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THERMAL EVALUATIONS OF HI-STORM UMAX AT HISTORE CIS FACILITY

FOR

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DOCUMENT CATEGORIZATION

In accordance with the Holtec Quality Assurance Manual and associated Holtec Quality Procedures (HQPs), this document is categorized as a:

- ☑ Calculation Package[3] (Per HQP 3.2)
- ☐ 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):

DOCUMENT FORMATTING

The formatting of the contents of this document is in accordance with the instructions of HQP 3.2 or 3.4 except as noted below:

DECLARATION OF PROPRIETARY STATUS

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2. A revision to this document will be ordered by the Project Manager and carried out if any of its contents including revisions to references is materially affected during evolution of this project. The determination as to the need for revision will be made by the Project Manager with input from others, as deemed necessary by him.

3. Revisions to this document may be made by adding supplements to the document and replacing the "Table of Contents", this page and the "Revision Log".

Table of Contents

Summary of Revisions

Revision 0: Initial revision.

1.0 Introduction

This report documents the site-specific thermal evaluations of HI-STORM UMAX System [1] deployed for long-term storage at HI-STORE CIS facility [2]. The calculations presented in this report support the evaluations related to UMAX in Chapter 6 of HI-STORE SAR [2]. HI-STORM UMAX, certified in the USNRC docket # 72-1040 [3], [16] is an underground vertical ventilated system with openings for air ingress and egress and internal air flow passages for ventilation cooling of loaded MPC.

It is designed to have an MPC sitting inside a thick steel divider shell. The divider shell is insulated to reduce the transmission of decay heat from the MPC to the down-coming cool air in the annular gap between divider shell and container shell (CEC). Large inlet passageway allows air flow from the ambient environment to the annular space between MPC shell and divider shell, through [PROPRIETARY PER 10CFR2.390]. The cooling air rises through the annulus between the divider shell and the MPC enclosure vessel due to the chimney effect created by the transfer of heat from the MPC shell to the air. The [PROPRIETARY PER 10CFR2.390

]. Large gap between the MPC lid and the VVM closure lid allows efficient heat dissipation from the MPC lid. [PROPRIETARY PER 10CFR2.390

].

Two different types of MPCs, MPC-37 and MPC-89, that are licensed previously for storage in HI-STORM FW [4] and HI-STORM UMAX [3] are allowed for storage in UMAX cavity at HI-STORE [1]. The MPCs deployed in HI-STORM UMAX cavity are exactly the same as those previously approved in HI-STORM FW FSAR [4] and HI-STORM UMAX FSAR [3].

With respect to normal storage in the HI-STORM UMAX Version C cavities at HI-STORE, it is recognized that the maximum heat load in any canister cannot exceed the limit in the transport cask that will be used to bring the canisters to the HI-STORE CIS site. These canisters are already backfilled with helium and some already under dry storage at power plants from where they are transported to the HI-STORE facility. As the heat removal capacity of the ventilated HI-STORM UMAX system is substantially in excess of the (unventilated) transport cask (viz., HI-STAR 190 [5]) that will be used to fetch the canisters, the peak cladding temperatures are expected to remain well below the normal, off-normal and accident conditions of storage postulated in NUREG-1567 [6] and NUREG-1536 [7]. The maximum allowable decay heat for storage in MPC-37 and MPC-89 are provided in Tables 1.1 and 1.2 respectively. Initial helium backfill range to which these canisters were backfilled is provided in Tables 1.3 and 1.4.

The interim storage of the canisters will occur in the HI-STORM UMAX Version C VVMs. The thermal-hydraulic configuration of the HI-STORM UMAX Version C VVMs at HI-STORE is essentially identical to Version B that is certified in the HI-STORM UMAX ECO [16]. Therefore, its heat rejection capacity would be virtually identical under identical conditions to

that analyzed and certified in [3] under all operation modes. However, the Design Basis heat load and the ambient temperature metrics for the HI-STORE ISFSI are less challenging than those for which the system is certified in [3]. Therefore, it is expected that the heat rejection performance of the canisters at the HI-STORE ISFSI will have even greater margins to the regulator-prescribed limit than that established in [3]. To ascertain this, long-term storage of canisters in HI-STORM UMAX with site-specific conditions from Table 1.5 is evaluated in this report.

1.1 Quality Essentials Applicable to this Report

This section contains quality related information on this document in conformance with the provisions in Holtec's Quality Assurance program.

