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		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
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FEB 21 1995 43

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ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT

610253

2. To: (Receiving Organization) FFTF Engineering	3. From: (Originating Organization) Thermal Hydraulic Analysis	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: FFTF/71120	6. Cog. Engr.: J. J. Irwin	7. Purchase Order No.: N/A
8. Originator Remarks: This document is a compilation of thermal evaluations that were performed to support the evaluation of the FFTF Vertical Sodium Storage Tank.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks:		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Impact Level	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-FF-ER-102	1	0	FFTF VERTICAL SODIUM STORAGE TANK PRELIMINARY THERMAL ANALYSIS	NA	1/2	/	/

16. KEY			
Impact Level (F)	Reason for Transmittal (G)		Disposition (H) & (I)
1, 2, 3, or 4 (see MRP 5.43)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

(G)	(H)	17. SIGNATURE/DISTRIBUTION (See Impact Level for required signatures)								(G)	(H)
Reason	Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	Reason	Disp.
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18. J. J. Irwin <i>J. J. Irwin</i> 1/24/95 Signature of EDT Originator	19. C. G. McCann <i>C. G. McCann</i> 2/10/95 Authorized Representative for Receiving Organization	20. T. B. McCann <i>T. B. McCann</i> 1/25/95 Cognizant/Project Engineer's Manager	21. DOE APPROVAL (if required) Ltr. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
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BD-7400-172-2 (07/89) (EF) GEF097

BD-7400-172-1

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Document Number: WHC-SD-FF-ER-102, REV. 0

Document Title: FFTF VERTICAL SODIUM STORAGE TANK PRELIMINARY
THERMAL ANALYSIS

Release Date: 2/17/95

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SUPPORTING DOCUMENT		1. Total Pages 26
2. Title FFTF Vertical Sodium Storage Tank Preliminary Thermal Analysis	3. Number WHC-SD-FF-ER-102	4. Rev No. 0
5. Key Words Thermal characteristics, storage tank, thermal analysis, FFTF Sodium Storage Facility	6. Author Name: J. J. Irwin <i>J. J. Irwin</i> Signature Organization/Charge Code 71410/B194N	
7. Abstract This report provides a thermal analysis evaluation of the FFTF Vertical Storage Tank within the FFTF Sodium Storage Facility as compared to the applicable requirements of the Specification for the FFTF Storage Facility for normal operating conditions.		
		8. RELEASE STAMP OFFICIAL RELEASE 43 BY WHC DATE FEB 21 1995 <i>Stall</i>

FFTF VERTICAL STORAGE TANK
PRELIMINARY THERMAL ANALYSIS

January 1995

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RICHLAND OPERATIONS OFFICE
RICHLAND, WASHINGTON

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Table of Contents

1.0 INTRODUCTION	1
2.0 SUMMARY OF RESULTS	1
3.0 DESCRIPTION OF THE VERTICAL FFTF VERTICAL STORAGE TANK DESIGN . . .	5
4.0 THERMAL MODEL DESCRIPTION	8
4.1 HEAT TRANSFER COMPUTER CODE DESCRIPTION	9
4.2 GENERAL MODELING TECHNIQUES	9
4.3 SUMMARY OF THERMAL PROPERTIES OF MATERIALS	10
4.4 Ambient Air Temperature	14
4.5 Ground Temperature	15
4.6 NATURAL CONVECTION	15
4.7 HEAT LOAD	16
4.8 Thermal Radiation Boundary Conditions	16
4.9 THERMAL MODEL CASE DESCRIPTIONS	16
5.0 ANALYSIS RESULTS	17
5.1 MAXIMUM TEMPERATURES - NORMAL OPERATING CONDITION	17
5.2 RECOMMENDATIONS	18
6.0 REFERENCES	22

