Thermal Analyses of SRS Pu Storage Cans Inside BNFL 3013 Container

P. K. Paul

October 1999

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10/19/99

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Thermal Analyses of SRS Pu Storage Cans Inside BNFL 3013 Container

by

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Aiken, South Carolina 29808

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Summary

Thermal analyses of plutonium ingot storage in the single SRS can and the two-stacked SRS cans (each containing a Pu ingot) inside a BNFL 3013 outer can configuration have been performed. The stacked can configuration is analyzed for two different variations. In one situation the stacked cans are sitting on a rack and in another situation the stacked cans are hanging freely in the ambient. Sensitivity analyses have been performed by using helium, air or a combination of helium and air as the enclosure medium between the Pu ingot and the SRS can. Sensitivity analyses also include choosing helium, air, nitrogen or a combination of air and helium as the enclosure medium between the inner SRS can and the outer BNFL can. In all analyses, the ambient temperature is assumed to be 95°F. The heat source in the Pu ingot is used as 10.5 watts for all cases except one that has 7.0 watts.

The highest temperature calculated is on the top of the Pu ingot at the centerline location for the single can configuration. The highest temperature for the single can configuration base case (10.5 watts heat source Pu button; 25% air and 75% He as the enclosure medium between the Pu ingot and the can; no convection inside the enclosure) is 184 °F. The highest temperature increases to 197°F as the enclosure medium becomes 100% air. The highest temperature drops to 171°F if convection heat transfer in addition to conduction heat transfer is included inside the enclosure medium which is 50% air and 50% helium. The base case highest temperature drops to 155°F if the heat source of the Pu ingot drops to 7.0 watts from 10.5 watts. The base case temperature on the outside top of the can is approximately 118°F.

For the two-stacked cans configuration sitting on a rack (10.5 watts heat source Pu ingot; enclosures between Pu button and SRS can filled with 25% air + 75% He; enclosures between SRS cans and outer can filled with air; no convection assumed inside the enclosures), the highest temperature is 181°F at the top of the upper Pu ingot in the centerline location. But when the two-stacked cans are hanging, the highest temperature increases to 185°F and this temperature is at the top of the lower Pu ingot. The temperatures at the top of the outer can for the two-stacked cans configuration is around 120°F.

1.0 Introduction

Plutonium metal is stored at the Savannah River Site (SRS) using different storage can configurations. The temperatures at different locations in the storage configuration play an important role in designing and configuring different storage arrangements. The present work consists of calculating temperatures at different locations in two different storage configurations. The configurations are: 1) storing Pu ingot in a single SRS storage can (Bagless Transfer Can) and 2) storing two Pu ingots in two stacked SRS cans (Bagless Transfer Cans) inside a BNFL 3013 outer can. The external dimensions of the SRS can and the BNFL 3013 outer can are given in Table 1. The schematics of the 2-D axisymmetric quarter plane along with necessary dimensions for the two configurations are presented in Figures 1, 2 and 3. The heat source in each Pu ingot is assumed to be 10.5 watts (with the exception of one case which is 7.0 watts), and the ambient temperature used for the analyses is 95°F.

The work has been performed in accordance with the WSRC E-7 Manual¹. The thermal analyses have been performed using a finite element based commercial code which meets site nuclear QA requirements².

Table 1. External Dimensions of Containers

Container	Diameter X Height (inch)	Drawing Number
SRS Can	4.6 X 4.625	WSRC Drawing R-R1-F-0039 Rev. 2
BNFL 3013 Outer Container	4.92 X 10.0	BNFL Drawing M-4-20-1-245 Mod C

2.0 Model and Analysis

The thermal models of the Pu storage configurations have been created using the general purpose finite element pre- and post-processor MSC/PATRAN³ Version 7.5. The analyses have been performed using the general purpose conduction-radiation based finite element code MSC/Thermal⁴ (P/Thermal).

Figure 1. A Schematic of Single SRS Can Containing a Pu Ingot on a Storage Rack

Figure 2. A Schematic of Two-Stacked SRS Can Sitting on a Storage Rack

Figure 3. An Schematic of Two-Stacked SRS Can Hanging in the Ambient

2.1 Model

The single SRS storage can containing a Pu ingot is modeled by a 2-D axisymmetric quarter plane. Figure 1 shows this quarter plane model with its dimensions. The 2-D axisymmetric model for the two stacked SRS storage cans (with a Pu ingot in each can) within the BNFL 3013 outer can is shown in Figure 2. In Figure 2, the two-stacked can configuration is sitting on a 304 stainless steel rack, whereas in Figure 3 the configuration is hanging in a free space. The quarter planes are modeled using 1300 nodes for the single can and 3000 nodes for the two-stacked can configurations. The fringe plot in Figures 4, 5, and 6 shows the materials for these configurations. The SRS can is made of 304 stainless steel and the BNFL outer can is made of 316 stainless steel.

