Pacific Gas and Electric Company®

James R. Becker
Site Vice President

Diablo Canyon Power Plant
Mail Code 104/5/601
P. O. Box 56
Avila Beach, CA 93424

805.545.3462
Internal: 691.3462
Fax: 805.545.6445

February 20, 2009

PG&E Letter DIL-09-004

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

Materials License No. SNM-2511, Docket No. 72-26
Diablo Canyon Independent Spent Fuel Storage Installation
Submittal of Holtec Nonproprietary Report

Dear Commissioners and Staff:

On April 7, 2008, Pacific Gas and Electric Company (PG&E) submitted an application for amendment to Materials License SNM-2511, Docket No. 72-26, for the Diablo Canyon (DC) Independent Spent Fuel Storage Installation (ISFSI). The application for amendment included a proposal to eliminate DC ISFSI Technical Specification 3.1.4, "Spent Fuel Storage Cask (SFSC) Time Limitation in Cask Transfer Facility (CTF)," based on an analysis of the thermal performance of the DC ISFSI site-specific HI-STORM 100 system, which shows that there is no need for a required time limitation while in the CTF.

A nonproprietary version of Holtec International Report HI-2053376, "Thermal-Hydraulic Analyses for Diablo Canyon Site-Specific HI-STORM System Design," Revision 5, is enclosed for use by the NRC staff in its review of the application for amendment.

If you have any questions regarding this matter, please contact Mr. L. Jearl Strickland at (805) 545-6080.

Sincerely,

James R. Becker

gwh
Enclosure
cc: Diablo Distribution
cc/enc: Shana R. Helton, NRC Project Manager, Division of Spent Fuel Storage and Transportation
Michael S. Peck, NRC Senior Resident Inspector

Document Components:
001PG&E Letter DIL-004.pdf 964,000 bytes (approximately)

HOLTEC INTERNATIONAL

Holtec Center, 555 Lincoln Drive West, Marlton, NJ 08053
Telephone (856) 797- 0900
Fax (856) 797 - 0909

THERMAL-HYDRAULIC ANALYSES FOR DIABLO CANYON SITE-SPECIFIC HI-STORM SYSTEM DESIGN

FOR

PG&E

Holtec Report No: HI-2053376

Holtec Project No: 1073

Report Class : SAFETY RELATED

HOLTEC INTERNATIONAL

DOCUMENT ISSUANCE AND REVISION STATUS[1]

DOCUMENT NAME: THERMAL HYDRAULIC ANALYSES FOR DIABLO CANYON SITE-SPECIFIC HI-STORM SYSTEM DESIGN

DOCUMENT NO.:	2053376	CATEGORY: ☐	GENERIC
PROJECT NO.:	1073	☒	PROJECT SPECIFIC

Rev. No.[2]	Date Approved	Author's Initials	VIR #	Rev. No.	Date Approved	Author's Initials	VIR #
5	2/5/08	ER	65045				

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

☒ Nonproprietary ☐ Holtec Proprietary ☐ Privileged Intellectual Property (PIP)

Documents labeled "Privileged Intellectual Property" contain extremely valuable intellectual/commercial property of Holtec International. They cannot be released to external organizations or entities without explicit approval of a company corporate officer. The recipient of Holtec's proprietary or Privileged Intellectual Property document bears full and undivided responsibility to safeguard it against loss or duplication.

Notes

1. This document has been subjected to review, verification and approval process set forth in the Holtec Quality Assurance Procedures Manual. Password controlled signatures of Holtec personnel who participated in the preparation, review, and QA validation of this document are saved on the company's network. The Validation Identifier Record (VIR) number is a random number that is generated by the computer after the specific revision of this document has undergone the required review and approval process, and the appropriate Holtec personnel have recorded their password-controlled electronic concurrence to the document.

2. A revision to this document will be ordered by the Project Manager and carried out if any of its contents 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: Original Revision.

Revision 1: Updated report to reflect design changes. The changes were replacement of the spacer beams on the underside of the MPC lid with a new, back-to-back c-channel design and elimination of the channels on the HI-STORM overpack inner shell in favor of guide plates. Revised portions of the report are marked with vertical bars in the right margin.

Revision 2: Updated report to recalculate the MPC internal pressure with the following changes: (1) the MPC internal free volume is calculated with worst-case combination of manufacturing tolerances (i.e., volume of contents maximized, volume of enclosure vessel minimized), and (2) the maximum backfill pressure assumed. In addition, all references to other documents are updated to reflect the latest revisions. Revised portions of the main body of the report are marked with vertical bars in the right margin.

Revision 3: Included MPC internal pressure calculations spreadsheet (mpc_pres.xls listed in Section 5.1.1) in new Appendix B. The file has been revised to add a header and footer only. No calculations in appendix B have been changed. Revised long-term normal storage condition (MPC in HI-STORM) calculations to reflect fuel age dependent temperature limits and decay heat loads. Portions of the main body of the report revised for these changes are marked with vertical bars in the right margin.

Revision 4: Incorporated editorial changes throughout the report in response to PG&E comments. No calculations have been changed. Revised portions of the report are marked with vertical bars in the right margin.

Revision 5: Added additional calculations to Section 5.1.6 (and new Table 10) to address effect of MPC internal pressure rise, due to 100% rod rupture, on MPC temperatures. Added additional calculations to Section 5.1.7 to address effect of 100% inlet vent blockage on MPC internal pressure. Revised portions of the report are marked with vertical bars in the right margin.

PREFACE

This work product has been labeled a *safety-significant* document in Holtec's QA 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 has been 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 a document of this genre must fulfill 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 must be drawn from referencable sources. Any assumed input data is so identified.

- All significant assumptions, as applicable, are stated.

- The analysis methodology, if utilized, is consistent with the physics of the problem.

- Any computer code and its specific versions that may be used in this work has been 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 this document is understandable to a reader with the requisite academic training and experience in the underlying technical disciplines.

