information Incorporated by Reference	Source of the Information	NRC Approval of Material Incorporated by Reference	Location in this FSAR where Material is Incorporated by Reference	Technical Justification of Applicability to HI-STORM UMAX
Canister Thermal Performance	NUHOMS FSAR Reference [I.1.2.1, Chapter 4, Section 4.4]	NUHOMS SER Reference [I.1.2.2]	I.4.4	The canister is the same as the one described in the FSAR and originally approved in the referenced SER.
Canister Material Properties	NUHOMS FSAR Reference [I.1.2.1, Chapter 4, Section 4.2]	NUHOMS SER Reference [I.1.2.2]	I.4.2	The canister is the same as the one described in the FSAR and originally approved in the referenced SER.
Canister in NUHOMS Transfer Cask thermal evaluation	NUHOMS FSAR Reference [I.1.2.1, Chapter 4, Subsection 4.4.3]	NUHOMS SER Reference [I.1.2.2]	I.4.5	The canister is the same as the one described in the FSAR and originally approved in the referenced SER.
Canister Design Pressure	NUHOMS FSAR Reference [I.1.2.1, Chapter 3, Table 3.1-6]	NUHOMS SER Reference [I.1.2.2]	I.4.4.6	The canister is the same as the one described in the FSAR and originally approved in the referenced SER.
Canister in NUHOMS Transfer Cask fire accident evaluation	NUHOMS FSAR Reference [I.1.2.1, Chapter 4, Subsection 4.6.4]	NUHOMS SER Reference [I.1.2.2]	I.4.6	The canister is the same as the one described in the FSAR and originally approved in the referenced SER.
NUHOMS AHSM Module description	NUHOMS FSAR Reference [I.1.2.1, Chapter 1, Section 1.1]	NUHOMS SER Reference [I.1.2.2]	I.4.4	The module is the same as the one described in the FSAR and originally approved in the referenced SER.

I.4.1 DESIGN BASIS HEAT LOAD

The 24PT1-DSC canister and fuel design heat loads are specified in Table I.2.1.2. The decay heat is conservatively modeled in the thermal analysis as non-uniformly distributed heat source in the active fuel region with peaking in the middle as defined in the main body of the UMAX FSAR (See Supplement I.2, Table I.2.1.4).

I.4.2 SUMMARY OF THERMAL PROPERTIES OF MATERIALS

Except for 24PT1-DSC the thermo-physical properties relevant to thermal evaluation are same as defined in the main body Section 4.2 of the FSAR which provides properties of materials present in the HI-STORM UMAX VVM such as carbon steel, insulation, concrete (in the Closure Lid) and air. These same properties are used herein. The 24PT1-DSC modeling as articulated in Section I.4.4 requires properties of its stainless steel pressure boundary which are obtained from the NUHOMS FSAR [I.1.2.1] and compiled in Table I.4.2.1.

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 NUHOMS FSAR [I.1.2.1].					

I.4.3 SPECIFICATIONS FOR COMPONENTS

Permissible temperatures for the HI-STORM UMAX VVM and 24PT1-DSC materials and components designated as "Important to Safety" (i.e., required to be maintained within safe operating temperatures to ensure their intended function) are defined in Chapter 2, Table 2.3.7 and Supplement I.2, Table I.2.2.1. Long-term integrity of SNF requires fuel cladding be maintained below ISG-11, Rev. 3 regulatory limits [4.0.2] which are tabulated in Table I.4.3.1.

Compliance with 10CFR72 requires, in part, identification and evaluation of short-term, off-normal and hypothetical accident events and compliance with corresponding FSAR limits. These limits are addressed in the tables cited above.

Table I.4.3.1: Fuel Cladding Temperature Limits

Condition	Limit (^oF) Notes 1, 2
Normal	752
Short Term Operations, Off-normal and Accident	1058
Note 1: Moderate burnup fuel limits tabulated in accordance with ISG-11, Rev. 3 [4.0.2]. Note 2: High burnup fuel not permitted in the 24PT1-DSC.	

