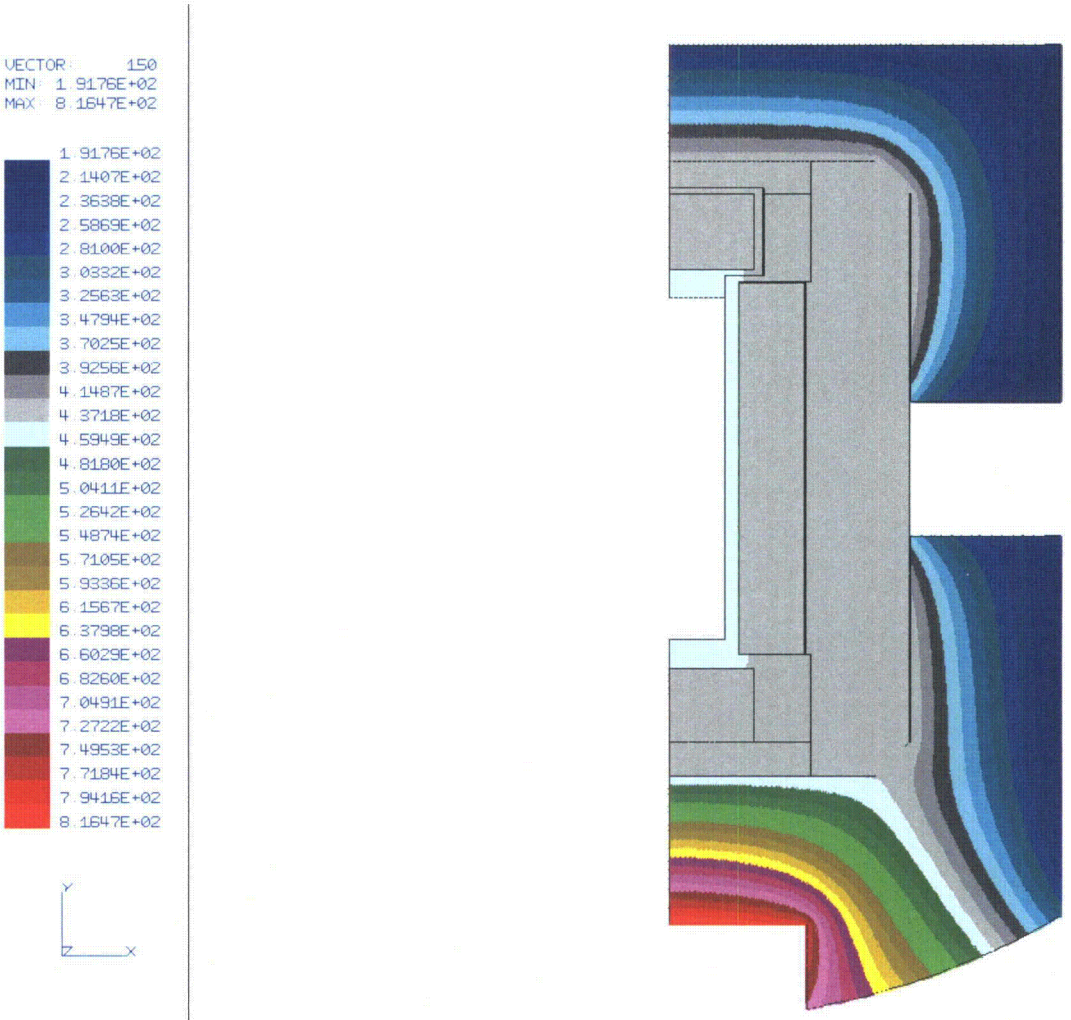

Figure 3-54. Load Case 112, Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Model AOS-050A

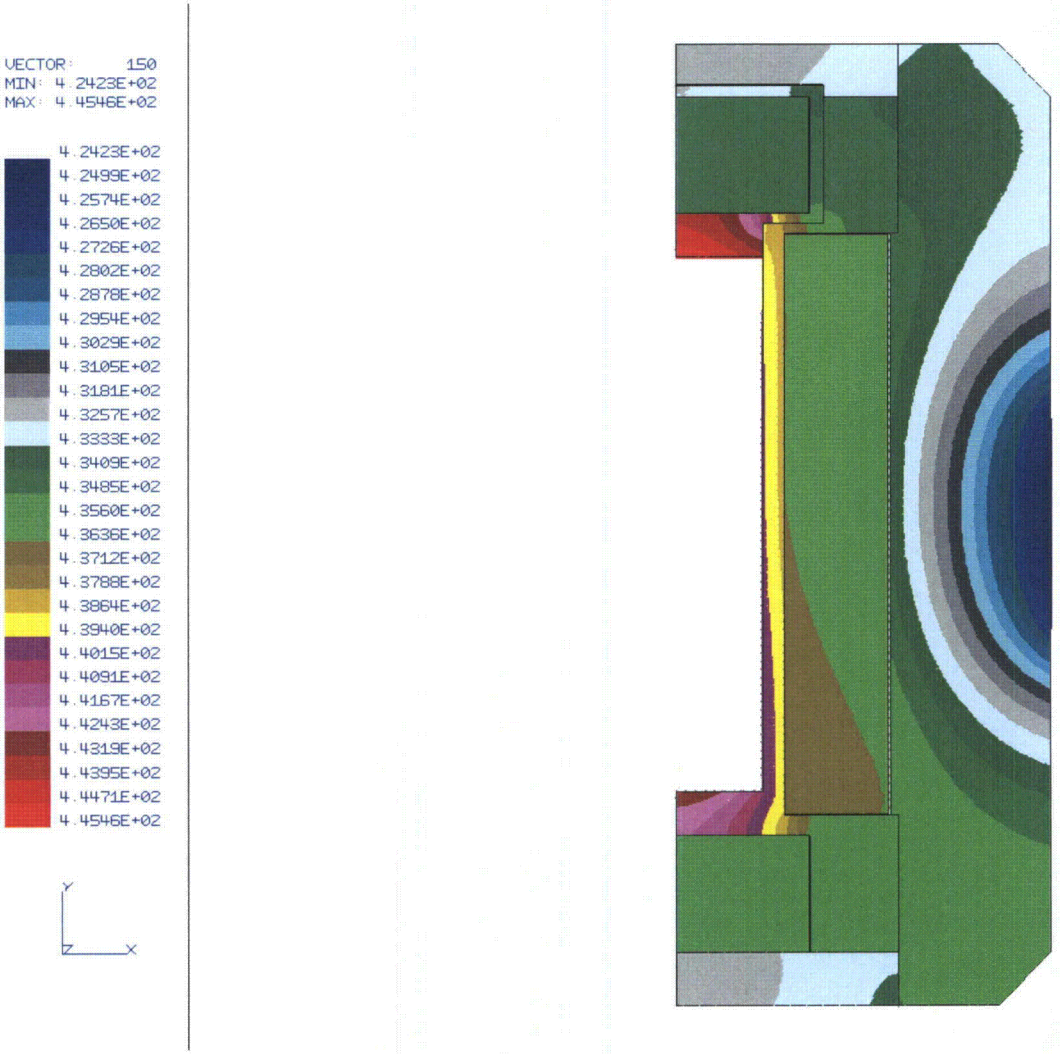

Figure 3-55. Load Case 112, Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Model AOS-050A

Table 3-45. Load Case 112, Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Model AOS-050A

Location	Node	Temp(C)	Temp(F)
1	5001	228.61	443.50
2	4532	223.39	434.10
3	4227	227.17	440.90
4	4752	224.11	435.40
5	4838	222.00	431.60
6	4993	222.28	432.10
7	3309	222.56	432.60
8	3351	222.33	432.20
9	678	220.22	428.40
10	2537	220.61	429.10
11	2533	220.72	429.30
12	4828	222.17	431.90
13	1888	214.83	418.70
14	583	221.39	430.50
15	579	221.50	430.70
16	4313	223.94	435.10
17	3001	223.78	434.80
18	3148	223.17	433.70
19	7533	223.44	434.20
20	7377	223.50	434.30
21	7371	221.67	431.00
22	6942	221.33	430.40
23	6267	222.06	431.70
24	6121	224.11	435.40
25	6001	224.11	435.40
26	15481	220.33	428.60
27	15941	219.89	427.80
28	16260	219.56	427.20
29	17311	167.00	332.60
30	11965	174.44	346.00
31	9785	220.94	429.70
32	9571	222.50	432.50
33	8197	225.28	437.50
34	15451	115.33	239.60
35	16160	113.22	235.80
36	17790	100.56	213.00
37	18750	88.94	192.10
38	11485	103.94	219.10
39	9900	132.06	269.70
40	8673	303.61	578.50
41	8225	347.11	656.80

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1887	3.7294E+02	7.0330E+02
Bottom Plate	3001	3232	3001	2.2383E+02	4.3490E+02
Cask Lid	3233	3424	3329	2.2289E+02	4.3320E+02
Shell Cavity	4001	4998	4532	2.5939E+02	4.9890E+02
Cask Lid Plug	5001	5404	5001	2.2972E+02	4.4550E+02
Tungsten Alloy	6001	7656	6938	2.6200E+02	5.0360E+02
Bottom Cavity	4227	4236	4236	2.3072E+02	4.4730E+02
Side Cavity	4372	4702	4532	2.5939E+02	4.9890E+02
Top Cavity	5001	5012	5001	2.2972E+02	4.4550E+02
Lid Seal	4993	4993	4993	2.2344E+02	4.3420E+02
Cask Vent Port	2537	2537	2537	2.2494E+02	4.3690E+02
Cask Vent Port Seal	2533	2533	2533	2.2511E+02	4.3720E+02
Vt.Conic.Seal	4828	4828	4828	2.2389E+02	4.3500E+02
Cask Drain Port	583	583	583	2.2689E+02	4.4040E+02
Cask Drain Port Seal	579	579	579	2.2700E+02	4.4060E+02
Drn.Conic.Seal	4313	4313	4313	2.2428E+02	4.3570E+02
Test Port	3351	3351	3351	2.2278E+02	4.3300E+02

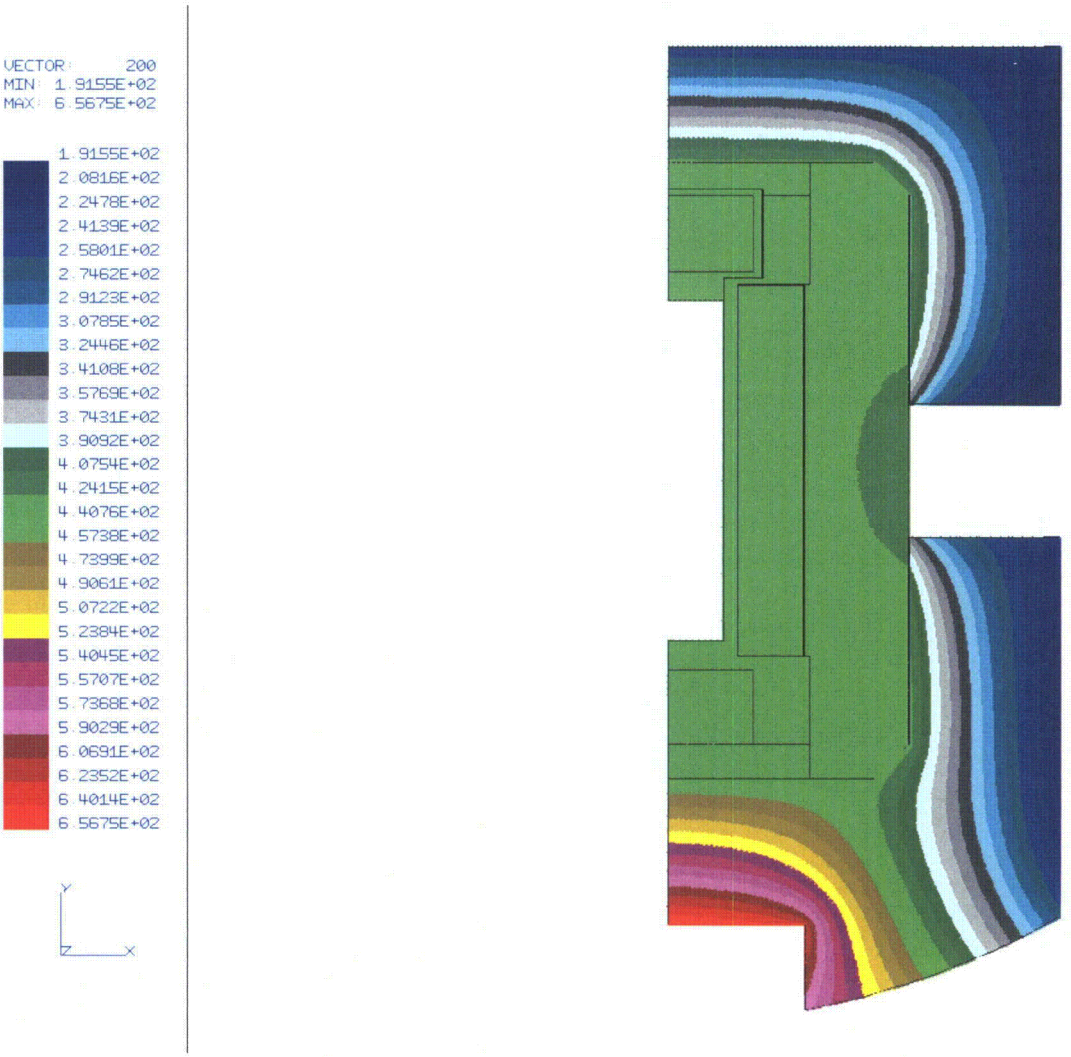

Figure 3-56. Load Case 112, Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Model AOS-050A

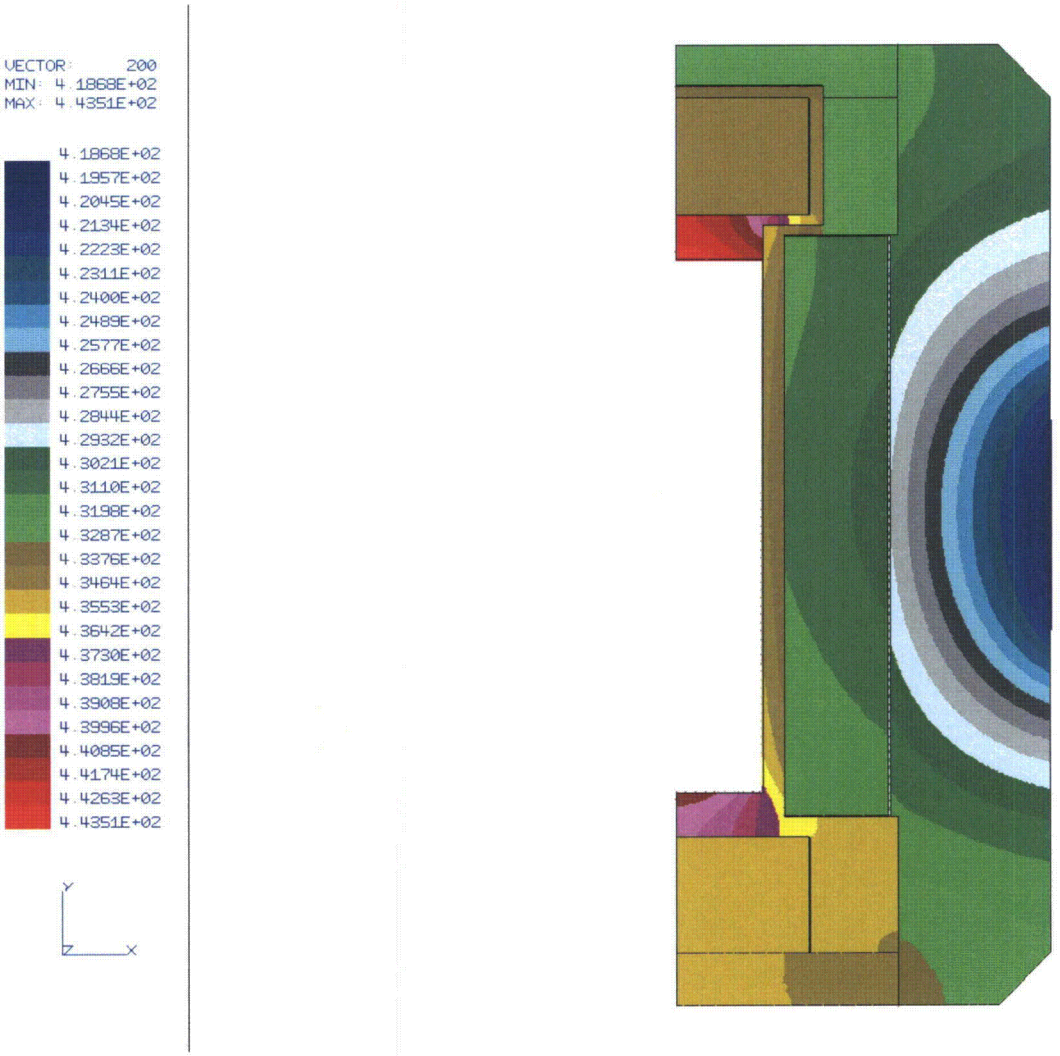

Figure 3-57. Load Case 112, Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Model AOS-050A

Table 3-46. Load Case 112, Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Model AOS-050A

Location	Node	Temp(C)	Temp(F)
1	5001	226.83	440.30
2	4532	221.00	429.80
3	4227	225.28	437.50
4	4752	222.11	431.80
5	4838	220.00	428.00
6	4993	220.44	428.80
7	3309	221.11	430.00
8	3351	220.78	429.40
9	678	217.89	424.20
10	2537	218.50	425.30
11	2533	218.61	425.50
12	4828	220.22	428.40
13	1888	212.50	414.50
14	583	219.22	426.60
15	579	219.28	426.70
16	4313	222.56	432.60
17	3001	222.67	432.80
18	3148	221.50	430.70
19	7533	221.94	431.50
20	7377	222.00	431.60
21	7371	219.39	426.90
22	6942	219.00	426.20
23	6267	219.72	427.50
24	6121	222.78	433.00
25	6001	222.72	432.90
26	15481	218.94	426.10
27	15941	218.06	424.50
28	16260	217.61	423.70
29	17311	165.44	329.80
30	11965	173.00	343.40
31	9785	218.67	425.60
32	9571	220.06	428.10
33	8197	223.00	433.40
34	15451	115.28	239.50
35	16160	113.22	235.80
36	17790	100.56	213.00
37	18750	88.78	191.80
38	11485	103.83	218.90
39	9900	120.06	248.10
40	8673	248.22	478.80
41	8225	283.50	542.30

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1887	3.7294E+02	7.0330E+02
Bottom Plate	3001	3232	3001	2.2383E+02	4.3490E+02
Cask Lid	3233	3424	3329	2.2289E+02	4.3320E+02
Shell Cavity	4001	4998	4532	2.5939E+02	4.9890E+02
Cask Lid Plug	5001	5404	5001	2.2972E+02	4.4550E+02
Tungsten Alloy	6001	7656	6938	2.6200E+02	5.0360E+02
Bottom Cavity	4227	4236	4236	2.3072E+02	4.4730E+02
Side Cavity	4372	4702	4532	2.5939E+02	4.9890E+02
Top Cavity	5001	5012	5001	2.2972E+02	4.4550E+02
Lid Seal	4993	4993	4993	2.2344E+02	4.3420E+02
Cask Vent Port	2537	2537	2537	2.2494E+02	4.3690E+02
Cask Vent Port Seal	2533	2533	2533	2.2511E+02	4.3720E+02
Vt.Conic.Seal	4828	4828	4828	2.2389E+02	4.3500E+02
Cask Drain Port	583	583	583	2.2689E+02	4.4040E+02
Cask Drain Port Seal	579	579	579	2.2700E+02	4.4060E+02
Drn.Conic.Seal	4313	4313	4313	2.2428E+02	4.3570E+02
Test Port	3351	3351	3351	2.2278E+02	4.3300E+02

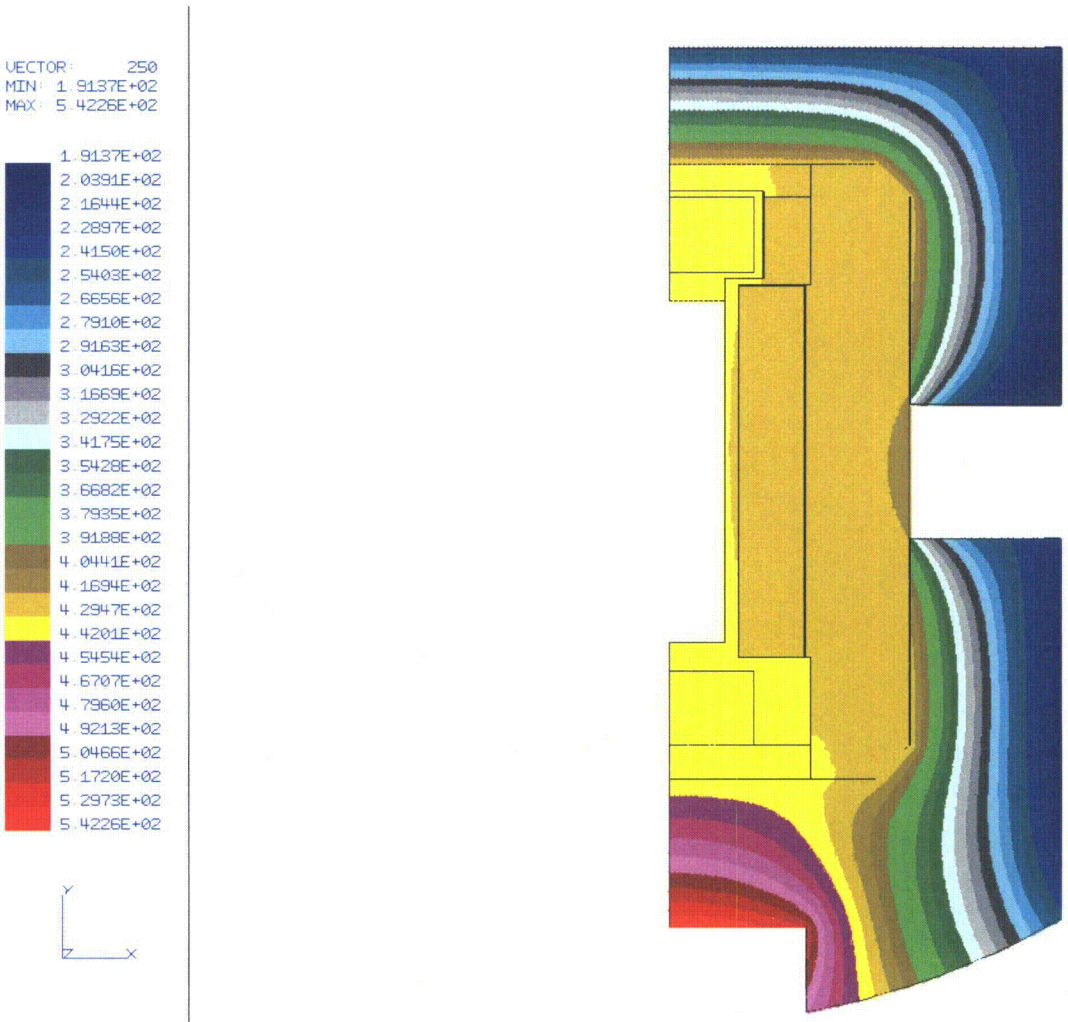

Figure 3-58. Load Case 112, Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Model AOS-050A

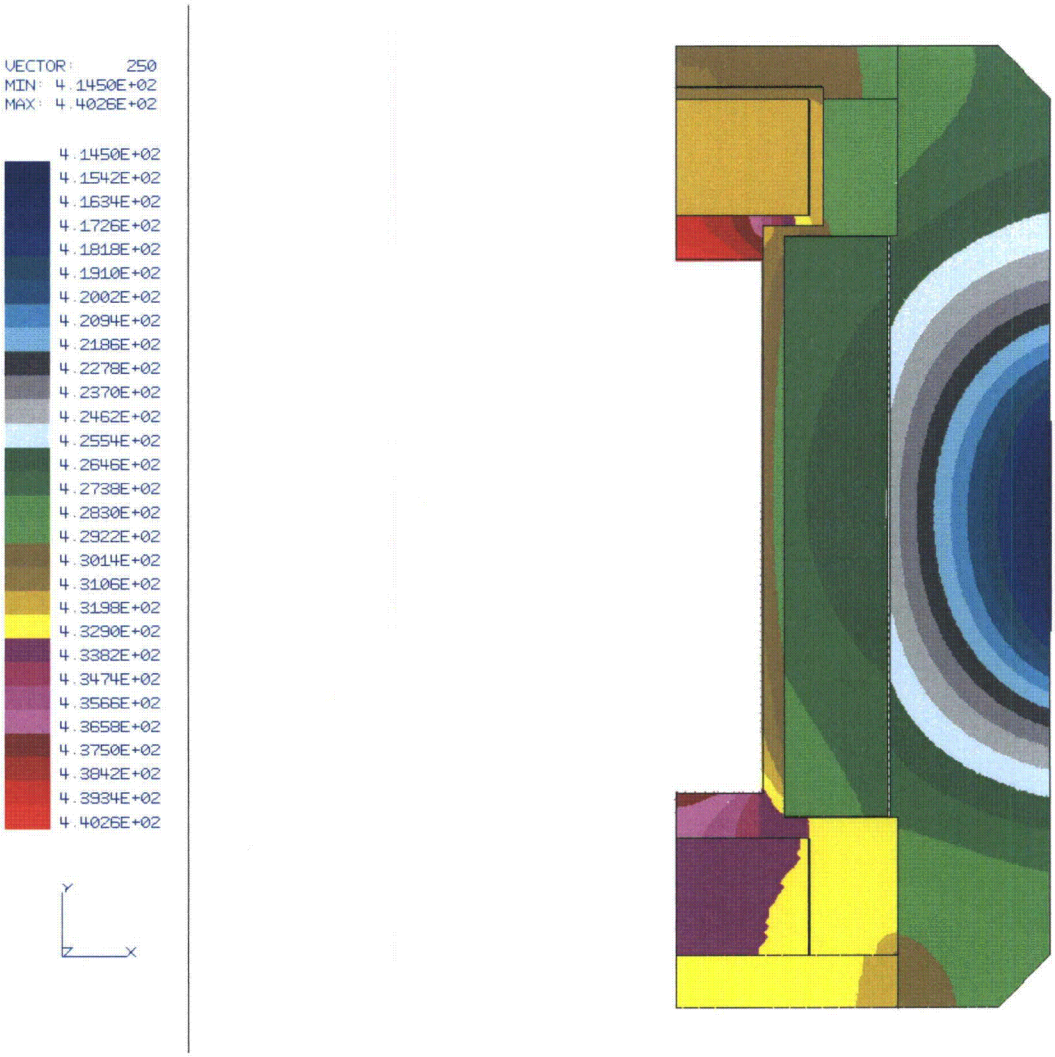

Figure 3-59. Load Case 112, Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Model AOS-050A

3.5.2.3 Thermal Evaluation Results – Models AOS-100A and AOS-100A-S

This appendix presents the following information, specific to the Model AOS-100A and AOS-100A-S transport packages:

- Normal Conditions of Transport Thermal Evaluation Results – Models AOS-100A and AOS-100A-S
- Fire Condition Thermal Evaluation Results – Model AOS-100A and AOS-100A-S

Table 3-47 lists the temperature monitoring points (nodes) for the Model AOS-100 (A, B, and A-S) transport packages, under Normal conditions of transport and the Fire condition.

Table 3-47. Temperature Monitoring Points, by Condition – Model AOS-100

Nodal Location	LIBRA Model Nodal Number, by Condition	
	Normal Conditions of Transport	Fire Condition
1	5001	5001
2	4532	4532
3	4227	4227
4	4752	4752
5	4838	4838
6	4993	4993
7	3309	3309
8	3351	3351
9	678	678
10	2537	2537
11	2533	2533
12	4828	4828
13	1888	1888
14	583	583
15	579	579
16	4313	4313
17	3148	3148
18	3001	3001
19	7533	7533
20	7377	7377
21	7371	7371
22	6942	6942
23	6267	6267
24	6121	6121
25	6001	6001
26	9501	15481
27	9950	15941
28	10014	16260
29	10781	17129
30	9091	11531
31	8463	9785
32	8462	9571
33	8197	8197
34	9711	15451
35	9821	16160

Table 3-47. Temperature Monitoring Points, by Condition – Model AOS-100 (Continued)

Nodal Location	LIBRA Model Nodal Number, by Condition	
	Normal Conditions of Transport	Fire Condition
36	10158	17608
37	10605	18360
38	9102	11051
39	8578	9900
40	8225	8673
41	8001	8225

3.5.2.3.1 Normal Conditions of Transport Thermal Evaluation Results – Models AOS-100A and AOS-100A-S

Table 3-48 lists the tables and figures in this appendix that present the Model AOS-100A and AOS-100A-S transport package results under Normal conditions of transport, for Load Cases 101 through 106. Each table provides a list of temperatures at each monitoring node. The tables for Load Cases 101, 102, 105, and 106 also include a list of maximum temperatures within each transport package component.

Figure 3-60 illustrates the location of each node on the Model AOS-100 (A, B, and A-S) transport packages, under Normal conditions of transport. (The node locations are listed in Table 3-47.)

Table 3-48. Normal Conditions of Transport Thermal Evaluation Results – Models AOS-100A and AOS-100A-S

Load Case	Description	Results Table	Entire Model	Cask Model
101	100°F Ambient, Maximum Decay Heat	Table 3-49	Figure 3-61	Figure 3-62
102	100°F Ambient, Maximum Decay Heat, Maximum Insolation	Table 3-50	Figure 3-63	Figure 3-64
103	-20°F Ambient, Zero Decay Heat, Zero Insolation	Table 3-51	Figure 3-65	–
104	-40°F Ambient, Zero Decay Heat, Zero Insolation	Table 3-52	Figure 3-66	–
105	-40°F Ambient, Maximum Decay Heat	Table 3-53	Figure 3-67	Figure 3-68
106	-20°F Ambient, Maximum Decay Heat	Table 3-54	Figure 3-69	Figure 3-70

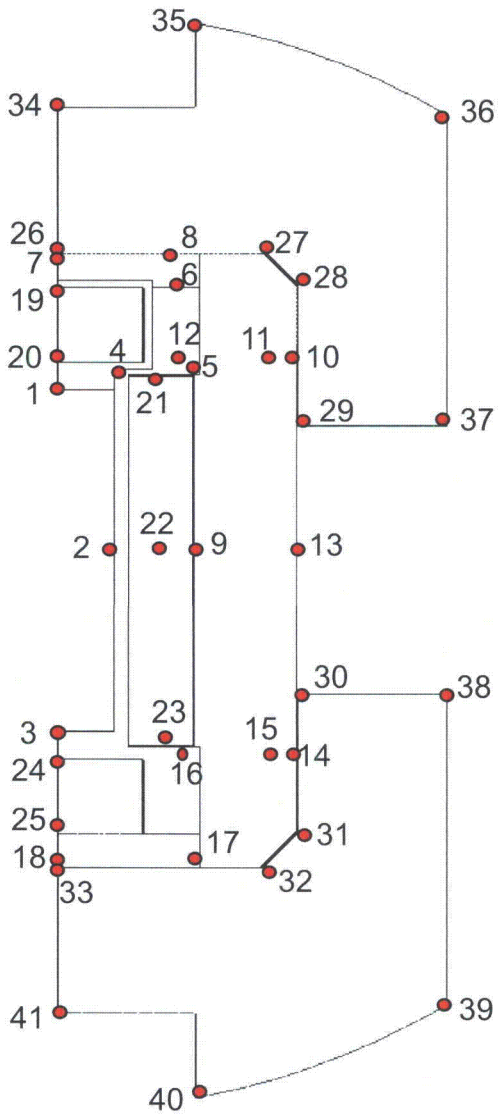

Figure 3-60. Selected Nodal Locations for Normal Conditions of Transport – Model AOS-100

Table 3-49. Load Case 101, 100°F Ambient, Maximum Decay Heat – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	114.78	238.60
2	4532	106.89	224.40
3	4227	111.06	231.90
4	4752	106.11	223.00
5	4838	101.00	213.80
6	4993	100.83	213.50
7	3309	101.11	214.00
8	3351	100.72	213.30
9	678	101.28	214.30
10	2537	99.06	210.30
11	2533	99.28	210.70
12	4828	101.06	213.90
13	1888	97.56	207.60
14	583	98.94	210.10
15	579	99.11	210.40
16	4313	102.00	215.60
17	3148	100.00	212.00
18	3001	100.39	212.70
19	7533	103.06	217.50
20	7377	103.22	217.80
21	7371	102.22	216.00
22	6942	102.39	216.30
23	6267	102.28	216.10
24	6121	102.28	216.10
25	6001	102.17	215.90
26	9501	100.39	212.70
27	9950	98.89	210.00
28	10014	98.06	208.50
29	10781	74.89	166.80
30	9091	72.56	162.60
31	8463	97.56	207.60
32	8462	98.67	209.60
33	8197	99.89	211.80
34	9711	39.39	102.90
35	9821	38.28	100.90
36	10158	38.22	100.80
37	10605	41.17	106.10
38	9102	40.33	104.60
39	8578	40.22	104.40
40	8225	48.28	118.90
41	8001	53.00	127.40

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	724	1.0133E+02	2.1440E+02
Bottom Plate	3001	3232	3103	1.0050E+02	2.1290E+02
Cask Lid	3233	3424	3233	1.0122E+02	2.1420E+02
Shell Cavity	4001	4998	4227	1.1106E+02	2.3190E+02
Cask Lid Plug	5001	5404	5001	1.1478E+02	2.3860E+02
Tungsten Alloy	6001	7656	7552	1.0333E+02	2.1800E+02
Bottom Cavity	4227	4236	4227	1.1106E+02	2.3190E+02
Side Cavity	4372	4702	4372	1.0694E+02	2.2450E+02
Top Cavity	5001	5012	5001	1.1478E+02	2.3860E+02
Lid Seal	4993	4993	4993	1.0083E+02	2.1350E+02
Cask Vent Port	2537	2537	2537	9.9056E+01	2.1030E+02
Cask Vent Port Seal	2533	2533	2533	9.9278E+01	2.1070E+02
Vt.Conic.Seal	4828	4828	4828	1.0106E+02	2.1390E+02
Cask Drain Port	583	583	583	9.8944E+01	2.1010E+02
Cask Drain Port Seal	579	579	579	9.9111E+01	2.1040E+02
Drn.Conic.Seal	4313	4313	4313	1.0200E+02	2.1560E+02
Test Port	3351	3351	3351	1.0072E+02	2.1330E+02

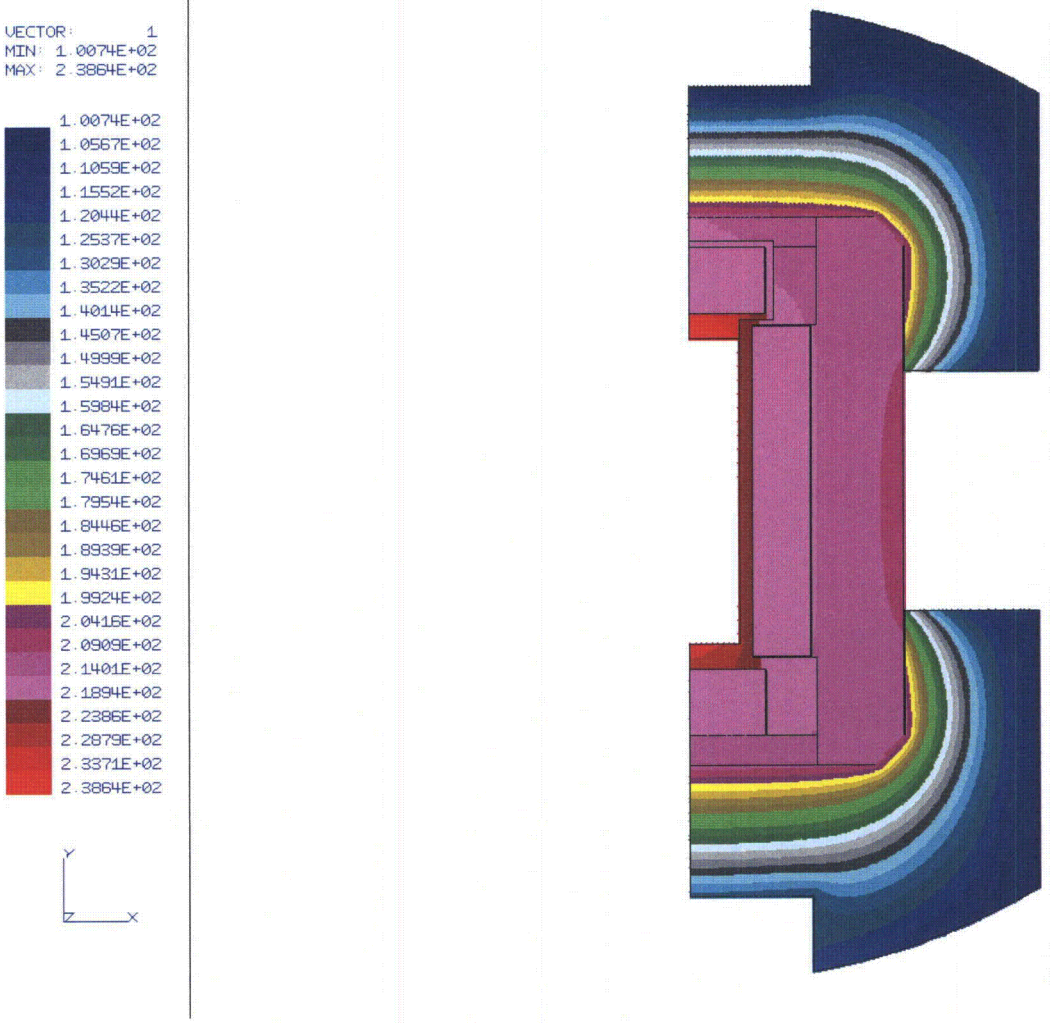

Figure 3-61. Load Case 101, 100°F Ambient, Maximum Decay Heat, Entire Model – Models AOS-100A and AOS-100A-S

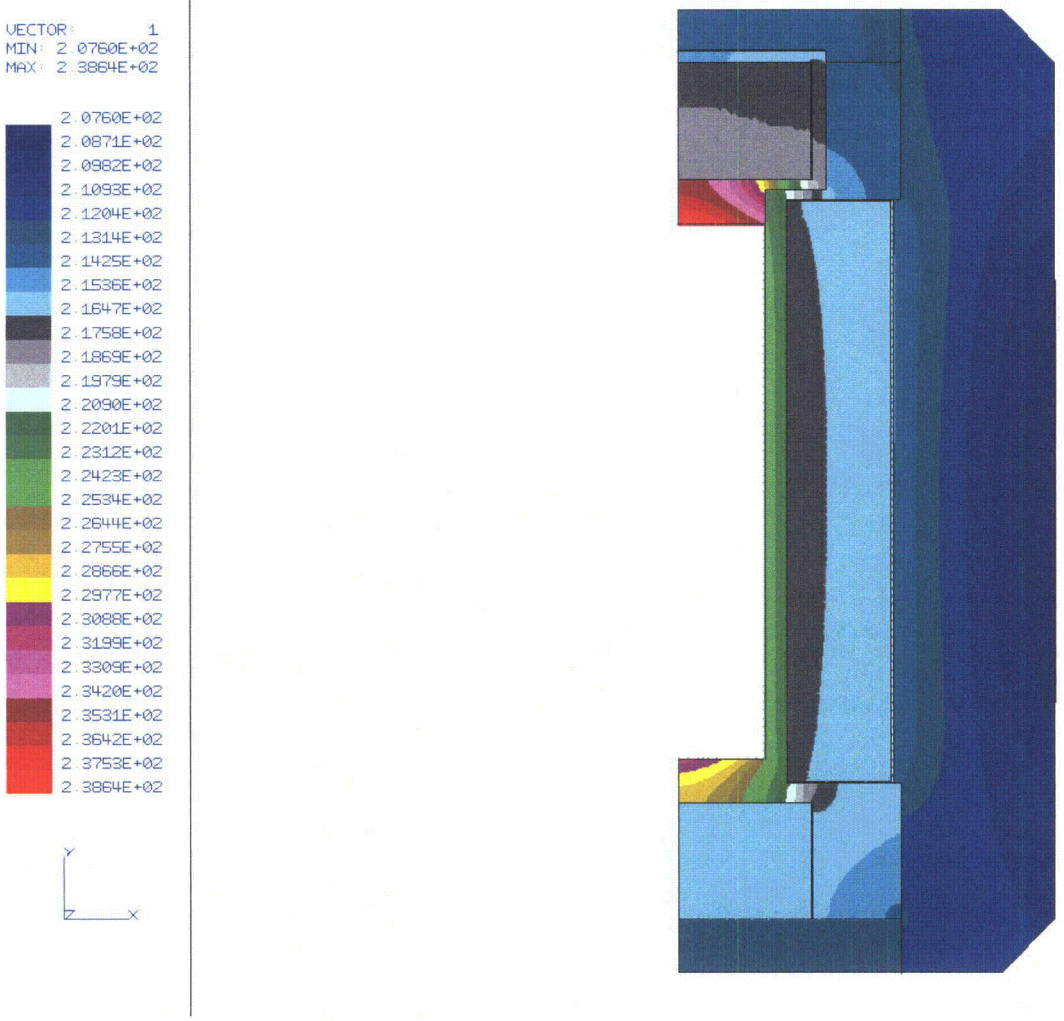

Figure 3-62. Load Case 101, 100°F Ambient, Maximum Decay Heat, Cask Model – Models AOS-100A and AOS-100A-S

Table 3-50. Load Case 102, 100°F Ambient, Maximum Decay Heat, Maximum Insolation – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	158.33	317.00
2	4532	151.11	304.00
3	4227	155.39	311.70
4	4752	150.17	302.30
5	4838	145.17	293.30
6	4993	145.00	293.00
7	3309	145.28	293.50
8	3351	144.94	292.90
9	678	145.78	294.40
10	2537	143.17	289.70
11	2533	143.44	290.20
12	4828	145.22	293.40
13	1888	142.22	288.00
14	583	144.11	291.40
15	579	144.22	291.60
16	4313	146.89	296.40
17	3148	145.00	293.00
18	3001	145.39	293.70
19	7533	147.06	296.70
20	7377	147.22	297.00
21	7371	146.56	295.80
22	6942	146.89	296.40
23	6267	147.00	296.60
24	6121	147.17	296.90
25	6001	147.00	296.60
26	9501	144.78	292.60
27	9950	143.33	290.00
28	10014	142.56	288.60
29	10781	113.94	237.10
30	9091	127.50	261.50
31	8463	143.28	289.90
32	8462	143.94	291.10
33	8197	144.89	292.80
34	9711	110.39	230.70
35	9821	100.06	212.10
36	10158	100.89	213.60
37	10605	83.33	182.00
38	9102	101.17	214.10
39	8578	90.17	194.30
40	8225	97.39	207.30
41	8001	101.56	214.80