Once a safety significant document produced under the company's QA System 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), revisions to Holtec *safety-significant* documents to amend grammar, to improve diction, or to add trivial calculations are made only if such editorial changes are warranted to prevent erroneous conclusions from being inferred by the reader. In other words, the focus in the preparation of this document is to ensure accuracy of the technical content rather than the cosmetics of presentation.

In accordance with the foregoing, this Calculation Package has been prepared pursuant to the provisions 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.

1.0 INTRODUCTION

The HI-STORM System consists of three major cask components: a multipurpose canister (MPC), a storage overpack (HI-STORM) and a transfer cask (HI-TRAC). Pacific Gas and Electric (PG&E) intends to use the HI-STORM System at an independent spent fuel storage installation (ISFSI) at the Diablo Canyon nuclear power plant site (DC ISFSI). The purpose and function of each of these major HI-STORM System components at the DC ISFSI is described in a site-specific 10 CFR 72 (Part 72) license [A] and a supporting site-specific Safety Analysis Report (SAR) [B].

Modifications to existing generic Holtec HI-STORM System components designs have been proposed to tailor them for most efficient use at the DC ISFSI. It is proposed to reduce the height of the MPC and the HI-TRAC by approximately 9 inches. It is also proposed to modify a HI-STORM design called the 100S [C] to make it compatible with the DC ISFSI, which anchors the cask to the ISFSI pad as described in the DC ISFSI SAR [B]. These proposed modifications have the potential to alter the thermal-hydraulic performance of the system.

The existing DC ISFSI license and SAR discusses the thermal performance of the HI-STORM System through reference to Holtec generic (i.e., not DC ISFSI site-specific) licensing documents [D], except for MPC internal pressure evaluations that are specific to the IFBA fuel in use at Diablo Canyon [K]. As the proposed modifications may cause the thermal performance of the HI-STORM Systems at the DC ISFSI to differ from that of Holtec's generic design, thermal-hydraulic analyses must be performed to demonstrate that the proposed modified HI-STORM System will continue to satisfy all license requirements related to temperature and internal pressure. These analyses are documented in this report.

2.0 METHODOLOGY AND ASSUMPTIONS

The methodologies used in all of the analyses documented in this report are identical to those described in the DC ISFSI SAR [B], the Holtec generic licensing documents [D], and the IFBA fuel pressure calculations [K]. *No new methodologies are used in performing any of the calculations described herein.* An overview of the methodology is as follows:

1. A two-dimensional axisymmetric computational fluid dynamics (CFD) model of the airflow through the proposed modified HI-STORM Overpack is constructed. The flow zones in the model consist of the overpack inlet and outlet vents (modeled as axisymmetric porous zones with equivalent hydraulic resistance properties) and the annular space between the MPC-32 outer shell and the overpack inner shell. The solid zones in the model include the MPC shell as well as all the overpack steel and concrete. The MPC decay heat is applied as a uniform flux on the inner surface of the MPC shell, and the buoyancy-driven airflow through the flow passages computed. By applying the entire decay heat to the MPC shell, computed temperatures of this component will be higher than actual. The results of this computation are the airflow rate through the overpack and the overpack temperature field.

2. The MPC shell temperature profile is extracted from the CFD model of the overpack. As stated in Step 1, applying the entire decay heat to the MPC shell, computed temperatures of this component will be higher than actual. A linear temperature profile, lowest near the MPC bottom and highest near the MPC top, is developed that bounds the actual profile at all points. This bounding linear profile, called an enveloping linear variation or ELV, will be used as a boundary condition in subsequent MPC thermal modeling.

3. A two-dimensional axisymmetric CFD model of the proposed modified MPC-32 is constructed. The fuel basket is modeled as a two-region (inner and outer) cylindrical porous medium with an effective thermal conductivity and effective hydraulic resistance properties. The MPC shell, lid and baseplate are included in the model, as is the pressurized MPC backfill helium. The fuel decay heat is applied as a volumetric heat generation to the fuel basket regions in the heated (active fuel) length, and includes axial peaking effects. The ELV is applied to the MPC shell and the MPC temperature field is computed.

More detailed descriptions on the analysis methodology, including the calculation of effective properties for the overpack inlet and outlet vents and the MPC fuel basket porous zones, can be found in Subsections 4.4.1.1.2 through 4.4.1.1.9 of the Holtec generic licensing documents [D].

To the extent possible the analysis models previously used [D and K] are continued to be used, albeit with dimensional and materials differences necessary to reflect the proposed modifications. Only model changes that are necessary to reflect the proposed modifications within the bounds of the existing methodologies were made. *No unnecessary changes to the analysis models were made.*

All of the assumptions described in the DC ISFSI SAR [B], the Holtec generic licensing documents [D], and the IFBA fuel pressure calculations [K] are applied without modification to the analyses documented in this report. These previously applied assumptions are, therefore, not revisited in this document.

One additional assumption is also applied. This additional assumption is an assumed boundary condition used in an evaluation of the loaded HI-STORM in the cask transfer facility (CTF), which is not described in either of these documents. The CTF is a steel cylinder backed by concrete. PROPRIETARY INFORMATION REMOVED

3.0 ACCEPTANCE CRITERIA

The thermal-hydraulic performance of the proposed modified HI-STORM System must continue to satisfy all component temperature and MPC internal pressure requirements of the DC ISFSI SAR [B] and the Holtec generic licensing documents [D].

4.0 INPUT DATA

The analyses documented in this report use the following types of input data: material properties, applied loads, specified boundary conditions and component geometries. Applied loads include decay heat loads (28.74 kW at 5 years cooling to 24.68 kW at 15 years cooling and solar heat loads (see Subsection 4.4.1.1.8 in the Holtec generic licensing documents [D]) as well as the quantities of backfill gas and gaseous fission products contained within the MPC. Boundary conditions include ambient temperatures (80ºF normal, 100ºF off-normal and 125ºF extreme hot) and exposed surface heat transfer coefficients.