Figures

1. Thermal Transient for FFTF Vertical Storage Tank with Calcium Silicate Insulation	3
2. Thermal Transient for FFTF Vertical Storage Tank with Refractory Fiber Insulation	4
3. Thermal Model of the FFTF Vertical Storage Tank Design	7
4. FFTF Vertical Storage Tank Steady-State Temperature vs Heater Power with Refractory Fiber Insulation	20
5. FFTF Vertical Storage Tank Steady-State Temperature vs Heater Power with Calcium Silicate Insulation	21

Tables

1. Expected Heat up Times And Temperatures for FFTF Vertical Storage Tank Designs	5
2. Material Properties of Nitrogen at 1 atm	11
3. Material Properties of Air at 1 atm.	11
4. Material Properties of Type 515 Carbon Steel	12
5. Material Properties of Sodium	12
6. Material Properties of Calcium Silicate	13
7. Material Properties of Refractory Fiber	13
8. Material Properties of Magnesium Oxide	14
9. Material Properties of Reinforced Concrete	14

FFTF VERTICAL STORAGE TANK PRELIMINARY THERMAL ANALYSIS

1.0 INTRODUCTION

In the FFTF Shutdown Program, sodium from the primary and secondary heat transport loops, Interim Decay Storage (IDS), and Fuel Storage Facility (FSF) will be transferred to four large storage tanks for temporary storage. Three of the storage tanks will be cylindrical vertical tanks having a diameter of 28 feet, height of 22 feet and fabricated from carbon steel. The fourth tank is a horizontal cylindrical tank but is not the subject of this report. The storage tanks will be located near the FFTF in the 400 Area and rest on a steel-lined concrete slab in an enclosed building.

The purpose of this work is to document the thermal analyses that were performed to ensure that the vertical FFTF sodium storage tank design is feasible from a thermal standpoint. The key criterion for this analysis is the time to heat up the storage tank containing frozen sodium at ambient temperature to 400 °F. Normal operating conditions include an ambient temperature range of 32 °F to 120 °F.

A key parameter in the evaluation of the sodium storage tank is the type of insulation. The baseline case assumed six inches of calcium silicate insulation. An alternate case assumed refractory fiber (Cerablanket) insulation also with a thickness of six inches. Both cases assumed a total electrical trace heat load of 60 kW, with 24 kW evenly distributed on the bottom head and 36 kW evenly distributed on the tank side wall.

2.0 SUMMARY OF RESULTS

The most important results derived from the thermal analysis for the baseline configuration (as depicted in Figure 1 and 2) include the following (these results are also summarized in Table 1):

- The calcium-silicate-insulated storage tank requires a 25.6 day period to heat up to 400 °F from an initial temperature of 32 °F. The average heat up rate was determined to be 15.7 °F/day.
- The refractory-fiber-insulated storage tank requires a 23.7 day period to heat up to 400 °F from an initial temperature of 32 °F. The average heat up rate was determined to be 17.3 °F/day.
- The maximum steady-state sodium temperature for the calcium-silicate-insulated storage tank was determined to be 767 °F with 60 kW heater power. The maximum concrete temperature below the tank was determined to be 63 °F for the same conditions.
- The maximum steady-state sodium temperature for the refractory-fiber-insulated storage tank was determined to be 920 °F with 60 kW heater power. The maximum concrete temperature below the tank was determined to be 65 °F for the same conditions.

- 19 kW of heater power is required to maintain a 400 °F sodium temperature in the storage tank while insulated with 6 inches calcium silicate insulation and with an ambient temperature of 120 °F. The maximum concrete temperature was determined to be 114 °F for the same conditions.
- 14 kW of heater power is required to maintain a 400 °F sodium temperature with the storage tank insulated with 6 inches of refractory fiber and with an ambient temperature of 120 °F. The maximum concrete temperature below the tank was determined to be 112 °F for the same conditions.

Figure 1. Thermal Transient for FFTF Vertical Storage Tank
with Calcium Silicate Insulation.

Figure 2. Thermal Transient for FFTF Vertical Storage Tank
with Refractory Fiber Insulation.

Table 1. Expected Heat up Times And Temperatures for FFTF Vertical Storage Tank Designs.

