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* NAME		MAIL ADDR		Thermal and hydraulic analyses of the System 81 Type I and II cold traps were completed except for thermal transients analysis.	
* T. Anderson		LB33		Results are evaluated, discussed, and reported in this document. Analytical models were developed to determine the physical dimensions of the cold traps and to predict the performance.	
* L. Cassort		LB33		The FFTF cold trap crystallizer performances were simulated using the thermal model. This simulation shows that the analytical model developed predicts reasonably conservative temperatures. Pressure drop and sodium residence time calculations indicate that the present design will meet the requirements specified in the E-Specification.	
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1.0 INTRODUCTION

The CRBRP System 81 (Auxiliary Liquid Metal System) cold trap is a part of the sodium purification system. In a large sodium system, impurities may be detrimental to plant operation. Of major concern are O_2 and H_2 present in the system as Na_2O and NaH . The solubility of these impurities in sodium decreases with decreasing temperatures, therefore, precipitation of oxide may be caused to occur at any point in a system by lowering the temperature below the system saturation temperature at that point. The sodium is circulated through a cold trap where cooling occurs in a mesh-packed region. Impurities are deposited in the mesh, while the cleaned sodium flows through a reheating section before returning to the main system. The major components of the cold trap consist of an economizer and a crystallizer. The economizer is a vertical tube and shell regenerative heat exchanger to lower the inlet sodium temperature to the crystallizer within design conditions and thereby require a smaller heat load for the cold trap coolant.

The crystallizer, which contains the stainless steel mesh, is a pressure vessel made of stainless steel. The cold trap, Type I (primary cold trap), has a NaK-cooled crystallizer, while the Type II (IHTS, EVS cold trap), is gas cooled. Since the heat removal capacity of gas per unit surface area is much less than that of liquid (NaK), the Type II cold trap crystallizer tank wall has 180 carbon steel fins and a longer shell to achieve the same heat transfer as the NaK-cooled crystallizer.

The basic design approach of the System 81 cold trap was to follow the FFTF cold trap crystallizer configuration as close as possible, and to design a vertical tube and shell type economizer maintaining commonalities in design between the two types of cold trap except the length of the economizer.

The objectives of this analysis are:

- a) To determine the design parameters of the cold traps,
- b) To predict the performances of the cold traps,
- c) and to generate structural temperature data of components for the assessment of thermal stress.

Only steady-state temperature data have been generated since thermal transient data for the cold traps are not available yet.

2.0 SUMMARY

Both computer and hand calculations have been made for the analyses presented in this report. The computer work was done by setting up nodal thermal models for use with the TAP program.⁽¹⁾

A brief summary of this analysis is presented here. A detailed discussion follows in the body of the report.

1. The natural convection effects of sodium in the crystallizer have been investigated. Calculations made for natural convection effects in the crystallizer with a 3/8-in. vertical flow divider yielded extremely large Grashof numbers which suggest that large buoyancy heads are generated at the vertical flow divider causing large convection currents at the surface of the flow divider. This type of flow field causes reduced effective trapping volume and a large temperature recovery in the crystallizer. To minimize the natural convection effects, increasing the flow divider thickness to 2 in. or installing staggered horizontal flow baffle on both sides of the flow divider was recommended. The present cold trap design is equipped with a vertical flow divider 2 in. thick.
2. The Type II crystallizer needs 180 carbon steel fins (fin height 2 in., fin thickness 0.25 in.) or the equivalent and a longer shell to attain the heat removal capacity required.

The economizer has 91 tubes which are 1 in. O.D. and 0.035 in. wall thick. The effective tube length is 61 in. for the Type I cold trap, and 39 in. for the Type II, respectively. A summary of the design dimensions is presented in Table 1.

TABLE 1
Summary of Design Dimensions

	<u>Type I</u> <u>(Primary)</u>	<u>Type II</u> <u>(IHTS, EVS)</u>
Crystallizer		
Shell I.D., in.	54.0	54.0
Cylindrical Shell Length, in.	50.0	92.0
Shell Thickness, in.	3/8	5/8
Flow Separator I.D., in.	34.38	34.38
Flow Separator Thickness, in.	2.	2.
Fin Height, in.	N/A	2.
Fin Thickness, in.	N/A	1/4
Number of Fins	N/A	180
Fin Length, in.	N/A	82
Fin Material	N/A	Carbon steel
Economizer		
Number of Tubes	91	91
Tube O.D., in.	1.0	1.0
Tube Wall Thickness, in.	0.035	0.035
Effective Tube Length, in.	61.	39
Shell O.D., in.	20.	20
Shell Wall Thickness	3/8	3/8
Shell Side Flow Area (in. ²)	115	115
NaK Cooling Jacket		
Jacket O.D., in.	60	N/A
Jacket I.D., in.	54.74	N/A

3. With a 2 in. vertical flow divider, a temperature recovery less than 5°F was calculated. To satisfy the temperature difference requirement of 50°F between inlet and outlet to the economizer, the sodium inlet temperature to the crystallizer should be about 285°F in the design conditions as shown in Table 2.
4. The NaK flow rate required to meet the design condition was calculated as 18000 lb/hr. Considering the maximum NaK flow rate of 40,000 lb/hr, there is a large design margin in the coolant flow rate for the primary cold trap. This excess design NaK flow rate and the large temperature recovery in the FFTF cold trap crystallizer caused the cold trap to meet the minimum temperature requirement of 230°F at the crystallizer bottom even though the horizontal toroidal economizer did not perform as expected in design.

For the Type II cold trap, a 7000 scfm gas flow rate will be required to meet the design condition for the IHTS cold trap. There is no margin in the gas flow rate for the Type II cold trap.

5. Sodium residence time has been calculated. The present design will meet the residence time requirements in the economizer and the crystallizer wire mesh. The residence times are summarized in Table 2.
6. Sodium, NaK, and gas pressure drop were calculated. There are enough design margins in the pressure drops. Results are summarized in Table 2.
7. All the cold trap operating conditions for both cold traps were examined. The present design satisfies all the design requirements specified in Reference 2. Temperatures, coolant flow rates

TABLE 2

Summary of Design Performance Parameters

	Type I	Type II	
	Primary	IHTS	EVS
Temperature			
Na Inlet Temperature ($^{\circ}\text{F}$)	850	675	625
Coolant Inlet Temp. ($^{\circ}\text{F}$)	125	100	80
Coolant Outlet Temp. ($^{\circ}\text{F}$)	239	163	165
Sodium Outlet Temp. ($^{\circ}\text{F}$)	798	625	580
Sodium Inlet Temperature to Crystallizer ($^{\circ}\text{F}$)	286	283	280
Na Temp. at Crystallizer Bottom ($^{\circ}\text{F}$)	230	230	230
Sodium Flow Rate (GPM)	60	60	60
Coolant Flow Rate			
Max. Design Flow Rate	40,000 lb/hr	7000 scfm	6400 scfm
Flow Rate Required to Meet the Design Conditions	18,000 lb/hr	7000 scfm	4500 scfm
Overall U ($\text{Btu/hr-ft}^2\text{-}^{\circ}\text{F}$)			
Economizer	1158.2	1158.2	1158.2
Vertical Flow Divider	29.7	38.3	38.3
UA ($\text{Btu/hr-}^{\circ}\text{F}$)			
Economizer	1.3535×10^5	8.675×10^4	8.675×10^4
Vertical Flow Divider	1179.1	2997	2997
Sodium Residence Time			
Economizer Shell Side (sec)	30.	19.5	19.5
Economizer Tube Side (sec)	16.3	10.4	10.4
Crystallizer Steel Mesh (min.)	6.7	13.0	13.0
Pressure Drop			
Sodium Pressure Drop (psi)	0.58	0.603	0.603
*NaK Pressure Drop (psi)	3.5		
**Gas Pressure Drop (inch of water)		3.09	3.09

* Based on 40,000 lb/hr flow rate.

** Based on 7000 scfm flow rate.

required to meet the operating conditions, sodium pressure drops, temperature differences between inlet and outlet to the economizer, and temperature recoveries in the crystallizer are summarized in Table 3.

8. The performance of the FFTF cold trap crystallizer have been simulated to check the validity of the thermal model generated for the cold trap analyses. Results indicate that the performance predicted by the thermal model which incorporated the natural convection effects are in better agreement with the corresponding test data than by the model ignoring the natural convection effects. On the whole, the prediction of the thermal model is in good agreement with the test data, and the results are conservative except the temperature recovery in the crystallizer. Temperature recovery in the performance test is 52°F vs 36°F predicted by the thermal model incorporating the natural convection effects. Without the natural convection effect, a temperature recovery of 18°F was predicted.

9. Thermal data have been generated for the component thermal stress evaluations. Only steady-state temperatures were calculated since transient data for the cold traps had not been established. This task will be completed in the final design stage.

TABLE 3
Cold Trap Operating Conditions

Type Conditions/Events	Type I		Type II			
	Primary		IHITS		EVS	
	Normal	Clean-up	Normal	Clean-up	Normal	Refueling
Na Flow Rate (gpm)	60	80	60	80	60	60
Na Flow Rate (lb/hr)	27,500	36,667	27,500	36,667	27,500	27,500
Na Inlet Temp. (⁰ F)	820	600	651	600	600	475
Coolant	NaK	NaK	Air	Air	N ₂	N ₂
Na Temp. at Crystallizer Bottom (⁰ F)	250	250	250	263	250	250
Coolant Inlet Temp. (⁰ F)	125	125	100	100	80	80
Na Outlet Temp. (⁰ F)	772	566	606	554	560	450
Na Inlet Temp. to Crystallizer (⁰ F)	303	286	300	314	295	279
Coolant Outlet Temp. (⁰ F)	270	257	185	177	185	195
Coolant Flow Rate	13000 lb/hr	14000 lb/hr	4430 scfm	7000 scfm	3250 scfm	1890 scfm
Na Pressure Drop (psi)	0.603	1.134	0.603	1.134	0.603	0.603
Na Delta T Between Inlet & Outlet Nozzles (⁰ F)	46	36	45	46	40	25
Temp. Recovery in Crystallizer	5	2	5	5	5	4

3.0 DISCUSSION

The cold trap thermal hydraulic analysis was based on the conceptual design analysis and the FFTF cold trap performance test results. The FFTF cold trap tests resulted in adapting a vertical tube and shell type economizer for the CRBRP System 81 cold traps to prevent thermal stratification problems. The buoyancy head due to temperature differences in the vertical tube and shell economizer exerts force in the same direction as the system flow so that the buoyancy effects enhance sodium flow.

3.1 DESCRIPTION OF SYSTEM

Figures 1 and 2 show the general layout drawings of the Type I and Type II cold traps. The sodium contaminated with impurities enters at the top of the vertical economizer and flows down around the tubes on the shell side. The sodium is cooled approximately 285°F by the outgoing sodium in the tubes. The flow enters the top of the crystallizer in the outer annulus and is cooled by the NaK (Type I) or by the gas (Type II) on the outer annulus surface and returning on the inner annulus surface. The crystallizer annulus and cylindrical core sections are packed with steel mesh which removes the precipitating impurities as the liquid sodium is cooled to the minimum temperature of 230°F (design condition) at the bottom of the crystallizer.

The sodium turns at the bottom of the crystallizer and is heated in the crystallizer core section, collected in a manifold at the junction of the crystallizer and economizer, continues upward inside the economizer tubes, is heated by the shell side incoming sodium, and recovers to approximately 50°F lower than the incoming sodium at the exit at the top of the economizer.

MODEL	Rev	FL	MA	L
N1	1295	060	5797	1
N2	1395	060	5797	1
N3	1412	072	5567	1
N4	1142	072	5567	1

WEIGHT, LBS	Z (N)
SECTION EMPTY FULL EMPTY F	
ECOM	1.271 1962 118.9
COST	9.732 2.426 45.8
TOTAL	1.023 11.342 54.3
SODIUM	49.85
MAK	909

FIG. 1 TYPE I COLD TRAP LAYOUT

CHECKING

CODE	YES/NO	PROJECT	DATE
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
9		9	
10		10

FIG. 2 TYPE II COLD TRAP LAYOUT

CODE	YES/NO	PROJECT	DATE
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
9		9	
10		10	

The required effective length of the tube bundle is 61.0 in. long for the Type I cold trap, and 39 in. for the Type II cold trap, respectively. The shell is 20 in. outside diameter. There is a hexagonal flow baffle around the tube bundle which creates a stagnant sodium region between the economizer shell and the shell side sodium flow. The shell side sodium flow area should be kept at less than 115 in.² to meet the minimum residence time of 30 seconds in the economizer shell side flow specified in Reference 2. The economizer tubes are 1.0 in. outside diameter, 0.035 in. wall thick. Ninety-one tubes are required.

The crystallizer has a 38.38 in. outside diameter, 2 in. thick stainless steel cylinder separator inside a 54 in. diameter vessel. The flow separator of 2 in. thickness was determined to minimize flow channeling and temperature recovery inside the crystallizer due to the natural convection effects. The downstream sodium in the annulus section is cooled by the NaK or gas which surrounded the crystallizer tank vessel. The outer crystallizer vessel wall is surrounded by a helical 8 in. by 2.625 in. NaK channel inside a NaK jacket. The gas-cooled crystallizer has 180. carbon steel fins attached to the sodium annulus outer shell replacing the NaK cooling jacket. The fins are 0.25 in. thick, 2 in. high, and 82 in. long.

3.2 THERMAL MODEL

Two thermal models were generated to determine the design parameters of the cold traps, to estimate the cold trap operating conditions, and to create temperature data for the corresponding thermal stress assessments. Finite difference, lumped parameter, digital computer models were developed using the TAP thermal code⁽¹⁾ and a subroutine calculating the TAP input data on the basis of the physical dimensions and material properties of the cold traps. The subroutine was also used to investigate the natural convection effects in the crystallizer.

3.2.1 Thermal Networks

The Type II cold trap thermal model was developed first, and the Type II model was modified for the Type I cold trap analysis.

The general nodal map is shown in Figure 3. The economizer was divided by 40 nodes axially, and the crystallizer was divided by 30 nodes (22 nodes for the cylindrical section, 8 nodes for the crystallizer bottom dome section). Each node shown in Figure 3 represents a flowing sodium or a gas node. Each downstream sodium node in the crystallizer annulus has a corresponding upstream sodium node in the cylinder core and a corresponding coolant node, and each downstream sodium node in the economizer shell side has a corresponding upstream sodium node in the tubes. There are three boundary nodes, Nos. 50, 300, and 999, representing the sodium inlet temperature to the economizer, the coolant inlet temperature, and ambient air temperature in the cell. Figure 4 shows the economizer nodal map and thermal network which is common for both cold traps (Types I and II). Figures 5 and 6 show the Type II cold trap crystallizer nodal map and thermal network, respectively.