1.1.1 Document Classification and QA Protocol

This document is classified as "Safety Significant" under Holtec International's quality assurance system. In order to gain acceptance as a safety-significant document in the company's quality assurance system, this document is required to undergo a prescribed review and concurrence process that requires the preparer and reviewer(s) of the document to answer a long list of questions crafted to ensure that the document is purged of all errors of any material significance. A record of the review and verification activities is maintained in electronic form within the company's network to enable future retrieval and recapitulation of the programmatic acceptance process leading to the acceptance and release of this document under the company's QA system. Among the numerous requirements that this document must fulfill, as applicable, to muster approval within the company's QA program are:

- The preparer(s) and reviewer(s) are technically qualified to perform their activities per the applicable Holtec Quality Procedure (HQP).
- The input information utilized in the work effort is drawn from referencable sources. Any assumed input data is so identified.
- All significant assumptions are stated.
- The analysis methodology is consistent with the physics of the problem.
- Any computer code and its specific versions used in the work are formally admitted for use within the company's QA system.
- The format and content of the document is in accordance with the applicable Holtec quality procedure.
- The material content of the calculation package is understandable to a reader with the requisite academic training and experience in the underlying technical disciplines.

Once a safety significant document, such as this calculation package, completes its review and certification cycle, it should be free of any materially significant error and should not require a revision unless its scope of treatment needs to be altered. Except for regulatory interface documents (i.e., those that are submitted to the NRC in support of a license amendment and request), editorial revisions to Holtec safety-significant documents are not made unless such editorial changes are deemed necessary by the Holtec Project Manager to prevent erroneous conclusions from being inferred by the reader. In other words, the focus in the preparation of this document is to ensure correctness of the technical content rather than the cosmetics of presentation.

In accordance with the foregoing, this Calculation Package is prepared pursuant to the revisions of Holtec Quality Procedures HQP 3.0 and 3.2, which require that all analyses utilized in support of the design of a safety-related or important-to-safety structure, component, or system be fully documented such that the analyses can be reproduced at any time in the future by a specialist trained in the discipline(s) involved. HQP 3.2 sets down a rigid format structure for the content and organization of Calculation Packages that are intended to create a document that is complete in terms of the exhaustiveness of content. The Calculation Packages, however, lack the narrational smoothness of a Technical Report, and are not intended to serve as a Technical Report.

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.

1.1.2 Quality Validation Questionnaire

The questionnaire below is a distilled version of the vast number of questions that the preparer and reviewer of a Holtec safety-significant report must answer and archive in the Company's network to gain a VIR number (the identifier of QA pedigree in Holtec's electronic configuration control system).

An affirmative answer (unless the question is "not applicable" or NA) to each of the following questions by the preparer of the report (or editor of a multi-author document) is an essential condition for this document to merit receiving a QA validated status.

	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	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

1.1.3 Computer Codes Used in this Work

Holtec International maintains an active list of QA validated computer codes on the Company’s network that are approved for use in Safety significant projects. The table below identifies the Code and its version (listed in the ACPL) that has been used in this work effort.

Generic Report & ACPL Information	
Generic Report # invoked in this Calc Package, if applicable	N/A
Code name (must be listed in the ACPL)	FLUENT
Code 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]

Table 1.1: MPC-37 Allowable Decay Heat Load Patterns [2]

Pattern	Region (Note 1)	Maximum Decay Heat Load per Assembly (kW) (Note 2)	Total Canister Heat Load (kW)
1	1	0.38	31.82
	2	1.7	
	3	0.50	
2	1	0.42	32.02
	2	1.54	
	3	0.61	
3	1	0.61	32.09
	2	1.23	
	3	0.74	
4	1	0.74	32.06
	2	1.05	
	3	0.8	
5	1	0.8	32.04
	2	0.95	
	3	0.84	
6	1	0.95	31.43
	2	0.84	
	3	0.8	

Note 1: For basket region numbering scheme refer to Figure 1.1.
Note 2: Sub-Design Basis Heat Load is defined as 80% of the design basis heat load in every storage location defined herein.

Table 1.2: MPC-89 Allowable Decay Heat Loads [2]

Pattern	Region (Note 1)	Maximum Decay Heat Load per Assembly (kW) (Note 2)	Total Canister Heat Load (kW)
1	1	0.15	32.15
	2	0.62	
	3	0.15	
2	1	0.18	32.02
	2	0.58	
	3	0.18	
3	1	0.27	32.03
	2	0.47	
	3	0.27	
4	1	0.32	32.08
	2	0.41	
	3	0.32	
5	1	0.35	31.95
	2	0.37	
	3	0.35	
Note 1: For basket region numbering scheme refer to Figure 1.2. Note 2: Sub-Design Basis Heat Load is defined as 80% of the design basis heat load in every storage location defined herein.			

Table 1.3: Initial MPC Helium Backfill Specification Requirements for Design Basis Heat Loads [2], [5]

MPC Type	Pressure Range (Note 1)
MPC-37	$\geq$ 39.0 psig and $\leq$ 46.0 psig
MPC-89	$\geq$ 39.0 psig and $\leq$ 47.5 psig
Note 1: Helium used for backfill of MPC shall have a purity of $\geq$ 99.995%. The pressure range is based on a reference temperature of 70°F.	