Case Number	Case Description	Time to 400 °F	Sodium Temperature °F	Support Steel Temperature ⁽²⁾ °F
1	31 day Transient, Cal. Sil. Insulation	25.6 d	472 ⁽¹⁾	54
2	31 day Transient, Ref. Fiber Insulation	23.7	518 ⁽¹⁾	54
3	Steady-State, 32 ° Amb. Cal. Sil. Insulation	NA	767	63
4	Steady-State, 32 ° Amb. Ref. Fiber Insulation	NA	920	65
5	Steady-State, 120 °F Amb., 30 kW, Ref. Fiber Insulation	NA	629	119
6	Steady-State, 120 °F Amb., 15 kW, Ref. Fiber Insulation	NA	416	113
7	Steady-State, 120 °F Amb., 12 kW, Ref. Fiber Insulation	NA	364	111
8	Steady-State, 120 °F Amb., 30 kW, Calcium Silicate Insulation	NA	524	118
9	Steady-State, 120 °F Amb., 18 kW, Calcium Silicate Insulation	NA	383	113
10	Steady-State, 120 °F Amb., 12 kW, Calcium Silicate Insulation	NA	302	110

- (1) Temperatures at the end of the 31 day transient or ultimate temperature for steady state cases.
(2) Temperature for support skirt at the floor location.

3.0 DESCRIPTION OF THE VERTICAL FFTF VERTICAL STORAGE TANK DESIGN

The vertical FFTF sodium storage tank has been designed to contain up to 80,000 gallons of sodium. The principal physical characteristics of the sodium storage tank consists of a right circular cylindrical tank with ellipsoidal heads and supported by a skirt attached to the tank at the lower head. The outer surface of the tank is covered with six inches of insulation. There is an air gap between the tank wall and the insulation. The air gap will contain trace heaters that will be utilized to heat up frozen sodium to a 400 °F operating temperature. The trace heaters are installed on the bottom head and the vertical side wall of the tank. The top head is not trace heated. The inside diameter of the tank is 336 inches and is 264 inches in

overall inside height. The skirt extends an additional 31 inches below the bottom head. The top head and side of the tank are 1 inch thick, while the bottom head is 1.125 inches thick. The skirt is 1 inch thick. The skirt is insulated on its inside and outside surface with 6 inches of insulation down to within 20 inches of the floor surface. A simplified depiction of the baseline FFTF sodium storage tank is shown in Figure 3.

The sodium storage tank will contain approximately 73,900 gallons of sodium, filling the tank to 219.5 inches. There will be a nitrogen cover gas above the sodium surface within the tank. The tank shell and skirt are fabricated from type SA-515 mild carbon steel. The insulations modelled in the analyses were either Calcium Silicate foam blocks or Refractory Fiber batting (Cerablanket). Both insulations have previously been used at the FFTF. The trace heaters are mineral insulated cable type heaters with magnesium oxide insulation within a incoloy sheath, the heating element is helical wound incoloy centered within the cable.

The storage tanks will be installed into a newly constructed facility near the FFTF in the 400 area. The tanks will be installed onto a steel-lined reinforced concrete slab floor. The sodium storage tank is further described in WHC 1994a.

Figure 3. Thermal Model of the FFTF Vertical Storage Tank Design.

The principal operating features of the FFTF sodium storage tank for thermal analysis, for normal operating conditions, are as follows:

- a. The trace heat power contained exterior to the tank walls is transferred by thermal radiation and gas conduction through an air gap between the steel tank walls and the inner surface of the insulation.
- b. The trace heat is then transferred by thermal conduction through the tank walls to the sodium contained in the tank.
- c. A portion of the trace heat is additionally transferred by conduction through the insulation and rejected to the ambient environment.
- d. The trace heat is transferred within the sodium and is rejected by thermal radiation and gas conduction at the sodium upper surface through the nitrogen cover gas to the top portion of the tank.
- e. The outer surface of the tank dissipates the heat to the ambient environment by combined thermal radiation and convection heat transfer. The ambient temperature is assumed to remain constant at 32 °F or 120 °F. The outer surface temperature limit is specified at 140 °F (WHC 1994a).
- f. A portion of the trace heat is conducted through the skirt support structure of the tank to the concrete floor slab. The soil three feet below the concrete surface is held at a constant temperature of 59.5 °F as specified in PNL 1982.
- h. The FFTF sodium storage tanks are stored within an enclosed structure, therefore the tanks will absorb no incident solar energy and there will be no forced convective cooling (only natural convection) due to ambient conditions.

