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BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

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2. Page 1 of 31

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Calculation of the Naval Long and Short Waste Package Three-Dimensional Thermal Interface Temperatures

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This calculation has been formatted in accordance with Desktop EG-DSK-3003 REV 002, "*Desktop Information For Format Of Calculations And Treatment Of Inputs And Assumptions*".

This calculation was initiated by Jason Viggato and completed by Hongyan Marr.

	Attachments	Total Number of Pages
I	Naval Long Canister Outer Top Surface Temperature Plots for Air Gas Fill Throughout	8
II	Naval Long Canister Outer Top Surface Temperature Plots for Helium Gas Fill in Pre-closure and Air in Post-closure	8
III	Temperature Boundary Conditions	3
IV	List of Files on Attachment V (CD)	17
V	Compact Disk (CD) (1 of 1)	N/A
VI	Reference 14	7

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. Approved/Accepted (Print/Sign/Date)
00A	Initial Issue	73	VI-6	Hongyan Marr 10/25/06	Timothy deBues 10/25/06	Michael Anderson 10/26/06

DISCLAIMER

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1. PURPOSE

The purpose of this calculation is to evaluate the thermal performance of the Naval Long and Naval Short spent nuclear fuel (SNF) waste packages (WP) in the repository emplacement drift. The scope of this calculation is limited to the determination of the temperature profiles upon the surfaces of the Naval Long and Short SNF waste package for up to 10,000 years of emplacement. The temperatures on the top of the outside surface of the naval canister are the thermal interfaces for the Naval Nuclear Propulsion Program (NNPP). The results of this calculation are intended to support Licensing Application design activities.

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2.3 OUTPUTS

None.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 Dimensions and materials of the Naval Long waste packages, corresponding to the configuration drawings in References 12 and 13 are assumed to be the same as the final definitive design. The Naval Short waste package represented in this calculation has the same dimensions (Ref. 24) as the Naval Long waste package except for the length difference as indicated in Reference 11, p.5. The rationale for this assumption is that the design is preliminary, and will require verification at the completion of the final definitive design. This assumption is used in Section 6.1.

3.1.2 Dimensions of the 21-PWR waste package, corresponding to the drawings in References 25 and 26 are assumed to be the same as the final definitive design. The rationale for this assumption is that the design is preliminary, and will require verification at the completion of the final definitive design. This assumption is used in Section 6.1.

3.1.3 Dimensions of the drip shield, corresponding to the drawings in Reference 23 are assumed to be the same as the final definitive design. The rationale for this assumption is that the design is preliminary, and will require verification at the completion of the final definitive design. This assumption is used in Section 6.1.

3.1.4 Dimensions of the invert, corresponding to the drawings in Reference 27 are assumed to be the same as the final definitive design. The rationale for this assumption is that the design is preliminary, and will require verification at the completion of the final definitive design. This assumption is used in Section 6.1.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 Representing only conduction and radiation heat transfer inside the waste package is assumed to provide conservative results (higher temperatures) for this calculation. The rationale for this assumption is that the gas placed inside the waste package will allow natural convective heat transfer to exist; however, since the enclosed cavities are small along the direction of gravity, natural convection effect is not significant. Thus, the problem may be represented with only the dominant heat transfer modes, providing a negligible and/or conservative impact upon the results. This assumption is used in Section 6.1.

3.2.2 Properties of helium and air at a pressure of one atmosphere are assumed to be representative of the conditions that will exist in the waste package. Even though the internal pressure of the waste package will increase due to the temperature rise, the thermal conductivity of most gases is pressure independent, provided the mass density remains constant (Reference 1, p. 255). Thus, using the thermal conductivity at one atmosphere is reasonable. Fill gas of helium is used in pre-closure only, and is assumed to have leaked out for post-closure results. This is a conservative and bounding assumption due to the lower thermal conductivity of air. This assumption is used in Section 6.1 and Section 6.3.

3.2.3 The naval canister is represented as a homogenous cylinder for the calculation. The rationale for this assumption is that the naval canister internal design is undisclosed, and it is beyond the scope of this calculation to calculate the internal temperatures of the naval canister. However, this assumption has little impact on the canister surface temperature and heat flux prediction since they are only related to the heat output of the naval canister and the waste package boundary conditions. This assumption is used in Sections 6.1 and 6.3.

3.2.4 A gap filled with air is represented in the 3-D representation between the waste package inner vessel and outer barrier. The rationale for this assumption is that although the inner vessel and outer barrier will have some local contacts with a horizontal emplacement position, assuming a uniform gap all around is conservative. Also since there is no fill gas requirement for the spacing between the inner vessel and the outer barrier, using air is reasonable. This assumption is used in Section 6.1.

3.2.5 The Naval Nuclear Propulsion Program has provided a range of densities for the naval SNF canister. The highest density value is used in the calculation. The rationale for this assumption is that the canister internal temperatures are not of concern for this calculation. Using the maximum density value has little impact to the calculation. This assumption is used in Section 6.3.

3.2.6 The boundary temperature history of the drift wall used in this calculation is assumed to be that near the 21 PWR (WP #6) in the 3-D twelve waste package calculation (Ref. 4, Figure 5-2). The rationale for this assumption is that the 11.8 kW 21 PWR waste package has the highest heat generation, thus the segment of the drift corresponding to the location of this package has the highest wall temperatures. Using the hottest waste package and the resulting temperatures on the drift is conservative and provides the bounding case. This assumption is used in Section 6.2.

3.2.7 The naval canister is assumed centered and floating within the waste package. The rationale for this assumption is that some local contacts are expected with horizontal emplacement position. Assuming no conduction through the contact simplifies the representation and creates the most thermally limiting configuration of components, ensuring that the calculation will give the highest possible temperatures (conservative) within the waste package. This assumption is used in Section 6.1.

3.2.8 The 21-PWR waste package internal is represented as a homogenous cylinder for the calculation. The rationale for this assumption is that the internal temperatures of the 21-

PWR waste package are not of interest for this calculation and representing the waste package internal as a homogenous cylinder has little impact on the waste package surface flux and temperature calculations. This assumption is used in Sections 6.1 and 6.3.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Reference 33). The Naval Long and Short waste packages are classified as Safety Category items (important to safety and important to waste isolation) on the *Q-list* (Reference 38 p. A-9). Therefore, this document is subject to the requirements of the *Quality Management Directive* (Reference 34, Sections 2.1.C.1.1.a.i and 17.E) and the approved version is designated as QA:QA.

4.2 USE OF COMPUTER SOFTWARE

The finite element computer code used for this calculation is ANSYS V8.0 (Reference 35), which is identified by the Software Tracking number 10364-8.0-00. Usage of ANSYS V8.0 in this calculation constitutes Level 1 software usage, as defined in IT-PRO-0011 (Reference 36, Section 1.1). ANSYS V8.0 is qualified, baselined, and listed in the current *Nuclear Safety Software Report*, as well as the *Repository Project Management Automation Plan* (Reference 39, Table 6-1).

Calculations using the ANSYS V8.0 software were executed on the following Hewlett-Packard (HP) 9000 Series workstations running operating system HP-UX 11.00:

Central Processing Unit (CPU) Name: Milo, Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) Tag Number: 151665
CPU Name: Opus, CRWMS M&O Tag Number: 151664
CPU Name: Rosebud, CRWMS M&O Tag Number: 150689
CPU Name: Hodge, CRWMS M&O Tag Number: 150690
CPU Name: Oliver, CRWMS M&O Tag Number: 150688

The ANSYS V8.0 evaluations performed in this calculation are fully within the range of the validation performed for ANSYS V8.0 (Reference 37). Therefore, ANSYS V8.0 is appropriate for the thermal analysis as performed in this calculation. Access to, and use of, the code for this calculation was granted by Software Configuration Management in accordance with the appropriate procedures. The details of the ANSYS analyses are described in Section 6 and the results are presented in Section 7 of this calculation.
Microsoft Excel 2000 (9.0.6926 SP-3), which is a component of Microsoft Office 2000, is used for calculating homogenous thermal properties in Section 6.3 and plotting results in Attachments

I and II. Usage of Microsoft Office in this calculation constitutes Level 2 software usage, as defined in IT-PRO-0011 (Reference 36, Section 1.2). Microsoft Office 2000 is listed in the current *Software Report*, as well as the *Repository Project Management Automation Plan* (Reference 39, Table 6-1).

Microsoft Excel 2000 SP-3 was executed on a PC running the Microsoft Windows 2000 SP-4 operating system. The results can be confirmed by visual inspection.

4.3 METHOD

The calculation method employed is a finite element analysis (FEA). The calculation is performed by representing a three-dimensional (3-D) drift segment with a naval waste package placed in between two 21-PWR waste packages using the ANSYS V 8.0 code (Reference 35), as described in Section 6.4. The problem is solved transiently for the first 120 days and at various steady state times of emplacement as listed in Reference 11, page 5, with a pre-closure ventilation of 50 years.

5. LIST OF ATTACHMENTS

The list of attachments is provided in Table 1.

Table 1. Attachment List

Attachment Number	Description	Pages
I	Naval Long Canister Outer Top Surface Temperature Plots for Air Gas Fill Throughout	8
II	Naval Long Canister Outer Top Surface Temperature Plots for Helium Gas Fill in Pre-closure and Air in Post-closure	8
III	Three-Dimensional Twelve Waste Package Repository Segment Drift Wall Surface Temperatures	3
IV	List of Files on CD (Attachment V)	17
V	Compact disk (CD) (1 of 1) containing ANSYS V 8.0 files and Excel 2000 files	N/A
VI	Reference 14 (Note: The secondary references in Ref. 14 are not applicable for this calculation.)	6

6. CALCULATION

6.1 ANSYS REPRESENTATION

The 3-D Naval Long and Short waste packages are represented in this calculation in a drift segment containing a single naval SNF waste package placed in between two 21-PWR waste packages.

The naval waste package contains an inner vessel, outer corrosion barrier, and the naval canister; and Helium fill gas is used between the waste package inner vessel and naval canister for pre-closure alone and not in the post-closure (Assumption 3.2.2). In post-closure, the helium is assumed to have escaped due to leakage, and air is the fill gas throughout. This is a conservative approach and results in bounding temperatures. Air is filled between the outer barrier and inner vessel (see Assumption 3.2.4). The naval canister is not explicitly represented with the internal structures, and instead, homogenous material properties are used throughout (see Assumption 3.2.3). The naval canister is assumed floating in the center of the waste package shells (see Assumption 3.2.7). Only conduction and radiation heat transfer inside the waste package are considered as the heat transfer modes in the waste package. Natural convection inside the waste package is ignored (see Assumption 3.2.1). Figure 1 shows the 2-D cross-section for the waste package with naval canister. Table 2 lists the key naval waste package dimensions used in the calculation taken from References 12, 13, Reference 15, p. 32, and Reference 11, p.5 (see Assumption 3.1.1).

The 21-PWR waste package is represented as homogenous cylinder with single-material shell, which represents the inner vessel and outer barrier (see Assumption 3.2.8). The 21-PWR waste package, drip shield, and invert dimensions are taken from References 25, 26, 23, and 27 (see Assumptions 3.1.2, 3.1.3, and 3.1.4).

Figure 2 shows the pre-closure geometry for the naval waste package and drift configuration. The post-closure geometry is the same as that in the pre-closure case except for the addition of the drip shield, as seen in Figure 3 (Reference 23).

Table 2. Key Dimensions Used in the Calculation

Description	Dimension
Naval Waste Package Outer Diameter	1.8637 m (Reference 12)
Naval Waste Package Outer Barrier Thickness	0.0254 m (Reference 13)
Naval Waste Package Inner Vessel Thickness	0.0508 m (Reference 13)
Gap Between Naval Waste Package Inner Vessel and Outer Barrier	0.0048 m (Reference 13)
Naval Canister Outer Diameter	1.690 m (Reference 15, p. 32)
Naval Long Canister Length	4.88 m (Reference 11, p. 5)
Naval Short Canister Length	4.24 m (Reference 11, p. 5)
21-PWR Waste Package Outer Diameter	1.637 m (Ref. 25)

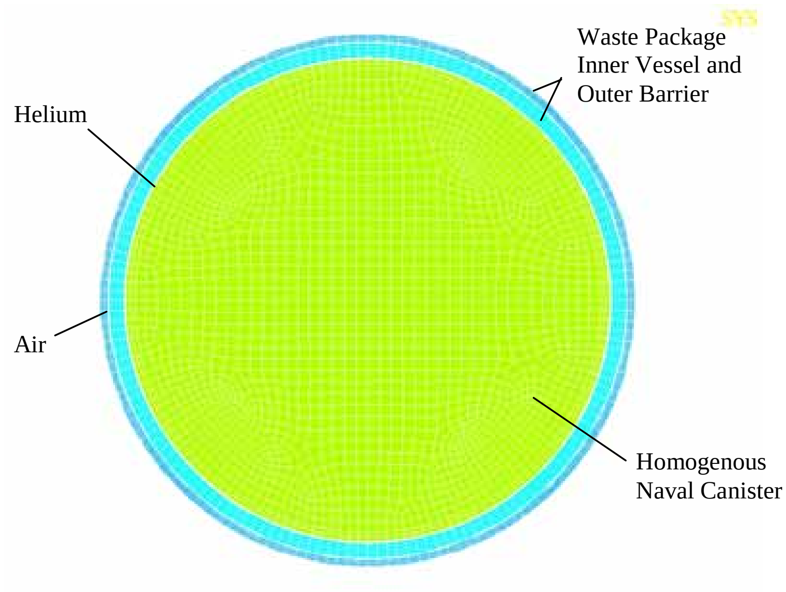

Figure 1. Waste Package Representation

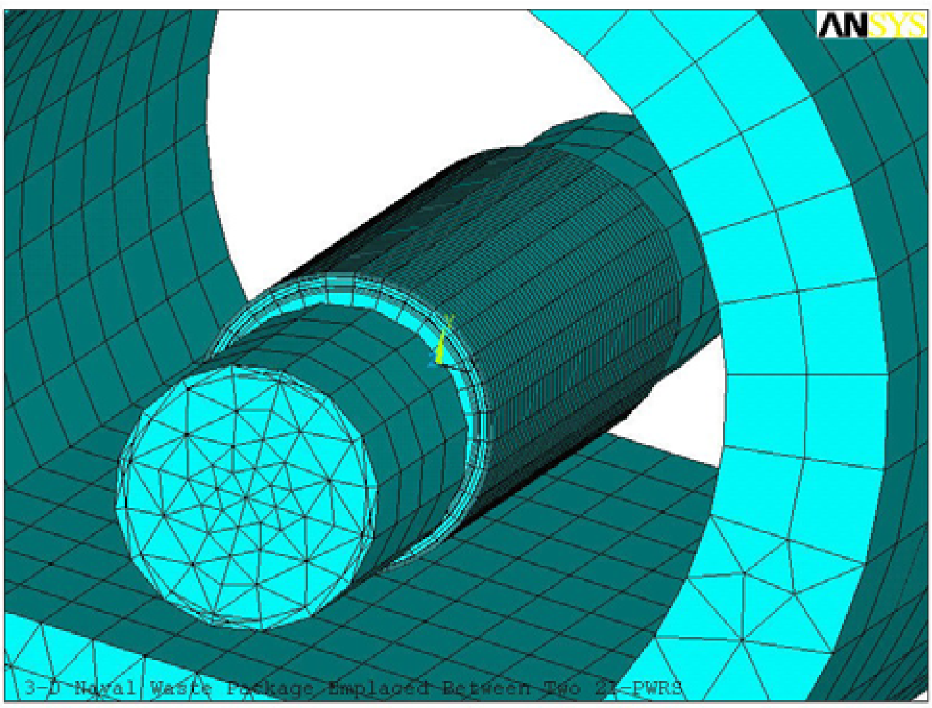

Figure 2. ANSYS Naval Waste Package emplaced between two 21-PWRs in Drift - Pre-Closure Representation

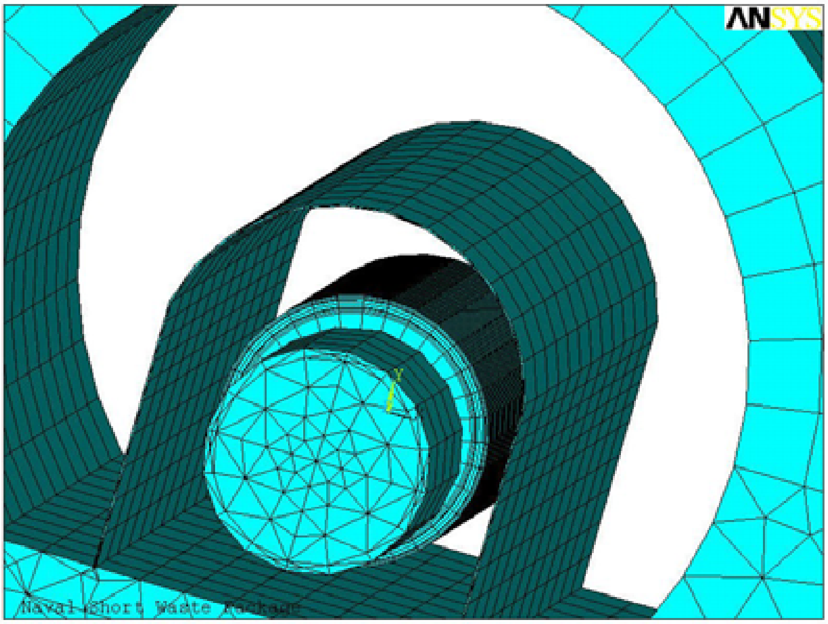

Figure 3. ANSYS Naval Waste Package emplaced between two 21-PWRs in Drift - Post-Closure Representation

6.2 HEAT LOAD AND BOUNDARY CONDITIONS

A range of linear heat loads are used to calculate the volumetric heat generation in the naval canister. The linear heat load varies along the length of the naval canister. Therefore, the varying volumetric heat generation rates are applied in the canister along the axial direction. Since there is no decay in the heat generation, the values of the linear heat remain constant throughout the entire simulation, thus maximum bounding temperatures result in the entire solution. Equation 1 shows the volumetric heat calculations based on the linear heat load.

$$q''' = \frac{P_{linear}}{\pi \cdot \frac{d_{naval\_outer}^{2}}{4}} \qquad \text{(Equation 1)}$$

Where
q''' = volumetric heat generation
P_{linear} = linear heat loads
D_{naval_outer} = outer diameter of the naval canister

The time dependent heat generation of the 21 PWR waste packages are based on the heat decay curve of the average 21 PWR-AP provided in Ref. 30, Table 7 and scaled from initial heat of 11.5 kW to 11.8 kW.

The boundary conditions for the calculation are the temperature histories calculated in Ref. 29, Attachment III for the surface facility and sub-surface drift emplacement conditions. The calculation performed in Ref. 29, Attachment III used the twelve waste package representation as described in Ref. 4 with 21 PWR waste package heat load of 11.8 kW. The drift wall and invert surfaces near the 21 PWR waste package (WP #6) (Ref. 4, Figure 5-2) are used in this calculation as boundary conditions. These are used because the 21 PWR has the highest heat output (11.8 kW), thus providing the location for the bounding temperatures of the drift wall (Assumption 3.2.6). The drift wall temperature boundary conditions obtained from the 3-D 12-waste package repository segment are based on an average linear heat load of 1.45 kW/m, waste package spacing of 0.1 m, drift spacing of 81 m, and ventilation efficiency of 80% indicated in Reference 14. Reference 14 is provided as Attachment VI. This calculation used the information from Reference 14 only for indirect input.