The material properties, applied loads and boundary conditions used in all of the analyses documented in this report are identical to those described in the DC ISFSI SAR [B], the Holtec generic licensing documents [D], and the IFBA fuel pressure calculations [K]. With respect to the MPC internal pressure, PROPRIETARY INFORMATION REMOVED

All other material properties, applied loads and boundary conditions are, therefore, not revisited in this document. *Except as just described for the quantity of backfill gas used in MPC internal pressure calculations, no new material properties, applied loads and boundary conditions are used in performing any of the calculations described herein.*

The proposed modifications, however, do require the use of some different component geometries necessary to reflect physical changes to the system components. Licensing drawings for the proposed modified HI-STORM System components [E through H] provide all of the component dimensional details. Table 1 presents a listing of the *primary changes*, made to the generic Holtec component designs to yield the proposed modified designs, which can affect thermal performance.

5.0 CALCULATIONS AND RESULTS

5.1 Storage in HI-STORM Overpack

The DC ISFSI SAR [B], the Holtec generic licensing documents [D], and the IFBA fuel pressure calculations [K] discuss a total of nine normal, off-normal and accident thermal and internal pressure conditions with the MPC in the HI-STORM overpack. Each of these conditions is addressed for the proposed modified designs, along with an additional condition of the loaded HI-STORM in the CTF for an extended period of time, in the following subsections. Before proceeding to the specific conditions, however, the changes to the loaded HI-STORM analysis model are discussed.

The evaluations of the MPC in a HI-STORM overpack are performed using a 2-D axisymmetric computational fluid dynamics (CFD) model. This model is created and evaluated using the commercially available CFD program FLUENT [I]. As stated in Section 2.0, the existing FLUENT model was modified only to the extent necessary to reflect the proposed modifications. An Excel worksheet was used to identify the changes needed to the cask dimensions in the model. In addition, for the evaluation of the loaded HI-STORM in the CTF the diameter of the hypothetical reflecting cylinder that surrounds the cask was reduced to match the CTF cylinder inner diameter.

The proposed changes also required changes to several user-specified model inputs. The change in the outlet vent geometry and the substitution of perforated plate for the wire mesh in the debris screens necessitated recalculating the inlet and outlet vent hydraulic resistance parameters. The elimination of the annulus channels would permit increasing the MPC-to-overpack annular gap to the actual physical gap, however a slightly conservative lower gap size was used. The change in the size of the gap between the top of the MPC closure lid and the bottom of the overpack lid led to a change in the equivalent conductivity of this gap.

The following computer files were generated in the course of these model modifications:

```
 Directory of G:\Projects\1073\REPORTS\HI-2053376

03/21/2005  01:03p              23,040 geometry.xls

 Directory of G:\Projects\1073\REPORTS\HI-2053376\ovp

03/21/2005  04:36p              80,623 LOVERD-S.mcd

 Directory of G:\Projects\1073\REPORTS\HI-2053376\mpc

03/09/2005  03:12p               8,216 Kairgap.mcd
```

Before proceeding to the specific conditions, one additional facet of the analysis must be addressed. The DC ISFSI license [A] and SAR [B] allow the use of three different MPC designs: MPC-24, MPC-24E and MPC-32. The thermal analysis [D] indicates that, of these three designs, the MPC-32 has the highest design-basis decay heat load and always yields the highest cask system component and contents temperatures and the highest MPC internal pressures. As such, only the MPC-32 is being evaluated herein. The MPC-24 and MPC-24E thermal performance will be bounded by that of the MPC-32 under all conditions.

5.1.1 Normal Long-Term Storage

Normal long-term storage is a steady-state condition that consists of the design-basis maximum decay heat load (as a function of fuel age), the annual average ambient temperature and maximum insolation (solar heating). The computations for this condition have been redone using the modified FLUENT CFD analysis model. The following computer files were generated in the course of these computations.

```
 Directory of G:\Projects\1073\REPORTS\HI-2053376\ovp

03/21/2005  01:55p            270,597 OVP_5YR.CAS
03/21/2005  01:55p            695,872 OVP_5YR.DAT
03/21/2005  01:04p          1,410,691 OVP_D.RAD
09/28/2007  11:01a            270,597 OVP_6YR.CAS
09/28/2007  11:01a            685,872 OVP_6YR.CAS
09/28/2007  11:26a            270,597 OVP_7YR.CAS
09/28/2007  11:26a            685,872 OVP_7YR.CAS
09/28/2007  11:36a            270,597 OVP_10YR.CAS
09/28/2007  11:36a            685,872 OVP_10YR.CAS
09/28/2007  11:53a            270,597 OVP_15YR.CAS
09/28/2007  11:53a            685,872 OVP_15YR.CAS
03/21/2005  01:56p              2,155 Tmpc5yr.txt
09/28/2007  11:00a              2,155 Tmpc6yr.txt
09/28/2007  11:26a              2,155 Tmpc7yr.txt
09/28/2007  11:36a              2,155 Tmpc10yr.txt
09/28/2007  11:53a              2,155 Tmpc15yr.txt
09/28/2007  12:09p             52,224 elv.xls

 Directory of G:\Projects\1073\REPORTS\HI-2053376\mpc

03/14/2005  04:11p            264,072 M32_5YR.CAS
03/14/2005  04:11p            721,897 M32_5YR.DAT
03/09/2005  02:02p            440,131 M32_D.RAD
09/28/2007  12:59p            264,082 M32_6YR.CAS
09/28/2007  12:59p            721,897 M32_6YR.DAT
09/28/2007  01:03p            264,082 M32_7YR.CAS
09/28/2007  01:03p            721,897 M32_7YR.DAT
09/28/2007  01:05p            264,082 M32_10YR.CAS
09/28/2007  01:05p            721,897 M32_10YR.DAT
09/28/2007  01:11p            264,082 M32_15YR.CAS
09/28/2007  01:11p            721,897 M32_15YR.DAT
08/10/2000  03:33p                580 P28P74KW.LOG
09/28/2007  10:20a                580 P27P95KW.LOG
09/28/2007  10:21a                580 P25P79KW.LOG
09/28/2007  10:22a                580 P25P26KW.LOG
09/28/2007  10:22a                580 P24P68KW.LOG

Directory of G:\Projects\1073\REPORTS\HI-2053376

03/23/2005  01:37p             12,374 FBtemp.mcd
05/08/2006  10:32a             12,032 vol_free.mcd
08/24/2007  03:08p             20,992 mpc_pres.xls
```