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.

I.4.4.2 UMAX Thermal Model

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I.4.4.3 Grid Sensitivity Studies

The grid sensitivity studies reported in Chapter 4, Subsection 4.4.2 in the main body of the FSAR remain applicable. The same licensing basis UMAX VVM mesh articulated in the main body is adopted herein.

I.4.4.4 Test Model

The HI-STORM UMAX thermal analysis is performed on the FLUENT [4.4.3] Computational Fluid Dynamics (CFD) program. To ensure a high degree of confidence in the HI-STORM UMAX thermal evaluations, the FLUENT code has been benchmarked using data from tests conducted with casks loaded with irradiated SNF ([4.4.4], [4.4.6]). The benchmark work is archived in QA validated Holtec reports ([4.4.1], [4.4.5]). These evaluations show that the FLUENT solutions are conservative in all cases. In view of these considerations, additional experimental verification of the thermal design is not necessary. Furthermore, FLUENT is relied to secure certification in all Holtec International Part 71 and Part 72 dockets.

I.4.4.5 Maximum and Minimum Temperatures

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I.4.4.6 Maximum Internal Pressure in the MPC

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

Thermal calculations do not rely on fuel conductivity as it is subsumed in the lumped parameter modeling of the canister interior space. See Section I.4.4.1.

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.

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

Table I.4.4.6: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.7: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.8: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Table I.4.4.9: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Figure I.4.4.1: **PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390**

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

I.4.5 SHORT-TERM OPERATIONS

Short-Term Operations as applicable to the 24PT1-DSC (See Supplement I.9) are those activities that are required to relocate it from a NUHOMS storage module to Holtec's licensed HI-TRAC VW followed by on-site transfer and placement in the "UMAX" VVM. In the regulatory literature, all activities that involve the handling and placement of canisters on the ISFSI pad or retrival from ISFSI under an unlikely scenario requiring fuel unloading are collectively referred to as Short Term Operations. These activities are required to comply with ISG-11, Rev. 3 temperature limits [I.4.0.2] (See Table I.4.3.1). All short term operations have one common feature: They all involve the transfer cask. The qualification of Short Term Operations, therefore, is integral to the certification of the transfer cask. This FSAR deploys the HI-TRAC VW transfer cask certified in the HI-STORM FW FSAR [I.I.1.2.3] for 24PT1-DSC transfer operations.

I.4.5.1 Thermally Limiting Evolutions During Short-Term Operations

The following scenarios are thermally limiting under 24PT1-DSC short term operational evolutions defined in Supplement I.9:

a) Horizontal transfer of 24PT1-DSC to NUHOMS Transfer Cask
b) Horizontal transfer to HI-TRAC VW Cask
c) Vertical on-site transfer of loaded HI-TRAC VW
d) 24PT1-DSC transfer to UMAX VVM and retrieval operations

Scenario a) is addressed in the NUHOMS FSAR [I.1.2.1, Chapter 4, Section 4.5]. The thermal evaluation is incorporated by reference (See Table I.4.0.1]. Scenarios b) and c) and d) are addressed in the following.

I.4.5.2 HI-TRAC VW Thermal Model

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I.4.5.3 Maximum Time Limit During Wet Transfer Operations

Not applicable, as the canister is already loaded and stored in NUHOMS.

I.4.5.4 Analysis of Limiting Thermal States During Short-Term Operations

I.4.5.4.1 Vacuum Drying

The canister is already loaded, therefore this evolution is not applicable.

I.4.5.4.2 Forced Helium Dehydration

The canister is already loaded, therefore this evolution is not applicable.

I.4.5.4.3 Normal On-Site Transfer

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I.4.5.4.4 Canister UMAX Loading and Retrieval Operations

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I.4.5.5 Fuel Retrievability

In accordance with ISG-2, Rev. 2‡‡, fuel retrievability is defined as:

> "Ready retrieval: The ability to safely remove the spent fuel from storage for further processing or disposal."