In the 3-D model, ventilation is applied via a convective boundary condition for the first 30 days to simulate a waste package in the surface facility and then turned off for the next 30 days to simulate a loss of ventilation. For the first 30 days of simulation the drift wall temperature is 50°C to represent the normal condition temperature on the concrete walls in the surface facility (Reference 16, p. 10). The following 30 days have no ventilation and the temperature of the surface facility wall is used for the boundary condition listed in Attachment I/DTF_50/Twall_wp_abn_plot.xls of Reference 16. Values for the surface facility wall temperature are listed in Table 4. The increasing trend of the surface facility wall temperatures is result of the adiabatic outer wall boundary temperatures used in Reference 16. The use of the waste package emplacement representation for this calculation is permissible due to the view factors in both the surface facility and drift geometry equaling 1.0. After the 60 days, drift wall temperatures are used from the 3-D calculations as boundary conditions. A total forced ventilation time of 50.2 years is used to account for the time the waste package spends in the surface facility in addition to the ventilation in the drift. An additional 30 days of ventilation loss one month after emplacement, is also imposed in the solution. A heat transfer coefficient of 2.0 $W/m^2 \cdot K$ is used as a conservative value for ventilation after emplacement (Reference 28, p. 15), with a mean bulk air temperature of 65°C (Reference 20, Analytical-LA-Course-Wet-vs-Dry-kth.xls – Wet vs. Dry. Reference 20 is cited in *IED Geotechnical and Thermal Parameters* (Reference 32), and, therefore, is approved and appropriate for the intended use in this calculation.).

Figures 4 and 5 show the locations of the applied the heat loads and boundary conditions for pre-closure and post-closure, respectively.

The calculation is solved transiently for the first 120 days and at various steady-state times afterward for up to 10,000 years with refined time steps at the beginning of the emplacement and the beginning of the post-closure period to capture the larger temperature changes. Table 3 lists the case summaries for air and helium as fill gases and the maximum linear heat load profiles which are in the navheatgen.dat files in Attachment V. The maximum volumetric heat loads are also listed in Table 3.

Table 3. Case Summary

Case Number	Corresponding Navy Case	Fill Gas	Number of Peaks	Maximum Linear Heat Load (kW/m)	Maximum Volumetric Heat Load (kW/m^3)
Case 1a	2.3_5 (Reference 11, p.8)	Air	2	5.0	2.229
Case 2a	2.2_3 (Reference 11, p.8)	Air	2	3.0	1.337
Case 3a	2.1_3 (Reference 11, p.8)	Air	2	3.0	1.337
Case 4a	2.2_1 (Reference 11, p.8)	Air	2	1.0	0.446
Case 5a	3.3_5 (Reference 11, p.8)	Air	3	5.0	2.229
Case 6a	3.2_3 (Reference 11, p.8)	Air	3	3.0	1.337
Case 7a	3.1_3 (Reference 11, p.8)	Air	3	3.0	1.337
Case 8a	3.2_1 (Reference 11, p.8)	Air	3	1.0	0.446
Case 1h	2.3_5 (Reference 11, p.8)	Helium	2	5.0	2.229
Case 2h	2.2_3 (Reference 11, p.8)	Helium	2	3.0	1.337
Case 3h	2.1_3 (Reference 11, p.8)	Helium	2	3.0	1.337
Case 4h	2.2_1 (Reference 11, p.8)	Helium	2	1.0	0.446
Case 5h	3.3_5 (Reference 11, p.8)	Helium	3	5.0	2.229
Case 6h	3.2_3 (Reference 11, p.8)	Helium	3	3.0	1.337
Case 7h	3.1_3 (Reference 11, p.8)	Helium	3	3.0	1.337
Case 8h	3.2_1 (Reference 11, p.8)	Helium	3	1.0	0.446

Table 4. Surface Facility Wall Temperatures after Loss of Ventilation

Time in hours (after loss of ventilation)	Temperature (C)
24	66.1266
48	71.3368
72	74.7926
96	77.4259
120	79.5829
144	81.4371
720	109.488

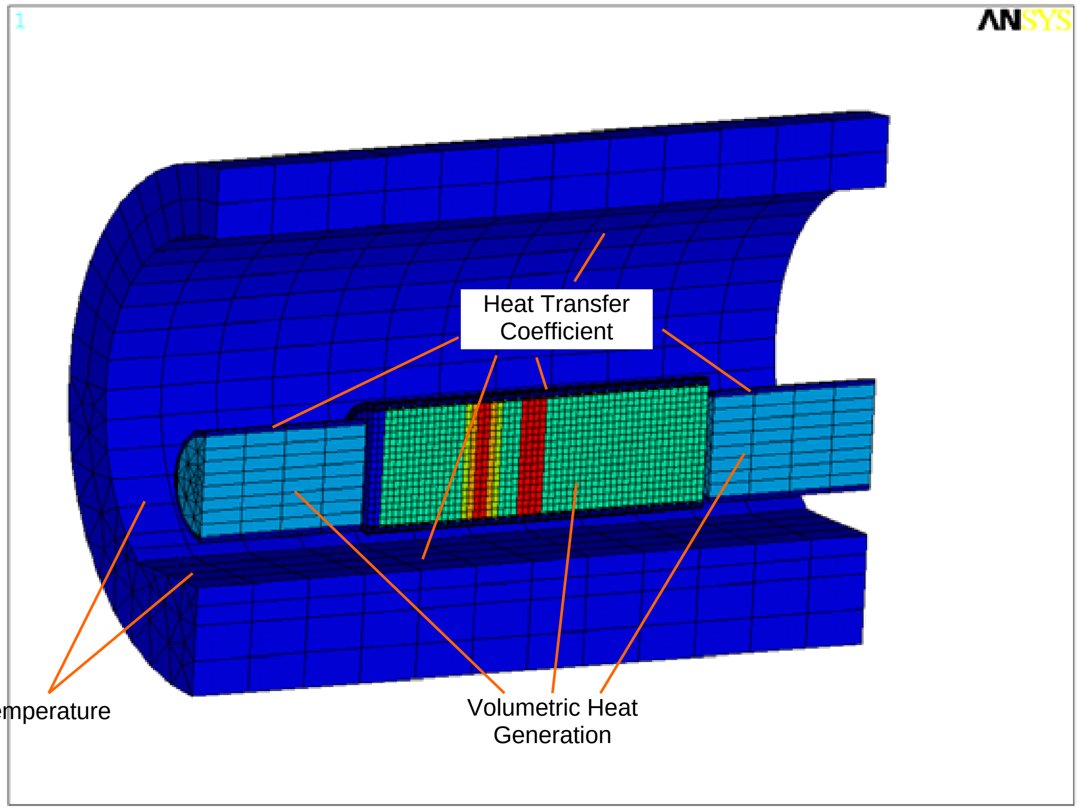

Figure 4. Heat Loads and Boundary Conditions Applied in ANSYS – Pre-Closure Representation

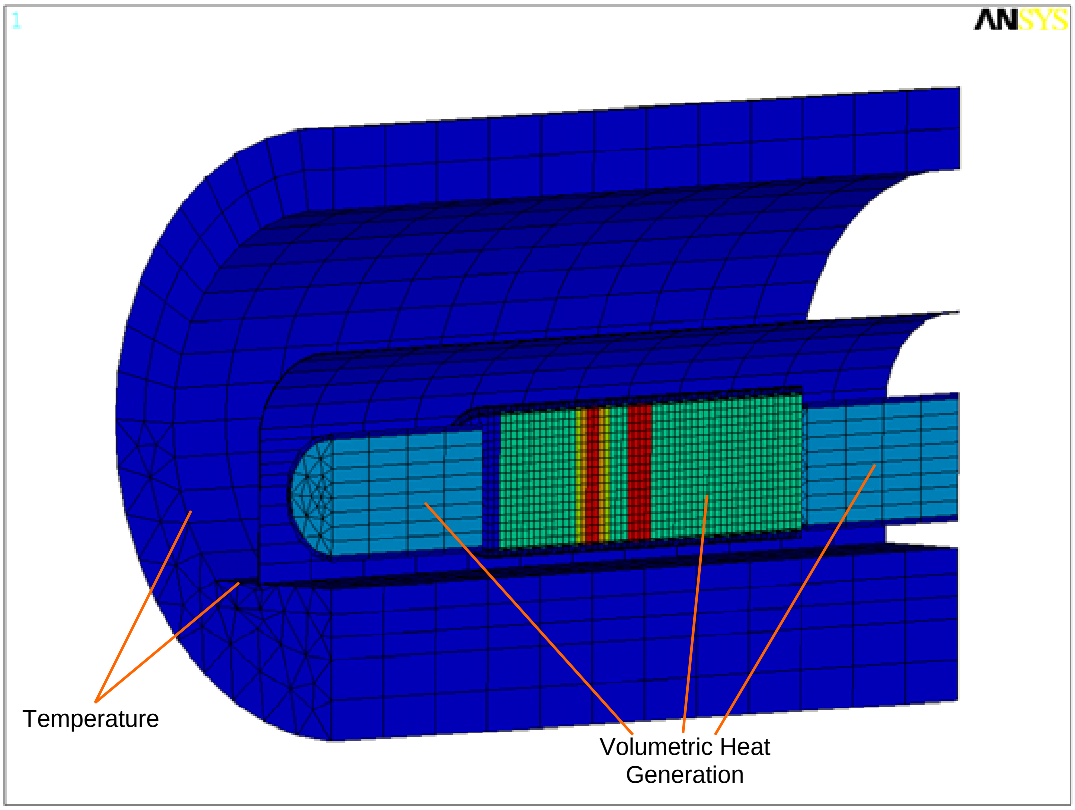

Figure 5. Heat Loads and Boundary Conditions Applied in ANSYS – Post-Closure Representation

6.3 THERMAL PROPERTIES

Table 5 summarizes the waste package and emplacement drift materials used in the calculation.

Table 5. Material List

Name	Material
Naval Waste Package Outer Barrier	Alloy 22 (UNS N06022) (Reference 13)
Naval Waste Package Inner Vessel	SA-240 S31600 (Reference 13)
Naval Canister Outer Barrier	SS 316L (Reference 5, Enclosure 3, p. 4)
Naval Canister Internal	Homogenous material (Assumption 3.2.3)
21-PWR Single-Material Shell	Combined material
21-PWR waste package Internal	Homogenous material (Assumption 3.2.8)
Drift Wall	Tptpll
Top Invert Layer	Homogenous Material
Bottom Inver Layer	Crushed Tuff

Table 6 lists the density (Reference 9, p. 7) and emissivity (Reference 3, p. 4-68) of stainless steel 316. Table 7 lists the thermal conductivity and specific heat of stainless steel 316. Values for thermal conductivity and thermal diffusivity are taken from Table TCD, Section II, Part D, of Reference 7, and are converted here to conductivity and specific heat in SI units. The conversion of thermal diffusivity (defined in Equation 2) to specific heat in Table 7 requires the density listed in Table 6. Stainless steel 316 is listed in the reference by its chemical composition (16Cr-12Ni-2Mo).

$$\text{Specific Heat (Btu/lb·°F)} = \frac{\text{Thermal Conductivity (Btu/hr·ft·°F)}}{\text{Density (lb/ft}^3\text{)} * \text{Thermal Diffusivity (ft}^2\text{/hr)}} \qquad \text{(Equation 2)}$$

Table 6. Density and Emissivity of Stainless Steel 316

Material	Density (kg/m^3)	Emissivity
Stainless Steel 316	7980	0.60

Table 7. Thermal Conductivity and Specific Heat of Stainless Steel 316

Temperature		Thermal Conductivity (Btu/hr·ft·°F)	Thermal Diffusivity (ft^2/hr)	Thermal Conductivity (W/m·K)	Specific Heat (J/kg·K)
(°F)	(°C)				
70	21.11	7.7	0.134	13.33	482.93
100	37.78	7.9	0.136	13.67	488.19
150	65.56	8.2	0.138	14.19	499.38
200	93.33	8.4	0.141	14.54	500.68
250	121.11	8.7	0.143	15.06	511.31
300	148.89	9.0	0.145	15.58	521.64
350	176.67	9.2	0.148	15.92	522.43
400	204.44	9.5	0.151	16.44	528.74
450	232.22	9.8	0.153	16.96	538.31
500	260.00	10.0	0.156	17.31	538.73
550	287.78	10.3	0.159	17.83	544.43
600	315.56	10.5	0.162	18.17	544.72
650	343.33	10.7	0.164	18.52	548.33
700	371.11	11.0	0.167	19.04	553.57
750	398.89	11.2	0.170	19.38	553.69
800	426.67	11.5	0.173	19.90	558.66
850	454.44	11.7	0.176	20.25	558.69
900	482.22	12.0	0.178	20.77	566.58
950	510.00	12.2	0.181	21.11	566.47
1000	537.78	12.4	0.184	21.46	566.37
1050	565.56	12.7	0.186	21.98	573.84
1100	593.33	12.9	0.189	22.33	573.62
1150	621.11	13.1	0.191	22.67	576.42
1200	648.89	13.3	0.194	23.02	576.17

1250	676.67	13.6	0.196	23.54	583.15
1300	704.44	13.8	0.199	23.88	582.81
1350	732.22	14.0	0.201	24.23	585.37
1400	760.00	14.2	0.203	24.58	587.88
1450	787.78	14.4	0.206	24.92	587.48
1500	815.56	14.6	0.208	25.27	589.91

Table 8 lists the density of Air and Table 10 lists the density of Helium. Helium is used in half of the cases as the waste package fill gas. The density is taken at one-atmosphere pressure (see Assumption 3.2.2) and a temperature of 300 K. Table 9 lists the thermal conductivity and specific heat of air. Table 11 lists the thermal conductivity and specific heat of helium. The values of density, specific heat, and thermal conductivity for air are taken from Reference 6, p. 19.77. The values of density, specific heat, and thermal conductivity for helium are taken from Reference 6, p. 19.71.

Table 8. Density of Air

Density (kg/m^3)
1.1774

Table 9. Thermal Conductivity and Specific Heat of Air

Temperature		Specific Heat		Thermal Conductivity	
(°F)	(°C)	(Btu/lb·°F)	(J/kg·K)	(Btu/hr·ft·F)	(W/m·K)
0	-17.78	0.2402	1005.6	0.01326	0.0229
20	-6.67	0.2402	1005.6	0.01372	0.0237
40	4.44	0.2403	1006.0	0.01419	0.0246
60	15.56	0.2403	1006.0	0.01465	0.0254
80	26.67	0.2404	1006.4	0.01510	0.0261
100	37.78	0.2405	1006.9	0.01554	0.0269
120	48.89	0.2407	1007.7	0.01599	0.0277
140	60.00	0.2408	1008.1	0.01642	0.0284
160	71.11	0.2410	1009.0	0.01685	0.0292
180	82.22	0.2412	1009.8	0.01728	0.0299
200	93.33	0.2414	1010.6	0.01771	0.0306
220	104.44	0.2417	1011.9	0.01813	0.0314
240	115.56	0.2420	1013.1	0.01854	0.0321
260	126.67	0.2423	1014.4	0.01896	0.0328
280	137.78	0.2426	1015.7	0.01937	0.0335
300	148.89	0.2430	1017.3	0.01978	0.0342
320	160.00	0.2433	1018.6	0.02019	0.0349

340	171.11	0.2437	1020.3	0.02059	0.0356
360	182.22	0.2442	1022.4	0.02099	0.0363
380	193.33	0.2446	1024.0	0.02140	0.0370
400	204.44	0.2451	1026.1	0.02180	0.0377
420	215.56	0.2455	1027.8	0.02220	0.0384
440	226.67	0.2460	1029.9	0.02260	0.0391
460	237.78	0.2465	1032.0	0.02299	0.0398
480	248.89	0.2471	1034.5	0.02339	0.0405
500	260.00	0.2476	1036.6	0.02378	0.0412
520	271.11	0.2482	1039.1	0.02418	0.0418
540	282.22	0.2487	1041.2	0.02457	0.0425
560	293.33	0.2493	1043.7	0.02496	0.0432
580	304.44	0.2499	1046.2	0.02536	0.0439
600	315.56	0.2505	1048.7	0.02575	0.0446
620	326.67	0.2511	1051.2	0.02614	0.0452
640	337.78	0.2517	1053.8	0.02653	0.0459
660	348.89	0.2524	1056.7	0.02692	0.0466
680	360.00	0.2530	1059.2	0.02731	0.0473
700	371.11	0.2536	1061.7	0.02770	0.0479
720	382.22	0.2543	1064.6	0.02808	0.0486
740	393.33	0.2549	1067.2	0.02847	0.0493
760	404.44	0.2555	1069.7	0.02885	0.0499
780	415.56	0.2562	1072.6	0.02924	0.0506
800	426.67	0.2568	1075.1	0.02962	0.0513
820	437.78	0.2574	1077.6	0.03001	0.0519
840	448.89	0.2581	1080.5	0.03039	0.0526
860	460.00	0.2587	1083.1	0.03078	0.0533
880	471.11	0.2594	1086.0	0.03116	0.0539
900	482.22	0.2600	1088.5	0.03154	0.0546

Table 10. Density of Helium

Density (kg/m^3)
0.1626

Table 11. Thermal Conductivity and Specific Heat of Helium

Temperature		Specific Heat		Thermal Conductivity	
(°F)	(°C)	(Btu/lb·°F)	(J/kg·K)	(Btu/hr·ft·F)	(W/m·K)
0	-17.78	1.2412	5196.3	0.08064	0.1396
20	-6.67	1.2412	5196.3	0.08304	0.1437
40	4.44	1.2412	5196.3	0.08542	0.1478

60	15.56	1.2412	5196.3	0.08776	0.1519
80	26.67	1.2411	5195.9	0.09008	0.1559
100	37.78	1.2411	5195.9	0.09238	0.1599
120	48.89	1.2411	5195.9	0.09465	0.1638
140	60.00	1.2411	5195.9	0.09690	0.1677
160	71.11	1.2411	5195.9	0.09912	0.1715
180	82.22	1.2411	5195.9	0.10133	0.1754
200	93.33	1.2411	5195.9	0.10351	0.1791
240	115.56	1.2411	5195.9	0.10783	0.1866
280	137.78	1.2411	5195.9	0.11207	0.1940
320	160.00	1.2411	5195.9	0.11624	0.2012
360	182.22	1.2411	5195.9	0.12036	0.2083
400	204.44	1.2411	5195.9	0.12441	0.2153
440	226.67	1.2411	5195.9	0.12841	0.2222
480	248.89	1.2411	5195.9	0.13236	0.2291
520	271.11	1.2411	5195.9	0.13626	0.2358
560	293.33	1.2411	5195.9	0.14011	0.2425
600	315.56	1.2411	5195.9	0.14392	0.2491
640	337.78	1.2412	5196.3	0.14768	0.2556
680	360.00	1.2412	5196.3	0.15141	0.2620
720	382.22	1.2412	5196.3	0.15509	0.2684
760	404.44	1.2412	5196.3	0.15874	0.2747
800	426.67	1.2412	5196.3	0.16236	0.2810

Table 12 lists the density and emissivity, and Table 13 lists the thermal conductivity and specific heat, of Alloy 22 used for the waste package outer barrier. The emissivity of Alloy 22 is taken from p. 10-297 of Reference 8, as that of nickel-chromium alloy. The density, thermal conductivity, and specific heat are taken from Reference 10, Table S04196_001. Refernece 10 is cited in *IED Waste Package Processes, Ground Motion Time Histories, and Testing and Materials* (Reference 31), and, therefore, is approved and appropriate for the intended use in this calculation.