The outside surface of the cold trap is insulated with a 8 in. thick insulation material for the economizer, and a 5 in. thick for the crystallizer.

The Type I cold trap crystallizer nodal map and thermal network are shown in Figure 7. Node summary is tabulated in Table 4. The thermal model computer listings are shown in Appendix A.

FIG. 3

TYPE I COLD TRAP
NODAL MAP

DESIGNED BY: K. K. W.		REPORT NO. 16
CHECKED BY:		DATE
DATE: 11.14.78	FIG. 4 ECONOMIZER MODEL M22 P47	MODEL NO.
THERMAL NETWORK

REPAIRO 17:

Rockwell International
Atomics International Division

PAGE NO. 100 3

CHECKED BY:

FIG. 6 TYPE II COLD TRAP CRYSTALLIZER
THERMAL NETWORK

REPORT NO.

MODEL NO.

Rockwell International
Atomic International Division

PAGE NO. 19
OR

REVIEW BY
CHECKED BY
DATE

FIG. 7 TYPE I GOLD TEE

REPORT NO.
MOORE NO.

CRYSTALLINE NODAL MAP
AND THERMAL NETWORK

TABLE 4

Node Summary

Type II Cold Trap

<u>Node No.</u>	<u>Description</u>
50	Sodium inlet temperature boundary node
51-90	Sodium downstream in economizer
91-129	Sodium downstream in crystallizer
130	Sodium at the bottom of the crystallizer
131-152	Sodium upstream in crystallizer
153-192	Sodium upstream in economizer
201-222	Outside surface temperature of the vertical flow divider
231-252	Inside surface temperature of the vertical flow divider
300	Coolant inlet temperature boundary node
301-330	Coolant flow nodes
501-680	Crystallizer tank wall
681-740	Cooling fins
741-800	Insulation on the crystallizer
801-840	Economizer shell
841-875, 881-915	Insulation on the economizer surface
916-917	Economizer shell on the joint region of the economizer and crystallizer
999	Ambient air in the cell, boundary node

Type I Cold Trap

Modification was made on the crystallizer tank wall and cooling fins of the Type II cold trap.

501-530	Inside surface of the crystallizer tank
601-630	Outside surface of the crystallizer tank, facing the NaK coolant

3.2.2 Material Properties

Material properties used in the analysis are shown in Table 5. Constant material properties at the average temperature have been used. Two constant properties (corresponding to the crystallizer and economizer, respectively) are used for the stainless steel and sodium since the temperature varies in wide range for these materials.

3.2.3 Thermal and Hydraulic Correlations

Thermal and hydraulic correlations used for the analyses are as follows:

1) Economizer shell side

$$Nu = A + B (Pe)^n \quad (\text{Reference 3})$$

where: Nu = Nusselt No.

Pe = Peclet No.

$$A = 0.25 + 6.2 (P/D)$$

$$B = -0.007 + 0.032 (P/D)$$

$$n = 0.8 - 0.024 (P/D)$$

P = Pitch

D = Tube outer diameter.

2) Economizer tube side

$$Nu = 5.0 + 0.025 (Pe)^{0.8} \quad (\text{Reference 4})$$

TABLE 5
Material Properties

	Thermal Conductivity (Btu/hr-ft- ⁰ F)	Specific Heat (Btu/lb- ⁰ F)	Viscosity (lb/ft-hr)	Density (lb/ft ³)	Pr.
Stainless Steel	9.4 (1) 10.1 (2)	0.122	X	495	X
Carbon Steel	33	0.12	X	490	X
Sodium	49 (1) 46.285 (2)	0.325	1.1	57.0 (1) 55.94 (2)	0.0055
NaK	13.92	0.2245	1.575	54.06	0.01905
N ₂	0.0167	0.249	0.0432	0.072 (3)	0.699
Air	0.0167	0.241	0.0484	0.074 (3)	0.699

Node (1) at the average temperature of 280⁰F
 (2) at the average temperature of 450⁰F
 (3) at 75⁰F

3) Crystallizer core

For forced convection $Nu = 5.0 + 0.025 (Pe)^{0.8}$

For natural convection (Reference 4)

$Nu_x = 0.508 Pr^{1/2} (0.952 + Pr)^{-1/4} Gr^{1/4}$ Laminar flow

$Nu_x = 0.0295 \left[\frac{Pr^{7/6} Gr_x}{1 + 0.444 Pr^{2/3}} \right]^{1/4}$ Turbulent flow

Natural convection boundary layer thickness

$\frac{\delta}{x} = 3.93 Pr^{-1/2} (0.952 + Pr)^{1/4} Gr_x^{-1/4}$ (Reference 5)

δ = Boundary layer thickness

Flow velocity in boundary layer thickness

$U_x = C_1 x^{1/2}$ (Reference 5)

$C_1 = 5.17 \nu \left(\frac{20}{21} + \frac{\nu}{\alpha} \right)^{-1/2} \left[\frac{g \beta (T_w - T_\infty)}{\nu^2} \right]^{1/2}$

4) Crystallizer annulus

For forced convection

$Nu = \alpha + \beta (\overline{Pe})^{\gamma}$ (Reference 4)

$\alpha = 5.54 - 0.023Y$

$\beta = 0.0189 + 0.00316 Y + 0.0000867 Y^2$

$$\gamma = 0.758 Y^{-0.0204}$$

$$Y = R_o/R_i$$

$$R_o = \text{Outer radius}$$

$$R_i = \text{Inner radius}$$

For natural convection

Used the same correlations as in the crystallizer core.

5) Cooling gas (fin surface convection)

$$Nu = 0.023 \times Re^{0.8} \times Pr^{0.4} \quad (\text{Reference 5})$$

$$Re = \text{Reynold's No.}$$

$$Pr = \text{Prandtl No.}$$

6) Tank wall (tank wall surface film coefficient, NaK side)

$$Nu = 5.0 + 0.025 (Pe)^{0.8}$$

7) Pressure drop in cold trap wire mesh

$$\Delta P = \frac{f_c l a \rho U^2}{g_c \epsilon^3} \quad (\text{Reference 6})$$

where: f_c = friction factor from Figure 5 in Reference 6

l = wire mesh thickness, ft

a = specific surface area, ft^2/ft^3

ρ = density, lb/ft^3

U = velocity, ft/sec

g_c = $32.2 \text{ lbm-ft}/\text{lbf-sec}^2$

ϵ = void fraction of mesh

3.3 FFTF COLD TRAP PERFORMANCE TEST SIMULATION

Two FFTF cold trap performance tests were simulated using the thermal model developed for the System 81 Type I cold trap. The Type I cold trap crystallizer is an exact duplicate of the FFTF crystallizer except for the vertical flow divider thickness. The test conditions for the FFTF performance tests are described in References 7 and 8. The sodium inlet temperature to the crystallizer, the NaK inlet temperature, and flow rates are shown in Table 6.

The natural convection effects in the crystallizer were incorporated in the thermal model A so that the sodium film coefficients on both sides of the vertical flow separator were calculated as functions of temperature differences between the surface of the flow separator and the flowing sodium, and also the distance on the direction of the buoyancy head due to density difference in the sodium. In the thermal model B, a constant film coefficient based on Peclet No. was used.

The comparison of the results is presented in Table 6. Major findings from the FFTF performance test simulation are as follows:

- 1) Heat loss rate from the sodium to the NaK coolant is in good agreement with the measured rate in the tests.
- 2) All the system temperatures are better predicted using the thermal model which incorporated the natural convection effects.
- 3) Temperature recoveries in the crystallizer core section are calculated to be less than those measured but with the natural convection effects, the recovery was 60-70% of the measured recovery in the tests. This discrepancy may be caused by

TABLE 6

FFTF Cold Trap Crystallizer Performance Test Simulation

Thermal Model A. Model incorporated natural convection effects.

$$\begin{aligned} \text{Nu}_x &= 0.508 \text{Pr}^{1/2} (0.952 + \text{Pr})^{-1/4} \text{Gr}^{1/4} \dots \text{laminar} \\ \text{Nu}_x &= 0.0295 \left[\frac{\text{Pr}^{7/6} \text{Gr}_x}{1+0.444 \text{Pr}^{2/3}} \right]^{1/4} \dots \text{turbulent} \end{aligned}$$

Thermal Model B. Model based on forced convection correlations.

$\text{Nu} = \text{constant}$

Test	FFTF TEST I			FFTF TEST II		
	Test	Thermal Model A	Thermal Model B	Test	Thermal Model A	Thermal Model B
Sodium Inlet Temp. ($^{\circ}\text{F}$)	305	305	305	358	358	358
Sodium Flow Rate (gpm)	60	60	60	60	60	60
NaK Flow Rate (gpm)	50	50	50	55	55	55
NaK Inlet Temp. ($^{\circ}\text{F}$)	225	225	225	145	145	145
NaK Outlet Temp. ($^{\circ}\text{F}$)	274	276	279	255	276	288
Min. Temp. at Bottom of Crystallizer ($^{\circ}\text{F}$)	257	261	265	230	241	253
Sodium Outlet Temp. from the Crystallizer ($^{\circ}\text{F}$)	278	274	272	282	277	271
Heat Loss to Coolant (Btu/hr)	2.64×10^5	2.74×10^5	2.89×10^5	6.79×10^5	7.05×10^5	7.72×10^5
$T_1 - T_2$ ($^{\circ}\text{F}$)	48	44	40	128	117	105
Temp. Recovery ($T_3 - T_2$) ($^{\circ}\text{F}$)	21	13	7	52	36	18

ignoring the stainless steel wire mesh in the modeling or by the heat transfer correlations used to incorporate the natural convection effects.

- 4) On conclusion, the overall results of the thermal model which incorporated the natural convection effects are reasonably conservative. The model is considered adequate to determine the design parameters and predict the normal operating conditions specified in Reference 2.

3.4 NATURAL CONVECTION EFFECTS IN THE CRYSTALLIZER

With a 3/8 in. thick stainless steel vertical flow separator in the Type II crystallizer, calculations made for the natural convection effects in the crystallizer core yielded an extremely large Grashof number (1.172×10^{12}). This suggests that very large buoyancy heads are generated at the vertical flow separator surface causing large convection currents along the flow separator. A comparison of the buoyancy head to the system dynamic head (Gr/Re) was made along the vertical flow separator length. The comparison indicates that the buoyancy head is a major driving force inside the crystallizer. In addition, a few FFTF performance test reports postulate that natural convection current exists inside the crystallizer.⁽⁸⁾ The effects of the natural convection in the crystallizer on temperatures, temperature recovery, and velocity of the natural convection current, are compared with the results ignoring the natural convection effects in Table 7.

The sodium film coefficient for the surface of the flow separator yields a value as high as $1370 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$ in the crystallizer core section, which causes a large temperature recovery. Average sodium velocity in the natural convection current (boundary layer) is more than 10 times higher than the flow velocity based on the system flow rate,

TABLE 7

Effects of Natural Convection in the Crystallizer

	<u>$h = f(\Delta T, X)$</u>	<u>$h = \text{CONST.}$</u>
Sodium Flow Rate (lbm/hr)	27,500	27,500
Sodium Inlet Temperature ($^{\circ}\text{F}$)	300	300
Sodium Temperature at the Bottom of Crystallizer ($^{\circ}\text{F}$)	212	233
Sodium Outlet Temperature from the Crystallizer ($^{\circ}\text{F}$)	250	244
Temperature Recovery in the Crystallizer ($^{\circ}\text{F}$)	38	11
Heat Loss to Sodium Upflow Na (Btu/hr)	3.4085×10^5	1.0823×10^5
Heat Loss to Gas (Btu/hr)	4.4398×10^5	4.9402×10^5
Average Na Velocity in the Upflow Sodium Boundary Layer (ft/min.)	11.6848	1.0*
Average Na Velocity in the Downflow Sodium Boundary Layer (ft/min.)	16.029	
Boundary Layer Thickness of the Upflow Sodium (inch)	3.558	
Boundary Layer Thickness of the Downflow Sodium (inch)	3.7909	

(1) 3/8 in. stainless steel flow divider.

(2) 180 carbon steel fins.

(3) Length of fin, 84 in.

(4) Fin height, 2 in.

(5) Fin thickness, 1/4 in.

* Average velocity based on the system flow rate.

and average boundary layer thickness is about 3.5 in. This result reveals that the flow distribution in the crystallizer is not uniform, and flow channeling occurs on the surface of the flow separator causing a reduced effective trapping volume.

To prevent the flow channeling and large temperature recovery in the crystallizer, means to reduce the natural convection have been considered as follows:

- 1) First concept considered was to provide horizontal staggered disc and donut shape baffles similar to the Hallam cold trap so that flow through this section is baffled to prevent channeling, thus forcing a uniform cooling of the entire flow and utilizing the whole mesh volume for trapping.⁽¹⁰⁾
- 2) The second concept investigated was to increase the thermal resistance of the flow separator causing small sodium density differentials along the crystallizer length. Suitable thermal barrier materials were studied and stainless steel was recommended.⁽⁹⁾

A parametric study was performed to determine an optimum thickness of the flow divider. Results are shown in Figure 8 and Table 8. The flow divider thickness of 2 in. has been chosen, since the results are approaching the temperature recovery and the system temperatures calculated without the natural convection effects.

TABLE 8

The Effects of Flow Divider Thickness

$$(1) \quad Nu_x = 0.508 Pr^{1/2} (0.952 + Pr)^{-1/4} Gr^{1/4} \dots\dots\dots \text{laminar}$$

$$Nu_{t,x} = 0.0295 \left[\frac{Pr^{7/6} Gr_x}{1 + 0.444 Pr^{2/3}} \right]^{2/5} \dots\dots\dots \text{turbulent}$$

$$(2) \quad Nu = 7.5 \text{ (for cylinder), } NU = 12.0 \text{ (for annulus)}$$

(3) Assuming the flow divider is adiabatic.