The DC ISFSI license [A] and SAR [B] permit two decay heat loading schemes, called uniform and regionalized loading, to be used at the DC ISFSI. In uniform loading, all fuel assemblies have the same allowable decay heat generation rate. Regionalized loading allows a higher assembly heat generation rate for fuel assemblies in the interior cells of the fuel basket, but requires a lower heat generation rate for assemblies on the fuel basket periphery and a lower total decay heat load. The existing thermal analysis [D] indicates that uniform loading always yields the highest cask system component and contents temperatures and the highest MPC internal pressures. As such, only uniform loading is being evaluated herein. The regionalized loading thermal performance will be bounded by that of uniform loading under all conditions.

The results of this evaluation are presented in Tables 2 and 9.

5.1.2 Off-Normal Hot Environmental Temperature

The off-normal hot environmental temperature condition consists of the design-basis maximum decay heat load with a 100°F ambient temperature and maximum insolation. This condition is evaluated by adding the difference between the 100°F ambient and the annual average ambient temperature to the temperature results of the calculations in Subsection 5.1.1.

The results of this evaluation are presented in Tables 3 and 9.

5.1.3 Off-Normal Pressure

The off-normal pressure condition is the coincident action of the off-normal hot environmental temperature condition discussed in Subsection 5.1.2 and the rupture of 10% fuel rods in the MPC. This condition is evaluated by using the MPC helium bulk temperature from the calculations in Subsection 5.1.2 and recalculating the MPC internal pressure with the additional gases released from the ruptured fuel rods. These calculations are performed using the Excel worksheet listed in Subsection 5.1.1.

The results of this evaluation are presented in Table 9.

5.1.4 Partial Blockage of Air Inlets (Off-Normal)

The partial blockage of air inlets off-normal condition is actually two conditions, consisting of the blockage of one-half and three-quarters of the air inlets. The computations for this condition have been redone using the modified FLUENT CFD analysis model. Along with the Mathcad and Excel worksheets listed in Subsection 5.1.1, the following computer files were generated in the course of these computations.

```
 Directory of G:\Projects\1073\REPORTS\HI-2053376\ovp

03/21/2005  04:31p            270,597 OVP_2DB.CAS
03/21/2005  04:31p            695,872 OVP_2DB.DAT
03/21/2005  04:57p            270,597 OVP_3DB.CAS
03/21/2005  04:57p            695,872 OVP_3DB.DAT
03/21/2005  04:31p              2,155 Tmpc-2db.txt
03/21/2005  04:57p              2,155 Tmpc-3db.txt

 Directory of G:\Projects\1073\REPORTS\HI-2053376\mpc

03/21/2005  05:06p            262,382 M32_2DB.CAS
03/21/2005  05:06p            721,897 M32_2DB.DAT
```

```
03/21/2005  05:10p             262,382 M32_3DB.CAS
03/21/2005  05:10p             721,897 M32_3DB.DAT
```

The results of these evaluations are presented in Tables 4 and 9.

5.1.5 Fire (Accident)

This accident condition consists of a 50-gallon flammable liquid fire that completely engulfs the HI-STORM. This event has previously [D] been evaluated in a two-step process. The effect of the fire on the HI-STORM overpack is evaluated in the first step and the effect of the fire on the MPC is evaluated in the second step.

The existing evaluation of the fire effect on the HI-STORM overpack [D] determines the amount of concrete that exceeds its allowable temperature limit. This evaluation neglects end effects and is, therefore, independent of the overpack height. The proposed modifications do not change the overpack diameter or thickness, so the existing evaluation will continue to bound the proposed modified HI-STORM overpack and is not revisited herein.

The evaluation of the fire effect on the MPC [D] uses a lumped capacitance model that combines the thermal capacity of the MPC and its contents. The weight of an empty MPC-32 with the proposed modifications is approximately 32,000 pounds, which is lower than the 39,000 pounds previously evaluated [D]. Thus, this calculation must be redone.

Using a conservative empty MPC weight of 30,000 pounds along with the net heat capacity of stainless steel of 0.12 Btu/(lb×°F) [D], the thermal capacity of the empty MPC is 3600 Btu/°F. Combining this with the previously calculated fuel assemblies thermal capacity of 2240 Btu/°F, the total loaded MPC thermal capacity is 4840 Btu/°F. For a 28.74 kW (98090 Btu/hr) decay heat load and a fire duration of 0.0604 hours, the MPC temperature rise during the fire is calculated as:

$$\Delta T = \frac{98090\frac{Btu}{hr} \times 0.0604\,hr}{4840\frac{Btu}{{}^\circ F}} = 1.224^\circ F$$

This small temperature rise is bounded by the off-normal hot environmental temperature condition evaluated in Subsection 5.1.2.

5.1.6 100% Fuel Rod Rupture (Accident)

The 100% fuel rod rupture accident condition is the rupture of 100% fuel rods in the MPC. This condition is evaluated by using the MPC helium bulk temperature from the calculations in Subsection 5.1.1 and recalculating the MPC internal pressure with the additional gases released from the ruptured fuel rods. These calculations are performed using the Excel worksheet listed in Subsection 5.1.1.

The results of this evaluation are presented in Table 9.

PROPRIETARY INFORMATION REMOVED

5.1.7 100% Blockage of Air Inlets (Accident)

The 100% blockage of air inlets accident condition consists of the blockage of all of the air inlets. A previous evaluation [D] of this event was performing using a two-step process where a decay heat load of 22.25 kW was evaluated with the thermosiphon natural convection mechanism within the MPC suppressed, and the effects of the thermosiphon mechanism qualitatively considered to apply the computed allowable blockage time up to 29 kW. This previous evaluation also used fuel basket density and heat capacity values approximately 50% less than actual, which will continue to bound the shortened MPC and fuel basket. None of the proposed modifications would invalidate the previous qualitative consideration of the thermosiphon mechanism, so the existing evaluation of temperatures within the MPC remains bounding and is not revisited herein.