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	616	1.4600E+02	2.9480E+02
Bottom Plate	3001	3232	3120	1.4550E+02	2.9390E+02
Cask Lid	3233	3424	3233	1.4539E+02	2.9370E+02
Shell Cavity	4001	4998	4227	1.5539E+02	3.1170E+02
Cask Lid Plug	5001	5404	5001	1.5833E+02	3.1700E+02
Tungsten Alloy	6001	7656	6320	1.4750E+02	2.9750E+02
Bottom Cavity	4227	4236	4227	1.5539E+02	3.1170E+02
Side Cavity	4372	4702	4372	1.5144E+02	3.0460E+02
Top Cavity	5001	5012	5001	1.5833E+02	3.1700E+02
Lid Seal	4993	4993	4993	1.4500E+02	2.9300E+02
Cask Vent Port	2537	2537	2537	1.4317E+02	2.8970E+02
Cask Vent Port Seal	2533	2533	2533	1.4344E+02	2.9020E+02
Vt.Conic.Seal	4828	4828	4828	1.4522E+02	2.9340E+02
Cask Drain Port	583	583	583	1.4411E+02	2.9140E+02
Cask Drain Port Seal	579	579	579	1.4422E+02	2.9160E+02
Drn.Conic.Seal	4313	4313	4313	1.4689E+02	2.9640E+02
Test Port	3351	3351	3351	1.4494E+02	2.9290E+02

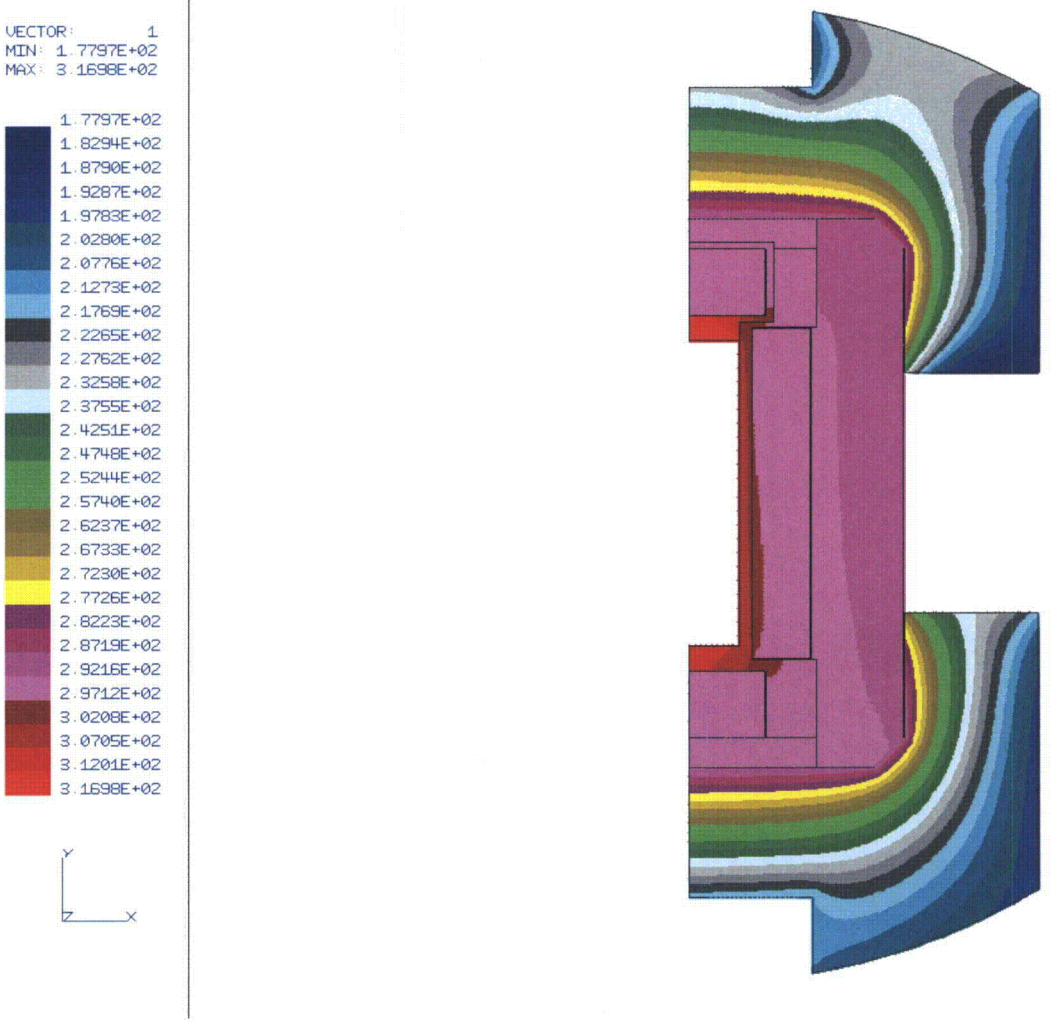

Figure 3-63. Load Case 102, 100°F Ambient, Maximum Decay Heat, Maximum Insolation, Entire Model – Models AOS-100A and AOS-100A-S

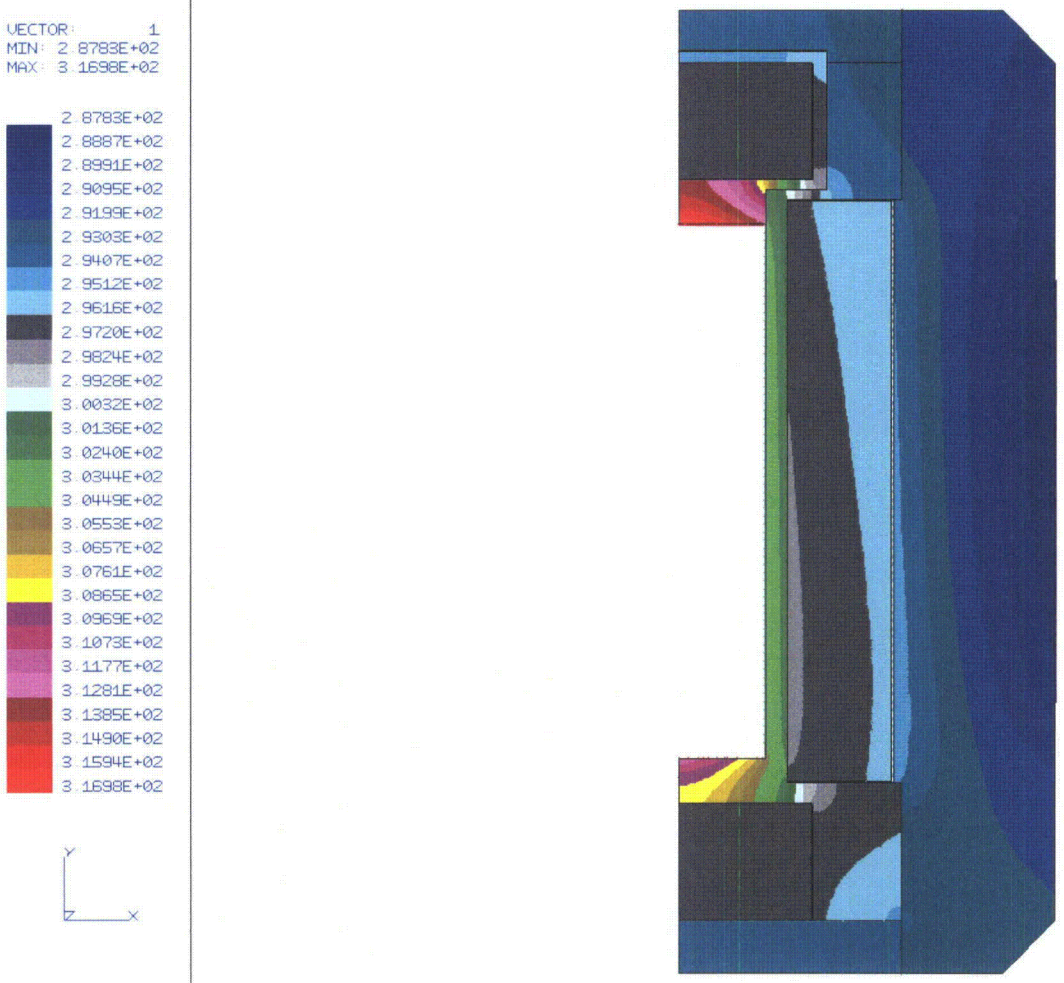

Figure 3-64. Load Case 102, 100°F Ambient, Maximum Decay Heat, Maximum Insolation, Cask Model – Models AOS-100A and AOS-100A-S

Table 3-51. Load Case 103, -20°F Ambient, Zero Decay Heat, Zero Insolation – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	-28.89	-20.00
2	4532	-28.89	-20.00
3	4227	-28.89	-20.00
4	4752	-28.89	-20.00
5	4838	-28.89	-20.00
6	4993	-28.89	-20.00
7	3309	-28.89	-20.00
8	3351	-28.89	-20.00
9	678	-28.89	-20.00
10	2537	-28.89	-20.00
11	2533	-28.89	-20.00
12	4828	-28.89	-20.00
13	1888	-28.89	-20.00
14	583	-28.89	-20.00
15	579	-28.89	-20.00
16	4313	-28.89	-20.00
17	3148	-28.89	-20.00
18	3001	-28.89	-20.00
19	7533	-28.89	-20.00
20	7377	-28.89	-20.00
21	7371	-28.89	-20.00
22	6942	-28.89	-20.00
23	6267	-28.89	-20.00
24	6121	-28.89	-20.00
25	6001	-28.89	-20.00
26	9501	-28.89	-20.00
27	9950	-28.89	-20.00
28	10014	-28.89	-20.00
29	10781	-28.89	-20.00
30	9091	-28.89	-20.00
31	8463	-28.89	-20.00
32	8462	-28.89	-20.00
33	8197	-28.89	-20.00
34	9711	-28.89	-20.00
35	9821	-28.89	-20.00
36	10158	-28.89	-20.00
37	10605	-28.89	-20.00
38	9102	-28.89	-20.00
39	8578	-28.89	-20.00
40	8225	-28.89	-20.00
41	8001	-28.89	-20.00

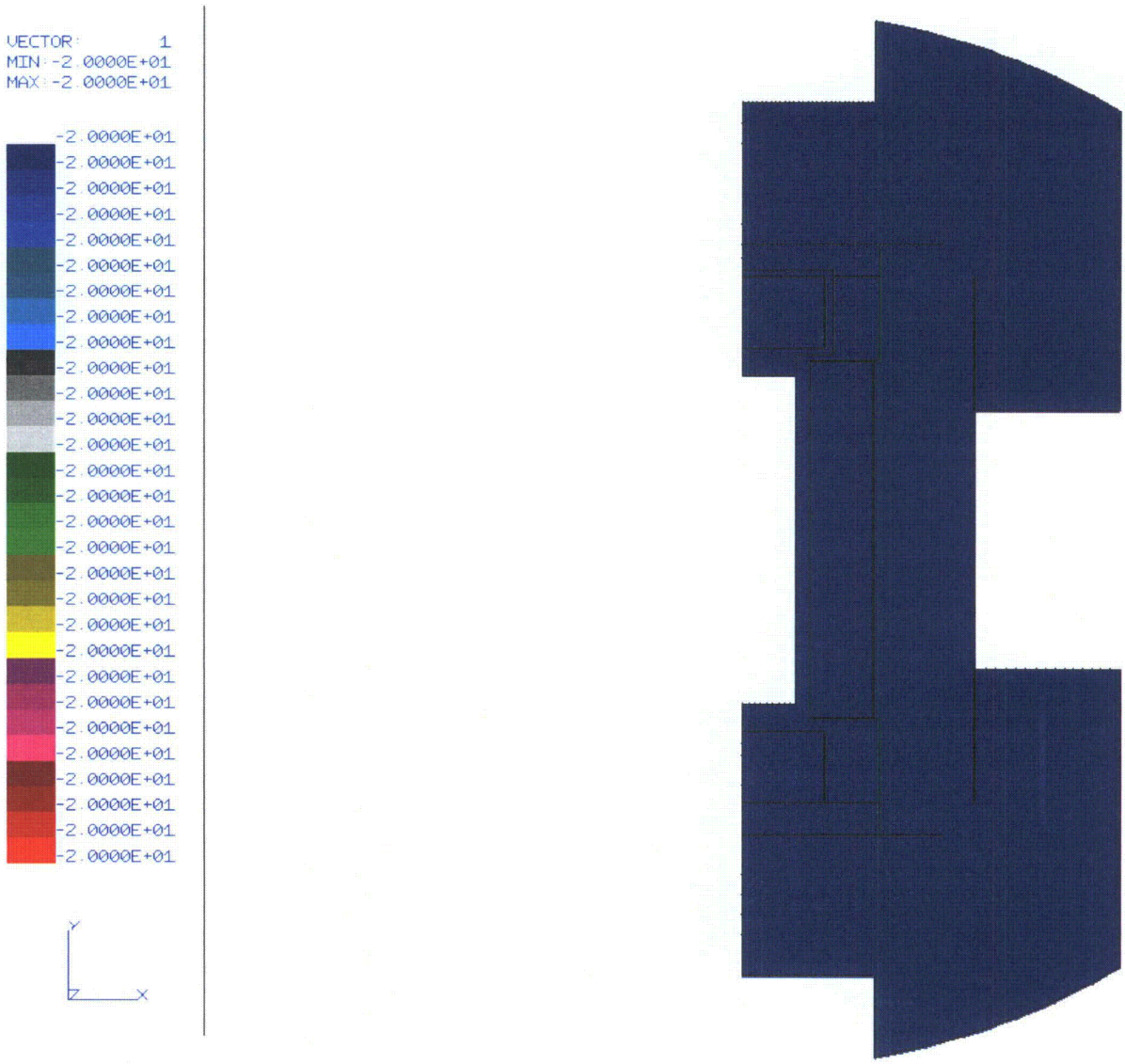

Figure 3-65. Load Case 103, -20°F Ambient, Zero Decay Heat, Zero Insolation, Entire Model – Models AOS-100A and AOS-100A-S

Table 3-52. Load Case 104, -40°F Ambient, Zero Decay Heat, Zero Insolation – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	-40.00	-40.00
2	4532	-40.00	-40.00
3	4227	-40.00	-40.00
4	4752	-40.00	-40.00
5	4838	-40.00	-40.00
6	4993	-40.00	-40.00
7	3309	-40.00	-40.00
8	3351	-40.00	-40.00
9	678	-40.00	-40.00
10	2537	-40.00	-40.00
11	2533	-40.00	-40.00
12	4828	-40.00	-40.00
13	1888	-40.00	-40.00
14	583	-40.00	-40.00
15	579	-40.00	-40.00
16	4313	-40.00	-40.00
17	3148	-40.00	-40.00
18	3001	-40.00	-40.00
19	7533	-40.00	-40.00
20	7377	-40.00	-40.00
21	7371	-40.00	-40.00
22	6942	-40.00	-40.00
23	6267	-40.00	-40.00
24	6121	-40.00	-40.00
25	6001	-40.00	-40.00
26	9501	-40.00	-40.00
27	9950	-40.00	-40.00
28	10014	-40.00	-40.00
29	10781	-40.00	-40.00
30	9091	-40.00	-40.00
31	8463	-40.00	-40.00
32	8462	-40.00	-40.00
33	8197	-40.00	-40.00
34	9711	-40.00	-40.00
35	9821	-40.00	-40.00
36	10158	-40.00	-40.00
37	10605	-40.00	-40.00
38	9102	-40.00	-40.00
39	8578	-40.00	-40.00
40	8225	-40.00	-40.00
41	8001	-40.00	-40.00

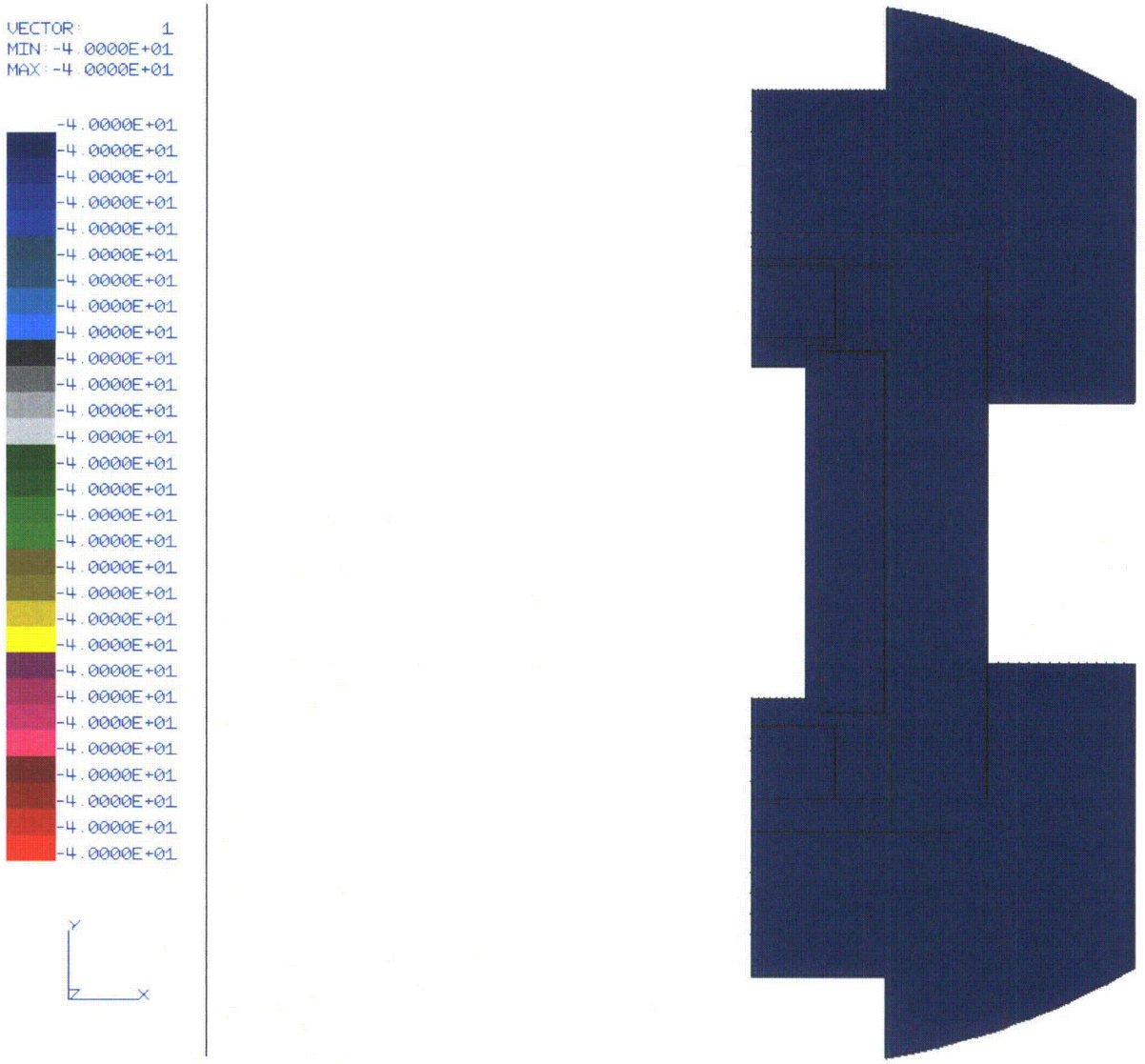

Figure 3-66. Load Case 104, -40°F Ambient, Zero Decay Heat, Zero Insolation, Entire Model – Models AOS-100A and AOS-100A-S

Table 3-53. Load Case 105, -40°F Ambient, Maximum Decay Heat – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	45.17	113.30
2	4532	36.38	97.49
3	4227	40.72	105.30
4	4752	35.49	95.89
5	4838	29.95	85.91
6	4993	29.79	85.63
7	3309	30.12	86.22
8	3351	29.69	85.45
9	678	30.14	86.26
10	2537	27.89	82.21
11	2533	28.11	82.59
12	4828	30.06	86.10
13	1888	26.08	78.95
14	583	27.64	81.76
15	579	27.85	82.13
16	4313	30.93	87.68
17	3148	28.74	83.74
18	3001	29.23	84.62
19	7533	32.47	90.45
20	7377	32.68	90.82
21	7371	31.14	88.05
22	6942	31.28	88.30
23	6267	31.13	88.04
24	6121	31.25	88.25
25	6001	31.10	87.98
26	9501	29.36	84.84
27	9950	27.46	81.42
28	10014	26.30	79.34
29	10781	2.58	36.64
30	9091	-1.81	28.75
31	8463	25.50	77.90
32	8462	27.09	80.76
33	8197	28.64	83.55
34	9711	-37.70	-35.86
35	9821	-39.18	-38.53
36	10158	-39.34	-38.81
37	10605	-34.23	-29.61
38	9102	-36.38	-33.48
39	8578	-36.78	-34.21
40	8225	-27.38	-17.29
41	8001	-21.91	-7.44

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	722	3.0211E+01	8.6380E+01
Bottom Plate	3001	3232	3120	2.9344E+01	8.4820E+01
Cask Lid	3233	3424	3233	3.0244E+01	8.6440E+01
Shell Cavity	4001	4998	4227	4.0722E+01	1.0530E+02
Cask Lid Plug	5001	5404	5001	4.5167E+01	1.1330E+02
Tungsten Alloy	6001	7656	7552	3.2756E+01	9.0960E+01
Bottom Cavity	4227	4236	4227	4.0722E+01	1.0530E+02
Side Cavity	4372	4702	4372	3.6422E+01	9.7560E+01
Top Cavity	5001	5012	5001	4.5167E+01	1.1330E+02
Lid Seal	4993	4993	4993	2.9794E+01	8.5630E+01
Cask Vent Port	2537	2537	2537	2.7894E+01	8.2210E+01
Cask Vent Port Seal	2533	2533	2533	2.8106E+01	8.2590E+01
Vt.Conic.Seal	4828	4828	4828	3.0056E+01	8.6100E+01
Cask Drain Port	583	583	583	2.7644E+01	8.1760E+01
Cask Drain Port Seal	579	579	579	2.7850E+01	8.2130E+01
Drn.Conic.Seal	4313	4313	4313	3.0933E+01	8.7680E+01
Test Port	3351	3351	3351	2.9694E+01	8.5450E+01

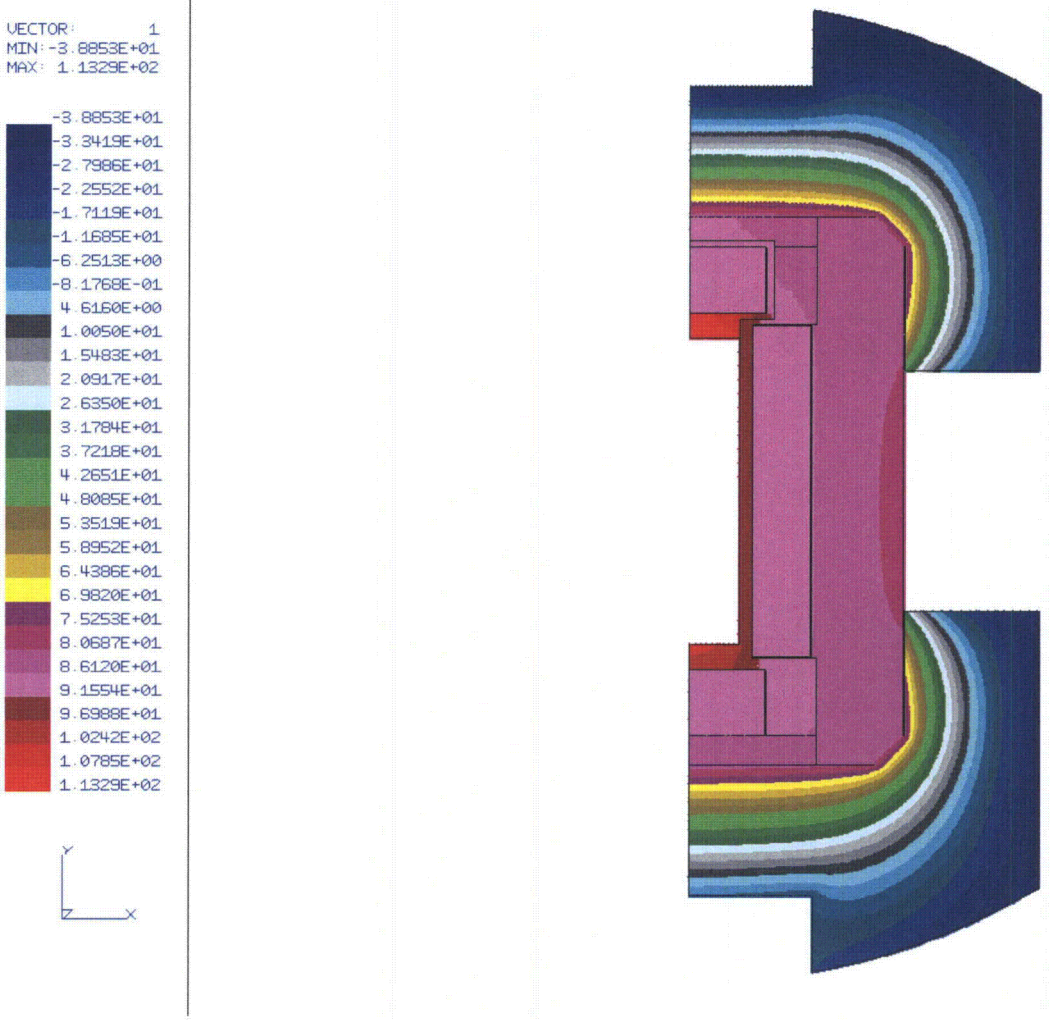

Figure 3-67. Load Case 105, -40°F Ambient, Maximum Decay Heat, Entire Model – Models AOS-100A and AOS-100A-S

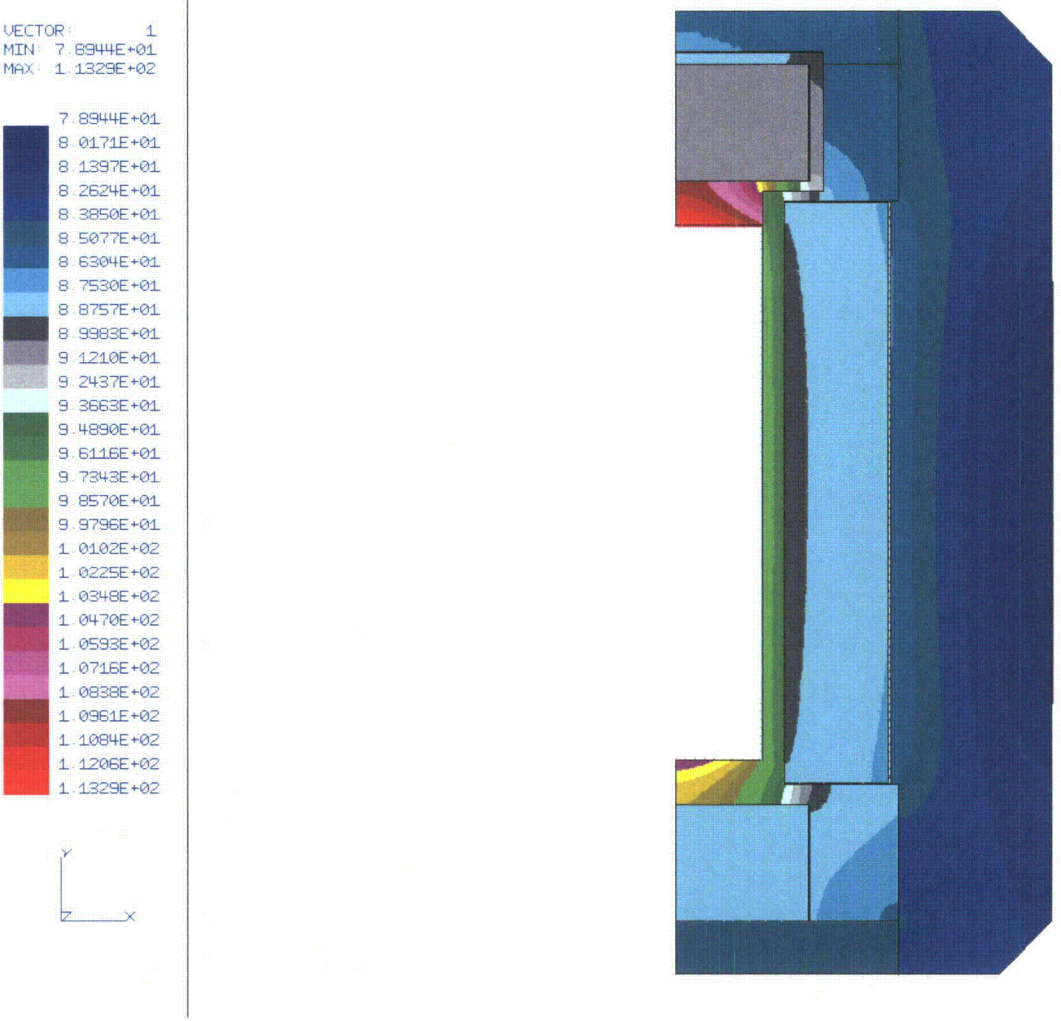

Figure 3-68. Load Case 105, -40°F Ambient, Maximum Decay Heat, Cask Model – Models AOS-100A and AOS-100A-S

Table 3-54. Load Case 106, -20°F Ambient, Maximum Decay Heat – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	55.39	131.70
2	4532	46.72	116.10
3	4227	51.06	123.90
4	4752	45.89	114.60
5	4838	40.39	104.70
6	4993	40.22	104.40
7	3309	40.56	105.00
8	3351	40.17	104.30
9	678	40.61	105.10
10	2537	38.33	101.00
11	2533	38.56	101.40
12	4828	40.50	104.90
13	1888	36.62	97.92
14	583	38.11	100.60
15	579	38.33	101.00
16	4313	41.39	106.50
17	3148	39.22	102.60
18	3001	39.67	103.40
19	7533	42.83	109.10
20	7377	43.06	109.50
21	7371	41.61	106.90
22	6942	41.72	107.10
23	6267	41.61	106.90
24	6121	41.67	107.00
25	6001	41.56	106.80
26	9501	39.78	103.60
27	9950	37.94	100.30
28	10014	36.84	98.31
29	10781	12.88	55.18
30	9091	8.62	47.52
31	8463	36.06	96.90
32	8462	37.59	99.67
33	8197	39.11	102.40
34	9711	-26.72	-16.09
35	9821	-28.13	-18.63
36	10158	-28.24	-18.84
37	10605	-23.56	-10.40
38	9102	-25.51	-13.91
39	8578	-25.68	-14.23
40	8225	-16.47	2.36
41	8001	-11.10	12.02

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	698	4.0667E+01	1.0520E+02
Bottom Plate	3001	3232	3103	3.9778E+01	1.0360E+02
Cask Lid	3233	3424	3233	4.0667E+01	1.0520E+02
Shell Cavity	4001	4998	4227	5.1056E+01	1.2390E+02
Cask Lid Plug	5001	5404	5001	5.5389E+01	1.3170E+02
Tungsten Alloy	6001	7656	7552	4.3111E+01	1.0960E+02
Bottom Cavity	4227	4236	4227	5.1056E+01	1.2390E+02
Side Cavity	4372	4702	4372	4.6778E+01	1.1620E+02
Top Cavity	5001	5012	5001	5.5389E+01	1.3170E+02
Lid Seal	4993	4993	4993	4.0222E+01	1.0440E+02
Cask Vent Port	2537	2537	2537	3.8333E+01	1.0100E+02
Cask Vent Port Seal	2533	2533	2533	3.8556E+01	1.0140E+02
Vt.Conic.Seal	4828	4828	4828	4.0500E+01	1.0490E+02
Cask Drain Port	583	583	583	3.8111E+01	1.0060E+02
Cask Drain Port Seal	579	579	579	3.8333E+01	1.0100E+02
Drn.Conic.Seal	4313	4313	4313	4.1389E+01	1.0650E+02
Test Port	3351	3351	3351	4.0167E+01	1.0430E+02

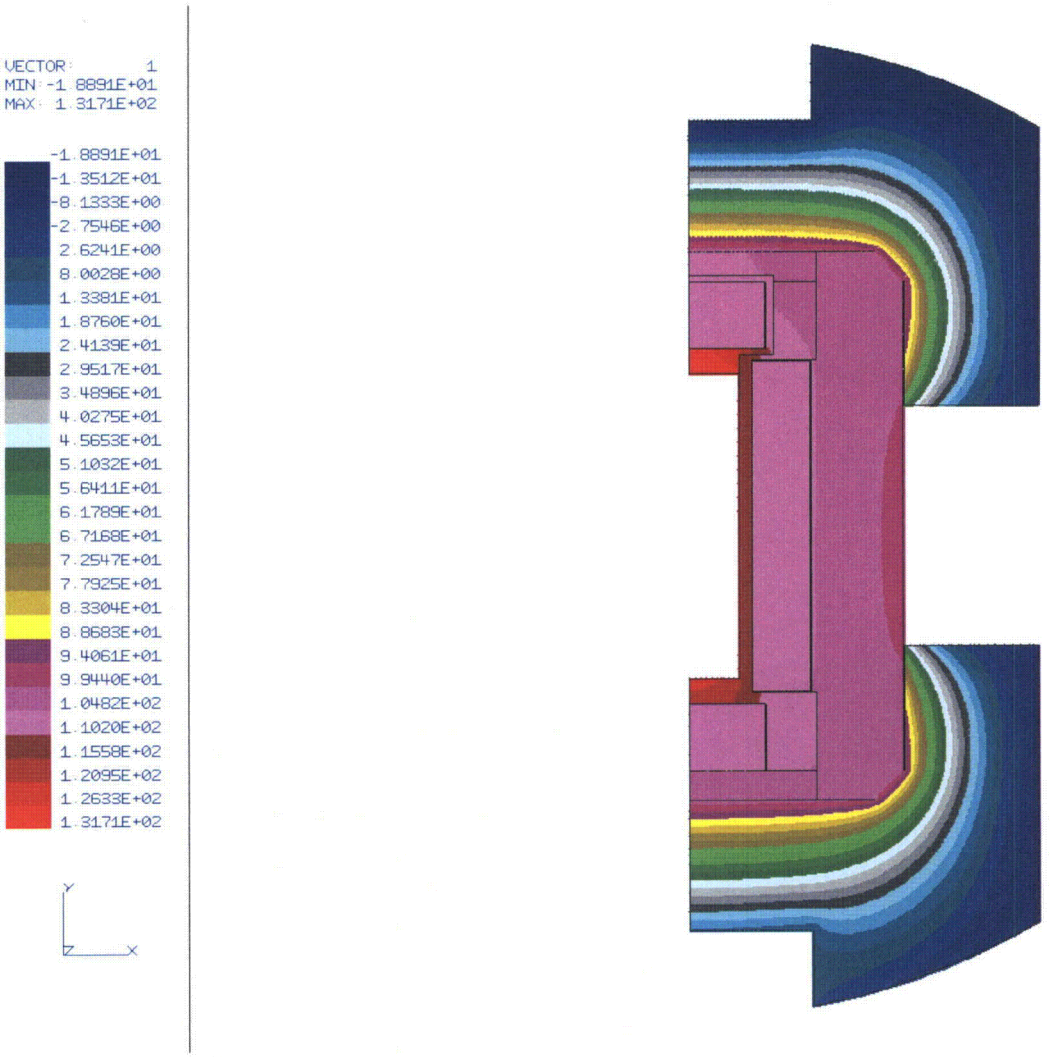

Figure 3-69. Load Case 106, -20°F Ambient, Maximum Decay Heat, Entire Model – Models AOS-100A and AOS-100A-S

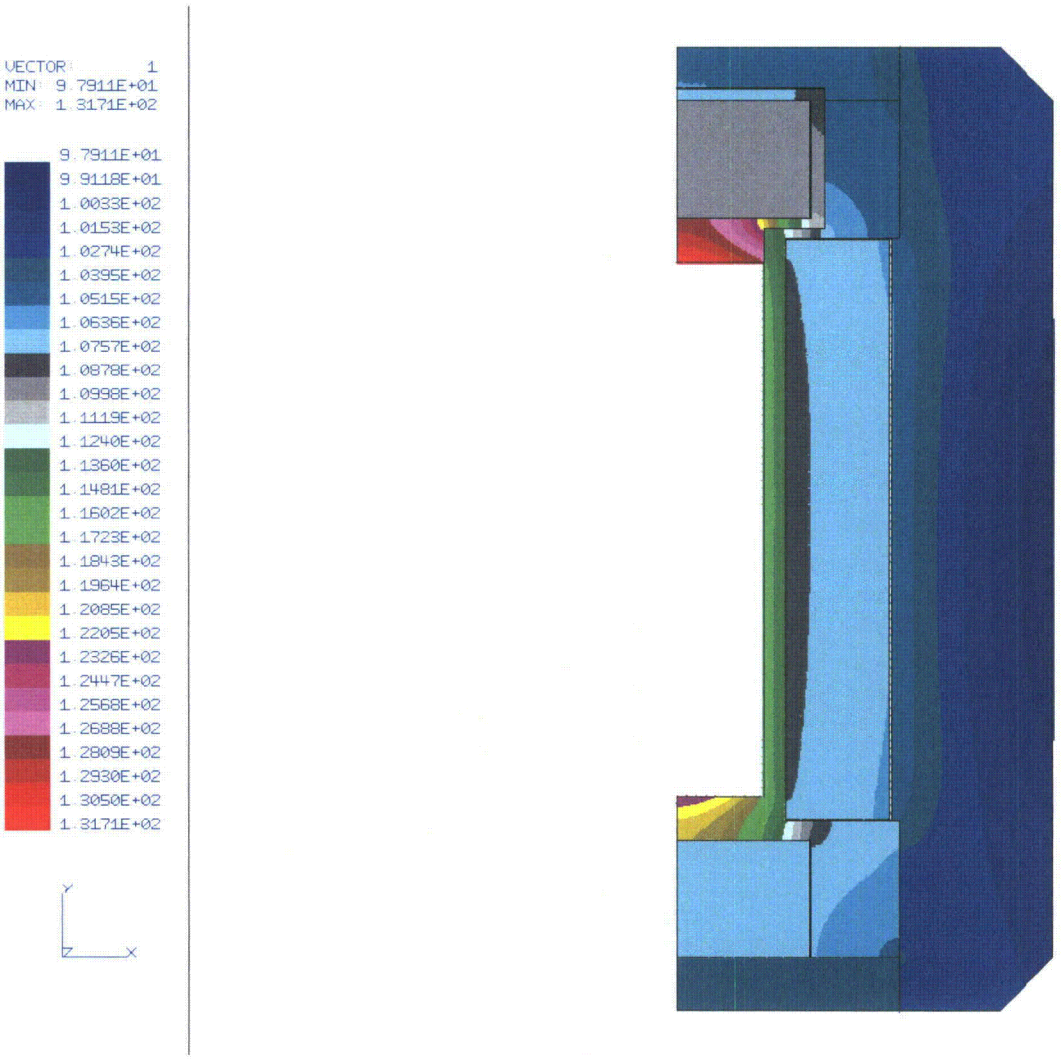

Figure 3-70. Load Case 106, -20°F Ambient, Maximum Decay Heat, Cask Model – Models AOS-100A and AOS-100A-S

3.5.2.3.2 Fire Condition Thermal Evaluation Results – Model AOS-100A and AOS-100A-S

Table 3-55 lists the tables and figures in this appendix that present the Model AOS-100A and AOS-100A-S transport package results under the Fire condition, for Load Cases 111 and 112. Each table provides a list of temperatures at each monitoring node. Also listed are the maximum temperatures within each transport package component.

Figure 3-71 illustrates the location of each node on the Model AOS-100 (A, B, and A-S) transport packages, under the Fire condition. (The node locations are listed in Table 3-47.)