Table 12. Density and Emissivity of Alloy 22

Material	Density (kg/m^3)	Emissivity
Alloy 22	8690	0.87

Table 13. Thermal Conductivity and Specific Heat of Alloy 22

Temperature (°C)	Thermal Conductivity (W/m·K)	Temperature (°C)	Specific Heat (J/kg·K)
48	10.1	52	414

100	11.1	100	423
200	13.4	200	444
300	15.5	300	460
400	17.5	400	476
500	19.5	500	485
600	21.3	600	514

The density of the naval canister is taken from Reference 5, Enclosure 1, p. 3. The maximum value is used for the calculation to be conservative (see Assumption 3.2.5). Effective thermal conductivity and specific heat of the canister are taken from Reference 5, Enclosure 1, p. 11 and p. 12 (The units of the lumped specific heat shown on p. 12 of Reference 5 are in error. They should be kcal/kg·°C). The emissivity of the 316L stainless steel canister surface is indicated in Reference 5, Enclosure 1, p. 4, which is the same as the value taken from Reference 3, p. 4-68. Table 14 through Table 16 list the thermal properties of the naval canister used in the calculation.

Table 14. Density and Surface Emissivity of Naval Canister

Density (kg/m^3)	Emissivity
4485	0.6

Table 15. Effective Thermal Conductivity of Naval Canister

Median Temperature (^{o}C)	Thermal Conductivity (W/m·K)
279.34	4.0
244.75	3.78
242.72	3.76
239.03	3.74
236.22	3.72
228.56	3.66
219.36	3.58
207.36	3.49
204.97	3.49
204.59	3.46
203.17	3.44
195.20	3.37
193.11	3.38
189.14	3.39
188.03	3.35
184.95	3.28
181.64	3.27
178.75	3.23
167.84	3.26
167.42	3.18
159.20	3.06
155.84	3.12
142.72	2.00

135.20	2.87
129.11	2.90
109.98	2.71
89.61	2.62
77.78	2.45

Note: Median temperature = (peak temp + canister surface temp)/2

Table 16. Lumped Specific Heats of the Naval Canister

Temperature (°C)	Specific Heat (J/kg·K)
0	397.48
38	418.40
93	435.14
148	451.87
204	472.79
260	481.16
316	493.71
371	502.08
400	506.26

The repository lies in the Tptpll layer, and the rock density and thermal conductivity for the drift are listed in Table 17 taken from Reference 17, ReadMe_DataFlow.doc, Table 7-10. Reference 17 is cited in *IED Geotechnical and Thermal Parameters* (Reference 32), and, therefore, is approved and appropriate for the intended use in this calculation. Table 18 lists the temperature dependent specific heat for Tptpll taken from Reference 18, Rock_GrainMass_heat_capacity_edited[1].zip. Reference 18 is cited in *IED Geotechnical and Thermal Parameters* (Reference 32), and, therefore, is approved and appropriate for the intended use in this calculation.

Table 17. Density and Thermal Conductivity of the Tptpll Rock Layer

Geologic Framework Unit	**Dry Bulk Density (kg/m^3)**	**Thermal Conductivity (W/m·K)**			
		T = 0 °C	**T = 97 °C**	**T = 102 °C**	**T = 200 °C**
Tptpll	1979	1.89	1.89	1.28	1.28

Table 18. Specific Heat of the Tptpll Rock Layer

Geologic Framework Unit	**Specific Heat (J/kg·K)**					
	T = 0 °C	**T = 94 °C**	**T = 95 °C**	**T = 114 °C**	**T = 115 °C**	**T = 200 °C**
Tptpll	926	926	3343	3343	990	990

Table 19 lists the effective density and emissivity of the invert top layer. The density in Table 19 is derived in Attachment III of Reference 21 (file "upper invert thermal props.mcd"). The emissivity in Table 19 is taken from Reference 19, Table A.8 (value for sand).

Table 20 lists the effective thermal conductivity of the invert top layer taken from Reference 22, Tables 6-8 and 6-16. The values are interpolated at a thermal conductivity of crushed tuff of 0.164 W/m-K .

Table 21 lists the effective specific heat of the invert top layer, derived in Attachment III of Reference 21 (file "upper invert thermal props.mcd").

Table 22 lists the thermal properties of the invert bottom layer (Reference 21, Table 5-4).

Table 19. Effective Density and Emissivity of the Invert Top Layer

Density (kg/m^3)	Emissivity
1890	0.90

Table 20. Effective Thermal Conductivity of the Invert Top Layer

Temperature (°C)	Thermal Conductivity (W/m·K)	
	Lateral	Vertical
50	1.701	7.041
100	1.686	7.126
150	1.665	7.133
200	1.639	7.074
250	1.609	6.964
300	1.574	6.815
350	1.537	6.641

Table 21. Effective Specific Heat of the Invert Top Layer

Temperature		Specific Heat (J/kg·K)
(°F)	(°C)	
70	21.11	523.09
100	37.78	524.65
150	65.56	526.07
200	93.33	526.99
250	121.11	528.52
300	148.89	529.63
350	176.67	530.71
400	204.44	531.54
450	232.22	532.59

500	260.00	533.72
550	287.78	534.38
600	315.56	535.16
650	343.33	536.14
700	371.11	537.20
750	398.89	538.35
800	426.67	539.61
850	454.44	541.04
900	482.22	542.55
950	510.00	543.90
1000	537.78	545.71
1050	565.56	547.73
1100	593.33	549.05

Table 22. Thermal Properties of Invert Bottom Layer (Crushed Tuff)

Density (kg/m^3)	**Specific Heat (J/kg·K)**	**Thermal Conductivity (W/m·K)**
1750	531.42	0.164

Tables 23 and 24 list the density, thermal conductivity, and specific heat of the smeared 21-PWR waste package internal. They are taken from Ref. 21, Tables 5-24 and 5-25.

Tables 25 through 27 list the thermal properties of the single-material shell of the 21-PWR waste package, which are taken from Ref. 21, Tables 5-16 to 5-18. The emissivity of the outer barrier is same as that for Alloy 22.

Table 23. Effective Density and Thermal Conductivity of the Homogeneous 21-PWR Waste Package Internal Cylinder

Thermal Conductivity (W/m·K)	**Density (kg/m^3)**
1.5	3077

Table 24. Effective Specific Heat of the Homogeneous 21-PWR Waste Package Internal Cylinder

Temperature (°C)	**Specific Heat (J/kg·K)**
52	343.1
100	348.6
200	360.1
300	371.5
400	382.9
500	394.3
600	405.8

Table 25. Density and Emissivity of Single-Material Shell

Density (kg/m^3)	Emissivity
8181	0.87

Table 26. Thermal Conductivity of Single-Material Shell

Temperature (°C)	Thermal Conductivity (W/m·K)
48	13.02
100	13.96
200	15.73
300	17.46
400	19.18
500	20.88
600	22.57

Table 27. Specific Heat of Single-Material Shell

Temperature (°C)	Specific Heat (J/kg·K)
52	477.9
100	485.5
200	501.3
300	517.1
400	532.9
500	548.7
600	564.5

7. RESULTS AND CONCLUSIONS

The results provided in this section are derived from the ANSYS executions. These calculations are presented in the input and output files in Attachment V (a compact disc [CD]). The input files for each of these calculations are also provided as part of the output file. Attachment IV is the list of files on the CD. Plots for each case are shown in Attachment I (Air) and Attachment II (Helium).

The number of digits in the values cited herein may be the result of a calculation or may reflect the input from another source; consequently, the number of digits should not be interpreted as an indication of accuracy. The results are suitable for the intended use and the outputs are reasonable compared to the inputs. The results are conservative based on the assumptions used in this calculation.

7.1 AIR FILL GAS THROUGHOUT

The cases with air fill gas throughout are plotted for the different Naval Long heat load profiles with two and three peaks (Reference 11, p. 8) in Attachment I. Only the temperatures at 60 days (30-day normal condition in the surface facility followed by 30-day loss of ventilation in surface facility) for pre-closure and 70 years after emplacement for post-closure are presented in the plots, since the peak temperatures occur around those times. Naval Short case temperature plots are shown in Attachment V in the Excel files in the “short” directories. As expected, a rise in the linear power produces an increase in the temperatures across the top outside surface of the naval canister. Different heat load profiles and number of peaks (two or three) affect the axial temperature distribution, as well as the location and number of peaks in the corresponding results. The effect of the increase may be seen in the plots in Attachment I and in the Excel file tables in Attachment V.

7.2 HELIUM FILL GAS IN PRE-CLOSURE AND AIR IN POST-CLOSURE

Attachment II shows all the plots of the cases for helium fill gas in the pre-closure and air fill gas in the post-closure period for the Naval Long. Only the temperatures at 60 days (30-day normal condition in the surface facility followed by 30-day loss of ventilation in surface facility) for pre-closure and 70 years after emplacement for post-closure are presented in the plots, since the peak temperatures occur around those times. Naval Short case temperature plots are shown in Attachment V in the Excel files in the “short” directories. The temperature histories for air in the post-closure are used after the ventilation period to account for leakage of the helium from the waste package. Since the waste package geometry and heat generation used are the same in post-closure with air as that in the pre-closure with helium, the naval canister temperatures after the ventilation period will rise sharply and are the same as those of the post-closure air cases. Similar trends in naval canister temperatures are witnessed in the helium cases as those in the air fill cases, except for lower maximum temperatures for those with helium. Attachment V contains the Excel file tables and graphs.

Attachment I - Naval Long Canister Outer Top Surface Temperature Plots for Air Gas Fill Throughout