Table 1.4: Initial MPC Helium Backfill Specification Requirements for Sub-Design Basis Heat Loads [2], [5]

MPC Type	Pressure Range (Note 1)
MPC-37	$\geq$ 39.0 psig and $\leq$ 50.0 psig
MPC-89	$\geq$ 39.0 psig and $\leq$ 50.0 psig
Note 1: Helium used for backfill of MPC shall have a purity of $\geq$ 99.995%. The pressure range is based on a reference temperature of 70°F. Note 2: Sub-Design Basis Heat Load is defined as 80% of the design basis heat load in every storage location defined in Tables 1.1 and 1.2 for MPC-37 and MPC-89 respectively.	

Table 1.5: Thermally Significant Parameters for the HI-STORM UMAX ISFSI at HI-STORE CIS Facility

Thermally Significant ISFSI parameter	Value [2]
Maximum Aggregate Heat Load, kW	Tables 1.1 and 1.2
Normal Ambient Temperature, ^{o}F	62
Elevation, ft	5000 (Note 1)
Minimum Ambient Temperature, ^{o}F	-11
Off-normal Ambient Temperature, ^{o}F	91
Accident Ambient Temperature, ^{o}F	108
Note 1: Elevation above sea level adopted for thermal evaluations conservatively bounds the site maximum elevation of 3540 feet [2].	