Table 3-55. Fire Condition Thermal Evaluation Results – Models AOS-100A and AOS-100A-S

Load Case	Description	Temperature versus Time	Results Table	Entire Model	Cask Model
111	Fire at 30 Minutes, 1,475°F Ambient, Maximum Decay Heat	Figure 3-72 Figure 3-73 Figure 3-74	Table 3-56	Figure 3-75	Figure 3-76
112	Post Fire at 60 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-57	Figure 3-77	Figure 3-78
	Post Fire at 90 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-58	Figure 3-79	Figure 3-80
	Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-59	Figure 3-81	Figure 3-82
	Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-60	Figure 3-83	Figure 3-84
	Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-61	Figure 3-85	Figure 3-86

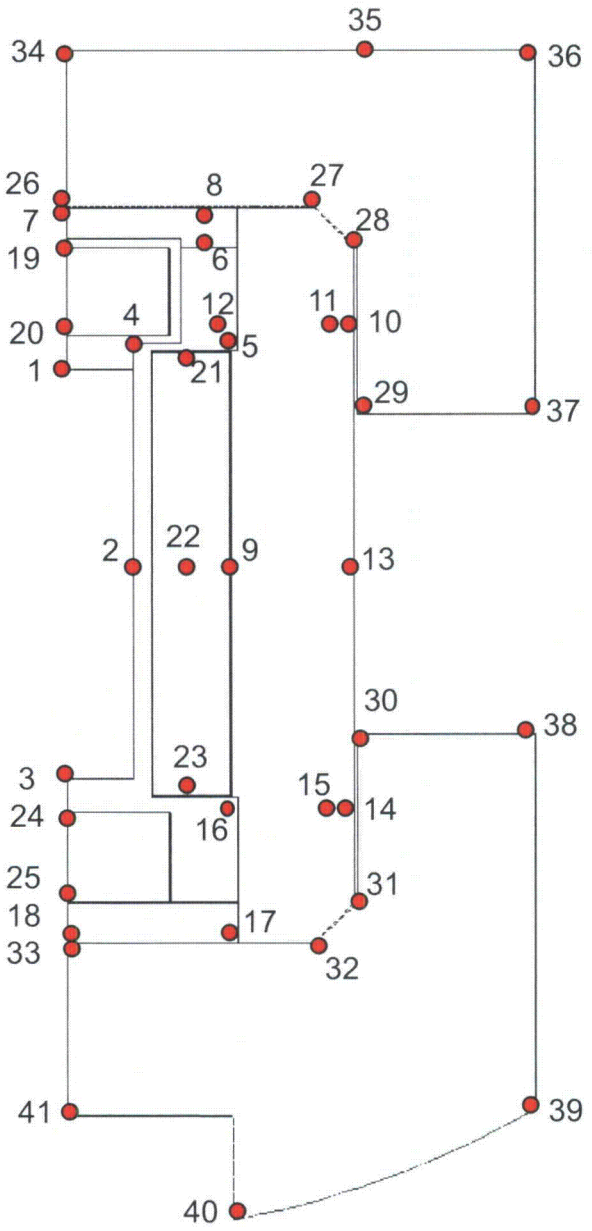

Figure 3-71. Selected Nodal Locations for Fire Condition – Model AOS-100

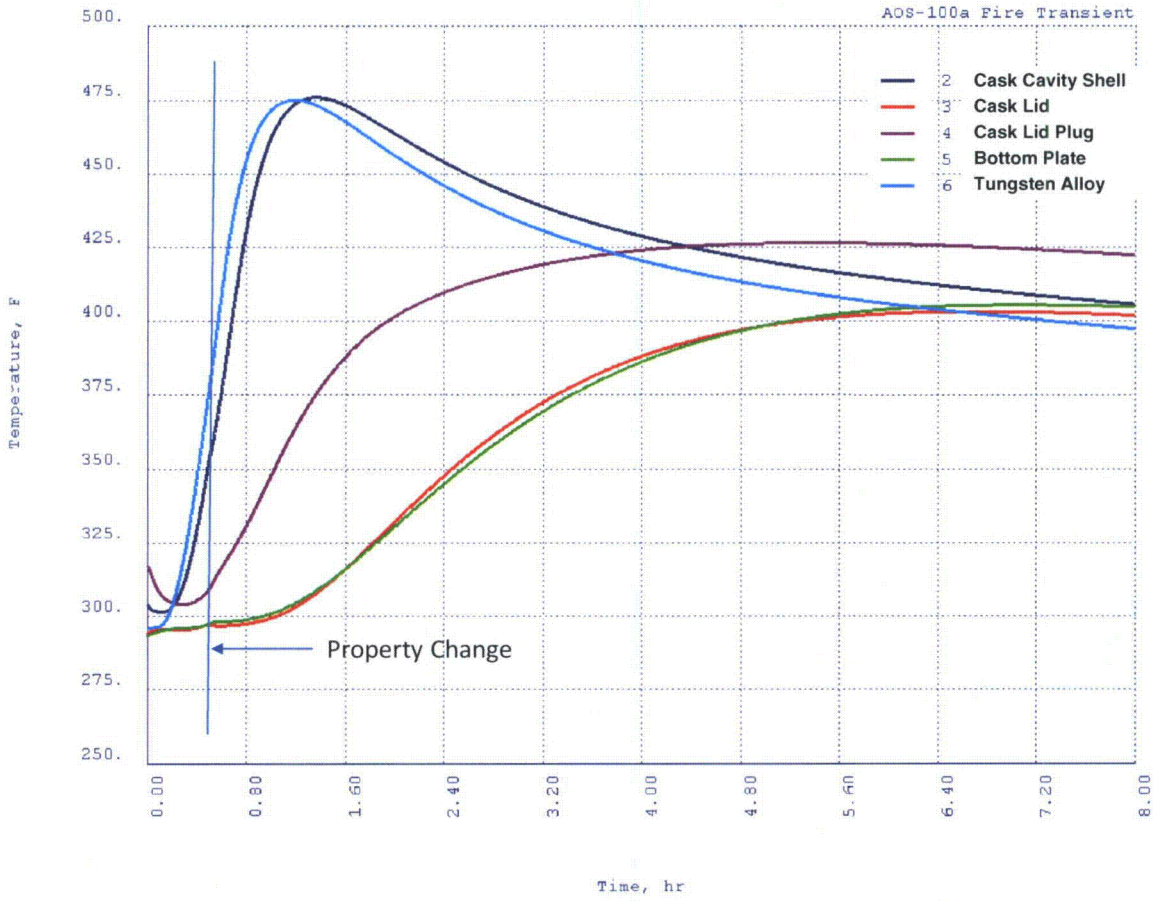

Figure 3-72. Fire for 30 Minutes and Post Fire Cool Down for 7.5 Hours, Temperature versus Time, for Cask Cavity Shell, Cask Lid, Cask Lid Plug, Bottom Plate, and Tungsten Alloy – Models AOS-100A and AOS-100A-S

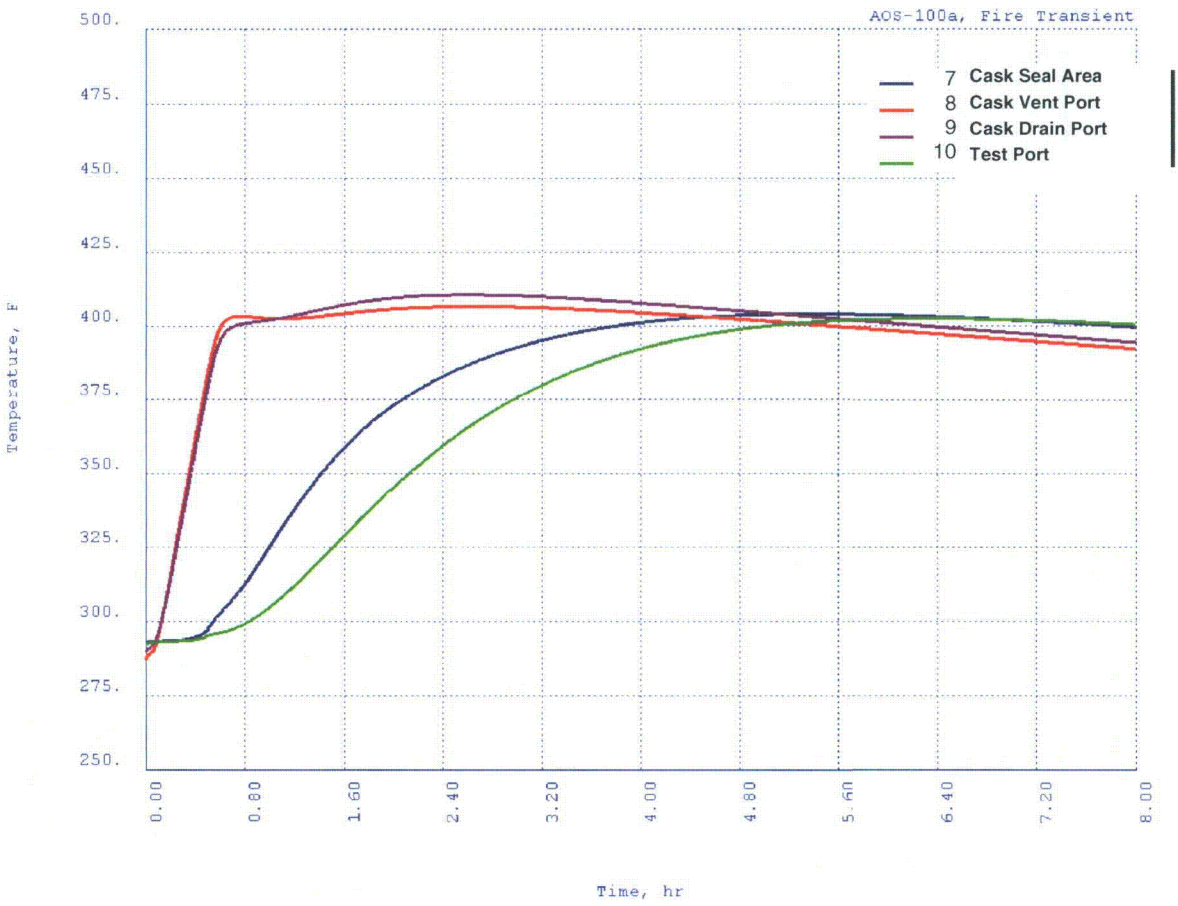

Figure 3-73. Fire for 30 Minutes and Post Fire Cool Down for 7.5 Hours, Temperature versus Time, for Cask Seal Area, Cask Vent Port, Cask Drain Port, and Test Port – Models AOS-100A and AOS-100A-S

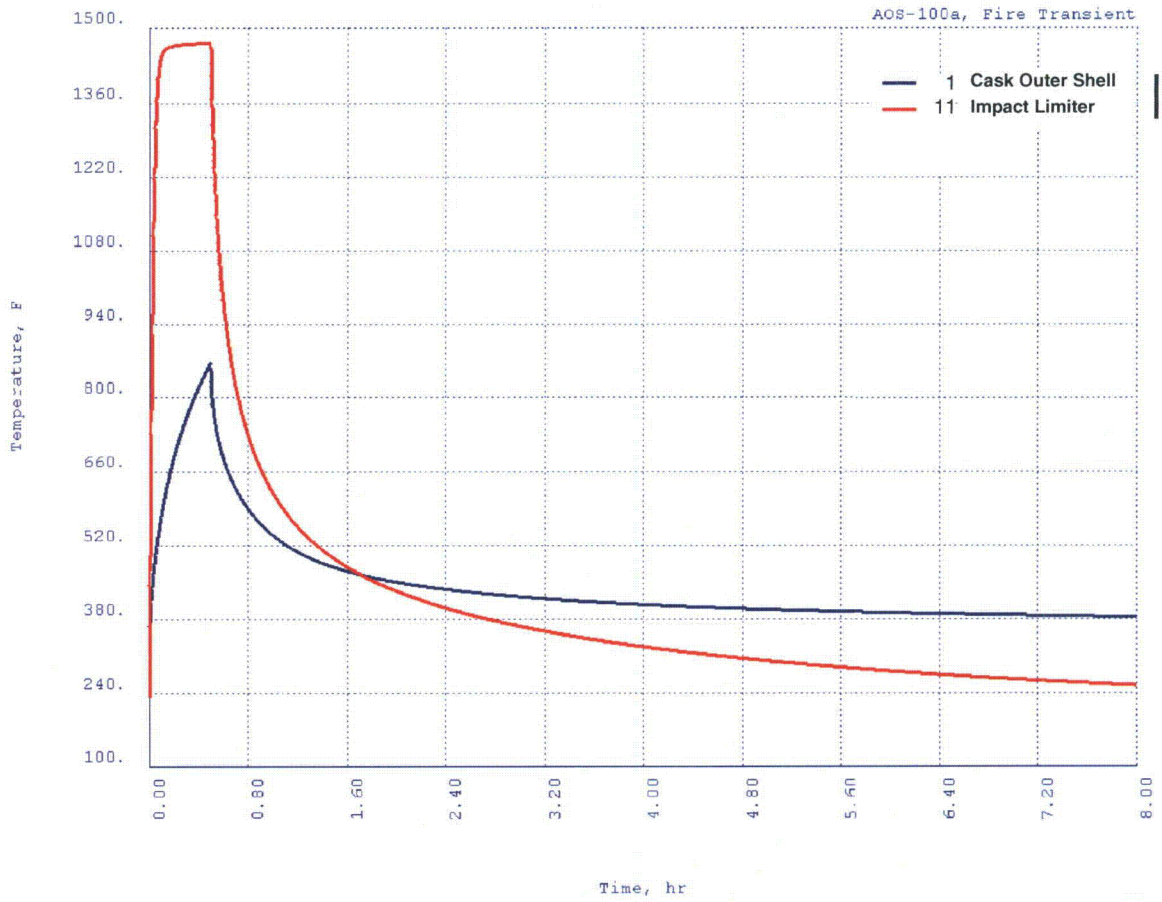

Figure 3-74. Fire for 30 Minutes and Post Fire Cool Down for 7.5 Hours, Temperature versus Time, for Cask Outer Shell and Impact Limiter – Models AOS-100A and AOS-100A-S

Table 3-56. Load Case 111, Fire at 30 Minutes, 1,475°F Ambient, Maximum Decay Heat – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	153.72	308.70
2	4532	177.89	352.20
3	4227	154.56	310.20
4	4752	154.61	310.30
5	4838	167.17	332.90
6	4993	147.00	296.60
7	3309	146.61	295.90
8	3351	146.00	294.80
9	678	211.39	412.50
10	2537	195.11	383.20
11	2533	192.11	377.80
12	4828	160.44	320.80
13	1888	463.11	865.60
14	583	192.61	378.70
15	579	189.83	373.70
16	4313	161.61	322.90
17	3148	146.67	296.00
18	3001	147.28	297.10
19	7533	148.33	299.00
20	7377	150.17	302.30
21	7371	165.06	329.10
22	6942	183.06	361.50
23	6267	165.00	329.00
24	6121	150.83	303.50
25	6001	148.94	300.10
26	15481	146.61	295.90
27	15941	146.89	296.40
28	16260	150.50	302.90
29	17129	443.72	830.70
30	11531	444.56	832.20
31	9785	151.33	304.40
32	9571	147.72	297.90
33	8197	147.28	297.10
34	15451	797.22	1467.00
35	16160	796.67	1466.00
36	17608	799.44	1471.00
37	18360	799.44	1471.00
38	11051	799.44	1471.00
39	9900	798.89	1470.00
40	8673	800.00	1472.00
41	8225	797.78	1468.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1888	4.6311E+02	8.6560E+02
Bottom Plate	3001	3232	3120	1.4872E+02	2.9970E+02
Cask Lid	3233	3424	3233	1.4739E+02	2.9730E+02
Shell Cavity	4001	4998	4531	1.7861E+02	3.5350E+02
Cask Lid Plug	5001	5404	5012	1.5878E+02	3.1780E+02
Tungsten Alloy	6001	7656	6938	1.9078E+02	3.7540E+02
Bottom Cavity	4227	4236	4236	1.6044E+02	3.2080E+02
Side Cavity	4372	4702	4527	1.7789E+02	3.5220E+02
Top Cavity	5001	5012	5012	1.5878E+02	3.1780E+02
Lid Seal	4993	4993	4993	1.4700E+02	2.9660E+02
Cask Vent Port	2537	2537	2537	1.9511E+02	3.8320E+02
Cask Vent Port Seal	2533	2533	2533	1.9211E+02	3.7780E+02
Vt.Conic.Seal	4828	4828	4828	1.6044E+02	3.2080E+02
Cask Drain Port	583	583	583	1.9261E+02	3.7870E+02
Cask Drain Port Seal	579	579	579	1.8983E+02	3.7370E+02
Drn.Conic.Seal	4313	4313	4313	1.6161E+02	3.2290E+02
Test Port	3351	3351	3351	1.4600E+02	2.9480E+02

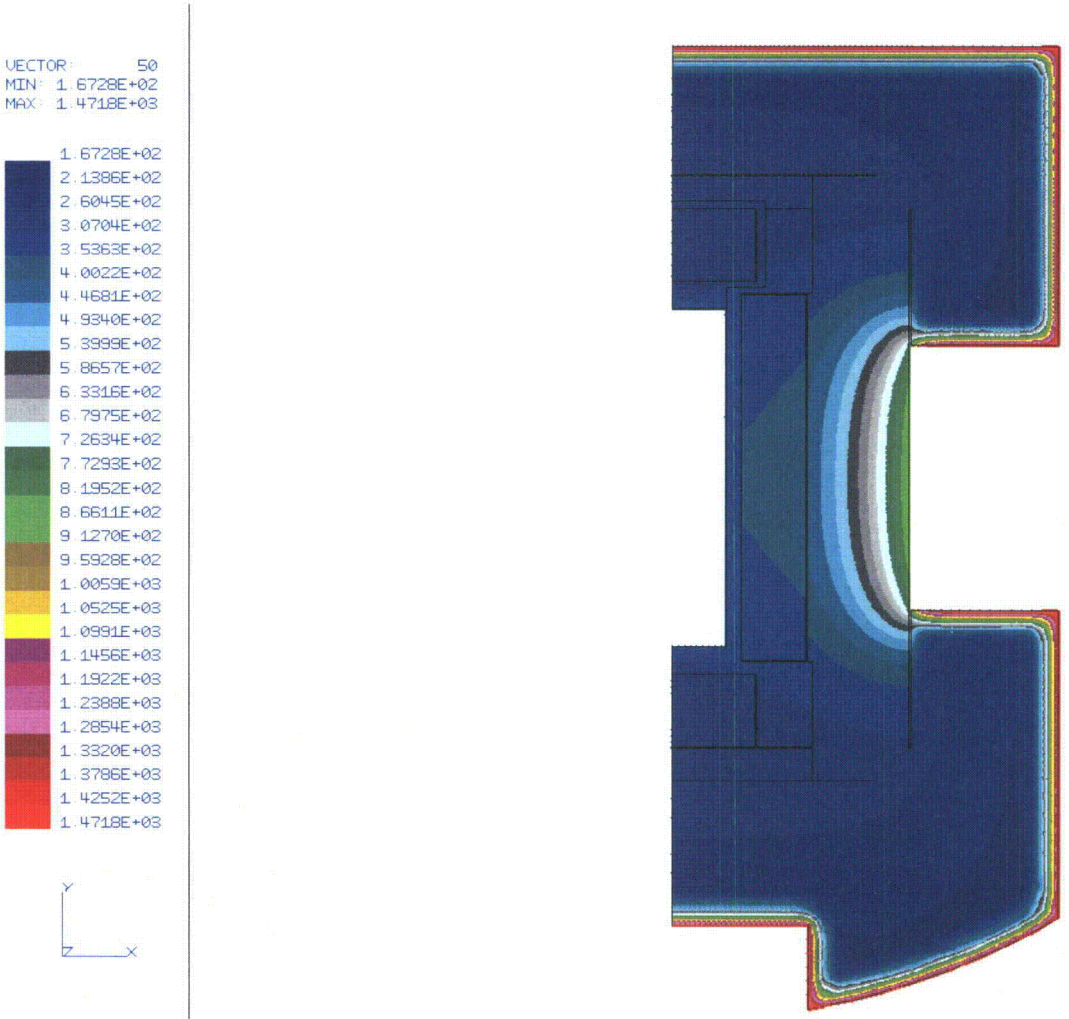

Figure 3-75. Load Case 111, Fire at 30 Minutes, 1,475°F Ambient, Maximum Decay Heat, Entire Model – Models AOS-100A and AOS-100A-S

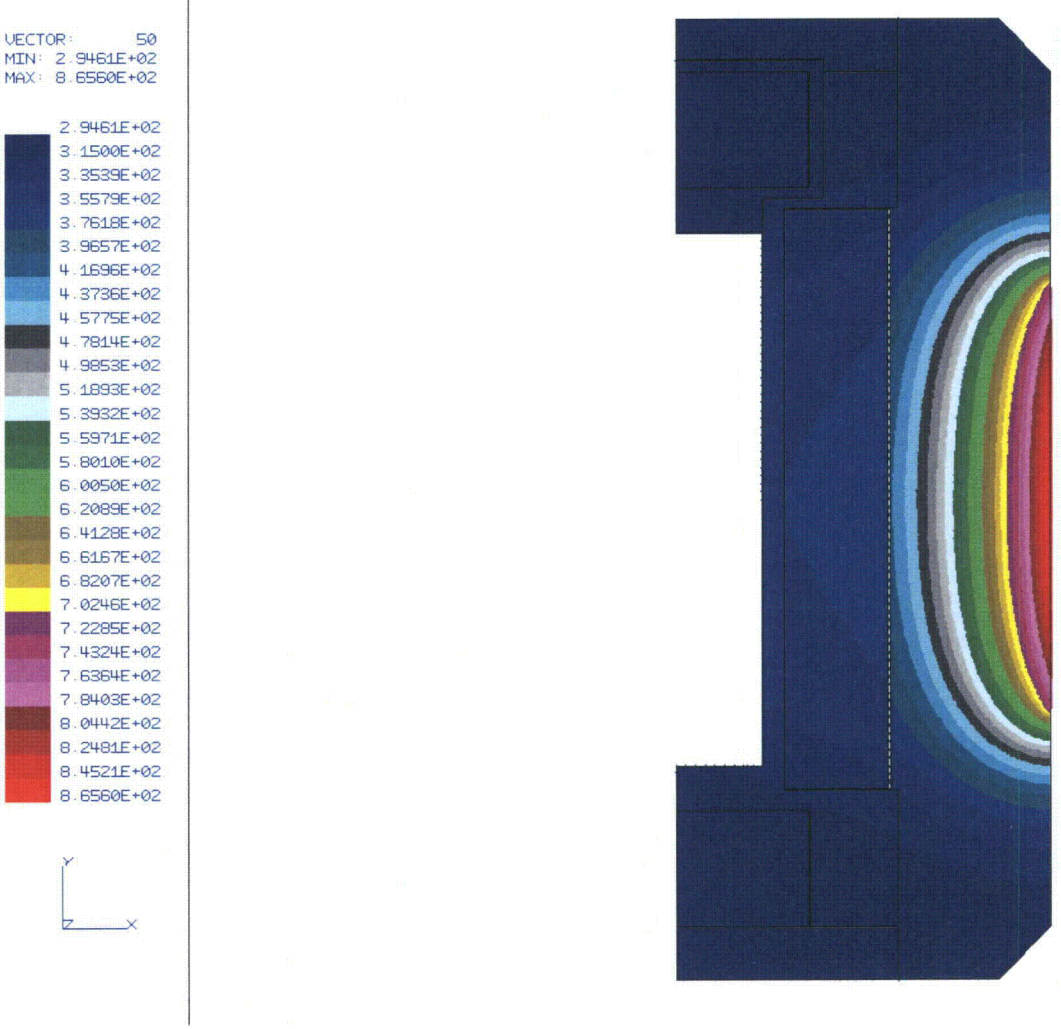

Figure 3-76. Load Case 111, Fire at 30 Minutes, 1,475°F Ambient, Maximum Decay Heat, Cask Model – Models AOS-100A and AOS-100A-S

Table 3-57. Load Case 112, Post Fire at 60 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	175.11	347.20
2	4532	238.78	461.80
3	4227	186.78	368.20
4	4752	193.61	380.50
5	4838	181.56	358.80
6	4993	162.61	324.70
7	3309	148.28	298.90
8	3351	151.39	304.50
9	678	253.89	489.00
10	2537	205.78	402.40
11	2533	205.50	401.90
12	4828	174.83	346.70
13	1888	281.17	538.10
14	583	205.50	401.90
15	579	205.33	401.60
16	4313	162.56	324.60
17	3148	159.22	318.60
18	3001	149.22	300.60
19	7533	153.22	307.80
20	7377	153.78	308.80
21	7371	223.50	434.30
22	6942	240.39	464.70
23	6267	223.28	433.90
24	6121	157.72	315.90
25	6001	156.94	314.50
26	15481	148.17	298.70
27	15941	162.61	324.70
28	16260	173.11	343.60
29	17129	184.00	363.20
30	11531	181.72	359.10
31	9785	176.94	350.50
32	9571	168.11	334.60
33	8197	154.44	310.00
34	15451	130.17	266.30
35	16160	130.39	266.70
36	17608	127.94	262.30
37	18360	128.39	263.10
38	11051	128.11	262.60
39	9900	325.33	617.60
40	8673	785.00	1445.00
41	8225	770.56	1419.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1888	4.2717E+02	8.0090E+02
Bottom Plate	3001	3232	3001	2.0733E+02	4.0520E+02
Cask Lid	3233	3424	3233	2.0606E+02	4.0290E+02
Shell Cavity	4001	4998	4527	2.4644E+02	4.7560E+02
Cask Lid Plug	5001	5404	5001	2.1894E+02	4.2610E+02
Tungsten Alloy	6001	7656	6938	2.4594E+02	4.7470E+02
Bottom Cavity	4227	4236	4227	2.1800E+02	4.2440E+02
Side Cavity	4372	4702	4527	2.4644E+02	4.7560E+02
Top Cavity	5001	5012	5001	2.1894E+02	4.2610E+02
Lid Seal	4993	4993	4993	2.0656E+02	4.0380E+02
Cask Vent Port	2537	2537	2537	2.0806E+02	4.0650E+02
Cask Vent Port Seal	2533	2533	2533	2.0850E+02	4.0730E+02
Vt.Conic.Seal	4828	4828	4828	2.0739E+02	4.0530E+02
Cask Drain Port	583	583	583	2.1022E+02	4.1040E+02
Cask Drain Port Seal	579	579	579	2.1061E+02	4.1110E+02
Drn.Conic.Seal	4313	4313	4313	2.0828E+02	4.0690E+02
Test Port	3351	3351	3351	2.0572E+02	4.0230E+02

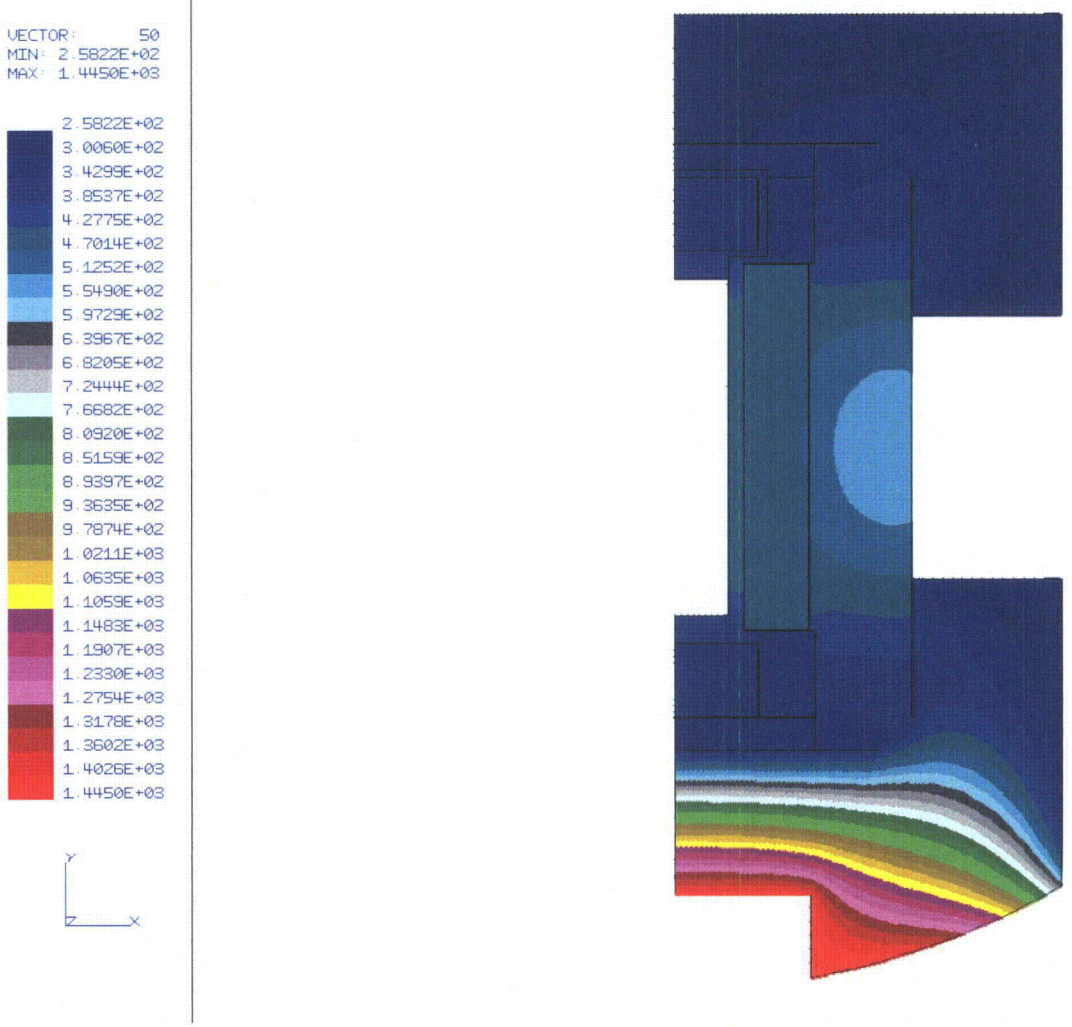

Figure 3-77. Load Case 112, Post Fire at 60 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Models AOS-100A and AOS-100A-S

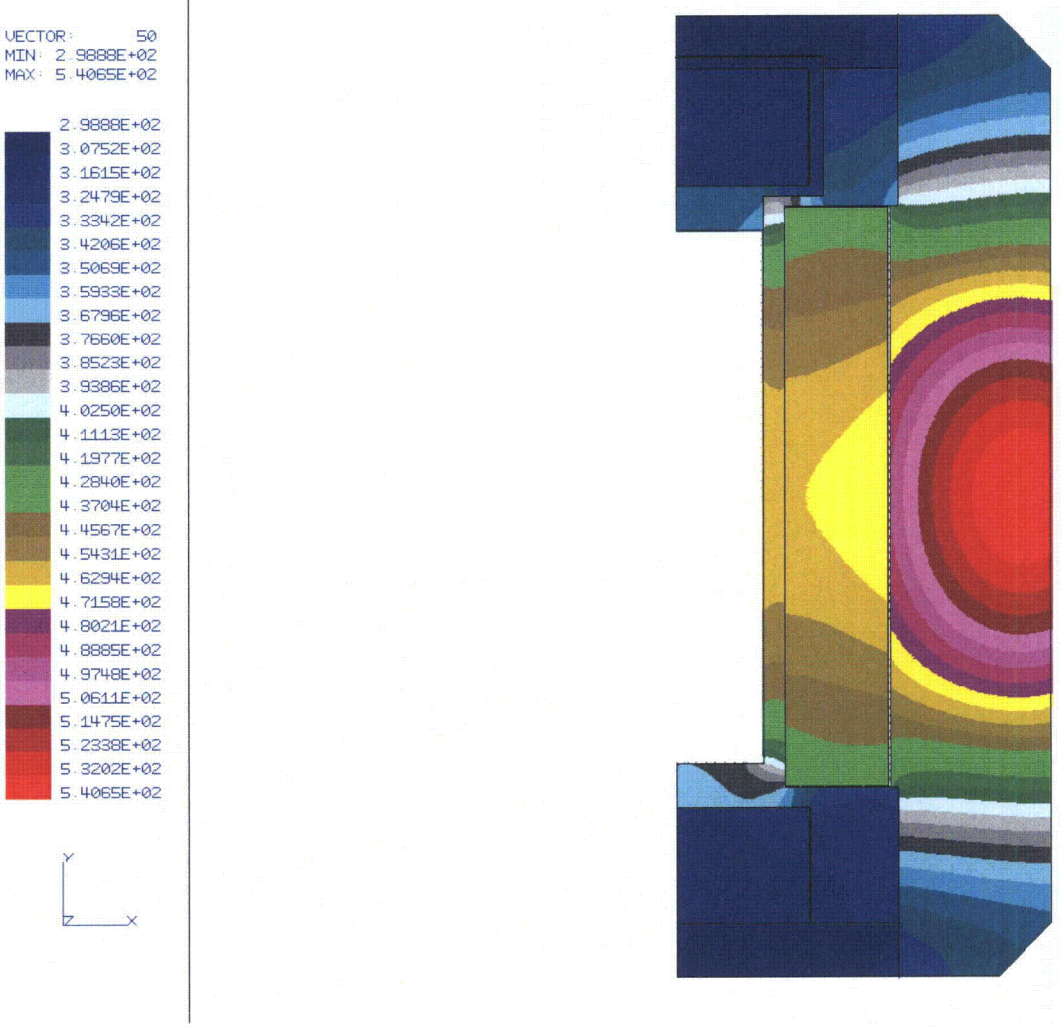

Figure 3-78. Load Case 112, Post Fire at 60 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Models AOS-100A and AOS-100A-S

Table 3-58. Load Case 112, Post Fire at 90 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	194.89	382.80
2	4532	245.83	474.50
3	4227	207.72	405.90
4	4752	209.11	408.40
5	4838	194.83	382.70
6	4993	178.67	353.60
7	3309	155.33	311.60
8	3351	162.33	324.20
9	678	245.78	474.40
10	2537	206.44	403.60
11	2533	206.83	404.30
12	4828	189.72	373.50
13	1888	247.00	476.60
14	583	207.89	406.20
15	579	208.22	406.80
16	4313	174.56	346.20
17	3148	172.67	342.80
18	3001	155.72	312.30
19	7533	163.33	326.00
20	7377	164.11	327.40
21	7371	231.22	448.20
22	6942	242.56	468.60
23	6267	231.00	447.80
24	6121	169.72	337.50
25	6001	168.72	335.70
26	15481	154.39	309.90
27	15941	177.56	351.60
28	16260	185.11	365.20
29	17129	163.00	325.40
30	11531	169.17	336.50
31	9785	189.39	372.90
32	9571	183.78	362.80
33	8197	161.56	322.80
34	15451	113.28	235.90
35	16160	113.06	235.50
36	17608	104.06	219.30
37	18360	92.72	198.90
38	11051	105.11	221.20
39	9900	255.94	492.70
40	8673	750.00	1382.00
41	8225	749.44	1381.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1888	4.2717E+02	8.0090E+02
Bottom Plate	3001	3232	3001	2.0733E+02	4.0520E+02
Cask Lid	3233	3424	3233	2.0606E+02	4.0290E+02
Shell Cavity	4001	4998	4527	2.4644E+02	4.7560E+02
Cask Lid Plug	5001	5404	5001	2.1894E+02	4.2610E+02
Tungsten Alloy	6001	7656	6938	2.4594E+02	4.7470E+02
Bottom Cavity	4227	4236	4227	2.1800E+02	4.2440E+02
Side Cavity	4372	4702	4527	2.4644E+02	4.7560E+02
Top Cavity	5001	5012	5001	2.1894E+02	4.2610E+02
Lid Seal	4993	4993	4993	2.0656E+02	4.0380E+02
Cask Vent Port	2537	2537	2537	2.0806E+02	4.0650E+02
Cask Vent Port Seal	2533	2533	2533	2.0850E+02	4.0730E+02
Vt.Conic.Seal	4828	4828	4828	2.0739E+02	4.0530E+02
Cask Drain Port	583	583	583	2.1022E+02	4.1040E+02
Cask Drain Port Seal	579	579	579	2.1061E+02	4.1110E+02
Drn.Conic.Seal	4313	4313	4313	2.0828E+02	4.0690E+02
Test Port	3351	3351	3351	2.0572E+02	4.0230E+02

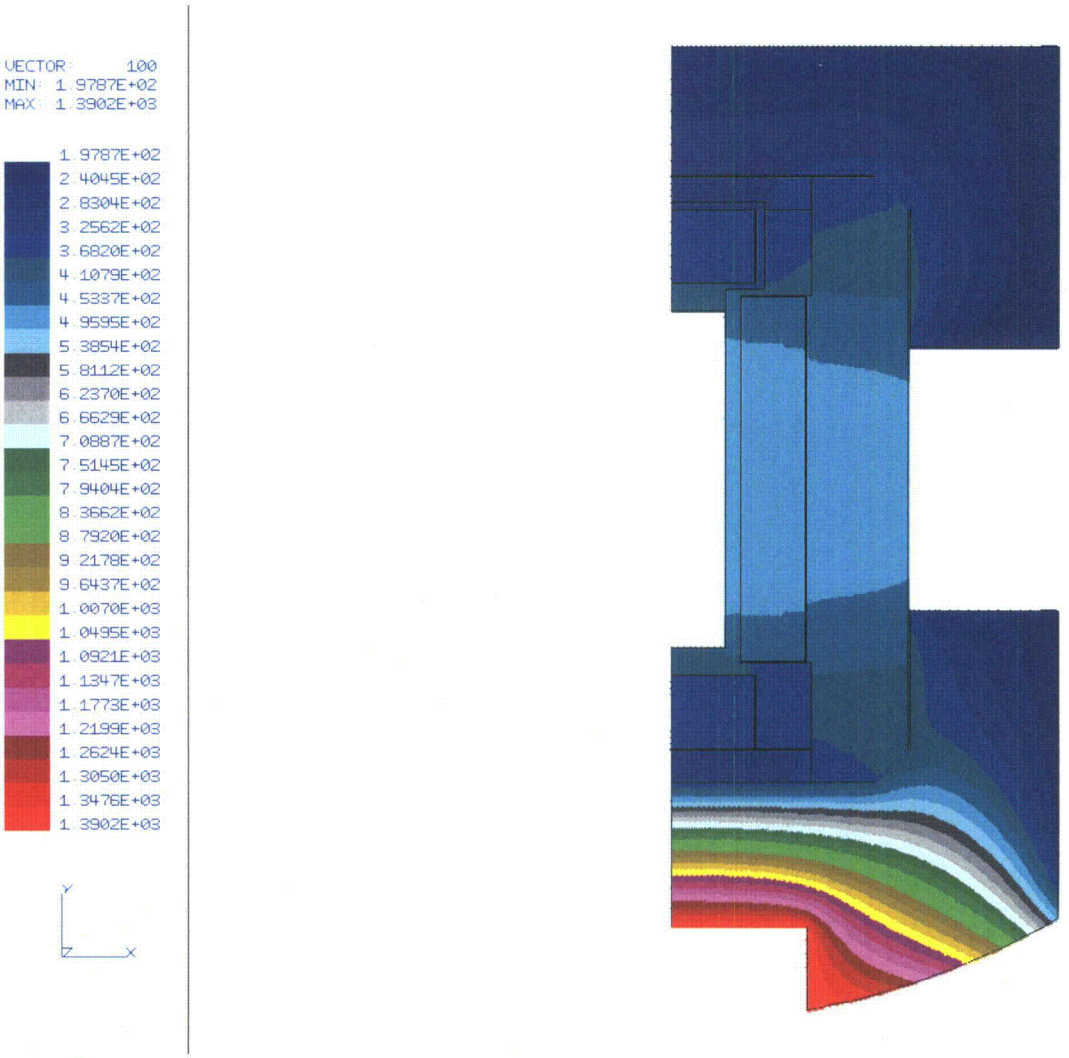

Figure 3-79. Load Case 112, Post Fire at 90 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Models AOS-100A and AOS-100A-S

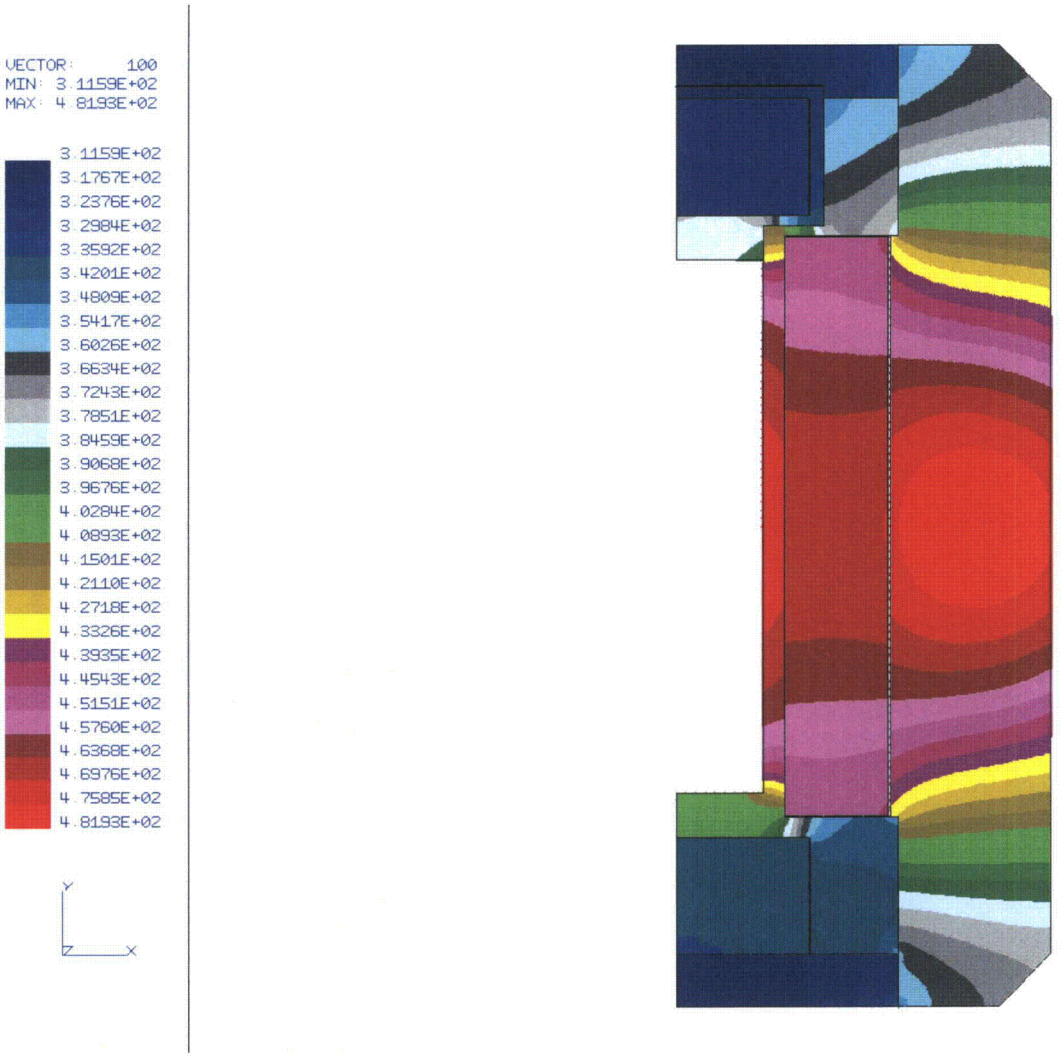

Figure 3-80. Load Case 112, Post Fire at 90 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Models AOS-100A and AOS-100A-S

Table 3-59. Load Case 112, Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	205.11	401.20
2	4532	239.61	463.30
3	4227	214.22	417.60
4	4752	213.11	415.60
5	4838	201.28	394.30
6	4993	189.28	372.70
7	3309	166.17	331.10
8	3351	173.72	344.70
9	678	236.06	456.90
10	2537	207.56	405.60
11	2533	208.06	406.50
12	4828	197.72	387.90
13	1888	231.50	448.70
14	583	209.61	409.30
15	579	210.00	410.00
16	4313	184.72	364.50
17	3148	182.83	361.10
18	3001	165.50	329.90
19	7533	174.67	346.40
20	7377	175.44	347.80
21	7371	227.89	442.20
22	6942	235.50	455.90
23	6267	227.89	442.20
24	6121	180.83	357.50
25	6001	179.94	355.90
26	15481	165.06	329.10
27	15941	187.72	369.90
28	16260	193.06	379.50
29	17129	158.72	317.70
30	11531	166.94	332.50
31	9785	197.44	387.40
32	9571	193.72	380.70
33	8197	171.00	339.80
34	15451	112.17	233.90
35	16160	111.72	233.10
36	17608	101.28	214.30
37	18360	86.61	187.90
38	11051	102.50	216.50
39	9900	222.06	431.70
40	8673	700.56	1293.00
41	8225	725.56	1338.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1888	4.2717E+02	8.0090E+02
Bottom Plate	3001	3232	3001	2.0733E+02	4.0520E+02
Cask Lid	3233	3424	3233	2.0606E+02	4.0290E+02
Shell Cavity	4001	4998	4527	2.4644E+02	4.7560E+02
Cask Lid Plug	5001	5404	5001	2.1894E+02	4.2610E+02
Tungsten Alloy	6001	7656	6938	2.4594E+02	4.7470E+02
Bottom Cavity	4227	4236	4227	2.1800E+02	4.2440E+02
Side Cavity	4372	4702	4527	2.4644E+02	4.7560E+02
Top Cavity	5001	5012	5001	2.1894E+02	4.2610E+02
Lid Seal	4993	4993	4993	2.0656E+02	4.0380E+02
Cask Vent Port	2537	2537	2537	2.0806E+02	4.0650E+02
Cask Vent Port Seal	2533	2533	2533	2.0850E+02	4.0730E+02
Vt.Conic.Seal	4828	4828	4828	2.0739E+02	4.0530E+02
Cask Drain Port	583	583	583	2.1022E+02	4.1040E+02
Cask Drain Port Seal	579	579	579	2.1061E+02	4.1110E+02
Drn.Conic.Seal	4313	4313	4313	2.0828E+02	4.0690E+02
Test Port	3351	3351	3351	2.0572E+02	4.0230E+02