Unlike the evaluation of temperatures within the MPC, the existing evaluation of MPC internal pressures is not bounding and must be re-performed for the shortened MPC. The formula for this evaluation is obtained from Section 11.2.13.2 of the Holtec generic licensing documents [D] as:

$$P_2 = \frac{P_1 T_2}{T_1}$$

where P_1 is the normal condition MPC absolute pressure, T_2 is the MPC average gas temperature during the 100% blockage event, and T_1 is the normal condition MPC average gas temperature. T_2 is computed as follows:

PROPRIETARY INFORMATION REMOVED

This value is below the accident condition pressure limit of 214.7 psia (see Table 9).

5.1.8 Burial Under Debris (Accident)

This accident condition consists of the complete burial of the HI-STORM under an indeterminate material. A lumped capacitance model that combines the thermal capacity of the MPC and the HI-STORM has been used previously [D] to evaluate this event. The previous evaluation considers a 300,000 lb total mass for the HI-STORM System. The proposed modifications would not reduce the thermal capacity of the system below this previously evaluated value, so the existing evaluation remains bounding and is not revisited herein.

5.1.9 Extreme Environmental Temperature (Accident)

The extreme environmental temperature accident condition consists of the design-basis maximum decay heat load with a 125°F ambient temperature and maximum insolation. This condition is evaluated by adding the difference between the 125°F ambient and the annual average ambient temperature to the temperature results of the calculations in Subsection 5.1.1.

The results of this evaluation are presented in Tables 5 and 9.

5.1.10 HI-STORM in CTF (Off-Normal)

This off-normal condition consists of a loaded HI-STORM overpack that cannot be removed from the CTF because of a failure of the equipment that lifts the HI-STORM. Under such a condition, the flow of air to the bottom inlet vents would be restricted. This condition has been evaluated using the modified FLUENT CFD analysis model. Along with the Mathcad and Excel worksheets listed in Subsection 5.1.1, the following computer files were generated in the course of these computations.

```
 Directory of G:\Projects\1073\REPORTS\HI-2053376\ovp

03/23/2005  10:01a           270,597 OVP_CTF.CAS
03/23/2005  10:01a           695,872 OVP_CTF.DAT
03/23/2005  09:51a         1,149,331 OVP_CTF.RAD
03/23/2005  10:02a             2,155 Tmpc-ctf.txt

 Directory of G:\Projects\1073\REPORTS\HI-2053376\mpc

03/23/2005  10:17a           262,382 M32_CTF.CAS
03/23/2005  10:17a           721,897 M32_CTF.DAT
```

The results of this evaluation are presented in Tables 6 and 9.

5.2 On-Site Handling in HI-TRAC Transfer Cask

The DC ISFSI SAR [B] and the Holtec generic licensing documents [D] discuss a total of four normal and accident thermal conditions with the MPC in the HI-TRAC transfer cask. Each of these conditions is addressed for the proposed modified designs in the following subsections. Before proceeding to the specific conditions, however, the changes to the loaded HI-TRAC analysis model are discussed.

The evaluations of the MPC in a HI-TRAC transfer cask are performed using a 2-D axisymmetric computational fluid dynamics (CFD) model. This model is created and evaluated using the commercially available CFD program FLUENT [I]. As stated in Section 2.0, the existing FLUENT model was modified only to the extent necessary to reflect the proposed modifications. The same Excel worksheet listed in Section 5.1 was used to identify the changes needed to the cask dimensions in the model.

The proposed changes also required changes to one user-specified model input, namely the water jacket effective thermal conductivity. The following computer file was generated in the course of this model modification:

```
 Directory of G:\Projects\1073\REPORTS\HI-2053376\trac

03/22/2005  10:34a            11,740 WJ-keff.mcd
```

Before proceeding to the specific conditions, one additional facet of the analysis must be addressed. The DC ISFSI license [A] and SAR [B] allow the use of three different MPC designs: MPC-24, MPC-24E and MPC-32. The existing thermal analysis [D] indicates that, of these three designs, the MPC-32 has the highest design-basis decay heat load and always yields the highest cask system component and contents temperatures and the highest MPC internal pressures. As such, only the MPC-32 is being evaluated herein. The MPC-24 and MPC-24E thermal performance will be bounded by that of the MPC-32 under all conditions.

5.2.1 Normal On-Site Handling

Normal on-site handling is a steady-state condition that consists of the design-basis maximum decay heat load, the annual average ambient temperature and maximum insolation (solar heating). The computations for this condition have been redone using the modified FLUENT CFD analysis model. Along with the Mathcad and Excel worksheets listed in Subsection 5.1.1, the following computer files were generated in the course of these computations:

```
 Directory of G:\Projects\1073\REPORTS\HI-2053376\trac

03/22/2005  10:40a            249,344 TRAC_D.CAS
03/22/2005  10:40a            522,145 TRAC_D.DAT
03/21/2005  11:32a            990,331 trac_D.RAD
07/28/2000  02:35p                580 B28P74KW.LOG
03/22/2005  10:53a              1,264 42temp.txt
03/21/2005  02:41p              1,265 42volu.txt
03/22/2005  10:53a              1,264 43temp.txt
03/21/2005  02:41p              1,265 43volu.txt
03/22/2005  10:53a              1,264 44temp.txt
03/21/2005  02:41p              1,265 44volu.txt
03/22/2005  10:53a              1,264 45temp.txt
03/21/2005  02:41p              1,265 45volu.txt
03/22/2005  11:20a             24,576 Twj-bulk.xls
```

The results of this evaluation are presented in Tables 7 and 9.