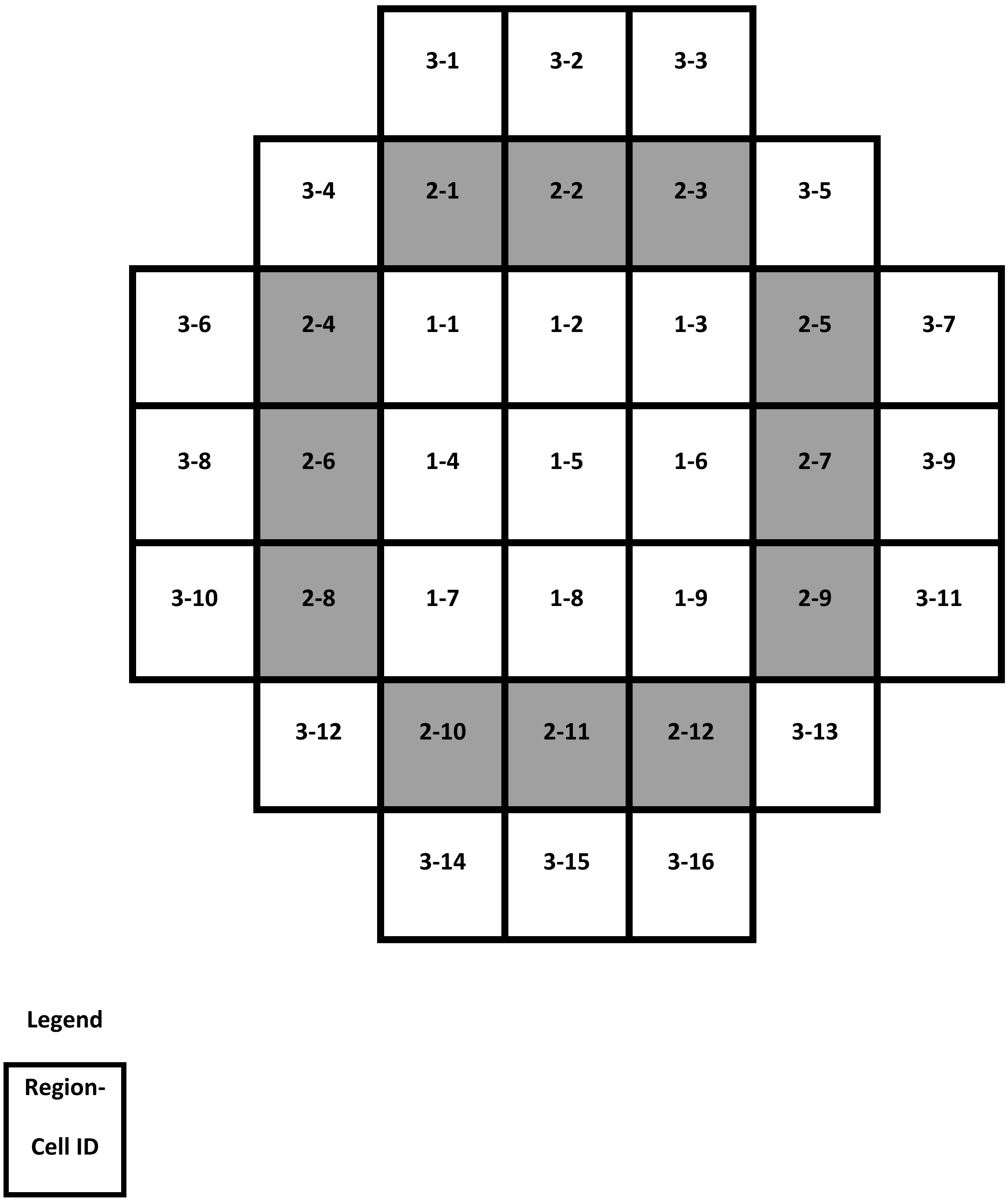

Figure 1.1: MPC-37 Region-Cell Identification

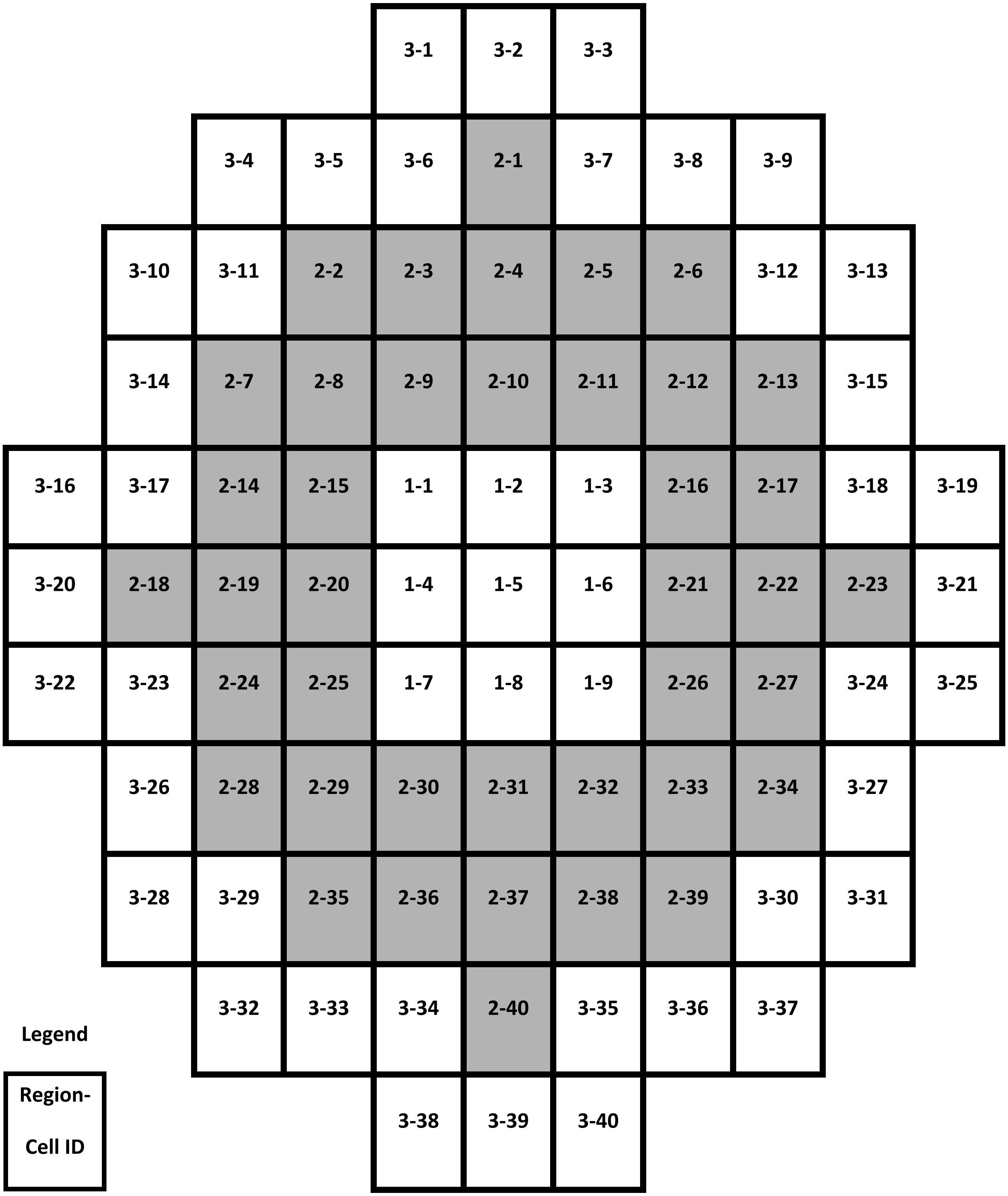

Figure 1.2: MPC-89 Region-Cell Identification

2.0 Methodology and Assumptions

Thermal evaluations of MPC-89 are bounded by MPC-37 under heat load patterns provided in Tables 1.1 and 1.2 as has been demonstrated in Section 3.3 of HI-STAR 190 SAR [5]. [PROPRIETARY PER 10CFR2.390]. Thermal analyses of normal storage conditions are carried out [PROPRIETARY PER 10CFR2.390] in Chapter 4 of HI-STORM UMAX FSAR [3]. The licensing basis MPC corresponds to MPC-37 with short fuel i.e. [PROPRIETARY PER 10CFR2.390] as was demonstrated in Chapter 4 of HI-STORM UMAX FSAR [3] and HI-STORM FW FSAR [4]. The storage cavity depth is made fixed (not variable, as permitted in the general UMAX certification [2]) at two discrete dimensions [1]. MPCs up to a certain maximum height can be placed within Type SL of UMAX Version C while MPCs taller than that will be placed within Type XL. See Table 2.1 which shows the maximum MPC heights allowed in each type and the minimum axial gap between the MPC and UMAX VVM cavity. As can be seen from Table 2.1, axial gap between the tallest MPC and UMAX cavity is still at or below the axial gap used in the licensing basis calculations presented in generic UMAX FSAR [3], [16]. Therefore, this change in depth of UMAX cavity between versions B and C will have no negative impact. This report presents the most limiting thermal scenario i.e. MPC-37 with short fuel placed in UMAX Version C Type SL. The justification on why this scenario is thermally most limiting is provided below:

a. MPC-37 with short fuel results in highest PCT and component temperatures as demonstrated in Section 4.4 of HI-STORM UMAX FSAR [3].
b. Active fuel height of short fuel is lowest among short, reference and long fuel assemblies. For the same heat load, lower active height results in higher heat load density.
c. Additionally, MPC-37 with short fuel also bounds the MPC-37 with [PROPRIETARY PER 10CFR2.390] as has been demonstrated by thermal evaluations in Section 4.5 of HI-STORM FW FSAR [4].

The axial air gap does not have a significant impact on heat dissipation from the MPC, as long as it is large enough to accommodate the airflow from the annular gap between MPC and divider shell to the open channel inside the closure lid. Therefore, the airflow resistance in UMAX version C design is expected to be similar or lower than the UMAX version B design. However, the variation of axial gap in Version C design due to the different MPC heights is expected to have a small effect on the airflow, considering the large gap existing for all MPC heights in version C.