A volumetric heat source of 10.5 watts is uniformly distributed over in each 1.75" diameter Pu ingot of 2300 grams. In one case, a volumetric heat source of 7.0 watts is used for sensitivity analysis. The ambient temperature is modeled as 95°F.

The heat dissipation is modeled as conduction heat transfer through the structural components of the storage configurations. Radiation heat transfer is modeled between the Pu ingot and the SRS can, between the inner can and the outer can (for Fig 2 and 3 configurations only), and from the outer surfaces to the ambient. An emissivity of value 0.3 is used for all surfaces, which may be considered conservative. Higher emissivity values would result in lower the temperatures. Laminar natural convection ($h = 0.363 \Delta T^{0.25}$ Btu/hr-ft²-°F) from the side of the outer can to the ambient and turbulent natural convection ($h = 0.22 \Delta T^{0.33}$ Btu/hr-ft²-°F) off the top of the outer can are used as boundary conditions. A turbulent natural convection ($h = 0.22 \Delta T^{0.33}$ Btu/hr-ft²-°F) is also applied to the to exposed part of the rack for the seating on a rack configuration and to the bottom part of the outer can for the hanging configuration. The convective heat transfer between the Pu ingot and the SRS can and between the inner can and the outer can is neglected in all cases but three (Cases F, G & H). In that case, the convective effects are implemented by adjusting the conductivity of the fill gas with a multiplication factor of 2.6 radially and 8.0 axially⁵.

2.2 Analysis

The general purpose conduction/radiation code MSC/Thermal Version 5.0 is used to perform the computations. The finite element mesh generation and pre- and post-processors are done using MSC/PATRAN Version 7.5. The quarter plane 2-D axisymmetric models contain about 1300 and 3000 nodes for the single can and double stacked can configurations, respectively. The material properties used for 304 stainless steel, helium, nitrogen, and air are from the MSC/Thermal material property package. Table 2 shows the material properties used in the analyses. The cases analyzed under three different configurations are presented in Table 3.

MSC/PATRAN Version 7.5 14-Dec-98 16:19:43
Fringe: Property Set Name

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-2.13+00
-2.27+00
-2.40+00
-2.53+00
-2.67+00
-2.80+00
-2.93+00
-3.07+00
-3.20+00
-3.33+00
-3.47+00
-3.60+00
-3.73+00
-3.87+00
-4.00+00

default_fringe :
Max -2.00+00 @ Elm 136.1
Min -4.00+00 @ Elm 1.1

Figure 4. Materials Display in Single Can Configuration

MSC/PATRAN Version 7.5 14-Dec-98 15:56:25

Fringe: Property Set Name

-1.00+00	
-1.27+00	
-1.53+00	
-1.80+00	
-2.07+00	
-2.33+00	
-2.60+00	
-2.87+00	
-3.13+00	
-3.40+00	
-3.67+00	
-3.93+00	
-4.20+00	
-4.47+00	
-4.73+00	
-5.00+00	

Figure 5. Material Display in Two-Stacked Can Configuration Sitting on a Rack

default Fringe :
Max -1.00+00 @Elm 188.1
Min -5.00+00 @Elm 178.1

MSC/PATRAN Version 7.5 14-Dec-98 15:43:02
Fringe: Property Set Name

Figure 6. Materials Display in Two-Stacked Can Configuration
Hanging in the Ambient

