Enclosure (1)

Evaluation
of Fort Calhoun Safety Injection
Pump Room Temperature Following
a Loss of Coolant Accident
by
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I. Introduction

At the request of OPPD, C-E has evaluated the temperature in the safety injection pump room for the 24 hour period following a LOCA. The double-ended hot leg slot (DEHLS) break was chosen for the analyses for consistency with the Fort Calhoun FSAR.* The evaluation uses data for stretch-power conditions of 1560 MWt and 2250 psia for conservatism.

The containment building and pump room were analyzed using the CONTRANS computer code, an NRC-approved code for predicting pressure and temperature transients following a LOCA. Documentation for the code is provided in CENPD-140.

II. Sequence of Events

The reactor coolant system (RCS) is assumed to be operating at steady state stretch power conditions of 1560 MWt and 2250 psia. At the start of the analysis, the pump room walls are assumed to be at a uniform temperature, consistent with assuming that there are no energy sources in the pump room prior to the start of the transient. At time t = o, a double-ended hot leg slot (DEHLS) break is assumed to occur with the subsequent blowdown of the RCS. Mass/energy release to the containment during the blowdown phase was modeled by the CEFLASH 4 computer code, an NRC-accepted code for post-LOCA blowdown as described in CENPD-133.

During blowdown, both SIAS and CSAS setpoints are reached. The SIAS starts the HPSI, LPSI and containment spray pumps. All pumps are assumed to start and operate at runout conditions to provide the maximum heat input to the room. The CSAS opens the valve to the containment spray header. Only one valve is assumed to open. This minimizes the flow rate through the headers and therefore maximizes the length of time before the recirculation actuation signal (RAS) is initiated. No credit is taken for the containment building fan coolers until after the RAS, to maximize the containment sump temperature. As an additional conservatism, post-blowdown mass/energy release to the containment was modeled using the "long term" capability of the CONTRANS code which includes a calculation of mass/energy source terms from decay heat and NSSS metal heat.

*Note: Sump temperatures from hot leg breaks are comparable to those from cold leg breaks, so that heating of the pump room by hot sump water in the piping (after the start of recirculation, is adequately modeled by the hot leg case.

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At 55 minutes after the event, the inventory in the SIRWT is assumed to reach the RAS level and recirculation is initiated. The RAS automatically stops the LPSI pumps. For conservatism, the containment spray is assumed to be terminated by the operator at this point. After RAS, containment spray pumps draw water from the containment sump and pump the sump water through the shutdown cooling heat exchanger to the containment sprays. By terminating the containment sprays at this point, this normal cooling path for the water following RAS is not available. This maximizes the containment sump temperature. Recirculation is assumed to continue throughout the remainder of the evaluation.

For conservatism, heat transfer within the pump room is considered only for the six walls in the room (north, east, south, west, floor and ceiling) and for the piping associated with the pumps. The piping carrying the water within the pump room is assumed to be at refueling tank water temperature prior to starting recirculation, and at sump water temperature after recirculation. No credit is taken in the analysis for any piping heat capacity; this is conservative since energy not stored in the piping metal becomes an input to the pump room. Credit is not taken for heat transfer to any other heat sinks in the room. No air flow in the room is considered.

The sequence of events described above is a realistic and reasonable sequence of events following a DEHLS break. The events have been chosen in a conservative manner to maximize the heat input to the SI pump room and minimize the heat removal from the room.

III. Parameters Used

CONTAINMENT BUILDING DATA

Free Volume	1.05×10^6 ft^3
Passive Heat Sinks	Attachment A
Initial Conditions	14.7 psia, 80% RH, 120°F
Spray Data	3 pumps, 1700 GPM each, 65 second delay time
Fan Data	1 high capacity and 1 low capacity
Start of Recirculation	55 minutes

PUMP ROOM DATA

Free Volume	27290 ft^3
Heat Generated Per Pump	62500 Btu/hr
Piping Surface Area	
1. Before Recirculation	1439 ft^2
2. After Recirculation	220 ft^2
Piping Temperature	
1. Before Recirculation	95°F
2. After Recirculation	Containment sump temperature
Piping Heat Transfer Coefficient	1.7 Btu/ft^2hr°F

Wall data (all concrete)