4.0 THERMAL MODEL DESCRIPTION

Common thermal analysis models were used for all transient and steady-state evaluations of the normal conditions of operations. All of the models used for the thermal analysis were developed using the PATRAN/PTHERMAL finite element code (PDA 1991).

A thermal analysis of the final configuration of the vertical FFTF sodium storage tank with a nitrogen cover gas is described. The thermal model utilized a longitudinal axisymmetric segment of the sodium storage tank i.e., the circumferential conduction effects were ignored. The thermal model coincided with the vertical midplane of the tank.

Configurations from WHC 1994a were utilized in developing the physical model of the storage tank. The tank was assumed to contain sodium up to an elevation of 219.5 inches above tank inside bottom. A nitrogen cover gas was assumed to fill the remainder of the tank. The latent heat of fusion for

sodium (ORNL 1972) was assumed in the model, the effect for the phase change was assumed to occur over a temperature range of 208 to 209 °F. Thermal conduction and convection with temperature dependent properties were modelled. Thermal radiation effects with constant thermal emissivity values were utilized.

Both transient and steady state analyses were performed utilizing the PATRAN/PTHERMAL and PATRAN/PVIEWFACTOR finite element computer codes (PDA 1991). A cross sectional depiction of the sodium storage tank, that formed the basis for the analysis, is shown in Figure 3.

4.1 HEAT TRANSFER COMPUTER CODE DESCRIPTION

The PATRAN/PTHERMAL computer code solves transient or steady-state temperature distributions using a finite difference method of solution. Multi-dimensional configurations can be analyzed using a combination of coordinates. Computations are performed with provisions for temperature-dependent material properties employing conduction, thermal radiation, and convection. Boundary conditions may be time-dependent temperatures or heat fluxes. Convection may be based upon local time dependent or variable temperature difference heat transfer coefficients. The PATRAN/PVIEWFACTOR computer code solves for the thermal radiation view factors of arbitrary surfaces.

The codes have been used extensively at Hanford and have completed the software quality assurance requirements for Impact Level 2 QA applications (WHC, 1991). Configuration control requirements, as outlined in the QA Manual WHC-CM-4-2, Section QI 3.3 Rev. 1, have been met and the study complies with the engineering practice EP-2.1, Rev. 2 computer Software Configuration Management.

4.2 GENERAL MODELING TECHNIQUES

Three modes of energy transfer were used in the analysis:

- 1) Conduction heat transfer within the materials of the storage tank and the concrete support pad.
- 2) Thermal radiation including:
 - a) heat transfer from external surfaces to the environment
 - b) heat transfer across internal air gap surfaces
 - c) heat transfer across internal cover gas surfaces.
- 3) Natural convection from the external surfaces of the tank and concrete support pad to still air in the environment.

The heat from the trace heat system was modeled as internal heat generation.

4.3 SUMMARY OF THERMAL PROPERTIES OF MATERIALS

Thermal material properties used for analyses were taken from WHC, 1994b. These properties are listed in Tables 2 through 9. Quadratic interpolation and linear extrapolation techniques were used to evaluate properties at temperatures not explicitly defined in the tables.

Table 2. Material Properties of Nitrogen at 1 atm.