The UMAX system is suitably designed to retrieve fuel in accordance with Option B permitted in the ISG-2, Rev. 2 wherein the applicant is required to demonstrate removal of loaded canister from the storage overpack. As described in Operations Supplement I.9 a loaded 24PT1-DSC canister is retrieved from the UMAX VVM by transfer to a HI-TRAC VW and on-site transport to facilitate further processing. Thermal compliance of the transfer configuration and on-site transfer are addressed in the sections above.

I.4.5.6 Maximum Internal Pressure

During on-site transfer operations in the HI-TRAC VW transfer cask, the 24PT1-DSC helium pressure will correspond in accordance with Ideal Gas Law to the thermal conditions within it as analyzed in Section I.4.5.4. The computed pressures are tabulated in Table I.4.5.1. The pressure remains within NUHOMS FSAR Table 3.1-6 [I.1.2.1] pressure limits.

I.4.5.7 Fuel Unloading from Canister

Sites requiring access to fuel assemblies may conduct unloading operations as evaluated in the NUHOMS FSAR [I.1.2.1, Chapter 3, Section 3.5.4]. This operation is non-mandatory under ISG-2, Rev. 2 Option B requirements as adopted in Subsection I.4.5.5.

‡‡ "Fuel Retrievability in Spent Fuel Storage Applications", Interim Staff Guidance-2, Rev. 2, Approved 4/26/16.

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

I.4.6 OFF-NORMAL AND ACCIDENT EVENTS

The HI-STORM UMAX System safety under off-normal and accident conditions specified in Supplement 2.I is evaluated in this section. The HI-STORM UMAX System is evaluated under design basis 24PT1-DSC heat load defined in Section I.4.1.

I.4.6.1 Off-Normal Events

I.4.6.1.1 Off-Normal Environmental Temperature

As justified in Chapter 4, Section 4.6 the UMAX System temperature elevation under off-normal ambient condition is suitably obtained by the difference $\delta = 20^{o}F$ in ambient temperature under off-normal ($100^{o}F$) 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 conclusion that safe operating temperatures under off-normal ambient condition is reasonably assured. 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 off-normal design limits [I.1.2.1, Chapter 3, Table 3.1-6].

I.4.6.1.2 Partial Blockage of Air Inlets

The HI-STORM UMAX system is designed with debris screens installed on the inlet and outlet openings. These screens ensure the air passages are protected from entry and blockage by foreign objects. However, as required by the design criteria presented in Chapter I.2, it is postulated that the HI-STORM UMAX air inlet vents are 50% blocked. The resulting decrease in flow area increases the flow resistance of the inlet ducts. The effect of the increased flow resistance on fuel temperature is analyzed assuming that steady state conditions have been reached. The computed temperatures and pressures are reported in Table I.4.6.1. The results are confirmed to be below the fuel cladding, UMAX VVM and DSC-24PT1 temperature limits.

I.4.6.1.3 Off-Normal Pressure

This event is defined as a combination of (a) helium backfill, (b) 10% fuel rods rupture, (c) design heat load and (d) normal ambient temperature defined in Section I.2.2. The principal objective of the analysis is to demonstrate that the 24PT1-DSC off-normal design pressure (Table I.2.2.1) is not exceeded. Table I.4.4.6 provides the computed pressures for the off-normal event as defined above which shows that the pressure complies with the off-normal pressure limit.

I.4.6.1.4 FHD Malfunction

FHD is not relied for operations involving the 24PT1-DSC, therefore this event is not applicable.

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 $\delta = 45^oF$ ambient temperature under extreme ambient (125^oF) and normal (80^oF) 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 mechanism for the HI-STORM UMAX to be completely buried under debris. However, as defense-in-depth, a complete burial under debris is postulated and evaluated below.