The thermal model is exactly the same as that adopted in HI-STORM UMAX FSAR [16] except the following changes:

[PROPRIETARY PER 10CFR2.390

].

For each type of MPC, the model of fuel assembly, basket and MPC vessel follows the same methodology and assumptions presented in Chapter 4 of HI-STORM FW FSAR [4]. The methodology used in this report is essentially same as that in HI-STORM UMAX FSAR [3]. To ensure an adequate representation of the features of MPC-37, fuel basket within MPC-37 and the HI-STORM UMAX system, a quarter-symmetric 3-D geometric model is constructed using the FLUENT CFD code pre-processor (GAMBIT) [10], as shown in Figures 2.1 and 2.2. A 3-D model is constructed for thermally most limiting MPC i.e. MPC-37 with short fuel. The 3-D model implemented to analyze the HI-STORM UMAX Version C system has the following key attributes:

[PROPRIETARY PER 10CFR2.390

].

The cross-section view of the quarter-symmetric 3-D geometric model is shown in Figure 2.1. An isometric view is shown in Figure 2.2. The 3-D model has the following major assumptions that render the results conservative. In addition to the assumptions that are relevant to MPC

thermal model (presented in Section 4.4 of HI-STORM FW FSAR [4]) and UMAX VVM thermal model (presented in Section 4.4 of HI-STORM UMAX FSAR [3]), following assumptions are made in thermal evaluations presented in this report:

[PROPRIETARY PER 10CFR2.390

].

Thermal evaluations presented in Chapter 3 of HI-STAR 190 SAR [5] clearly demonstrate that heat load pattern 1 in MPC-37 results in bounding peak cladding temperatures. Therefore, heat load pattern 1 presented in Table 1.1 above is adopted for long-term storage evaluations presented in this report.

Table 2.1: Allowable MPCs in Different Types of UMAX Version C

UMAX Version C Type	UMAX Cavity Height (in) [1]	Maximum Allowable MPC Height (in) [1]	Minimum Axial Gap Between MPC and UMAX Lid (in)
SL	[PROPRIETARY PER 10CFR2.390]	[PROPRIETARY PER 10CFR2.390]	[PROPRIETARY PER 10CFR2.390]
XL	[PROPRIETARY PER 10CFR2.390]	[PROPRIETARY PER 10CFR2.390]	[PROPRIETARY PER 10CFR2.390]
Note 1: The minimum axial gap between MPC and HI-STORM UMAX in [3] is [PROPRIETARY PER 10CFR2.390] [15]. Therefore the minimum axial gap between MPC and UMAX at HI-STORE is larger than that was adopted for licensing basis calculations in generic UMAX FSAR [3].			