Temperature (°F)	Thermal Conductivity (BTU/Hr-Ft-°F)	Thermal Conductivity (Btu/Sec-Inch-°F)	Specific Heat (Btu/Lbm-°F)
-100	0.01076	0.000000249	0.248
32	0.01387	0.000000321	0.248
212	0.01806	0.000000418	0.249
392	0.02195	0.000000508	0.251
572	0.02553	0.000000591	0.255
752	0.02795	0.000000647	0.260
1000	0.03300	0.000000764	0.269
1500	0.04230	0.000000979	0.284

Density of 0.078 Lbm/ft³ or 0.000045 (lbm/in³) at STP,
Data from Bailey (1987) and WHC 1994b.

Table 3. Material Properties of Air at 1 atm.

Temperature (°F)	Thermal Conductivity (BTU/Hr-Ft-°F)	Thermal Conductivity (BTU/Sec-Inch-°F)	Specific Heat (BTU/Lbm-°F)
-110	0.0118	0.000000273	0.2393
40	0.0143	0.000000331	0.2396
90	0.0156	0.000000361	0.2399
240	0.0191	0.000000442	0.2416
440	0.0237	0.000000549	0.2458
640	0.0280	0.000000648	0.2516
840	0.0320	0.000000741	0.2579
1040	0.0370	0.000000856	0.2642
1240	0.0410	0.000000949	0.2698
1440	0.0450	0.000001042	0.2750
1640	0.0480	0.000001111	0.2794

Density of 0.0812 lbm/cu. ft. or 0.000047 lbm/in³ at STP,
Data from WHC 1994b.

Table 4. Material Properties of Type 515 Carbon Steel.

Temperature (°F)	Thermal Conductivity (BTU/Hr-Ft-°F)	Thermal Conductivity (BTU/Sec-Inch-°F)	Specific Heat (BTU/Lbm-°F)
70	29.891	0.000692	0.09852
100	29.762	0.000689	0.10261
200	29.221	0.000676	0.11354
300	28.524	0.000660	0.12110
400	27.694	0.000641	0.12627
500	26.750	0.000619	0.13003
600	25.716	0.000595	0.13337

Density of 490 lbm/cu. ft. or 0.284 lbm/in³,
Thermal emissivity of 0.8,
Data from ORNL 1987.

Table 5. Material Properties of Sodium.

Temperature (°F)	Thermal Conductivity (BTU/Hr-Ft-°F)	Thermal Conductivity (Btu/Sec-Inch-°F)	Specific Heat (Btu/Lbm-°F)
32	78.98	0.001828	0.2865
100	75.34	0.001744	0.2959
150	72.66	0.001682	0.3074
200	69.98	0.001620	0.3229
208	50.49	0.001169	0.3307
250	49.74	0.001151	0.3281
300	48.86	0.001131	0.3250
350	47.99	0.001111	0.3222
400	47.13	0.001091	0.3195
450	46.28	0.001071	0.3170
500	45.44	0.001052	0.3146

Density of Solid 60.22 lbm/cu. ft. (100°F) or 0.03485 lbm/in³,
Density of Liquid 57.56 lbm/cu. ft. (250°F) or 0.03331 lbm/in³,
Thermal emissivity of 0.9 for Solid & 0.2 for Liquid,
Heat of Fusion 48.69 Btu/lbm at 208°F,
Data from ORNL 1987.

Table 6. Material Properties of Calcium Silicate.

Temperature (°F)	Thermal Conductivity (BTU/Hr-Ft-°F)	Thermal Conductivity (Btu/Sec-Inch-°F)	Specific Heat (Btu/Lbm-°F)
32	0.03215	0.000000744	0.23
100	0.03419	0.000000791	0.23
150	0.03607	0.000000835	0.23
200	0.03828	0.000000886	0.23
250	0.04080	0.000000945	0.23
300	0.04365	0.000001011	0.23
350	0.04683	0.000001084	0.23
400	0.05032	0.000001165	0.24
450	0.05415	0.000001253	0.24
500	0.05829	0.000001349	0.24

Density of 14 lbm/cu. ft. or 0.0081 lbm/in³,
Thermal emissivity of 0.9,
 $k = 0.0313988 + 2.14484E-005*T + 6.46826E-008*T^2$, Btu/hr-ft-°F,
Data from WHC 1976.