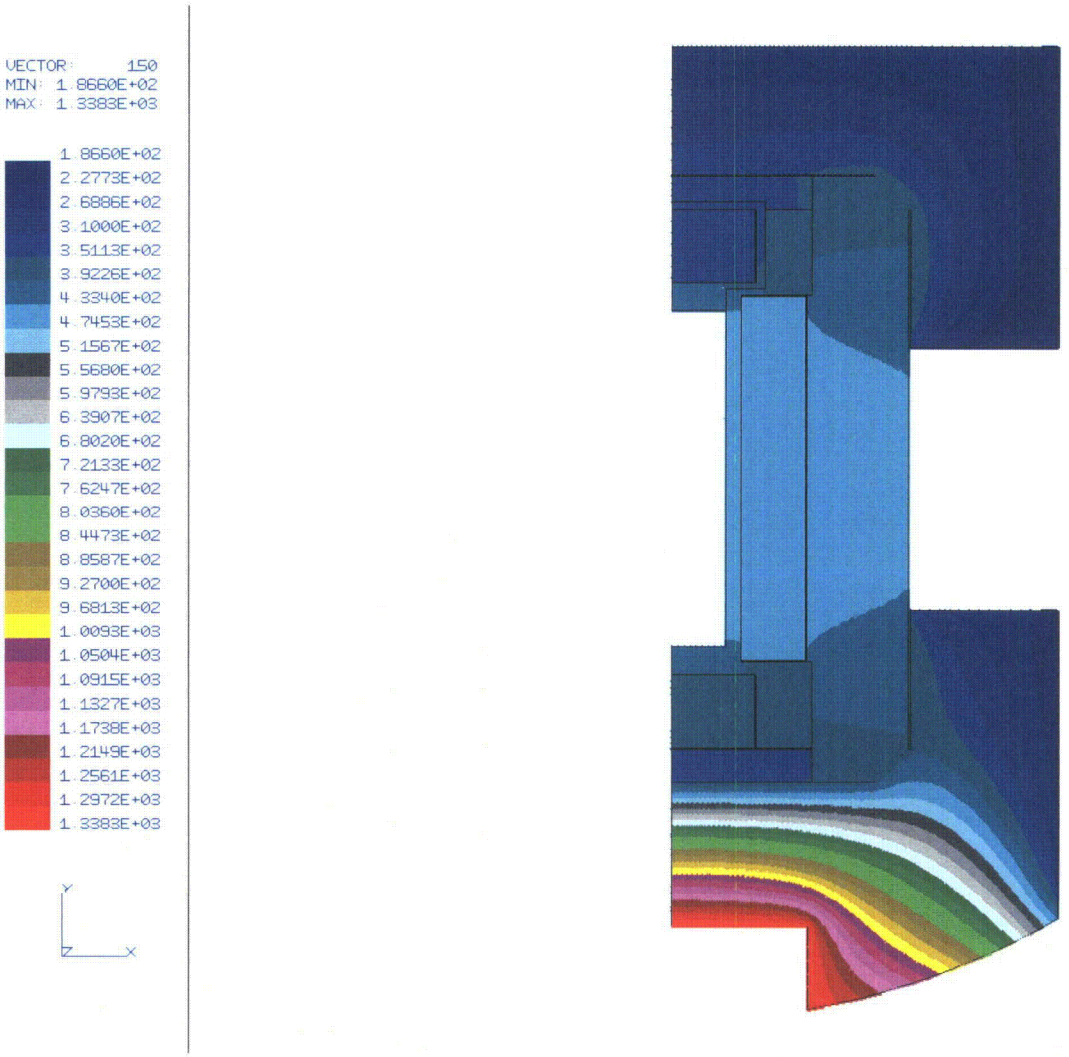

Figure 3-81. Load Case 112, Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Models AOS-100A and AOS-100A-S

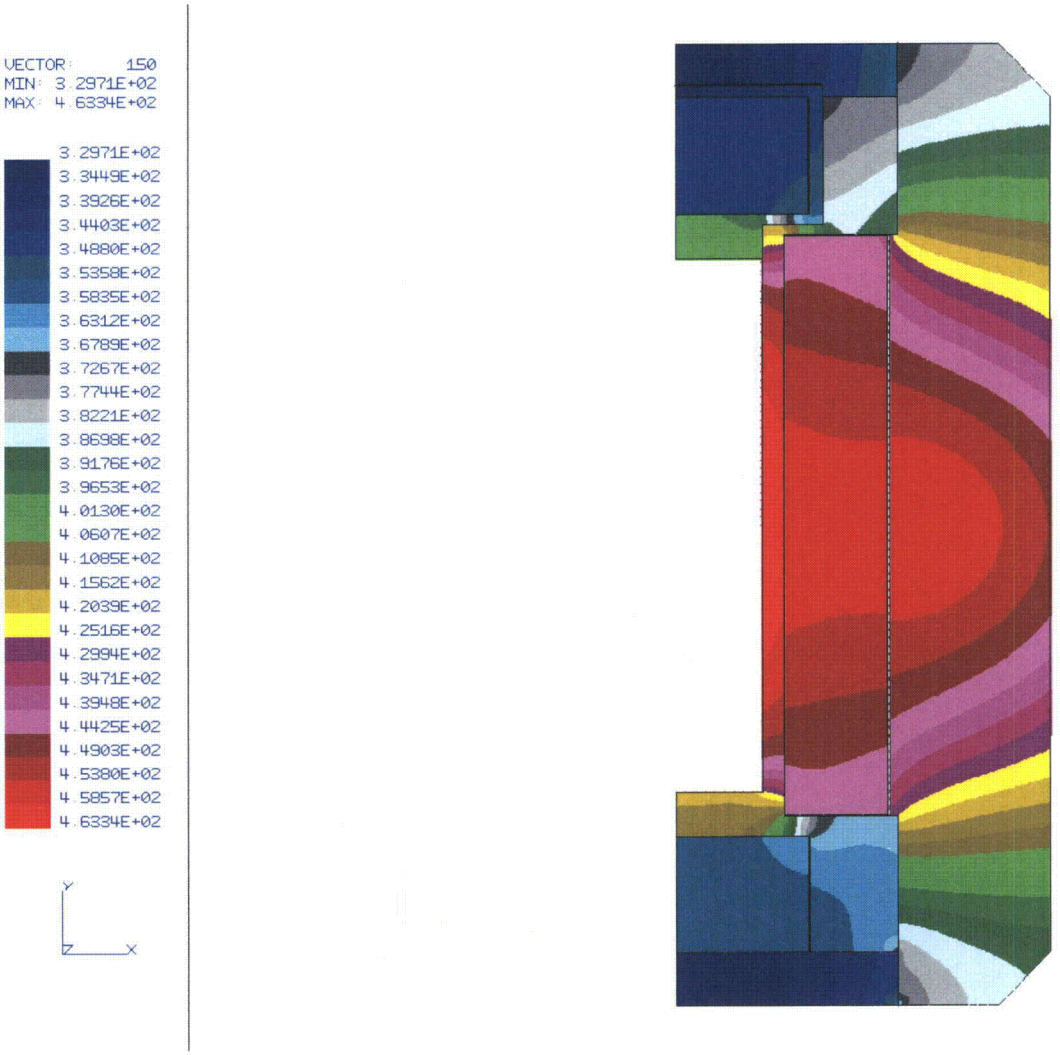

Figure 3-82. Load Case 112, Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Models AOS-100A and AOS-100A-S

Table 3-60. Load Case 112, Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	210.56	411.00
2	4532	233.00	451.40
3	4227	216.44	421.60
4	4752	214.06	417.30
5	4838	204.61	400.30
6	4993	196.00	384.80
7	3309	176.94	350.50
8	3351	183.33	362.00
9	678	228.33	443.00
10	2537	208.00	406.40
11	2533	208.50	407.30
12	4828	202.17	395.90
13	1888	222.22	432.00
14	583	210.22	410.40
15	579	210.56	411.00
16	4313	192.44	378.40
17	3148	190.50	374.90
18	3001	175.50	347.90
19	7533	184.39	363.90
20	7377	185.00	365.00
21	7371	223.56	434.40
22	6942	228.78	443.80
23	6267	223.72	434.70
24	6121	189.50	373.10
25	6001	188.78	371.80
26	15481	175.78	348.40
27	15941	194.44	382.00
28	16260	198.06	388.50
29	17129	157.06	314.70
30	11531	165.78	330.40
31	9785	202.11	395.80
32	9571	199.89	391.80
33	8197	180.50	356.90
34	15451	112.17	233.90
35	16160	111.61	232.90
36	17608	100.94	213.70
37	18360	85.50	185.90
38	11051	102.17	215.90
39	9900	200.61	393.10
40	8673	650.00	1202.00
41	8225	695.00	1283.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1888	4.2717E+02	8.0090E+02
Bottom Plate	3001	3232	3001	2.0733E+02	4.0520E+02
Cask Lid	3233	3424	3233	2.0606E+02	4.0290E+02
Shell Cavity	4001	4998	4527	2.4644E+02	4.7560E+02
Cask Lid Plug	5001	5404	5001	2.1894E+02	4.2610E+02
Tungsten Alloy	6001	7656	6938	2.4594E+02	4.7470E+02
Bottom Cavity	4227	4236	4227	2.1800E+02	4.2440E+02
Side Cavity	4372	4702	4527	2.4644E+02	4.7560E+02
Top Cavity	5001	5012	5001	2.1894E+02	4.2610E+02
Lid Seal	4993	4993	4993	2.0656E+02	4.0380E+02
Cask Vent Port	2537	2537	2537	2.0806E+02	4.0650E+02
Cask Vent Port Seal	2533	2533	2533	2.0850E+02	4.0730E+02
Vt.Conic.Seal	4828	4828	4828	2.0739E+02	4.0530E+02
Cask Drain Port	583	583	583	2.1022E+02	4.1040E+02
Cask Drain Port Seal	579	579	579	2.1061E+02	4.1110E+02
Drn.Conic.Seal	4313	4313	4313	2.0828E+02	4.0690E+02
Test Port	3351	3351	3351	2.0572E+02	4.0230E+02

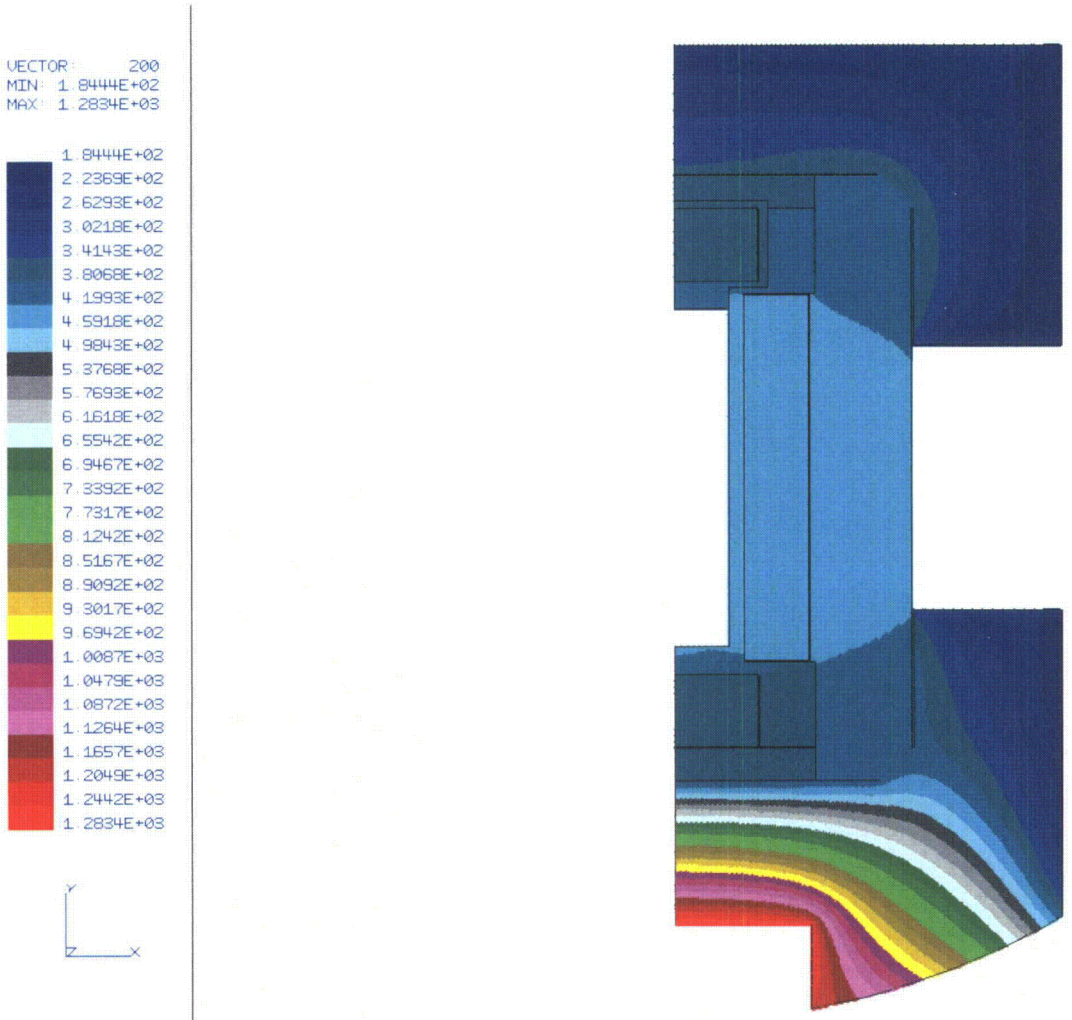

Figure 3-83. Load Case 112, Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Models AOS-100A and AOS-100A-S

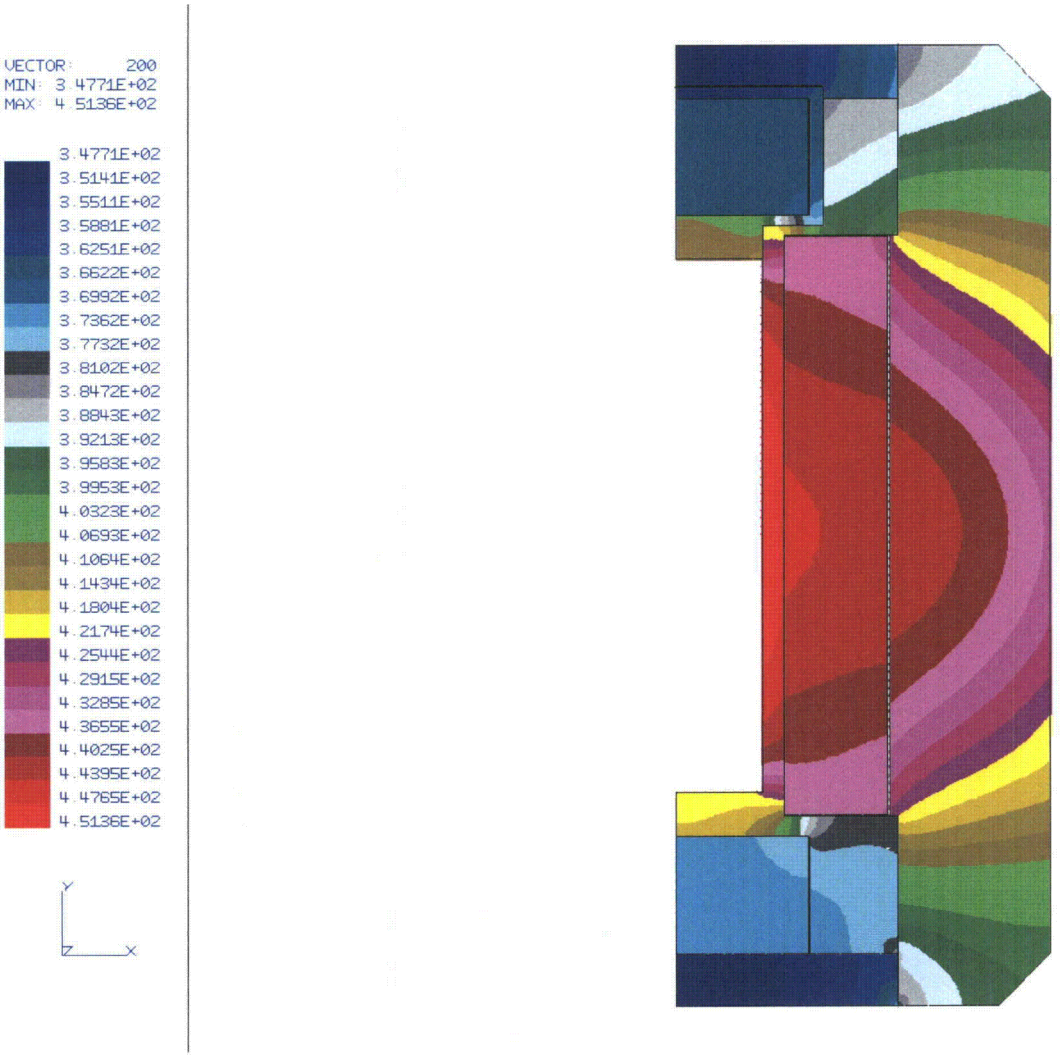

Figure 3-84. Load Case 112, Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Models AOS-100A and AOS-100A-S

Table 3-61. Load Case 112, Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Models AOS-100A and AOS-100A-S

Location	Node	Temp(C)	Temp(F)
1	5001	213.94	417.10
2	4532	227.61	441.70
3	4227	217.39	423.30
4	4752	214.22	417.60
5	4838	206.39	403.50
6	4993	200.39	392.70
7	3309	185.83	366.50
8	3351	190.83	375.50
9	678	222.56	432.60
10	2537	207.89	406.20
11	2533	208.39	407.10
12	4828	204.78	400.60
13	1888	215.89	420.60
14	583	210.00	410.00
15	579	210.39	410.70
16	4313	198.00	388.40
17	3148	196.17	385.10
18	3001	184.22	363.60
19	7533	191.94	377.50
20	7377	192.44	378.40
21	7371	219.78	427.60
22	6942	223.44	434.20
23	6267	220.17	428.30
24	6121	195.89	384.60
25	6001	195.33	383.60
26	15481	184.72	364.50
27	15941	198.78	389.80
28	16260	201.06	393.90
29	17129	155.89	312.60
30	11531	164.72	328.50
31	9785	204.67	400.40
32	9571	203.67	398.60
33	8197	188.72	371.70
34	15451	112.28	234.10
35	16160	111.67	233.00
36	17608	100.89	213.60
37	18360	85.22	185.40
38	11051	102.06	215.70
39	9900	185.22	365.40
40	8673	602.22	1116.00
41	8225	660.00	1220.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1888	4.2717E+02	8.0090E+02
Bottom Plate	3001	3232	3001	2.0733E+02	4.0520E+02
Cask Lid	3233	3424	3233	2.0606E+02	4.0290E+02
Shell Cavity	4001	4998	4527	2.4644E+02	4.7560E+02
Cask Lid Plug	5001	5404	5001	2.1894E+02	4.2610E+02
Tungsten Alloy	6001	7656	6938	2.4594E+02	4.7470E+02
Bottom Cavity	4227	4236	4227	2.1800E+02	4.2440E+02
Side Cavity	4372	4702	4527	2.4644E+02	4.7560E+02
Top Cavity	5001	5012	5001	2.1894E+02	4.2610E+02
Lid Seal	4993	4993	4993	2.0656E+02	4.0380E+02
Cask Vent Port	2537	2537	2537	2.0806E+02	4.0650E+02
Cask Vent Port Seal	2533	2533	2533	2.0850E+02	4.0730E+02
Vt.Conic.Seal	4828	4828	4828	2.0739E+02	4.0530E+02
Cask Drain Port	583	583	583	2.1022E+02	4.1040E+02
Cask Drain Port Seal	579	579	579	2.1061E+02	4.1110E+02
Drn.Conic.Seal	4313	4313	4313	2.0828E+02	4.0690E+02
Test Port	3351	3351	3351	2.0572E+02	4.0230E+02

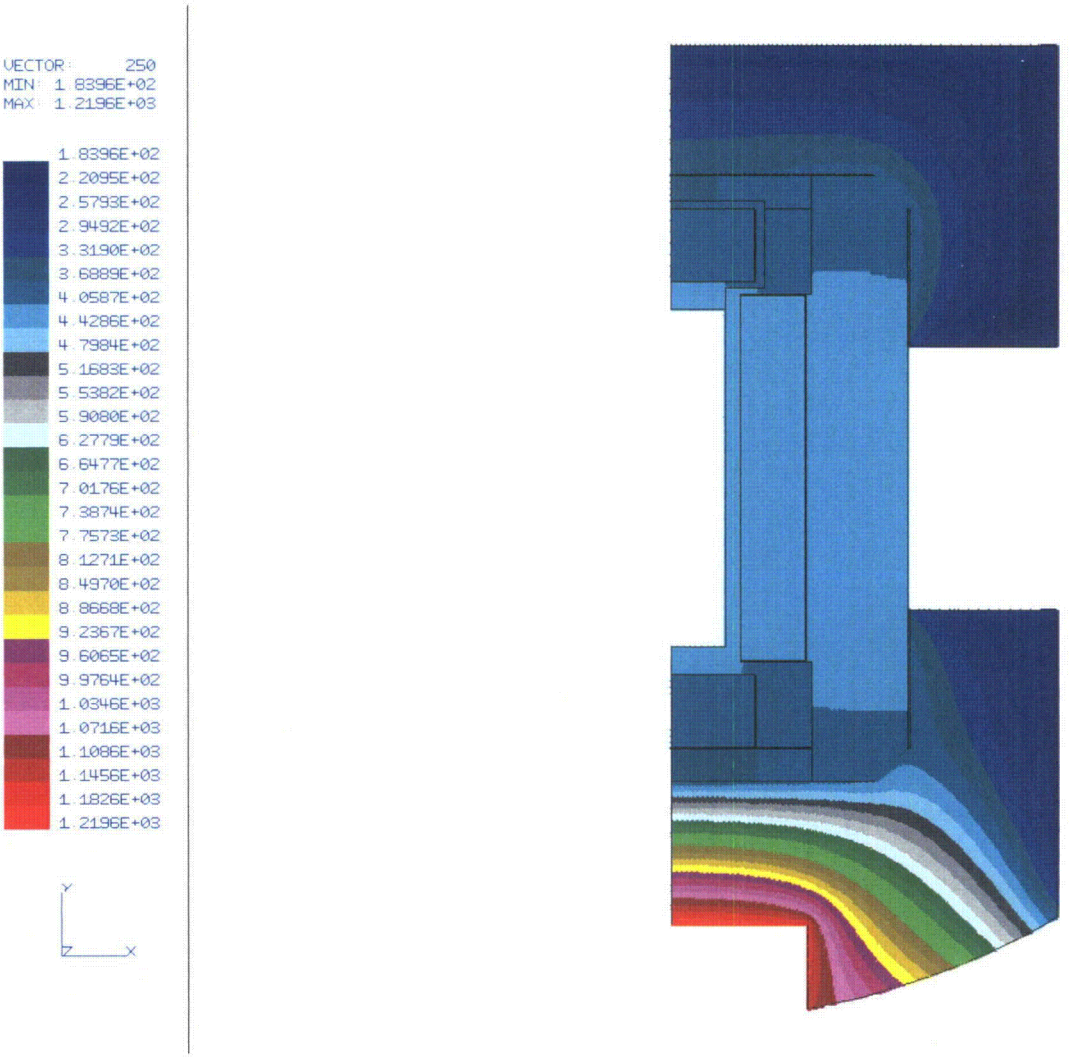

Figure 3-85. Load Case 112, Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Models AOS-100A and AOS-100A-S

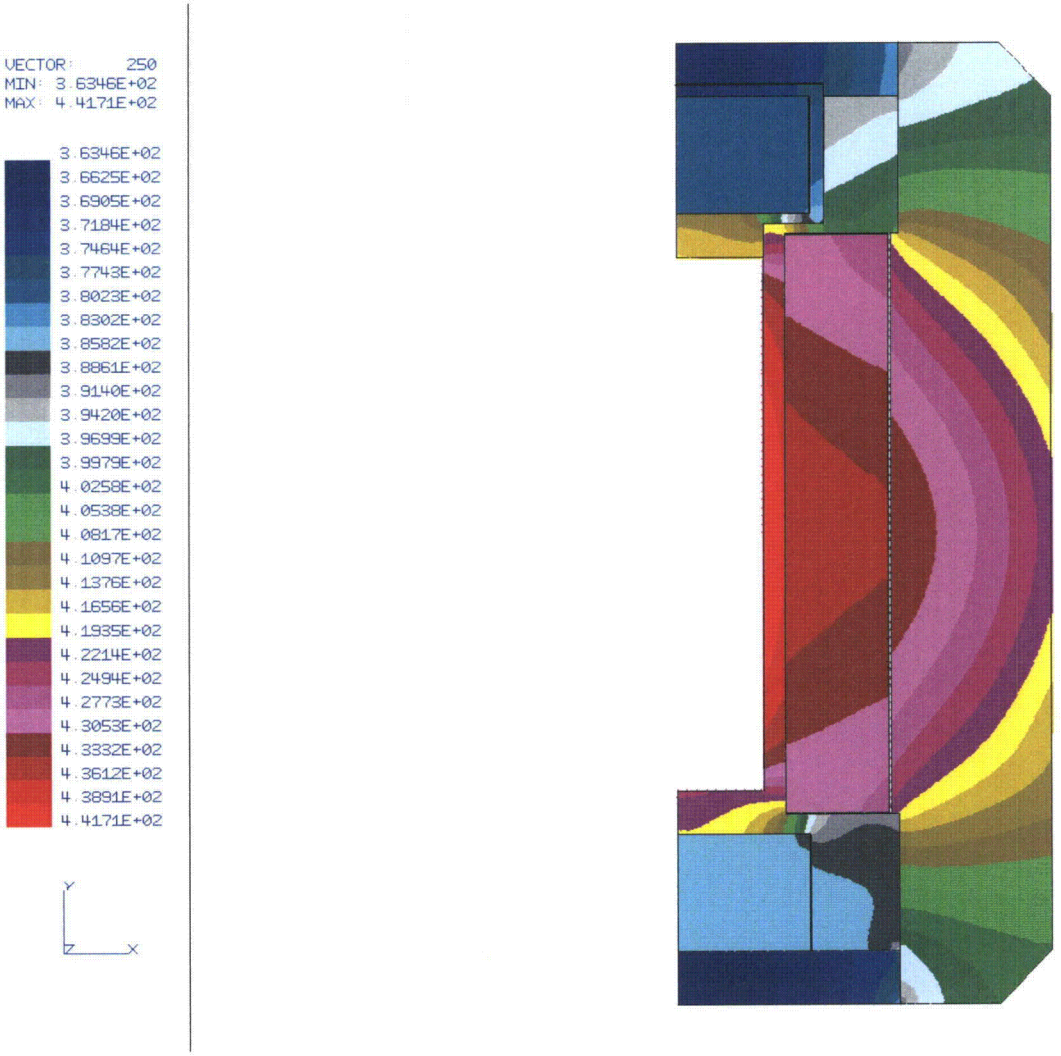

Figure 3-86. Load Case 112, Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Models AOS-100A and AOS-100A-S

3.5.2.4 Thermal Evaluation Results – Model AOS-100B

This appendix presents the following information, specific to the Model AOS-100B transport package:

- Normal Conditions of Transport Thermal Evaluation Results – Model AOS-100B
- Fire Condition Thermal Evaluation Results – Model AOS-100B

Table 3-47 lists the temperature monitoring points (nodes) for the Model AOS-100 (A, B, and A-S) transport packages, under Normal conditions of transport and the Fire condition.

3.5.2.4.1 Normal Conditions of Transport Thermal Evaluation Results – Model AOS-100B

Table 3-62 lists the tables and figures in this appendix that present the Model AOS-100B transport package results under Normal conditions of transport, for Load Cases 101 through 106. Each table provides a list of temperatures at each monitoring node. The tables for Load Cases 101, 102, 105, and 106 also include a list of maximum temperatures within each transport package component.

Figure 3-60 illustrates the location of each node on the Model AOS-100 (A, B, and A-S) transport packages, under Normal conditions of transport. (The node locations are listed in Table 3-47.)

Table 3-62. Normal Conditions of Transport Thermal Evaluation Results – Model AOS-100B

Load Case	Description	Results Table	Entire Model	Cask Model
101	100°F Ambient, Maximum Decay Heat	Table 3-63	Figure 3-87	Figure 3-88
102	100°F Ambient, Maximum Decay Heat, Maximum Insolation	Table 3-64	Figure 3-89	Figure 3-90
103	-20°F Ambient, Zero Decay Heat, Zero Insolation	Table 3-65	Figure 3-91	–
104	-40°F Ambient, Zero Decay Heat, Zero Insolation	Table 3-66	Figure 3-92	–
105	-40°F Ambient, Maximum Decay Heat	Table 3-67	Figure 3-93	Figure 3-94
106	-20°F Ambient, Maximum Decay Heat	Table 3-68	Figure 3-95	Figure 3-96

Table 3-63. Load Case 101, 100°F Ambient, Maximum Decay Heat – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	114.94	238.90
2	4532	107.17	224.90
3	4227	111.17	232.10
4	4752	106.28	223.30
5	4838	101.00	213.80
6	4993	100.83	213.50
7	3309	101.11	214.00
8	3351	100.72	213.30
9	678	101.28	214.30
10	2537	99.06	210.30
11	2533	99.28	210.70
12	4828	101.11	214.00
13	1888	97.56	207.60
14	583	98.94	210.10
15	579	99.11	210.40
16	4313	102.06	215.70
17	3148	100.00	212.00
18	3001	100.44	212.80
19	7533	103.11	217.60
20	7377	103.33	218.00
21	7371	102.33	216.20
22	6942	102.56	216.60
23	6267	102.39	216.30
24	6121	102.39	216.30
25	6001	102.22	216.00
26	9501	100.39	212.70
27	9950	98.89	210.00
28	10014	98.06	208.50
29	10781	74.89	166.80
30	9091	72.56	162.60
31	8463	97.56	207.60
32	8462	98.67	209.60
33	8197	99.89	211.80
34	9711	39.39	102.90
35	9821	38.28	100.90
36	10158	38.22	100.80
37	10605	41.17	106.10
38	9102	40.33	104.60
39	8578	40.22	104.40
40	8225	48.28	118.90
41	8001	53.00	127.40

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	626	1.0128E+02	2.1430E+02
Bottom Plate	3001	3232	3120	1.0056E+02	2.1300E+02
Cask Lid	3233	3424	3233	1.0122E+02	2.1420E+02
Shell Cavity	4001	4998	4227	1.1117E+02	2.3210E+02
Cask Lid Plug	5001	5404	5001	1.1494E+02	2.3890E+02
Carbon Steel	6001	7656	7552	1.0344E+02	2.1820E+02
Bottom Cavity	4227	4236	4227	1.1117E+02	2.3210E+02
Side Cavity	4372	4702	4372	1.0717E+02	2.2490E+02
Top Cavity	5001	5012	5001	1.1494E+02	2.3890E+02
Lid Seal	4993	4993	4993	1.0083E+02	2.1350E+02
Cask Vent Port	2537	2537	2537	9.9056E+01	2.1030E+02
Cask Vent Port Seal	2533	2533	2533	9.9278E+01	2.1070E+02
Vt.Conic.Seal	4828	4828	4828	1.0111E+02	2.1400E+02
Cask Drain Port	583	583	583	9.8944E+01	2.1010E+02
Cask Drain Port Seal	579	579	579	9.9111E+01	2.1040E+02
Drn.Conic.Seal	4313	4313	4313	1.0206E+02	2.1570E+02
Test Port	3351	3351	3351	1.0072E+02	2.1330E+02

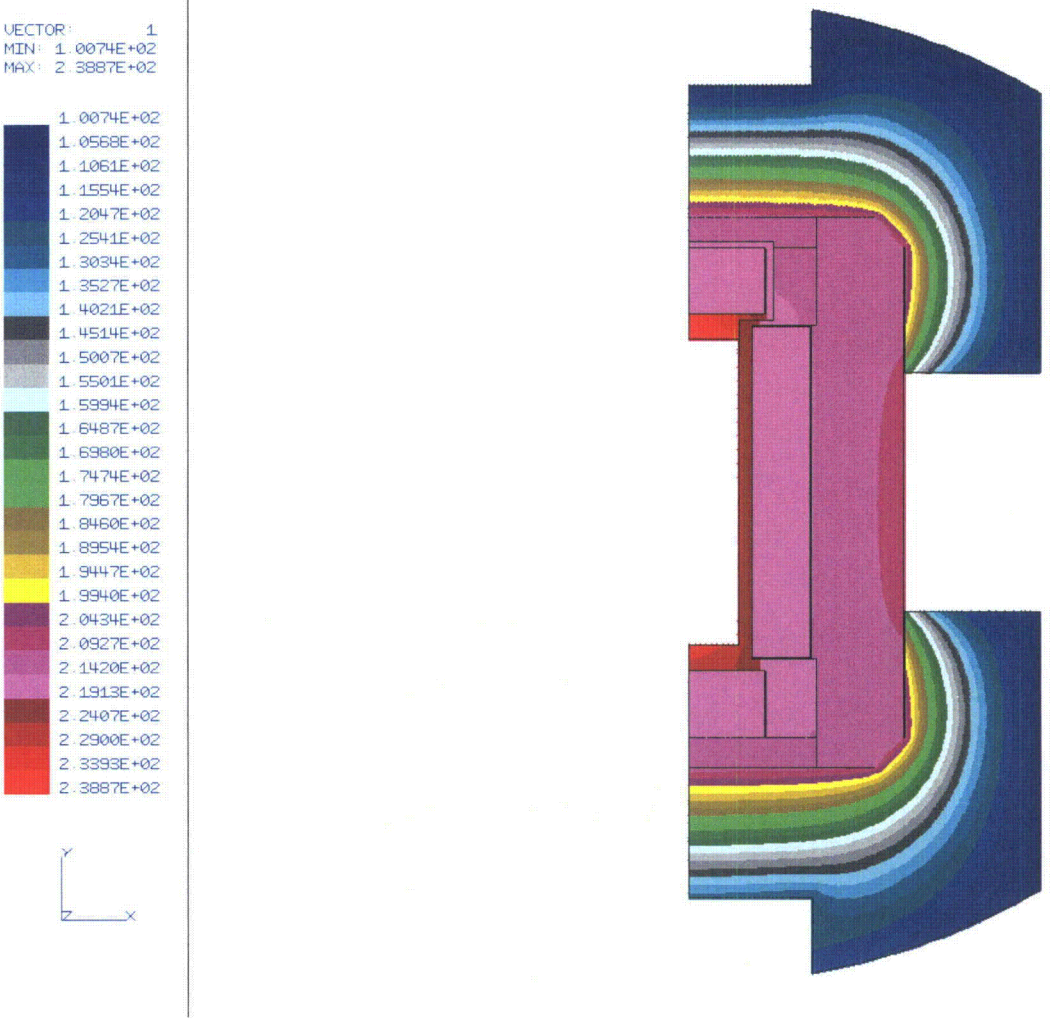

Figure 3-87. Load Case 101, 100°F Ambient, Maximum Decay Heat, Entire Model – Model AOS-100B

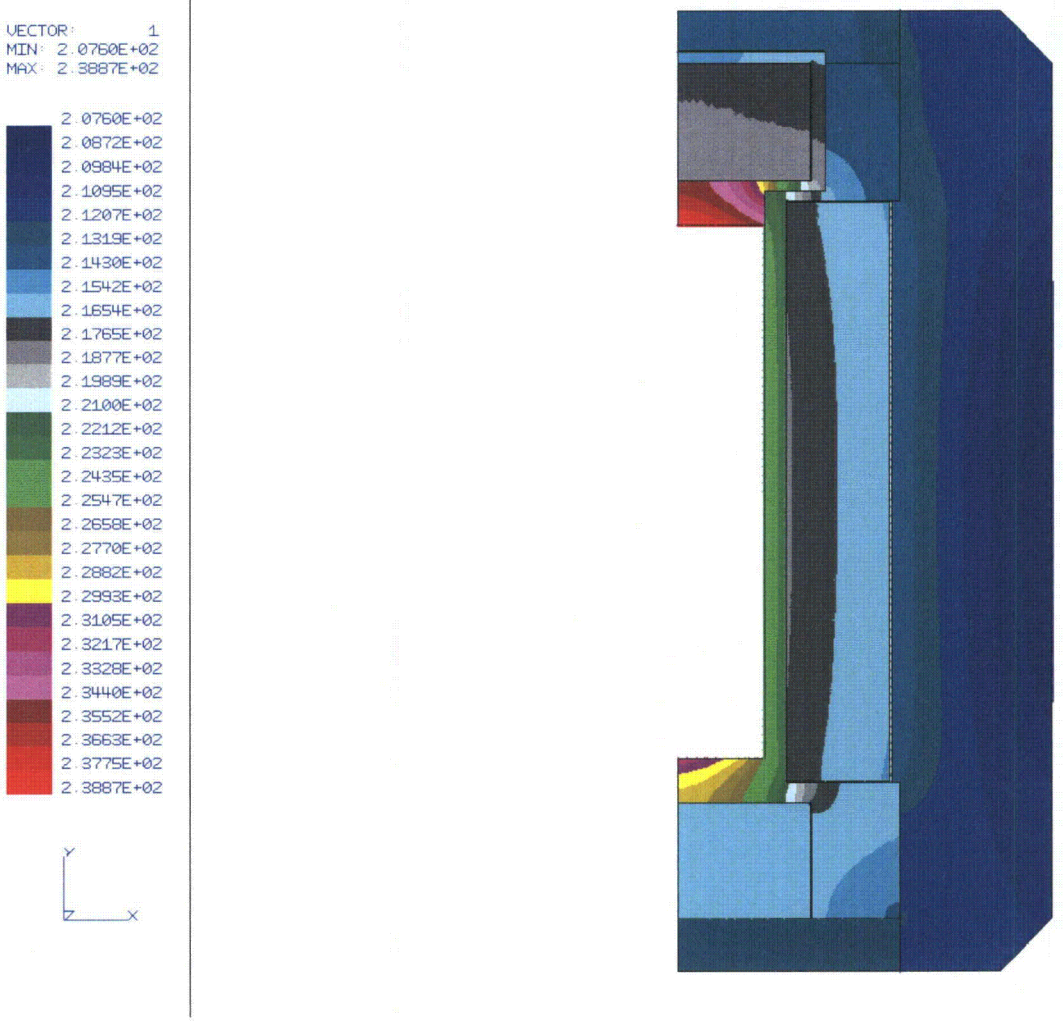

Figure 3-88. Load Case 101, 100°F Ambient, Maximum Decay Heat, Cask Model – Model AOS-100B

Table 3-64. Load Case 102, 100°F Ambient, Maximum Decay Heat, Maximum Insolation – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	158.44	317.20
2	4532	151.39	304.50
3	4227	155.61	312.10
4	4752	150.33	302.60
5	4838	145.17	293.30
6	4993	145.00	293.00
7	3309	145.28	293.50
8	3351	144.89	292.80
9	678	145.78	294.40
10	2537	143.17	289.70
11	2533	143.39	290.10
12	4828	145.22	293.40
13	1888	142.22	288.00
14	583	144.11	291.40
15	579	144.28	291.70
16	4313	147.00	296.60
17	3148	145.06	293.10
18	3001	145.44	293.80
19	7533	147.06	296.70
20	7377	147.28	297.10
21	7371	146.61	295.90
22	6942	147.06	296.70
23	6267	147.17	296.90
24	6121	147.28	297.10
25	6001	147.11	296.80
26	9501	144.72	292.50
27	9950	143.33	290.00
28	10014	142.50	288.50
29	10781	113.89	237.00
30	9091	127.50	261.50
31	8463	143.33	290.00
32	8462	144.00	291.20
33	8197	144.94	292.90
34	9711	110.39	230.70
35	9821	100.06	212.10
36	10158	100.89	213.60
37	10605	83.33	182.00
38	9102	101.17	214.10
39	8578	90.17	194.30
40	8225	97.39	207.30
41	8001	101.61	214.90

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	614	1.4600E+02	2.9480E+02
Bottom Plate	3001	3232	3103	1.4556E+02	2.9400E+02
Cask Lid	3233	3424	3233	1.4533E+02	2.9360E+02
Shell Cavity	4001	4998	4227	1.5561E+02	3.1210E+02
Cask Lid Plug	5001	5404	5001	1.5844E+02	3.1720E+02
Carbon Steel	6001	7656	6324	1.4789E+02	2.9820E+02
Bottom Cavity	4227	4236	4227	1.5561E+02	3.1210E+02
Side Cavity	4372	4702	4372	1.5167E+02	3.0500E+02
Top Cavity	5001	5012	5001	1.5844E+02	3.1720E+02
Lid Seal	4993	4993	4993	1.4500E+02	2.9300E+02
Cask Vent Port	2537	2537	2537	1.4317E+02	2.8970E+02
Cask Vent Port Seal	2533	2533	2533	1.4339E+02	2.9010E+02
Vt.Conic.Seal	4828	4828	4828	1.4522E+02	2.9340E+02
Cask Drain Port	583	583	583	1.4411E+02	2.9140E+02
Cask Drain Port Seal	579	579	579	1.4428E+02	2.9170E+02
Drn.Conic.Seal	4313	4313	4313	1.4700E+02	2.9660E+02
Test Port	3351	3351	3351	1.4489E+02	2.9280E+02

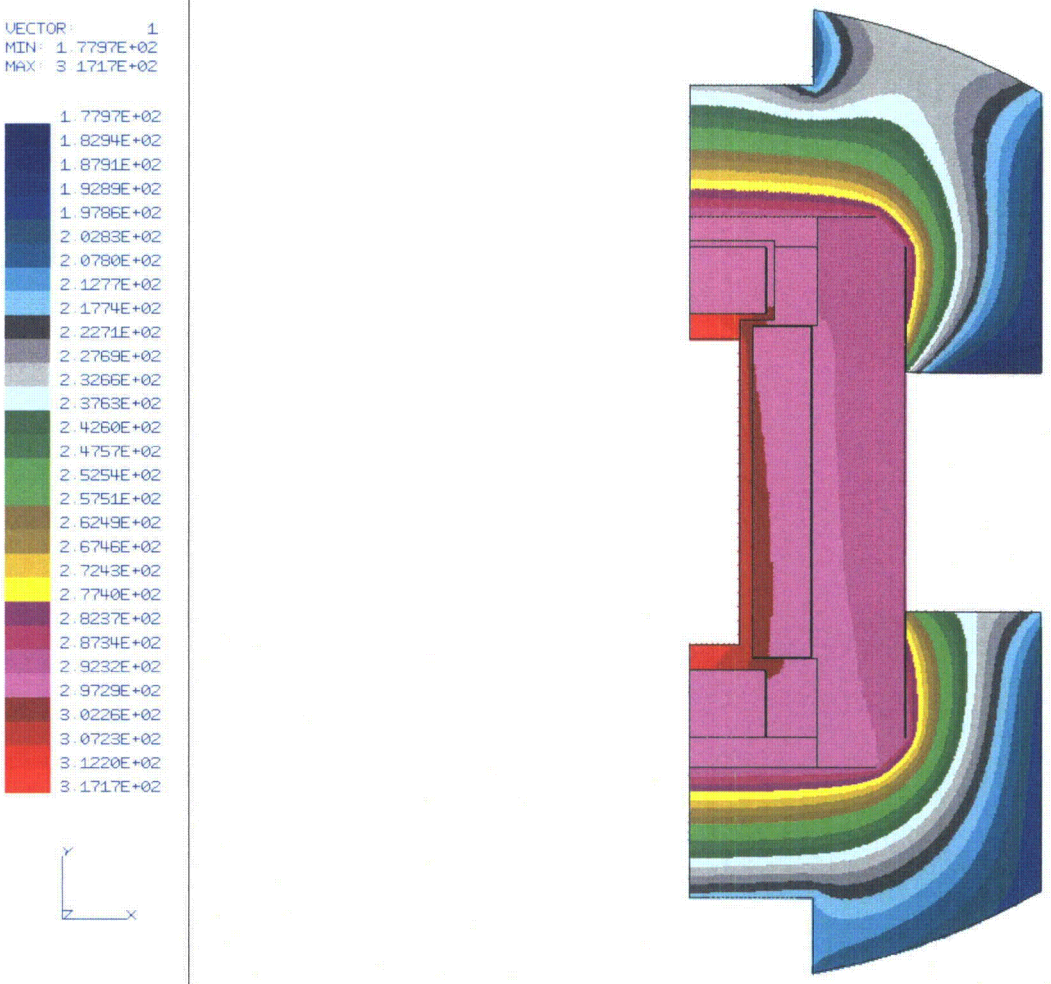

Figure 3-89. Load Case 102, 100°F Ambient, Maximum Decay Heat, Maximum Insolation, Entire Model – Model AOS-100B