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I.4.6.2.5 Flood

The flood accident temperatures under 24PT1-DSC storage are bounded by the MPC in UMAX flood accident analyzed in Chapter 4, Section 4.6 as supported by following reasoning:

a) Reduced ventilation cooling demand due to substantially lower heat load under 24PT1-DSC storage.
b) Enhanced canister cooling supported by enlarged annulus flow area under 24PT1-DSC storage.
c) Lower fuel, canister and UMAX storage temperatures under 24PT1-DSC storage.

In light of the above the UMAX flood accident temperatures under MPC storage tabulated in

Chapter 4, Table 4.6.9 are adopted for 24PT1-DSC evaluation. Inspection of the temperatures support compliance with fuel and DSC accident temperature limits specified in Tables I.4.3.1 and I.2.2.1.

Flood Recovery Actions

It is required in this FSAR to treat the recovery operation from flood as a blocked duct event (analyzed in the foregoing) for the affected VVM cavity by the ISFSI Owner *with the time clock to remove water and clear up the flow passages beginning as soon as the water in the cavity drops below the top surface of the stored MPC.*

I.4.6.2.6 Jacket Water Loss

The Jacket Water loss accident involves the loss of water medium in the HI-TRAC VW overpack peripheral spaces. This results in an increased resistance to the lateral dissipation of heat and a concomitant temperature adder to the loaded canister and stored fuel. This event is analyzed using the same thermal model articulated in Section I.4.5 assuming all water in the jacket is replaced by air. The computed temperatures and pressures are tabulated in Table I.4.6.2. The temperatures comply with fuel, DSC and HI-TRAC VW accident limits specified in Tables I.4.3.1, I.2.2.1 and main body Table 2.3.7 and 24PT1-DSC pressure limits specified in NUHOMS FSAR Table 3.1-6 [I.1.2.1].

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.4.7 REGULATORY COMPLIANCE

Thermal compliance pursuant to the provisions of NUREG [4.0.1] and ISG-11 [4.0.2] of 24PT1-DSC in the HI-STORM UMAX system has been considered in this supplement. NUREG-1536 [4.0.1] and ISG-11 [4.0.2] define thermal acceptance criteria that must be applied to evaluations of normal conditions of storage. These are addressed in Sections I.2.1 and I.4.1. Each of the pertinent criteria and the conclusion of the evaluations are summarized herein.

As required by ISG-11 [4.0.2], the fuel cladding temperature at the beginning of dry storage is maintained below the anticipated damage-threshold temperatures for normal conditions for the licensed life of the HI-STORM UMAX System. Maximum fuel cladding temperatures for long-term storage conditions are reported in Section I.4.4.

As required by NUREG-1536 [4.0.1], the maximum internal pressure of the canister remains within its design pressure for normal conditions, under postulated rupture of 1 percent of the fuel rods. Assumptions for pressure calculations include release of 100 percent of the fill gas and 30 percent of the significant radioactive gases in the fuel rods. Maximum internal pressures are reported in Section I.4.4 and shown to remain below the normal design pressures specified in Table 3.1-6 of NUHOMS FSAR [I.1.2.1].

As required by NUREG-1536 [4.0.1], all VVM, DSC components and fuel materials are maintained within their minimum and maximum temperature for normal and off-normal conditions in order to enable components to perform their intended safety functions. Maximum and minimum temperatures for normal, off-normal and accident long-term storage conditions are reported in Sections I.4.4 and I.4.6 which are evaluated to be well below their respective Design temperature limits summarized in Tables 2.3.7, I.2.2.1 and I.4.3.1.

As required by NUREG-1536 [4.0.1], the system ensures a very low probability of cladding breach during long-term storage. For long-term normal conditions, the maximum CSF cladding temperature remains below the ISG-11 [4.0.2] limit of 400°C (752°F).

As required by NUREG-1536 [4.0.1], the system is passively cooled. All heat rejection mechanisms described in this chapter, including conduction, natural convection, and thermal radiation, are passive.

As required by NUREG-1536 [4.0.1], the thermal performance of the system is within the allowable design criteria specified in SAR Supplements I.2 and I.4 for normal conditions. All thermal results reported in Section I.4.4 are within the design criteria under all normal conditions of storage.