default_Fringe :
Max -1.00+00 @ Elm 157.1
Min -5.00+00 @ Elm 147.1

Table 2. Material Properties used in the Analyses

Material	Density (lb/ft ³)	Specific Heat (Btu/lb°F)	Thermal Conductivity (Btu/hr-ft-°F)
Stainless Steel 304	494.4	0.120 @ 32°F 0.135 @ 752°F	7.74 @ 32°F 9.43 @ 212°F
Stainless Steel 316	494.4	0.120 @ 32°F 0.135 @ 752°F	7.61 @ 32°F 8.79 @ 212°F
Plutonium	1198.6	0.032 @ 32°F 0.0328 @ 212°F	4.596 @ 63°F 5.806 @ 135°F 7.257 @ 207°F
Nitrogen	0.0781	0.245	0.01389 @ 32°F 0.01807 @ 212°F
Helium	0.0115	1.24	0.0818 @ 32°F 0.0868 @ 77°F 0.0909 @ 120°F 0.0984 @ 212°F
Air	0.0805	0.237	0.0139 @ 32°F 0.0184 @ 212°F
25% Air + 75% Helium	0.0284	0.989	0.0648 @ 32°F 0.0784 @ 212°F
50% Air + 50% Helium	0.0460	0.7385	0.03935 @ 32°F 0.0484 @ 212°F

Table 3. Listing of Cases Analyzed

Configuration	Case	Description
Single SRS Can	A	7.0 watts heat source Pu button; enclosure between Pu button and can filled with He; no convection inside the enclosure (He medium)
Single SRS Can	B	Same as Case A except 10.5 watts heat source
Single SRS Can	C	Same as Case B except medium filled with air
Single SRS Can	D	Same as Case B except medium filled with 25% air + 75% He (Base Case)
Single SRS Can	E	Same as Case B except medium filled with 50% air + 50% He
Single SRS Can	F	Same as Case E except convection inside enclosure is included.
Single SRS Can	G	Same as Case D except convection inside enclosure is included
Single SRS Can	H	Same as A except medium filled with 25% air + 75% He and convection inside enclosure included
Double SRS cans sitting on a rack	AA	10.5 watts heat Pu button in each enclosure; enclosures between Pu button and SRS can filled with 25% air + 75% He; enclosure between SRS cans and outer can filled with air; no convection inside the enclosures
Double SRS cans sitting on a rack	BB	Same as Case AA except enclosure between SRS cans and outer can filled with nitrogen
Double SRS cans sitting on a rack	CC	Same as Case AA except enclosure between SRS cans and outer can filled with helium
Double SRS cans hanging in air	AAA	10.5 watts heat Pu button in each enclosure; enclosures between Pu button and SRS can filled with 25% air + 75% He; enclosure between SRS cans and outer can filled with air; no convection inside the enclosures
Double SRS cans hanging in air	BBB	Same as Case AAA except enclosure between SRS cans and outer can filled with nitrogen
Double SRS cans hanging in air	CCC	Same as Case AAA except enclosure between SRS cans and outer can filled with helium
Double SRS cans hanging in air	DDD	Same as Case BBB except insulated boundary at the bottom

Results and Discussions

The temperatures at different node locations for the single can configuration (Case A through H) are presented in Table 4, and the locations of the nodes are shown in Figure 7. A brief description of the cases is provided in Table 3. The highest temperature calculated is at the center on the top of Pu button (node # 631) for all cases. The highest temperature calculated for the Base Case (Case D) is 184°F. The temperature at the top of the can is about 119°F for this case. The centerline temperature in the Pu ingot decreases from top to bottom. The high thermal conductivity of stainless steel on the can bottom facilitates heat loss through the bottom of the ingot. The temperature of Pu ingot decreases from top to bottom. The enclosure filled with gases of higher thermal conductivity enhances heat transfer from the Pu button to the stainless steel at the top of the can. As a result, the centerline temperature at the top of the can (node #1239) increases as the composition of the enclosure increases from air to helium. No credit for internal convection within the enclosure inside the can has been taken except Cases F, G and H. In Case F, the internal convection is implemented by increasing the conductivity of the enclosure medium. As a result, the centerline temperature at the top of the Pu button is 19°F lower in Case F than that in Case E. On the other hand, the centerline temperature at the top of the can is 11.5°F higher in Case F than that in Case E. The temperatures in Case G is derived from Case D by applying the enclosure medium convection effect based on Cases E and F. In deriving the temperatures in Case H, the effect of 25% air instead of helium based on Cases D and E is incorporated into Case A in addition to the enclosure medium convection effect based on Cases E and F. The temperature contour plots for Cases A through F are presented in Figures 8 through 13.