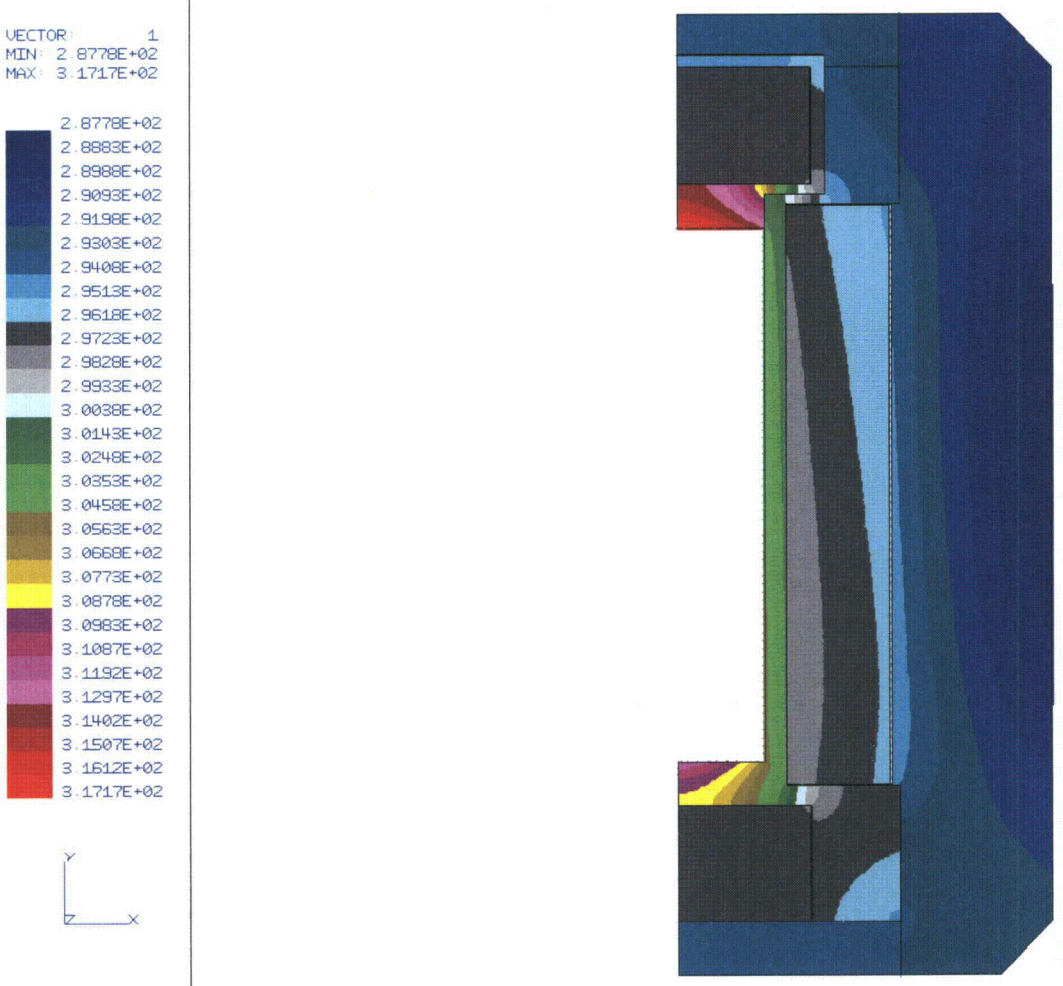

Figure 3-90. Load Case 102, 100°F Ambient, Maximum Decay Heat, Maximum Insolation, Cask Model – Model AOS-100B

Table 3-65. Load Case 103, -20°F Ambient, Zero Decay Heat, Zero Insolation – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	-28.89	-20.00
2	4532	-28.89	-20.00
3	4227	-28.89	-20.00
4	4752	-28.89	-20.00
5	4838	-28.89	-20.00
6	4993	-28.89	-20.00
7	3309	-28.89	-20.00
8	3351	-28.89	-20.00
9	678	-28.89	-20.00
10	2537	-28.89	-20.00
11	2533	-28.89	-20.00
12	4828	-28.89	-20.00
13	1888	-28.89	-20.00
14	583	-28.89	-20.00
15	579	-28.89	-20.00
16	4313	-28.89	-20.00
17	3148	-28.89	-20.00
18	3001	-28.89	-20.00
19	7533	-28.89	-20.00
20	7377	-28.89	-20.00
21	7371	-28.89	-20.00
22	6942	-28.89	-20.00
23	6267	-28.89	-20.00
24	6121	-28.89	-20.00
25	6001	-28.89	-20.00
26	9501	-28.89	-20.00
27	9950	-28.89	-20.00
28	10014	-28.89	-20.00
29	10781	-28.89	-20.00
30	9091	-28.89	-20.00
31	8463	-28.89	-20.00
32	8462	-28.89	-20.00
33	8197	-28.89	-20.00
34	9711	-28.89	-20.00
35	9821	-28.89	-20.00
36	10158	-28.89	-20.00
37	10605	-28.89	-20.00
38	9102	-28.89	-20.00
39	8578	-28.89	-20.00
40	8225	-28.89	-20.00
41	8001	-28.89	-20.00

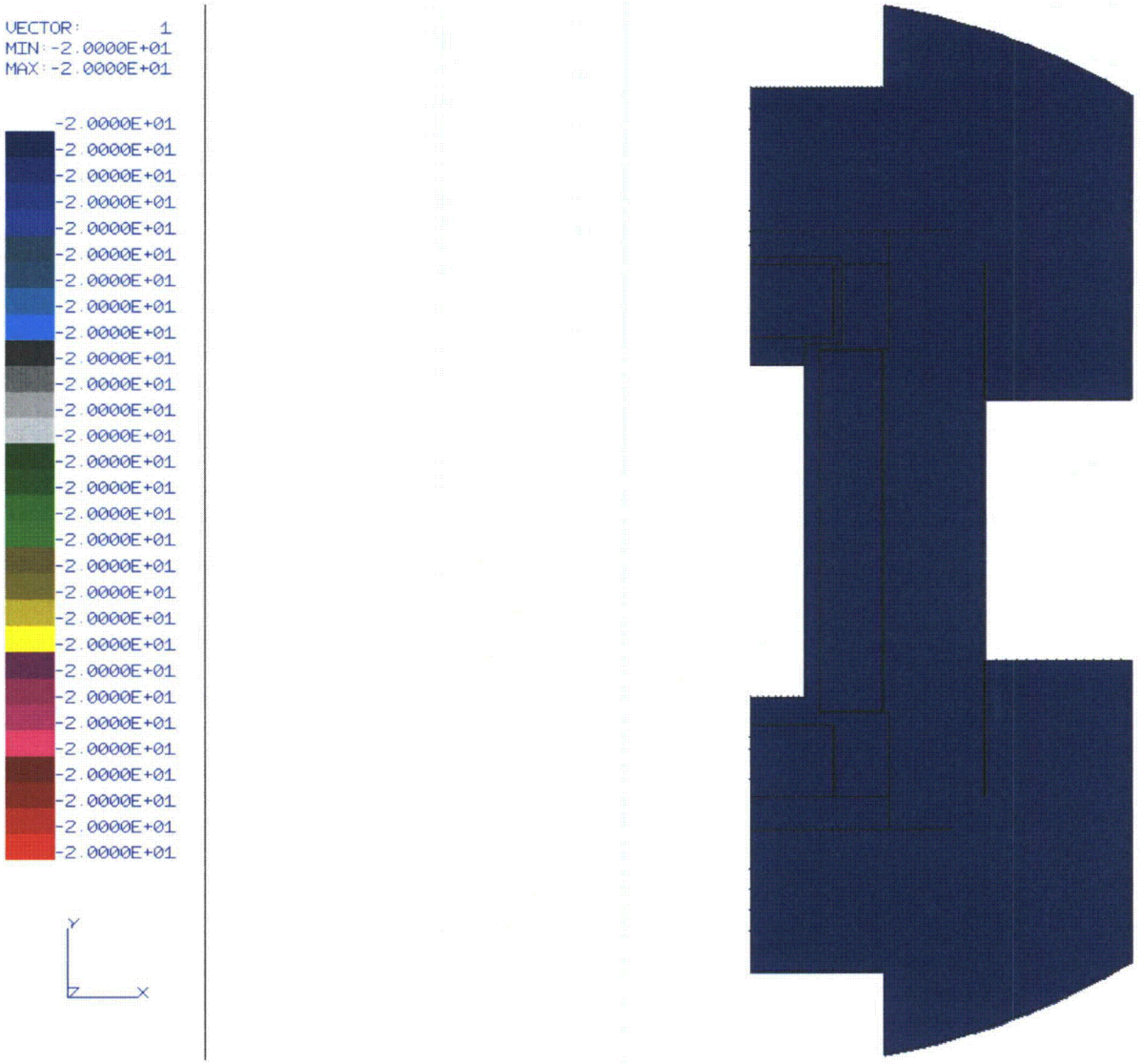

Figure 3-91. Load Case 103, -20°F Ambient, Zero Decay Heat, Zero Insolation, Entire Model – Model AOS-100B

Table 3-66. Load Case 104, -40°F Ambient, Zero Decay Heat, Zero Insolation – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	-40.00	-40.00
2	4532	-40.00	-40.00
3	4227	-40.00	-40.00
4	4752	-40.00	-40.00
5	4838	-40.00	-40.00
6	4993	-40.00	-40.00
7	3309	-40.00	-40.00
8	3351	-40.00	-40.00
9	678	-40.00	-40.00
10	2537	-40.00	-40.00
11	2533	-40.00	-40.00
12	4828	-40.00	-40.00
13	1888	-40.00	-40.00
14	583	-40.00	-40.00
15	579	-40.00	-40.00
16	4313	-40.00	-40.00
17	3148	-40.00	-40.00
18	3001	-40.00	-40.00
19	7533	-40.00	-40.00
20	7377	-40.00	-40.00
21	7371	-40.00	-40.00
22	6942	-40.00	-40.00
23	6267	-40.00	-40.00
24	6121	-40.00	-40.00
25	6001	-40.00	-40.00
26	9501	-40.00	-40.00
27	9950	-40.00	-40.00
28	10014	-40.00	-40.00
29	10781	-40.00	-40.00
30	9091	-40.00	-40.00
31	8463	-40.00	-40.00
32	8462	-40.00	-40.00
33	8197	-40.00	-40.00
34	9711	-40.00	-40.00
35	9821	-40.00	-40.00
36	10158	-40.00	-40.00
37	10605	-40.00	-40.00
38	9102	-40.00	-40.00
39	8578	-40.00	-40.00
40	8225	-40.00	-40.00
41	8001	-40.00	-40.00

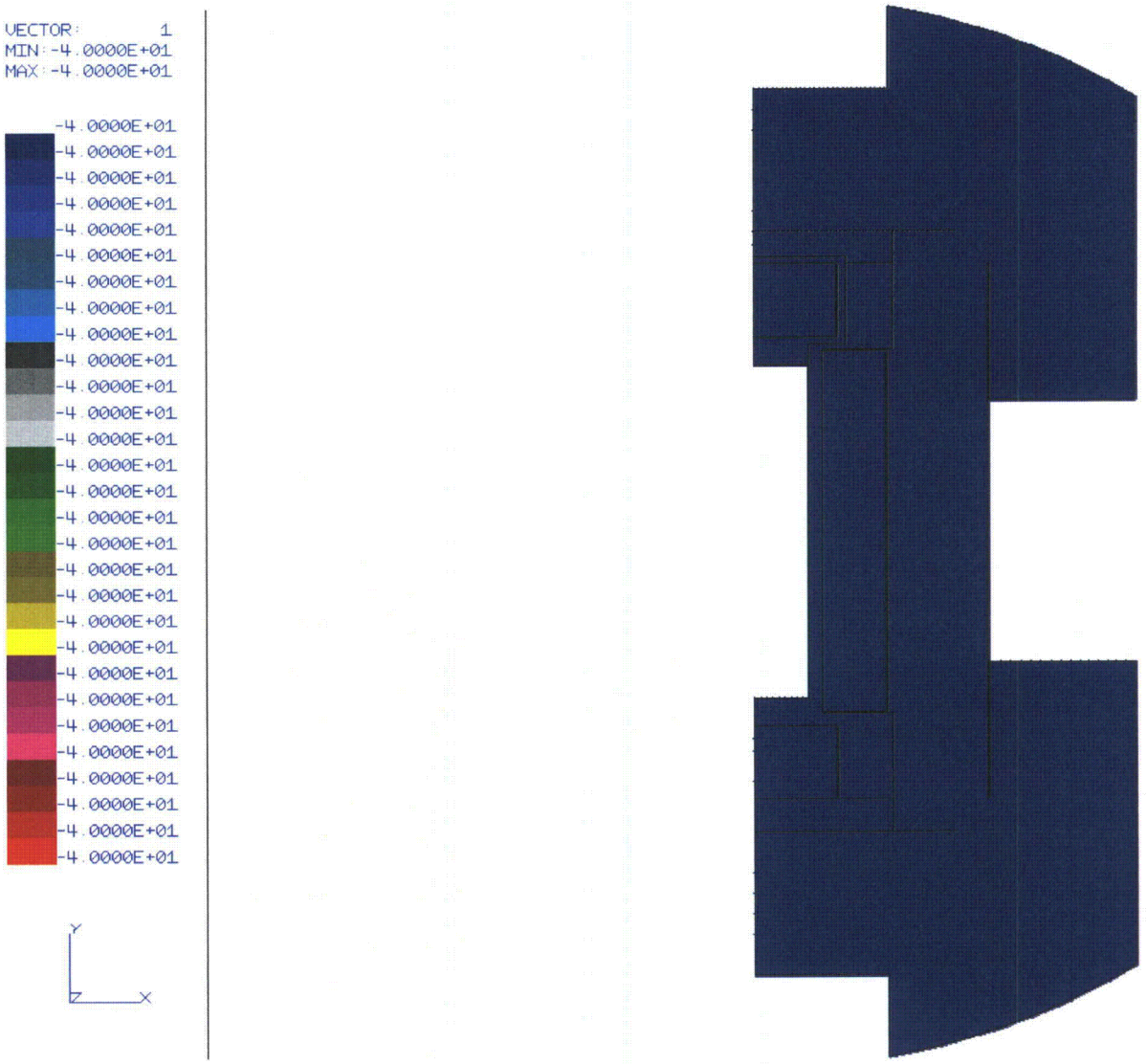

Figure 3-92. Load Case 104, -40°F Ambient, Zero Decay Heat, Zero Insolation, Entire Model – Model AOS-100B

Table 3-67. Load Case 105, -40°F Ambient, Maximum Decay Heat – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	45.28	113.50
2	4532	36.61	97.89
3	4227	40.83	105.50
4	4752	35.62	96.11
5	4838	29.97	85.94
6	4993	29.81	85.66
7	3309	30.13	86.23
8	3351	29.70	85.46
9	678	30.14	86.26
10	2537	27.89	82.21
11	2533	28.11	82.59
12	4828	30.07	86.13
13	1888	26.08	78.95
14	583	27.64	81.75
15	579	27.84	82.12
16	4313	30.98	87.76
17	3148	28.75	83.75
18	3001	29.24	84.64
19	7533	32.51	90.51
20	7377	32.76	90.97
21	7371	31.22	88.19
22	6942	31.39	88.51
23	6267	31.21	88.18
24	6121	31.32	88.37
25	6001	31.13	88.03
26	9501	29.36	84.85
27	9950	27.46	81.43
28	10014	26.31	79.35
29	10781	2.58	36.64
30	9091	-1.81	28.75
31	8463	25.50	77.90
32	8462	27.09	80.77
33	8197	28.65	83.57
34	9711	-37.70	-35.86
35	9821	-39.18	-38.53
36	10158	-39.34	-38.81
37	10605	-34.23	-29.61
38	9102	-36.38	-33.48
39	8578	-36.78	-34.21
40	8225	-27.38	-17.29
41	8001	-21.91	-7.43

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	722	3.0211E+01	8.6380E+01
Bottom Plate	3001	3232	3120	2.9361E+01	8.4850E+01
Cask Lid	3233	3424	3233	3.0250E+01	8.6450E+01
Shell Cavity	4001	4998	4227	4.0833E+01	1.0550E+02
Cask Lid Plug	5001	5404	5001	4.5278E+01	1.1350E+02
Carbon Steel	6001	7656	7552	3.2856E+01	9.1140E+01
Bottom Cavity	4227	4236	4227	4.0833E+01	1.0550E+02
Side Cavity	4372	4702	4527	3.6606E+01	9.7890E+01
Top Cavity	5001	5012	5001	4.5278E+01	1.1350E+02
Lid Seal	4993	4993	4993	2.9811E+01	8.5660E+01
Cask Vent Port	2537	2537	2537	2.7894E+01	8.2210E+01
Cask Vent Port Seal	2533	2533	2533	2.8106E+01	8.2590E+01
Vt.Conic.Seal	4828	4828	4828	3.0072E+01	8.6130E+01
Cask Drain Port	583	583	583	2.7639E+01	8.1750E+01
Cask Drain Port Seal	579	579	579	2.7844E+01	8.2120E+01
Drn.Conic.Seal	4313	4313	4313	3.0978E+01	8.7760E+01
Test Port	3351	3351	3351	2.9700E+01	8.5460E+01

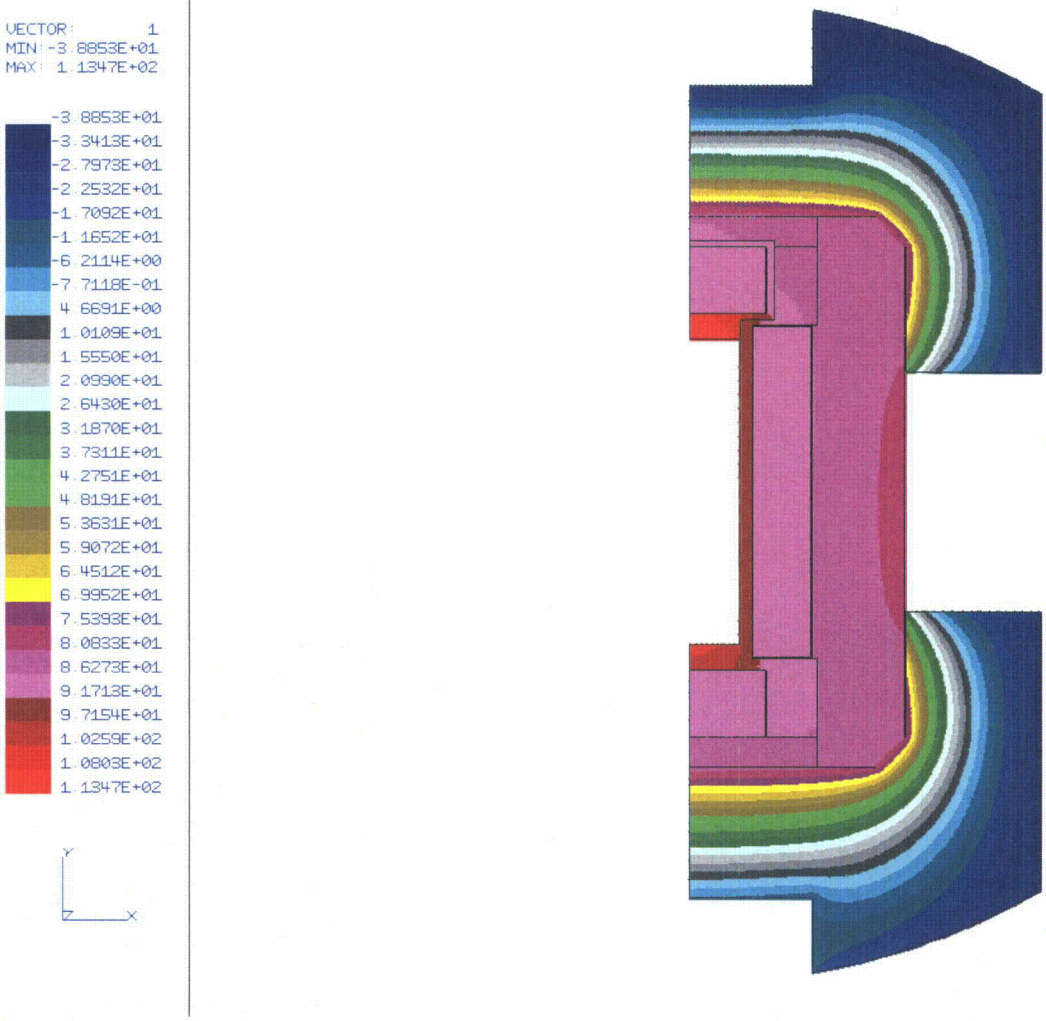

Figure 3-93. Load Case 105, -40°F Ambient, Maximum Decay Heat, Entire Model – Model AOS-100B

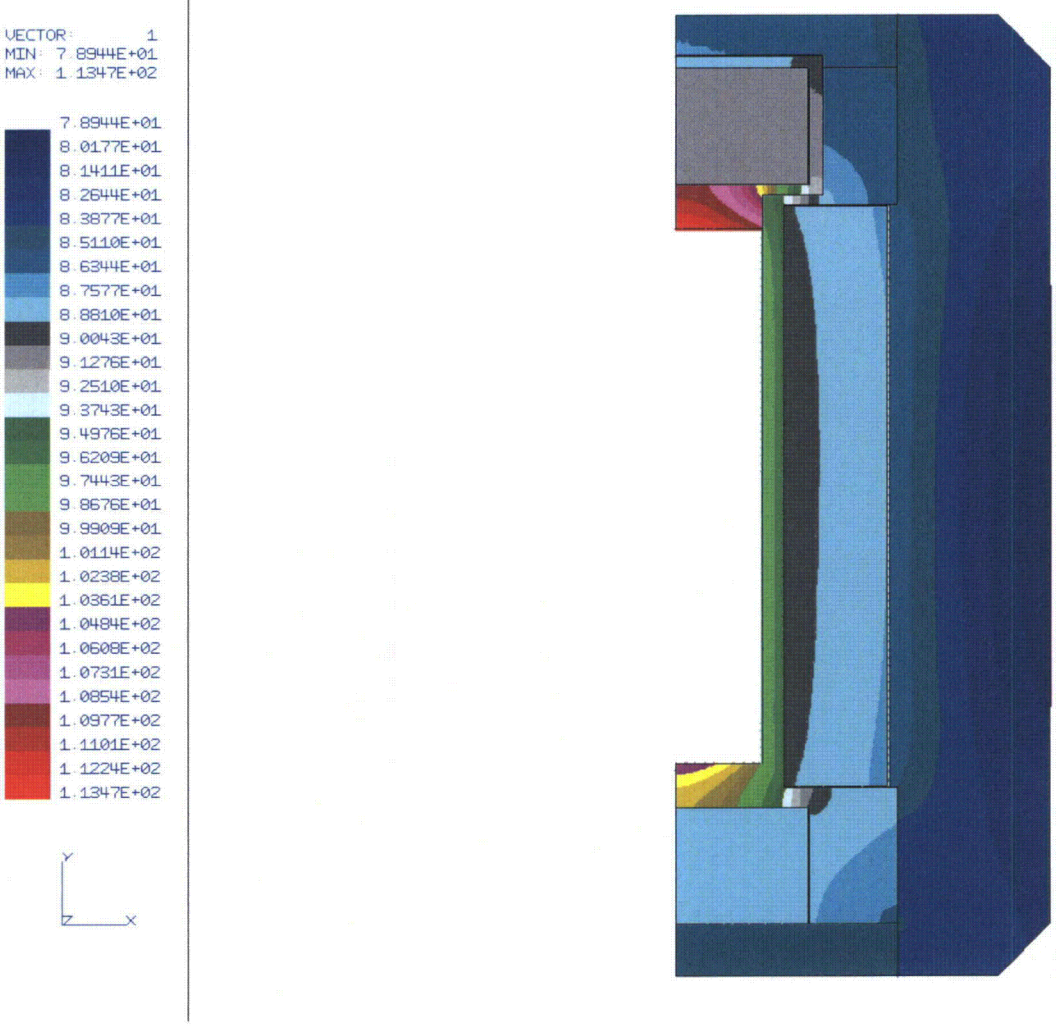

Figure 3-94. Load Case 105, -40°F Ambient, Maximum Decay Heat, Cask Model – Model AOS-100B

Table 3-68. Load Case 106, -20°F Ambient, Maximum Decay Heat – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	55.50	131.90
2	4532	47.00	116.60
3	4227	51.17	124.10
4	4752	46.00	114.80
5	4838	40.39	104.70
6	4993	40.28	104.50
7	3309	40.56	105.00
8	3351	40.17	104.30
9	678	40.61	105.10
10	2537	38.39	101.10
11	2533	38.56	101.40
12	4828	40.50	104.90
13	1888	36.62	97.92
14	583	38.11	100.60
15	579	38.33	101.00
16	4313	41.44	106.60
17	3148	39.22	102.60
18	3001	39.72	103.50
19	7533	42.89	109.20
20	7377	43.17	109.70
21	7371	41.67	107.00
22	6942	41.89	107.40
23	6267	41.67	107.00
24	6121	41.78	107.20
25	6001	41.56	106.80
26	9501	39.78	103.60
27	9950	37.94	100.30
28	10014	36.84	98.32
29	10781	12.88	55.18
30	9091	8.62	47.51
31	8463	36.06	96.91
32	8462	37.60	99.68
33	8197	39.11	102.40
34	9711	-26.72	-16.09
35	9821	-28.13	-18.63
36	10158	-28.24	-18.84
37	10605	-23.56	-10.40
38	9102	-25.51	-13.91
39	8578	-25.68	-14.23
40	8225	-16.47	2.36
41	8001	-11.10	12.02

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	696	4.0667E+01	1.0520E+02
Bottom Plate	3001	3232	3120	3.9833E+01	1.0370E+02
Cask Lid	3233	3424	3233	4.0667E+01	1.0520E+02
Shell Cavity	4001	4998	4227	5.1167E+01	1.2410E+02
Cask Lid Plug	5001	5404	5001	5.5500E+01	1.3190E+02
Carbon Steel	6001	7656	7552	4.3222E+01	1.0980E+02
Bottom Cavity	4227	4236	4227	5.1167E+01	1.2410E+02
Side Cavity	4372	4702	4507	4.7000E+01	1.1660E+02
Top Cavity	5001	5012	5001	5.5500E+01	1.3190E+02
Lid Seal	4993	4993	4993	4.0278E+01	1.0450E+02
Cask Vent Port	2537	2537	2537	3.8389E+01	1.0110E+02
Cask Vent Port Seal	2533	2533	2533	3.8556E+01	1.0140E+02
Vt.Conic.Seal	4828	4828	4828	4.0500E+01	1.0490E+02
Cask Drain Port	583	583	583	3.8111E+01	1.0060E+02
Cask Drain Port Seal	579	579	579	3.8333E+01	1.0100E+02
Drn.Conic.Seal	4313	4313	4313	4.1444E+01	1.0660E+02
Test Port	3351	3351	3351	4.0167E+01	1.0430E+02

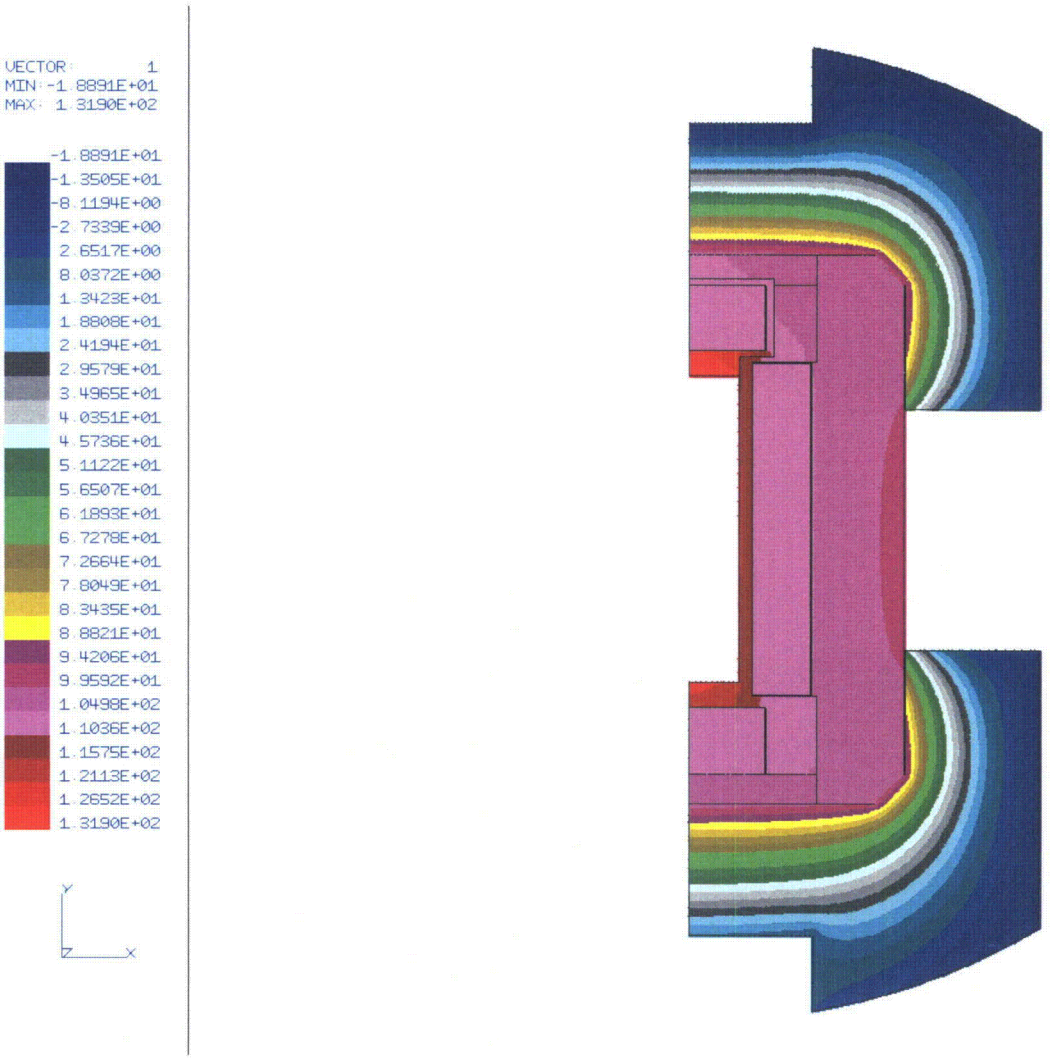

Figure 3-95. Load Case 106, -20°F Ambient, Maximum Decay Heat, Entire Model – Model AOS-100B

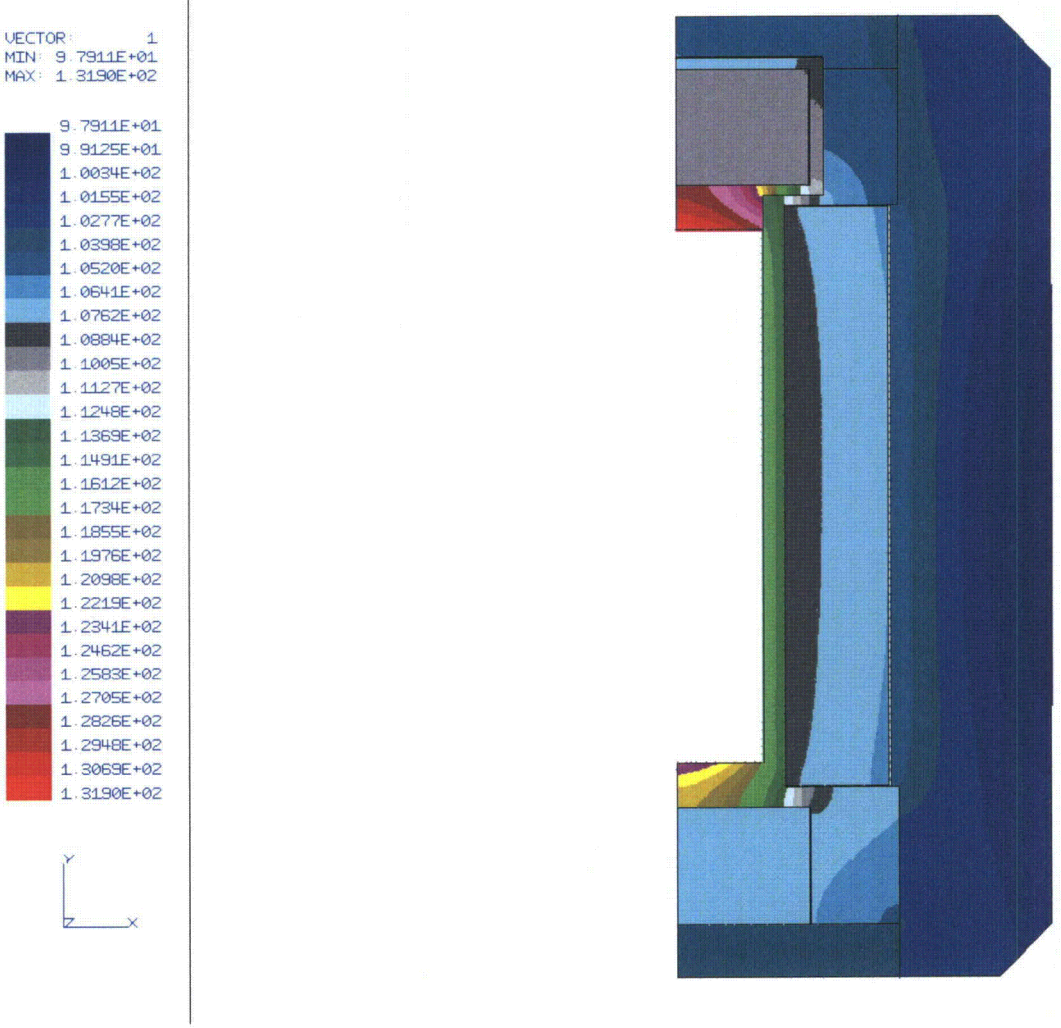

Figure 3-96. Load Case 106, -20°F Ambient, Maximum Decay Heat, Cask Model – Model AOS-100B

3.5.2.4.2 Fire Condition Thermal Evaluation Results – Model AOS-100B

Table 3-69 lists the tables and figures in this appendix that present the Model AOS-100B transport package results under the Fire condition, for Load Cases 111 and 112. Each table provides a list of temperatures at each monitoring node. Also listed are the maximum temperatures within each transport package component.

Figure 3-60 illustrates the location of each node on the Model AOS-100 (A, B, and A-S) transport packages, under Normal conditions of transport. (The node locations are listed in Table 3-47.)

Table 3-69. Fire Condition Thermal Evaluation Results – Model AOS-100B

Load Case	Description	Temperature versus Time	Results Table	Entire Model	Cask Model
111	Fire at 30 Minutes, 1,475°F Ambient, Maximum Decay Heat	Figure 3-97 Figure 3-98 Figure 3-99	Table 3-70	Figure 3-100	Figure 3-101
112	Post Fire at 60 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-71	Figure 3-102	Figure 3-103
	Post Fire at 90 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-72	Figure 3-104	Figure 3-105
	Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-73	Figure 3-106	Figure 3-107
	Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-74	Figure 3-108	Figure 3-109
	Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation		Table 3-75	Figure 3-110	Figure 3-111

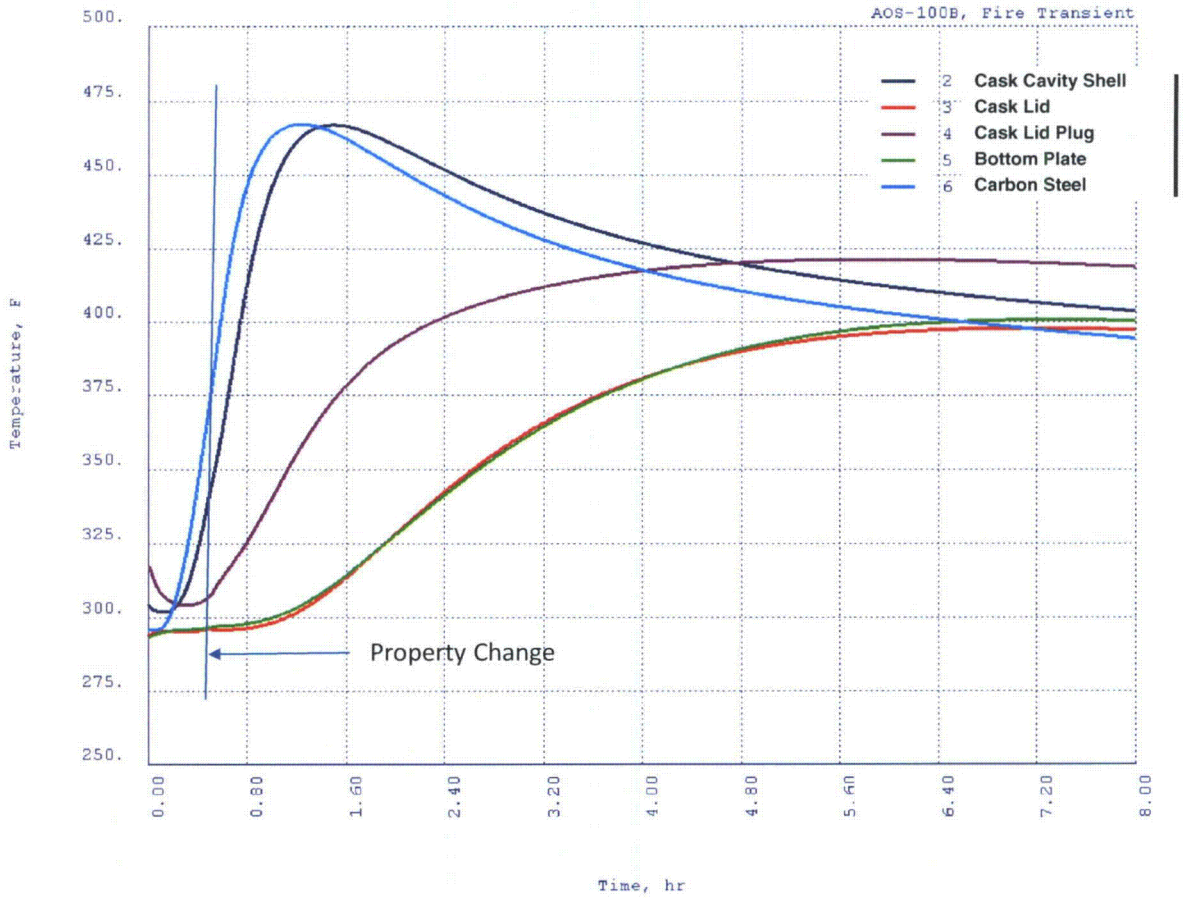

Figure 3-97. Fire for 30 Minutes and Post Fire Cool Down for 7.5 Hours, Temperature versus Time, for Cask Cavity Shell, Cask Lid, Cask Lid Plug, Bottom Plate, and Carbon Steel – Model AOS-100B

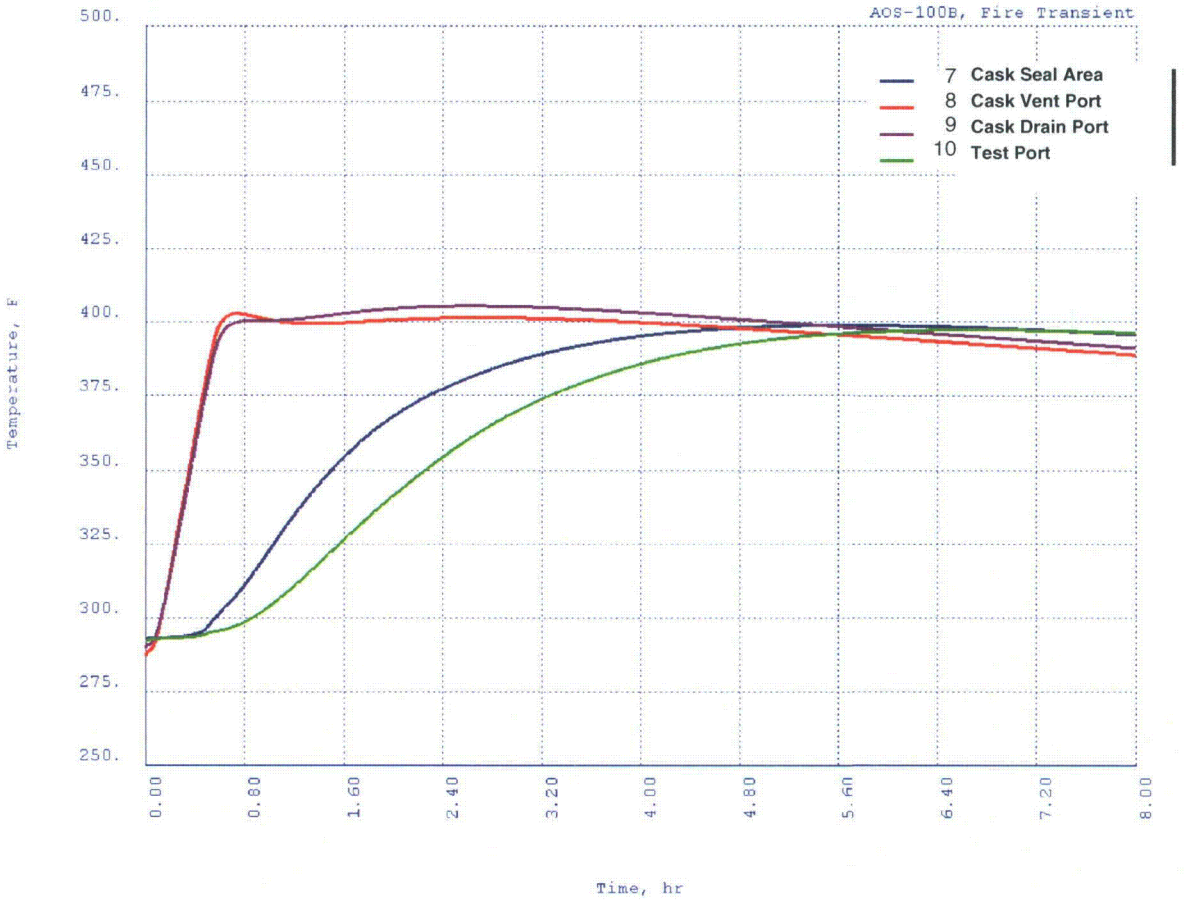

Figure 3-98. Fire for 30 Minutes and Post Fire Cool Down for 7.5 Hours, Temperature versus Time, for Cask Seal Area, Cask Vent Port, Cask Drain Port, and Test Port – Model AOS-100B