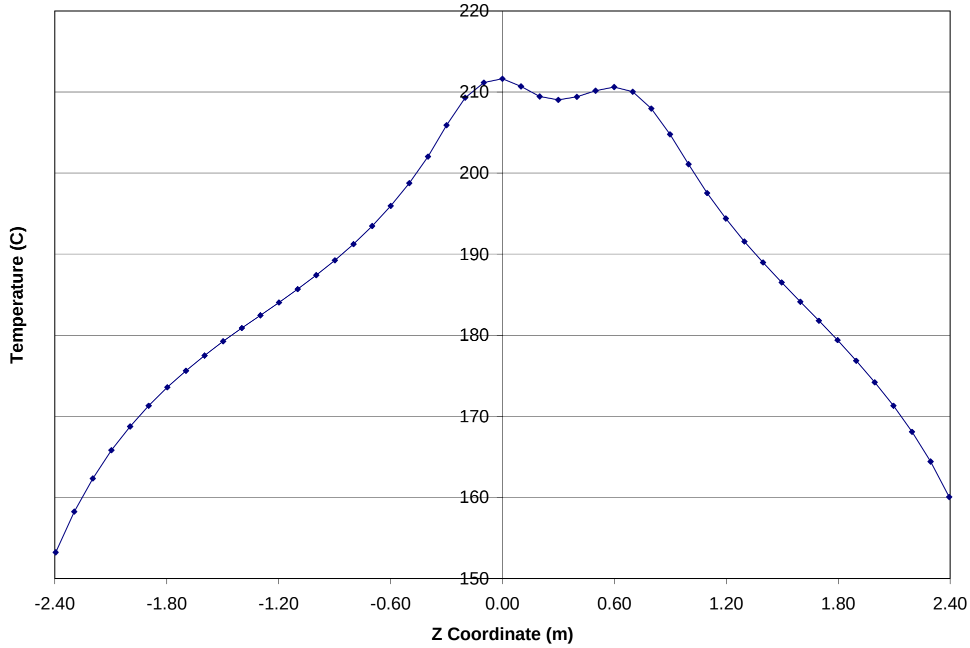

Figure 6. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 1a

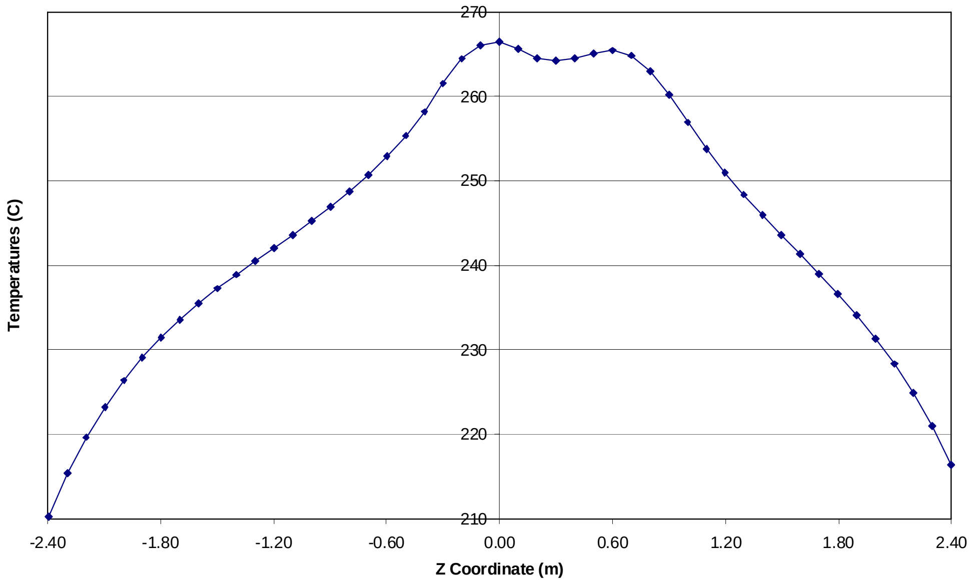

Figure 7. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 1a post

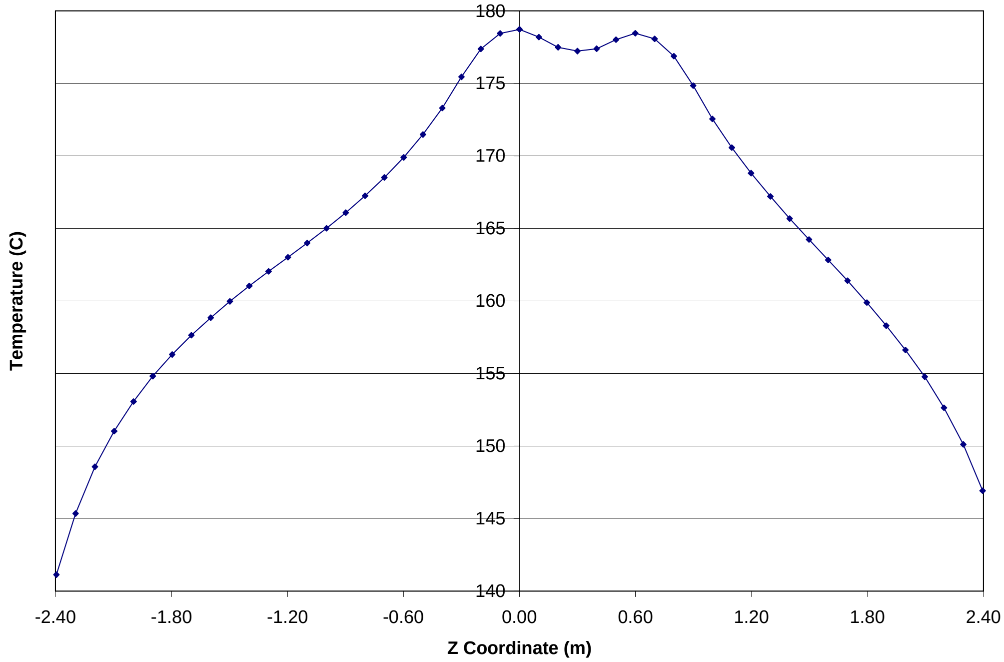

Figure 8. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 2a

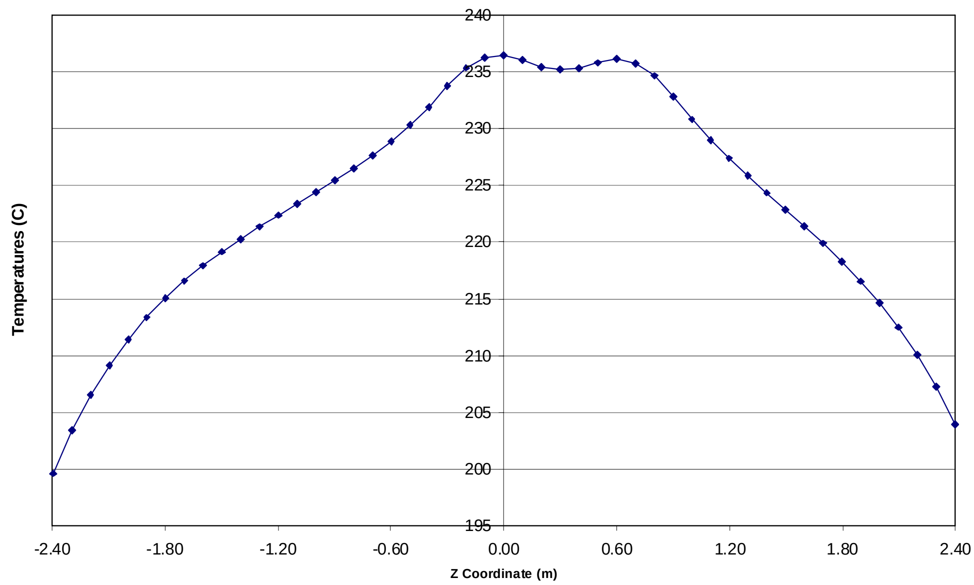

Figure 9. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 2a post

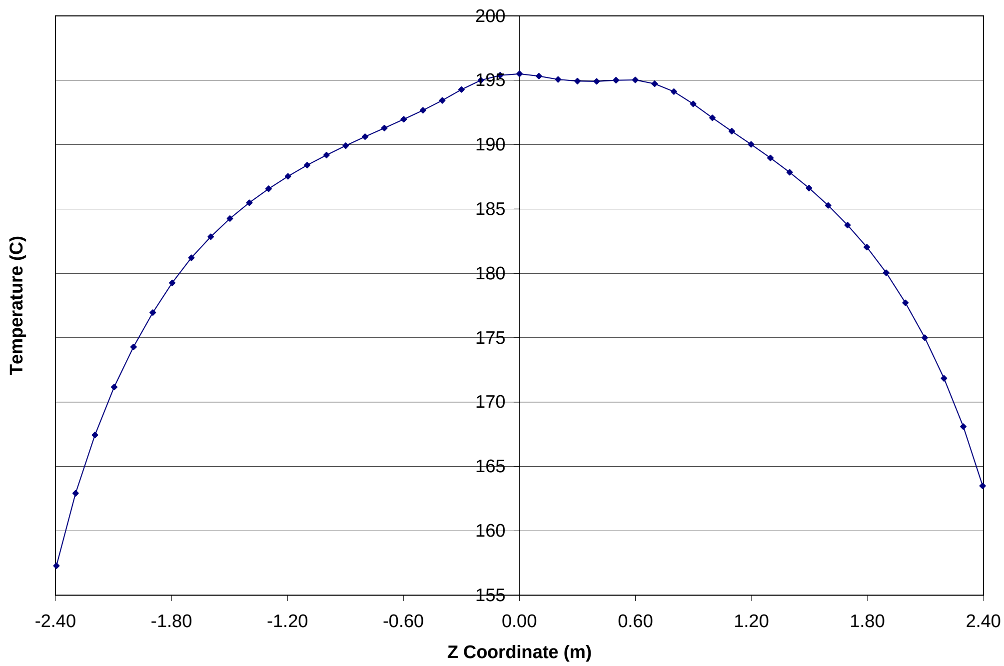

Figure 10. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 3a

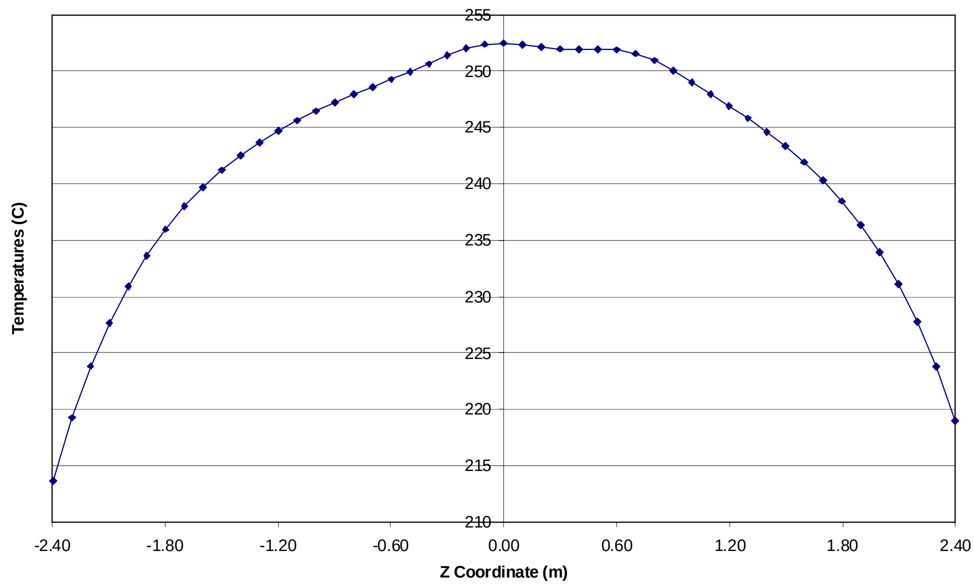

Figure 11. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 3a post

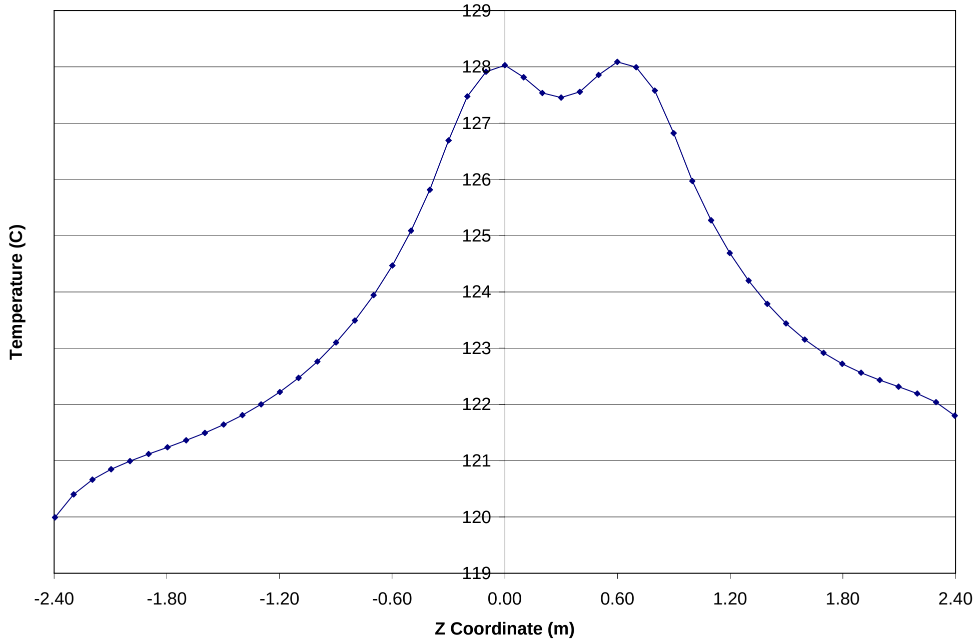

Figure 12. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 4a

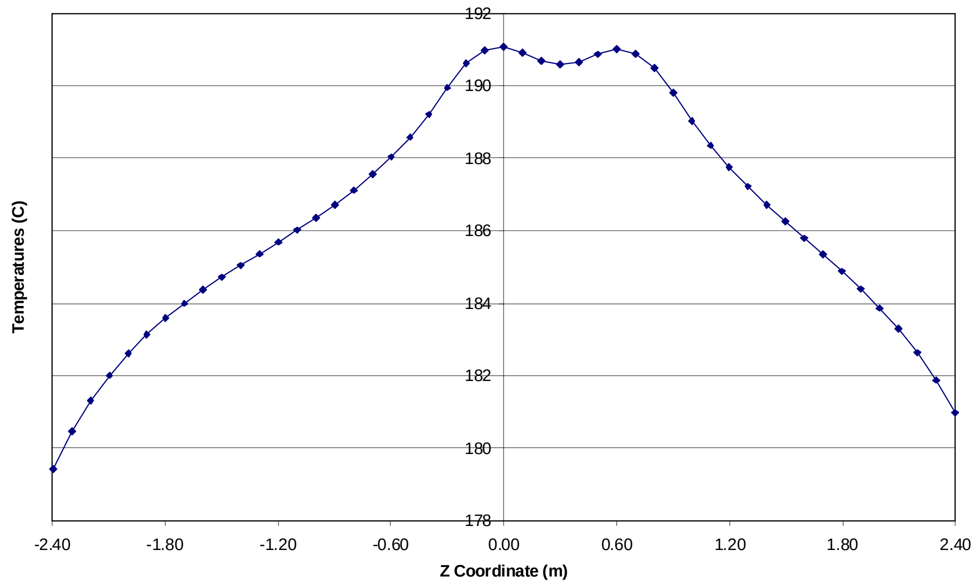

Figure 13. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 4a post

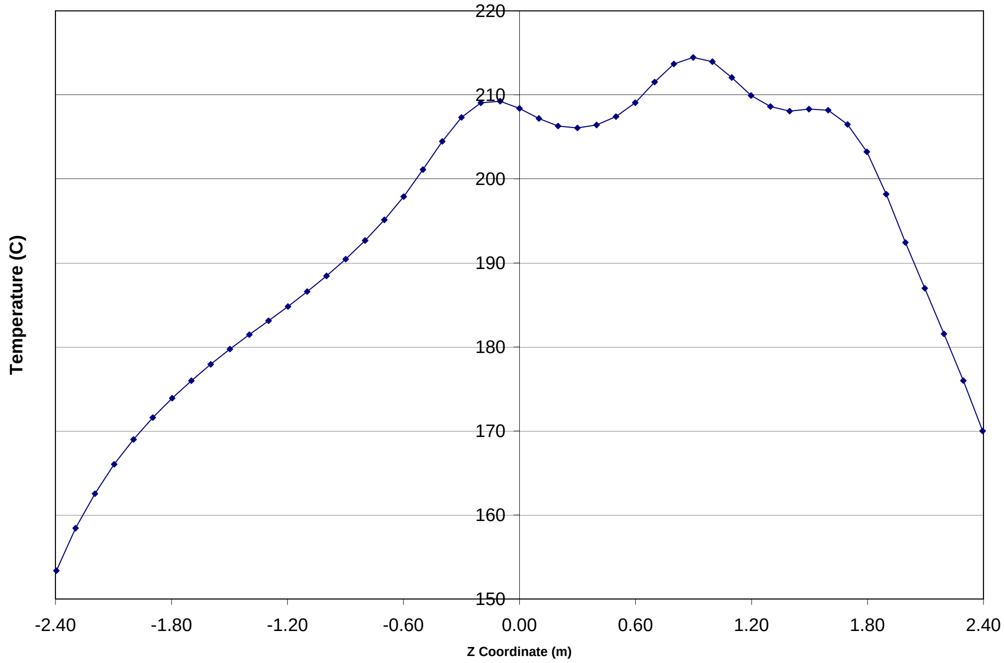

Figure 14. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 5a

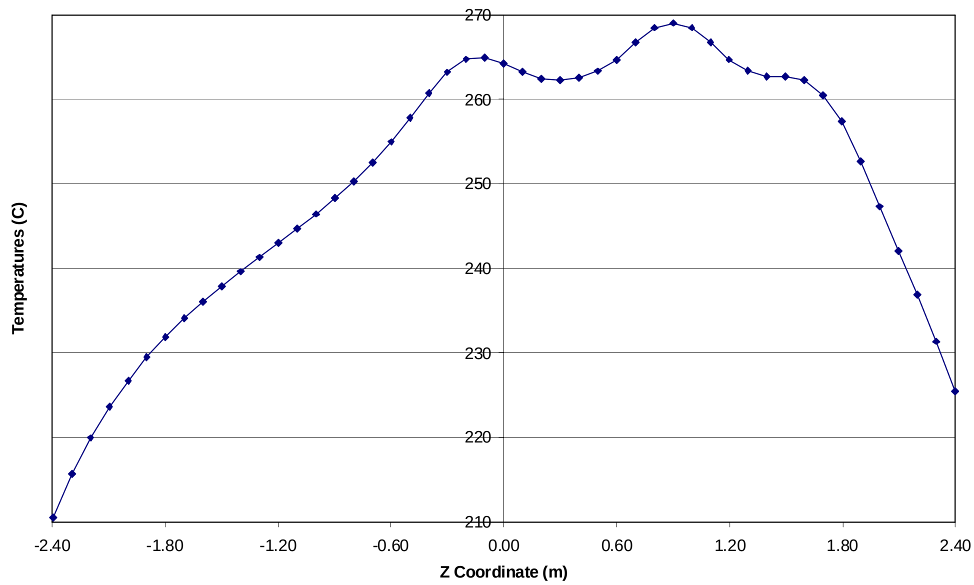

Figure 15. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 5a post

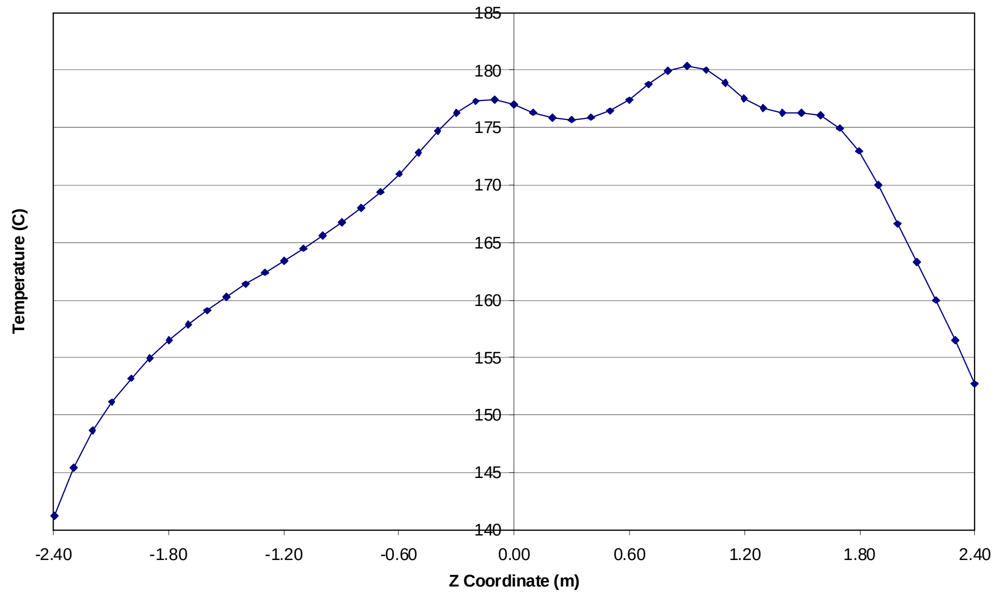

Figure 16. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 6a

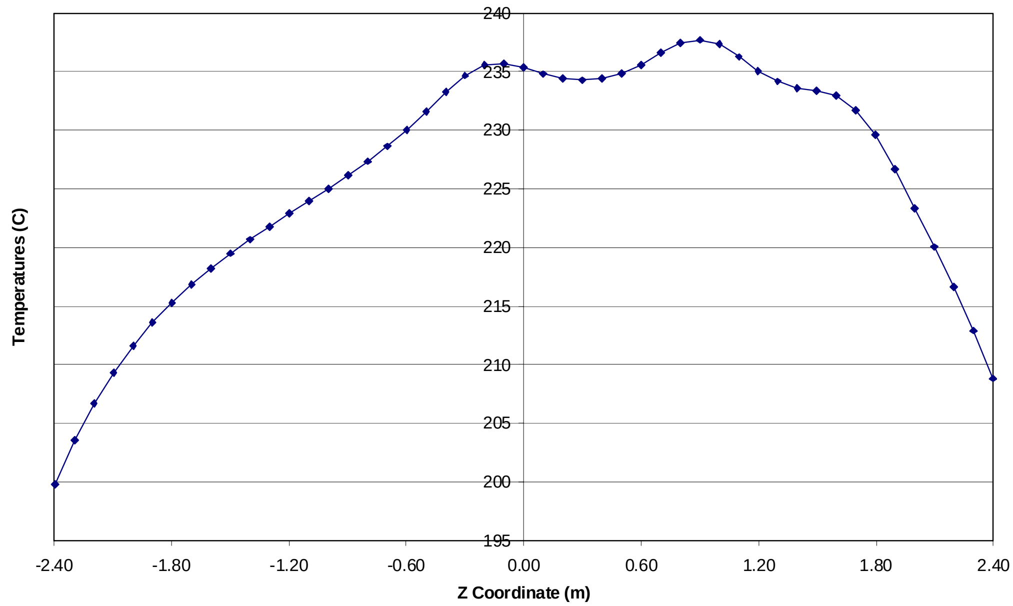

Figure 17. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 6a post

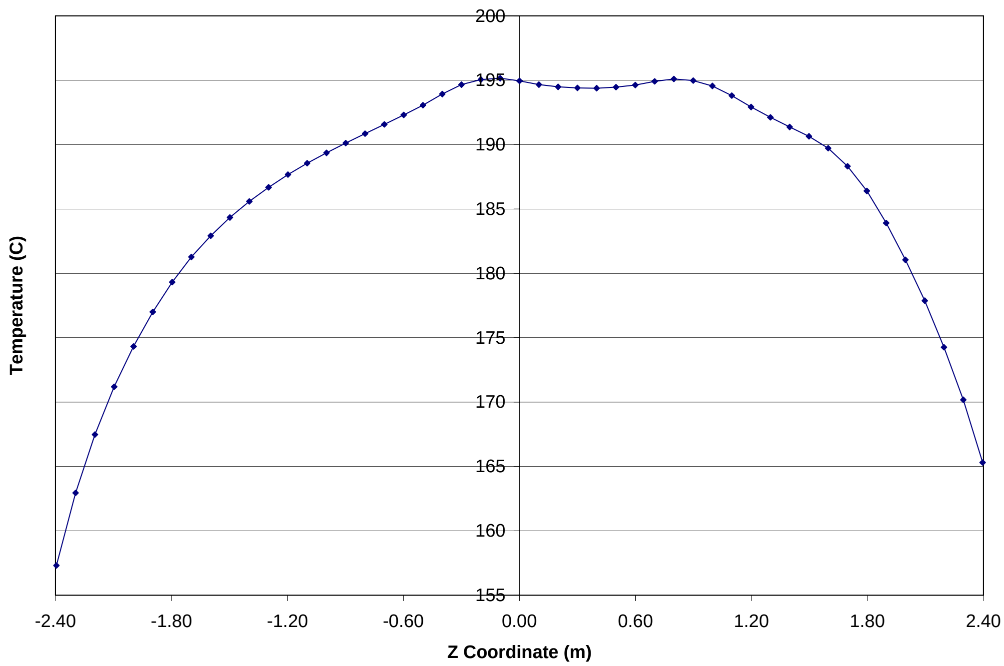

Figure 18. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 7a

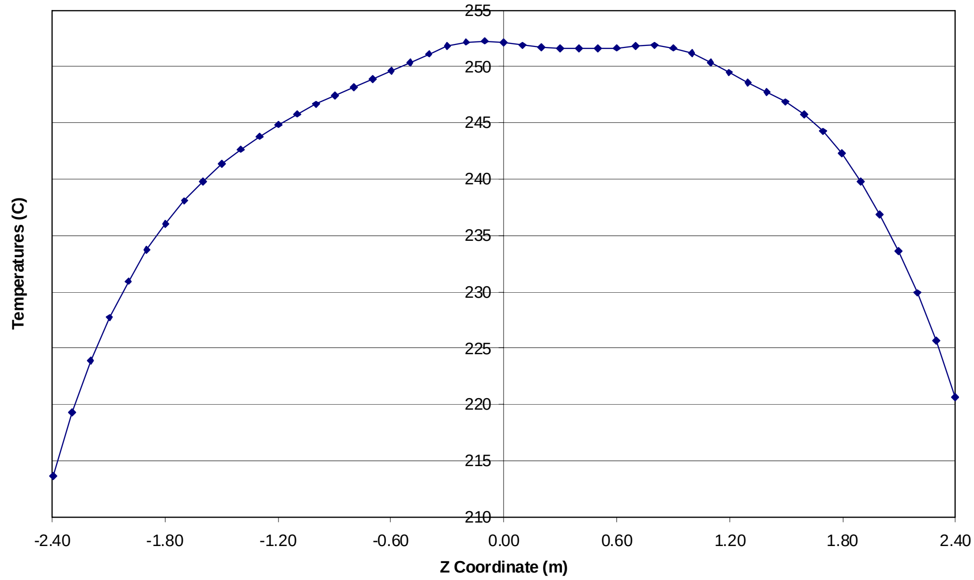

Figure 19. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 7a post

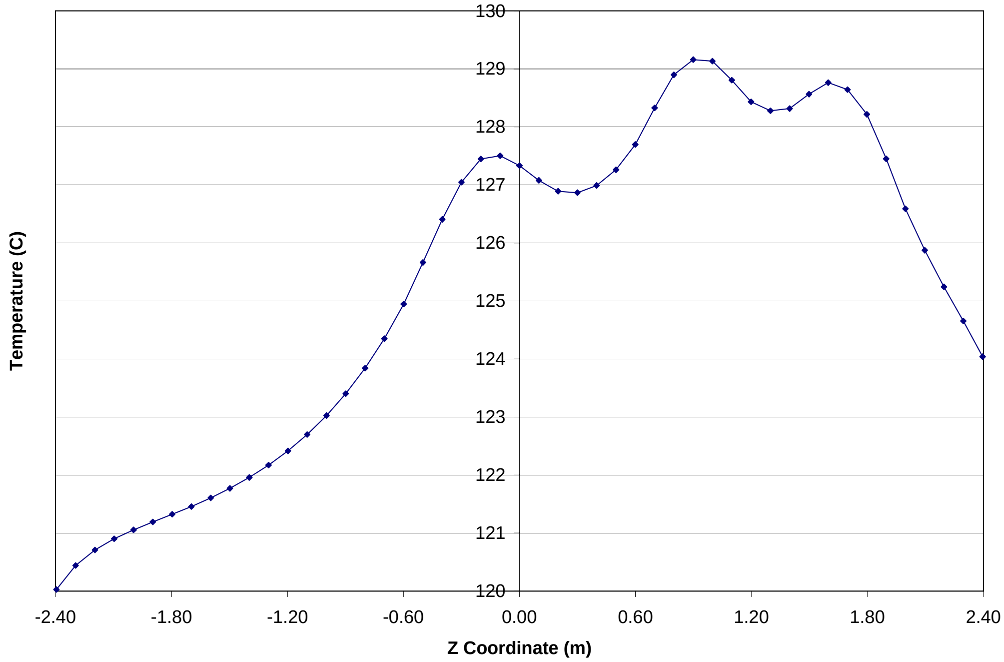

Figure 20. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 8a

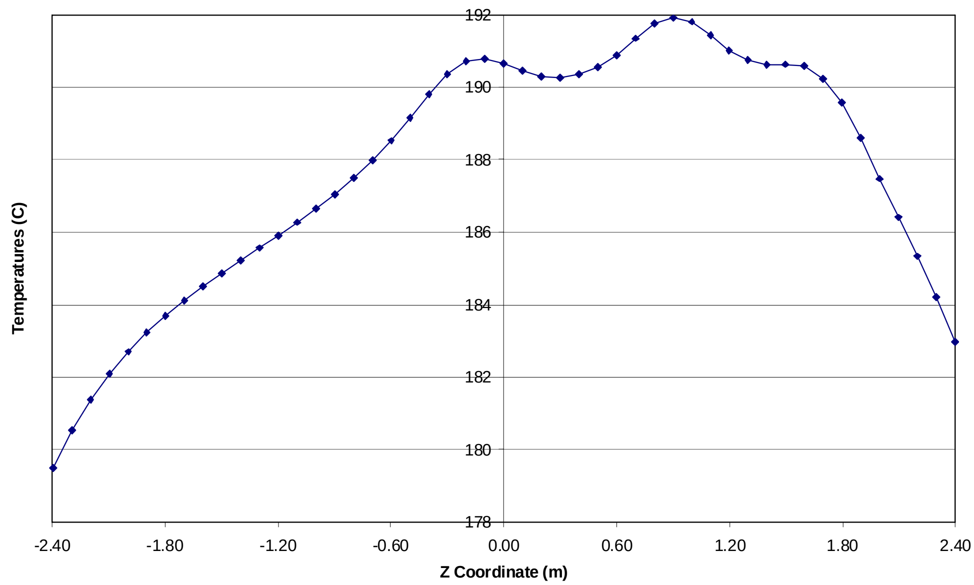

Figure 21. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 8a post

Attachment II – Naval Long Canister Outer Top Surface Temperature Plots for Helium Gas Fill in PRE-Closure And AIR In Post-Closure