Table 7. Material Properties of Refractory Fiber.

Temperature (°F)	Thermal Conductivity (BTU/Hr-Ft-°F)	Thermal Conductivity (Btu/Sec-Inch-°F)	Specific Heat (Btu/Lbm-°F)
32	0.02044	0.000000473	0.23
100	0.02202	0.000000510	0.23
150	0.02352	0.000000545	0.23
200	0.02532	0.000000586	0.23
250	0.02740	0.000000634	0.23
300	0.02977	0.000000689	0.23
350	0.03243	0.000000751	0.23
400	0.03538	0.000000819	0.23
450	0.03862	0.000000894	0.23
500	0.04214	0.000000976	0.23

Density of 8 lbm/cu. ft. or 0.0046 lbm/in³,
Thermal emissivity of 0.9,
 $k = 0.019881 + 1.56547E-005*T + 5.77381E-008*T^2$, Btu/hr-ft-°F,
Data from WHC 1976.

Table 8. Material Properties of Magnesium Oxide.

Temperature (°F)	Thermal Conductivity (BTU/Hr-Ft-°F)	Thermal Conductivity (Btu/Sec-Inch-°F)	Specific Heat (Btu/Lbm-°F)
32	38.70	0.0008959	0.21
212	26.12	0.0006047	0.25
392	18.87	0.0004367	0.265
572	14.03	0.0003247	
752	11.12	0.0002575	0.285
1112	7.25	0.0001679	
1472	4.83	0.0001119	
1832	4.11	0.0000952	0.31
2372	3.63	0.0000840	
2912	4.11	0.0000952	0.34

Density of 223 lbm/cu. ft. or 0.1293 lbm/in³,
Thermal emissivity of 0.9,
Data from Bailey 1987.

Table 9. Material Properties of Reinforced Concrete.

Temperature (°F)	Thermal Conductivity (BTU/Hr-Ft-°F)	Thermal Conductivity (Btu/Sec-Inch-°F)	Specific Heat (Btu/Lbm-°F)
0	1.67	0.0000386	0.20
250	1.67	0.0000386	0.20

Density of 300 lbm/cu. ft. or 0.1741 lbm/in³,
Thermal emissivity of 0.9,
Data from WHC 1994b.

4.4 Ambient Air Temperature

For this analysis, the ambient air temperature was specified in WHC 1994a to be in the range of 32 °F to 120 °F. For a conservative assessment for tank heat up, the lower ambient temperature of 32 °F was assumed. This assumption will produce the longest heat up time. For the steady-state analysis to determine maximum concrete temperatures, an ambient temperature of 120 °F was assumed. For this analysis, the ambient air temperature was assumed to be constant.

4.5 Ground Temperature

For the Hanford site specific ground temperatures, pertinent data from Climatological Summary for the Hanford Area (PNL 1983), may be used in thermal assessments. A yearly average soil temperature 59.5 °F at 36 inches below the surface is recommended. At this depth, the soil temperature remains nearly constant throughout the year. This temperature was applied as a fixed node (constant) temperature on the bottom side of the concrete floor. Note, the concrete floor was assumed to be 36 inches thick, in practice the floor will be thinner but the difference in thermal properties of concrete and soil is minor.

4.6 NATURAL CONVECTION

Heat is also rejected from external surfaces of the tank to the environment by natural convection heat transfer. This mode of heat transfer depends on the temperature difference between the heat rejecting surface and the ambient air, the orientation of the heat rejecting surface, the velocity of air flowing past the surface and the thermophysical properties of air. For this analysis the air is assumed to be still (zero flow velocity) in accordance with conservative practices. The tank was modelled as a vertical right circular cylinder. The equations describing natural convection that were used in the thermal model were taken from Holman, 1972. The equations utilized were:

$$h_c = 0.19\Delta T^{1/3}$$

for a vertical cylindrical surface;

$$h_c = 0.22\Delta T^{1/3}$$

for a horizontal cylindrical surface (facing up);

$$h_c = 0.12\Delta T^{1/4}$$

for a horizontal cylindrical surface (facing down);

where;

h_c = convective heat transfer coefficient, Btu/hr-sq-ft-°F,
 ΔT = Temperature difference between convective surface and ambient, °F.