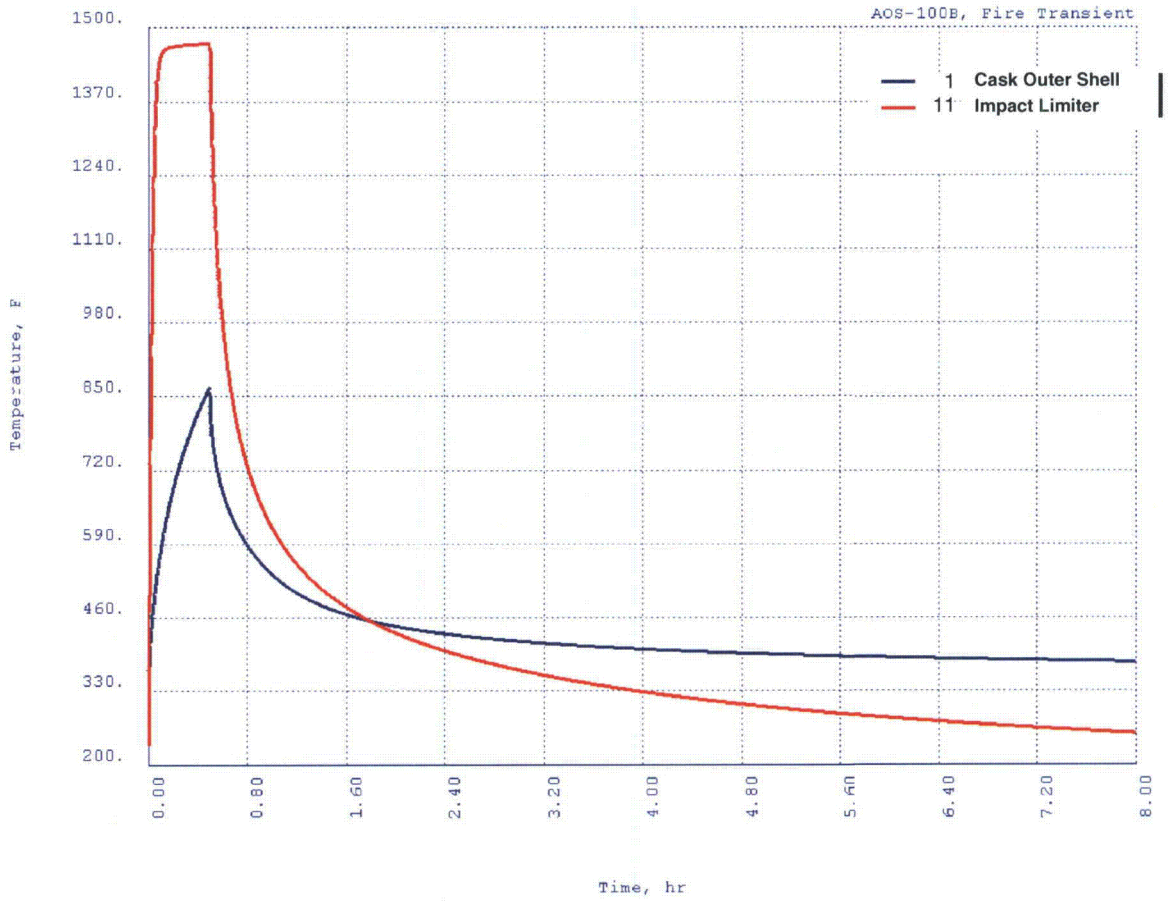

Figure 3-99. Fire for 30 Minutes and Post Fire Cool Down for 7.5 Hours, Temperature versus Time, for Cask Outer Shell and Impact Limiter – Model AOS-100B

Table 3-70. Load Case 111, Fire at 30 Minutes, 1,475°F Ambient, Maximum Decay Heat – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	152.83	307.10
2	4532	172.22	342.00
3	4227	153.56	308.40
4	4752	152.50	306.50
5	4838	165.44	329.80
6	4993	146.72	296.10
7	3309	146.28	295.30
8	3351	145.83	294.50
9	678	210.22	410.40
10	2537	195.00	383.00
11	2533	192.00	377.60
12	4828	158.50	317.30
13	1888	463.06	865.50
14	583	192.61	378.70
15	579	189.83	373.70
16	4313	159.78	319.60
17	3148	146.67	296.00
18	3001	146.94	296.50
19	7533	147.28	297.10
20	7377	149.17	300.50
21	7371	160.44	320.80
22	6942	177.83	352.10
23	6267	160.56	321.00
24	6121	149.78	301.60
25	6001	147.89	298.20
26	15481	146.28	295.30
27	15941	146.83	296.30
28	16260	150.44	302.80
29	17129	443.67	830.60
30	11531	444.50	832.10
31	9785	151.33	304.40
32	9571	147.72	297.90
33	8197	146.89	296.40
34	15451	797.22	1467.00
35	16160	796.67	1466.00
36	17608	799.44	1471.00
37	18360	799.44	1471.00
38	11051	799.44	1471.00
39	9900	798.89	1470.00
40	8673	800.00	1472.00
41	8225	797.78	1468.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1877	4.6306E+02	8.6550E+02
Bottom Plate	3001	3232	3232	1.4783E+02	2.9810E+02
Cask Lid	3233	3424	3360	1.4700E+02	2.9660E+02
Shell Cavity	4001	4998	4531	1.7261E+02	3.4270E+02
Cask Lid Plug	5001	5404	5001	1.5817E+02	3.1670E+02
Carbon Steel	6001	7656	6949	1.8906E+02	3.7230E+02
Bottom Cavity	4227	4236	4236	1.5728E+02	3.1510E+02
Side Cavity	4372	4702	4532	1.7222E+02	3.4200E+02
Top Cavity	5001	5012	5001	1.5817E+02	3.1670E+02
Lid Seal	4993	4993	4993	1.4672E+02	2.9610E+02
Cask Vent Port	2537	2537	2537	1.9500E+02	3.8300E+02
Cask Vent Port Seal	2533	2533	2533	1.9200E+02	3.7760E+02
Vt.Conic.Seal	4828	4828	4828	1.5850E+02	3.1730E+02
Cask Drain Port	583	583	583	1.9261E+02	3.7870E+02
Cask Drain Port Seal	579	579	579	1.8983E+02	3.7370E+02
Drn.Conic.Seal	4313	4313	4313	1.5978E+02	3.1960E+02
Test Port	3351	3351	3351	1.4583E+02	2.9450E+02

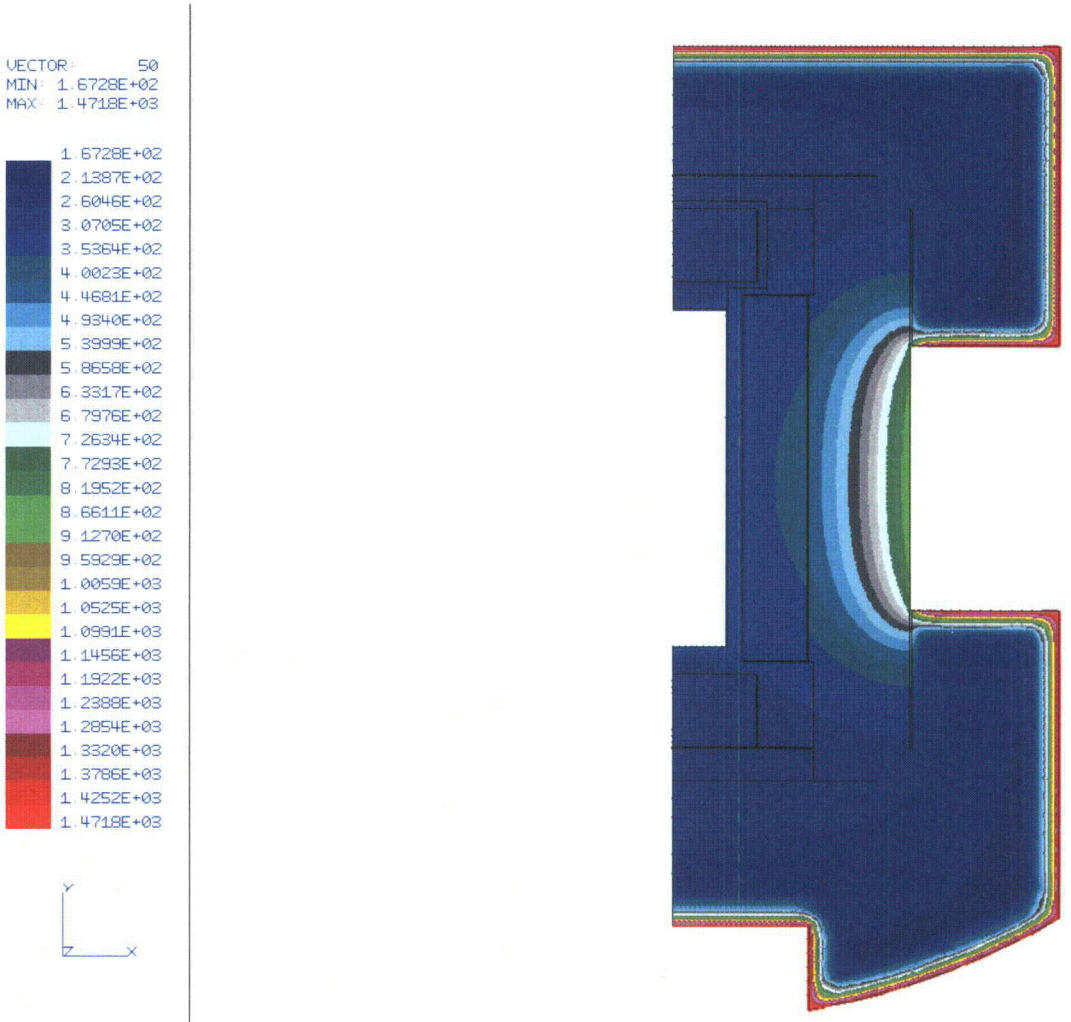

Figure 3-100. Load Case 111, Fire at 30 Minutes, 1,475°F Ambient, Maximum Decay Heat, Entire Model – Model AOS-100B

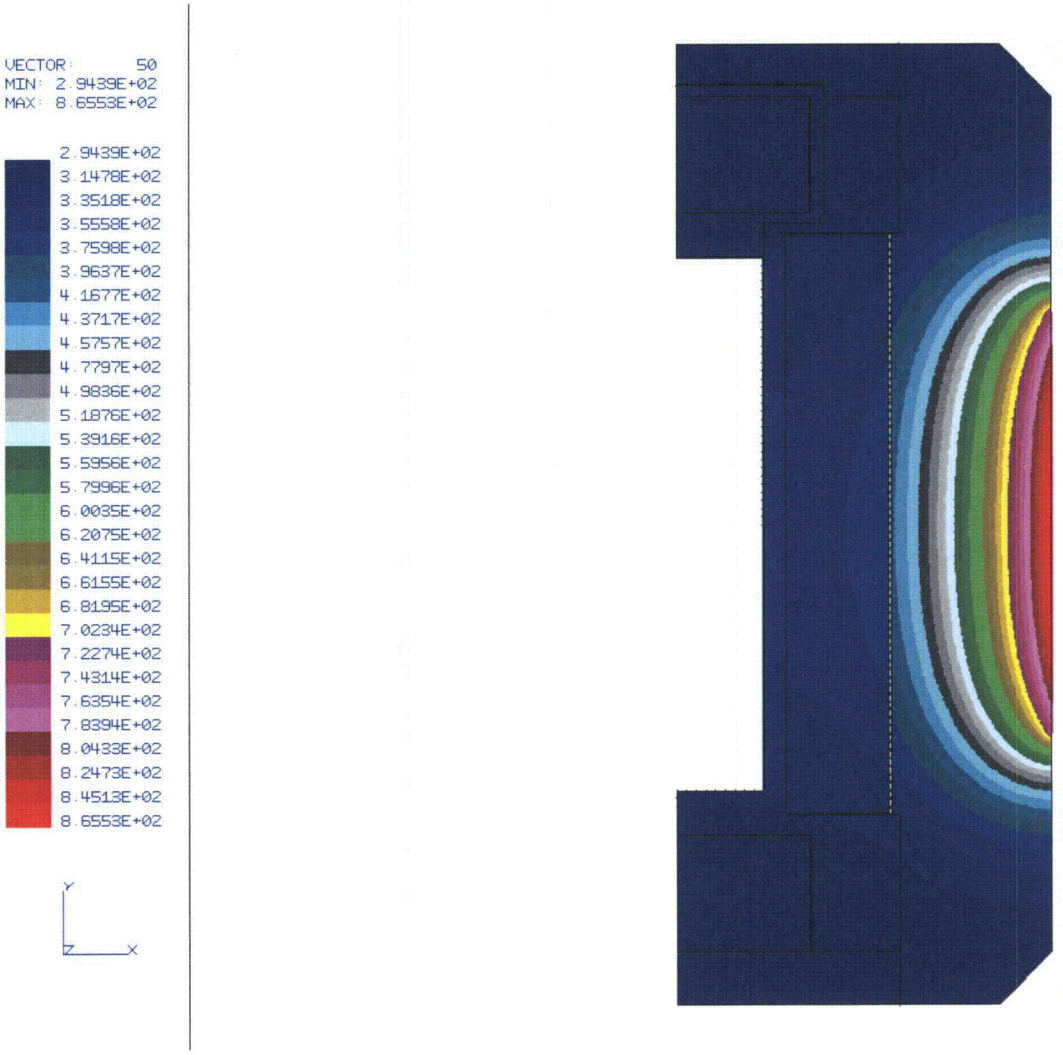

Figure 3-101. Load Case 111, Fire at 30 Minutes, 1,475°F Ambient, Maximum Decay Heat, Cask Model – Model AOS-100B

Table 3-71. Load Case 112, Post Fire at 60 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	171.00	339.80
2	4532	229.72	445.50
3	4227	180.22	356.40
4	4752	186.00	366.80
5	4838	178.61	353.50
6	4993	161.39	322.50
7	3309	147.72	297.90
8	3351	150.89	303.60
9	678	249.83	481.70
10	2537	204.72	400.50
11	2533	204.33	399.80
12	4828	172.39	342.30
13	1888	280.00	536.00
14	583	204.56	400.20
15	579	204.28	399.70
16	4313	160.22	320.40
17	3148	158.83	317.90
18	3001	148.72	299.70
19	7533	151.06	303.90
20	7377	151.67	305.00
21	7371	211.78	413.20
22	6942	232.94	451.30
23	6267	211.61	412.90
24	6121	155.00	311.00
25	6001	154.17	309.50
26	15481	147.78	298.00
27	15941	162.33	324.20
28	16260	172.78	343.00
29	17129	183.44	362.20
30	11531	181.28	358.30
31	9785	176.67	350.00
32	9571	167.94	334.30
33	8197	154.11	309.40
34	15451	130.17	266.30
35	16160	130.39	266.70
36	17608	127.94	262.30
37	18360	128.39	263.10
38	11051	128.11	262.60
39	9900	325.33	617.60
40	8673	785.00	1445.00
41	8225	770.56	1419.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1877	4.2711E+02	8.0080E+02
Bottom Plate	3001	3232	3001	2.0472E+02	4.0050E+02
Cask Lid	3233	3424	3233	2.0311E+02	3.9760E+02
Shell Cavity	4001	4998	4532	2.4144E+02	4.6660E+02
Cask Lid Plug	5001	5404	5001	2.1617E+02	4.2110E+02
Carbon Steel	6001	7656	6949	2.4161E+02	4.6690E+02
Bottom Cavity	4227	4236	4227	2.1528E+02	4.1950E+02
Side Cavity	4372	4702	4532	2.4144E+02	4.6660E+02
Top Cavity	5001	5012	5001	2.1617E+02	4.2110E+02
Lid Seal	4993	4993	4993	2.0367E+02	3.9860E+02
Cask Vent Port	2537	2537	2537	2.0589E+02	4.0260E+02
Cask Vent Port Seal	2533	2533	2533	2.0556E+02	4.0200E+02
Vt.Conic.Seal	4828	4828	4828	2.0450E+02	4.0010E+02
Cask Drain Port	583	583	583	2.0733E+02	4.0520E+02
Cask Drain Port Seal	579	579	579	2.0767E+02	4.0580E+02
Drn.Conic.Seal	4313	4313	4313	2.0561E+02	4.0210E+02
Test Port	3351	3351	3351	2.0283E+02	3.9710E+02

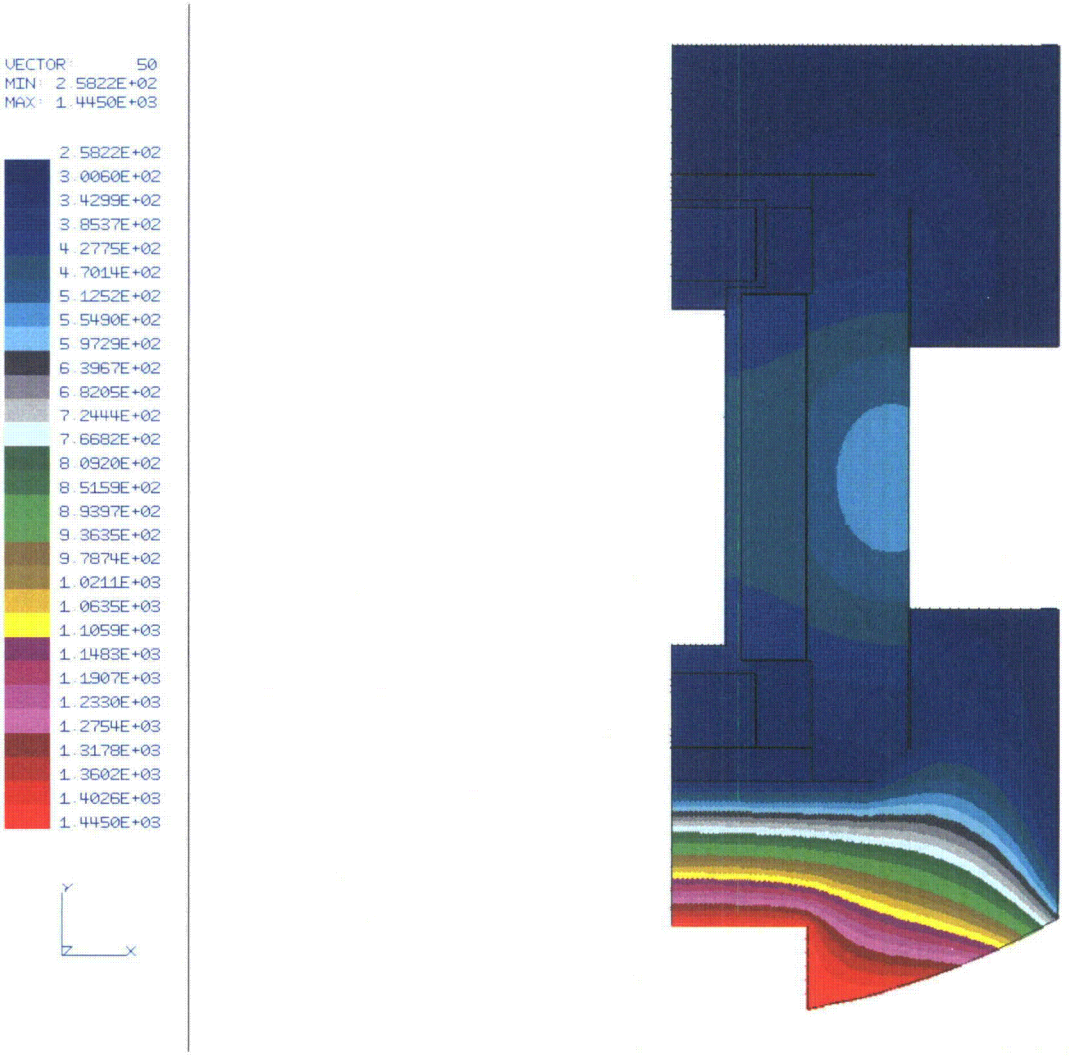

Figure 3-102. Load Case 112, Post Fire at 60 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Model AOS-100B

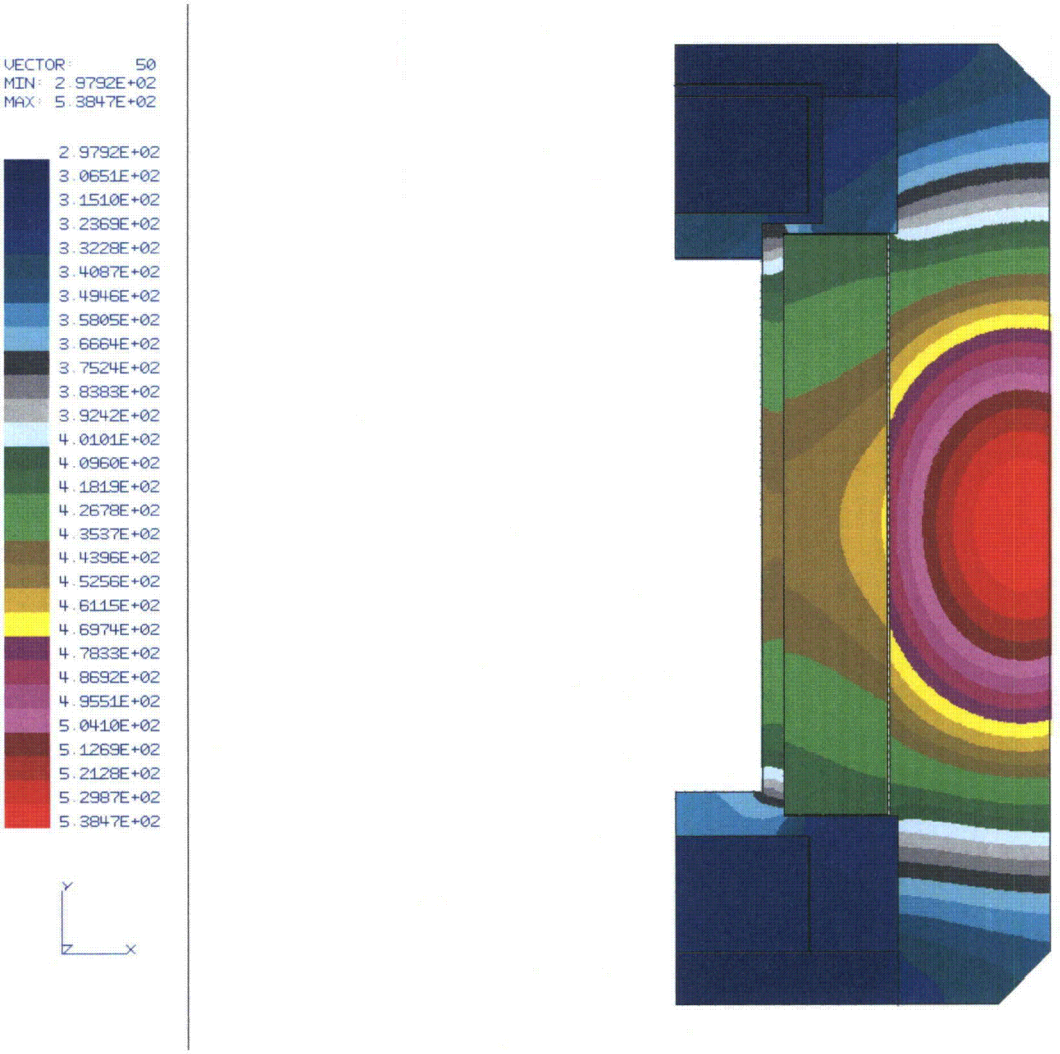

Figure 3-103. Load Case 112, Post Fire at 60 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Model AOS-100B

Table 3-72. Load Case 112, Post Fire at 90 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	189.56	373.20
2	4532	241.44	466.60
3	4227	201.06	393.90
4	4752	203.11	397.60
5	4838	191.33	376.40
6	4993	176.44	349.60
7	3309	154.22	309.60
8	3351	161.17	322.10
9	678	242.39	468.30
10	2537	204.11	399.40
11	2533	204.39	399.90
12	4828	186.56	367.80
13	1888	244.33	471.80
14	583	205.61	402.10
15	579	205.89	402.60
16	4313	171.11	340.00
17	3148	171.56	340.80
18	3001	154.89	310.80
19	7533	159.22	318.60
20	7377	160.11	320.20
21	7371	223.72	434.70
22	6942	238.78	461.80
23	6267	223.39	434.10
24	6121	165.28	329.50
25	6001	164.11	327.40
26	15481	153.61	308.50
27	15941	176.50	349.70
28	16260	183.83	362.90
29	17129	161.50	322.70
30	11531	167.83	334.10
31	9785	188.28	370.90
32	9571	182.83	361.10
33	8197	160.94	321.70
34	15451	113.22	235.80
35	16160	113.06	235.50
36	17608	104.06	219.30
37	18360	92.67	198.80
38	11051	105.06	221.10
39	9900	255.89	492.60
40	8673	750.00	1382.00
41	8225	749.44	1381.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1877	4.2711E+02	8.0080E+02
Bottom Plate	3001	3232	3001	2.0472E+02	4.0050E+02
Cask Lid	3233	3424	3233	2.0311E+02	3.9760E+02
Shell Cavity	4001	4998	4532	2.4144E+02	4.6660E+02
Cask Lid Plug	5001	5404	5001	2.1617E+02	4.2110E+02
Carbon Steel	6001	7656	6949	2.4161E+02	4.6690E+02
Bottom Cavity	4227	4236	4227	2.1528E+02	4.1950E+02
Side Cavity	4372	4702	4532	2.4144E+02	4.6660E+02
Top Cavity	5001	5012	5001	2.1617E+02	4.2110E+02
Lid Seal	4993	4993	4993	2.0367E+02	3.9860E+02
Cask Vent Port	2537	2537	2537	2.0589E+02	4.0260E+02
Cask Vent Port Seal	2533	2533	2533	2.0556E+02	4.0200E+02
Vt.Conic.Seal	4828	4828	4828	2.0450E+02	4.0010E+02
Cask Drain Port	583	583	583	2.0733E+02	4.0520E+02
Cask Drain Port Seal	579	579	579	2.0767E+02	4.0580E+02
Drn.Conic.Seal	4313	4313	4313	2.0561E+02	4.0210E+02
Test Port	3351	3351	3351	2.0283E+02	3.9710E+02

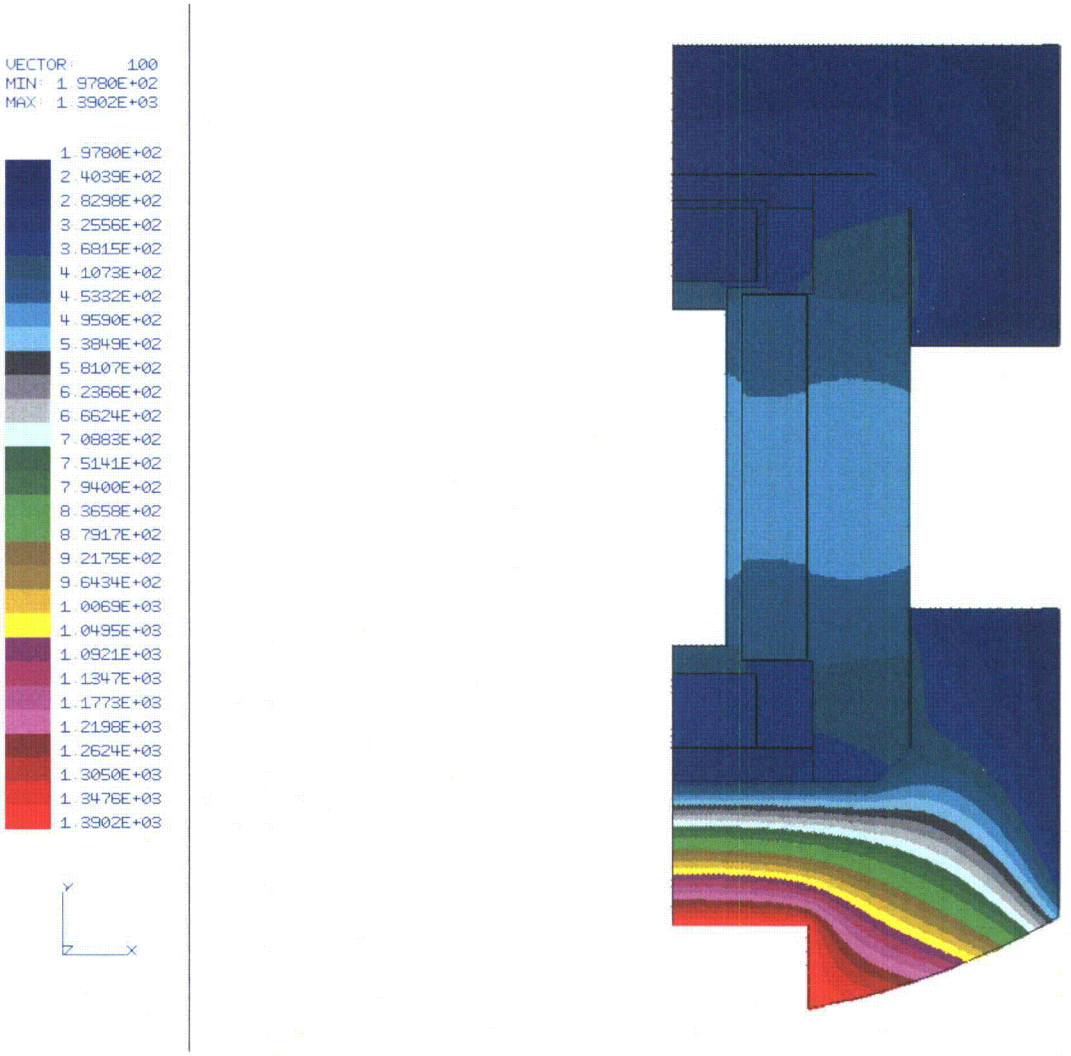

Figure 3-104. Load Case 112, Post Fire at 90 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Model AOS-100B

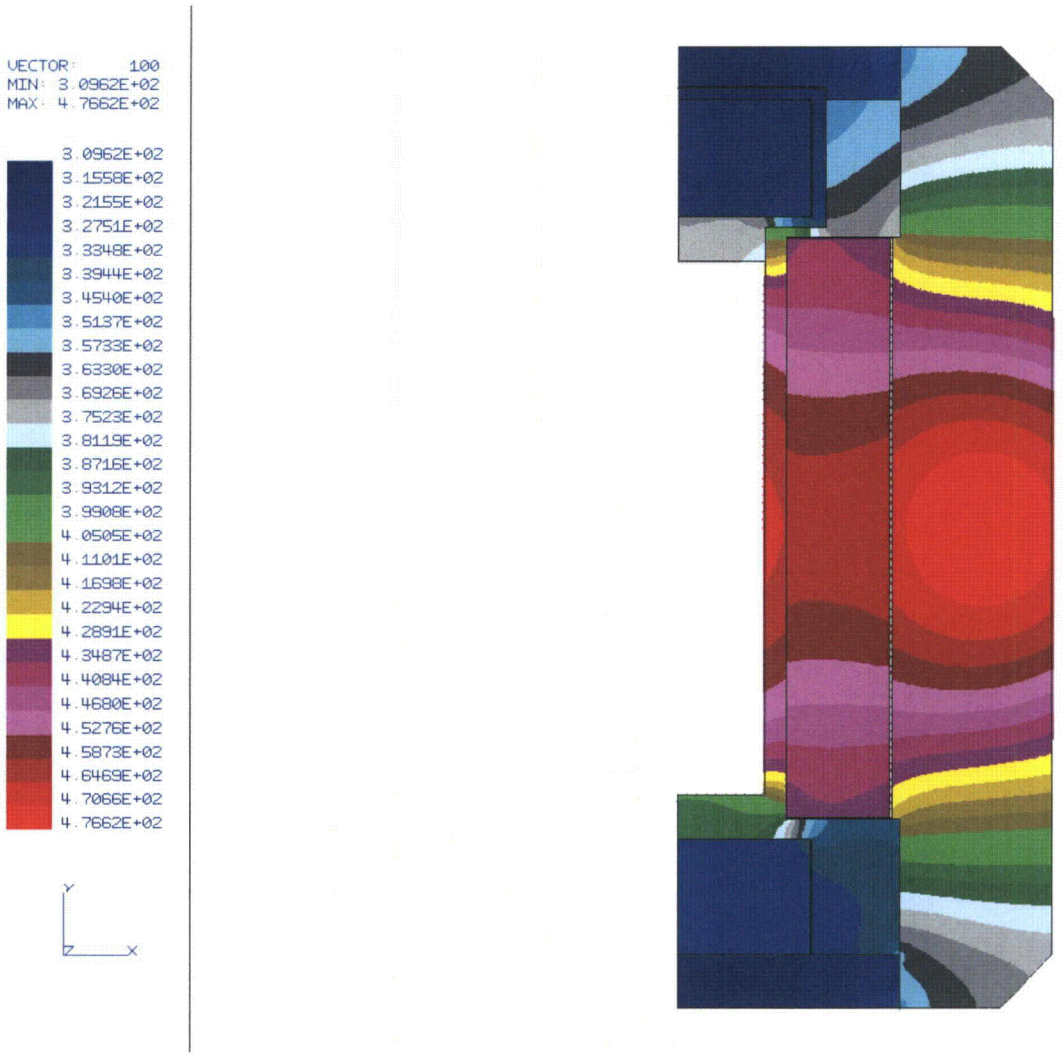

Figure 3-105. Load Case 112, Post Fire at 90 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Model AOS-100B

Table 3-73. Load Case 112, Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	200.33	392.60
2	4532	237.61	459.70
3	4227	209.17	408.50
4	4752	208.72	407.70
5	4838	197.89	388.20
6	4993	186.39	367.50
7	3309	164.17	327.50
8	3351	171.67	341.00
9	678	233.61	452.50
10	2537	204.67	400.40
11	2533	205.11	401.20
12	4828	194.44	382.00
13	1888	228.50	443.30
14	583	206.83	404.30
15	579	207.17	404.90
16	4313	180.72	357.30
17	3148	180.94	357.70
18	3001	164.06	327.30
19	7533	169.22	336.60
20	7377	170.22	338.40
21	7371	223.22	433.80
22	6942	233.61	452.50
23	6267	223.06	433.50
24	6121	175.78	348.40
25	6001	174.61	346.30
26	15481	163.44	326.20
27	15941	185.83	366.50
28	16260	190.89	375.60
29	17129	156.83	314.30
30	11531	165.28	329.50
31	9785	195.39	383.70
32	9571	191.89	377.40
33	8197	169.89	337.80
34	15451	112.11	233.80
35	16160	111.72	233.10
36	17608	101.28	214.30
37	18360	86.56	187.80
38	11051	102.50	216.50
39	9900	222.06	431.70
40	8673	700.56	1293.00
41	8225	725.56	1338.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1877	4.2711E+02	8.0080E+02
Bottom Plate	3001	3232	3001	2.0472E+02	4.0050E+02
Cask Lid	3233	3424	3233	2.0311E+02	3.9760E+02
Shell Cavity	4001	4998	4532	2.4144E+02	4.6660E+02
Cask Lid Plug	5001	5404	5001	2.1617E+02	4.2110E+02
Carbon Steel	6001	7656	6949	2.4161E+02	4.6690E+02
Bottom Cavity	4227	4236	4227	2.1528E+02	4.1950E+02
Side Cavity	4372	4702	4532	2.4144E+02	4.6660E+02
Top Cavity	5001	5012	5001	2.1617E+02	4.2110E+02
Lid Seal	4993	4993	4993	2.0367E+02	3.9860E+02
Cask Vent Port	2537	2537	2537	2.0589E+02	4.0260E+02
Cask Vent Port Seal	2533	2533	2533	2.0556E+02	4.0200E+02
Vt.Conic.Seal	4828	4828	4828	2.0450E+02	4.0010E+02
Cask Drain Port	583	583	583	2.0733E+02	4.0520E+02
Cask Drain Port Seal	579	579	579	2.0767E+02	4.0580E+02
Drn.Conic.Seal	4313	4313	4313	2.0561E+02	4.0210E+02
Test Port	3351	3351	3351	2.0283E+02	3.9710E+02

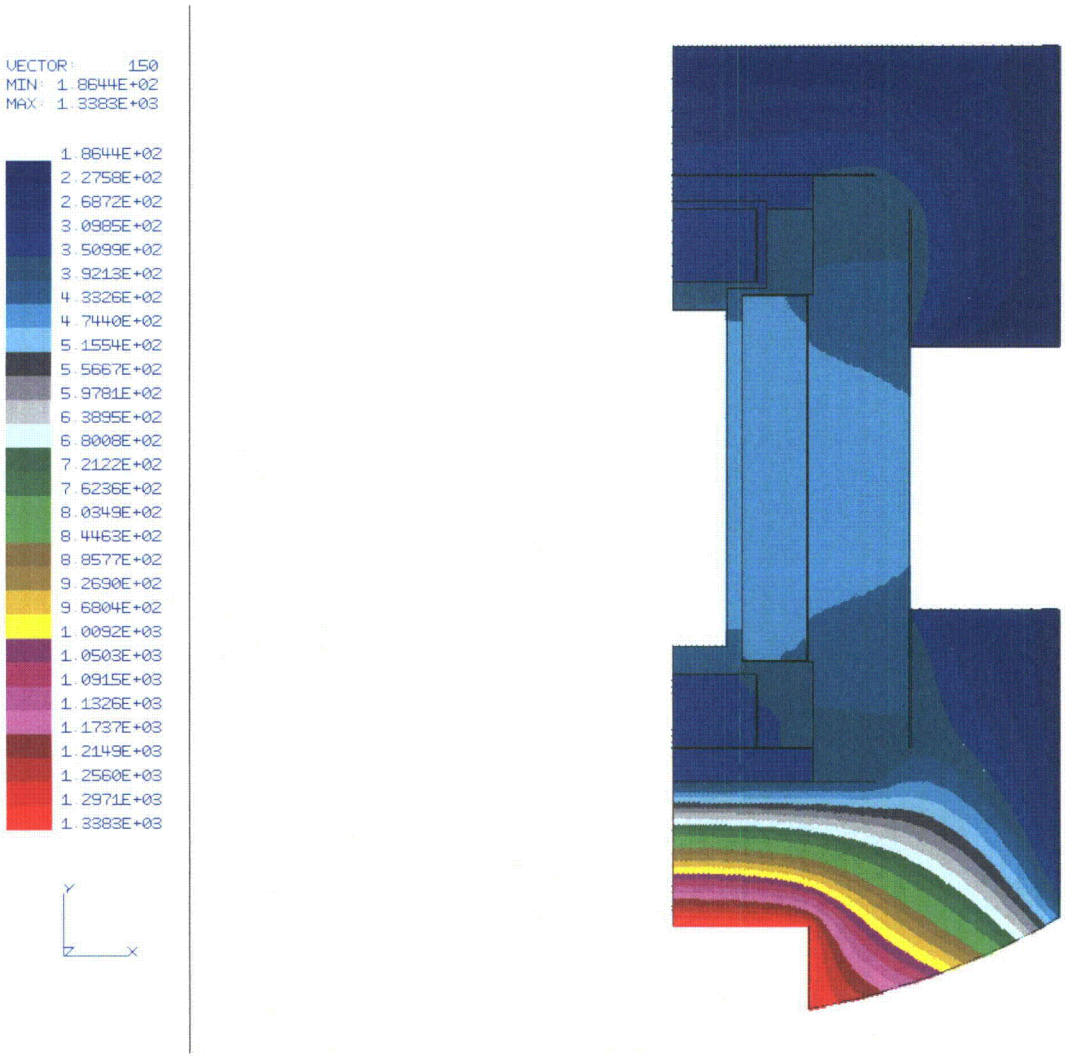

Figure 3-106. Load Case 112, Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Model AOS-100B

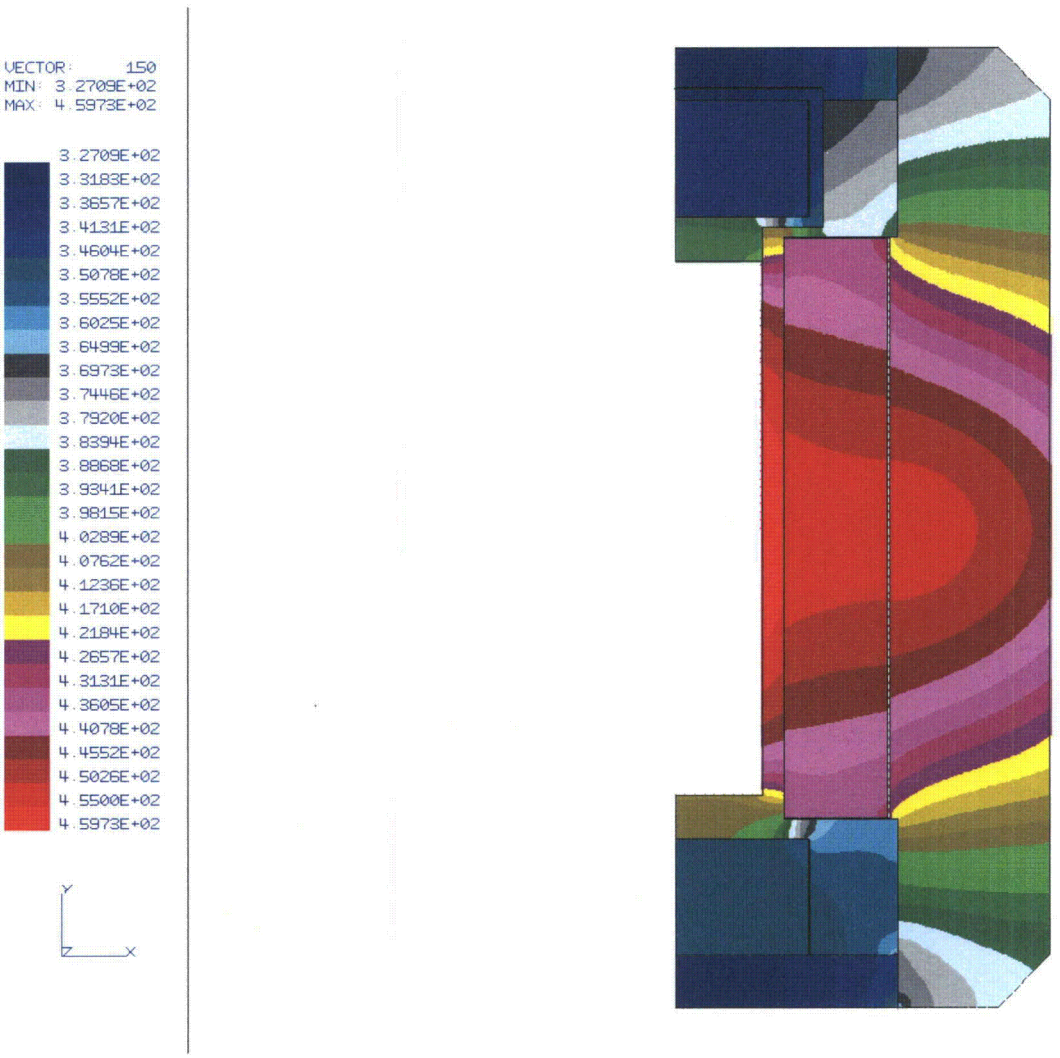

Figure 3-107. Load Case 112, Post Fire at 120 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Cask Model – Model AOS-100B