Flow Divider Thickness (in.)	T1 (°F) Inlet	T2 (°F) Bottom	T3 (°F) Outlet	T3 - T2 Temp. Recovery	T1 - T3 Heat Loss	h (Btu/hr-fr ² -°F) (Cylinder)	h Annulus	Remarks
0.375	300.	212	250	38	50	@ Bottom 124 350~1364	432~951	(1)
0.938	300.	224	247	23	53	@ Bottom 124 321~810	348~625	(1)
1.875	300.	231	245	14	55	@ Bottom 124 296~701	348~542	(1)
2.815	300.	234	244	10	56	@ Bottom 124 279~638	348~494	(1)
4.70	300.	237	244	7	56	@ Bottom 124 258~562	310~437	(1)
0.375	300.	228	246	18	54	124	432	(2)
0.375	300.	239	239	0	61			(3)

3.5 PERFORMANCE CALCULATIONS

3.5.1 Design Performance Calculations

The physical dimensions of the System 81 cold traps were determined using the thermal models described in Section 3.2. The design dimensions are summarized in Table 1, and the design performance summary is shown in Table 2. With a vertical flow separator 2 in. thick, steady-state temperatures calculated by the thermal model incorporating the natural convection effects are equivalent to the temperatures computed without natural convection effects. Therefore, the physical dimensions and performance predictions were made using the thermal model without the natural convection effects, since this model is less costly to run.

The IHTS cold trap design performances are shown in Figures 9 and 10. Figures 9 and 10 were calculated using the thermal model with and without the natural convection effects, respectively. These two performance curves are almost identical. The air flow rate required to meet the IHTS cold trap design conditions is 7000 scfm which is the upper limit on coolant flow rate specified in Reference 2.

The EVS cold trap design performance curves are shown in Figures 11 through 13. The EVS cold trap design performance summary is shown in Figure 14. A 4500 scfm nitrogen cooling flow rate is required to meet the design conditions.

The primary cold trap design performance is shown in Figure 15. The NaK flow rate required to meet the design conditions is 18000 lb/hr, which is 45% of the upper limit on the NaK flow rate specified in Reference 2. Because of this large design margin in the NaK flow rate and temperature recovery, the FFTF cold trap was able to cool the sodium at the design temperature of 230°F even though the economizer did not perform as expected in design.

FIG. 9 . ZHTS COLD TRAP PERFORMANCE (DESIGN CONDITION)

FIG. 10. IHTS COLD TRAP PERFORMANCE WITH NATURAL CONVECTION
(DESIGN CONDITION)

FIG. 11 EVS COLD TRAP PERFORMANCE (DESIGN CONDITION, 4000 SCFH)

FIG. 12 EVS COLD TRAP PERFORMANCE (DESIGN CONDITION, 5000 SCFH)

CASE NO. 2

HE FLOW RATE 5000 SCFH

180.0 CARBON STEEL FINS

TAP - 44

071217-25

04/12/77

041277 0002

FIG. 13 . EVS COLD TRAP PERFORMANCE (DESIGN CONDITION, 6000 SCFH)

FIG. 15 PRIMARY COLD TRAP PERFORMANCE (DESIGN CONDITION)

3.5.2 Operating Conditions

All the operating conditions for the Type I and II cold traps are summarized in Table 3. Steady-state temperature calculations were made to determine the coolant flow rate required to meet the operating conditions specified in Reference 2. Results are shown in Figures 16 through 35.

3.6 PRESSURE DROP CALCULATIONS

Pressure drop calculations were made for the sodium, the NaK, and gas flows. All the coolants (NaK, air, and N_2) pressure drop calculations were carried out based on the maximum flow rates specified in Reference 2. The results are shown in Tables 2 and 3, and the detailed calculations are in Appendix B.

The pressure drops meet the requirements of the E-spec⁽²⁾ for a clean trap. Actually, the flow velocities through the economizer and crystallizer are so low that most of the pressure drop comes from entrance and exit losses due to fluid momentum changes. In the calculations, the loss factor K for entrance and exit losses are given conservative values. The pressure drop through the crystallizer mesh was estimated based on experimental data obtained with water passing through a wire mesh.⁽⁶⁾ The detailed calculations are shown in Appendix B.

3.7 SODIUM RESIDENCE TIME

Residence time calculations were made for the economizer and the crystallizer for the design sodium flow rate (60 gpm). The results are shown in Table 2, and the detailed calculations are presented in Appendix C. Results indicate that the present design meets the residence time requirements specified in Reference 2.

FIG. 16 IHTS COLD TRAP NORMAL OPERATING CONDITION (4000 SCFM)

FIG. 17 IHTS COLD TRAP NORMAL OPERATING CONDITION (5000 SCFH)

FIG. 18. IHTS COLD TRAP NORMAL OPERATING CONDITION (6000 SCFH)

FIG. 20. EVS COLD TRAP NORMAL OPERATING CONDITION (2000 SCFH)

FIG. 21 EVS COLD TRAP NORMAL OPERATING CONDITION (3000 SCFH)

FIG. 22. EVS COLD TRAP NORMAL OPERATING CONDITION (4000 SCFM)

FIG. 24 EVS COLD TRAP REFUELING CONDITION (1000 SCFH)

FIG. 25 EVS COLD TRAP REFUELING CONDITION (2000 SCFH)

NE FLOW RATE 2000 SCFH

TAP - 44

07717217-45

180.0 CARBON STEEL FINS

04/21/77

042577 0002

CASE NO. 2

TEMPERATURE (DEGREES F.)

FIG. 26 EVS COLD TRAP REFUELING CONDITION (3000 SCFH)

FIG. 28 PRIMARY COLD TRAP NORMAL OPERATING CONDITION (NAK 12000 $\frac{L^3}{HR}$)

FIG. 29 PRIMARY COLD TRAP NORMAL OPERATING CONDITION (NAK 15000 ⁴⁵-2)

FIG. 30 PRIMARY COLD TRAP NORMAL OPERATING CONDITION (NAX 14000 $\frac{lb}{hr}$)

FIG. 32 PRIMARY COLD TRAP CLEAN-UP CONDITION (NAK 12000 LB/HR)

FIG. 33 PRIMARY COLD TRAP CLEAN-UP CONDITION (NAK 14000 LB/HR)

FIG. 34 PRIMARY COLD TRAP CLEAN-UP CONDITION (NAK 16000 ⁵/₂)

3.8 COMPONENT STRUCTURAL TEMPERATURE CALCULATIONS

Temperature data at a number of critical sections of the structure were generated to assess the magnitude of the thermal stress. The temperature calculations were made by setting up nodal thermal models for use with the TAP programs.⁽¹⁾ Since transient thermal data were not available, only steady-state temperature calculations were made. Further efforts will be required to investigate the effects of the thermal transients on the components.

Thermal models were developed for the following critical sections:

- 1) The junction of the inlet nozzle and the economizer head.
- 2) The junction of the upper tubesheet and the economizer shell.
- 3) The junction of the upper tubesheet and the economizer tube.
- 4) The junction of the bellows support and the flow divider.
- 5) The junction of the economizer shell and the crystallizer upper head (two models for Types I and II).

These component models were generated assuming that the cold traps were completely insulated. The boundary sodium temperatures were calculated using the thermal model described in Section 3.2 and on the basis of the cold trap design conditions which generate temperature gradients larger than for the operating conditions.

The nodal maps and the structural steady-state temperatures are shown in Appendix D. These data were informally transmitted to the Stress Unit. The parameter calculations are shown in Appendix E.

The axial temperature differences for the economizer shell, economizer tubes, crystallizer tank wall, fins, and the vertical flow separator in the crystallizer were generated using the thermal models described in Section 3.2. The steady-state temperatures are shown in Appendix D.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Since the FFTF cold trap crystallizer simulation predicted reasonably conservative temperatures and the physical dimensions of the cold trap were determined using conservative heat transfer correlations, the performances predicted in this analysis will be reasonably conservative.

Thermal and hydraulic analyses have been performed on the basis of ignoring the presence of the stainless steel wire mesh, and also assuming that the cold traps are free from impurities. The wire mesh has a considerably large surface area (about 49,700 ft² for the Type II cold trap), which may affect sodium flow distribution and heat transfer in the crystallizer. The past experience revealed that the major difficulty in use of the cold trap was plugging in a localized region before reaching the design capacity of the trap. Further study might be required to investigate the effects of the wire mesh combined with the impurities on the temperature and flow distributions.

The air flow rate required to meet the design conditions of the IHTS cold trap is 7000 scfm which is the upper limit on the flow rate specified in the E-spec.⁽²⁾ Considering uncertainties in analysis, increasing the upper limit on the air flow rate by at least 10~20% is recommended.

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REQUESTED OPTIONS:

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(42) SIZE(MAX) AUTODBL(NONE)
 SOURCE FBCDIC HOLIST NODDECK OBJECT MAP NOFORMAT GOSTMT NOXREF ALG NOANSF NOTERM FLAG(1)

ISN 0002	SUBROUTINE SUB9B	00000170
ISN 0003	IMPLICIT REAL(I-N)	00000175
ISN 0004	DIMENSION T(1500),Y(4500),U(1500),D(3000),C(1500)	00000180
ISN 0005	COMMON Z7(24132)	00000190
ISN 0006	EQUIVALENCE (Z7(1),TIME),(Z7(2),D(1)), (Z7(3002),Y(1)),	00000200
	1 (Z7(7502),T(1)), (Z7(10502),C(1)), (Z7(12002),U(1)),	00000210
	1 (Z7(18024),DTHETA), (D(1),TOLEN), (D(2),NLENG),	00000220
	1 (D(3),NUMOD), (D(4),ADIV1), (D(5),IDDIV), (D(6),NOFIN),	00000230
	1 (D(7),MFLOW), (D(8),TOMAS), (D(9),RECYL), (D(10),NUSUD),	00000240
	1 (D(11),HODIV1), (D(12),KSUD), (D(13),HANUI), (D(14),IDWAL),	00000250
	1 (D(15),ODDIV), (D(16),KSS), (D(17),HWALI), (D(18),ADOME),	00000260
	1 (D(19),ADUMET), (D(20),THFIN), (D(21),ODWAL), (D(22),PERGS),	00000270
	1 (D(23),IDINS), (D(24),ODINS), (D(25),AGAS), (D(26),HUFIN),	00000280
	1 (D(27),DHGAS), (D(28),REGAS), (D(29),NUGAS), (D(30),HGAS),	00000290
	1 (D(31),KGAS), (D(32),PRGAS), (D(33),KCS), (D(34),KINS),	00000300
	1 (D(41),AINS0), (D(42),ARADW), (D(43),ARADF), (D(44),CPSUD),	00000310
	1 (D(45),CPGAS), (D(46),TGFLOW), (D(47),N), (D(48),NLUGS),	00000320
	1 (D(49),OLDSN), (D(50),PRSUD), (D(38),GFLOW),	00000325
	1 (D(51),ATUBE), (D(52),NUTUB), (D(53),ASHEL), (D(54),IDSHEL),	00000330
	1 (D(55),UDTUBF), (D(56),IDTUBE), (D(57),RETUB), (D(58),DHSHEL),	00000340
	1 (D(59),RESHEL), (D(60),HTUBE), (D(61),HSHEL), (D(62),ACUTI),	00000350
	1 (D(63),ACITU), (D(64),NLENG1), (D(65),IDIS), (D(66),ODIS),	00000360
	1 (D(67),ARADS), (D(68),AINSUE), (D(69),UDSHEL), (D(70),TOLENE),	00000370
	1 (D(71),HOMODE), (D(72),KSSE), (D(73),KSODE)	00000380
ISN 0007	EQUIVALENCE (D(74),AEC(1), (D(75),ABAF), (D(76),UAECL),	00000381
	1 (D(77),UABAF), (D(78),UECO), (D(79),UBAF)	00000382
ISN 0008	N=N+1.0	00001010
ISN 0009	IF (H.GT.1.0) GO TO 100	00001020
ISN 0011	NLENG=TOLEN/HOMOD	00001100
ISN 0012	ADIV1=3.1416*IDDIV*NLENG/HOFIN	00001110
ISN 0013	ADIV0=3.1416*IDDIV*NLENG/HOFIN	00001115
ISN 0014	MFLOW=TOMAS/HOFIN	00001120
ISN 0015	RECYL=MFLOW*IDDIV/(3.1416*IDDIV**2/4.0/HOFIN)/NUSUD	00001130
ISN 0016	HODIV1=5.0*KSUD/IDDIV	00001140
ISN 0017	HANUI=5.5*KSUD/(IDWAL-(IDDIV)	00001150