The thermal compliance of short term operations is presented in Section I.4.5 wherein complete compliance with the provisions of ISG-11 [4.0.2] is demonstrated. In particular, the ISG-11 requirement to ensure that maximum cladding temperatures under all fuel loading and short-term operations be below 570°C (1058°F) under authorized burnups (moderate burnup fuel) is demonstrated.

As required by NUREG-1536 [4.0.1], the maximum internal pressure of the 24PT1-DSC is evaluated and shown to remain within its off-normal and accident design pressure, assuming rupture of 10 percent and 100 percent of the fuel rods, respectively. Assumptions for pressure calculations include release of 100 percent of the fill gas and 30 percent of the significant radioactive gases in the fuel rods.

It is therefore concluded that all applicable regulatory requirements and guidelines germane to demonstrating the integrity of the 24PT1-DSC canister in the "UMAX" storage system have been addressed and satisfied in this chapter.

I.4.8 REFERENCES

~~None.~~

[I.4.4.1] Holtec ~~Proprietary Report:~~International, "Thermal Evaluation of HI-STORM UMAX System Loaded with 24PT1-DSC,"~~,~~ HI-2167272, Rev. ~~$(AM~~1~~)~~.

SUPPLEMENT I.6: CRITICALITY EVALUATION

I.6.0 INTRODUCTION

This supplement to Chapter 6 presents the criticality safety evaluation of the HI-STORM UMAX system loaded with the 24PT1-DSC canister. The evaluation shows that the maximum k_{eff} value, including all applicable biases and uncertainties is below 0.95 for all normal, off-normal and accident conditions.

The initial criticality safety evaluation of the 24PT1-DSC canister, with the canister either residing in the NUHOMS-MP187 transfer cask or the Standardized Advanced NUHOMS modules (AHSMs) under both wet and dry conditions, is documented in Chapter 6 of the Standardized Advanced NUHOMS FSAR [I.1.2.1].

Since there are no wet conditions during the operation of HI-STORM UMAX with the 24PT1-DSC canister (no canister loading / unloading), the canister will always be internally dry, hence criticality safety is demonstrated in this supplement for 24PT1-DSC in the HI-TRAC VW and HI-STORM UMAX under dry conditions only, and without any reference to evaluations in [I.1.2.1].

In the calculations presented here, only the assemblies are considered to be present inside the canister. All other materials, i.e. the basket including the neutron absorber, are neglected. This is conservative, resulting in an upper-bound multiplication factor due to neglecting all neutron-absorbing materials. This also avoids the need to specify any design details of those parts. Despite this extreme conservatism, the maximum k_{eff} of the system remains well below the regulatory limit, due to the absence of water in the canister. This provides a substantial margin to the acceptance criteria that would be available to offset any uncertainties not explicitly considered in the analyses presented here.

Apart from this simplifying and conservative assumption, analysis methodologies and modeling assumptions utilized in the evaluation documented in this supplement are based on those used in the licensing of HI-STORM FW in Docket #72-1032 [2.0.1]. For clarity, Table I.6.0.1 below identifies the information incorporated by reference in this supplement, the source of the information, a reference to the NRC approval of the information (SER), where in this supplement it is incorporated, and a discussion of the applicability of the previously approved information.