Table 3-74. Load Case 112, Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	206.22	403.20
2	4532	231.83	449.30
3	4227	212.39	414.30
4	4752	210.50	410.90
5	4838	201.33	394.40
6	4993	192.83	379.10
7	3309	174.00	345.20
8	3351	180.56	357.00
9	678	226.44	439.60
10	2537	205.06	401.10
11	2533	205.56	402.00
12	4828	198.89	390.00
13	1888	219.56	427.20
14	583	207.28	405.10
15	579	207.67	405.80
16	4313	188.22	370.80
17	3148	188.06	370.50
18	3001	173.44	344.20
19	7533	178.44	353.20
20	7377	179.28	354.70
21	7371	220.22	428.40
22	6942	227.50	441.50
23	6267	220.28	428.50
24	6121	184.39	363.90
25	6001	183.39	362.10
26	15481	173.28	343.90
27	15941	191.94	377.50
28	16260	195.39	383.70
29	17129	155.11	311.20
30	11531	164.11	327.40
31	9785	199.56	391.20
32	9571	197.44	387.40
33	8197	178.72	353.70
34	15451	112.17	233.90
35	16160	111.61	232.90
36	17608	100.89	213.60
37	18360	85.39	185.70
38	11051	102.11	215.80
39	9900	200.61	393.10
40	8673	650.00	1202.00
41	8225	695.00	1283.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1877	4.2711E+02	8.0080E+02
Bottom Plate	3001	3232	3001	2.0472E+02	4.0050E+02
Cask Lid	3233	3424	3233	2.0311E+02	3.9760E+02
Shell Cavity	4001	4998	4532	2.4144E+02	4.6660E+02
Cask Lid Plug	5001	5404	5001	2.1617E+02	4.2110E+02
Carbon Steel	6001	7656	6949	2.4161E+02	4.6690E+02
Bottom Cavity	4227	4236	4227	2.1528E+02	4.1950E+02
Side Cavity	4372	4702	4532	2.4144E+02	4.6660E+02
Top Cavity	5001	5012	5001	2.1617E+02	4.2110E+02
Lid Seal	4993	4993	4993	2.0367E+02	3.9860E+02
Cask Vent Port	2537	2537	2537	2.0589E+02	4.0260E+02
Cask Vent Port Seal	2533	2533	2533	2.0556E+02	4.0200E+02
Vt.Conic.Seal	4828	4828	4828	2.0450E+02	4.0010E+02
Cask Drain Port	583	583	583	2.0733E+02	4.0520E+02
Cask Drain Port Seal	579	579	579	2.0767E+02	4.0580E+02
Drn.Conic.Seal	4313	4313	4313	2.0561E+02	4.0210E+02
Test Port	3351	3351	3351	2.0283E+02	3.9710E+02

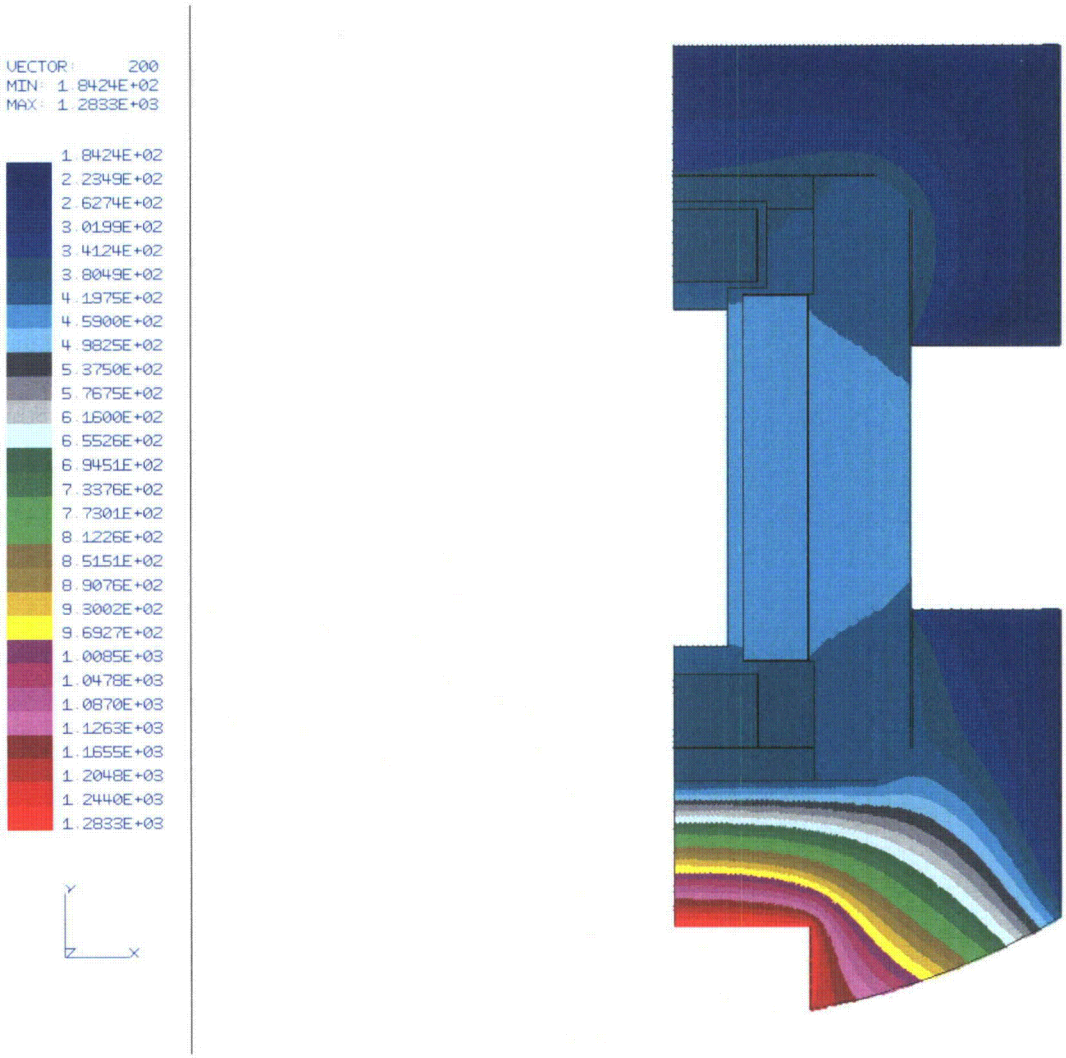

Figure 3-108. Load Case 112, Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Model AOS-100B

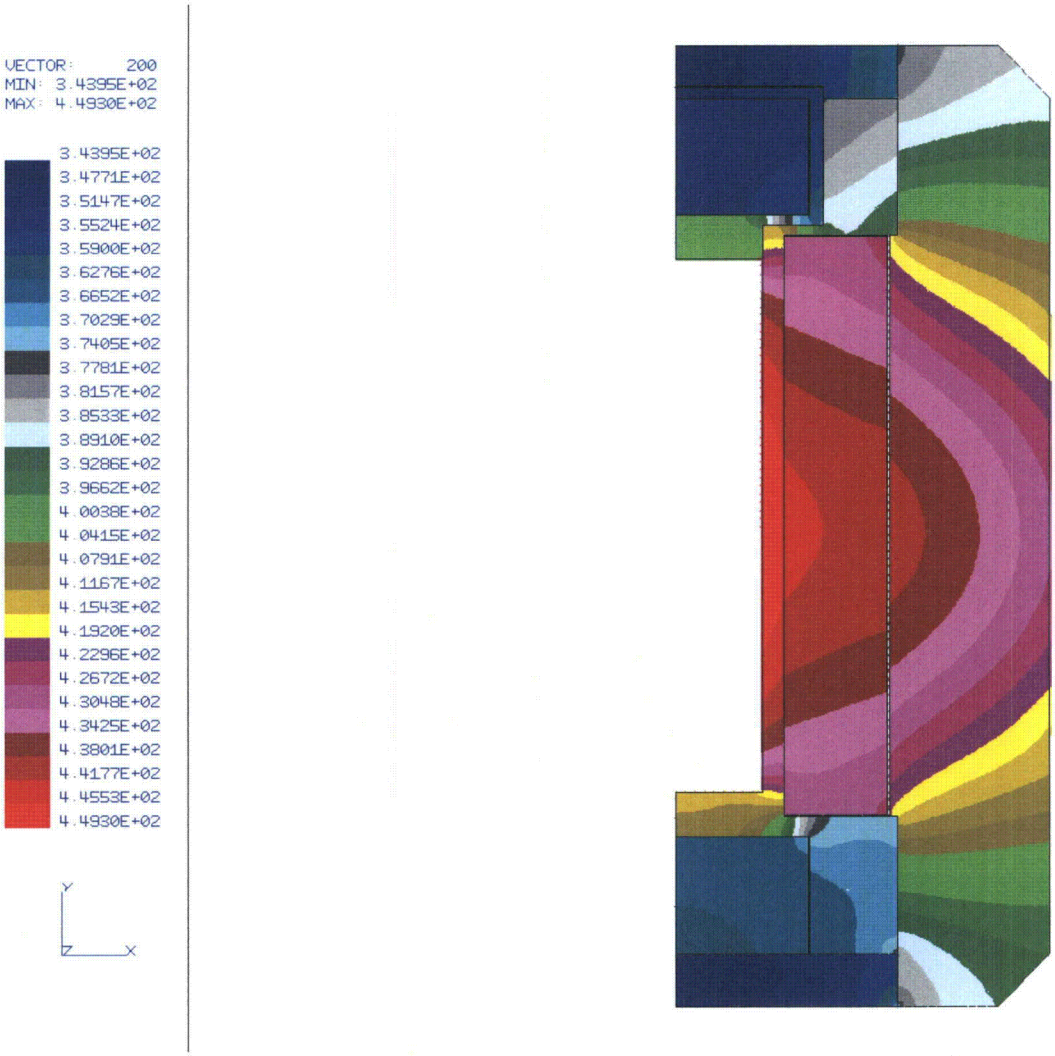

Figure 3-109. Load Case 112, Post Fire at 150 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Cask – Model AOS-100B

Table 3-75. Load Case 112, Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation – Model AOS-100B

Location	Node	Temp(C)	Temp(F)
1	5001	209.89	409.80
2	4532	226.72	440.10
3	4227	213.94	417.10
4	4752	211.00	411.80
5	4838	203.22	397.80
6	4993	197.00	386.60
7	3309	182.33	360.20
8	3351	187.50	369.50
9	678	220.89	429.60
10	2537	205.06	401.10
11	2533	205.50	401.90
12	4828	201.50	394.70
13	1888	213.56	416.40
14	583	207.17	404.90
15	579	207.50	405.50
16	4313	193.89	381.00
17	3148	193.33	380.00
18	3001	181.67	359.00
19	7533	186.00	366.80
20	7377	186.72	368.10
21	7371	217.17	422.90
22	6942	222.33	432.20
23	6267	217.44	423.40
24	6121	191.00	375.80
25	6001	190.22	374.40
26	15481	181.56	358.80
27	15941	195.94	384.70
28	16260	198.22	388.80
29	17129	154.06	309.30
30	11531	163.17	325.70
31	9785	201.89	395.40
32	9571	200.89	393.60
33	8197	186.33	367.40
34	15451	112.22	234.00
35	16160	111.67	233.00
36	17608	100.89	213.60
37	18360	85.17	185.30
38	11051	102.06	215.70
39	9900	185.22	365.40
40	8673	602.22	1116.00
41	8225	659.44	1219.00

Maximum Component Temperatures

Component	Node_1	Node_2	Node	Max_Temp(C)	Max_Temp(F)
Cask Outer Shell	101	2894	1877	4.2711E+02	8.0080E+02
Bottom Plate	3001	3232	3001	2.0472E+02	4.0050E+02
Cask Lid	3233	3424	3233	2.0311E+02	3.9760E+02
Shell Cavity	4001	4998	4532	2.4144E+02	4.6660E+02
Cask Lid Plug	5001	5404	5001	2.1617E+02	4.2110E+02
Carbon Steel	6001	7656	6949	2.4161E+02	4.6690E+02
Bottom Cavity	4227	4236	4227	2.1528E+02	4.1950E+02
Side Cavity	4372	4702	4532	2.4144E+02	4.6660E+02
Top Cavity	5001	5012	5001	2.1617E+02	4.2110E+02
Lid Seal	4993	4993	4993	2.0367E+02	3.9860E+02
Cask Vent Port	2537	2537	2537	2.0589E+02	4.0260E+02
Cask Vent Port Seal	2533	2533	2533	2.0556E+02	4.0200E+02
Vt.Conic.Seal	4828	4828	4828	2.0450E+02	4.0010E+02
Cask Drain Port	583	583	583	2.0733E+02	4.0520E+02
Cask Drain Port Seal	579	579	579	2.0767E+02	4.0580E+02
Drn.Conic.Seal	4313	4313	4313	2.0561E+02	4.0210E+02
Test Port	3351	3351	3351	2.0283E+02	3.9710E+02

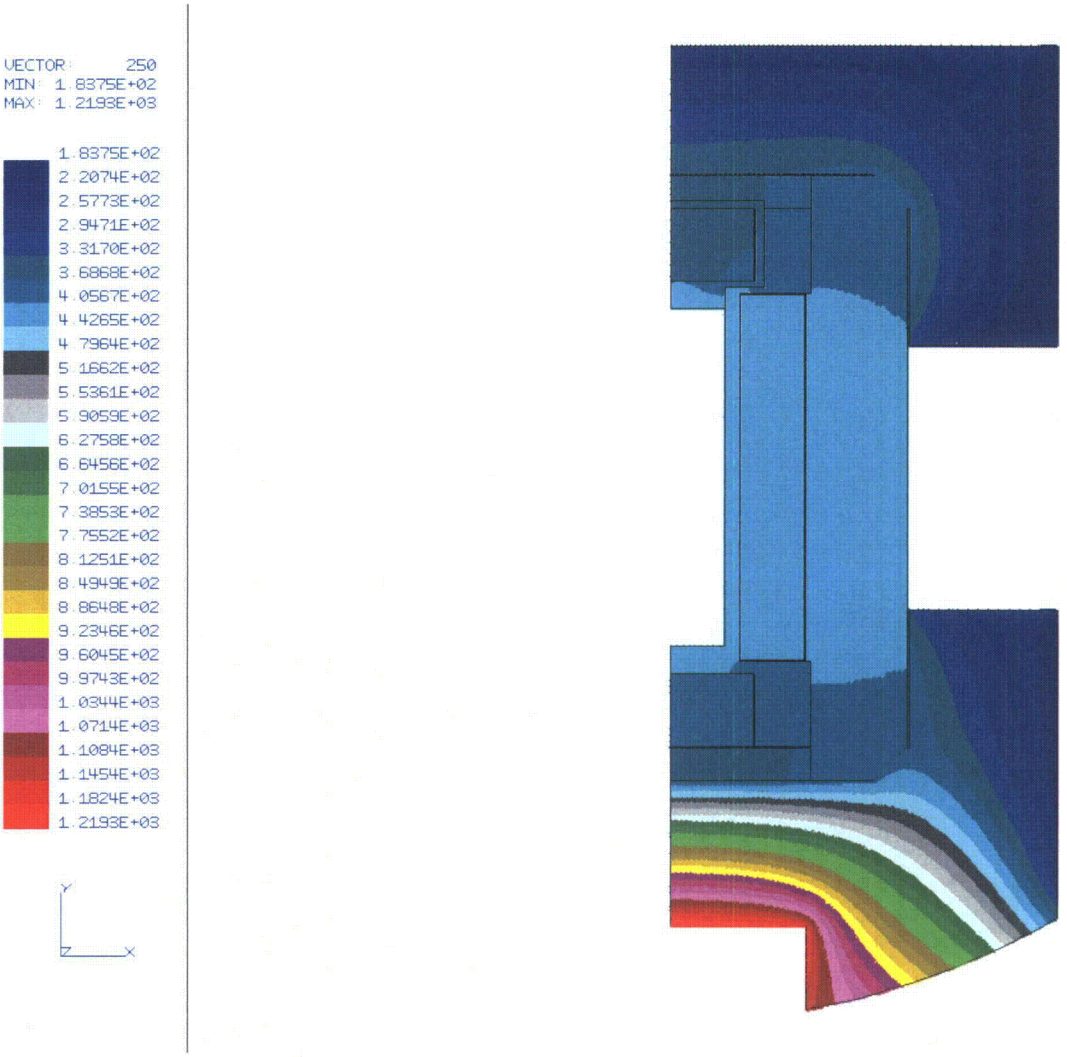

Figure 3-110. Load Case 112, Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Model – Model AOS-100B

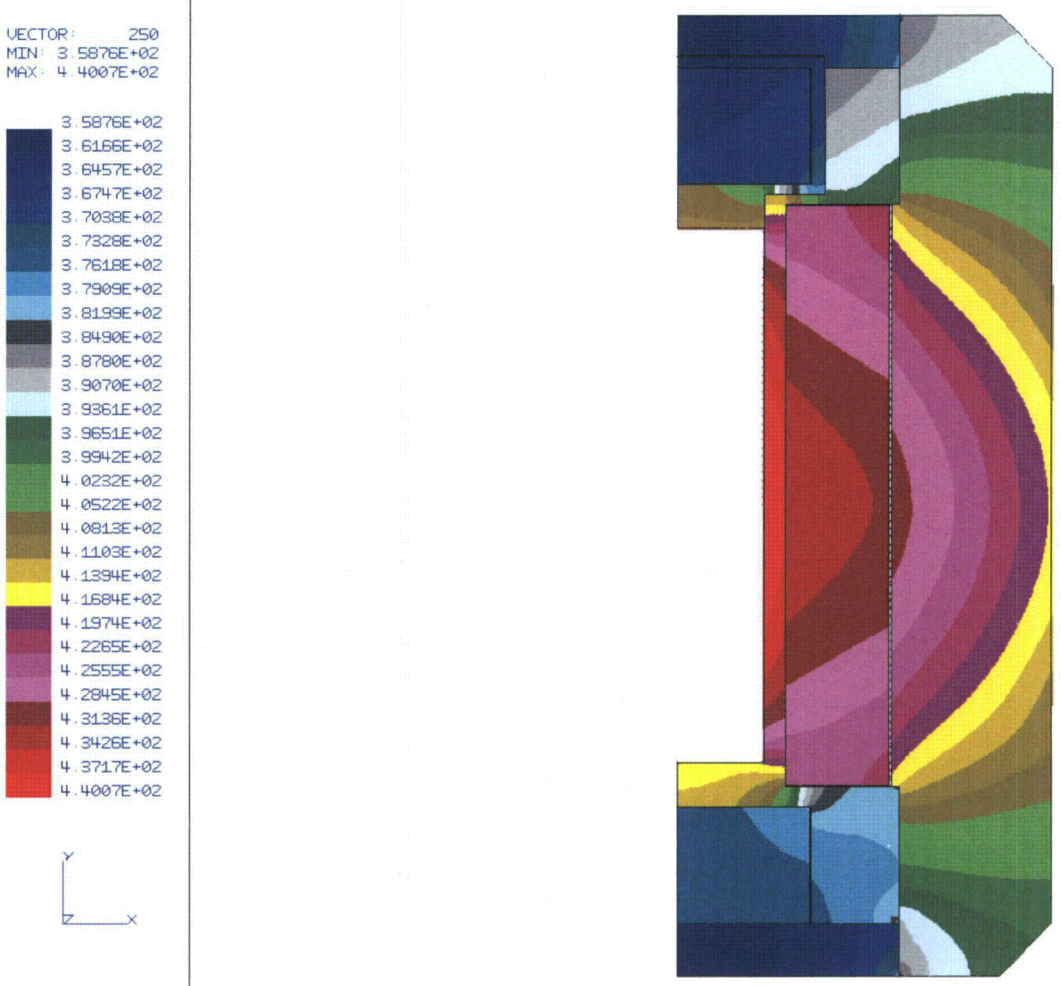

Figure 3-111. Load Case 112, Post Fire at 180 Minutes, 100°F, Maximum Decay Heat, Maximum Insolation, Entire Cask – Model AOS-100B

3.5.3 LIBRA Finite Element Program Heat Transfer Module

3.5.3.1 Description of the LIBRA Heat Transfer Program

The LIBRA heat transfer program performs steady-state and transient analyses of two- and three-dimensional structures. The LIBRA heat transfer code is compatible with the structural code in that essentially the same model can be used for both structural and thermal analyses, and temperature fields determined in thermal analyses can be saved and applied in subsequent structural analyses.

For transient thermal problems, the user can control the integration scheme by specifying the integration parameter. A zero (0) value of this parameter gives an explicit integration scheme, while values between zero (0) and one (1) give implicit schemes. Usually, a value of one (1) for the integration parameter was used, and this value corresponds to a backward difference integration technique.

The LIBRA user can specify property changes at user-directed intervals in transient problems. At such times, the LIBRA code passes control to a user-written subroutine, which allows the introduction of temperature-dependent properties. This program feature was widely used in the analysis of the transport package.

3.5.3.2 Qualification and Verification of LIBRA Program

To assess the accuracy of the LIBRA computer program, a qualification and verification program was conducted. The program included verification against exact solution type of problems and benchmarking in the thermal area. The GE Model 2000 heat tests were performed to verify thermal properties used in the analytical mode. In particular, the Model 2000 heat tests were used to validate thermal conduction properties for cask structural and shielding materials. The LIBRA program accuracy is demonstrated by a number of verification problems, described below, and by tests applied to the AOS-165A prototype.

3.5.3.3 Heat Transfer Problems with Exact Solution

Six example problems were solved analytically and by application of the LIBRA heat transfer program. The problems solved included plane and axisymmetric (2D) geometry and involved convective, radiative, and fixed temperature boundary conditions. In all problems solved, both steady-state and transient problems, agreement between the analytical solutions and the LIBRA program was within 1%. Table 3-76 summarizes these problems and the comparison of results.

3.5.3.4 Heat Transfer Benchmarking Test

A thermal test was performed on a GE Model 2000 transport package. The content heat load was simulated by electric heaters. Thermocouples were placed at the following strategic locations:

- Inside the cask cavity
- On the outside cask surface
- On the inside impact limiter surfaces
- Exterior to impact limiter structure

Temperatures were periodically recorded, because the heater power was varied from 0 to 3 kW. Steady-state temperatures were recorded for various heater powers from 1 to 3 kW.

A finite element model of the package was developed and was applied to a thermal analysis using the LIBRA Heat Transfer Program. A comparison of heat test (HT) and LIBRA results are provided in Table 3-77.

A more detailed description of the GE Model 2000 heat tests is provided in Appendix 3.5.3.5.

Table 3-76. Summary of Heat Transfer Exact Solution Properties and their Results

Problem Type	Problem Statement	Theory	LIBRA	References
Transient conduction	Concrete wall at initial temperature (Ti), suddenly exposed on one side to hot gas at (Tg).	X/L: 0.000, 0.167, 0.333, 0.500, 0.667, 0.833, 1.000 T(°F): 508.8, 538.2, 625.3, 766.3, 954.7, 1,180.7, 1,431.8	T(°F): 507, 535, 622, 763, 952, 1,180, 1,430	Kreith, Frank, *Principles of Heat Transfer*, International Textbook Company, Pennsylvania, 2nd Ed., 1969, Example 4-4.
Steady-state conduction	Concrete slab has its two (2) surfaces maintained at T_1 and T_2. Obtain heat transfer rate.	120 Btu/h-ft^2	120 Btu/h-ft^2	Gebhart, Benjamin, *Heat Transfer*, The McGraw-Hill Companies, New York, 2nd Ed., 1971, Example 2-1.
Internal heat generation/ steady-state	A uniformly heat-generating plate of thickness t, subjected to a temperature T_1 on inside and T_2 on the other side.	X/L: 0.000, 0.125, 0.250, 0.375, 0.500, 0.625, 0.750, 0.875, 1.000 T(°F): 141, 330, 471, 562, 605, 599, 544, 440, 288	T(°F): 142, 331, 471, 562, 605, 599, 544, 440, 287	Garret, J. K., *THTD Verification Manual*, General Electric Company, San Jose, CA, 1980.
Conduction with radiation and convection boundaries	A plate has a heat flux on one side, and the other side radiates to two (2) sinks.	Surface Temperature 659.7°F	Surface Temperature 659.7°F	Ibid.
Axisymmetric (2D), transient conduction	An infinitely long rod of radius R having a uniform initial temperature T~ is plunged suddenly into a bath at T∞.	r/R: 0.8, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0 T(°F): 6.6, 87.0, 87.6, 88.5, 89.7, 91.2, 92.8, 94.6, 96.5, 98.3, 100.0	T(°F): 86.6, 87.0, 87.6, 88.5, 89.7, 91.2, 92.9, 94.7, 96.5, 98.3, 100.0	

Table 3-76. Summary of Heat Transfer Exact Solution Properties and their Results (Continued)

Problem Type	Problem Statement	Theory		LIBRA	References
Axisymmetric (2D), transient conduction with convective boundary	A rod having a uniform initial temperature Ti is quenched in an oil bath at T∞.	r/R	T(°F)	T(°F)	Ibid, Example 5-13.
		0	490.0	490	
		0.1	489.0	488	
		0.2	485.7	485	
		0.3	480.2	479	
		0.4	472.6	472	
		0.5	462.9	462	
		0.6	451.3	450	
		0.7	437.8	437	
		0.8	422.5	421	
		0.9	405.6	404	
		1.0	387.2	386	

Table 3-77. Comparison of Heat Test GE Model 2000 and LIBRA Results

Location	p = 1.1 kW		p = 2 kW		p = 3 kW	
	HT (°F)	LIBRA (°F)	HT (°F)	LIBRA (°F)	HT (°F)	LIBRA (°F)
Cavity	264	248	395	372	527	474
Cask Surface	166	179	243	256	319	308
Inside Jacket	101	99	139	138	168	158
Outside Jacket	80	82	98	107	102	111

3.5.3.5 GE Model 2000 Heat Test Description

The GE Model 2000 heat tests were conducted outside, using a test structure only partially enclosed by plywood. In addition, tests were conducted over an extended time period, during which the ambient temperature varied by over 20°F. Consequently, test convective values could not be accurately identified. However, thermal conduction values can be evaluated without accurate convection properties, by matching test and analytical temperature patterns. To this end, approximate ambient temperature and convection values were applied in the analysis of the test event. While the approximate convection properties produced the consistently low temperature correlation, the calculated temperature patterns correlated well with test results validating the model.

The AOS-165A prototype test was performed under a more-controlled environment, and the correlation between analytical and test temperatures were very good. Accuracy of the LIBRA code is further demonstrated by the following eight (8) solutions, presented in the LIBRA program verification documentation. These problems were chosen to exercise the LIBRA program elements and features used in the AOS thermal analyses. The LIBRA input models for these problems are located on the **LIBRA** program CD, in the **Libra64** folder's **verification** sub-folder.

ver_prob.1 (Main 12, Elements 34 & 32)

Axisymmetric, steady-state heat transfer of carbon resistor, graphite core, and michanite conductor, model 1. Solution from Edwards, Denny, and Mills, *Transfer Processes*, 2nd Ed., p. 27 **[3.15]**.

```
graphite temperature = 368.8
Libra node 15 temperature = 368.5
```

ver_prob.2 (Main 12, Elements 34 & 32)

Axisymmetric, steady-state heat transfer of carbon resistor, graphite core, and michanite conductor, model 2. Solution from Edwards, Denny, and Mills, *Transfer Processes*, 2nd Ed., p. 27 **[3.15]**.

```
graphite temperature = 368.8
Libra node 39 temperature = 368.5
```

ver_prob.3 (Main 12, Elements 34 & 32)

Axisymmetric, steady-state heat transfer of carbon resistor, graphite core, and michanite conductor, model 3. Solution from Edwards, Denny, and Mills, *Transfer Processes*, 2nd Ed., p. 27 **[3.15]**.

```
graphite temperature = 368.8
Libra node 39 temperature = 368.5
```

ver_prob.4 (Main 12, Elements 34 & 32)

Axisymmetric, steady-state heat transfer of carbon resistor, graphite core, and michanite conductor, model 4. Solution from Edwards, Denny, and Mills, *Transfer Processes*, 2nd Ed., p. 27 **[3.15]**.

```
core temperature = 434.8
Libra node 6 temperature = 434.8
```

ver_prob.5 (Main 12, Elements 34 & 32)

Axisymmetric, transient heat transfer of copper wire initially at 300°F immersed in water. Solution from Kreith, *Principals of Heat Transfer*, 2nd Ed., p. 131 [3.14].

Item	Theory	Libra
time step 16 temp	173.7	175.2
time step 32 temp	127.1	128.3
time step 48 temp	110.0	110.6
time step 64 temp	103.7	104.0
time step 90 temp	101.4	101.5

ver_prob.6 (Main 12, Elements 34 & 32)

Axisymmetric, transient heat transfer of copper wire initially at 300°F, immersed in air. Solution from Kreith, *Principals of Heat Transfer*, 2nd Ed., p. 131 [3.14].

Item	Theory	Libra
temperature @ time step 32	217.5	217.3
temperature @ time step 64	169.0	168.8
temperature @ time step 96	140.5	140.3
temperature @ time step 128	123.8	123.7
temperature @ time step 160	114.0	113.9

ver_prob.7 (Main 12, Elements 34 & 32)

Transient heat transfer of concrete wall initially at 100°F exposed to gas at 1,600°F. Solution from Kreith, *Principals of Heat Transfer*, 2nd Ed., p. 151 [3.14].

Item	Theory	Libra
temperature @ x/L 0.0	500.8578	500.5
temperature @ x/L 0.2	543.3878	543.1
temperature @ x/L 0.4	668.5285	668.5
temperature @ x/L 0.6	868.4861	868.7
temperature @ x/L 0.8	1129.25	1130.0
temperature @ x/L 1.0	1430.378	1431.1

ver_prob.8 (Main 12, Element 34)

Steady-state heat transfer of two-layer furnace wall. Solution from Kreith, *Principals of Heat Transfer*, 2nd Ed., p. 34 [3.14].

```
temperature @ inside surface  = 2957.0, Libra node  1 = 2957.3
temperature @ outside surface =  336.0, Libra node 50 =  335.8
```

3.5.4 Analysis Modeling Data

This appendix provides the following analysis modeling data:

- Material Properties
  - SS304 Stainless Steel Thermal Properties
  - Tungsten Alloy Thermal Properties
  - SA-105 Carbon Steel Thermal Properties
  - Air Properties
- Model Dimensions
  - Model Dimensions – Normal Conditions of Transport
  - Model Dimensions – 30-ft. Drop Deformation
  - Model Dimensions – Hypothetical Accident Conditions of Transport
  - Surface Identification
  - Sensitivity Study – Impact Limiter Geometry
- Analysis FEA Models
- Enclosed Gaps, Equivalent Conductivity
  - Enclosed Gaps – Models AOS-025A, AOS-050A, AOS-100A, and AOS-100A-S
  - Enclosed Gaps – Model AOS-100B
  - Air Gap Grashof Number Evaluation
- Surface Convective Coefficients
  - Surface Convective Coefficients, Normal Conditions of Transport, by model
  - Surface Convective Coefficients, Hypothetical Accident Conditions of Transport, by model
  - Surface Convective Coefficient Sample Calculations – Model AOS-100
- Curved Vertical Plates Used as Flat Vertical Plates, Criteria Check
- Insolation Heat Load Analysis for FR-3700 Series Foam under Condition 1 of Table 3-3
- Impact Limiter Rib Study
- Sensitivity Study – Foam Properties
  - Density
  - Specific Heat

3.5.4.1 Material Properties

Selected material properties are also provided in Appendix 2.12.5, "Selected Material Properties References."

3.5.4.1.1 SS304 Stainless Steel Thermal Properties

Table 3-78. SS304 Stainless Steel Thermal Properties

Temperature	Thermal Diffusivity, α		Specific Heat, Cp	Conductivity, K
°F	ft^2/hr	in^2/hr	Btu/lb-°F	Btu/hr-in-°F
70	0.151	21.744	0.114	0.717
100	0.152	21.888	0.114	0.725
200	0.156	22.464	0.119	0.775
300	0.160	23.040	0.122	0.817
400	0.165	23.760	0.126	0.867
500	0.170	24.480	0.128	0.908
600	0.174	25.056	0.130	0.942
700	0.179	25.776	0.132	0.983
800	0.184	26.496	0.132	1.017
900	0.189	27.216	0.134	1.058
1,000	0.194	27.936	0.136	1.100
1,100	0.198	28.512	0.137	1.133
1,200	0.203	29.232	0.138	1.167
1,300	0.208	29.952	0.139	1.208
1,400	0.212	30.528	0.140	1.242
1,500	0.216	31.104	0.141	1.275

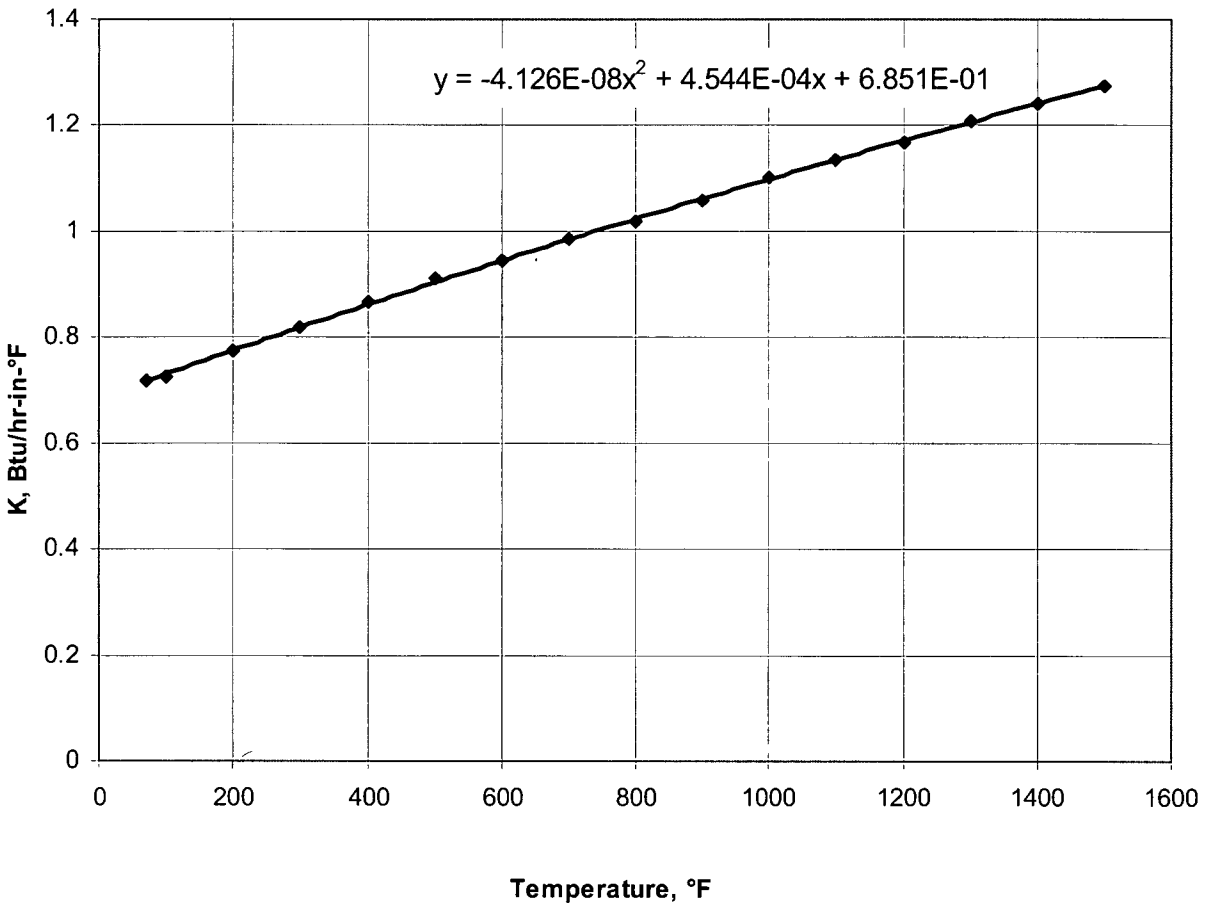

Figure 3-112. SS304 Stainless Steel Thermal Conductivity

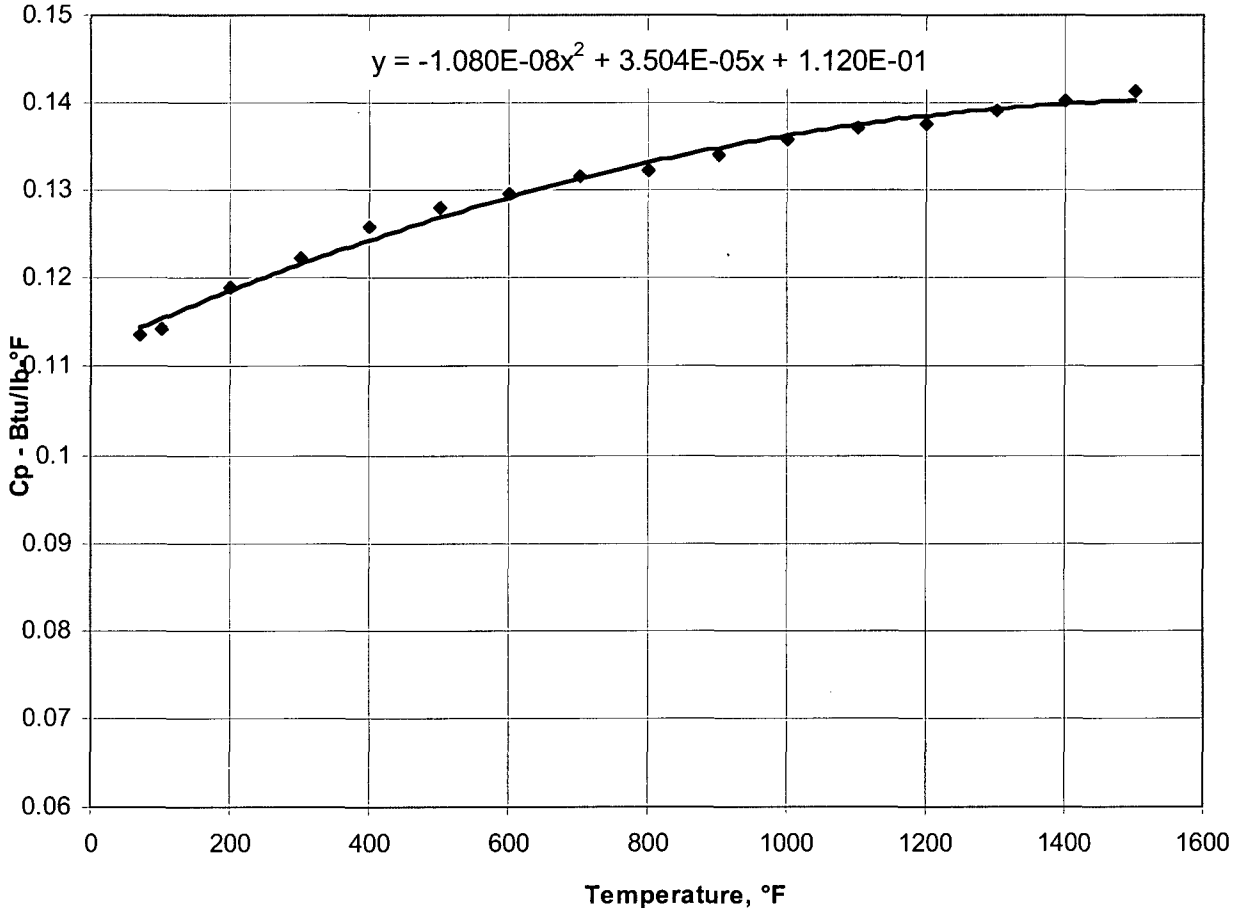

Figure 3-113. SS304 Stainless Steel Specific Heat

3.5.4.1.2 Tungsten Alloy Thermal Properties

Table 3-79. Tungsten Alloy Thermal Properties[a]

Temperature	Specific Heat, Cp	Conductivity, K	
°F	Btu/lb-°F	W/m-°K	Btu/hr-in-°F
77	0.0369	76.8	3.70
207	0.0380	77.8	3.75
403	0.0390	77.6	3.74
601	0.0407	78.8	3.79
801	0.0410	77.2	3.72

a. Density – 0.654 lb/in^3 = 1,130 lb/ft^3.