The temperatures for two-stacked can configuration cases are presented Table 5. The Cases AA, BB and CC are for stacked cans sitting on a rack, and in Cases AAA, BBB, CCC and DDD, the stacked cans are hanging free. The node locations are shown in Figure 14. The calculated highest temperature for the base case (Case AA) is 181°F at the top of upper Pu ingot on the centerline location. The temperature at the top of the outer can is about 120°F for this case. The temperature differences among Cases AA and BB are insignificant because the conductivity of nitrogen is almost the same as that of air. The same explanation is applicable for AAA and BBB. The temperatures along the centerline are higher in the hanging configuration than those in the seating configuration. The temperature differential for the cases with and without the rack is the greatest at the can bottom, and generally decreases from bottom to the top. The configuration with the rack results in overall lower temperatures because of the increased surface area for heat transfer to the ambient. The temperature contours for case AA, BB, CC, AAA, BBB, CCC, and DDD are presented in Figures 15 through 18.

Table 4. Temperature at Different Locations for Single Can Configuration

Case Node #	Case A Temp °F	Case B Temp °F	Case C Temp °F	Case D Temp °F	Case E Temp °F	Case F Temp °F	Case G* Temp °F	Case H* Temp °F
123	143.4	164.1	174.0	166.1	169.6	158.0	154.7	136.4
235	149.0	172.0	183.9	174.4	178.7	164.8	160.8	140.8
393	152.8	177.3	191.1	180.1	185.0	169.1	164.6	143.5
631	155.2	180.6	196.8	183.9	189.7	170.5	165.3	143.9
132	140.4	159.8	168.7	161.6	164.8	154.2	151.2	134.0
244	148.7	171.4	183.5	173.9	178.2	164.3	160.3	140.5
402	152.5	176.8	190.9	179.7	184.7	168.6	164.0	143.1
640	154.3	179.4	196.4	182.9	188.9	168.8	163.4	142.4
995	113.1	119.9	114.7	118.9	117.1	128.6	130.6	122.3
1239	113.0	119.9	114.7	118.8	117.0	128.5	130.5	122.2
1248	112.8	119.6	114.7	118.6	117.0	127.3	129.0	121.1
1285	112.4	118.9	114.8	118.1	116.7	123.7	125.2	117.7
1287	112.4	118.9	114.7	118.1	116.6	123.7	125.3	117.7
1283	112.4	118.9	114.8	118.1	116.6	123.7	125.3	117.7
1274	112.4	119.0	114.8	118.2	116.7	123.9	125.5	117.8
1280	112.4	119.0	114.8	118.2	116.7	123.8	125.4	117.7
1004	112.9	119.6	114.7	118.6	116.9	127.4	129.3	117.8
1228	112.5	119.1	115.0	118.3	116.8	123.7	125.3	117.6
72	132.9	148.6	154.8	150.0	152.7	144.2	141.7	127.8
102	130.5	145.0	150.7	146.2	148.2	150.0	148.0	133.9
174	132.6	148.1	153.9	149.3	151.3	143.9	142.0	127.8
342	126.4	139.1	140.8	139.5	140.1	136.6	136.0	123.8
494	121.6	132.1	131.0	131.9	131.5	130.8	131.2	120.6
864	115.9	124.0	120.3	123.3	122.0	125.3	126.6	117.8

* Case G and Case H are derived from the results of other cases

Figure 7. Node Location for Single Can Configuration

MSC/PATRAN Version 7.5 27-Jul-98 16:04:05
Fringe: TIME: 0.000000000D+00 HOURS S.S. ITERATIONS: 1713, nr0.nr02: Temperature, -(NON-LAYERED)

Figure 8. Temperature Plot for Case A
(7.0 watts heat source and He enclosure medium)

default_Fringe :
Max 1.55+02 @ Nd 601
Min 1.12+02 @ Nd 1287

MSC/PATRAN Version 7.5 27-Jul-98 14:37:49
Fringe: TIME: 0.000000000D+00 HOURS S.S. ITERATIONS: 1976, nr0, nr01: Temperature, -(NON-LAYERED)

1.19+02

1.81+02

1.77+02

1.72+02

1.68+02

1.64+02

1.60+02

1.56+02

1.52+02

1.48+02

1.44+02

1.40+02

1.35+02

1.31+02

1.27+02

1.23+02

1.19+02

Figure 9. Temperature Plot for Case B
(10.5 watts heat source and He enclosure medium)

default_Fringe :
Max 1.81+02 @ Nd 601
Min 1.19+02 @ Nd 1287

MSC/PATRAN Version 7.5 28-Jul-98 15:13:32
Fringe: TIME: 0.000000000D+00 HOURS S.S. ITERATIONS: 2075, nr0, nr03: Temperature, -(NON-LAYERED)