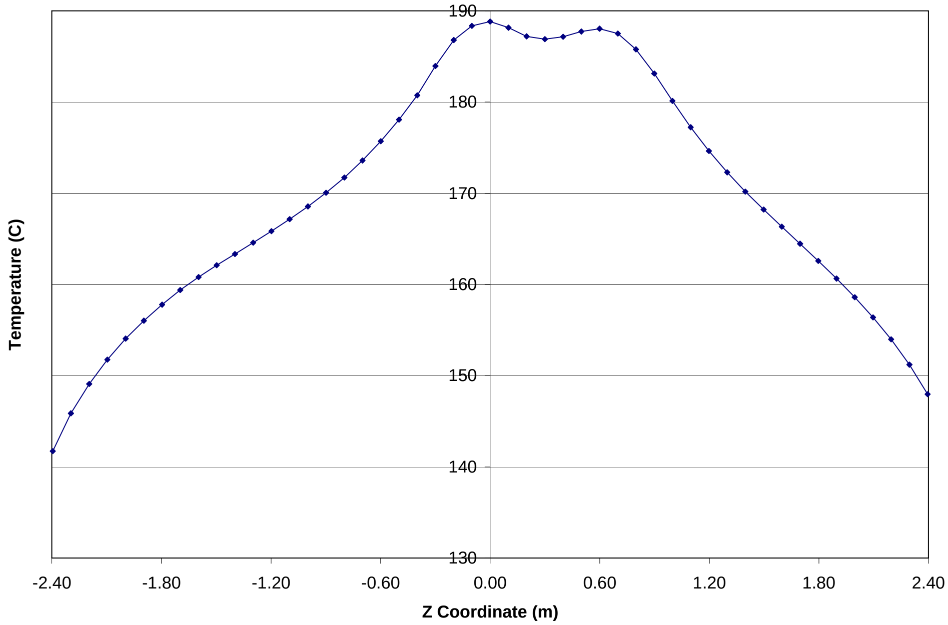

Figure 22. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 1h

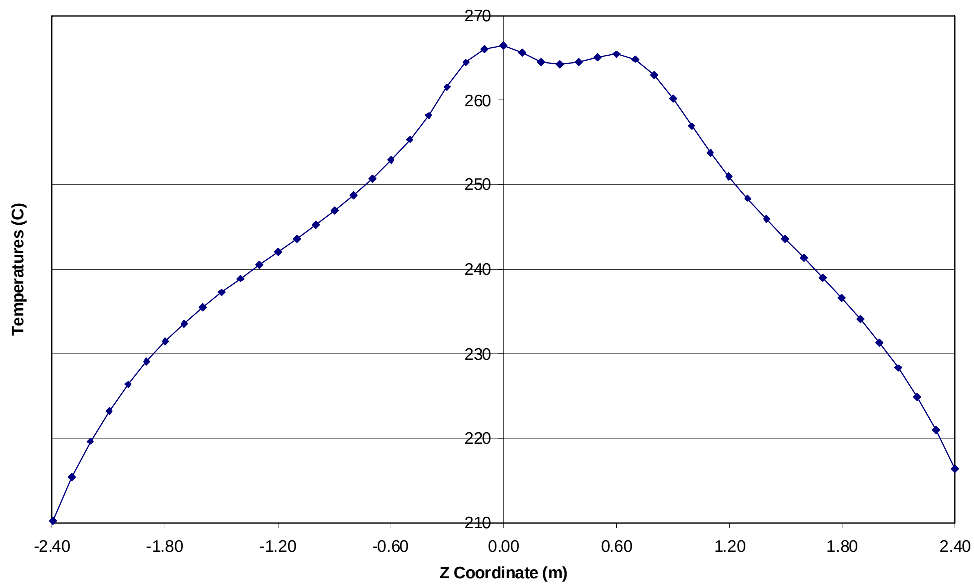

Figure 23. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 1a post

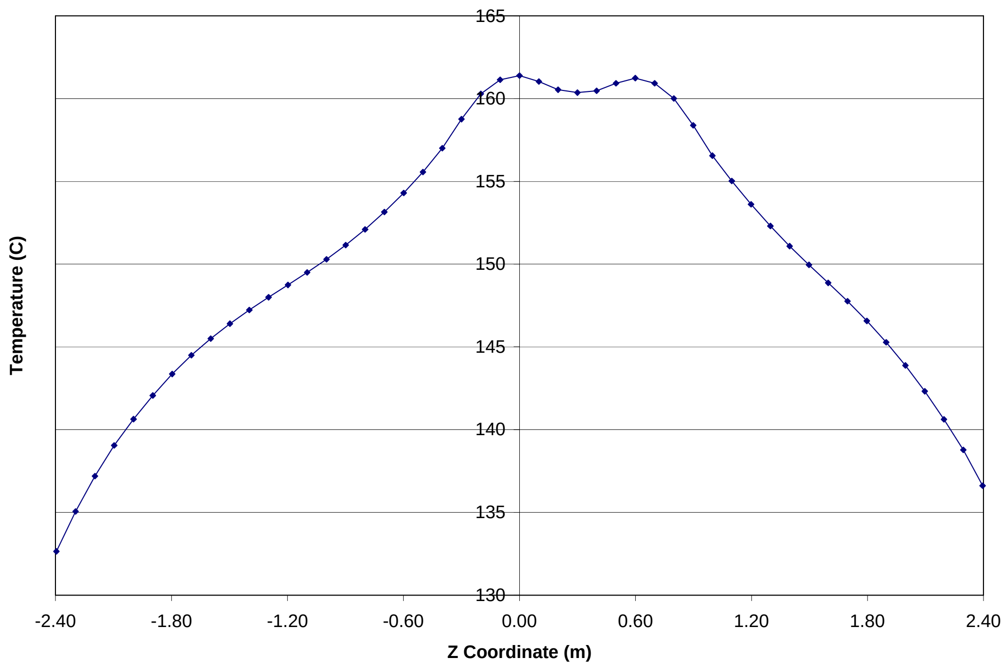

Figure 24. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 2h

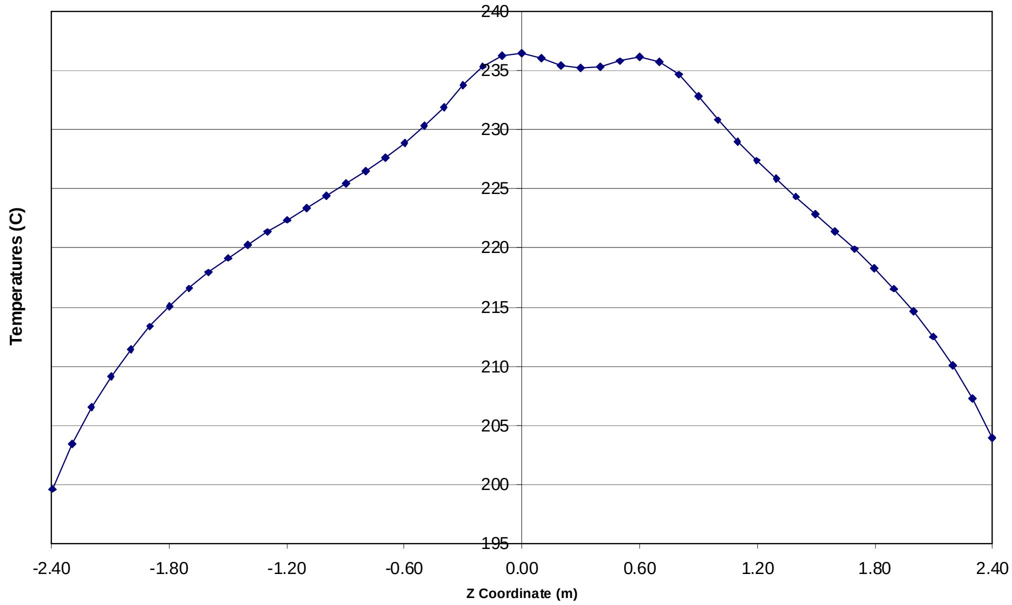

Figure 25. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 2a post

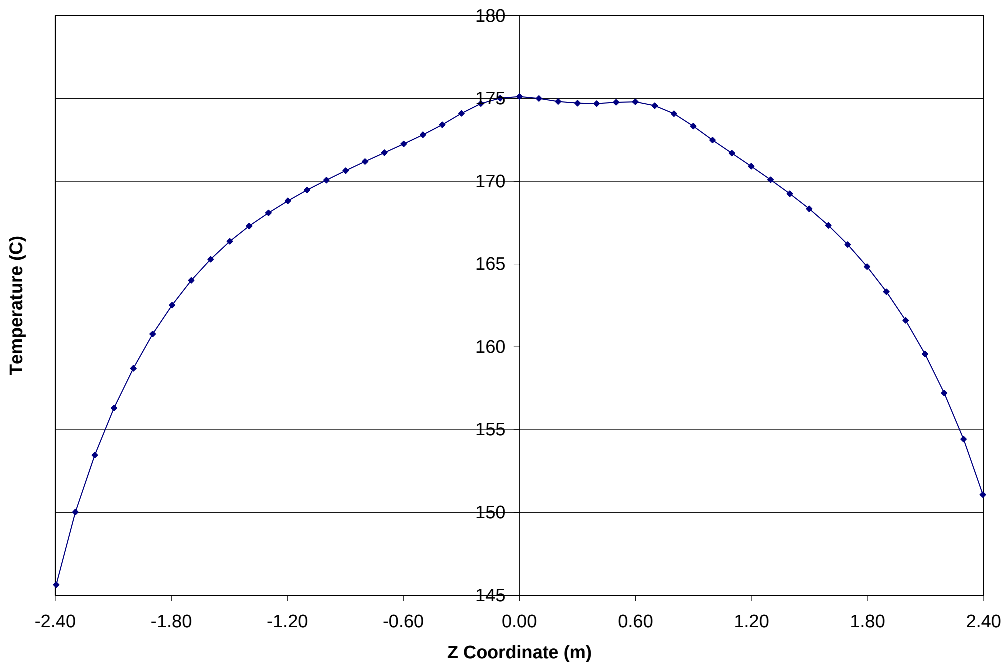

Figure 26. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 3h

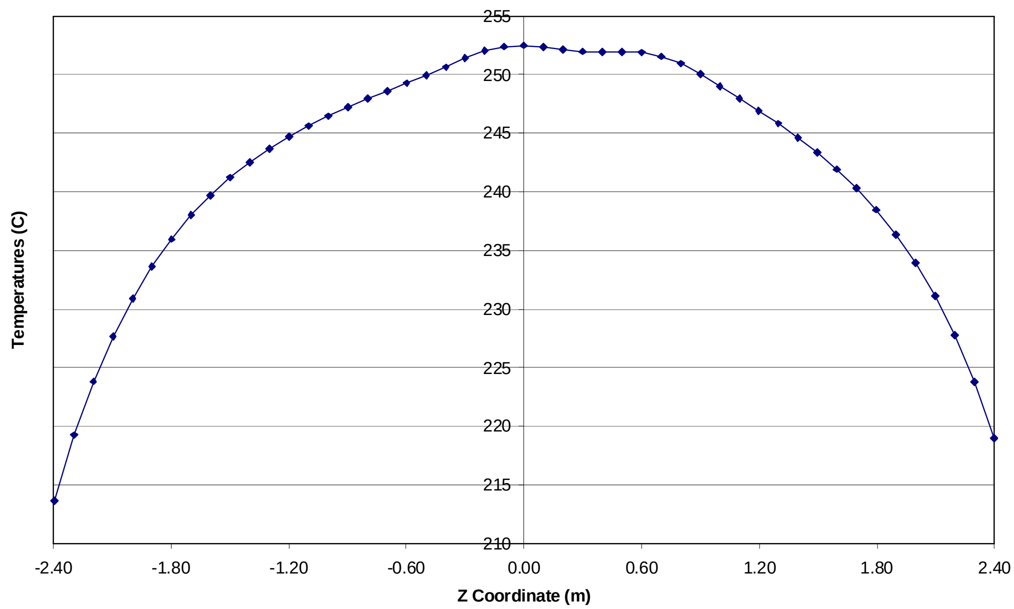

Figure 27. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 3a post

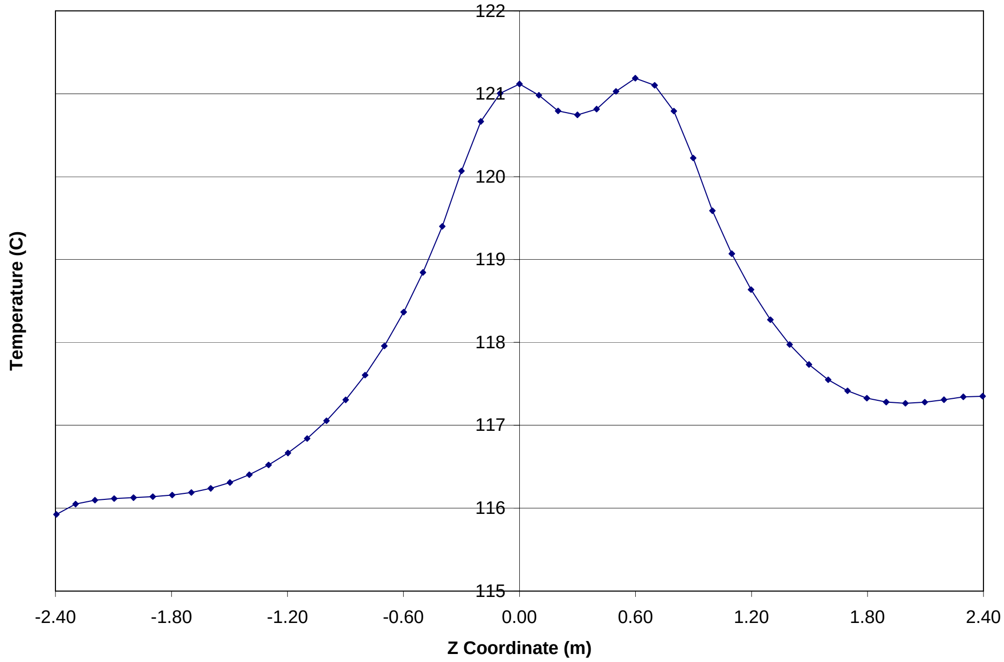

Figure 28. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 4h

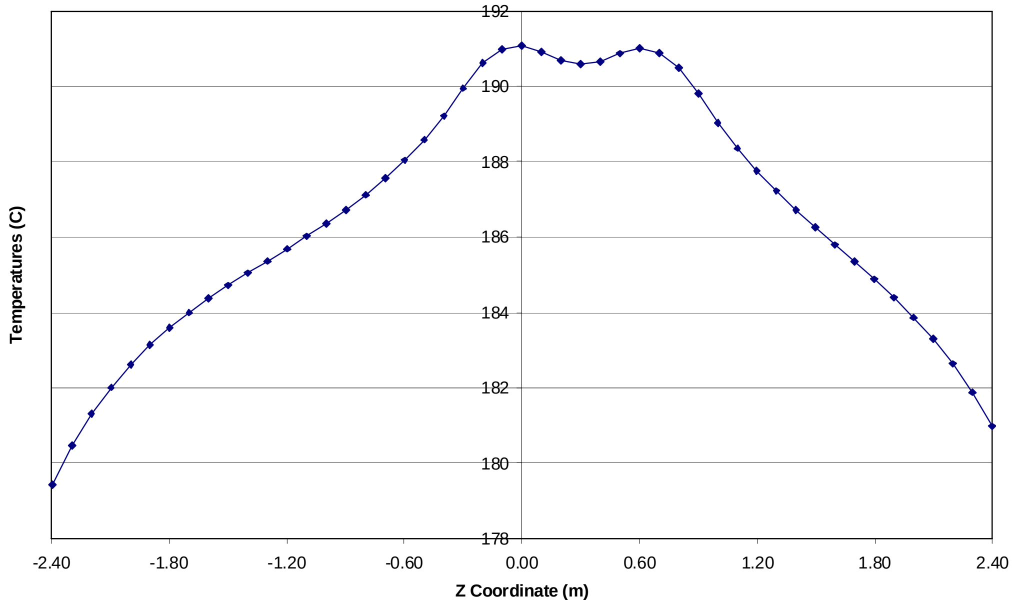

Figure 29. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 4a post

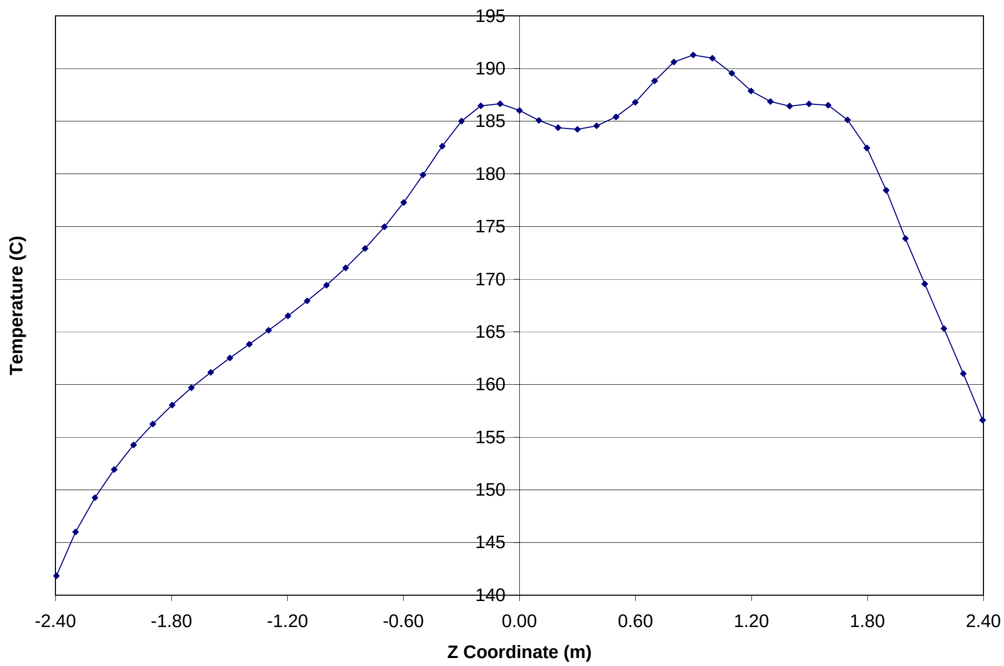

Figure 30. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 5h

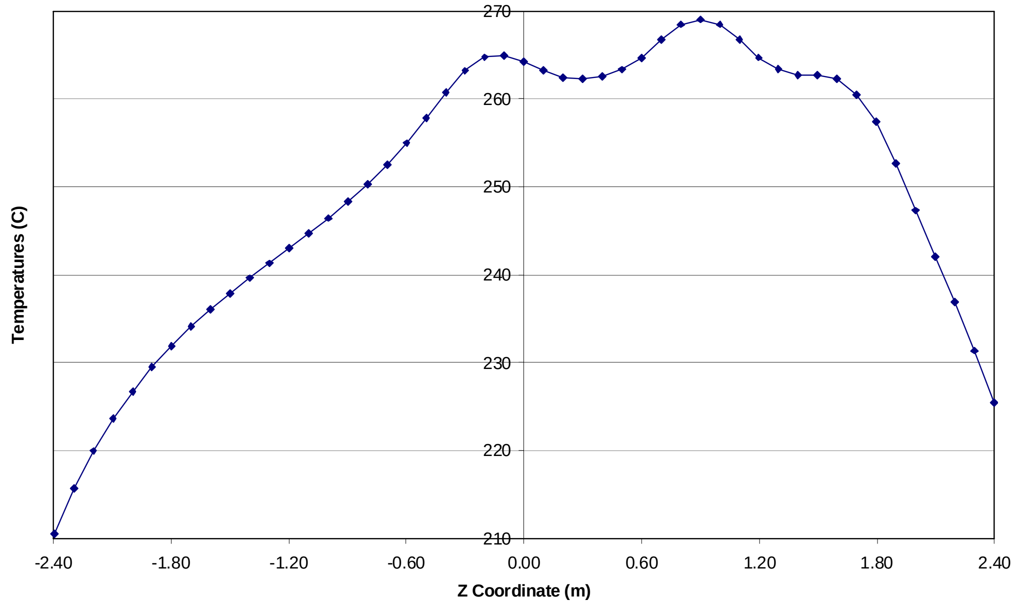

Figure 31. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 5a post

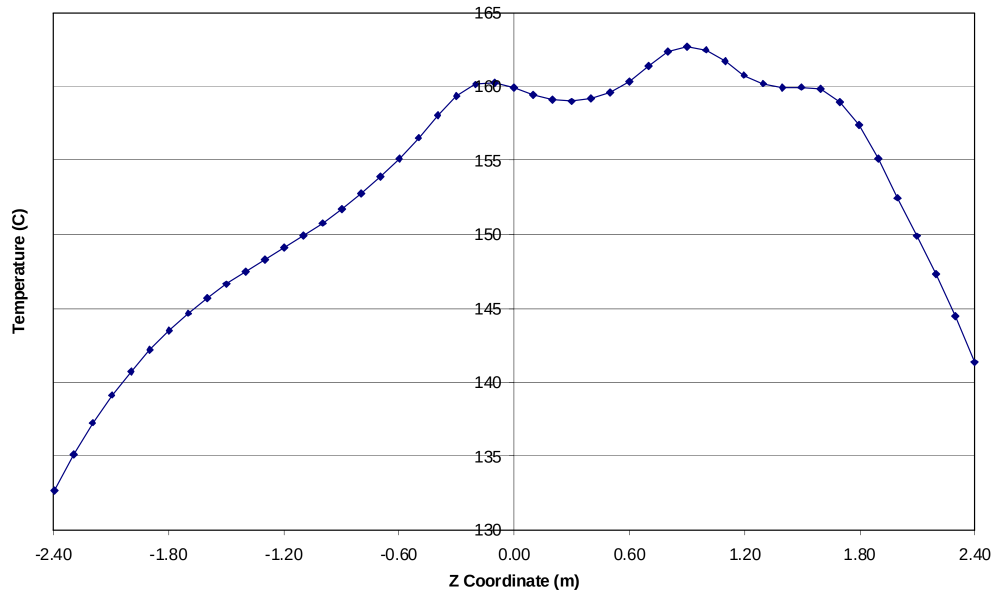

Figure 32. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 6h

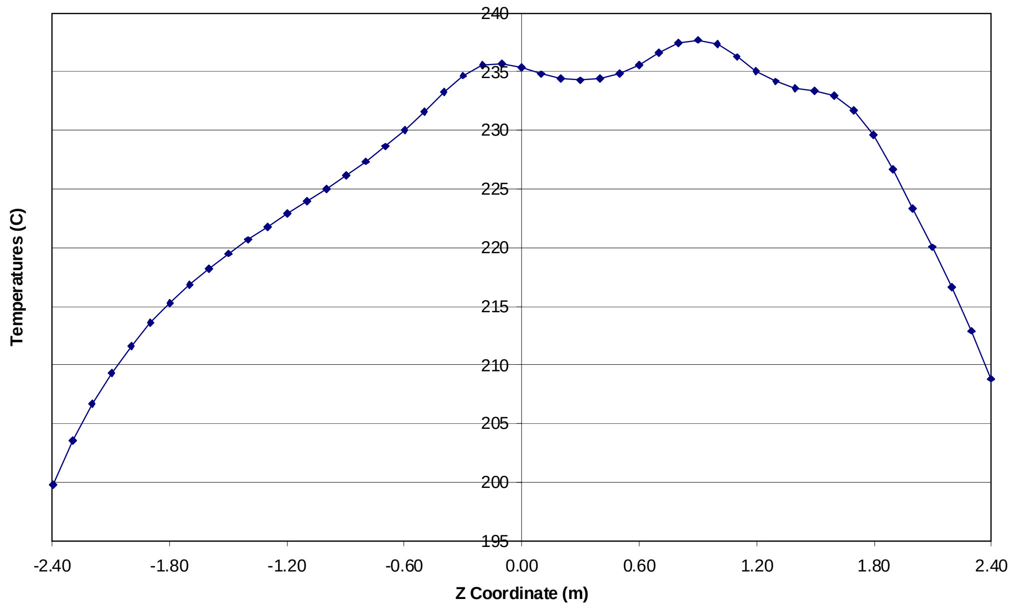

Figure 33. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 6a post

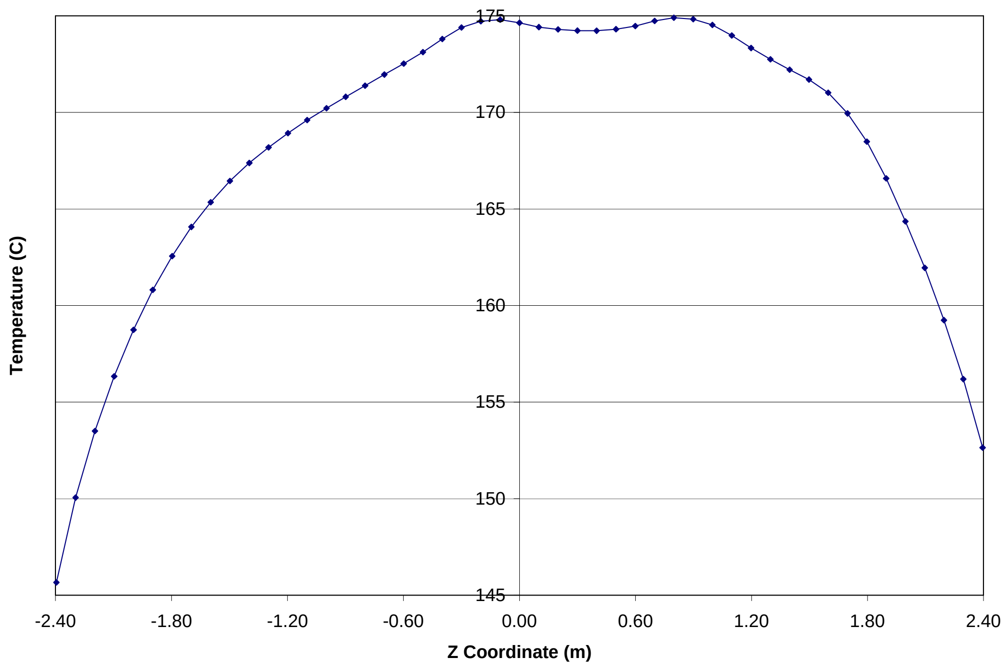

Figure 34. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 7h

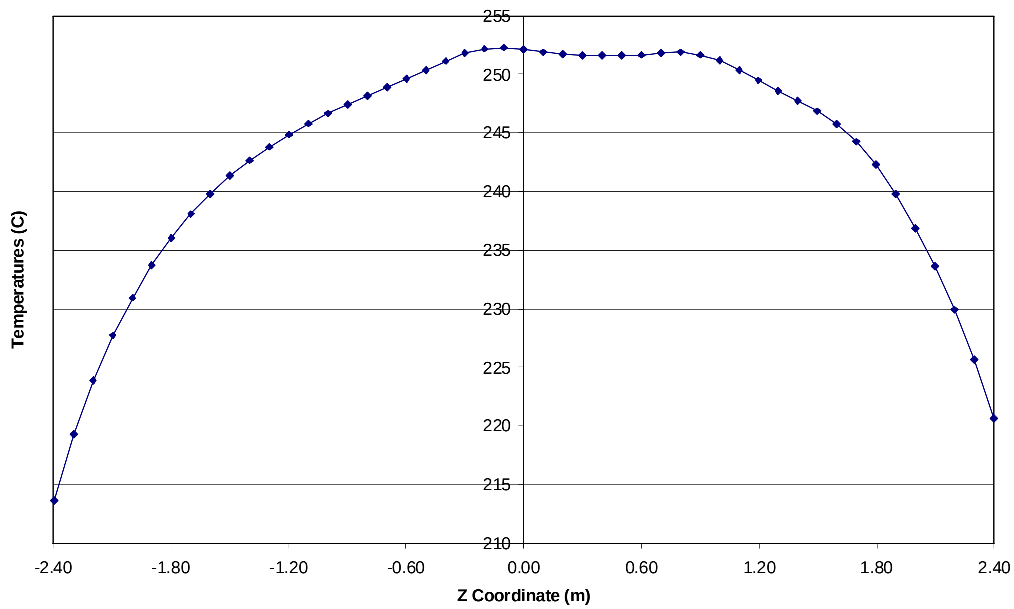

Figure 35. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 7a post

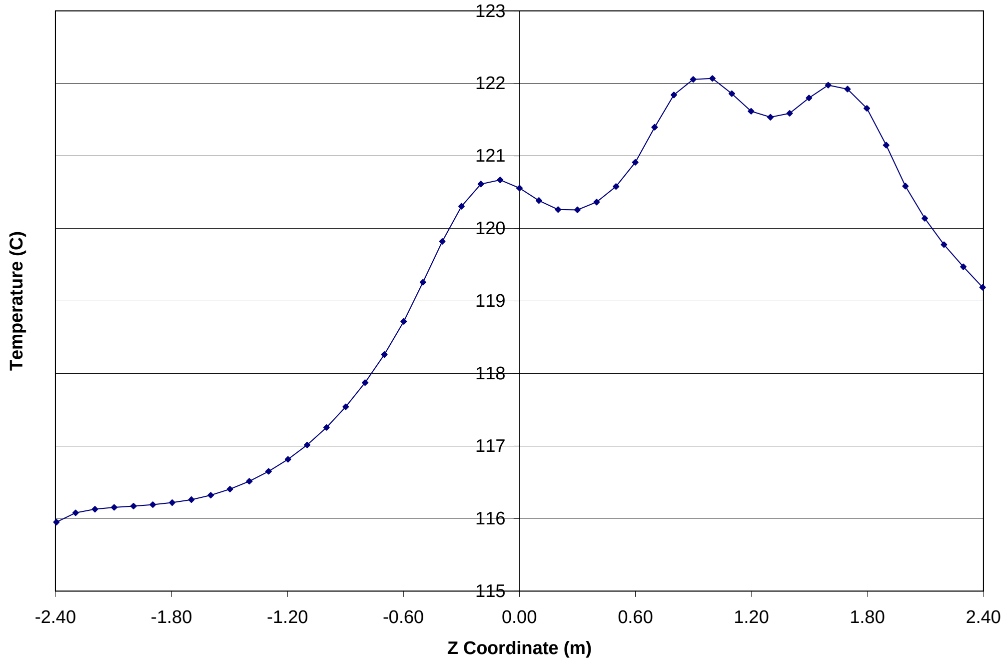

Figure 36. Naval Long Canister Temperatures along the Z axis for Peak Pre-closure at 60 days – Case 8h

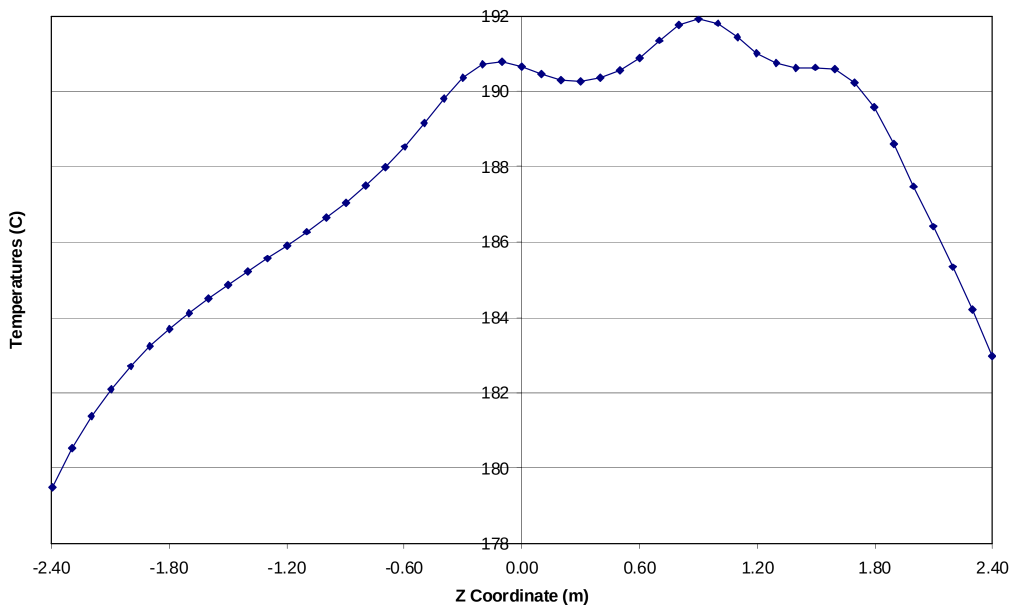

Figure 37. Naval Long Canister Temperatures along the Z axis for Peak Post-closure at 70 years after emplacement – Case 8a post

Attachment III – Temperature Boundary Conditions

Table 28 contains drift wall and invert temperature boundary conditions used in this calculation, which were calculated in Ref. 29, Attachment III. They represent the temperature conditions in both surface facility and subsurface drift emplacement as discussed in Section 6.2.

