Enclosure 2 to E-25259

Transnuclear, Inc. Calculation NUH32PTH1-0421, "Thermal Analysis of HSM-H Loaded with 32PTH1 DSC," Revision 0 (Non-proprietary version, without discs)

TRANSNUCLEAR AN AREVA COMPANY	**Calculation Cover Sheet**	Calculation No.: NUH32PTH1-0421 Revision No.: 0 Page: 1 of 45

DCR NO:	N/A	PROJECT NAME:	NUHOMS® 32PTH1 Transportable and Storage System
PROJECT NO:	NUH32PTH1	CLIENT:	Transnuclear, Inc

CALCULATION TITLE:

Thermal Analysis of HSM-H Loaded with 32PTH1 DSC

SUMMARY DESCRIPTION:

The calculation presents thermal analysis of the HSM-H loaded with 32PTH1 DSC for normal, off-normal, and accident storage conditions The calculation determines the temperature distribution of 32PTH1 DSC shell and HSM-H components to support an amendment application of the NUHOMS®COC 1004

If original issue, is licensing review per TIP 3.5 required?

Yes ☐ No ☒ (explain below) **Licensing Review No.:**

This calculation is one of the design basis calculations to support the current licensing submittal for the NUHOMS® 32PTH1 system. Therefore, a 72.48 review by Transnuclear is not necessary

Software Utilized:	Version:	Number of CDs:
ANSYS	8.1	3

Calculation is complete: Originator Signature:	Date: 6/28/06
Calculation has been checked for consistency, completeness and correctness: Checker Signature:	6/28/06 Date:
Calculation is approved for use: Miguel A Manzo Project Engineer Signature:	7/28/06 Date:

REVISION SUMMARY

REV.	DATE	DESCRIPTION	AFFECTED PAGES	AFFECTED DISKS
0	7/28/06	Initial Issue	All	All

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1 Purpose

The purpose of this calculation is to determine the temperature distribution of the HSM-H concrete, heat shields, support structure, and DSC shell for normal, off-normal and accident storage conditions in support of an amendment to the NUHOMS® COC 1004 to allow high burnup fuel to be loaded in the 32PTH1 DSC with up to 40.8 kW total heat load [1]. [redacted]

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2 References

1. [redacted]
2. Report, *Safety Analysis Report for the NUHOMS®-HD Horizontal Modular Storage System For Irradiated Nuclear Fuel*, NRC Docket No. 72-01030, Rev.4

[redacted]

[redacted]

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9. Siegel, Howell, *Thermal Radiation Heat Transfer*, 4th Edition, 2002.
10. Bentz, *A Computer Model to Predict the Surface Temperature and Time-of-wetness of Concrete Pavements and Bridge Decks*, Report # NISTIR 6551, National Institute of Standards and Technology, 2000.
11. *On-Line User's Manual for ANSYS*, Revision 8.1.

[redacted]

13. NRC, Code of Federal Regulations, Part 71, *Packaging and Transportation of Radioactive Material*, 2003.
14. Final Safety Analysis Report, *Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel*, Transnuclear Inc, NUH-003, Rev. 8, Docket No. 72-1004.

[redacted]

3 Assumptions and Conservatism

The assumptions and conservatism as described for 32PTH DSC/HSM-H model [3] are applied in this analysis. [redacted]

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[redacted]

4 Design Input

4.1 Material Properties

Stainless Steel SA 240, type 304 [redacted]

Table 4-1 Thermal properties of Stainless Steel SA 240, type 304

[redacted]

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[redacted]

Carbon Steel ASTM A36 [redacted]

Table 4-2 Thermal properties of Carbon Steel ASTM A36

[redacted]

[redacted]

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[redacted]

Concrete [redacted]

The thermal properties of concrete are discussed in detail in [4]. These properties are listed in Table 4-3.

Table 4-3 Thermal properties of concrete

[redacted]

Soil [redacted]

The properties of soil (Mat 3) are discussed in [4] and summarized in Table 4-4 below.

Table 4-4 Thermal properties of soil

[redacted]

Air [redacted]

Table 4-5 Thermal properties of Air

[redacted]

[redacted]

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4.2 Effective Properties for NUHOMS-32PTH1 DSC Basket [redacted]

The bounding effective thermal properties for 32PTH1-S DSC basket [redacted] are calculated in Appendix B of [15]. 95% of the calculated thermal conductivity values are listed in Table 4-6 and conservatively applied to HSM-H DSC thermal analysis.