For the internal gas gaps at the interface between the tank and the insulation, heat is transferred by a combination of conduction and convection. This mode of heat transfer depends on the temperature difference between the heat rejecting surfaces, the orientation of the heat rejecting surfaces, the gap width and the thermophysical properties of air at the mean air

temperature. Because of the small gap size and the small temperature gradient across the gap there will be no convective effect and only gas conduction was assumed.

4.7 HEAT LOAD

For the baseline case the highest internal heat generation for the total tank was specified at 60 kWatts. This heat generation was apportioned at 24 kWatts over the bottom head (except for the area just adjacent to the skirt attachment location) and 36 kWatts apportioned over the entire vertical side of the tank (96 inches in length). This apportionment was based upon an equal volume basis, ie., the volume of sodium contained in the bottom head relative to the volume contained in the cylindrical portion of the tank. No heat generation was applied to the top of the tank.

The trace heater elements were assigned a specific heat generation of $1.3358\text{E-}3$ and $8.309\text{E-}4$ Btu/sec. per cu. inch. respectively for the tank side and bottom head. The trace heaters were modelled as a 1/4 inch thick elements with uniformly distributed along the length of the tank bottom head and tank vertical side.

4.8 Thermal Radiation Boundary Conditions

The view factor for thermal radiation to the environment was assumed to be 1 for the tank top and vertical side. For the internal gas gaps of the tank, the effective thermal emissivity of the gap surfaces are required boundary conditions. All emissivity values were entered as constants within the PTHERMAL model with the emissivity values for carbon steel and sodium specified at 0.8 and the insulation surface at 0.9.

The model assumed a thermal radiation boundary at the top of the sodium surface exchanging energy with the top head of the tank. A second set of thermal radiation boundary conditions was applied to the air gap between the tank outer surface and the insulation inner surface, a gap of 1/4 inch was assumed. A third set of thermal radiation boundary conditions was assumed for the surfaces below the tank within the support skirt region, this included the lower insulation surface, the inside skirt surface and the concrete floor under the tank.

The view factors for the various surfaces are calculated by the PATRAN/PVIEWFACTOR computer program from the geometric description of the thermal model.

4.9 THERMAL MODEL CASE DESCRIPTIONS

The case descriptions for the thermal analysis of the sodium storage tank are as follows.

- Case 1 consisted of a transient analysis progressing for 31 days of simulated heat up. The baseline vertical storage tank is assumed

with 60 kWatts total heat, 32 °F initial and ambient temperature and 6 inches of calcium silicate insulation.

- Case 2 consisted of a transient analysis progressing for 31 days of simulated heat up. The baseline vertical storage tank is assumed with 60 kWatts total heat, 32 °F initial and ambient temperatures and 6 inches of refractory fiber insulation.
- Case 3 consisted of a steady state analysis. The baseline vertical storage tank is assumed with 60 kWatts total heat, 32 °F ambient temperature and 6 inches of calcium silicate insulation.
- Case 4 consisted of a steady state analysis. The baseline vertical storage tank is assumed with 60 kWatts total heat, 32 °F ambient temperature and 6 inches of refractory fiber insulation.
- Case 5 consisted of a steady-state analysis with 30 kW of heater power, 120 °F ambient, and 6 inches of refractory fiber insulation.
- Case 6 consisted of a steady-state analysis with 15 kW of heater power, 120 °F ambient, and 6 inches of refractory fiber insulation.
- Case 7 consisted of a steady-state analysis with 12 kW of heater power, 120 °F ambient, and 6 inches refractory fiber insulation.
- Case 8 consisted of a steady-state analysis with 30 kW of heater power, 120 °F ambient, and 6 inches calcium silicate insulation.
- Case 9 consisted of a steady-state analysis with 18 kW of heater power, 120 °F ambient, 6 inches calcium silicate insulation.
- Case 10 consisted of a steady-state analysis with 12 kW of heater power, 120 °F ambient, 6 inches calcium silicate insulation