Figure 10. Temperature Plot for Case C
(10.5 watts heat source and air enclosure medium)

default_Fringe :
Max 1.97+02 @Nd 621
Min 1.15+02 @Nd 1262

MSC/PATRAN Version 7.5 28-Jul-98 16:19:43
Fringe: TIME: 0.00000000DD+00 HOURS

S.S. ITERATIONS: 2034, nr0.nrf04: Temperature, -(NON-LAYERED)

1.18+02

1.84+02

1.80+02

1.75+02

1.71+02

1.66+02

1.62+02

1.58+02

1.53+02

1.49+02

1.44+02

1.40+02

1.36+02

1.31+02

1.27+02

1.22+02

1.18+02

default Fringe:

Max 1.84+02 @ Nd 611

Min 1.18+02 @ Nd 1287

Figure 11. Temperature Plot for Case D

(10.5 watts heat source and 25% air + 75% He enclosure medium)

MSC/PATRAN Version 7.5 28-Oct-98 10:41:21
Fringe: TIME: 0.000000000D+00 HOURS S.S. ITERATIONS: 1996, nro.nf05: Temperature, -(NON-LAYERED)

Figure 12. Temperature Plot for Case E
(10.5 watts heat source and 50% air + 50% He enclosure medium)

default_Fringe :
Max 1.90+02 @Nd 621
Min 1.17+02 @Nd 1287

MSC/PATRAN Version 7.5 28-Oct-98 16:49:39
Fringe: TIME: 0.000000000D+00 HOURS S.S. ITERATIONS: 2690, nr0.nrf06: Temperature, -(NON-LAYERED)

Figure 13. Temperature Plot for Case F
(10.5 watts heat source and 50% air + 50% He enclosure medium
and convection effects within enclosure medium)

default_fringe :
Max 1.71+02 @Nd 581
Min 1.24+02 @Nd 1225

Table 5. Temperature at Different Locations for Two-Stack Can Configuration

Cases	Case AA	Case BB	Case CC	Case AAA	Case BBB	Case CCC	Case DDD
Node # / Temp	°F	°F	°F	°F	°F	°F	°F
1	149.97	149.96	149.82	N/A	N/A	N/A	N/A
11	150.15	150.14	150.00	159.42	159.42	159.21	174.06
183	154.57	154.55	154.41	163.09	163.09	162.88	177.21
725	178.00	177.98	177.85	185.10	185.10	184.91	197.10
1103	160.29	160.27	159.98	162.91	162.91	162.60	167.42
1385	161.73	161.71	161.43	164.33	164.33	164.02	168.80
2040	180.82	180.79	180.54	183.10	183.10	182.82	187.02
2736	124.66	124.63	124.02	125.99	125.98	125.32	128.26
2836	119.52	119.50	119.88	120.64	120.63	121.02	122.53
2916	119.46	119.43	119.80	120.57	120.56	120.93	122.46
192	150.79	150.78	150.63	159.19	159.19	158.98	173.37
734	177.32	177.31	177.18	184.37	184.37	184.18	196.30
1394	156.74	156.72	156.43	159.38	159.38	159.06	163.91
2049	179.86	179.84	179.59	182.14	182.13	181.86	186.05
3005	120.38	120.52	120.36	121.54	121.54	121.69	123.52
1384	138.85	138.83	138.87	141.52	141.52	141.54	146.12
54	140.52	140.51	140.43	148.69	148.69	148.57	162.18
59	138.90	138.89	138.82	N/A	N/A	N/A	N/A

Figure 14. Node Locations for Two-Stack Can Configuration

MSC/PATRAN Version 7.5 07-Dec-98 13:06:40

Fringe: TIME: 0.000000000D+00 HOURS

S.S. ITERATIONS: 4406, nrl.nrf01, Temperature,, (NON-LAYERED)

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1.81+02

1.77+02

1.73+02

1.69+02

1.65+02

1.60+02

1.56+02

1.52+02

1.48+02

1.44+02

1.40+02

1.36+02

1.32+02

1.28+02

1.24+02

1.19+02

default_Fringe :

Max 1.81+02 @Nd 2020

Min 1.19+02 @Nd 2916

Figure 15. Temperature Plot for Case AA

(outer enclosure medium air and configuration sitting on a rack)

MSC/PATRAN Version 7.5 10-Dec-98 10:47:30
Fringe: TIME: 0.000000000D+00 HOURS

S.S. ITERATIONS: 4190, nr1.nr03, Temperature,, (NON-LAYERED)