Table 4-6 Effective Thermal properties of 32PTH1 DSC Basket [15]

[redacted]

4.3 32PTH1 DSC Configuration

[redacted]

Table 4-7 32PTH1 DSC Configurations [1]

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

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5 Methodology

Horizontal Storage Module, model H (HSM-H) is designed to provide an independent, passive system with substantial structural capacity to ensure safe storage of spent fuel assemblies in 32PTH1 DSCs. The decay heat load from stored DSCs is removed via combination of radiation, convection and conduction. Ambient air enters the HSM-H through ventilation inlet openings in the lower part of the HSM-H side walls and circulates around the DSC and the side heat shields. Warm air passes through the top heat shield and exits the HSM-H through the outlet openings in the upper part of the HSM-H side walls.

Decay heat is rejected from the DSC to the HSM-H air space by convection and then is removed from the HSM-H cavity by natural air circulation. Heat is also radiated from the DSC surface to the heat shields and HSM-H walls, where natural air circulation and conduction through the walls remove the heat.

This analysis determines the temperature distribution on the DSC shell, which is used to calculate the fuel peak cladding temperature in a detailed model of the DSC. The HSM-H wall temperatures are also determined in this analysis.

Two maximum decay heat loads are considered for the NUHOMS-32PTH1 system: 31.2 kW and 40.8 kW. [redacted]

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Ambient temperatures of 0 °F and 106°F are considered as normal storage conditions. The lowest ambient temperature of -40°F and maximum ambient temperature of 117°F are used for off-normal storage condition [4]. Ambient temperature of 133°F is used for accident condition [1]. [redacted]

Since the HSM-H is located outdoors, there is a remote probability that the air inlet and outlet openings become blocked by debris from such events as flooding, high wind, and tornados. The perimeter security fence around ISFSI and the location of the air inlet and outlet openings reduces the probability of such an accident. A complete blockage of all inlets and outlets simultaneously is not a credible event. Nevertheless, to bound this scenario, analysis is carried out assuming complete blockage of the inlet and outlet vents as an accident case.

[redacted]

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The temperature distributions for the normal, off-normal and accident conditions are determined using a steady-state model [redacted]. For accident blocked vent case, a transient model includes [redacted]. The models are described in Section 5.1. The boundary conditions are described in Sections 5.2 and 5.3 for steady-state and transient models, respectively.

5.1 ANSYS Finite Element Models

[redacted] For the analysis, a half symmetric, three dimensional, finite element model of the HSM-H is developed by using ANSYS [11] to determine the temperature profiles for normal, off-normal and accident conditions.

[redacted]

[redacted]

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The material properties used in the finite element models are listed in Section 4.

5.2 Boundary conditions for Normal, Off-Normal and Accident Conditions (Steady State)

The thermal test of HSM-H documented in [5] and the methodology described in [4] are basis for defining the boundary conditions for normal, off-normal and accident conditions.

The exit air temperatures used in the HSM-H model are listed in Table 5-1 below.

Table 5-1 HSM-H Exit Air Temperature Applied

Heat Load, kW	Conditions	Ambient Temperature, °F	Exit Air Temperature [12], °F
40.8	Normal Storage	0	78
		106	203
	Off-Normal Storage	-40	30
		117	216
	Accident	133	235
31.2	Normal Storage	0	64
		106	187
	Off-Normal Storage	-40	18
		117	199
	Accident	133	217

[redacted]

[redacted]

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[redacted]

Insolance is considered on the roof and front wall of the HSM-H, which are exposed to the ambient. [redacted] The values of the applied heat fluxes are listed in Table 5-2 below.

Table 5-2 HSM-H Insolation

Component	Insolance [13], gcal/cm^2	[redacted]
HSM-H roof	800	[redacted]
HSM-H front wall	200	[redacted]

To maximize thermal gradients in the HSM-H concrete structure, insolance is not considered for the minimum ambient temperature of -40°F.

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[redacted]

[redacted]

[redacted] The applied decay heat flux is:

$$\textit{Decay heat flux},\ \dot{q} = \frac{Q}{\pi D_i L} \qquad \frac{Btu}{hr \cdot in^2}$$

where

Q = total decay heat load (31.2 kW and 40.8 kW)

D_i = inner DSC diameter [redacted]

L = Cavity length [redacted]

[redacted]

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[redacted]

[redacted]

5.3 Boundary Conditions for Accident Blocked Vent Conditions (Transient)

To determine the maximum temperatures of the HSM-H and the DSC shell for the blocked vent accident case, the finite element model of the HSM-H is modified to a transient model. [redacted]

[redacted] The amount of generated heat per unit volume of the homogenized basket is calculated as follows:

$$\textit{Heat generating rate,}\ \ \ddot{q} = \frac{Q}{(\pi/4\ D_i^2\ L)} \qquad \frac{Btu}{hr \cdot in^3}$$

Where

Q = decay heat load (31.2 kW and 40.8 kW),

D_i = inner DSC diameter [redacted],

L = DSC cavity length [redacted].

[redacted]

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[redacted]

[redacted] Only air conduction is considered within the HSM-H cavity during blockage.