[PROPRIETARY PER 10CFR2.390]

[PROPRIETARY PER 10CFR2.390]

3.0 Inputs

As mentioned earlier, the MPC model is the same as that previously approved by USNRC in HI-STORM UMAX FSAR [3] and HI-STORM FW FSAR [4]. The principal input data for the storage overpack i.e. HI-STORM UMAX VVM at HI-STORE CIS facility, used in these analyses, are taken from design drawing [1].

All physical properties of the materials used for the simulation of the fuel assemblies, basket and MPC-37 vessel are specified in Section 4.2 of HI-STORM UMAX FSAR [3]. The physical properties of the common materials present within HI-STORM UMAX, such as carbon steel and concrete are same as that specified in specified in Section 4.2 of HI-STORM UMAX FSAR [3]. The physical properties of insulation are also provided in Section 4.2 of HI-STORM UMAX FSAR [3]. Thermal conductivity of insulation adopted in the thermal evaluations presented in this report [PROPRIETARY PER 10CFR2.390] presented in the UMAX FSAR [9].

The design ambient temperature used in the analysis of long-term storage is provided in Table 1.5. The bottom of the HI-STORM UMAX overpack base is assumed supported on a subgrade at the same temperature as the ambient temperature (Section 2.7 of HI-STORE SAR [2]). Surface emissivity data for key materials of construction are specified in Reference [2]. The thermal loads and applicable environmental conditions are summarized in Table 1.5.

[PROPRIETARY PER 10CFR2.390

]. The effective planar and axial thermal conductivities, density and specific heat capacity of fuel assembly are calculated in Reference [8]. [PROPRIETARY PER 10CFR2.390

].

4.0 Acceptance Criteria

The acceptance criteria are stated below:

1. The fuel cladding temperature for long term storage shall be limited to 400°C (752°F).
2. The fuel cladding temperature for short-term operations shall be limited to 400°C (752°F) for high burnup fuel and 570°C (1058°F) for moderate burnup fuel.
3. The fuel cladding temperature should be maintained below 570°C (1058°F) for off-normal and accident conditions.
4. The internal pressure of the system should remain within its design pressures for normal, off-normal, and accident conditions. The design pressure is specified in Chapter 4 of HI-STORE SAR [2].
5. The MPC and UMAX component materials should be maintained within their minimum and maximum temperature criteria under normal, off-normal, and accident conditions. Material temperature limits are provided in Section 4.4 of Chapter 4 of SAR [2].

5.0 Computer Codes and Calculation Files

ANSYS FLUENT version 14.5.7 is used to perform CFD calculations documented in this report. A list of computer files supporting the calculations is provided below:

[PROPRIETARY PER 10CFR2.390

].

6.0 Results and Conclusions

6.1 Maximum Temperatures

A steady state thermal analysis of the governing “thermal configuration” (meaning the combination of canister type, heat load pattern and fuel type that produces highest fuel cladding

temperature) was performed using the 3-D FLUENT model described in Section 2.0 to quantify the thermal margins under long term storage conditions. To summarize, thermal analyses of the MPC-37 with short fuel under heat load pattern 1 provided in Table 1.1 is performed.

The maximum spatial values of the computed temperatures of the fuel cladding, the fuel basket material, the divider shell, the closure lid concrete, the MPC lid, the MPC shell and the average air outlet temperature are summarized in Table 6.1. The following conclusions are reached from the solution data:

a. The PCT is well below the temperature limit set forth in ISG-11 Rev 3 [11].

b. The maximum temperatures of all MPC and VVM constituent parts are also below their respective limits set down in Section 4.4 of HI-STORE FSAR [2].

It is therefore concluded that the HI-STORM UMAX system provides a thermally acceptable storage environment for all eligible MPCs under all allowable heat load patterns. It should also be noted that the PCT and other component temperatures are well below the licensing basis results presented in Section 4.4 of generic HI-STORM UMAX FSAR [3]. This confirms the assertion made in Section 1.0 that the heat rejection performance of the canisters at the HI-STORE ISFSI has even greater margins to the regulator-prescribed limit than that established in [3].

6.2 Maximum MPC Cavity Pressures

The MPC from HI-STAR 190 is already filled with dry pressurized helium. During normal storage in UMAX VVM, the gas temperature within the MPC rises to its maximum operating basis temperature. The gas pressure inside the MPC will also increase with rising temperature. The pressure rise is determined using the ideal gas law. The MPC gas pressure is also subject to substantial pressure rise under hypothetical rupture of fuel rods.