1.19+02

1.81+02

1.77+02

1.73+02

1.69+02

1.64+02

1.60+02

1.56+02

1.52+02

1.48+02

1.44+02

1.40+02

1.36+02

1.32+02

1.28+02

1.24+02

1.19+02

Figure 16. Temperature Plot for Case BB
(outer enclosure medium nitrogen and configuration sitting on a rack)

default_Fringe :
Max 1.81+02 @Nd 2020
Min 1.19+02 @Nd 2916

MSC/PATTRAN Version 7.5 08-Dec-98 15:14:20

Fringe: TIME: 0.0000000000D+00 HOURS

S.S. ITERATIONS: 4516, nr1.nr02_2, Temperature,, (NON-LAYERED)

1.20+02

1.81+02

1.77+02

1.73+02

1.68+02

1.64+02

1.60+02

1.56+02

1.52+02

1.48+02

1.44+02

1.40+02

1.36+02

1.32+02

1.28+02

1.24+02

1.20+02

Figure 17. Temperature Plot for Case CC

(outer enclosure medium helium and configuration sitting on a rack)

default_Fringe :
Max 1.81+02 @Nd 2020
Min 1.20+02 @Nd 2916

MSC/PATRAN Version 7.5 14-Dec-98 14:22:30

Fringe: TIME: 0.000000000D+00 HOURS

S.S. ITERATIONS: 4538, nr1.nrf05: Temperature, -(NON-LAYERED)

1.21+02

1.85+02

1.81+02

1.77+02

1.72+02

1.68+02

1.64+02

1.59+02

1.55+02

1.51+02

1.46+02

1.42+02

1.38+02

1.33+02

1.29+02

1.25+02

1.21+02

default Fringe :

Max 1.85+02 @Nd 678

Min 1.21+02 @Nd 2879

Figure 18. Temperature Plot for Case AAA
(outer enclosure medium air and configuration hanging in ambient)

MSC/PATRAN Version 7.5 14-Dec-98 08:42:07
Fringe: TIME: 0.000000000D+00 HOURS

S.S. ITERATIONS: 4597, nr1, nr03, Temperature,, (NON-LAYERED)

1.85+02

1.81+02

1.77+02

1.72+02

1.68+02

1.64+02

1.59+02

1.55+02

1.51+02

1.46+02

1.42+02

1.38+02

1.33+02

1.29+02

1.25+02

1.21+02

Figure 19. Temperature Plot for Case BBB

(outer enclosure medium nitrogen and configuration hanging in ambient)

default Fringe :
lax 1.85+02 @Nd 678
wlin 1.21+02 @Nd 2879

MSC/PATRAN Version 7.5 14-Dec-98 12:46:55
Fringe: TIME: 0.000000000D+00 HOURS

S.S. ITERATIONS: 4508, nrl.nrl05: Temperature, -(NON-LAYERED)

Figure 20. Temperature Plot for Case CCC
(outer enclosure medium helium and configuration hanging in ambient)

default_Fringe :

Max 1.85+02 @ Nd 678

Min 1.21+02 @ Nd 2879

1.21+02
1.25+02
1.29+02
1.34+02
1.38+02
1.42+02
1.47+02
1.51+02
1.55+02
1.59+02
1.64+02
1.68+02
1.72+02
1.76+02
1.81+02
1.85+02

MSC/PATRAN Version 7.5 11-Dec-98 14:32:14
Fringe: TIME: 0.000000000D+00 HOURS S.S. ITERATIONS: 4518, nr1.nrf02, Temperature,, (NON-LAYERED)

Figure 21. Temperature Plot for Case DDD
(outer enclosure medium nitrogen and configuration hanging in
ambient and bottom insulated boundary)

default_Fringe :
Max 1.97+02 @Nd 678
Min 1.22+02 @Nd 2879

References

1. Conduct of Engineering Manual, E7, Westinghouse Savannah River Co., 1998.
2. Hensel, S. J., "Dedication Package for P3/Thermal (U)," SRT-EMS-950007, 1995.
3. MSC/PATRAN, MacNeal-Schwendler Corporation, Los Angeles, CA 90041.
4. MSC/Thermal, MacNeal-Schwendler Corporation, Los Angeles, CA 90041.
5. Hensel, S. J. and Lee, S. Y., "Thermal Analysis of Storage Cans (U)," WSRC-TR-96-0078, 1996.