5.2.2 HI-TRAC Transfer Cask Handling Accident

This accident condition, consisting of a drop of the loaded HI-TRAC, has the potential to breach the water jacket on the HI-TRAC transfer cask. While the primary purpose of the water is neutron shielding, it also assists in transferring heat from the interior of the transfer cask to the transfer cask surface. A breach in the water jacket would result in loss of water, which would be replaced by lower thermal conductivity air. The computations for this condition have been redone using the modified FLUENT CFD analysis model. Along with the Mathcad and Excel worksheets listed in Subsection 5.1.1, the following computer files were generated in the course of these computations:

```
 Directory of G:\Projects\1073\REPORTS\HI-2053376\trac

03/22/2005  11:07a            249,344 TRAC_WJ.CAS
03/22/2005  11:07a            522,145 TRAC_WJ.DAT
```

The results of this evaluation are presented in Tables 8 and 9.

5.2.3 Fire (Accident)

This accident condition consists of a 50-gallon flammable liquid fire that completely engulfs the HI-TRAC transfer cask. A lumped capacitance model that combines the thermal capacity of the

MPC and the HI-TRAC has been used previously [D] to evaluate this event. The previous evaluation, however, considers a 100-ton HI-TRAC instead of the 125-ton HI-TRAC to be used at the DC ISFSI. The proposed modifications would not reduce the thermal capacity of the 125-ton HI-TRAC below that of a 100-ton HI-TRAC, so the existing evaluation remains bounding and is not revisited herein.

5.2.4 Tornado (Accident)

During a tornado, it is possible for a tornado-driven missile to breach the water jacket on the HI-TRAC transfer cask. From a thermal-hydraulic performance perspective, this is identical to the condition evaluated in Subsection 5.2.2.

6.0 CONCLUSIONS

The results of the evaluations described in Section 5.0 indicate that the thermal-hydraulic performance of the proposed modified HI-STORM System components continues to satisfy all applicable component temperature and MPC internal pressure limits. It can therefore be concluded that the proposed modifications are acceptable from a thermal-hydraulic perspective.

Additionally, the proposed modifications have been found acceptable, from a thermal-hydraulic perspective, without needing to change any existing loads, boundary conditions or analysis methodologies prescribed by the DC ISFSI license [A] and SAR [B]. As such it can also be concluded, again from a thermal-hydraulic perspective, that the proposed modifications can be instituted via the 10 CFR 72.48 design change process [J].

7.0 REFERENCES

[A] Materials License No. SNM-2511 Amendment 0, Docket 72-26, dated 22 March 2004.

[B] "Diablo Canyon Independent Spent Fuel Storage Installation Final Safety Analysis Report," Docket 72-26, Revision 0, 0 June 2004.

[C] "HI-STORM 100S Licensing Drawing," Holtec Drawing 3669, Revision 13.

[D] HI-STORM 100 System FSAR, Revision 0 as modified by LAR 1014-1, Attachment 2 to Holtec Document ID 5014442.

[E] "MPC-32 Fuel Basket Licensing Drawing," Holtec Drawing 4458, Revision 2.

[F] "MPC-32 Enclosure Vessel Licensing Drawing," Holtec Drawing 4459, Revision 2.

[G] "HI-TRAC 125D Licensing Drawing," Holtec Drawing 4460, Revision 4.

[H] "HI-STORM 100SA Licensing Drawing," Holtec Drawing 4461, Revision 4.

[I] "Documentation and Validation of FLUENT Versions 4.48 and 4.56," Holtec Report HI-981921, Revision 1.

[J] United States Code of Federal Regulations, Title 10, Part 72, Section 48.

[K] "Evaluation of IFBA Fuel Storage in the HI-STORM System," Holtec Position Paper DS-265, Revision 1.

Table 1

PRIMARY CHANGES MADE TO GENERIC HOLTEC COMPONENT DESIGNS
TO YIELD THE PROPOSED MODIFIED DESIGNS

MPC	
Overall Height	Reduced by 9 inches
Internal Cavity Height	Reduced by 9 inches
Fuel Basket Height	Reduced by 14 inches
Closure Lid	1-7/8” × 5” C-channels mounted on bottom surface
HI-STORM Overpack	
Overall Height	Reduced by 1 3/4 inches
Internal Cavity Height	Reduced by 1/2 inch
Outlet Duct Width	Increased by 1/2 inch
Outlet Duct Height	Reduced by 1 1/4 inch
Duct Debris Screens	Changed from screen to perforated plate
Lid Shield (Concrete) Diameter	Increased by 42 inches
Annulus Channels	Replaced by small guide plates
HI-TRAC Transfer Cask	
Overall Height	Reduced by 9 inches
Water Jacket Radial Thickness	Increased by 0.389 inches
Number of Water Jacket Ribs	Reduced from 28 to 8
Thickness of Water Jacket Ribs	Increased from 1/2 inch to 2 inch

Table 2

TEMPERATURE RESULTS FOR LONG-TERM NORMAL STORAGE CONDITION

Fuel Cladding			
Fuel Age [yr]	**MPC Decay Heat Load [kW]**	**Computed Temperature [°F]**	**Allowable Temperature [°F]**
5	28.74	**	691
6	27.95	**	676
7	25.79	**	635
10	25.26	**	625
15	24.68	**	614

Component	Computed Temperature [°F]	Allowable Temperature [°F]
MPC Basket	**	725
Basket Periphery	**	725
MPC Shell	**	450
MPC Helium Bulk	**	N/A
Inner Shell	**	350
Outer Shell	**	350
Lid Bottom Plate	**	350
Lid Top Plate	**	350
MPC Pedestal Plate	**	350
Baseplate	**	350
Radial Shield	**	200
Air Outlet	**	N/A

Table 3

TEMPERATURE RESULTS FOR OFF-NORMAL HOT ENVIRONMENTAL TEMPERATURE CONDITION

Component	Computed Temperature [°F]	Allowable Temperature [°F]
Fuel Cladding	**	1058
MPC Basket	**	950
Basket Periphery	**	950
MPC Shell	**	775
MPC Helium Bulk	**	N/A
Inner Shell	**	350 (see Note 1)
Outer Shell	**	350 (see Note 1)
Lid Bottom Plate	**	400
Lid Top Plate	**	550
MPC Pedestal Plate	**	400
Baseplate	**	400
Radial Shield	**	350
Air Outlet	**	N/A

Note 1: Inner and outer shell allowable temperatures are 400°F and 600°F, respectively. This table conservatively compares temperatures of these two shells to the allowable temperature of the concrete (radial shield) that fills the space between them, to ensure that even local concrete temperatures are acceptable.