Case 1 and 2 are used to determine heat up rates for the two different insulation designs, the steady state cases, case 3 and 4, are used to determine the ultimate thermal capability of the tank design. Case 4 through 10 are used to determine the amount of heater power to maintain the sodium temperature at 400 °F and the maximum concrete temperature when the sodium temperature is at 400 °F.

5.0 ANALYSIS RESULTS

5.1 MAXIMUM TEMPERATURES - NORMAL OPERATING CONDITION

Table 1 represents a set of steady-state and peak transient temperature predictions for the various tank configurations that are evaluated at the prescribed ambient temperature for normal operating conditions. The transient cases were modelled with up to 31 days of heat up from the initial ambient

temperature. These cases represent the maximum normal condition temperatures for the tank. The pertinent results from the analyses are listed below.

- The calcium silicate insulated storage tank requires a 25.6 day period to heat up to 400 °F from an initial temperature of 32 °F. The average heat up rate was determined to be 15.7 °F/day. The sodium temperature at the end of the 31 day transient was determined to be 479 °F. The maximum insulation outer surface temperature (accessible by plant personnel) was determined to be 59 °F. The concrete temperature at the skirt support was determined to be 54 °F.
- The refractory fiber insulated storage tank requires a 23.7 day period to heat up to 400 °F from an initial temperature of 32 °F. The average heat up rate was determined to be 17.3 °F/day. The sodium temperature at the end of the 31 day transient was determined to be 527 °F. The maximum insulation outer surface temperature (accessible by plant personnel) was determined to be 54 °F. The concrete temperature at the skirt support was determined to be 54 °F.
- The maximum steady state sodium temperature for the calcium silicate insulated storage tank was determined to be 767 °F. The maximum concrete temperature below the tank was determined to be 63 °F for the same conditions. The maximum insulation outer surface temperature (accessible by plant personnel) was determined to be 80 °F.
- The maximum steady state sodium temperature for the refractory fiber insulated storage tank was determined to be 920 °F. The maximum concrete temperature below the tank was determined to be 65 °F for the same conditions. The maximum insulation outer surface temperature (accessible by plant personnel) was determined to be 79 °F.
- Figure 4 depicts the results of the parametric study to determine the heater power required to maintain a refractory fiber insulated storage tank at various sodium temperatures. This figure shows that 14 kW of power is required to maintain the sodium at 400 °F with a 120 °F ambient temperature. The figure also shows that the concrete temperatures are near ambient temperature for all cases. For this condition, the insulation outer surface temperature are less than the 140 °F limit.
- Figure 5 depicts the results of the parametric study to determine the heater power required to maintain a calcium silicate insulated storage tank at various sodium temperatures. This figure shows that 19 kW of heater power is required to maintain the sodium at 400 °F with a 120 °F ambient temperature. The figure also shows that the concrete temperatures are near ambient temperature for all cases. For this condition, the insulation outer surface temperature are less than the 140 °F limit.

5.2 RECOMMENDATIONS

Either of the two insulation designs is acceptable from a thermal standpoint. The refractory fiber design has a slightly better thermal performance. The total cost between the two designs should be the deciding factor.

The effect on heat-up-time to 450 °F can be determined from Figures 1 or 2. By assuming an initial temperature of 120 °F, instead of 32 °F, on Figure 1 or 2, the time to heat up to 450 °F can be read directly from these figures.

Figure 4. FFTF Vertical Storage Tank Steady-State Temperature vs Heater Power with Refractory Fiber Insulation.

Figure 5. FFTF Vertical Storage Tank Steady-State Temperature
vs Heater Power with Calcium Silicate Insulation.

6.0 REFERENCES

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