1. TYPE II. COLD TRAP THERMAL MODEL LISTINGS
 APPENDIX A LISTINGS OF THERMAL MODELS

ISN 0018	Y(231)=ADIV)*HDIV	00001160
ISN 0019	Y(201)=ADIV)*HANUI	00001165
ISN 0020	HWALI=5.5*KSD/(IDWAL-IDDIV)	00001170
ISN 0021	ADIME=ADHET/HOFIN*0.0417	00001180
ISN 0022	Y(501)=HWALI*ADIME	00001190
ISN 0023	Y(531)=Y(501)	00001200
ISN 0024	Y(561)=Y(531)	00001210
ISN 0025	Y(509)=HWALI*(3.1416*IDWAL/HOFIN-THFIN)*0.5*NLENG	00001220
ISN 0026	Y(539)=HWALI*THFIN*NLENG	00001230
ISN 0027	Y(569)=Y(509)	00001240
ISN 0028	Y(701)=KSS*0.5*(IDWAL-IDWAL)*NLENG/(3.1416*IDWAL/HOFIN/4.0)	00001250
ISN 0029	Y(731)=Y(701)	00001260
ISN 0030	Y(601)=(3.1416*IDWAL/HOFIN-THFIN)/2.0*NLENG/(IDWAL-IDWAL)*2.0*KSS	00001270
ISN 0031	Y(631)=(THFIN*NLENG)/(IDWAL-IDWAL)*2.0*KSS	00001280
ISN 0032	Y(661)=Y(601)	00001290
ISN 0033	Y(881)=Y(701)	00001300
ISN 0034	Y(911)=Y(731)	00001310
ISN 0035	PERGS=3.1416*(IDWAL+IDINS)/HOFIN+2.0*HOFIN	00001320
ISN 0036	AGAS=3.1416/4.0*(IDINS**2-IDWAL**2)/HOFIN-THFIN	00001330
ISN 0037	DHGAS=4.0*AGAS/PERGS	00001340
ISN 0038	GFLW=TGFLW/HOFIN	00001345
ISN 0039	REGAS=GFLW*DHGAS/(AGAS*HUGAS)	00001350
ISN 0040	HGAS=KGAS/DHGAS*0.023*REGAS*0.0*PRGAS*0.4	00001360
ISN 0041	Y(1091)=ADIME*HGAS	00001365
ISN 0042	Y(1099)=(3.1416*IDWAL/HOFIN-THFIN)/2.0*NLENG*HGAS	00001370
ISN 0043	Y(1121)=THFIN*NLENG*HGAS	00001380
ISN 0044	Y(1189)=HOFIN*NLENG*HGAS	00001390
ISN 0045	Y(1219)=(HOFIN+THFIN)*NLENG*HGAS	00001400
ISN 0046	Y(1541)=(3.1416*IDINS*NLENG/HOFIN)*HGAS	00001410
ISN 0047	Y(821)=KCS*THFIN*NLENG*4.0/HOFIN	00001420
ISN 0048	Y(851)=Y(821)*0.5	00001430
ISN 0049	Y(1571)=(2.0*3.1416*NLENG*INS/ALOG(IDINS/IDINS))/HOFIN	00001440
ISN 0050	AINSI=(3.1416*IDINS)/HOFIN*NLENG	00001450
ISN 0051	ARADW=(3.1416*IDWAL/HOFIN-THFIN)*NLENG*0.5	00001460
ISN 0052	ARADF=(THFIN+HOFIN)*NLENG	00001470
ISN 0053	Y(161)=MFLW*CPSID	00001480
ISN 0054	Y(301)=GFLW*CPGAS	00001490
ISN 0055	NLENG=TUENE/NUMIDE	00001500
ISN 0056	ATURE=3.1416*IDTURE**2/4.0*NUITUR	00001510
ISN 0057	ASHEL=0.7986	00001520

```

1SN 0058      RETUB=(TOMAS*IDTUBE)/(ATUBE*NUSUD)                00001522
1SN 0059      DHSHEL=4.0*ASHEL/(3.1416*ODTUBE*NDTUB+6.0*0.7241) 00001524
1SN 0060      RESHEL=(TOMAS*DHSHEL)/(ASHEL*NUSUD)                00001525
1SN 0061      HTUBE=KSODE/IDTUBE*(5.0+0.025*(RETUB*PRSD))**0.8) 00001526
1SN 0062      HSHEL=KSODE/DHSHEL*(9.2170+0.03928*(RESHEL*PRSD))**0.7653) 00001527
1SN 0063      ACOTI=3.1416*IDTUBE*NDTUB*NLENGE/NOFIN             00001528
1SN 0064      ACOTI=3.1416*ODTUBE*NDTUB*NLENGE/NOFIN             00001530
1SN 0065      Y(2001)=1.0/(1.0/(HTUBE*ACOTI))+1.0/(HSHEL*ACOTI)+ALOG(IDTUBE/ 00001532
1IDTUBE)*NOFIN/(2.0*3.1416*NLENGE*KSSE*NDTUB))                00001534
1SN 0066      Y(2041)=1.0/(1.0/(HSHEL*3.1416*IDSHEL*NLENGE/NOFIN)+NOFIN* 00001536
1ALOG(ODSHEL/IDSHEL)/(4.0*3.1416*NLENGE*KSSE))                00001538
1SN 0067      Y(2841)=1.0/((NOFIN/(4.0*3.1416*NLENGE))*(ALOG(ODSHEL/IDSHEL)/ 00001540
1KSSE+2.0*ALOG(IDIS/ODSHEL)/KGAS))                             00001542
1SN 0068      Y(3041)=2.0*3.1416*NLENGE*KINS/ALOG(ODIS/IDIS)/NOFIN 00001545
1SN 0069      AINSIE=3.1416*ODIS*NLENGE/NOFIN                   00001547
1SN 0070      ARADS=3.1416*ODSHEL*NLENGE/NOFIN                  00001549
1SN 0071      AECD=0.5*(ACOTI+ACOTI)*NONODE*NOFIN               00001550
1SN 0072      ABAF=0.5*(ADIVI+ADIVI)*22.0*NOFIN                 00001552
1SN 0073      UAFCD=Y(2001)*NONODE*NOFIN                         00001554
1SN 0074      UABAF=NONUD*NOFIN/(1.0/Y(201)+1.0/Y(231)+1.0/Y(401)) 00001556
1SN 0075      UECD=UAFCD/AECD                                     00001558
1SN 0076      UBAF=UABAF/ABAF                                    00001560
1SN 0077      100 QLOGS=(T(330)-T(300))*TGFLOW*CPGAS             00001600
1SN 0078      QLOSD=(T(152)-T(131))*TOMAS*CPSUD                00001610
1SN 0079      RETURN                                             00001900
1SN 0080      END                                                 00001910

```

NO971811046
 Page 66

				/ SUB98 /				SIZE OF PROGRAM 000998 HEXADECIMAL BYTE					
NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	
C	CF	R*4	00A414	D	CE	R*4	000004	N	SF	CE	R*4	0000BC	U
T	F	CE	R*4	Y	SF	CE	R*4	22	CE	R*4	000000	CLS	
KSS	F	CE	R*4	ABAF	SF	CE	R*4	AECD	SF	CE	R*4	000128	AGAS
ALOG	F	XF	R*4	HGAS	SF	CE	R*4	IDIS	FA	CE	R*4	000104	KGAS
KINS	F	CE	R*4	KSUD	F	CE	R*4	KSSE	F	CE	R*4	000120	UDIS
TIME	CE	R*4	000000	UBAF	S	CE	R*4	UECD	S	CE	R*4	000138	ACOTI
ACOTI	SF	CE	R*4	ADIVI	SF	CE	R*4	ADIVI	SF		R*4	000194	ADIME
AINS	S	CE	R*4	ARAD	S	CE	R*4	ARADS	S	CE	R*4	00010C	ARADW
ASHEL	SF	CE	R*4	ATUBE	SF	CE	R*4	CPGAS	F	CE	R*4	0000B4	LPSUD

ALL NEW INPUT DATA FOR THIS RUN

TAP - 4H

06/02/77

CASE 1

* 1

00005000

*** STAR 001 - TITLES & STORED COMMENTS

1	INTS COLD TRAP	00005010
	DESIGN CONDITION	00005015
2	180.0 CARBON STEEL FINS	00005020
3	SODIUM INLET TEMP. TO THE ECONOMIZER 475.0 DEG.F	00005030
4	NUMBER OF TUBES 91	00005040
5	CRYSTALLIZER 130.0 IN.	00005050
6	ECONOMIZER TUBE 1.0 OD, 0.035 IN WALL THICK	00005060
7	EFFECTIVE ECONOMIZER LENGTH 39.0 IN	00005070
	SODIUM FLOW RATE 27500 LB/HR	00005100
	***** NU=CONSTANT *****	00005300
		00100000

* 10

*** STAR 010 - STATIC NETWORK DESCRIPTION

Y201	Y222	0	.0	.0	T122	T201	-1	1	1	00100201
Y231	Y252	0	.0	.0	T131	T231	1	1	1	00100231
Y401	Y422	0	.0	.0	T201	T231	1	1	1	00100401
Y501	Y530	0	.0	.0	T501	T130	1	-1	1	NA TO TANK WALL
Y531	Y560	0	.0	.0	T531	T130	1	-1	1	(INDISE)
Y561	Y590	0	.0	.0	T561	T130	1	-1	1	00100501
Y601	Y690	0	.0	.0	T501	T591	1	1	1	00100601
Y701	Y760	0	.0	.0	T501	T531	1	1	1	00100701
Y829	Y847	0	.0	.0	T629	T689	1	1	1	TANK WALL TO F1
Y859	Y877	0	.0	.0	T689	T719	1	1	1	FIN1 TO FIN2
Y881	Y940	0	.0	.0	T591	T621	1	1	1	00100801
I 91	I120	0	.0	.0	T591	T301	1	1	1	TANK WALL TO GAS
I121	I150	0	.0	.0	T621	T301	1	1	1	TANK WALL TO GAS
I151	I180	0	.0	.0	T651	T301	1	1	1	TANK WALL TO GAS
I189	I207	0	.0	.0	T689	T309	1	1	1	FIN1 TO GAS
I219	I237	0	.0	.0	T719	T309	1	1	1	FIN2 TO GAS
I391	I420	0	.0	.0	T591	T741	1	1	1	NAO
										00101391

1451	1480	0	.0	.0	1651	1741	1	1	1	RAD	00101451
1519	1537	0	.0	.0	1719	1749	1	1	1	RAD	00101511
1541	1570	0	.0	.0	1741	1301	1	1	1	INS TO GAS	00101541
1571	1600	0	.0	.0	1741	1771	1	1	1	INS(IN) TO OUT	00101571
1601	1630	0	.0	.0	1771	1999	1	0	1	RAD AMBIENT	00101601
1631	1660	0	.0	.0	1771	1999	1	0	1	CONV. AMBIENT	00101631
2 1	2 40	0	.0	.0	T 90	T153	-1	1	1	NA IN TO NA OUT	00102001
2 41	2 80	0	.0	.0	T 51	T801	1	1	1	NA TO SHELL	00102041
2841	2873	0	.0	.0	T801	T841	1	1	1	COND	00102841
2874	2880	0	.0	.0	T834	T 91	1	0	1		00102874
2891	0	0	.0	.0	T 91	T100	0	0	1		00102891
2892	2893	0	.0	.0	T 91	T910	9	1	1		00102892
2941	2973	0	.0	.0	T801	T841	1	1	1	RAD	00102941
2974	2975	0	.0	.0	T916	T874	1	1	1	RAD	00102974
2976	2977	0	.0	.0	T916	T874	1	1	1	COND.	00102976
3 41	3 75	0	.0	.0	T841	T881	1	1	1		00103041
3141	3175	0	.0	.0	T881	T999	1	0	1	RAD	00103141
3241	3275	0	.0	.0	T881	T999	1	0	1	CONV	00103241
* 11											00110000

*** STAR 011 - FLOW NETWORK DESCRIPTION

Y 51	Y 90	0	.0	.0	T 50	T 51	1	1	1		00110051
Y 91	Y 92	0	.0	.0	T 90	T 91	1	9	1		00110091
Y101	Y152	0	.0	.0	T100	T101	1	1	1	NA FLOW	00110101
Y153	Y192	0	.0	.0	T152	T153	1	1	1		00110153
Y301	Y330	0	.0	.0	T300	T301	1	1	1	GAS FLOW	00110301
* 20											00200000

*** STAR 020 - INITIALIZATION & CONSTANT DATA

T 50	0	-1	675.00	.0	0	0	0	0	1		00210050
T 51	T 90	0	675.00	-8.7500	0	0	0	0	1		00210051
T 91	0	0	290.00	.0	0	0	0	0	1		00210091
T100	T130	0	300.00	-2.3333	0	0	0	0	1		00210100
T131	T152	0	250.00	2.2700	0	0	0	0	1		00210131
T153	T192	0	250.00	8.7500	0	0	0	0	1		00210153
T201	T222	0	250.00	2.2700	0	0	0	0	1		00210201
T231	T252	0	250.00	2.2700	0	0	0	0	1		00210231
T300	0	-1	100.00	.0	0	0	0	0	1		00210300
T301	T330	0	100.00	2.0000	0	0	0	0	1		00210301

T501	T530	0	250.00	1.6670	0	0	0	0	1	00210501
T531	T560	0	250.00	1.6670	0	0	0	0	1	00210531
T561	T590	0	250.00	1.6670	0	0	0	0	1	00210561
T591	T620	0	200.00	2.3000	0	0	0	0	1	00210591
T621	T650	0	200.00	2.3000	0	0	0	0	1	00210621
T651	T680	0	200.00	2.3000	0	0	0	0	1	00210651
T681	T710	0	185.00	2.3000	0	0	0	0	1	00210681
T711	T740	0	165.00	2.3000	0	0	0	0	1	00210711
T741	T770	0	120.00	2.3000	0	0	0	0	1	00210741
T771	T800	0	105.00	2.3000	0	0	0	0	1	00210771
T801	T840	0	475.00	-4.8750	0	0	0	0	1	00210801
T841	T875	0	450.00	-4.8750	0	0	0	0	1	00210841
T881	T915	0	130.00	-5.0000	0	0	0	0	1	00210881
T916	T917	0	300.00	.0	0	0	0	0	1	00210916
T999	0	-1	100.00	.0	0	0	0	0	1	00210999
D 1	0	0	10.833	.0	0	0	0	0	1	00220010
D 3	0	0	30.000	.0	0	0	0	0	1	00220030
D 5	0	0	2.8540	.0	0	0	0	0	1	00220050
D 6	0	0	180.00	.0	0	0	0	0	1	00220060
D 8	0	0	27500.	.0	0	0	0	0	1	00220080
D 10	0	0	1.1000	.0	0	0	0	0	1	00220100
D 12	0	0	49.000	.0	0	0	0	0	1	00220120
D 14	0	0	4.5000	.0	0	0	0	0	1	00220140
D 15	0	0	3.1667	.0	0	0	0	0	1	00220150
D 16	0	0	9.4000	.0	0	0	0	0	1	00220160
D 19	0	0	26.722	.0	0	0	0	0	1	00220190
D 20	0	0	2.0833E-02	.0	0	0	0	0	1	00220200
D 21	0	0	4.6042	.0	0	0	0	0	1	00220210
D 23	0	0	4.9792	.0	0	0	0	0	1	00220230
D 24	0	0	5.6250	.0	0	0	0	0	1	00220240
D 26	0	0	.16667	.0	0	0	0	0	1	00220260
D 29	0	0	5.7400E-02	.0	0	0	0	0	1	00220290
D 31	0	0	2.0300E-02	.0	0	0	0	0	1	00220310
D 32	0	0	.68100	.0	0	0	0	0	1	00220320
D 33	0	0	33.000	.0	0	0	0	0	1	00220330
D 34	0	0	4.5000E-02	.0	0	0	0	0	1	00220340
D 35	0	0	.0	.0	0	0	0	0	1	00220350
D 36	0	0	.19000	.0	0	0	0	0	1	00220360
D 37	0	0	.33330	.0	0	0	0	0	1	00220370
D 44	0	0	.32500	.0	0	0	0	0	1	00220440
D 45	0	0	.24000	.0	0	0	0	0	1	00220450
D 46	0	0	29763.	.0	0	0	0	0	1	00220460
D 50	0	0	5.5000E-03	.0	0	0	0	0	1	00220500