Wall	Thickness, ft.	Area, ft^2
North	3.0	421
East	3.0	941
South	3.0	421
West	3.0	941
Ceiling	3.5	1882
Floor	5.5	1882

Density	145 lbm/ft^3
Specific Heat	.156 Btu/lbm°F

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ATTACHMENT A

TABLE 1

No.	Description	Material	Thickness	Surface Area (Ft^2)	Exposed To Side #1	Exposed To Side #2
1.	Containment Cylindrical Wall	Paint	3 mil	43,420	Containment Vapor Region	Outside Environment
		Steel	0.25 in			
		Concrete	3.875 ft			
2.	Containment Dome	Paint	3 mil	6,400	Containment Vapor Region	Outside
		Steel	0.25 in			
		Concrete	3 ft			
3.	Foundation Slab	Paint	3 mil	8,550	Containment Liquid Region	Ground
		Steel	0.25 in			
		Concrete	12 ft			
4.	Misc. Concrete Slab	Paint	6 mil	53.600	Containment Vapor Region	Containment Vapor Region
		Concrete	2 ft			
		Paint	6 mil			
5.	Misc. Concrete	Paint	6 mil	4,560*	Containment Vapor Region	Containment Vapor Region
		Concrete	1 ft			
		Paint	6 mil			
6.	Misc. Concrete	Paint	6 mil	19,490*	Containment Vapor Region	Containment Vapor Region
		Concrete	7.5 ft			
		Paint	6 mil			
7.	Misc. Sttel	Paint	3 mil	5,700*	Containment Vapor Region	Containment Vapor Region
		Steel	.125 in			

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ATTACHMENT A

TABLE 1

No.	Description	Material	Thickness	Surface Area (Ft^2)	Exposed To Side #1	Exposed To Side #2
8.	Misc. Steel Slab	Paint Paint	3 mil 3 mil	10,960*	Containment Vapor Region	Containment Vapor Region
9.	Ventilation Ducts	Galvanized Steel	0.125 in	72,000*	Containment Vapor Region	Containment Vapor Region

* Tabulated surface area includes areas of both sides.

TABLE 2

MATERIAL PROPERTIES

Material	Thermal Conductivity (Btu/hr-ft-F)	Volumetric Thermal Capacity (Btu/ft^3-F)
Concrete	0.85	32.0
Steel	26.0	59.0
Paint for Steel Surfaces	1.5	57.6
Paint for Concrete Surfaces	0.3	43.2

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Conductivity	1.05 Btu/hrft°F
Heat Transfer Coefficient	2.0 Btu/ft^{2}hr°F
Room Initial Conditions	14.7 psia, 80% RH, 95°F

NSSS DATA

Blowdown Mass/Energy Release Rates	CENPD-133 and Supp. 1, 2, 3
Post-Blowdown Mass/Energy Rates	CONTRANS code

IV. Results

Results of the analyses are presented in Figures 1 through 4. As shown by Figure 2, the maximum pump room temperature occurs at the start of recirculation and is approximately 117°F. This maximum temperature is based on a conservative analytical calculation of the temperature rise within the pump room.

A test was run at the site by OPPD to measure the temperature rise in the pump room with all four pumps running and actual plant conditions rather than the conservative conditions of the analysis. The average measured temperature rise in the room was only 10°F after 55 minutes compared to the calculated average temperature rise of 22°F. Therefore, the analysis can be considered to provide a conservative upper limit temperature for the SI pump room during the 24 hour period following a LOCA.

V. Conclusions

Based on the results shown in Figure 2, it is concluded that, during the 27 hour period following a LOCA, the SI pump room temperature will not exceed the 117°F peak reached at 55 minutes. At this time shutdown cooling is assumed to be available for reducing the containment sump water temperature.