Table I.6.0.1: Material Incorporated by Reference

Information Incorporated by Reference	Source of the Information	NRC Approval of Material Incorporated by Reference	Location in this FSAR where Material is Incorporated	Technical Justification of Applicability to HI-STORM UMAX
General Criticality Discussions for Holtec Systems	Section 6.1, Reference [2.0.1];	SER HI-STORM FW Amendment 0, Reference [I.1.2.3];	I.6.1	In general, methodology and assumptions for criticality safety evaluations are the same as that used for the HI-STORM FW, including codes used for the analyses.
HI-TRAC VW design	Section 1.2.1.3 Reference [2.0.1]	SER HI-STORM FW Amendment 0, Reference [I.1.2.3]	I.6.3	The HI-TRAC VW used with the 24PT1-DSC is the same as the one originally approved in the referenced SER.
Materials and Cross Section Sets	Section 6.3.2, Reference [2.0.1];	SER HI-STORM FW Amendment 0, Reference [I.1.2.3];	I.6.3.2	Same materials and cross section sets used here.
Methodology	Sections 6.4.1, 6.4.3 and 6.5, Reference [2.0.1];	SER HI-STORM FW Amendment 0, Reference [I.1.2.3];	I.6.4.1, I.6.4.4, I.6.5	In general, methodology and assumptions for criticality safety evaluations are the same as that used for the HI-STORM FW, including codes used for the analyses.

I.6.1 DISCUSSION AND RESULTS

The results in this chapter demonstrate that the effective multiplication factor (k_{eff}) of the HI-STORM UMAX system loaded with the 24PT1-DSC, including all biases and uncertainties evaluated with a 95% probability at the 95% confidence level, does not exceed 0.95 under all credible normal, off-normal, and accident conditions. The results demonstrate that at least two unlikely, independent, and concurrent or sequential changes must occur to the conditions essential to criticality safety before a nuclear criticality accident is possible. These criteria provide a large subcritical margin, sufficient to assure the criticality safety of the HI-STORM UMAX system when loaded with the 24PT1-DSC.

The acceptance criteria for criticality evaluations for the HI-STORM UMAX system loaded with the 24PT1-DSC canister are presented in Subsection I.2.0 of this FSAR. Those are identical to the acceptance criteria for criticality evaluations for all other canisters loaded into the HI-STORM UMAX system.

During storage conditions in the HI-STORM UMAX system, the maximum k_{eff} will be significantly below the regulatory limit since the canister is internally dry. This results in a large margin to acceptance criteria.

To assure the true reactivity will always be less than the calculated reactivity, the following conservative design criteria and assumptions were made:

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The off-normal and accident conditions defined in Supplement I.2 and considered in Supplement I.12 have no adverse effect on the design parameters important to criticality safety and thus, from the criticality safety standpoint, the off-normal and accident conditions are identical to those for normal conditions.

For additional details and justifications, the reader is referred to Section 6.1 of the HI-STORM FW FSAR [2.0.1].

The design basis criticality safety calculations are performed for the internally dry HI-TRAC VW and HI-STORM UMAX (limiting case for the HI-STORM UMAX system with the 24PT1-DSC canister), and include the calculational bias, uncertainties, and calculational statistics.

The calculations in this supplement use the same computer code, cross-section library and methodologies that are used in the HI-STORM FW FSAR [2.0.1], hence the benchmark calculations, and specifically the bias and bias uncertainty remain applicable. The results are listed in Table I.6.1.1 and confirm that the maximum k_{eff} values for the HI-STORM UMAX system with the 24PT1-DSC canister under storage conditions (dry inert environment) is substantially below the limiting design criteria (k_{eff} < 0.95). Analyses for various conditions of external flooding are presented in Subsection I.6.4.4 to establish the bounding condition with respect to the external flooding.

TABLE I.6.1.1

MAXIMUM K_{eff} VALUES FOR THE HI-STORM UMAX SYSTEM WITH THE 24PT1-DSC

Overpack/Module	**Maximum k_{eff}[1]**
HI-TRAC VW	0.5559
HI-STORM UMAX	0.4742

[1] Includes bias, bias uncertainties, and calculational statistics.

I.6.2 SPENT FUEL LOADING

The 24PT1-DSC canister is only qualified for the two assembly types specified in Table I.2.1.1. The analyses explicitly model those types, applying several conservative assumptions as discussed in Section I.6.1.