[redacted]

6 Computations

A summary of ANSYS runs, macros and associated files used is shown in Table and Table 6-2.

Table 6-1 ANSYS Run Summary

[redacted]

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[redacted]

Table 6-2 Associated files and macros

[redacted]

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7 Results

The maximum 32PTH1-S DSC component temperatures for the normal, off-normal and accident cases are summarized in Table 7-1. The temperature plots for steady state normal, off-normal and accident storage conditions, and transient accident blocked vent condition under 31.2 kW and 40.8 kW heat loads are shown in Figure 7-1 through Figure 7-6.

Table 7-1 Maximum Component Temperatures for Normal/Off-Normal and Accident Conditions

Operating conditions	T_{amb} °F	[redacted]	$T_{DSC\ Shell}$ °F	$T_{Concrete}$ °F	[redacted]	[redacted]	[redacted]
40.8 kW Heat Load							
Off-normal	-40	[redacted]	326	126	[redacted]	[redacted]	[redacted]
	117	[redacted]	469	295	[redacted]	[redacted]	[redacted]
Accident	133	[redacted]	484	311	[redacted]	[redacted]	[redacted]
		[redacted]	484	311	[redacted]	[redacted]	[redacted]
Normal	0	[redacted]	363	168	[redacted]	[redacted]	[redacted]
	106	[redacted]	460	283	[redacted]	[redacted]	[redacted]
31.2 kW Heat Load							
Off-normal	-40	[redacted]	261	94	[redacted]	[redacted]	[redacted]
	117	[redacted]	409	260	[redacted]	[redacted]	[redacted]
Accident	133	[redacted]	424	277	[redacted]	[redacted]	[redacted]
Normal	0	[redacted]	300	135	[redacted]	[redacted]	[redacted]
	106	[redacted]	399	249	[redacted]	[redacted]	[redacted]

[redacted]

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[redacted]

[redacted]

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The maximum component temperatures for the blocked vent accident cases without convection in HSM-H cavity are listed in Table 7-2. [redacted]

Table 7-2 Maximum Component Temperatures for Accident Blocked Vent Case, °F
(31.2 kW / 40.8 kW)

Component	$T_{DSC\ Shell}$		$T_{Concrete}$		[redacted]
Time, hrs	31.2 kW	40.8 kW	31.2 kW	40.8 kW	[redacted]
0	400	459	288	319	[redacted]
5	470	543	316	355	[redacted]
10	500	576	332	377	[redacted]
15	520	599	346	395	[redacted]
20	535	615	358	410	[redacted]
25	547	628	368	423	[redacted]
28	-	635	-	431	[redacted]
30	557	640	378	436	[redacted]
35	567	650	387	447	[redacted]
40	575	660	396	458	[redacted]

[redacted]

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Figure 5-1 Finite Element Model

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Figure 5-2 Finite Element Model, DSC and Support Structure

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Figure 5-3 Finite Element Model, Concrete Structure

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Figure 5-4 Finite Element Model, Heat Shields and Support Structure

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Figure 5-5 Convection Boundary Condition on DSC Shell

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Figure 5-6 Convection Boundary Conditions for HSM-H

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Figure 5-7 Heat Flux and Fixed Temperature Boundary Conditions for HSM-H

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Figure 5-8 Convection Boundary Conditions Applied on HSM-H Walls

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Figure 7-1 Temperature Plot for Normal Storage Conditions (0°F ambient, 40.8 kW)

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Figure 7-2 Temperature Plot for Normal Storage Conditions (106°F ambient, 40.8 kW)

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Figure 7-4 Temperature Plot for Off-Normal Storage Conditions (117°F ambient, 40.8 kW)

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Figure 7-3 Temperature Plot for Off-Normal Storage Conditions (-40°F ambient, 40.8 kW)

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Figure 7-5 Temperature Plot for Accident Storage Conditions (133°F ambient, 31.2 kW)

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Figure 7-6 Temperature Plot for Accident Storage Conditions (133°F ambient, 40.8 kW)

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Figure 7-7 Temperature Plot for Blocked Vent Accident Storage Conditions (31.2 kW, 40 hrs)

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Figure 7-8 Temperature Plot for Blocked Vent Accident Storage Conditions (40.8 kW, 35 hrs)

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Figure 7-9 Temperature History for Blocked Vent Accident Storage Conditions (31.2 kW)

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Figure 7-10 Temperature History for Blocked Vent Accident Storage Conditions (40.8 kW)

Appendix A – Thermal Input for DSC Ends Structure Analysis

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Figure A- 1 DSC shell temperature plots for 40.8 kW, off-normal -40°F and 117°F ambient storage conditions (Input for DSC ends structural analysis)

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Figure A- 2 DSC shell temperature plots for 31.2 kW, off-normal -40°F and 117°F ambient storage conditions (Input for DSC ends structural analysis)