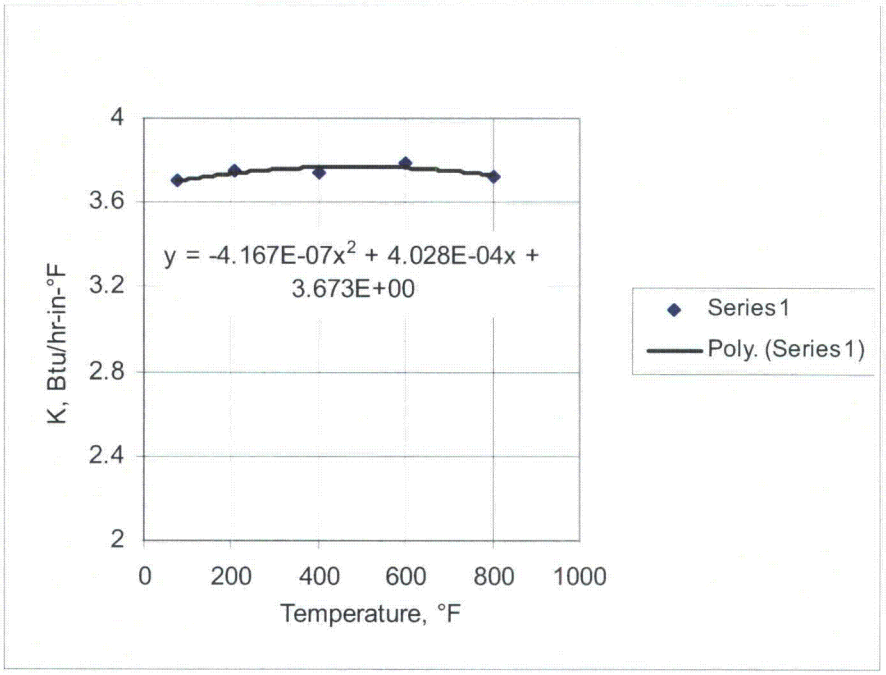

Figure 3-114. Tungsten Alloy Conductivity

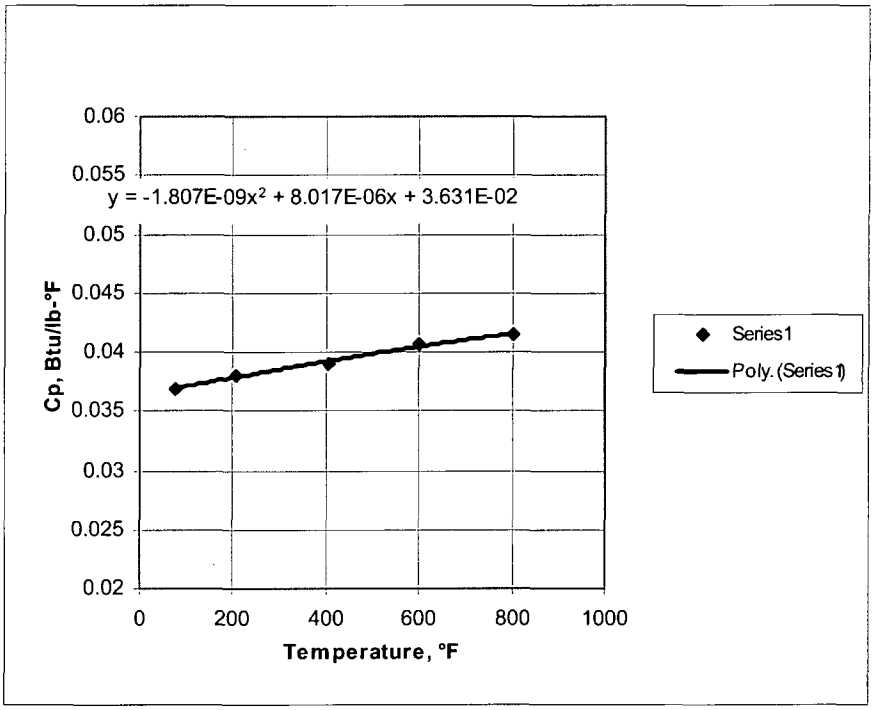

Figure 3-115. Tungsten Alloy Specific Heat

3.5.4.1.3 SA-105 Carbon Steel Thermal Properties

Table 3-80. SA-105 Carbon Steel Thermal Properties[a, b]

Temperature	Conductivity		Specific Heat
°F	Btu/hr-ft-°F	Btu/hr-in-°F	Btu/lb-°F
70	35.10	2.925	0.103
100	34.70	2.892	0.105
150	34.10	2.842	0.108
200	33.60	2.800	0.112
250	32.90	2.742	0.115
300	32.30	2.692	0.118
400	30.90	2.575	0.123
500	29.50	2.458	0.128
600	28.00	2.333	0.132
650	27.30	2.275	0.135
700	26.60	2.217	0.138
750	25.90	2.158	0.142
800	25.20	2.100	0.145
850	24.50	2.042	0.150
900	23.80	1.983	0.154

a. *Density – 0.283 lb/in^3 = 489.0 lb/ft^3.*

b. *Reference – 2001 ASME BPV Code, Section II, Part D (Reference [3.16]).*

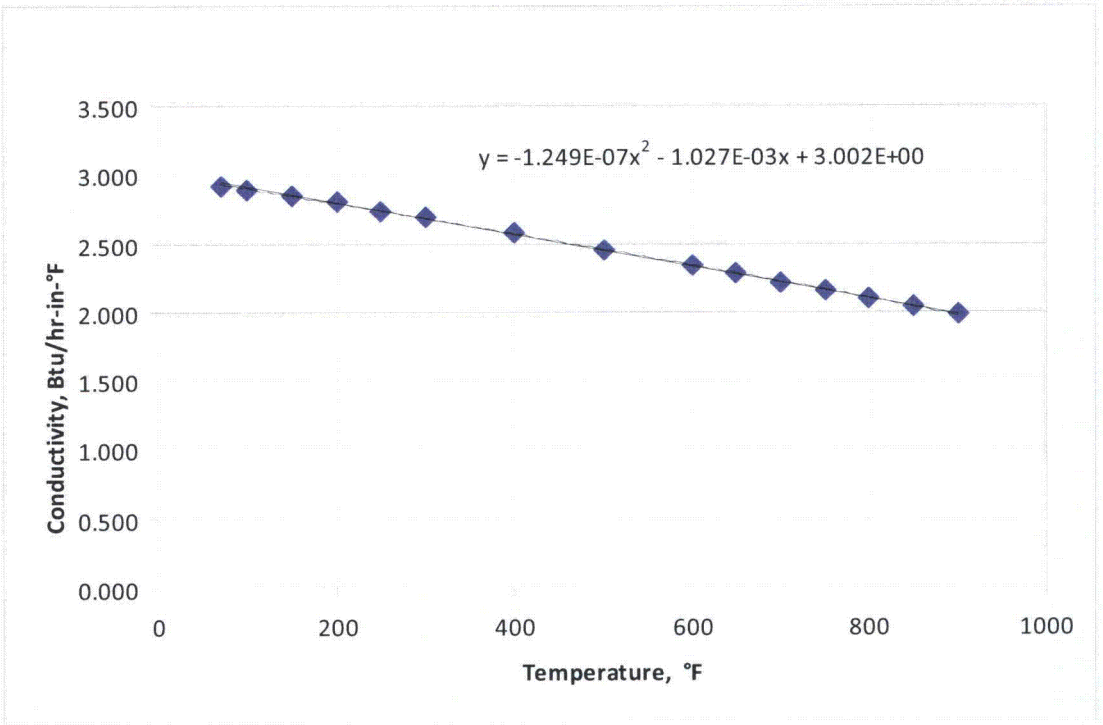

Figure 3-116. SA-105 Carbon Steel Conductivity

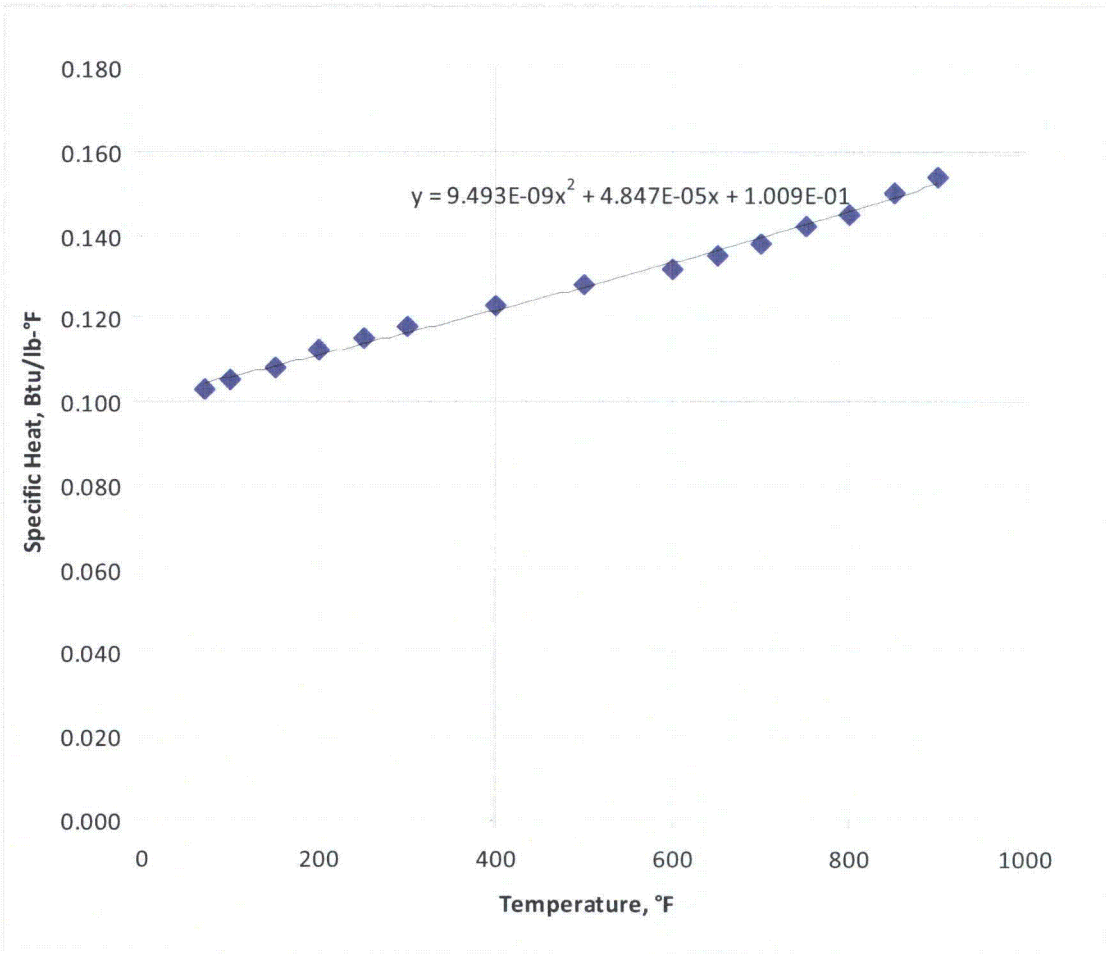

Figure 3-117. SA-105 Carbon Steel Specific Heat

3.5.4.1.4 Air Properties

Table 3-81. Air Properties

Temperature (°F)	Rho (lb/in^3)	Cp (Btu/lb-°F)	Mu (lb/hr-in)	Nu (in^2/hr)	K (Btu/hr-in-°F)	Alpha (in^2/hr)	Pr
-99.67	6.30731E-05	0.24051	2.671E-03	4.235E+01	8.715E-04	5.747E+01	0.737
-9.67	5.03884E-05	0.24027	3.218E-03	6.384E+01	1.074E-03	8.872E+01	0.720
80.33	4.19596E-05	0.24051	3.722E-03	8.867E+01	1.266E-03	1.256E+02	0.707
170.33	3.59478E-05	0.24099	4.197E-03	1.167E+02	1.445E-03	1.668E+02	0.700
260.33	3.14715E-05	0.24218	4.639E-03	1.474E+02	1.627E-03	2.137E+02	0.690
350.33	2.79634E-05	0.24386	5.054E-03	1.807E+02	1.796E-03	2.634E+02	0.686
440.33	2.51599E-05	0.24601	5.445E-03	2.164E+02	1.960E-03	3.164E+02	0.684
530.33	2.28657E-05	0.24839	5.814E-03	2.543E+02	2.114E-03	3.722E+02	0.683
620.33	2.09690E-05	0.25102	6.165E-03	2.940E+02	2.258E-03	4.291E+02	0.685
710.33	1.93504E-05	0.25389	6.502E-03	3.360E+02	2.393E-03	4.871E+02	0.690
800.33	1.79739E-05	0.25675	6.830E-03	3.800E+02	2.523E-03	5.468E+02	0.695
890.33	1.67744E-05	0.25962	7.149E-03	4.261E+02	2.643E-03	6.082E+02	0.702
980.33	1.57303E-05	0.26249	7.455E-03	4.739E+02	2.759E-03	6.696E+02	0.709
1,070.33	1.48018E-05	0.26511	7.747E-03	5.234E+02	2.870E-03	7.310E+02	0.716
1,160.33	1.39745E-05	0.26774	8.026E-03	5.742E+02	2.985E-03	7.979E+02	0.720
1,250.33	1.32447E-05	0.27013	8.292E-03	6.261E+02	3.096E-03	8.649E+02	0.723
1,340.33	1.25799E-05	0.27252	8.556E-03	6.802E+02	3.212E-03	9.374E+02	0.726

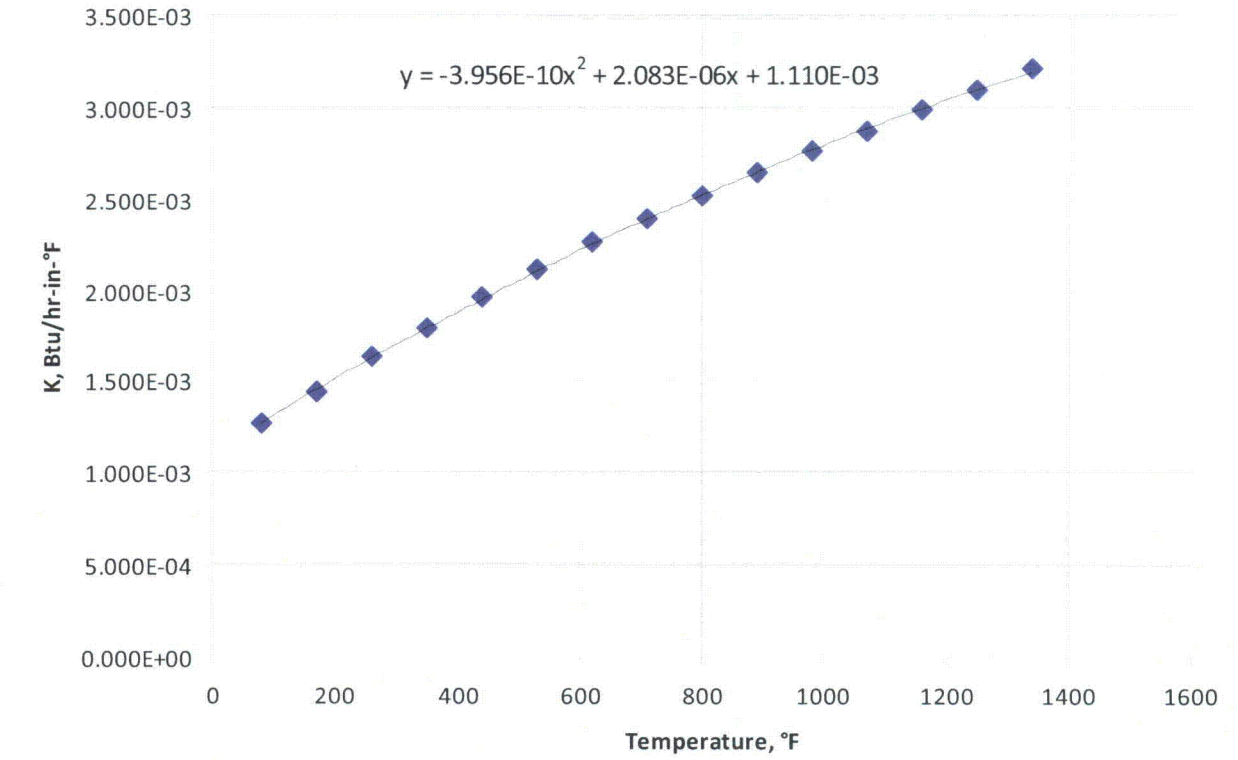

Figure 3-118. Air Conductivity

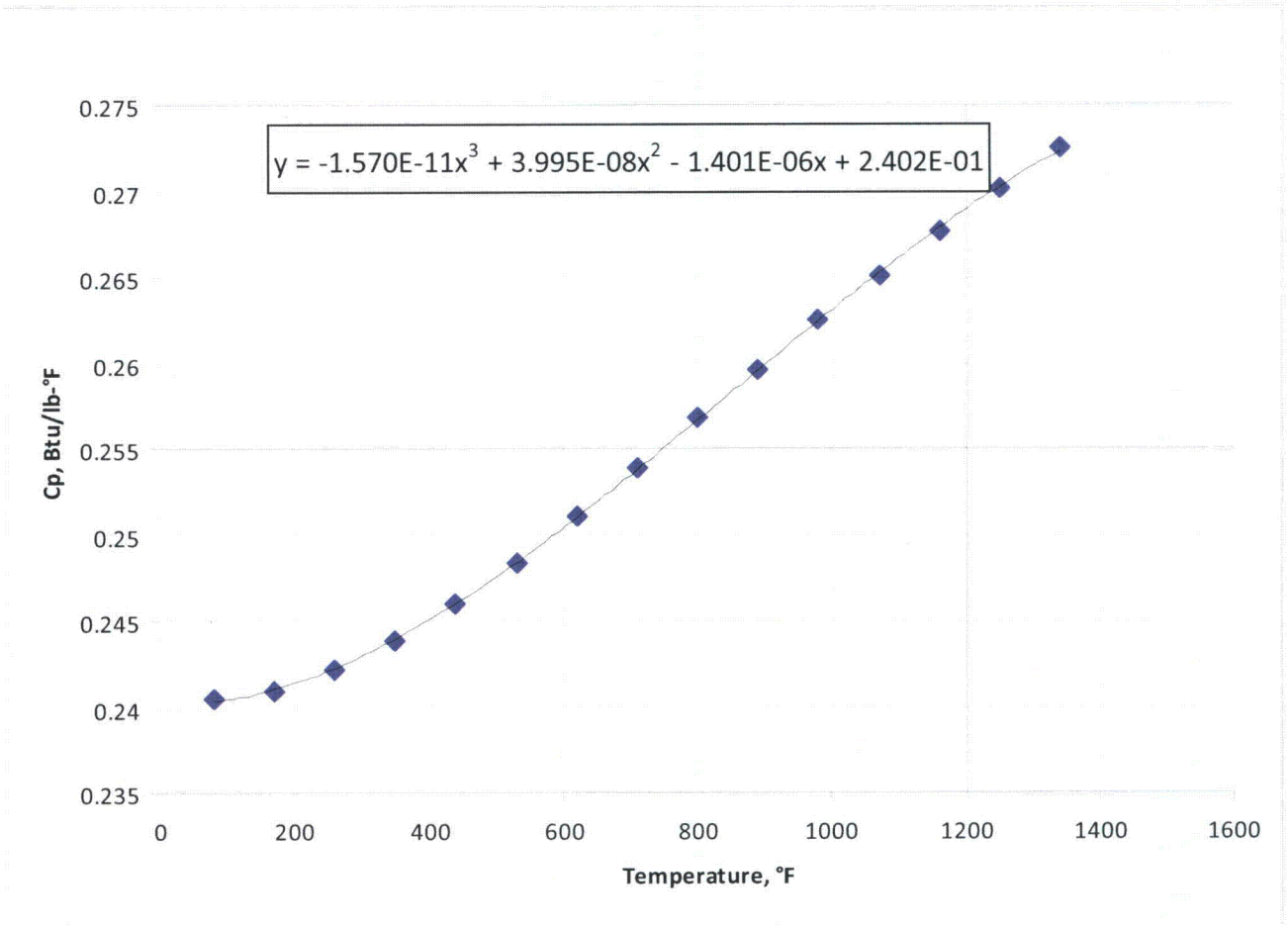

Figure 3-119. Air Specific Heat

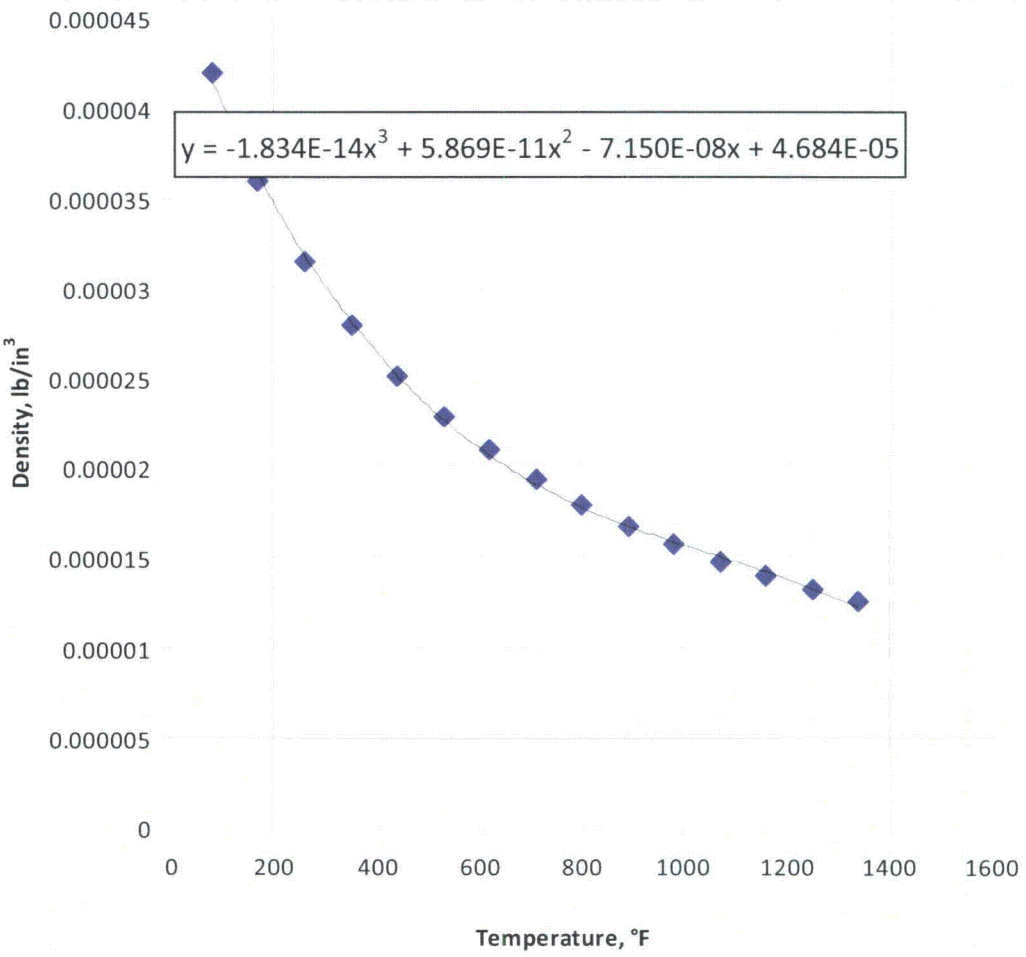

Figure 3-120. Air Density

3.5.4.2 Model Dimensions

3.5.4.2.1 Model Dimensions – Normal Conditions of Transport

Figure Withheld Under 10 CFR 2.390

Figure 3-121. Normal Conditions of Transport Model Dimensions – Model AOS-025

Note: *Dimensions are in inches.*

Figure Withheld Under 10 CFR 2.390

Figure 3-122. Normal Conditions of Transport Model Dimensions – Model AOS-050

Note: *Dimensions are in inches.*

Figure Withheld Under 10 CFR 2.390

Figure 3-123. Normal Conditions of Transport Model Dimensions – Model AOS-100

Note: *Dimensions are in inches.*

3.5.4.2.2 Model Dimensions – 30-ft. Drop Deformation

The model dimensions provided within this paragraph define the Impact Limiter Crushed geometry, and are used in the Fire and Post Fire analyses.

The geometry in the thermal evaluation for Hypothetical Accident conditions of transport used a crushed impact limiter, approximated by the 30-ft. Head-On Drop condition. Table 3-82 lists the assumed deformation used in the analysis. For the Model AOS-100, the value used is not the same as that provided in Chapter 2, "Structural Evaluation." The use of a 5.9-in. versus 6.1-in. crush can be justified by the study presented in Appendix 3.5.4.2. In this appendix, it is demonstrated that there are minimal differences in component temperatures between geometries, using an uncrushed impact limiter versus a crushed impact limiter having deformations caused by a 30-ft. Head-On Drop.

Table 3-82. Fire Condition Impact Limiter Crushed Geometry 30-Ft. Head-On Drop Analysis Results – All Models

Model	Head On (in.)
AOS-025	1.35
AOS-050	3.40
AOS-100	5.9

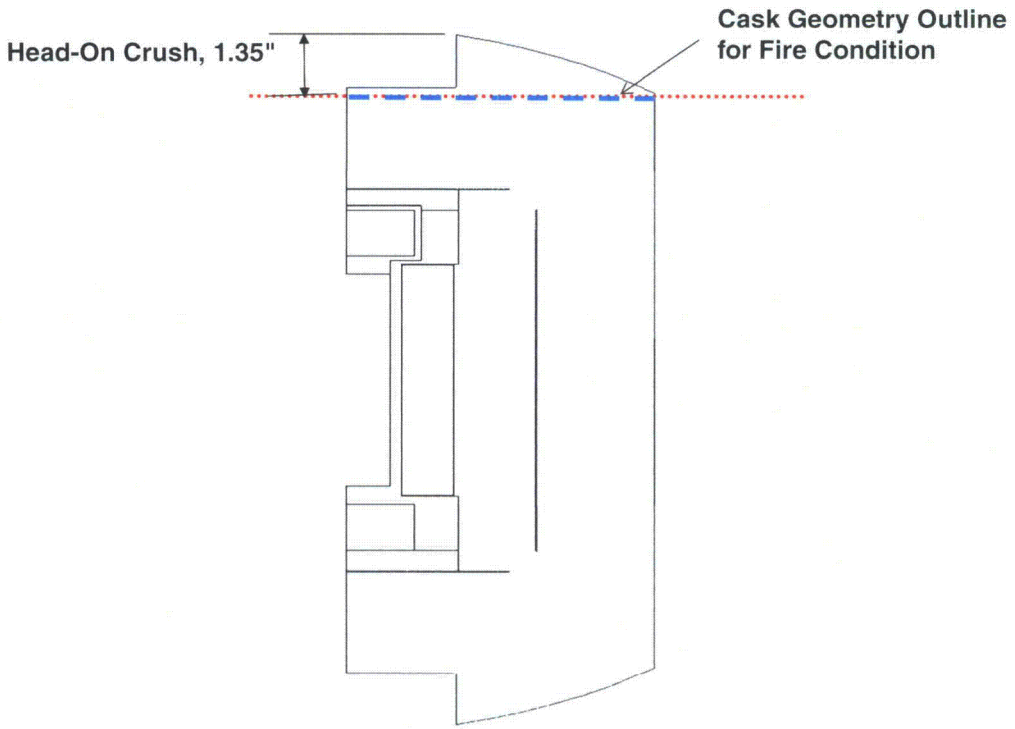

Figure 3-124. Applied 30-ft. Drop Deformations – Model AOS-025

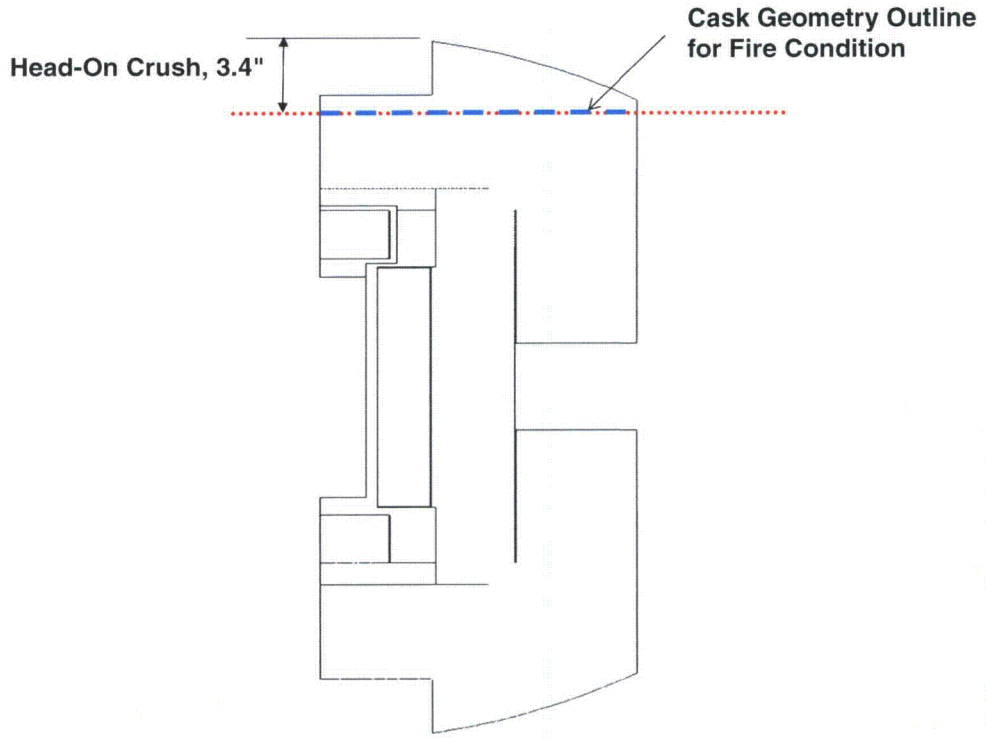

Figure 3-125. Applied 30-ft. Drop Deformations – Model AOS-050

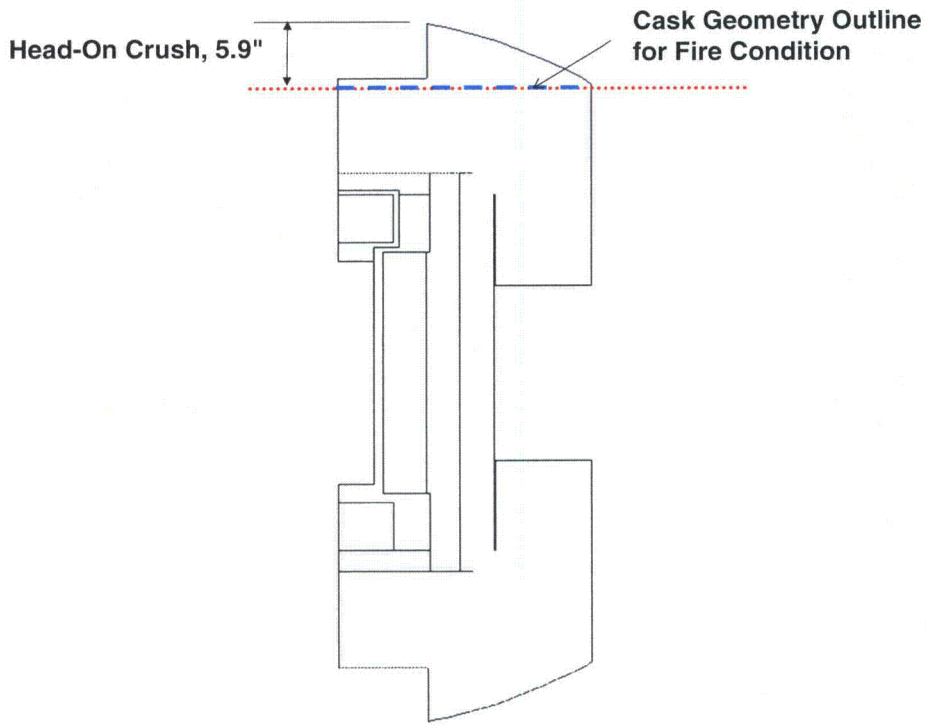

Figure 3-126. Applied 30-ft. Drop Deformations – Model AOS-100

3.5.4.2.3 Model Dimensions – Hypothetical Accident Conditions of Transport

Figure Withheld Under 10 CFR 2.390

Figure 3-127. Hypothetical Accident Conditions of Transport Model Dimensions – Model AOS-025

Note: *Dimensions are in inches.*

Figure Withheld Under 10 CFR 2.390

Figure 3-128. Hypothetical Accident Conditions of Transport Model Dimensions – Model AOS-050

Note: *Dimensions are in inches.*

Figure Withheld Under 10 CFR 2.390

Figure 3-129. Hypothetical Accident Conditions of Transport Model Dimensions – Model AOS-100

Note: *Dimensions are in inches.*

3.5.4.2.4 Surface Identification

3.5.4.2.4.1 Surface Identification – Normal Conditions of Transport

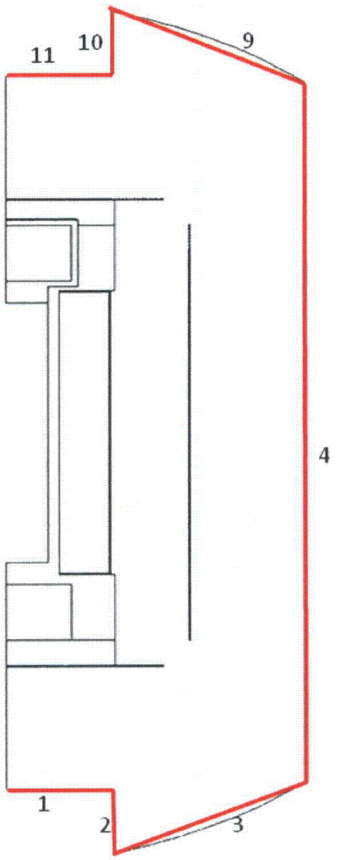

Figure 3-130. Cask Assembly External Surface Identification, Normal Conditions of Transport – Model AOS-025

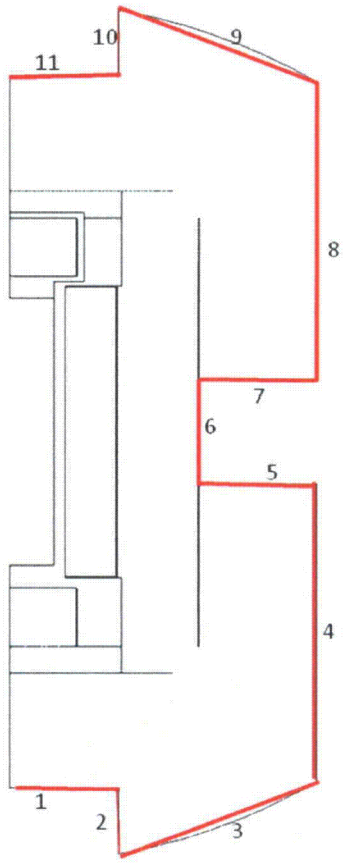

Figure 3-131. Cask Assembly External Surface Identification, Normal Conditions of Transport – Model AOS-050

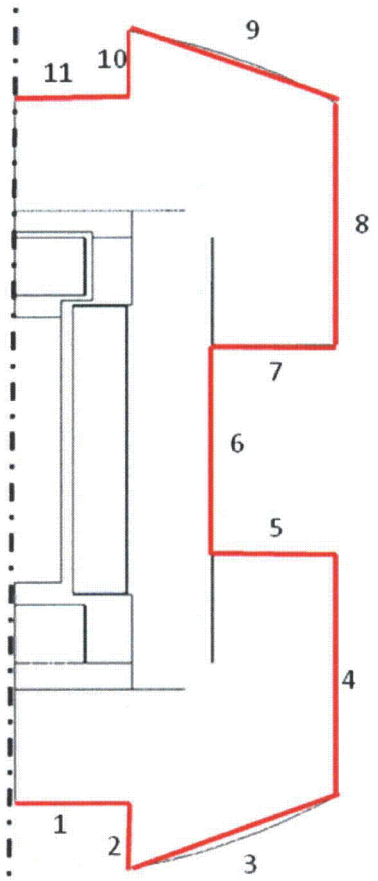

Figure 3-132. Cask Assembly External Surface Identification, Normal Conditions of Transport – Model AOS-100

3.5.4.2.4.2 Surface Identification – Hypothetical Accident Conditions of Transport

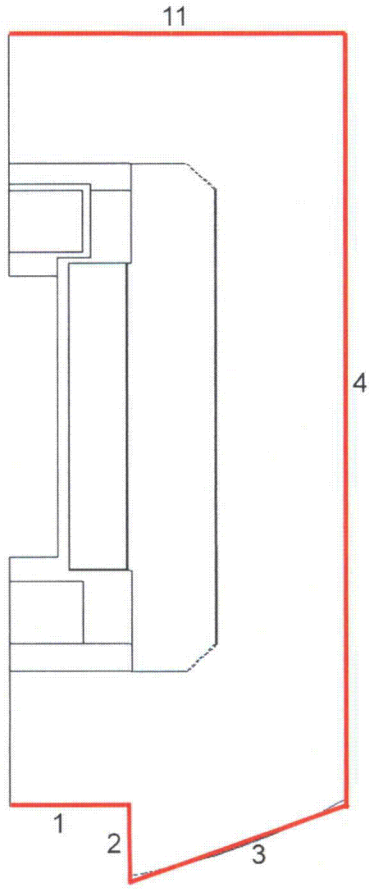

Figure 3-133. Cask Assembly External Surface Identification, Hypothetical Accident Conditions of Transport – Model AOS-025

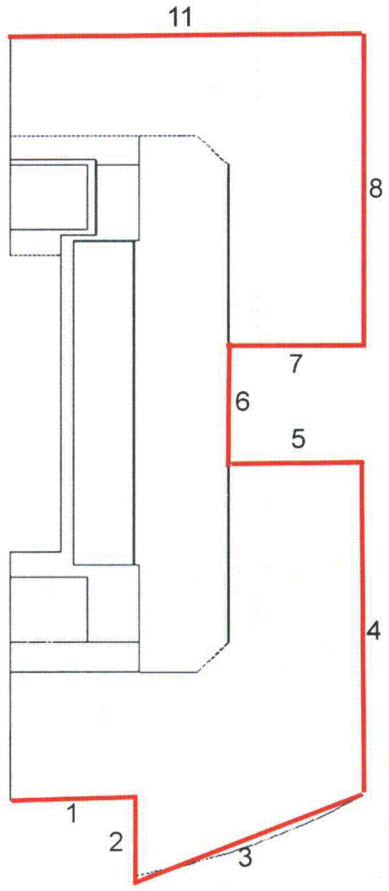

Figure 3-134. Cask Assembly External Surface Identification, Hypothetical Accident Conditions of Transport – Model AOS-050

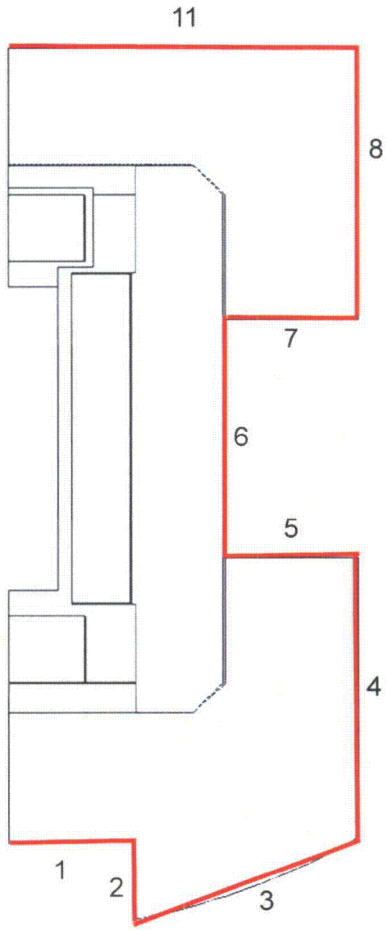

Figure 3-135. Cask Assembly External Surface Identification, Hypothetical Accident Conditions of Transport – Model AOS-100

3.5.4.2.5 Sensitivity Study – Impact Limiter Geometry

This analysis evaluates the 30-minute fire with the post-fire cool-down transient, and compares the results for three (3) different impact limiter crush configurations (refer to Table 3-83):

- Configuration 1 has an upper impact limiter crush equal to 100% of the predicted crush as a result of a 30-ft. head-on drop. The lower impact limiter remains uncrushed. This is the configuration used in the SAR for Hypothetical Accident conditions of transport, and is discussed in Section 3.4.
- Configuration 2 has no crush deformations.
- Configuration 3 contains full value deformations from all three (3) 30-ft. directional drops, applied simultaneously.

The Model AOS-100A transport package is used for this study. Figure 3-136, Figure 3-137, and Figure 3-138 illustrate the Model AOS-100A FEA models for Configurations 1, 2, and 3, respectively. This analysis assumes that the Model AOS-100A is in a horizontal position.

The foam density increases as the impact limiter is crushed. For this study, foam density is assumed to vary linearly with changes in volume, and the total impact limiter weight remains the same. The uncrushed foam density, as used in Configuration 2, is 12 pcf. (Refer to Table 3-84.)

Maximum component temperature results show that temperatures are the highest for Configuration 2, the uncrushed geometry. The temperature differences between Configurations 1 and 2 are small – the maximum difference between any component is 1°F. Table 3-85 lists the comparative results between the Configuration 1 and 2 maximum component temperatures for the 30-minute fire transient. Table 3-86 lists the comparative results between the Configuration 1 and 2 maximum component temperatures for the 7.5-hour cool-down transient.

Maximum component temperatures are the lowest in Configuration 3. At the end of 30 minutes, there is a difference of 12°F at the cask vent port between Configurations 1 and 3. Temperature differences at all other components are approximately 6 to 8°F. Table 3-87 lists the comparative results between the Configuration 1 and 3 maximum component temperatures for the 30-minute fire transient. Table 3-88 lists the comparative results between the Configuration 1 and 3 maximum component temperatures for the 7.5-hour cool-down transient.

Table 3-83. 30-Ft. Drop Deformations – Model AOS-100A

Configuration	Head-On (in.)	Side (in.)	Cg/Corner (in.)
1	5.9	0.0	0.0
2	0.0	0.0	0.0
3	5.9	5.45	10.7

Table 3-84. Impact Limiter Foam Properties – Model AOS-100A[a]

Configuration	Upper Impact Limiter		Lower Impact Limiter	
	Density (pcf)	Conductivity (Btu/hr-in-°F)	Density (pcf)	Conductivity (Btu/hr-in-°F)
1	14.6	0.00192	12	0.00167
2	12	0.00167	12	0.00167
3	50	0.00572	24	0.00251

a. Specific heat = 0.353 Btu/lb-°F.

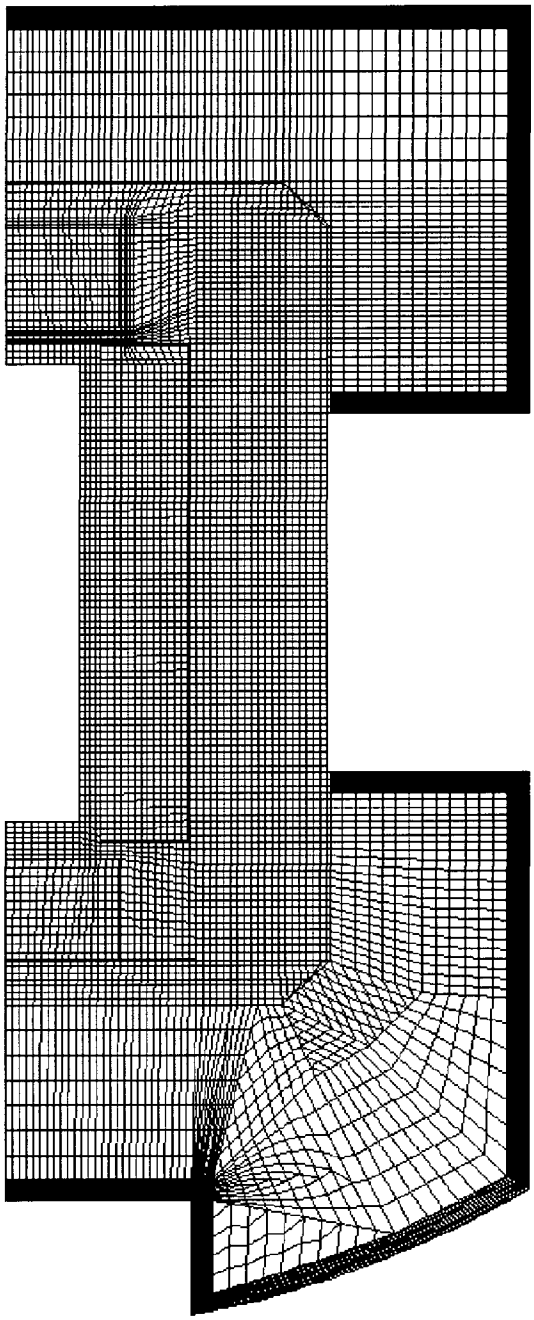

Figure 3-136. Configuration 1, Impact Limiters with 30-Ft. Head-On Drop Deformation – Model AOS-100A FEA Model