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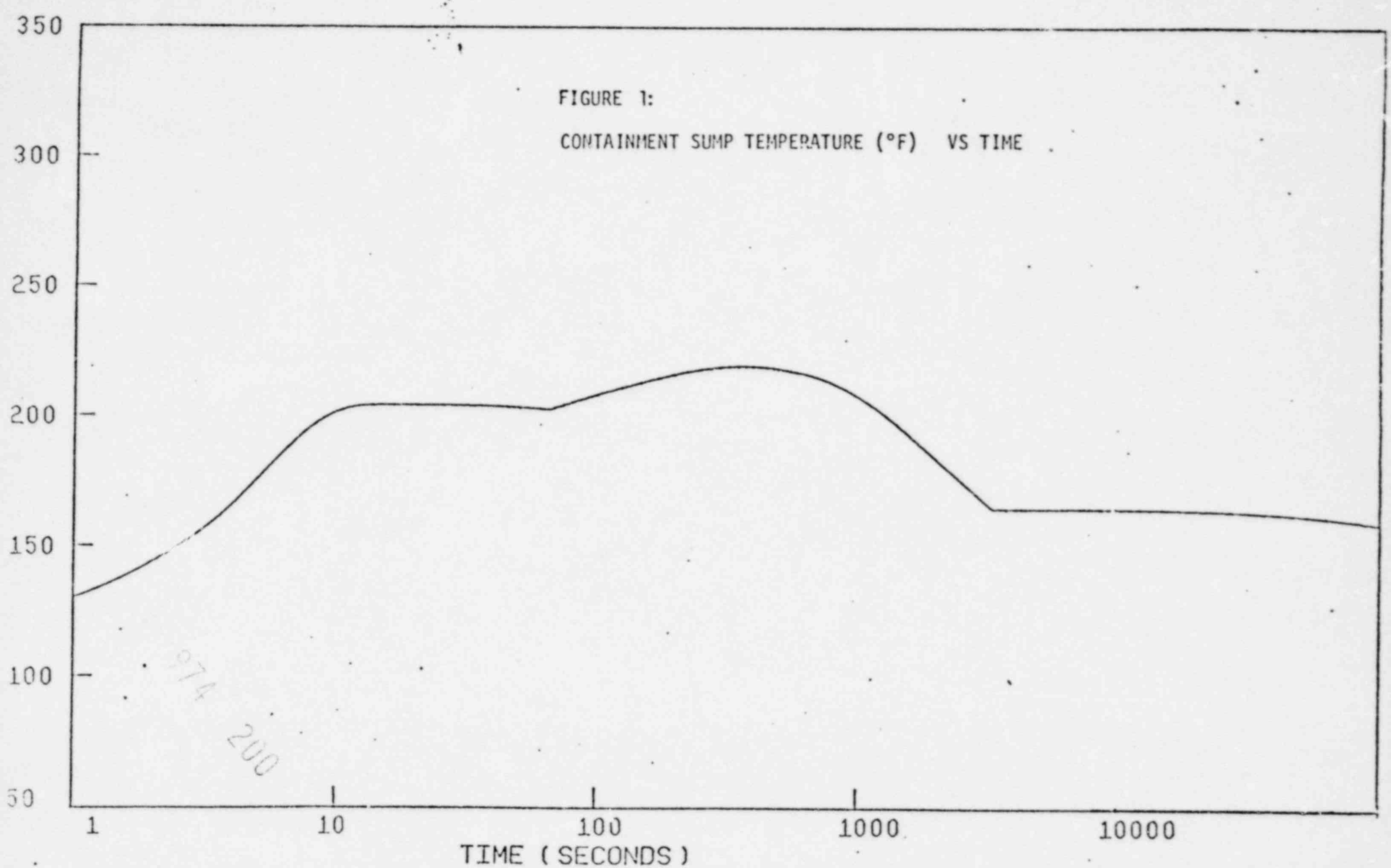

FIGURE 1:
CONTAINMENT SUMP TEMPERATURE (°F) VS TIME
350
300
250
200
150
100
50
1
10
100
1000
10000
TIME (SECONDS)
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K-E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS

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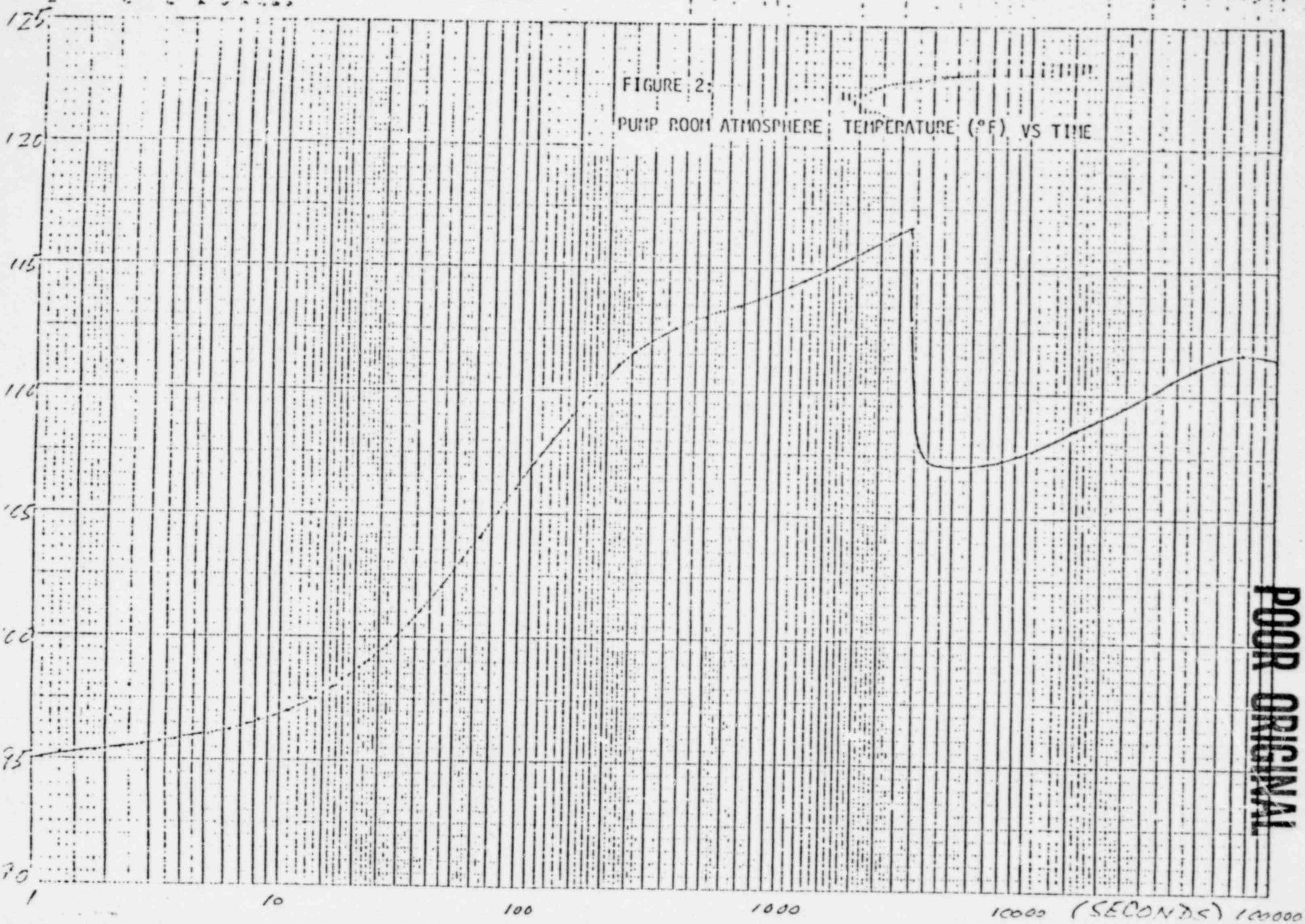

FIGURE 2:

PUMP ROOM ATMOSPHERE TEMPERATURE (°F) VS TIME

POOR ORIGINAL

Figure 3:

PUMP ROOM ENERGY BALANCE AT START OF RECIRCULATION

	0 seconds	3300 seconds
Mass of steam (lbm)	47	47
Mass of sump (lbm)	62	62
Energy of steam (Btu)	49233	49582
Energy of sump (Btu)	3907	3907
Energy of air (Btu)	20314	27350
Total heat in (Btu)	0.	229167
Total heat removal (Btu)	0.	221782

Sum of mass at 0 sec = 47 + 62 = 109 lbm

Sum of mass at 3300 sec = 47 + 62 = 109 lbm

Energy at 3300 sec = (Total Energy at 0 sec) + (total heat in at 3300 sec) - (total heat removal at 3300 sec) = (49233 + 3907 + 20314) + (229167) - 221782) = 80839 Btu

or

Energy at 3300 sec = 49582 + 3907 + 27350 = 80839 Btu

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Figure 4:
PUMP ROOM ENERGY BALANCE AT END OF 10^5 SECONDS