Table 4

TEMPERATURE RESULTS FOR PARTIAL BLOCKAGE OF AIR INLETS CONDITION

Component	**Computed Temperature [°F]**	**Allowable Temperature [°F]**
Two Ducts Blocked		
Fuel Cladding	**	1058
MPC Basket	**	950
MPC Shell	**	775
MPC Helium Bulk	**	N/A
Inner Shell	**	400
Outer Shell	**	600
Air Outlet	**	N/A
Three Ducts Blocked		
Fuel Cladding	**	1058
MPC Basket	**	950
MPC Shell	**	775
MPC Helium Bulk	**	N/A
Inner Shell	**	400
Outer Shell	**	600
Air Outlet	**	N/A

Table 5

TEMPERATURE RESULTS FOR EXTREME ENVIRONMENTAL TEMPERATURE CONDITION

Component	Computed Temperature [°F]	Allowable Temperature [°F]
Fuel Cladding	**	1058
MPC Basket	**	950
Basket Periphery	**	950
MPC Shell	**	775
MPC Helium Bulk	**	N/A
Inner Shell	**	350 (see Note 1)
Outer Shell	**	350 (see Note 1)
Lid Bottom Plate	**	400
Lid Top Plate	**	550
MPC Pedestal Plate	**	400
Baseplate	**	400
Radial Shield	**	350
Air Outlet	**	N/A

Note 1: Inner and outer shell allowable temperatures are 400°F and 600°F, respectively. This table conservatively compares temperatures of these two shells to the allowable temperature of the concrete (radial shield) that fills the space between them, to ensure that even local concrete temperatures are acceptable.

Table 6

TEMPERATURE RESULTS FOR HI-STORM IN CTF CONDITION

Component	**Computed Temperature [°F]**	**Allowable Temperature [°F]**
Fuel Cladding	**	1058
MPC Basket	**	950
MPC Shell	**	775
MPC Helium Bulk	**	N/A
Inner Shell	**	400
Outer Shell	**	600
Radial Shield	**	350
CTF Inner Surface	**	N/A

Table 7

TEMPERATURE RESULTS FOR NORMAL ON-SITE HANDLING CONDITION

Component	**Computed Temperature [°F]**	**Allowable Temperature [°F]**
Fuel Cladding	**	1058
MPC Basket	**	950
Basket Periphery	**	950
MPC Shell	**	775
MPC Helium Bulk	**	N/A
Inner Shell Inner Surface	**	400
Water Jacket Inner Surface	**	350
Enclosure Shell Outer Surface	**	350
Water Jacket Bulk Water	**	307
Axial Neutron Shield	**	300

Table 8

TEMPERATURE RESULTS FOR HI-TRAC TRANSFER CASK HANDLING ACCIDENT CONDITION

Component	**Computed Temperature [°F]**	**Allowable Temperature [°F]**
Fuel Cladding	**	1058
MPC Basket	**	950
Basket Periphery	**	950
MPC Outer Shell Surface	**	775
MPC Helium Bulk	**	N/A
Inner Shell Inner Surface	**	600
Water Jacket Inner Surface	**	700
Enclosure Shell Outer Surface	**	700
Axial Neutron Shield	**	300

Table 9

MPC INTERNAL PRESSURE RESULTS FOR ALL CONDITIONS

Condition	0% Rods Ruptured [psia]	1% Rods Ruptured [psia]	10% Rods Ruptured [psia]	100% Rods Ruptured [psia]
Storage in HI-STORM Overpack				
Long-Term Normal Storage[1]	***	***	***	***
Off-Normal Hot Environmental Temperature	***	***	***	***
Partial Blockage of Air Inlets 2 Blocked 3 Blocked	 *** ***	 *** ***	 *** ***	 *** ***
Extreme Environmental Temperature	***	***	***	***
HI-STORM in CTF	***	***	***	***
On-Site Handling in HI-TRAC Transfer Cask				
Normal On-Site Handling	***	***	***	***
Transfer Cask Handling Accident	***	***	***	***

ALLOWABLE MPC INTERNAL PRESSURE LIMITS

Condition	Pressure Limit [psia]
Normal	114.7
Off-Normal	114.7
Accident	214.7

[1] Although five separate decay heat loads are evaluated to obtain system-wide temperatures, only the bounding scenario (5 year old fuel, 28.74 kW) is evaluated for pressure. All other scenarios have lower temperatures and correspondingly lower internal pressures.

Table 10

PROPRIETARY TABLE REMOVED

HOLTEC APPROVED COMPUTER PROGRAM LIST				REV. 74 January 31, 2005	
PROGRAM (Category)	**VERSION**	**CERTIFIED USERS**	**OPERATING SYSTEM**	**REMARKS**	**CODE USED**
ANSYS (A)	5.7,7.0	JZ, ER, PK, CWB, SPA, AIS, IR, SP, AK, SJ, RW, VRP	Windows		
AIRCOOL	5.2I, 6.1		Windows		
BACKFILL	2.0		DOS/ Windows		
BONAMI (Scale)	4.3, 4.4		Windows		
BULKTEM	3.0		DOS/ Windows		
CASMO-4 (A)	1.13.04 (UNIX), 2.05.03 (WINDOWS)	ERD, SPA, DMM, KC, ST,VJB, MM	UNIX/ Windows	Version 1.13.04 should not be used for new projects and should only be used when necessary for additional calculations on previous projects. The user should refer to the error notice documented in c4ser.04-results.pdf located in \generic\library\nuclear\error notices\ concerning the use of version 1.13.04. Library N should be used with version 2.05.03 for all new reports issued after June 1st, 2003. Revisions to reports issued prior to June 1st, 2003 may continue to use the old Library L.	
CASMO-3 (A)	4.4, 4.7	ERD, SPA, DMM, KC, ST	UNIX		
CELLDAN	4.4.1		Windows		
CHANBP6 (A)	1.0	SJ, PK, CWB, AIS, SP,AK	DOS/Windows		
CHAP08 (CHAPLS10)	1.0		Windows		
CONPRO	1.0		DOS/Windows		
CORRE	1.3		DOS/Windows		
DECAY	1.4, 1.5		DOS/Windows		
DÉCOR	1.0		DOS/Windows		
DR.BEAMPRO	1.0.5		Windows		
DR.FRAME	2.0		Windows		