I.6.3 MODEL SPECIFICATION

I.6.3.1 Description of Calculational Model

Figures I.6.3.1 through I.6.3.4 show cross sections of the criticality models. Figures I.6.3.1 and I.6.3.2 show the planar cross-section of HI-TRAC VW and HI-STORM UMAX overpack/module models, respectively, whereas Figures I.6.3.3 and I.6.3.4 show the axial cross-section of HI-TRAC VW and HI-STORM UMAX overpack/module models, respectively. Relevant dimensions of the modeled canister and overpacks are summarized in Tables I.6.3.2 and I.6.3.3. The bases for the dimensions are as follows:

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I.6.3.2 Cask Regional Densities

Compositions of the various components used in the calculations are listed in Table 6.3.4 of the HI-STORM FW FSAR [2.0.1] and repeated here in Table I.6.3.1. The cross section set for each nuclide is listed in Table 6.3.8 of the HI-STORM FW FSAR [2.0.1], and is consistent with the cross section sets used in the benchmarking calculations documented in Appendix A of the HI-STORM FW FSAR [2.0.1]. Note that these are the default cross sections chosen by the code.

TABLE I.6.3.1

[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]

TABLE I.6.3.2

[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]

TABLE I.6.3.3

[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]

TABLE I.6.3.3 (continued)
[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]

[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]

Figure I.6.3.1: Calculational Model (planar cross-section) of HI-TRAC VW

[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]

Figure I.6.3.2: Calculational Model (planar cross-section) of HI-STORM UMAX

[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]

Figure I.6.3.3: Calculational Model (axial cross-section) of HI-TRAC VW

[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]

Figure I.6.3.4: Calculational Model (axial cross-section) of HI-STORM UMAX

I.6.4 CRITICALITY CALCULATIONS

I.6.4.1 Calculational Methodology

Calculational methodologies are generally the same as those described in Subsection 6.4.1 of the HI-STORM FW FSAR [2.0.1] except for the calculation parameters as noted below.

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I.6.4.2 External Moderation

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I.6.4.3 Damaged Fuel

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I.6.4.4 Criticality Results

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[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390
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TABLE I.6.4.1

[PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]

I.6.5 CRITICALITY BENCHMARK EXPERIMENTS

The calculations in this supplement use the same computer code, cross-section library and methodologies that are used in the HI-STORM FW FSAR [2.0.1], hence the benchmark calculations, and specifically the bias and bias uncertainty remain applicable. The reader is referred to Section 6.5 of the HI-STORM FW FSAR [2.0.1] for a comprehensive discussion of the benchmarking.

I.6.6 REGULATORY COMPLIANCE

This section documents the criticality evaluation of the HI-STORM UMAX system for the storage of spent nuclear fuel in the 24PT1-DSC canister. This evaluation demonstrates that the HI-STORM UMAX system is in full compliance with the criticality requirements of 10CFR72 and NUREG-1536.

Structures, systems, and components important to criticality safety, as well as the limiting fuel characteristics, are either described in sufficient detail in this chapter or provided with a reference on the HI-STORM FW and/or HI-STORM 100 FSARs to enable an evaluation of their effectiveness.

Criticality safety of the 24PT1-DSC canister in the NUHOMS-MP187 transfer cask and the Standardized Advanced NUHOMS modules (AHSMs) under both wet and dry conditions is demonstrated by criticality evaluations documented in Chapter 6 of the Standardized Advanced NUHOMS FSAR [I.1.2.1].

Since there are no wet conditions during the operation of HI-STORM UMAX with the 24PT1-DSC canister (no canister loading / unloading), criticality safety is demonstrated in this supplement for 24PT1-DSC in the HI-TRAC VW and HI-STORM UMAX under dry conditions only. The results confirm that the maximum k_{eff} values for the HI-STORM UMAX system with the 24PT1-DSC canister under storage conditions (dry inert environment) is substantially below the limiting design criteria ($k_{eff} < 0.95$).

Therefore, it is concluded that the criticality design features for the HI-STORM UMAX system are in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The criticality evaluation provides reasonable assurance that the HI-STORM UMAX system will allow safe storage of spent fuel.