The MPC maximum gas pressure is computed for a postulated release of fission product gases from fuel rods into this free space. The amount of fission gas and fill gas release due to rod rupture is exactly the same as that adopted in HI-STORM UMAX FSAR [3] and HI-STORM FW FSAR [4][*]. For these scenarios, the amounts of each of the release gas constituents in the MPC cavity are summed and the resulting total pressures determined from the ideal gas law. A concomitant effect of rod ruptures is the increased pressure and molecular weight of the cavity gases with enhanced rate of heat dissipation by internal helium convection and lower cavity temperatures. As these effects are substantial under large rod ruptures the 100% rod rupture accident is evaluated without any credit for increased heat dissipation under increased pressure and molecular weight of the cavity gases. Based on fission gases release fractions (NUREG 1536

[*] The actual values of fission and fill gas are provided in input/output files supporting Reference [12].

criteria), rods' net free volume and initial fill gas pressure, maximum gas pressures with 1% (normal), 10% (off-normal) and 100% (accident condition) rod rupture are given in Table 6.2. The maximum calculated gas pressures reported in Table 6.2 are all below the MPC internal design pressures for normal, off-normal and accident conditions specified in Chapter 4 of HI-STORE SAR [2]. It should also be noted that the MPC cavity pressure is also bounded by the licensing basis results presented in Section 4.4 of generic HI-STORM UMAX FSAR [3].

6.3 Differential Thermal Expansion

Since the component temperatures presented in Section 6.1 under long-term storage at HI-STORE are bounded by the temperatures presented for the licensing basis scenario in Section 4.4 of HI-STORM UMAX FSAR [3], the differential thermal expansions will also be bounded by those presented in Section 4.4 of the FSAR [3]. Therefore, it can be concluded that differential growth at HI-STORE is bounded by the design cold gaps.

The differential thermal expansion between basket, basket shims and MPC Shell is explicitly determined following the methodology provided in previously approved Holtec report [12] supporting UMAX FSAR [3]. This calculation is performed to support the basket periphery region hot gap adopted in the thermal evaluations presented in this report. The result from this evaluation is presented in Table 6.3. [PROPRIETARY PER 10CFR2.390

]. The overstated gap increases the heat resistance and is therefore conservative.

Additional basket design options using solid shim plates between the basket and basket shims are permitted as described in Chapter 1 of HI-STORM FW FSAR [4] and MPC drawing [13]. However, as also noted in Section 4.5 of HI-STORM FW FSAR [4], the most limiting thermal design scenario corresponds to the case when solid shim plates are not present. Therefore, based on those thermal evaluations, it can be concluded that the all design options provided in Chapter 1 of FW FSAR [4] are also acceptable and ensure safe integrity of fuel and MPC confinement boundary.

6.4 Effect of Sustained Wind

Thermal evaluation of sustained wind on HI-STORM UMAX cask arrays at HI-STORE CIS is bounded by that in Sub-section 4.4.9 of the HI-STORM UMAX FSAR [3] due to the following facts:

- The MPC and VVM component temperatures at HI-STORE are lower than that presented for the same MPC in Section 4.4 of the HI-STORM UMAX FSAR [3] under normal long-term storage condition.
- Wind effects at the site [2] are bounded by those evaluated in Sub-section 4.4.9 of the HI-STORM UMAX FSAR [3] due to UMAX evaluation under worst case combination of wind speed and direction.
- The airflow path design of UMAX Version C [1] is the same as UMAX Version B [15].

Therefore, the effect of winds summarized in Sub-section 4.4.9 of the HI-STORM UMAX FSAR [3] remains bounding and is adopted herein. The PCT and other component temperatures under sustained wind conditions are confirmed to remain below their respective temperature limits. Moreover, the MPC cavity pressure accounting for the effect of wind is also calculated and presented in Table 6.4. Results confirm that it is below the design pressure limit.

6.5 Thermal Evaluations of Sub-Design Basis Heat Load

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 conclusions drawn for design basis heat loads in Sections 6.1 and 6.2 remain applicable to sub-design basis heat loads also.

6.6 Fire Accident Condition

The HI-STORM UMAX fire accident is evaluated for the same conditions described in a separate Holtec report that evaluates the effects of VCT fire on HI-STORM FW System [14]. The fire evaluation for limiting MPC-37 with short fuel length stored in HI-STORM UMAX is bounded by the analysis reported in this report [14] due to the following facts:

- The initial PCT and component temperatures of MPC stored in HI-STORM UMAX at HI-STORE are lower than that of the same MPC in the HI-STORM FW system [4].
- HI-STORM UMAX system has much less surface directly exposed to fire than that of the above-ground system.

- Amount of combustibles that can cause a VCT fire is the same.

Consequently, the conclusion that PCT and components' temperatures and MPC pressure are below temperature and pressure limits for the Design Basis Fire event drawn in this fire report [14] will remain valid for the HI-STORM UMAX system.