AT 280 F

AT 280 F

0.25 GAP TIPIN

D 52	0	0	91.000	.0	0	0	0	0	1	00220520
D 54	0	0	1.6000	.0	0	0	0	0	1	00220540
D 55	0	0	8.3330E-02	.0	0	0	0	0	1	00220550
D 56	0	0	7.7500E-02	.0	0	0	0	0	1	00220560
D 65	0	0	1.7875	.0	0	0	0	0	1	00220650
D 66	0	0	2.4542	.0	0	0	0	0	1	00220660
D 68	0	0	1.7250	.0	0	0	0	0	1	00220680
D 69	0	0	1.7250	.0	0	0	0	0	1	00220690
D 70	0	0	3.2500	.0	0	0	0	0	1	00220700
D 71	0	0	40.000	.0	0	0	0	0	1	00220710
D 72	0	0	10.100	.0	0	0	0	0	1	00220720
D 73	0	0	46.285	.0	0	0	0	0	1	00220730
D704	0	0	55.000	.0	0	0	0	0	1	00227640
D705	0	0	6.5000E-02	.0	0	0	0	0	1	00227050
D711	0	0	31.480	.0	0	0	0	0	1	00227110
D712	0	0	5.1754	.0	0	0	0	0	1	00227120
Y401	0	0	1.1034	.0	0	0	0	0	1	00230010
* 30										00300000

AT 450 F
AT 450 F

*** STAR 030 - FUNCTION STATEMENTS

1 D999	0	98	.0	1.0000	0	0	0	0	1	00310010
2 D998	0	191	.0	1.0000	0	0	0	0	1	00310011
3 Y 51 Y 92	101		.0	1.0000	Y101	0	0	0	1	00310012
4 Y153 Y192	101		.0	1.0000	Y101	0	0	0	1	00310015
5 2 2 2 40	101		.0	1.0000	2 1	0	0	0	1	00310020
6 2 42 2 80	101		.0	1.0000	2 41	0	0	0	1	00310030
7 2842 2873	101		.0	1.0000	2841	0	0	0	1	00310040
8 2874 2880	101		.0	1.0000	2 74	0	0	0	1	00310050
9 2941 2973	49		.0	.36360	0 D 67	0	0	0	1	00310060
10 2974 2975	1		.0	10.000	2941	0	0	0	1	00310070
11 2976 2977	101		.0	10.000	2841	0	0	0	1	00310075
12 3 42 3 73	101		.0	1.0000	3 41	0	0	0	1	00310080
13 3 74 3 75	101		.0	10.000	3 41	0	0	0	1	00310090
14 3141 3173	49		.0	.80000	0 D 68	0	0	0	1	00310100
15 3174 3175	1		.0	10.000	3141	0	0	0	1	00310110
16 F241 F275	66		.0	.19000	3241 D 37	1	0	0	1	00310120
17 3241 3275	52		.0	1.0000	F241 D 68	1	0	0	1	00310130
18 3274 3275	1		.0	10.000	3274	0	1	0	1	00310140
19 2891	0	1	.0	2.3833	2 41	0	0	0	1	00310150
20 2892 2893	101		.0	10.000	2 41	0	0	0	1	00310160
21 Y502 Y508	101		.0	1.0000	Y501	0	0	0	1	00320010

22	Y510	Y530	101	.0	1.0000	Y509	0	0	0	1	00320020
23	Y532	Y538	101	.0	1.0000	Y531	0	0	0	1	00320030
24	Y540	Y560	101	.0	1.0000	Y539	0	0	0	1	00320040
25	Y561	Y590	101	.0	1.0000	Y501	0	1	0	1	00320050
26	Y602	Y630	101	.0	1.0000	Y601	0	0	0	1	00320060
27	Y632	Y660	101	.0	1.0000	Y631	0	0	0	1	00320070
28	Y661	Y690	101	.0	1.0000	Y601	0	1	0	1	00320080
29	Y702	Y730	101	.0	1.0000	Y701	0	0	0	1	00320090
30	Y732	Y760	101	.0	1.0000	Y731	0	0	0	1	00320100
31	Y762	Y782	101	.0	1.0000	Y761	0	0	0	1	00320110
32	Y822	Y850	101	.0	1.0000	Y821	0	0	0	1	00320120
33	Y852	Y880	101	.0	1.0000	Y851	0	0	0	1	00320130
34	1 92	1 98	101	.0	1.0000	1 91	0	0	0	1	00320140
35	1 99	1120	101	.0	1.0000	1 99	0	0	0	1	00320150
36	1122	1128	101	.0	1.0000	1121	0	0	0	1	00320160
37	1147	1150	101	.0	1.0000	1121	0	0	0	1	00320170
38	1151	1180	101	.0	1.0000	1 91	0	1	0	1	00320180
39	Y881	Y910	101	.0	1.0000	Y761	0	0	0	1	00320190
40	Y911	Y940	101	.0	1.0000	Y701	0	0	0	1	00320200
41	1190	1208	101	.0	1.0000	1189	0	0	0	1	00320210
42	1220	1238	101	.0	1.0000	1219	0	0	0	1	00320220
43	1542	1570	101	.0	1.0000	1541	0	0	0	1	00320230
44	1572	1600	101	.0	1.0000	1571	0	0	0	1	00320240
45	F 1	F 30	66	.0	.19000	1631	D 37	1	0	1	00320250
46	1631	1638	52	.0	1.0000	D 18	F 1	0	1	1	00320260
47	1639	1660	52	.0	1.0000	D 41	F 9	0	1	1	00320265
48	1391	1420	49	.0	.12500	0 D 42	0	0	0	1	00320270
49	1451	1460	1	.0	1.0000	1391	0	1	0	1	00320280
50	1511	1540	49	.0	.12500	0 D 42	0	0	0	1	00320290
51	1601	1608	49	.0	.80000	0 D 18	0	0	0	1	00320300
52	1609	1630	49	.0	.80000	0 D 41	0	0	0	1	00320305
53	Y102	Y152	101	.0	1.0000	Y101	0	0	0	1	00320310
54	Y302	Y330	101	.0	1.0000	Y301	0	0	0	1	00320320
55	E 2	E 41	150	.0	1.0000	E 1	D 64	1	0	1	00330010
56	E 42	E 71	150	.0	1.0000	E 41	D 2	1	0	1	00330020
57	E 1	E 71	161	.0	12.000	F 1	0	1	0	1	00330025
58	E100	E140	1	.0	1.0000	1 50	0	1	0	1	00330030
59	E141	E170	1	.0	1.0000	T101	0	1	0	1	00330040
60	E200	E261	1	.0	1.0000	T192	0	-1	0	1	00330050
61	E300	E330	1	.0	1.0000	T330	0	-1	0	1	00330060
62	Y202	Y222	101	.0	1.0000	Y201	0	0	0	1	00330070
63	Y232	Y252	101	.0	1.0000	Y231	0	0	0	1	00330080
64	Y402	Y422	101	.0	1.0000	Y401	0	0	0	1	00330090

DIST. FROM TOP E
 CRYSI.
 TEMP. NA DOWN
 FLUX
 NA, UPFLUX
 GAS

65	E401	F440	55	.0	1.0000	T192 T 51	-1	1	1	TUBE TEMP.	00330100
66	F501	F522	55	.0	1.0000	T201 T231	1	1	1	F BAFFLE TEMP.	00330110
67	1	0	93	.0	71.000	E100 E 1	1	1	1	NA. DOWN FLOW	00340010
68	2	0	93	.0	62.000	E200 E 2	1	1	1	NA. UPFLOW	00340020
69	3	0	93	.0	30.000	E300 E 42	1	1	1	GAS.	00340030
* 60											00600000

*** STAR 060 - VARIABLE PLOT CRT DATA

PLOT 1, Y AXIS LABEL IS	TEMPERATURE (DEG.F)	WITH LIMITS OF	0.0	0.0	00610010
PLOT 1, X AXIS LABEL IS	DIST. FROM TOP(IN.)	WITH LIMITS OF	0.0	0.0	00610020
PLOT 1, CURVE NO. 1 LABEL IS	NA DOWN				00610030
PLOT 1, CURVE NO. 2 LABEL IS	NA UP				00610040
PLOT 1, CURVE NO. 3 LABEL IS	GAS UP				00610050

*** STAR 070 - SPECIAL CONTROL CONSTANTS

4	5.0000E-04	CONVERGENCE TEST ON RATE OF TEMPERATURE CHANGE	00710040
5	1.0000	0. = TRANSIENT; +1. = STEADY STATE	00710050
6	1.0000	+1. = DUMP DYTCH AT END OF CASE	00710060
9	1.7140E-09	STEFAN-BOLTZMANN CONSTANT	00710090
15	1.0000	+1.0 FOR 100 SERIES EVAL. AT END OF RUNS	00710150
* 80			00800000

*** STAR 080 - PRINTOUT SPECIFICATIONS

D 1 D 79	0	.0	.0	0	0	0	0	1	00810010
D701 D714	0	.0	.0	0	0	0	0	1	00810011
T 50 T 90	0	.0	.0	0	0	0	0	4	00810017
T100 T192	0	.0	.0	0	0	0	0	4	00810020
T201 T222	0	.0	.0	0	0	0	0	3	00810022
T231 T252	0	.0	.0	0	0	0	0	3	00810025
T300 T330	0	.0	.0	0	0	0	0	3	00810030
T505 T915	0	.0	.0	0	0	0	0	5	00810040
* 90									00900000

*** STAR 090 - PRINTOUT & STOP TIMES

0	0	0	.0	10.000	0	0	0	0	1
0	0	0	100.00	50.000	0	0	0	0	1
0	0	0	1000.0	100.00	0	0	0	0	1
0	0	0	3000.0	.0	0	0	0	0	1

* 99

00910010
00910020
00910030
00910040
99999999

*** ELAPSED CPU TIME FOR INPUT = 5. SEC ***

REQUESTED OPTIONS:

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(42) SIZE(MAX) AUTOHPL(NONE)
 SOURCE ERCDIC NOLIST NODACK OBJECT MAP NOFORMAT GUSTNT NOXREF ALC NOANSF NOTERMAL FLAG(1)

ISN 0002	SUBROUTINE SUB98	00000170
ISN 0003	IMPLICIT REAL(1,K-N)	00000175
ISN 0004	DIMENSION T(1500),Y(4500),Q(1500),D(3000),C(1500)	00000180
ISN 0005	DIMENSION HI(30),GR(30),FL(30),X(30),DELT1(30),DELTU(30)	00000182
ISN 0006	DIMENSION HO(30),GRAN(30),FLAN(30),HUP(30),UDUWN(30),	00000183
	1 HTUP(30),HTDU(30),XAN(30),HUP(30),MDU(30)	00000184
ISN 0007	COMMON ZZ(24132)	00000190
ISN 0008	EQUIVALENCE (ZZ(1),TIME),(ZZ(2),D(1)), (ZZ(3002),Y(1)),	00000200
	1 (ZZ(7502),T(1)), (ZZ(10502),C(1)), (ZZ(12002),Q(1)),	00000210
	1 (ZZ(18624),DTHETA), (D(1),TULEN), (D(2),NLENG),	00000220
	1 (D(3),NONOD), (D(4),ADIVI), (D(5),IDDIV), (D(6),HUFIN),	00000230
	1 (D(7),MFLOW), (D(8),TOMAS), (D(9),RECYL), (D(10),NUSOD),	00000240
	1 (D(11),HODIV), (D(12),KSOD), (D(13),HANUI), (D(14),IDWAL),	00000250
	1 (D(15),ODDIV), (D(16),KSS), (D(17),HWALI), (D(18),ADOME),	00000260
	1 (D(19),ADOMET), (D(20),THFIN), (D(21),ODWAL), (D(22),PERGS),	00000270
	1 (D(23),IDINS), (D(24),ODINS), (D(25),AGAS), (D(26),HUFIN),	00000280
	1 (D(27),DHGAS), (D(28),REGAS), (D(29),NUGAS), (D(30),HGAS),	00000290
	1 (D(31),KGAS), (D(32),PRGAS), (D(33),KCS), (D(34),KINS),	00000300
	1 (D(41),AINSU), (D(42),ARADW), (D(43),ARADF), (D(44),CPSOD),	00000310
	1 (D(45),CPGAS), (D(46),IGFLOW), (D(47),N), (D(48),QLUGS),	00000320
	1 (D(49),QLUSO), (D(50),PRSOD), (D(51),GFLOW), (D(52),REAN),	00000325
	1 (D(51),ATUBE), (D(52),MUTUB), (D(53),ASHEL), (D(54),IDSHEL),	00000330
	1 (D(55),ODTUBE), (D(56),IDTUBE), (D(57),RE TUB), (D(58),DUSHEL),	00000340
	1 (D(59),RESHEL), (D(60),HTUBE), (D(61),HSHEL), (D(62),ACUT1),	00000350
	1 (D(63),ACUT0), (D(64),NLENGE), (D(65),IDIS), (D(66),IDIS),	00000360
	1 (D(67),ARADS), (D(68),AINSUE), (D(69),IDSHEL), (D(70),TULENE)	00000370
ISN 0009	EQUIVALENCE (D(71),NONODE), (D(72),KSSE), (D(73),KSODE),	00000380
	1 (D(101),GR(1)), (D(131),FL(1)), (D(161),HI(1)), (D(191),HO(1)),	00000390
	1 (D(221),GRAN(1)), (D(251),FLAN(1)), (D(281),HUP(1)),	00000400
	1 (D(311),UDUWN(1)), (D(341),HTUP(1)), (D(371),HTDU(1)),	00000410
	1 (D(401),DELTU(1)), (D(431),XAN(1)), (D(501),X(1)),	00000420
	1 (D(531),VUP), (D(532),VDU), (D(533),ABTU), (D(534),ABTD),	00000430
	1 (D(601),HUP(1)), (D(631),MDU(1)), (D(801),DELT1(1))	00000440
ISN 0010	N=N+1.0	00001010
ISN 0011	IF(N.GT.1.0) GO TO 100	00001020