Table 28. Three-Dimensional Twelve Waste Package Repository Segment Drift Wall Surface Temperatures

Time (s)	Time (years)	Drift Wall – Side Temperature (°C)	Drift Wall – Top Temperature (°C)	Top of Invert Temperature (°C)
0	0.00	50.0000	50.0000	50.0000
2592000	0.08	50.0000	50.0000	50.0000
2678400	0.08	66.1266	66.1266	66.1266
2764800	0.09	71.3368	71.3368	71.3368
2851200	0.09	74.7926	74.7926	74.7926
2937600	0.09	77.4259	77.4259	77.4259
3024000	0.10	79.5829	79.5829	79.5829
3110400	0.10	81.4371	81.4371	81.4371
5184000	0.16	109.488	109.488	109.488
5184000	0.16	25.2465	25.2329	25.2611
5184032	0.16	25.2758	25.2596	25.2843
5702430	0.18	46.1805	45.0206	45.6881
6220800	0.20	44.1508	43.2685	43.6821
6739200	0.21	43.7889	42.9751	43.3284
7257600	0.23	43.9733	43.1857	43.5323
7776000	0.25	57.1322	55.2251	56.4325
8035200	0.25	67.8838	65.3357	67.3433
8294400	0.26	75.3491	72.5895	74.8846
8553600	0.27	80.9320	78.1117	80.4073
8812800	0.28	85.4662	82.6360	84.8406
9072000	0.29	89.3344	86.5144	88.6069
9331200	0.30	92.7370	89.9364	91.9177
9590400	0.30	95.7906	93.0139	94.8916
9849600	0.31	98.5701	95.8198	97.6029
10108800	0.32	101.129	98.4062	100.104
10368000	0.33	96.5326	94.4347	95.6093
15166000	0.48	62.8242	62.2003	62.2184
19964000	0.63	60.3717	59.7736	59.9189
24762000	0.79	60.3195	59.7020	59.8870
29560000	0.94	60.8775	60.2466	60.4467
36742000	1.17	61.9973	61.3613	61.5663
68299000	2.17	65.7580	65.1525	65.3381
99857000	3.17	68.1590	67.5780	67.7504
131414000	4.17	69.7644	69.2034	69.3664
162974000	5.17	70.8822	70.3380	70.4935
194534000	6.17	71.6594	71.1305	71.2793
226084000	7.17	72.2296	71.7129	71.8579
257644000	8.17	72.6009	72.0966	72.2369
289204000	9.17	72.8614	72.3669	72.5054

320764000	10.17	73.0187	72.5345	72.6688
478544000	15.17	72.8855	72.4422	72.5660
636334000	20.18	71.9961	71.5859	71.7032
794124000	25.18	70.8531	70.4715	70.5827
951914000	30.18	69.6826	69.3258	69.4313
1109684000	35.19	68.4401	68.1063	68.2072
1267484000	40.19	67.2215	66.9080	67.0056
1425284000	45.20	66.0403	65.7452	65.8398
1583084000	50.20	64.9232	64.6446	64.7366
1583107232	50.20	64.9152	64.6376	64.7311
1583366430	50.21	67.4920	66.6550	67.5367
1583625630	50.22	71.7178	70.2894	72.4054
1583884830	50.22	74.8942	73.1537	75.9246
1584144000	50.23	77.3506	75.4477	78.5261
1584403200	50.24	79.3460	77.3540	80.5742
1584662400	50.25	81.0318	78.9883	82.2714
1584921600	50.26	82.4968	80.4225	83.7291
1585180800	50.27	83.7961	81.7034	85.0128
1585440000	50.27	84.9661	82.8629	86.1637
1585699200	50.28	86.0325	83.9238	87.2097
1586263000	50.30	88.0696	85.9594	89.2035
1589418800	50.40	95.7382	93.6933	96.7106
1592574500	50.50	100.3030	98.4857	101.1850
1595730200	50.60	103.7910	101.6960	104.8220
1598886200	50.70	107.5090	105.4660	108.5120
1602042200	50.80	110.6400	108.8550	111.5660
1605197200	50.90	112.8100	111.0150	113.7600
1608353200	51.00	114.6840	112.8140	115.6060
1611509200	51.10	116.6190	114.7500	117.4830
1614665200	51.20	118.6550	116.7930	119.4650
1646222200	52.20	131.5480	129.8780	132.1570
1677780200	53.20	140.9990	139.4870	141.5780
1709337200	54.20	145.4820	144.0290	146.0220
1740897200	55.20	150.8470	149.4870	151.2360
1772457200	56.20	154.4770	153.1450	154.9280
1804007200	57.20	156.6730	155.3650	157.1280
1835567200	58.21	157.9600	156.6860	158.3950
1867127200	59.21	159.2100	157.9770	159.6010
1898687200	60.21	160.7770	159.5940	161.1130
2214257200	70.21	164.7120	163.6720	165.0410
2529837200	80.22	162.1230	161.1920	162.4370
2845407200	90.23	159.8450	158.9610	160.1230
3161007200	100.23	157.4650	156.6220	157.7210
3476607200	110.24	155.8090	155.0080	156.0580
3792107200	120.25	153.9300	153.1690	154.1740
4107707200	130.25	151.6390	150.9140	151.8780
4423307200	140.26	148.9510	148.2610	149.1850
4738907200	150.27	145.8840	145.2290	146.1130
7894607200	250.34	136.6200	136.1130	136.8210

11050407200	350.41	132.5400	132.1080	132.7180
14206107200	450.47	129.6030	129.2240	129.7640
17362107200	550.55	127.0100	126.6730	127.1570
20518107200	650.62	124.6990	124.3940	124.8330
23673107200	750.67	122.4640	122.1860	122.5890
26829107200	850.75	120.3230	120.0680	120.4400
29985107200	950.82	118.2680	118.0320	118.3780
33141107200	1050.90	116.5040	116.2810	116.6090
64698107200	2051.56	97.1565	97.01340	97.2309
96256107200	3052.26	83.5470	83.4199	83.6214
1.27813E+11	4052.93	74.3076	74.1854	74.3844
1.59373E+11	5053.69	67.8375	67.7188	67.9157
1.90933E+11	6054.45	63.1127	62.9980	63.1909
2.22483E+11	7054.89	59.5235	59.4128	59.6013
2.54043E+11	8055.65	56.6585	56.5518	56.7352
2.85603E+11	9056.42	54.2876	54.1849	54.3629
3.17163E+11	10057.18	52.2645	52.1655	52.3382

Attachment IV – List of Files on Attachment V (CD)

* File sizes and times may vary with operating system.

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Volume in drive D is nav-3d
 Volume Serial Number is 340A-2DBF

 Directory of D:\

10/03/2005  02:08p      <DIR>          ANSYS files
10/03/2005  12:54p      <DIR>          Excel Data
               0 File(s)              0 bytes

 Directory of D:\ANSYS files

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10/03/2005  02:08p      <DIR>          ..
10/03/2005  03:07p      <DIR>          Long
10/03/2005  01:57p      <DIR>          Short
               0 File(s)              0 bytes

 Directory of D:\ANSYS files\Long

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10/03/2005  02:30p      <DIR>          post_air
10/03/2005  03:40p      <DIR>          pre_air
10/03/2005  03:03p      <DIR>          pre_helium
               0 File(s)              0 bytes

