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LAR 1014-3 HI-STORM THERMAL-HYDRAULIC ANALYSES

FOR

GENERIC

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4.	Appendix D	-	-	-	-	-	-	-	-	-
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6.	Appendix F	-	-	-	-	-	-	IR	1/31/2007	324118
7.	Appendix G	-	-	-	-	-	-	-	-	-
8.	Appendix H	IR	5/18/06	309965	-	-	-	Deleted	-	-
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11.										
12.										

†† Chapter , section or appendix number. * Including Appendix A.

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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:

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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 in the N-drive of 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".

SUMMARY OF REVISIONS LOG

Holtec Report HI-2043317

Revision 1: Appendix B updated with an evaluation of MPC-24E where the flow through the flux traps has been blocked.

Revision 2: Appendices F and G added. 3-Dimensional HI-STORM Model adopted for normal storage evaluations.

Revision 3: Appendix H added

Revision 4: Adopted 3-Zone flow resistance model for HI-STORM 3D licensing basis calculations.

Revision 5: (i) Removed axi-symmetric thermal modeling. (ii) Added off-normal and accident 3D model solutions.

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APPENDIX A
HOLTEC APPROVED COMPUTER PROGRAM LIST

(Total No. of Pages = 5)

HOLTEC APPROVED COMPUTER PROGRAM LIST			REV. 82 November 14, 2005		
PROGRAM (Category)	**VERSION**	**CERTIFIED USERS**	**OPERATING SYSTEM**	**REMARKS**	**CODE USED**
ANSYS (A)	5.7,7.0,9.0	JZ, ER, PK, CWB, SPA, AIS, IR, SP, AK, RW, VRP	Windows		*7.0*
AIRCOOL	5.21, 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), 2.05.14 (WINDOWS)	ERD, SPA, DMM, KC, ST,VJB, MM	UNIX/ Windows	Versions 1.13.04 and 2.05.03 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 \program\errors\casmo\ concerning the use of version 1.13.04. Library N should be used with version 2.05.14 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	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		

HOLTEC APPROVED COMPUTER PROGRAM LIST **REV. 82**

November 14, 2005

PROGRAM (Category)	VERSION	CERTIFIED USERS	OPERATING SYSTEM	REMARKS	CODE USED
DR.FRAME	2.0		Windows		
DYNAMO (A)	2.51	AIS, SP, CWB, PK	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, 6.1.18,6.2.16	ER, IR, DMM, SPA	Windows, Linux (Version 6.2.16 only)	Do not use porous medium with zero velocity.	6.2.16
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	DOS/Windows	For use in wet storage analysis only.	

HOLTEC APPROVED COMPUTER PROGRAM LIST				REV. 82 November 14, 2005	
PROGRAM (Category)	**VERSION**	**CERTIFIED USERS**	**OPERATING SYSTEM**	**REMARKS**	**CODE USED**
MR216 (A)	1.0, 2.0, 2.2,2.4,3.0	AIS, SP, CWB, PK, 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, 4.0		DOS/Windows		
SIFATIG	1.0		DOS/Windows		
SLABLOAD	1.0		DOS/Windows		

HOLTEC APPROVED COMPUTER PROGRAM LIST				REV. 82 November 14, 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, 2.0.0		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. 82 November 14, 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.) MAYBE USED ANYTIME.

Appendix B

Three-Dimensional Computational Fluid Dynamics Model of HI-STORM 100 System

Appendix C

HI-TRAC Thermal Modeling

Appendix D

HI-STORM and HI-TRAC Fire Accident Analyses

Appendix E

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Appendix F: Evaluation of HI-STORM 100 for Use at Elevated Plant Sites

1.0 Introduction

Use of HI-STORM 100 aboveground system at elevated plant sites requires an evaluation of the effects of reduced air pressure. Reduced air pressures act to reduce the ventilation air mass flow, resulting in a net elevation of the peak cladding temperature. However, the ambient temperature (i.e., temperature of the feed air entering the overpack) also drops with increase in elevation. Because the peak cladding temperature (PCT) also depends on the feed air temperature (the effect is one-for-one within a small range, i.e., 1°F drop in the feed air temperature results in ~ 1°F drop in the peak cladding temperature), the adverse effect of increased elevation is partially offset by the ambient air temperature decrease. In this appendix the effect of a HI-STORM situated at an elevated plant site is evaluated.

2.0 Ambient Pressure Attenuation

Table F-1 illustrates the variation of air pressure and ambient temperature as a function of elevation (See barometric tables attached to this appendix). The table shows a monotonic reduction of ambient pressure and temperature. A survey of the elevation of nuclear plants in the U.S. shows that nuclear plants are situated near about sea level or elevated slightly (~1000 ft). Representative elevation data is presented in Table F-2. For a bounding evaluation, fuel temperatures in a HI-STORM 100 System situated at 1500 ft elevation are calculated in the next section. The ambient temperature at this elevation is reduced by about 5°F (Table F-1). For a conservatively bounding evaluation, the ambient temperature lowering effect is neglected in the evaluation.