2. SUBROUTINE CALCULATING NATURAL CONVECTION EFFECTS

ISN 0013	NLENG=TOLEN/NOINOD	00001100
ISN 0014	ADIVI=3.1416*IDDIV*NLENG/HOFIN	00001110
ISN 0015	ADIVO=3.1416*ODDIV*NLENG/HOFIN	00001112
ISN 0016	MFLOW=TMAS/HOFIN	00001120
ISN 0017	RECYL=MFLOW*IDDIV/(3.1416*IDDIV**2/4.0/HOFIN)/NUSOD	00001130
ISN 0018	REAN=TMAS/0.7854/(IDWAL+ODDIV)/NUSOD	00001135
ISN 0019	HODIV=8.0*KSD/IDDIV	00001140
ISN 0020	HANUI=12.0*KSD/(IDWAL-ODDIV)	00001150
ISN 0021	HWALI=5.5*KSD/(IDWAL-ODDIV)	00001170
ISN 0022	ADOME=ADOMET/HOFIN*0.0417	00001175
ISN 0023	TRES=0.03125/(KSS*ADIVI)+0.03125/(KSS*ADIVO)+0.0833/((ADIVI+ADIVO)*1/2.0*3.5*KSD)	00001180
ISN 0024	Y(501)=HWALI*ADOME	00001182
ISN 0025	Y(531)=Y(501)	00001190
ISN 0026	Y(561)=Y(531)	00001200
ISN 0027	Y(509)=HWALI*(3.1416*IDWAL/HOFIN-THFIN)*0.5*NLENG	00001210
ISN 0028	Y(539)=HWALI*THFIN*NLENG	00001220
ISN 0029	Y(569)=Y(509)	00001230
ISN 0030	Y(701)=KSS*0.5*(ODWAL-IDWAL)*NLENG/(3.1416*IDWAL/HOFIN/4.0)	00001240
ISN 0031	Y(731)=Y(701)	00001250
ISN 0032	Y(601)=(3.1416*IDWAL/HOFIN-THFIN)/2.0*NLENG/(ODWAL-IDWAL)*2.0*KSS	00001260
ISN 0033	Y(631)=(THFIN*NLENG)/(ODWAL-IDWAL)*2.0*KSS	00001270
ISN 0034	Y(661)=Y(601)	00001280
ISN 0035	Y(881)=Y(701)	00001290
ISN 0036	Y(911)=Y(731)	00001300
ISN 0037	PERGS=3.1416*(ODWAL+IDINS)/HOFIN+2.0*HOFIN	00001310
ISN 0038	AGAS=3.1416/4.0*(IDINS**2-IDWAL**2)/HOFIN-HOFIN*THFIN	00001320
ISN 0039	DHGAS=4.0*AGAS/PERGS	00001330
ISN 0040	GFLOW=TFLOW/HOFIN	00001340
ISN 0041	REGAS=GFLOW*DHGAS/(AGAS*HUGAS)	00001345
ISN 0042	HGAS=KGAS/DHGAS*0.023*REGAS*0.8*PRGAS*0.4	00001350
ISN 0043	Y(1091)=ADOME*HGAS	00001360
ISN 0044	Y(1099)=(3.1416*ODWAL/HOFIN-THFIN)/2.0*NLENG*HGAS	00001365
ISN 0045	Y(1121)=THFIN*NLENG*HGAS	00001370
ISN 0046	Y(1189)=HOFIN*NLENG*HGAS	00001380
ISN 0047	Y(1219)=(HOFIN+THFIN)*NLENG*HGAS	00001390
ISN 0048	Y(1541)=(3.1416*IDINS*NLENG/HOFIN)*HGAS	00001400
ISN 0049	Y(821)=KCS*THFIN*NLENG*4.0/HOFIN	00001410
ISN 0050	Y(851)=Y(821)*0.5	00001420
ISN 0051	Y(1571)=(2.0*3.1416*NLENG*KINS/ALOG(ODINS/IDINS))/HOFIN	00001430
		00001440

ISN 0052	AINSD=(3.1416*ODINS)/NOFIN*NLENG	00001450
ISN 0053	ARADW=(3.1416*ODWAL/NOFIN*(HFIN)*NLENG*0.5	00001460
ISN 0054	ARADF=(THFIN+HOFIN)*NLENG	00001470
ISN 0055	Y(101)=MFLOW*CPSSD	00001480
ISN 0056	Y(301)=GFLOW*CPGAS	00001490
ISN 0057	NLENGE=TOLENE/NOHOF	00001500
ISN 0058	ATUBE=3.1416*IDTUBE**2/4.0*NOTUB	00001510
ISN 0059	ASHEL=3.1416/4.0*(IDSHEL**2-ODTUBE**2*NOTUB)	00001520
ISN 0060	RETUB=(TOMAS*IDTUBE)/(ATUBE*NUSSD)	00001522
ISN 0061	DHSHEL=4.0*ASHEL/(3.1416*(IDSHEL+ODTUBE*NOTUB))	00001524
ISN 0062	RESHEL=(TOMAS*DHSHEL)/(ASHEL*NUSSD)	00001525
ISN 0063	HTUBE=KSODE/IDTUBE*(5.0+0.025*(RETUB*PRSD)**0.8)	00001526
ISN 0064	HSHFL=KSODE/DHSHEL*(15.75+0.073*(RESHEL*PRSD)**0.74)	00001527
ISN 0065	ACOTI=3.1416*IDTUBE*NOTUB*NLENG/NOFIN	00001528
ISN 0066	ACOTU=3.1416*ODTUBE*NOTUB*NLENG/NOFIN	00001530
ISN 0067	Y(2001)=1.0/(1.0/(HTUBE*ACOTI)+1.0/(HSHFL*ACOTU)+ALOG(ODTUBE/	00001532
	IDTUBE)*NOFIN/(2.0*3.1416*NLENG*KSSE*NOTUB))	00001534
ISN 0068	Y(2041)=1.0/(1.0/(HSHFL*3.1416*IDSHEL*NLENG/NOFIN)+NOFIN*	00001536
	1ALOG(ODSHEL/IDSHEL)/(4.0*3.1416*NLENG*KSSE))	00001538
ISN 0069	Y(2041)=1.0/((NOFIN/(4.0*3.1416*NLENG))*ALOG(ODSHEL/IDSHEL)/	00001540
	1KSSE+2.0*ALOG(IDIS/ODSHEL)/KGAS))	00001542
ISN 0070	Y(3041)=2.0*3.1416*NLENG*KINS/ALOG(ODIS/IDIS)/NOFIN	00001545
ISN 0071	AINSD=3.1416*ODIS*NLENG/NOFIN	00001547
ISN 0072	ARADS=3.1416*ODSHFL*NLENG/NOFIN	00001549
ISN 0073	X(1)=NLENG/2.0	00001560
ISN 0074	DO 5 J=2,30	00001570
ISN 0075	5 X(J)=X(J-1)+NLENG	00001580
ISN 0076	100 QLOG9=(T(330)-T(300))*TGFLOW*CPGAS	00001600
ISN 0077	QLIISD=(T(152)-T(131))*TOMAS*CPSSD	00001610
ISN 0078	DO 90 J=1,22	00001710
ISN 0079	XAN(J)=X(23-J)	00001712
ISN 0080	IF(DELT(I(J)) 10,10,20	00001720
ISN 0081	10 GR(J)=0.0	00001730
ISN 0082	HI(J)=HDIIV	00001740
ISN 0083	UUP(J)=0.0	00001750
ISN 0084	BTUP(J)=0.0	00001760
ISN 0085	GO TO 200	00001780
ISN 0086	20 GR(J)=1.09E08*X(J)**3*DELT(I(J)	00001790
ISN 0087	UUP(J)=99.996*DELT(I(J)**0.5*X(J)**0.5	00001795
ISN 0088	BTUP(J)=0.4046/DELT(I(J)**0.25*X(J)**0.25	00001797

ISN 0089	FL(J)=GR(J)/RECYL**2	00001800
ISN 0090	IF(GR(J)-4.0E08) 30,30,35	00001810
ISN 0091	30 HI(J)=241.0/X(J)**0.25*(DELTI(J))**0.25	00001820
ISN 0092	GO TO 40	00001830
ISN 0093	35 HI(J)=258.56*X(J)**0.2*(DELTI(J))**0.4	00001840
ISN 0094	40 IF(GR(J).GT.3.0E08.AND.GR(J).LT.5.0E08) HI(J)=(241.0/X(J)**0.25	00001842
	1 *DELTI(J)**0.25+258.56*X(J)**0.2*DELTI(J)**0.4)/2.0	00001845
ISN 0096	IF(FL(J).LE.1.0) HI(J)=HDI	00001850
ISN 0098	200 IF(DELTO(J)) 110,110,120	00001860
ISN 0099	110 GRAN(J)=0.0	00001870
ISN 0100	HO(J)=HANOI	00001880
ISN 0101	UDOWN(J)=0.0	00001890
ISN 0102	BTDO(J)=0.0	00001900
ISN 0103	GO TO 50	00001910
ISN 0104	120 GRAN(J)=1.09E08*XAN(J)**3*DELTO(J)	00001920
ISN 0105	UDOWN(J)=99.996*DELTO(J)**0.5*XAN(J)**0.5	00001930
ISN 0106	BTDO(J)=0.4046/DELTO(J)**0.25*XAN(J)**0.25	00001940
ISN 0107	FLAN(J)=GRAN(J)/REAN**2	00001950
ISN 0108	IF(GRAN(J)-4.0E08) 130,130,135	00001960
ISN 0109	130 HO(J)=241.0/XAN(J)**0.25*DELTO(J)**0.25	00001970
ISN 0110	GO TO 140	00001980
ISN 0111	135 HO(J)=258.56*XAN(J)**0.2*DELTO(J)**0.4	00001990
ISN 0112	140 IF(GRAN(J).GT.3.0E08.AND.GRAN(J).LT.5.0E08) HO(J)=(241.0/XAN(J)	00001992
	1 **0.25*DELTO(J)**0.25+258.56*XAN(J)**0.2*DELTO(J)**0.4)/2.0	00001995
ISN 0114	IF(FLAN(J).LE.1.0) HO(J)=HANOI	00002000
ISN 0116	50 Y(200+J)=HO(J)*ADIV	00002010
ISN 0117	Y(230+J)=HI(J)*ADIV	00002020
ISN 0118	HUP(J)=57.16*HUP(J)*0.7854*(INDIV**2-(INDIV-BTUP(J)*2.0)**2)	00002030
ISN 0119	HDO(J)=57.16*UDOWN(J)*0.7854*((UDIV+BTDO(J)*2.0)**2-(UDIV**2)	00002040
ISN 0120	90 CONTINUE	00002050
ISN 0121	VUP=0.0	00002060
ISN 0122	VDO=0.0	00002070
ISN 0123	ABTU=0.0	00002080
ISN 0124	ABTD=0.0	00002090
ISN 0125	DO 160 J =1,22	00002100
ISN 0126	VUP=VUP+HUP(J)	00002110
ISN 0127	VDO=VDO+UDOWN(J)	00002120
ISN 0128	ABTU=ABTU+BTUP(J)	00002130
ISN 0129	ABTD=ABTD+BTDO(J)	00002140
ISN 0130	160 CONTINUE	00002150

LEVEL 2.1 (JAN 75)

SUB98

DS/360 FORTRAN II EXTENDED

DATE 77.075/23.25.48

ISN 0131
ISN 0132
ISN 0133
ISN 0134
ISN 0135
ISN 0136

VUP=VUP/22.0
VDO=VDO/22.0
ABTU=ABTU/22.0
ABTD=ABTD/22.0
RETURN
END

00002160
00002170
00002180
00002190
00003900
00003910

REQUESTED OPTIONS:

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE(1) LINECOUNT(42) SIZE(MAX) AUTODBL(NONE)
 SOURCE EBCDIC NOLIST NUDECK OBJECT MAP NOFORMAT GOSTMT NOXREF ALC NOANSF NOTERM FLAG(1)

ISN 0002	SUBROUTINE SUB9H	00000170
ISN 0003	IMPLICIT REAL(1,K=N)	00000175
ISN 0004	DIMENSION T(1500),Y(4500),Q(1500),D(3000),C(1500)	00000180
ISN 0005	DIMENSION HI(30),GR(30),FL(30),X(30),DELTI(30),DELTD(30)	00000182
ISN 0006	DIMENSION HO(30),GRAN(30),FLAH(30),UUP(30),UDOWN(30), BTUP(30),BTDD(30),XAN(30),MUP(30),MDU(30)	00000183
ISN 0007	COMMON ZZ(24132)	00000184
ISN 0008	EQUIVALENCE (ZZ(1),TIME), (ZZ(2),D(1)), (ZZ(3002),Y(1)), 1 (ZZ(7502),T(1)), (ZZ(10502),C(1)), (ZZ(12002),Q(1)), 1 (ZZ(18624),DTHETA), (D(1),IDLEN), (D(2),NLENG), 1 (D(3),NONOD), (D(4),ADIVI), (D(5),IDDIV), (D(6),NOFIN), 1 (D(7),MFLOW), (D(8),TOMAS), (D(9),RECYL), (D(10),NUSHD), 1 (D(11),HODIV), (D(12),K90D), (D(13),HANUI), (D(14),IDWAL), 1 (D(15),ODDIV), (D(16),K99), (D(17),HVALI), (D(18),ADOME), 1 (D(19),ADOMET), (D(20),KINS), (D(21),ODWAL), (D(22),AINSO), 1 (D(23),IDINS), (D(24),ODINS), (D(25),CPSID), (D(26),H), 1 (D(27),QLONAK), (D(28),QLOSD), (D(29),REAN), (D(30),PRSD), 1 (D(51),ATUBE), (D(52),NOTUB), (D(53),ASHEL), (D(54),IDSHEL), 1 (D(55),ODTUBE), (D(56),IDTUBE), (D(57),RETUR), (D(58),DHSHEL), 1 (D(59),RESHEL), (D(60),HTUBE), (D(61),HSHEL), (D(62),ACUT1), 1 (D(63),ACOTO), (D(64),NLENGE), (D(65),IDIS), (D(66),ODIS), 1 (D(67),ARADS), (D(68),AINSDE), (D(69),ODSHEL), (D(70),IDLENE), 1 (D(71),NONODE), (D(72),KSSE), (D(73),KSHDE) ISN 0009 EQUIVALENCE (D(74),AECO), (D(75),AHAF), (D(76),UAECO), 1 (D(77),UABAF), (D(78),UECU), (D(79),UBAF) ISN 0010 EQUIVALENCE (D(80),IDJKT), (D(81),NKFLW), (D(82),HTCHA), 1 (D(83),DHNAK), (D(84),RENAK), (D(85),HNAK), 1 (D(86),NUNAK), (D(87),KNAK), (D(88),CPNAK), 1 (D(89),PRNAK), (D(90),NUSLN) ISN 0011 N=N+1.0 ISN 0012 IF(N.GT.1.0) GO TO 100 ISN 0014 NLENG=IDLEN/NONOD ISN 0015 ADIVI=3.1416*IDDIV*NLENG/NOFIN ISN 0016 ADIVD=3.1416*ODDIV*NLENG/NOFIN ISN 0017 MFLOW=TOMAS/NOFIN	00000190 00000200 00000210 00000220 00000230 00000240 00000250 00000260 00000270 00000280 00000290 00000330 00000340 00000350 00000360 00000370 00000380 00000381 00000382 00000450 00000460 00000470 00000480 00001010 00001020 00001100 00001110 00001115 00001120