	0 Seconds	10^5 Seconds
Mass of steam (lbm)	47	47
Mass of sump (lbm)	62	62
Energy of steam (Btu)	49233	49496
Energy of sump (Btu)	3907	3907
Energy of air (Btu)	20314	25616
Total heat in (Btu)	0.	1908404
Total heat removal (Btu)	0.	1902839

Sum of mass at 0 sec = 47 + 62 = 109 lbm
Sum of mass at 10^5 sec = 47 + 62 = 109 lbm

Energy at 10^5 sec = (total energy at 0 sec) + (total heat in at 10^5 sec) - (total heat removal at 10^5 sec) = (49233 + 3907 + 20314) + (1908404 - 1902839) = 79019 Btu

or

Energy at 10^5 sec = 49496 + 3907 + 25616 = 79019 Btu

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List of Acronyms Used

SIAS - Safety Injection Acutation Signal

CSAS - Containment Spray Actuation Signal

RAS - Recirculation Actuation Signal

Steady State Temperature of SI Pump Room

$$q = \sum_{i=1}^{6} U_i A_i (T_{ROOM} - T_{\infty i}) + U_{PIPE} A_{PIPE} (T_{ROOM} - T_{PIPE}) + \dot{M}_A C_P (T_{ROOM} - T_{VENT})$$

$$U_1(\text{FLOOR}) = \frac{1}{\frac{1}{2.0} + \frac{5.5}{1.05} + \frac{1}{10.0}} = .17 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

$A_1 = 1882 \text{ ft}^2$

$T_{\infty 1} = 55^\circ F$

$$U_2(\text{CEILING}) = \frac{1}{\frac{1}{2.0} + \frac{3.5}{1.05} + \frac{1}{2.0}} = .23$$

$A_2 = 1882$

$T_{\infty 2} = 95$

$$U_3(\text{W. WALL}) = U_4(\text{E. WALL}) = \frac{1}{\frac{1}{2.0} + \frac{3.0}{1.05} + \frac{1}{2.0}} = .26$$

$A_3 = 941$

$T_{\infty 3} = 95$

$$U_5(\text{S. WALL}) = \frac{1}{\frac{1}{2.0} + \frac{3.0}{1.05} + \frac{1}{5.0}} = .28$$

$A_5 = 421$

$T_{\infty 5} = 80$

$$U_6(\text{N. WALL}) = \frac{1}{\frac{1}{2.0} + \frac{3.0}{1.05} + \frac{1}{10.0}} = .29$$

$A_6 = 421$

$T_{\infty 6} = 55$

$U_{PIPE} = 1.7$

$A_{PIPE} = 220 \text{ ft}^2$

$T_{PIPE} = 165^\circ F$

$q = 62{,}500$ Btu/hr (PUMP MOTOR)

$\dot{M}_A C_P = (.0715)(60)(.24)(\text{cfm}) = (1.03)(\text{cfm})$

$T_{VENT} = 95$

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$$62{,}500 = (.17)(1882)(T_{ROOM} - 55) + (.23)(1882)(T_{ROOM} - 95) + (2)(.26)(941)(T_{ROOM} - 95) + (.28)(421)(T_{ROOM} - 80) + (.29)(421)(T_{ROOM} - 55) + (1.7)(220)(T_{ROOM} - 165) + (1.03)(cfm)(T_{ROOM} - 95)$$

$$62{,}500 = 320\ T_{ROOM} - 17{,}597 + 433\ T_{ROOM} - 41{,}122 + 489\ T_{ROOM} - 46{,}485 + 118\ T_{ROOM} - 9430 + 122\ T_{ROOM} - 6715 + 374\ T_{ROOM} - 61{,}710 + (1.03)(cfm)T_{ROOM} - (98)(cfm)$$

$$= T_{ROOM}\left[1856 + (1.03)(cfm)\right] - 183{,}059 - (98)(cfm)$$

$$T_{ROOM} = \frac{245{,}559 + (98)(cfm)}{1856 + (1.03)(cfm)}$$

cfm	T_{ROOM}
0	132°F
1500	115
3000	109
5500	104

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