Table F-1: Ambient Pressure Attenuation		
Elevation (ft)	Pressure (in. Hg)	Temperature (°F)
Sea Level (0)	29.92	59.0
2000	27.82	51.9
4000	25.84	44.7
6000	23.98	37.6
8000	22.22	30.5
10000	20.57	23.3

Table F-2: Plants Elevation Data [1]	
Comanche Peak	900
D.C. Cook	620
Diablo Canyon	200
Duane Arnold	750
Fermi	600
Fort Calhoun	1000
Grand Gulf	140
Harris	260
Millstone	50
Nine Mile Point	300
Hanford	460
Palo Verde	1000
San Onofre	100
Sequoyah	700
Three Mile Island	300
Shoreham	100
Watts Bar	800
Wolf Creek	1100

3.0 Calculations and Results

The HI-STORM 100 fuel temperatures for baseline conditions (sea-level pressure (1 atm) and normal ambient temperature (T_o = 80°F)) are computed and reported in *Appendix B.* The results show that the highest peak cladding temperatures (PCT) are reached under non-uniform storage at X = 0.5 (X is the ratio of inner-to-outer region fuel decay heats in an MPC). For elevated sites evaluation the HI-STORM 100 PCT is computed for this bounding storage configuration *using the 3-D thermal models constructed to evaluate HI-STORM storage (See Appendix B).* The principal inputs to the thermal model are given below:

Bounding Elevation: 1500 ft (Section 2.0)

Ambient Pressure (P): 0.9465 atm (From Table F-2)

Air Mol. Wt. (M): 28.996 [2]

Universal Gas Constant (R): 0.7302 lbm-ft^3/lbmol-°R [3]

Air Density (ρ): PM/R(T_o+460)

= 0.06961 lbm/ft^3

The *results of elevation on PCT* are given in Table F-4 *and compared to normal (@sea level) storage temperatures computed in Appendix B.* From the highlighted results the PCT in a HI-STORM situated at an elevated site is below the regulatory cladding temperature limit (ISG-11, 752°F). In light of the above evaluation, it is not necessary to place any ISFSI elevation constraints for HI-STORM deployment in the United States.

3.1 List of Computer Files

(FLUENT v 6.2.16)

```
Directory of G:\Projects\5014\REPORTS\HI-2043317\Appendix-F\HI-ELEV
01/06/2007  10:27 AM        75,953,686 3d32-x0p5.cas
01/06/2007  10:27 AM        81,403,646 3d32-x0p5.dat
10/19/2006  04:28 PM       407,312,970 3d32.ray
01/02/2007  11:07 AM       118,138,500 3d68-x0p5.cas
01/02/2007  11:07 AM       155,194,721 3d68-x0p5.dat
04/23/2005  01:10 PM       791,195,955 3d68.ray
```

Table F-3: Elevated Sites HI-STORM 100 PCT, °F		
Storage Canister	PCT @ Sea Level	PCT @ 1500 ft
MPC-*32*	*711.4*	*723.8*
MPC-*68*	*697.1*	*718.2*

4.0 References

[1] "FW: Plant Elevations", Internal e-mail from D. Majumdar to I. Rampall, (12/12/2005).

[2] "Handbook of Heat Transfer", W.M. Rohsenow, J.P. Hartnett and Y.I. Cho, McGraw Hill, 3rd Ed., (1998).

[3] "Engineering Thermodynamics", R.E. Balzhiser & M.R. Samuels, Prentice Hall (1977).

Barometric Tables

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Air Temperature and Altitude

Altitude and air temperature and air density

The standard values for pressure, temperature and density (ignoring the slight effect of humidity) at altitudes from sea level to 16,000 feet (about 4500 m).

Altitude (feet)	Pressure (in. Hg)	Temp. (F)	Density (%)
sea level	29.92	59.0	100
2,000	27.82	51.9	94.3
4,000	25.84	44.7	88.8
6,000	23.98	37.6	83.6
8,000	22.22	30.5	78.6
10,000	20.57	23.3	73.8
12,000	19.02	16.2	69.3
14,000	17.57	9.1	65.0
16,000	16.21	1.9	60.9

- 1 ft (foot) = 0.3048 m
- 1 in mercury (Hg) = 3,376.8 N/m^2 (Pa)= 0.49 lb/in^2 (psi) = 12.6 in water
- T(°C) = 5/9[T(°F) - 32]

Appendix G

Support Material for Response to NRC RAI 4-7

Appendix H

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