6.7 Off-Normal and Accident Conditions

The predicted temperatures and MPC cavity pressures presented for all the off-normal and accident conditions in Section 4.6 of HI-STORM UMAX FSAR [3] are bounding due to the following reasons:

- As stated in Section 6.1 of this report, PCT and component temperatures at HI-STORE under long-term storage condition are bounded by those presented for generic UMAX system (Section 4.4 of FSAR [3]).
- As stated in Section 6.2 of this report, MPC cavity pressure at HI-STORE under long-term storage condition is bounded by that presented for MPCs in generic UMAX system (Section 4.4 of FSAR [3]).
- Design basis heat loads (Tables 1.1 and 1.2) at HI-STORE are well below the design basis maximum heat loads in generic FSAR [3].

Table 6.1: HI-STORM UMAX Normal Long-Term Storage Temperatures for MPC-37 with Short Fuel under Heat Load Pattern 1

Component	Temperature ºC (ºF)	Temperature Limit [3] ºC (ºF)
Fuel Cladding	323 (613)	400 (752)
MPC Basket	289 (552)	400 (752)
Basket Periphery	244 (471)	400 (752)
Aluminum Basket Shims	224 (435)	400 (752)
MPC Shell	189 (372)	343 (650)
MPC Baseplate[1]	151 (304)	400 (752)
MPC Lid[1]	187 (369)	400 (752)
Divider Shell	134 (273)	343 (650)
CEC Shell	44 (111)	343 (650)
Closure Lid Concrete[2]	69 (156)	177 (350)
Insulation	132 (270)	343 (650)
Average Air Outlet[3]	67 (153)	-

1 Maximum section average temperature reported.
2 Maximum section average temperature reported.
3 Section average temperature on the cross section area of outlet duct below the outlet vent screen reported. Reported herein for the option of temperature measurement surveillance of outlet duct air temperature as set forth in the Technical Specifications.

Table 6.2: Summary of MPC Cavity Pressure for Limiting MPC-37 with Short Fuel under Heat Load Pattern 1

<table>
<tr><th colspan="2">Condition</th><th>Gauge Pressure, psig[1]</th><th>MPC Cavity Average Temperature ºC (ºF)</th></tr>
<tr><td rowspan="2">Normal condition</td><td>no rods rupture</td><td>88.2</td><td rowspan="4">226 (439)</td></tr>
<tr><td>1% rods ruptured</td><td>89.2</td></tr>
<tr><td colspan="2">Off-normal (10% rods ruptured)</td><td>98.3</td></tr>
<tr><td colspan="2">Accident (100% rods ruptured)</td><td>188.7</td></tr>
<tr><td colspan="4">Note 1: The MPC pressure reported in this table do not include the effect of wind.</td></tr>
</table>

Table 6.3: Differential Thermal Expansion during Long-Term Storage for Limiting MPC-37 with Short Fuel under Heat Load Pattern 1

Gap Description	Minimum Gap [13], mm (inch)	Differential Expansion, mm (inch)
Fuel Basket-to-MPC Radial Gap	[PROPRIETARY PER 10CFR2.390]	[PROPRIETARY PER 10CFR2.390]

[1] The pressures reported in this table are computed assuming the helium backfill pressure is at its upper bound limit (Table 1.3).

Table 6.4: Summary of MPC Cavity Pressure for Limiting MPC-37 with Short Fuel under Heat Load Pattern 1 under Sustained Wind

Condition		**Gauge Pressure, psig**[1]	**MPC Cavity Average Temperature ºC (ºF)**
Normal condition	no rods rupture	91.5	242 (468)
	1% rods ruptured	92.5	
Off-normal (10% rods ruptured)		101.8	
Accident (100% rods ruptured)		195.0	
Note 1: The MPC pressure reported in this table includes the effect of wind.			

[1] The pressures reported in this table are computed assuming the helium backfill pressure is at its upper bound limit (Table 1.3).

7.0 References

[1] [PROPRIETARY PER 10CFR2.390].

[2] HI-STORE SAR, Holtec Report HI-2167374, Revision 0.

[3] HI-STORM UMAX FSAR, Holtec Report HI-2115090, Latest Revision.

[4] HI-STORM FW FSAR, Holtec Report HI-2114830, Latest Revision.

[5] HI-STAR 190 SAR, Holtec Report HI-2146214, Latest Revision.

[6] NUREG-1567, Latest Revision.

[7] NUREG-1536, Latest Revision.

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

[9] Holtec Engineering Change Order (ECO) 5021-26, Revision 0.

[10] ANSYS FLUENT Computational Fluid Dynamics Software.

[11] Interim Staff Guidance, ISG-11, Revision 3.

[12] "Thermal-Hydraulic Evaluation of HI-STORM UMAX", Holtec Report HI-2114807, Latest Revision.

[13] [PROPRIETARY PER 10CFR2.390].

[14] "Evaluation of Effects of Tracked VCT Fire on HI-STORM FW System", Holtec Report HI-2135677, Revision 5.

[15] [PROPRIETARY PER 10CFR2.390].

[16] Holtec Engineering Change Order (ECO) 5021-24, Revision 0.