3. TYPE I COLD TRAP THERMAL MODEL LISTING

ISN 0018	RECYL=MFLDWA*IDDIV/(3.1416*IDDIV**2/4.0/NOFIN)/NUSUD	00001130
ISN 0019	REAN=TOMAS/0.7854/(IDWAL+ODDIV)/NUSUD	00001135
ISN 0020	HDIVI=(5.0+0.025*(RECYL*PRSD))**0.8)*KSUD/IDDIV	00001140
ISN 0021	HANUI=5.50*KSUD/(IDWAL-ODDIV)	00001150
ISN 0022	HWALI=5.50*KSUD/(IDWAL-ODDIV)	00001170
ISN 0023	ADOME=ADOMET/NOFIN/8.0	00001175
ISN 0024	Y(401)=2.0*3.1416*NLENG*KSS/ALOG(ODDIV/IDDIV)	00001185
ISN 0025	Y(501)=HWALI*ADOME	00001190
ISN 0026	Y(509)=HWALI*(3.1416*IDWAL/NOFIN)*NLENG	00001195
ISN 0027	DHNAK=2.0*(IDJKT-IDWAL)*HTCHA/(IDJKT-IDWAL+2.0*HTCHA)	00001200
ISN 0028	RENAK=NKFLW*DHNAK/((IDJKT-IDWAL)/2.0*HTCHA*NUNAK)	00001210
ISN 0029	NUSLN=5.0+0.025*(RENAK*PRNAK)**0.8	00001225
ISN 0030	HNAK=NUSLN*KNAK/DHNAK	00001230
ISN 0031	Y(601)=100.0*ADOME	00001240
ISN 0032	Y(609)=HNAK*(3.1416*(IDWAL/NOFIN)*NLENG	00001252
ISN 0033	Y(701)=KSS*ADOME/(0.5*(IDWAL-IDWAL))	00001254
ISN 0034	Y(709)=KSS*(3.1416*0.5*(IDWAL+IDWAL)/NOFIN)*NLENG 1/(0.5*(IDWAL-IDWAL))	00001256 00001258
ISN 0035	Y(1541)=HNAK*(3.1416*IDJKT/NOFIN)*NLENG	00001270
ISN 0036	Y(1571)=(2.0*3.1416*NLENG*KINS/ALOG(ODINS/IDINS))/NOFIN	00001440
ISN 0037	AINSD=(3.1416*(IDINS)/NOFIN)*NLENG	00001450
ISN 0038	Y(201)=ADIVI*HANUI	00001460
ISN 0039	Y(231)=ADIVI*HDIVI	00001470
ISN 0040	Y(101)=MFLDWA*CPSD	00001480
ISN 0041	Y(301)=NKFLW*CPNAK	00001490
ISN 0042	NLENGE=TOLENE/NOFIDE	00001500
ISN 0043	ATUBE=3.1416*IDTUBE**2/4.0*NOTUH	00001510
ISN 0044	ASHEL=0.7986	00001520
ISN 0045	RETUB=(TOMAS*IDTUBE)/(ATUBE*NUSUD)	00001522
ISN 0046	DHSHEL=4.0*ASHEL/(3.1416*IDTUBE*NOTUH+6.0*0.7241)	00001524
ISN 0047	RESHEL=(TOMAS*DHSHEL)/(ASHEL*NUSUD)	00001525
ISN 0048	HTUBE=KSODE/IDTUBE*(5.0+0.025*(RETUB*PRSD))**0.8)	00001526
ISN 0049	HSHEL=KSODE/DHSHEL*(9.2170+0.03928*(RESHEL*PRSD))**0.7653)	00001527
ISN 0050	ACOTI=3.1416*IDTUBE*NOTUH*NLENGE/NOFIN	00001528
ISN 0051	ACOTI=3.1416*IDTUBE*NOTUH*NLENGE/NOFIN	00001530
ISN 0052	Y(2001)=1.0/(1.0/(HTUBE*ACOTI)+1.0/(HSHEL*ACOTI))+ALOG(ODTUBE/ IDTUBE)*NOFIN/(2.0*3.1416*NLENGE*KSS*NOTUH))	00001532 00001534
ISN 0053	Y(2041)=1.0/(1.0/(HSHEL*3.1416*IDTUBE*NLENGE/NOFIN)+NOFIN* 1ALOG(ODSHEL/IDSHEL)/(4.0*3.1416*NLENGE*KSS))	00001536 00001538
ISN 0054	Y(2841)=1.0/((NOFIN/(4.0*3.1416*NLENGE))*(ALOG(ODSHEL/IDSHEL)/	00001540

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      1KSSE+2.0*ALOG(IDIS/ODSHEL)/0.0203))
ISN 0055      Y(3041)=2.0*3.1416*NLENGE*KINS/ALOG(IDIS/IDIS)/NOFIN
ISN 0056      AINSOE=3.1416*ODIS*NLENGE/NOFIN
ISN 0057      ARADS=3.1416*ODSHEL*NLENGE/NOFIN
ISN 0058      AECU=0.5*(ACOTI+ACOTO)*NONODE*NOFIN
ISN 0059      ABAF=0.5*(ADIVI+ADIVO)*22.0*NOFIN
ISN 0060      UAECU=Y(2001)*NONODE*NOFIN
ISN 0061      UABAF=NONOD*NOFIN/(1.0/Y(201)+1.0/Y(231)+1.0/Y(401))
ISN 0062      UECU=UAECU/AECU
ISN 0063      UBAF=UABAF/ABAF
ISN 0064      100 QLONAK=(T(330)-T(300))*NKFLW*CPNAK
ISN 0065      QLOSO=(T(152)-T(131))*TOMAS*CPSOND
ISN 0066      RETURN
ISN 0067      END

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00001542
00001545
00001547
00001549
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00001558
00001560
00001600
00001610
00001900
00001910

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NO99T1811046
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/ SUB98 /

SIZE OF PROGRAM 000866 HEXADECEMAL BYTES

NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.		
C	CE	R*4	00A414	D	CE	R*4	000004	N	SF	CE	R*4	000068	Q				
T	F	CE	R*4	X		R*4	NR	Y	SF	CE	R*4	002EE4	FL				
GR			R*4	HI		R*4	NR	HO			R*4	NR	ZZ				
KSS	F	CE	R*4	MDI		R*4	NR	MUP			R*4	NR	UUP				
XAN			R*4	ABAF	SF	CE	R*4	00012C	AECU	SF	CE	R*4	000128	ALUG	F		
BTDO			R*4	BTUP			R*4	NR	FLAN			R*4	NR	GRAN			
HNAK	SF	CE	R*4	IDIS	FA	CE	R*4	000104	KINS	F	CE	R*4	000050	KNAK	F		
KSON	F	CE	R*4	KSSE	F	CE	R*4	000120	ODIS	FA	CE	R*4	000108	KEAN	S		
TIME			R*4	UBAF	S	CE	R*4	00013C	UECU	S	CE	R*4	000138	ACHII	SF		
ACOTO	SF	CE	R*4	ADIVI	SF	CE	R*4	000010	ADIVO	SF		R*4	000160	ADUME	SF		
AINSO	S	CE	R*4	ARADS	S	CE	R*4	00010C	ASHEL	SF	CE	R*4	0000D4	ATUBE	SF		
CPNAK	F	CE	R*4	CPSON	F	CE	R*4	000064	DELT			R*4	NR	DELTU			
DHNAK	SF	CE	R*4	HANUI	SF	CE	R*4	000034	HDIVI	SF	CE	R*4	00002C	HSHEL	SF		
HTCHA	F	CE	R*4	HTURE	SF	CE	R*4	0000F0	HWALI	SF	CE	R*4	000044	IDDIV	F		
IDINS	FA	CE	R*4	INDKT	F	CE	R*4	000140	IDWAL	F	CE	R*4	000038	KSONE	F		
MFLOW	SF	CE	R*4	NKFLW	F	CE	R*4	000144	NLENG	SF	CE	R*4	000008	NOFIN	F		
NONOD	F	CE	R*4	NOTUB	F	CE	R*4	0000D0	NUNAK	F	CE	R*4	000158	NUSLN	SF		
NUSOD	F	CE	R*4	NDPIV	FA	CE	R*4	00003C	ODINS	FA	CE	R*4	000060	ODKAL	F		
PRNAK	F	CE	R*4	PRSON	F	CE	R*4	000078	QLOSO	S	CE	R*4	000070	RECYL	SF		
RENAK	SF	CE	R*4	RETHB	SF	CE	R*4	0000E4	SUB98			R*4	000164	TULEN	F		
TOMAS	F	CE	R*4	UABAF	SF	CE	R*4	000134	UAECU	SF	CE	R*4	000130	UDOWN			

ALL NEW INPUT DATA FOR THIS RUN

TAP = 4H

04/12/77

CASE 1

* 1

00005000

*** STAR 001 - TITLES & STORED COMMENTS

1 PRIMARY SODIUM COLD TRAP
2 NAK COOLED CRYSTALLIZER
SODIUM INLET TEMPERATURE TO ECONOMIZER 600 F
SODIUM FLOW RATE 80 GPM
NAK INLET TEMP. 125.DEG F
NAK FLOW RATE 12000 LB/HR
2 IN. FLOW HAFFLE
NUMBER OF TUBES 91.0
TUBE OD 1.0 IN 0.035 IN WALL THICK
EFFECTIVE TUBE LENGTH 61 IN
***** NU=CONSTANT *****

00005010
00005020
00005030
00005040
00005050
00005060
00005070
00005080
00005090
00005100
00005300
00005310
00005320
00100000

CLEAN UP CONDITION

* 10

*** STAR 010 - STATIC NETWORK DESCRIPTION

Y201	Y222	0	.0	.0	T122	T201	-1	1	1	00100201
Y231	Y252	0	.0	.0	T131	T231	1	1	1	00100231
Y401	Y422	0	.0	.0	T201	T231	1	1	1	00100401
Y501	Y530	0	.0	.0	T501	T130	1	-1	1	TANK WALL TO NA 00100501
Y601	Y630	0	.0	.0	T601	T301	1	1	1	TANK WALL-NAK 00100601
Y701	Y730	0	.0	.0	T501	T601	1	1	1	00100701
1541	1570	0	.0	.0	T741	T301	1	1	1	JKT TO NAK 00101541
1571	1600	0	.0	.0	T741	T771	1	1	1	INS(IN) TO OUT 00101571
1601	1630	0	.0	.0	T771	T999	1	0	1	RAD AMBIENT 00101601
1631	1660	0	.0	.0	T771	T999	1	0	1	CONV. AMBIENT 00101631
2 1 2 40	0	.0	.0	.0	T 90	T153	-1	1	1	NA IN. TO NA OUT 00102001
2 41 2 80	0	.0	.0	.0	T 51	T801	1	1	1	NA TO SHELL 00102041
2841	2873	0	.0	.0	T801	T841	1	1	1	COND 00102841
2874	2880	0	.0	.0	T834	T 91	1	0	1	00102874

2891	0	0	.0	.0	T 91	T100	0	0	1	00102891
2892	2893	0	.0	.0	T 91	T916	9	1	1	00102892
2941	2973	0	.0	.0	T801	T841	1	1	1	00102941
2974	2975	0	.0	.0	T916	T874	1	1	1	00102974
2976	2977	0	.0	.0	T916	T874	1	1	1	00102976
3 41	3 75	0	.0	.0	T841	T881	1	1	1	00103041
3141	3175	0	.0	.0	T881	T999	1	0	1	00103141
3241	3275	0	.0	.0	T881	T999	1	0	1	00103241
* 11										00110000

*** STAR 011 - FLOW NETWORK DESCRIPTION

Y 51	Y 90	0	.0	.0	T 50	T 51	1	1	1	00110051
Y 91	Y 92	0	.0	.0	T 90	T 91	1	9	1	00110091
Y101	Y152	0	.0	.0	T100	T101	1	1	1	00110101
Y153	Y192	0	.0	.0	T152	T153	1	1	1	00110153
Y301	Y330	0	.0	.0	T300	T301	1	1	1	00110301
* 20										00200000

*** STAR 020 - INITIALIZATION & CONSTANT DATA

T 50	0	-1	600.00	.0	0	0	0	0	1	00210050
T 51	T 90	0	600.00	-7.5000	0	0	0	0	1	00210051
T 91	0	0	300.00	.0	0	0	0	0	1	00210091
T100	T130	0	300.00	-2.3333	0	0	0	0	1	00210100
T131	T152	0	230.00	2.3330	0	0	0	0	1	00210131
T153	T192	0	300.00	13.750	0	0	0	0	1	00210153
T201	T222	0	230.00	2.3330	0	0	0	0	1	00210201
T231	T252	0	230.00	2.3330	0	0	0	0	1	00210231
T300	0	-1	125.00	.0	0	0	0	0	1	00210300
T301	T330	0	125.00	2.5000	0	0	0	0	1	00210301
T501	T530	0	230.00	2.3330	0	0	0	0	1	00210501
T601	T630	0	125.00	2.5000	0	0	0	0	1	00210601
T741	T770	0	125.00	2.5000	0	0	0	0	1	00210741
T771	T800	0	105.00	2.3000	0	0	0	0	1	00210771
T801	T840	0	600.00	-7.5000	0	0	0	0	1	00210801
T841	T875	0	600.00	-7.5000	0	0	0	0	1	00210841
T881	T915	0	130.00	-5.0000	0	0	0	0	1	00210881
T916	T917	0	300.00	.0	0	0	0	0	1	00210916
T999	0	-1	100.00	.0	0	0	0	0	1	00210999
D 1	0	0	4.1667	.0	0	0	0	0	1	00220010