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10/04/2005  09:15a      <DIR>          nav3d_2a
10/04/2005  09:16a      <DIR>          nav3d_3a
10/04/2005  09:16a      <DIR>          nav3d_4a
10/04/2005  09:16a      <DIR>          nav3d_5a
11/17/2005  03:10p      <DIR>          nav3d_6a
10/04/2005  09:17a      <DIR>          nav3d_7a
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09/12/2005  06:56a               8,657 navheatgen.dat
09/12/2005  06:56a              41,519 navy_post.inp
09/12/2005  07:02a              14,382 props.dat
```

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09/15/2005  12:18p              44,063 temps_post.out
09/12/2005  06:56a              17,842 temps_post.parm
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09/12/2005  06:59a               8,657 navheatgen.dat
09/12/2005  06:59a              41,519 navy_post.inp
09/12/2005  06:59a              14,382 props.dat
09/15/2005  12:18p              44,063 temps_post.out
09/12/2005  06:59a              17,842 temps_post.parm
               7 File(s)        133,141 bytes

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09/12/2005  07:03a               8,657 navheatgen.dat
09/12/2005  07:03a              41,519 navy_post.inp
09/12/2005  07:02a              14,382 props.dat
09/15/2005  12:18p              44,063 temps_post.out
09/12/2005  07:02a              17,842 temps_post.parm
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09/12/2005  07:06a               8,657 navheatgen.dat
09/12/2005  07:06a              41,519 navy_post.inp
09/12/2005  07:06a              14,382 props.dat
09/15/2005  12:19p              44,063 temps_post.out
09/12/2005  07:06a              17,842 temps_post.parm
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09/12/2005  07:09a               8,657 navheatgen.dat
09/12/2005  07:09a           1,104,872 navy_post.out
09/12/2005  07:09a              14,382 props.dat
09/15/2005  12:19p              44,063 temps_post.out
09/12/2005  07:09a              17,842 temps_post.parm
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11/17/2005  03:10p               8,657 navheatgen.dat
09/12/2005  07:13a              41,519 navy_post.inp
11/17/2005  03:10p           1,075,080 navy_post.out
09/12/2005  07:13a              14,382 props.dat
09/12/2005  07:13a              17,842 temps_post.parm
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09/12/2005  07:18a               8,657 navheatgen.dat
09/12/2005  07:18a              41,519 navy_post.inp
09/12/2005  07:16a              14,382 props.dat
09/15/2005  12:20p              44,063 temps_post.out
09/12/2005  07:16a              17,842 temps_post.parm
               7 File(s)        133,141 bytes

 Directory of D:\ANSYS files\Long\post_air\nav3d_8a

10/04/2005  09:17a      <DIR>          .
10/04/2005  09:17a      <DIR>          ..
09/12/2005  07:22a               5,502 AnsysBin1.dat
09/15/2005  09:27a               1,176 get_temps.inp
09/12/2005  07:21a               8,657 navheatgen.dat
09/12/2005  07:21a              41,519 navy_post.inp
09/12/2005  07:19a              14,382 props.dat
09/15/2005  12:20p              44,063 temps_post.out
09/12/2005  07:19a              17,842 temps_post.parm
               7 File(s)        133,141 bytes

 Directory of D:\ANSYS files\Long\pre_air

10/03/2005  03:40p      <DIR>          .
10/03/2005  03:40p      <DIR>          ..
10/04/2005  09:18a      <DIR>          nav3d_1a
10/04/2005  09:18a      <DIR>          nav3d_2a
10/04/2005  09:18a      <DIR>          nav3d_3a
10/04/2005  09:18a      <DIR>          nav3d_4a
10/04/2005  09:19a      <DIR>          nav3d_5a
11/17/2005  03:07p      <DIR>          nav3d_6a
10/04/2005  09:19a      <DIR>          nav3d_7a
10/04/2005  09:19a      <DIR>          nav3d_8a
```

```
               0 File(s)              0 bytes

 Directory of D:\ANSYS files\Long\pre_air\nav3d_1a

10/04/2005  09:18a      <DIR>          .
10/04/2005  09:18a      <DIR>          ..
09/09/2005  07:12a               5,502 AnsysBin1.dat
09/15/2005  09:16a               1,172 get_temps.inp
09/09/2005  07:12a               8,657 navheatgen.dat
09/09/2005  07:12a              37,616 navy_pre.inp
09/09/2005  07:12a           1,285,840 navy_pre.out
09/09/2005  08:45a              14,382 props.dat
09/15/2005  09:16a              59,405 temps_pre.out
09/09/2005  08:45a              10,897 temps_pre.parm
               8 File(s)      1,423,471 bytes

 Directory of D:\ANSYS files\Long\pre_air\nav3d_2a

10/04/2005  09:18a      <DIR>          .
10/04/2005  09:18a      <DIR>          ..
09/09/2005  08:48a               5,502 AnsysBin1.dat
09/15/2005  09:16a               1,172 get_temps.inp
09/09/2005  08:49a               8,657 navheatgen.dat
09/09/2005  08:48a              37,616 navy_pre.inp
09/09/2005  08:48a           1,289,462 navy_pre.out
09/09/2005  08:48a              14,382 props.dat
09/15/2005  09:16a              59,405 temps_pre.out
09/09/2005  08:48a              10,897 temps_pre.parm
               8 File(s)      1,427,093 bytes

 Directory of D:\ANSYS files\Long\pre_air\nav3d_3a

10/04/2005  09:18a      <DIR>          .
10/04/2005  09:18a      <DIR>          ..
09/09/2005  09:10a               5,502 AnsysBin1.dat
09/15/2005  09:16a               1,172 get_temps.inp
09/09/2005  09:11a               8,657 navheatgen.dat
09/09/2005  09:11a              37,616 navy_pre.inp
09/09/2005  09:11a           1,284,544 navy_pre.out
09/09/2005  09:24a              14,382 props.dat
09/15/2005  09:16a              59,405 temps_pre.out
09/09/2005  09:24a              10,897 temps_pre.parm
               8 File(s)      1,422,175 bytes

 Directory of D:\ANSYS files\Long\pre_air\nav3d_4a

10/04/2005  09:18a      <DIR>          .
10/04/2005  09:18a      <DIR>          ..
09/09/2005  09:42a               5,502 AnsysBin1.dat
09/15/2005  09:17a               1,172 get_temps.inp
09/09/2005  09:42a               8,657 navheatgen.dat
09/09/2005  09:42a              37,616 navy_pre.inp
09/09/2005  09:42a           1,275,872 navy_pre.out
09/09/2005  09:42a              14,382 props.dat
```

```
09/15/2005  09:17a              59,405 temps_pre.out
09/09/2005  09:42a              10,897 temps_pre.parm
               8 File(s)      1,413,503 bytes

 Directory of D:\ANSYS files\Long\pre_air\nav3d_5a

10/04/2005  09:19a      <DIR>          .
10/04/2005  09:19a      <DIR>          ..
09/09/2005  11:48a               5,502 AnsysBin1.dat
09/15/2005  09:17a               1,172 get_temps.inp
09/09/2005  11:48a               8,657 navheatgen.dat
09/09/2005  11:48a              37,616 navy_pre.inp
09/09/2005  11:48a           1,285,718 navy_pre.out
09/09/2005  11:48a              14,382 props.dat
09/15/2005  09:17a              59,405 temps_pre.out
09/09/2005  11:48a              10,897 temps_pre.parm
               8 File(s)      1,423,349 bytes

 Directory of D:\ANSYS files\Long\pre_air\nav3d_6a

11/17/2005  03:07p      <DIR>          .
11/17/2005  03:07p      <DIR>          ..
09/09/2005  12:18p               5,502 AnsysBin1.dat
09/15/2005  09:17a               1,172 get_temps.inp
11/17/2005  03:07p               8,657 navheatgen.dat
09/09/2005  12:17p              37,616 navy_pre.inp
11/17/2005  03:07p           1,258,490 navy_pre.out
09/09/2005  12:14p              14,382 props.dat
09/09/2005  12:14p              10,897 temps_pre.parm
11/17/2005  03:07p              58,488 temp_pre.out
               8 File(s)      1,395,204 bytes

 Directory of D:\ANSYS files\Long\pre_air\nav3d_7a

10/04/2005  09:19a      <DIR>          .
10/04/2005  09:19a      <DIR>          ..
09/09/2005  12:32p               5,502 AnsysBin1.dat
09/15/2005  09:18a               1,172 get_temps.inp
09/09/2005  12:31p               8,657 navheatgen.dat
09/09/2005  12:31p              37,616 navy_pre.inp
09/09/2005  12:31p           1,284,544 navy_pre.out
09/15/2005  09:18a              59,405 temps_pre.out
09/09/2005  12:31p              10,897 temps_pre.parm
               7 File(s)      1,407,793 bytes

 Directory of D:\ANSYS files\Long\pre_air\nav3d_8a

10/04/2005  09:19a      <DIR>          .
10/04/2005  09:19a      <DIR>          ..
09/09/2005  12:42p               5,502 AnsysBin1.dat
09/15/2005  09:18a               1,172 get_temps.inp
09/09/2005  12:41p               8,657 navheatgen.dat
09/09/2005  12:41p              37,616 navy_pre.inp
09/09/2005  12:41p           1,275,872 navy_pre.out
```

```
09/09/2005  12:41p              14,382 props.dat
09/15/2005  09:18a              59,405 temps_pre.out
09/09/2005  12:41p              10,897 temps_pre.parm
               8 File(s)      1,413,503 bytes

 Directory of D:\ANSYS files\Long\pre_helium

10/03/2005  03:03p      <DIR>          .
10/03/2005  03:03p      <DIR>          ..
10/04/2005  09:19a      <DIR>          nav3d_1h
10/04/2005  09:20a      <DIR>          nav3d_2h
10/04/2005  09:20a      <DIR>          nav3d_3h
10/04/2005  09:20a      <DIR>          nav3d_4h
10/04/2005  09:20a      <DIR>          nav3d_5h
11/17/2005  03:02p      <DIR>          nav3d_6h
10/04/2005  09:21a      <DIR>          nav3d_7h
10/04/2005  09:21a      <DIR>          nav3d_8h
               0 File(s)              0 bytes

 Directory of D:\ANSYS files\Long\pre_helium\nav3d_1h

10/04/2005  09:19a      <DIR>          .
10/04/2005  09:19a      <DIR>          ..
09/09/2005  12:59p               5,502 AnsysBin1.dat
09/15/2005  09:13a               1,172 get_temps.inp
09/09/2005  12:59p               8,657 navheatgen.dat
09/09/2005  12:59p              37,633 navy_pre.inp
09/09/2005  12:59p           1,290,576 navy_pre.out
09/09/2005  12:58p              14,382 props.dat
09/15/2005  09:13a              59,405 temps_pre.out
09/09/2005  12:58p              10,897 temps_pre.parm
               8 File(s)      1,428,224 bytes

 Directory of D:\ANSYS files\Long\pre_helium\nav3d_2h

10/04/2005  09:20a      <DIR>          .
10/04/2005  09:20a      <DIR>          ..
09/09/2005  01:05p               5,502 AnsysBin1.dat
09/15/2005  09:13a               1,172 get_temps.inp
09/09/2005  01:05p               8,657 navheatgen.dat
09/09/2005  01:13p              37,633 navy_pre.inp
09/09/2005  01:13p           1,293,744 navy_pre.out
09/09/2005  01:13p              14,382 props.dat
09/15/2005  09:13a              59,405 temps_pre.out
09/09/2005  01:13p              10,897 temps_pre.parm
               8 File(s)      1,431,392 bytes

 Directory of D:\ANSYS files\Long\pre_helium\nav3d_3h

10/04/2005  09:20a      <DIR>          .
10/04/2005  09:20a      <DIR>          ..
09/09/2005  01:39p               5,502 AnsysBin1.dat
09/15/2005  09:14a               1,172 get_temps.inp
09/09/2005  01:38p               8,657 navheatgen.dat
```

```
09/09/2005  01:38p              37,633 navy_pre.inp
09/09/2005  01:38p           1,292,705 navy_pre.out
09/09/2005  01:38p              14,382 props.dat
09/15/2005  09:14a              59,405 temps_pre.out
09/09/2005  01:38p              10,897 temps_pre.parm
               8 File(s)      1,430,353 bytes

 Directory of D:\ANSYS files\Long\pre_helium\nav3d_4h

10/04/2005  09:20a      <DIR>          .
10/04/2005  09:20a      <DIR>          ..
09/09/2005  01:44p               5,502 AnsysBin1.dat
09/15/2005  09:14a               1,172 get_temps.inp
09/09/2005  01:43p               8,657 navheatgen.dat
09/09/2005  01:43p              37,633 navy_pre.inp
09/09/2005  01:43p           1,275,456 navy_pre.out
09/09/2005  01:43p              14,382 props.dat
09/15/2005  09:14a              59,405 temps_pre.out
09/09/2005  01:43p              10,897 temps_pre.parm
               8 File(s)      1,413,104 bytes

 Directory of D:\ANSYS files\Long\pre_helium\nav3d_5h

10/04/2005  09:20a      <DIR>          .
10/04/2005  09:20a      <DIR>          ..
09/09/2005  01:50p               5,502 AnsysBin1.dat
09/15/2005  09:14a               1,172 get_temps.inp
09/09/2005  01:49p               8,657 navheatgen.dat
09/09/2005  01:49p              37,633 navy_pre.inp
09/09/2005  01:49p           1,289,559 navy_pre.out
09/09/2005  01:49p              14,382 props.dat
09/15/2005  09:14a              59,405 temps_pre.out
09/09/2005  01:49p              10,897 temps_pre.parm
               8 File(s)      1,427,207 bytes

 Directory of D:\ANSYS files\Long\pre_helium\nav3d_6h

11/17/2005  03:02p      <DIR>          .
11/17/2005  03:02p      <DIR>          ..
09/09/2005  01:59p               5,502 AnsysBin1.dat
09/15/2005  09:14a               1,172 get_temps.inp
11/17/2005  03:02p               8,657 navheatgen.dat
09/09/2005  01:59p              37,633 navy_pre.inp
11/17/2005  03:02p           1,263,598 navy_pre.out
09/09/2005  01:58p              14,382 props.dat
09/09/2005  01:58p              10,897 temps_pre.parm
11/17/2005  03:02p              58,488 temp_pre.out
               8 File(s)      1,400,329 bytes

 Directory of D:\ANSYS files\Long\pre_helium\nav3d_7h

10/04/2005  09:21a      <DIR>          .
10/04/2005  09:21a      <DIR>          ..
09/09/2005  02:03p               5,502 AnsysBin1.dat
```

```
09/15/2005  09:15a               1,172 get_temps.inp
09/09/2005  02:03p               8,657 navheatgen.dat
09/09/2005  02:04p              37,633 navy_pre.inp
09/09/2005  02:03p           1,292,030 navy_pre.out
09/09/2005  02:03p              14,382 props.dat
09/15/2005  09:15a              59,405 temps_pre.out
09/09/2005  02:03p              10,897 temps_pre.parm
               8 File(s)      1,429,678 bytes

 Directory of D:\ANSYS files\Long\pre_helium\nav3d_8h

10/04/2005  09:21a      <DIR>          .
10/04/2005  09:21a      <DIR>          ..
09/09/2005  02:36p               5,502 AnsysBin1.dat
09/15/2005  09:15a               1,172 get_temps.inp
09/09/2005  02:35p               8,657 navheatgen.dat
09/09/2005  02:35p              37,633 navy_pre.inp
09/09/2005  02:35p           1,275,492 navy_pre.out
09/09/2005  02:35p              14,382 props.dat
09/15/2005  09:15a              59,405 temps_pre.out
09/09/2005  02:35p              10,897 temps_pre.parm
               8 File(s)      1,413,140 bytes

 Directory of D:\ANSYS files\Short

10/03/2005  01:57p      <DIR>          .
10/03/2005  01:57p      <DIR>          ..
10/03/2005  01:18p      <DIR>          post_air
10/03/2005  02:07p      <DIR>          pre_air
10/03/2005  01:53p      <DIR>          pre_helium
               0 File(s)              0 bytes

 Directory of D:\ANSYS files\Short\post_air

10/03/2005  01:18p      <DIR>          .
10/03/2005  01:18p      <DIR>          ..
10/04/2005  09:22a      <DIR>          nav3d_1a
10/04/2005  09:22a      <DIR>          nav3d_2a
10/04/2005  09:22a      <DIR>          nav3d_3a
10/04/2005  09:22a      <DIR>          nav3d_4a
10/04/2005  09:23a      <DIR>          nav3d_5a
11/17/2005  03:09p      <DIR>          nav3d_6a
10/04/2005  09:23a      <DIR>          nav3d_7a
10/04/2005  09:23a      <DIR>          nav3d_8a
               0 File(s)              0 bytes

 Directory of D:\ANSYS files\Short\post_air\nav3d_1a

10/04/2005  09:22a      <DIR>          .