HOLTEC APPROVED COMPUTER PROGRAM LIST				REV. 74 January 31, 2005	
PROGRAM (Category)	**VERSION**	**CERTIFIED USERS**	**OPERATING SYSTEM**	**REMARKS**	**CODE USED**
DYNAMO (A)	2.51	AIS, SP, CWB, PK, SJ	DOS/Windows	Personnel qualified to use MR216 are automatically qualified to use DYNAMO.	
DYNAPOST	2.0		DOS/Windows		
FIMPACT	1.0		DOS/Windows		
FLUENT (A)	4.32, 4.56, 6.1.18	ER, IR, DMM, SPA	Windows	Do not use porous medium with zero velocity.	4.56
FTLOAD	1.4		DOS		
GENEQ	1.3		DOS		
HXFLOW	1.0		DOS/Windows		
INSYST	2.01		Windows		
KENO-5A (A)	4.3, 4.4	ERD, SPA, DMM, KC, ST,VJB,MM	Windows		
LONGOR	1.0		DOS/Windows		
LNSMTH2	1.0		DOS/Windows		
LS-DYNA3D (A)	936, 940, 950, 960, 970	JZ, AIS, SPA, SP, KPS,VRP	Windows		
MAXDISP8	1.8		DOS/Windows		
MAXDIS16	1.0		DOS/Windows		
MCNP (A)	4A, 4B	ERD, SPA, KC,ST,DMM, VJB, MAP,MM	Windows/ UNIX	CASMO-4 Lumped Fission Products (IDs 401 and 402) and Isotope Pm148M (ID 61248) can be modeled in MCNP 4A using the cross sections documented in HI-2033031. Use of these cross sections is restricted to MCNP 4A, and to material specifications in atom densities.	
MASSINV	1.4, 1.5, 2.1		DOS/Windows		
MR2	1.7	AIS, SP, CWB, PK, SJ	DOS/Windows	For use in wet storage analysis only.	

HOLTEC APPROVED COMPUTER PROGRAM LIST				REV. 74 January 31, 2005	
PROGRAM (Category)	**VERSION**	**CERTIFIED USERS**	**OPERATING SYSTEM**	**REMARKS**	**CODE USED**
MR216 (A)	1.0, 2.0, 2.2,2.4	AIS, SP, CWB, PK, SJ,AK	DOS/Windows	Versions 2.2 and 2.4 for use in dry storage analyses only. Use DYNAMO for liquefaction problems.	
MSREFINE	1.2,1.3, 2.1		DOS/Windows		
MULPOOLD	2.1		DOS/Windows		
MULTI1	1.3, 1.4, 1.5, 1.54, 1.55		Windows		
NITAWL (Scale)	4.3, 4.4		Windows		
NASTRAN DESKTOP (WORKING MODEL)	6.2, 2001,6.4,2002, 2003,2004		Windows		
ONEPOOL	1.4.1, 1.5, 1.6		DOS/Windows		
ORIGENS (Scale)	4.3, 4.4		Windows		
PD16	1.1, 1.0,2.1		Windows		
PREDYNA1	1.5, 1.4		DOS/Windows		
PREMULT8	1.0		DOS/Windows		
PRESPRG8	1.0		DOS/Windows		
PSD1	1.0		DOS/Windows		
QAD	CGGP		DOS/Windows		
SAS2H (Scale)	4.3, 4.4		Windows		
SFMR2A	1.0		DOS/Windows		
SHAPEBUILDER	3.0		DOS/Windows		
SIFATIG	1.0		DOS/Windows		

HOLTEC APPROVED COMPUTER PROGRAM LIST				REV. 74 January 31, 2005	
PROGRAM (Category)	**VERSION**	**CERTIFIED USERS**	**OPERATING SYSTEM**	**REMARKS**	**CODE USED**
SOLIDWORKS	2001PLUS, 2003		DOS/Windows	This program may be used to calculate Weight, Volume, Centroid and Moment of Inertia. As a precaution, user should avoid keeping more than one drawing files open at any given time during a Solidworks session. If there is a need for multiples drawing files to be open at once, user should ensure that the part names for all open files are uniquely named (i.e. no two parts have the same name.)	
SPG16	1.0, 2.0, 3.0		DOS/Windows		
SHAKE2000	1.1.0, 1.4.0		DOS/Windows		
STARDYNE (A)	4.4, 4.5	SP	Windows		
STER	5.04		Windows		
TBOIL	1.7, 1.9		DOS/Windows	See HI-92832 for restriction on v1.7.	
THERPOOL	1.2, 1.2A		DOS/Windows		
TRIEL	2.0		DOS/Windows		
VERSUP	1.0		DOS		
VIB1DOF	1.0		DOS/Windows		

HOLTEC APPROVED COMPUTER PROGRAM LIST				REV. 74 January 31, 2005	
PROGRAM (Category)	**VERSION**	**CERTIFIED USERS**	**OPERATING SYSTEM**	**REMARKS**	**CODE USED**
VMCHANGE	1.4, 1.3		Windows		
WEIGHT	1.0		Windows		

NOTES:

1. XXXX = ALPHANUMERIC COMBINATION
2. GENERAL PURPOSES UTILITY CODES (MATHCAD, EXCEL, ETC.) MAY BE USED ANYTIME.