10/04/2005  09:22a      <DIR>          ..
09/15/2005  06:57a               5,502 AnsysBin1.dat
09/15/2005  02:24p               1,173 get_temps.inp
09/15/2005  06:56a               8,657 navheatgen.dat
09/15/2005  06:56a              41,517 navy_post.inp
```

```
09/15/2005  06:56a           1,084,368 navy_post.out
09/15/2005  06:56a              14,382 props.dat
09/15/2005  02:24p              43,253 temps_post.out
09/15/2005  06:56a              17,842 temps_post.parm
               8 File(s)      1,216,694 bytes

 Directory of D:\ANSYS files\Short\post_air\nav3d_2a

10/04/2005  09:22a      <DIR>          .
10/04/2005  09:22a      <DIR>          ..
09/15/2005  07:04a               5,502 AnsysBin1.dat
09/15/2005  02:24p               1,173 get_temps.inp
09/15/2005  07:03a               8,657 navheatgen.dat
09/15/2005  07:03a              41,517 navy_post.inp
09/15/2005  07:03a           1,084,080 navy_post.out
09/15/2005  07:03a              14,382 props.dat
09/15/2005  02:24p              43,253 temps_post.out
09/15/2005  07:03a              17,842 temps_post.parm
               8 File(s)      1,216,406 bytes

 Directory of D:\ANSYS files\Short\post_air\nav3d_3a

10/04/2005  09:22a      <DIR>          .
10/04/2005  09:22a      <DIR>          ..
09/15/2005  08:31a               5,502 AnsysBin1.dat
09/15/2005  02:24p               1,173 get_temps.inp
09/15/2005  08:30a               8,657 navheatgen.dat
09/15/2005  08:30a              41,517 navy_post.inp
09/15/2005  08:30a           1,084,224 navy_post.out
09/15/2005  08:29a              14,382 props.dat
09/15/2005  02:24p              43,253 temps_post.out
09/15/2005  08:29a              17,842 temps_post.parm
               8 File(s)      1,216,550 bytes

 Directory of D:\ANSYS files\Short\post_air\nav3d_4a

10/04/2005  09:22a      <DIR>          .
10/04/2005  09:22a      <DIR>          ..
09/15/2005  08:34a               5,502 AnsysBin1.dat
09/15/2005  02:25p               1,173 get_temps.inp
09/15/2005  08:33a               8,657 navheatgen.dat
09/15/2005  08:33a              41,517 navy_post.inp
09/15/2005  08:33a           1,083,517 navy_post.out
09/15/2005  08:32a              14,382 props.dat
09/15/2005  02:25p              43,253 temps_post.out
09/15/2005  08:32a              17,842 temps_post.parm
               8 File(s)      1,215,843 bytes

 Directory of D:\ANSYS files\Short\post_air\nav3d_5a

10/04/2005  09:23a      <DIR>          .
10/04/2005  09:23a      <DIR>          ..
09/15/2005  08:38a               5,502 AnsysBin1.dat
09/15/2005  02:25p               1,173 get_temps.inp
```

```
09/15/2005  08:37a               8,657 navheatgen.dat
09/15/2005  08:37a              41,517 navy_post.inp
09/15/2005  08:37a           1,084,656 navy_post.out
09/15/2005  08:36a              14,382 props.dat
09/15/2005  02:25p              43,253 temps_post.out
09/15/2005  08:36a              17,842 temps_post.parm
               8 File(s)      1,216,982 bytes

 Directory of D:\ANSYS files\Short\post_air\nav3d_6a

11/17/2005  03:09p      <DIR>          .
11/17/2005  03:09p      <DIR>          ..
09/15/2005  08:41a               5,502 AnsysBin1.dat
09/15/2005  02:25p               1,173 get_temps.inp
11/17/2005  03:09p               8,657 navheatgen.dat
09/15/2005  08:40a              41,517 navy_post.inp
11/17/2005  03:09p           1,055,419 navy_post.out
09/15/2005  08:39a              14,382 props.dat
09/15/2005  08:39a              17,842 temps_post.parm
11/17/2005  03:09p              42,512 temp_post.out
               8 File(s)      1,187,004 bytes

 Directory of D:\ANSYS files\Short\post_air\nav3d_7a

10/04/2005  09:23a      <DIR>          .
10/04/2005  09:23a      <DIR>          ..
09/15/2005  08:50a               5,502 AnsysBin1.dat
09/15/2005  02:25p               1,173 get_temps.inp
09/15/2005  08:49a               8,657 navheatgen.dat
09/15/2005  08:49a              41,517 navy_post.inp
09/15/2005  08:49a           1,084,368 navy_post.out
09/15/2005  08:48a              14,382 props.dat
09/15/2005  02:25p              43,253 temps_post.out
09/15/2005  08:48a              17,842 temps_post.parm
               8 File(s)      1,216,694 bytes

 Directory of D:\ANSYS files\Short\post_air\nav3d_8a

10/04/2005  09:23a      <DIR>          .
10/04/2005  09:23a      <DIR>          ..
09/15/2005  08:56a               5,502 AnsysBin1.dat
09/15/2005  02:25p               1,173 get_temps.inp
09/15/2005  08:56a               8,657 navheatgen.dat
09/15/2005  08:56a              41,517 navy_post.inp
09/15/2005  08:56a           1,083,517 navy_post.out
09/15/2005  08:54a              14,382 props.dat
09/15/2005  02:26p              43,253 temps_post.out
09/15/2005  08:54a              17,842 temps_post.parm
               8 File(s)      1,215,843 bytes

 Directory of D:\ANSYS files\Short\pre_air

10/03/2005  02:07p      <DIR>          .
10/03/2005  02:07p      <DIR>          ..
```

```
10/04/2005  09:24a      <DIR>          nav3d_1a
10/04/2005  09:24a      <DIR>          nav3d_2a
10/04/2005  09:24a      <DIR>          nav3d_3a
10/04/2005  09:24a      <DIR>          nav3d_4a
10/04/2005  09:24a      <DIR>          nav3d_5a
11/17/2005  03:05p      <DIR>          nav3d_6a
10/04/2005  09:24a      <DIR>          nav3d_7a
10/04/2005  09:25a      <DIR>          nav3d_8a
               0 File(s)              0 bytes

 Directory of D:\ANSYS files\Short\pre_air\nav3d_1a

10/04/2005  09:24a      <DIR>          .
10/04/2005  09:24a      <DIR>          ..
09/20/2005  09:18a               5,502 AnsysBin1.dat
09/20/2005  09:18a               1,169 get_temps.inp
09/20/2005  09:17a               8,657 navheatgen.dat
09/20/2005  09:17a              37,615 navy_pre.inp
09/20/2005  09:17a           1,399,484 navy_pre.out
09/20/2005  09:17a              14,382 props.dat
09/20/2005  09:17a              58,147 temps_pre.out
09/20/2005  09:17a              10,897 temps_pre.parm
               8 File(s)      1,535,853 bytes

 Directory of D:\ANSYS files\Short\pre_air\nav3d_2a

10/04/2005  09:24a      <DIR>          .
10/04/2005  09:24a      <DIR>          ..
09/20/2005  09:31a               5,502 AnsysBin1.dat
09/20/2005  09:30a               1,169 get_temps.inp
09/20/2005  09:30a               8,657 navheatgen.dat
09/20/2005  09:30a              37,615 navy_pre.inp
09/20/2005  09:30a           1,402,184 navy_pre.out
09/20/2005  09:30a              14,382 props.dat
09/20/2005  09:30a              58,147 temps_pre.out
09/20/2005  09:30a              10,897 temps_pre.parm
               8 File(s)      1,538,553 bytes

 Directory of D:\ANSYS files\Short\pre_air\nav3d_3a

10/04/2005  09:24a      <DIR>          .
10/04/2005  09:24a      <DIR>          ..
09/20/2005  09:32a               5,502 AnsysBin1.dat
09/20/2005  09:32a               1,169 get_temps.inp
09/20/2005  09:31a               8,657 navheatgen.dat
09/20/2005  09:31a              37,615 navy_pre.inp
09/20/2005  09:31a           1,400,321 navy_pre.out
09/20/2005  09:31a              14,382 props.dat
09/20/2005  09:31a              58,147 temps_pre.out
09/20/2005  09:31a              10,897 temps_pre.parm
               8 File(s)      1,536,690 bytes

 Directory of D:\ANSYS files\Short\pre_air\nav3d_4a
```

```
10/04/2005  09:24a    <DIR>          .
10/04/2005  09:24a    <DIR>          ..
09/20/2005  09:33a             5,502 AnsysBin1.dat
09/20/2005  09:33a             1,169 get_temps.inp
09/20/2005  09:33a             8,657 navheatgen.dat
09/20/2005  09:33a            37,615 navy_pre.inp
09/20/2005  09:33a         1,389,386 navy_pre.out
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        432 File(s)     62,632,278 bytes
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BECHTEL SAIC COMPANY, LLC

Interoffice Memorandum

MOL.20030501.0081

QA: QA

To:	Distribution	**No.:**	0205035938
From:	Nancy H. Williams NHWilliams	**Date:**	4-4-03
Re:	Thermal Inputs for Evaluations Supporting TSPA-LA, Supplement	**CC:**	

This interoffice memorandum provides some key thermal inputs (goals, design features, and operational characteristics) selected for the Total System Performance Assessment-License Application evaluation and all supporting models and analyses. This memorandum restates the thermal inputs from an earlier interoffice memorandum (Williams, N. H., 2002, Tables 1 and 2) and provides some supplementary details of waste package inventory (Table 3). These thermal inputs represent a high thermal operating mode and are consistent with the inputs used in the Total System Performance Assessment-Site Recommendation. Information from the earlier interoffice memorandum has been incorporated in Information Exchange Drawings (BSC 2003). These Information Exchange Drawings should be updated to include the supplementary information from this interoffice memorandum as appropriate.

If there are any questions, please contact Thomas W. Doering (702) 295-7414.

DAT:NHW:cjp

Enclosures:
1. Table 1 *"Recommended Thermal Goals"*
2. Table 2 *"Recommended Design Features and Operational Characteristics"*
3. Table 3 "*WP Inventory Information*"

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DATE: 04/04/2003

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References:

67 FR 19432, Surplus Plutonium Disposition Program. Readily available.

Board, M. P.; Linden, A.; and Zhu, M. 2002. Design Evolution Study – Underground Layout. TDR-MGR-MG-000003 REV 00. Las Vegas, Nevada: BSC. ACC: MOL.20020429.0023.

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Table 1 Recommended Thermal Goals

Requirement	Discussion
Pillar Drainage	This goal is intended to ensure that pore water liberated from the host rock matrix and percolation flux drains through sub-boiling region of the fracture network to the water table rather than accumulate above the repository horizon.
$T_{clad}^{max} \leq 350°C$	Goal is to limit cladding temperature to less than 350°C to provide margin to failure by creep rupture.
$T_{DW}^{max}\|_{pre\text{-}closure} \leq 96°C$	Goal is to limit pre-closure drift wall temperature to 96°C or less to not preclude cool operating modes.
$T_{DW}^{max}\|_{post\text{-}closure} \leq 200°C$	Goal is to limit post-closure drift wall temperature to 200°C or less to avoid adverse mineralogical transitions.

Table 2 Recommended Design Features and Operational Characteristics

Description/Value	Comments/Reference
Design Features	
Waste Package Suite/ 44-BWR 24-BWR 12-PWR Naval-Long Naval-Short 5 DHLW/DOE SNF-Short 5 DHLW/DOE SNF Long 2 MCO/2-DHLW 21-PWR w/ Absorber Plates 21-PWR w/ Control Rods	The same as TSPA-SR (CRWMS 2000a)
Number of Waste Packages/ (See Table 3)	The same as TSPA-SR (CRWMS 2000a, p.228)
Drift Diameter/5.5 m	The same as TSPA-SR (CRWMS 2000a)
Drift Pitch/81 m	The same as TSPA-SR (CRWMS 2000a)
Subsurface Layout	Layout from Design Evolution Study (Board, et al. 2002) formally documented in the Information Exchange Drawing (Chestney, R. and Thomas, E. 2002)
Operational Characteristics	
Waste Stream/ 1999 Design Basis Waste Stream Case A Legal-Limit Scenario	The same as TSPA-SR (CRWMS 1999 and CRWMS 2000b)
Average waste package skirt-to-skirt spacing/0.1 m	The same as TSPA-SR (CRWMS 2000a)
Average thermal line load/1.45 kW/m	The same as TSPA-SR (CRWMS 2000a)

Table 2 Recommended Design Features and Operational Characteristics (continued)

Average waste package thermal power at time of emplacement/This value is about 7.54 kW for the recommended waste stream	This value is dependent on the waste stream selected, and, thus, is the same as the SR baseline.
Maximum waste package power at emplacement/11.8 kW	The same as TSPA-SR (CRWMS 2000a)
Average length of all waste packages within inventory/This value is about 5.1 m for the recommended waste stream	This value is dependent on the waste stream selected, and, thus, is the same as the SR baseline.
Ventilation Volumetric Flow Rate/15 m^3/s	Will provide acceptable performance.
Duration of Ventilation/50 Years after final emplacement	The same as TSPA-SR (CRWMS 2000a)
Duration of waste emplacement/23 years	Value from the CRD (DOE 2001)
CSNF Waste Emplacement Rate By Year/ 2010 400 MT 2011 600 MT 2012 1200 MT 2013 2000 MT 2014 to 2032+ 3000 MT 2033 1800 MT	Value from the CRD (DOE 2001)
Naval Canister Emplacement Rate By Year/ 2010 3 2011 3 2012 6 2013 6 2014 12 2015 to 2029 14 2030 to 2033 15	McKenzie 2001

Table 3 WP Inventory Information

Waste Package Configuration	Nominal Quantity for SR[a]	Nominal Quantity for LA[b]	Not to Exceed Quantity[c]
21 PWR AP	4299[d]	4299[d]	4500
21 PWR CR	95[d]	95[d]	100
12 PWR AP Long	163[d]	163[d]	170
44 BWR AP	2831[d]	2831[d]	3000
24 BWR AP	84[d]	84[d]	90
5 IPWF	95	0	1200[e]
5 HLW Short/1 DOE SNF Short	1052	1147	
5 HLW Long/1 DOE SNF Long	1406	1406	1500
2 MCO/2 HLW	149	149	160
5 HLW Long/1 DOE SNF Short	126	31	730[f]
5 HLW Long Only	584	679	
Naval Short	200	144[g]	300[g]
Naval Long	100	156[g]	
Total	11184	11184	-

[a] Nominal quantities for Site Recommendation are from the Project Description Document (PDD) (Curry 2001) and represent the potential number of each waste package (WP) configuration to accommodate the legal limit of 70,000 MTHM, including IPWF packages.
[b] Nominal quantities for LA are those for SR and represent the potential number of each WP configuration to accommodate the legal limit of 70,000 MTHM, except that IPWF packages are no longer considered (67 FR 19432) and the Navy has revised its estimate of WPs (McKenzie 2001). The HLW short canisters that would have contained the Plutonium have been redistributed among the co-disposal WPs in a manner consistent with the expected number of short DOE SNF canisters. This results in fewer short DOE SNF canisters to co-dispose with long HLW canisters.
[c] The "not to exceed quantities" are for each WP configuration separately. The total of this column would clearly make the repository exceed 70,000 MTHM. If the quantity of one configuration increases above the nominal value, the quantity for another configuration must decrease to maintain the maximum legal limit of 70,000 MTHM.
[d] The nominal number of WPs for CSNF (CRWMS 2000b) are for the Case A Legal Limit scenario from the 1999 Design Basis Waste Input Report, as used for Site Recommendation.
[e] Since the IPWF configuration is no longer being considered, the "not to exceed" quantities from the PDD for the "IPWF" and "5 HLW Short/1 DOE SNF Short" configurations are combined for LA.
[f] Since the IPWF configuration is no longer being considered, the necessary redistribution of the short DOE SNF canisters among different co-disposal WPs results in more "5 HLW Long Only" WPs than in the PDD. Therefore, the "not to exceed" quantities for the "5 HLW Long/1 DOE SNF Short" and "5 HLW Long Only" WPs are combined for LA.
[g] Because of the revised Navy WP estimates, the "not to exceed" values for "Naval Short" and "Naval Long" configurations from the PDD are combined for LA. It should be noted that the estimated thermal sources for Naval WPs do not distinguish between short and long WPs.