D 3	0	0	22.000	.0	0	0	0	0	1	00220030
D 5	0	0	2.8650	.0	0	0	0	0	1	00220050
D 6	0	0	1.0000	.0	0	0	0	0	1	00220060
D 8	0	0	36667.	.0	0	0	0	0	1	00220080
D 10	0	0	1.1000	.0	0	0	0	0	1	00220100
D 12	0	0	48.000	.0	0	0	0	0	1	00220120
D 14	0	0	4.5000	.0	0	0	0	0	1	00220140
D 15	0	0	3.1983	.0	0	0	0	0	1	00220150
D 16	0	0	9.4000	.0	0	0	0	0	1	00220160
D 19	0	0	26.722	.0	0	0	0	0	1	00220190
D 20	0	0	4.5000E+02	.0	0	0	0	0	1	00220200
D 21	0	0	4.5625	.0	0	0	0	0	1	00220210
D 23	0	0	4.9583	.0	0	0	0	0	1	00220230
D 24	0	0	5.6250	.0	0	0	0	0	1	00220240
D 25	0	0	.32500	.0	0	0	0	0	1	00220250
D 26	0	0	.0	.0	0	0	0	0	1	00220260
D 30	0	0	5.0000E+03	.0	0	0	0	0	1	00220300
D 35	0	0	.0	.0	0	0	0	0	1	00220350
D 36	0	0	.19000	.0	0	0	0	0	1	00220360
D 37	0	0	.33330	.0	0	0	0	0	1	00220370
D 38	0	0	.36110	.0	0	0	0	0	1	00220380
D 52	0	0	91.000	.0	0	0	0	0	1	00220520
D 54	0	0	1.6000	.0	0	0	0	0	1	00220540
D 55	0	0	8.3330E+02	.0	0	0	0	0	1	00220550
D 56	0	0	7.7500E+02	.0	0	0	0	0	1	00220560
D 65	0	0	1.7875	.0	0	0	0	0	1	00220650
D 66	0	0	2.4542	.0	0	0	0	0	1	00220660
D 69	0	0	1.7250	.0	0	0	0	0	1	00220690
D 70	0	0	5.0833	.0	0	0	0	0	1	00220700
D 71	0	0	40.000	.0	0	0	0	0	1	00220710
D 72	0	0	10.100	.0	0	0	0	0	1	00220720
D 73	0	0	46.285	.0	0	0	0	0	1	00220730
D 80	0	0	5.0000	.0	0	0	0	0	1	00220800
D 81	0	0	12000.	.0	0	0	0	0	1	00220810
D 82	0	0	.75000	.0	0	0	0	0	1	00220820
D 86	0	0	1.5750	.0	0	0	0	0	1	00220860
D 87	0	0	13.920	.0	0	0	0	0	1	00220870
D 88	0	0	.22450	.0	0	0	0	0	1	00220880
D 89	0	0	1.9050E+02	.0	0	0	0	0	1	00220890
D704	0	0	55.000	.0	0	0	0	0	1	00221040
D705	0	0	6.5000E+02	.0	0	0	0	0	1	00221050
D711	0	0	31.480	.0	0	0	0	0	1	00221110
D712	0	0	5.1754	.0	0	0	0	0	1	00221120

LENG(NODE) POME

AT 450 F

AT 450 F

Y401 0 0 1.1034 .0 0 0 0 0 1
 * 30

00230010
 00300000

*** STAR 030 - FUNCTION STATEMENTS

1	D999	0	98	.0	1.0000	0	0	0	0	1	00310010
2	D998	0	191	.0	1.0000	0	0	0	0	1	00310011
3	Y 51	Y 92	101	.0	1.0000	Y101	0	0	0	1	00310012
4	Y153	Y192	101	.0	1.0000	Y101	0	0	0	1	00310015
5	2 2 2 40	101	.0	1.0000	2 1	0	0	0	0	1	00310020
6	2 42 2 80	101	.0	1.0000	2 41	0	0	0	0	1	00310030
7	2842 2873	101	.0	1.0000	2841	0	0	0	0	1	00310040
8	2874 2880	101	.0	1.0000	2 74	0	0	0	0	1	00310050
9	2941 2973	49	.0	.36360	0 D 67	0	0	0	0	1	00310060
10	2974 2975	1	.0	10.000	2941	0	0	0	0	1	00310070
11	2976 2977	101	.0	10.000	2841	0	0	0	0	1	00310075
12	3 42 3 73	101	.0	1.0000	3 41	0	0	0	0	1	00310080
13	3 74 3 75	101	.0	10.000	3 41	0	0	0	0	1	00310090
14	3141 3173	49	.0	.80000	0 D 68	0	0	0	0	1	00310100
15	3174 3175	1	.0	10.000	3141	0	0	0	0	1	00310110
16	F241 F275	66	.0	.19000	3241 D 37	1	0	0	0	1	00310120
17	3241 3275	52	.0	1.0000	F241 D 68	1	0	0	0	1	00310130
18	3274 3275	1	.0	10.000	3274	0	1	0	0	1	00310140
19	2891 0	1	.0	2.3833	2 41	0	0	0	0	1	00310150
20	2892 2893	101	.0	10.000	2 41	0	0	0	0	1	00310160
21	Y502 Y508	101	.0	1.0000	Y501	0	0	0	0	1	00320010
22	Y510 Y530	101	.0	1.0000	Y509	0	0	0	0	1	00320020
23	Y602 Y608	101	.0	1.0000	Y601	0	0	0	0	1	00320060
24	Y610 Y630	101	.0	1.0000	Y609	0	0	0	0	1	00320070
25	Y702 Y708	101	.0	1.0000	Y701	0	0	0	0	1	00320080
26	Y710 Y730	101	.0	1.0000	Y709	0	0	0	0	1	00320090
27	1542 1570	101	.0	1.0000	1541	0	0	0	0	1	00320230
28	1572 1600	101	.0	1.0000	1571	0	0	0	0	1	00320240
29	F 1 F 30	66	.0	.19000	1631 D 37	1	0	0	0	1	00320250
30	1631 1638	52	.0	1.0000	D 18 F 1	0	1	0	0	1	00320260
31	1639 1660	52	.0	1.0000	D 22 F 9	0	1	0	0	1	00320265
32	1601 1608	49	.0	.80000	0 D 18	0	0	0	0	1	00320300
33	1609 1630	49	.0	.80000	0 D 22	0	0	0	0	1	00320305
34	Y102 Y152	101	.0	1.0000	Y101	0	0	0	0	1	00320310
35	Y302 Y330	101	.0	1.0000	Y301	0	0	0	0	1	00320320
36	E 2 E 41	150	.0	1.0000	E 1 D 64	1	0	0	0	1	00330010
37	E 42 E 63	150	.0	1.0000	E 41 D 2	1	0	0	0	1	00330020

DIST. FROM TOP E

38 E 64 E 71 150	.0	1.0000	E 63 D 38	1	0	1	00330022
39 E 1 E 71 101	.0	12.000	E 1 0	1	0	1	00330025
40 E100 E140 1	.0	1.0000	T 50 0	1	0	1	00330030
41 E141 E170 1	.0	1.0000	T101 0	1	0	1	00330040
42 E200 E261 1	.0	1.0000	T192 0	-1	0	1	00330050
43 E300 E330 1	.0	1.0000	T330 0	-1	0	1	00330060
44 Y202 Y222 101	.0	1.0000	Y201 0	0	0	1	00330070
45 Y232 Y252 101	.0	1.0000	Y231 0	0	0	1	00330080
46 Y402 Y422 101	.0	1.0000	Y401 0	0	0	1	00330090
47 E401 E440 55	.0	1.0000	T192 T 51	-1	1	1	00330100
48 E501 E522 55	.0	1.0000	T201 T231	1	1	1	00330110
49 1 0 93	.0	71.000	E100 E 1	1	1	1	00340010
50 2 0 93	.0	62.000	E200 E 2	1	1	1	00340020
51 3 0 93	.0	30.000	E300 E 42	1	1	1	00340030
* 60							00600000

*** STAR 060 - VARIABLE PLOT CRT DATA

PLOT 1, Y AXIS LABEL IS TEMPERATURE (DEG.F) WITH LIMITS OF	0.0	0.0	00610010
PLOT 1, X AXIS LABEL IS DIST. FROM TOP (IN.) WITH LIMITS OF	0.0	0.0	00610020
PLOT 1, CURVE NO. 1 LABEL IS NA DOWN			00610030
PLOT 1, CURVE NO. 2 LABEL IS NA UP			00610040
PLOT 1, CURVE NO. 3 LABEL IS GAS UP			00610050

*** STAR 070 - SPECIAL CONTROL CONSTANTS

4	5.0000E-04	CONVERGENCE TEST ON RATE OF TEMPERATURE CHANGE	00710040
5	1.0000	0. = TRANSIENT; +1. = STEADY STATE	00710050
6	1.0000	+1. = DUMP DYTCQ AT END OF CASE	00710060
9	1.7140E-09	STEFAN-BOLTZMANN CONSTANT	00710090
15	1.0000	+1.0 FOR 100 SERIES EVAL. AT END OF RUNS	00710150

* 80

00800000

*** STAR 080 - PRINTOUT SPECIFICATIONS

D 1 D 30	0	.0	.0	0	0	0	0	1	00800010
D 51 D 79	0	.0	.0	0	0	0	0	1	00800020
D 80 D 90	0	.0	.0	0	0	0	0	1	00810010
D701 D714	0	.0	.0	0	0	0	0	1	00810011

T 50	T 90	0	.0	.0	0	0	0	0	4
T100	T192	0	.0	.0	0	0	0	0	4
T201	T222	0	.0	.0	0	0	0	0	3
T231	T252	0	.0	.0	0	0	0	0	3
T300	T330	0	.0	.0	0	0	0	0	3
T505	T530	0	.0	.0	0	0	0	0	5
T605	T630	0	.0	.0	0	0	0	0	5
T745	T915	0	.0	.0	0	0	0	0	5

* 90

00010017
00010020
00010022
00010025
00010030
00010040
00010050
00010060
00900000

*** STAR 090 - PRINTOUT & STOP TIMES

0	0	0	.0	10.000	0	0	0	0	1
0	0	0	100.00	50.000	0	0	0	0	1
0	0	0	1000.0	.0	0	0	0	0	1

* 97

00910010
00910020
00910030
00970000

*** ELAPSED CPU TIME FOR INPUT = 4, SEC ***

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	PRESSURE DROP CALCULATION	MODEL NO.

HTS/EVS COLD TRAP PRESSURE DROP CALCULATION

SODIUM FLOW RATE 27,500 LB/HR
 THE PRESSURE DROP IN THE COLD TRAP CRYSTALLIZER WIRE MESH
 WAS CALCULATED FROM YORK AND PEPPETE'S DATA +.

* York, O. H, and E. W. Peppete.

"Wire Mesh Mist Eliminators", Chemical Engineering Progress,
 Vol. 59 No. 6 June 1963.

$$\Delta P = f_c L a \rho U^2 / g_c \epsilon^3$$

Where f_c = friction factor from Fig. 5

L = Wire Mesh Thickness, ft.

a = Specific surface Area ft^2/ft^3

ρ = density, lb/ft^3

U = velocity ft/sec

$g_c = 32.2 \text{ lbm} \cdot \text{ft}/\text{lb}_f \cdot \text{sec}^2$

ϵ = Void fraction of mesh

Annulus

$$Re = \rho U / a \mu$$

a = specific surface area.

Wire diameter 0.006 in.

density of wire mesh 25 lb/ft^3

$$\frac{\pi}{4} \left(\frac{0.006}{12} \right)^2 (\text{ft}^2) \times L (\text{ft}) \times 490 \frac{\text{lb}}{\text{ft}^3} = 25 \text{ lb}$$

$L = 259800 \text{ ft}/\text{ft}^3$ of wire mesh.

Total surface area

$$\pi (0.006/12) \times 259800 = 408 \text{ ft}^2/\text{ft}^3$$

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$$U = \frac{27500 (\text{lb/hr})}{57.6 (\text{lb/hr}^3) \left\{ \left(\frac{54}{12} \right)^2 - \left(\frac{38}{12} \right)^2 \right\} \frac{\pi}{4} (\text{ft}^2)}$$

$$= 59.88 \text{ ft/hr} = 0.0166 \text{ ft/sec}$$

$$E = 0.96$$

$$\mu = 1.5 \text{ lb/hr-ft} = 4.1667 \times 10^{-4} \text{ lb/ft-sec}$$

$$Re = \frac{\rho U}{\mu} = \frac{57.6 (\text{lbm/hr}^3) \times 0.01667 (\text{ft/sec})}{408 (\text{lb/ft}^3) \times 4.1667 \times 10^{-4} (\text{lbm/ft-sec})}$$

$$= 5.6481$$

$$\text{From Fig. 5} \quad f_c = 1.8$$

$$\Delta P = f_c L a \rho U^2 / g_c \epsilon^3$$

$$= \frac{1.8 \times 7.6667 (\text{ft}) \times 408 (\text{lbm/ft}^3) \times 57.6 (\text{lb/hr}^3) \times 0.0166^2 (\text{ft/sec})^2}{32.2 (\frac{\text{ft-lb}}{\text{lb-sec}^2}) \times 0.96^3}$$

$$= 3.1623 \text{ PSF}$$

$$= \underline{\underline{0.02196 \text{ PSI}}}$$

Cylinder Core

$$U = \frac{27500 (\text{lb/hr})}{57.6 (\text{lbm/hr}^3) \times \left(\frac{34}{12} \right)^2 \times \frac{\pi}{4} (\text{ft}^2)}$$

$$= 75.7225 \text{ ft/hr} = 0.02103 \text{ ft/sec}$$

$$Re = \frac{\rho U}{\mu} = \frac{57.6 \times 0.02103}{408 \times 4.1667 \times 10^{-4}} = 7.1258$$

$$\text{from fig. 5} \quad f_c = 1.8$$

$$\Delta P = f_c L a \rho U^2 / g_c \epsilon^3$$

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$$= \frac{1.8 \times 7.6667 (45) \times 437 (45^2/143) \times 57.6 (26.25^3) \times (0.2123)^2 (45/\text{sec})^2}{32.2 \left(\frac{16\text{in} - 45}{143 - 143} \right) \times 0.96^3}$$

$$= 5.0347 \text{ PSI}$$

$$= 0.03496 \text{ PSI}$$

Total pressure drop in the crystallizer mesh.

$$= 0.03496 + 0.02196 = 0.05692 \text{ PSI}$$

Economizer Shell Side Pressure Drop.

$$Re = \frac{PVD}{\mu} = \frac{m D_H}{A \mu}$$

$$A = 115 \text{ in}^2 = 0.7986 \text{ ft}^2$$

$$\mu = 1.0892 \text{ lbm/ft-sec}$$

$$P = 57.6$$

$$m = 27500 \text{ lb/hr}$$

$$D_H = \frac{4A}{P} = \frac{4 \times 0.7986 (45^2)}{\pi \left(\frac{1}{12} \right) \times 91 - (8.48328 \times 6)/12}$$

$$= 0.11382 (45)$$

$$V = \frac{m}{PA} = \frac{27500}{57.6 \times 115/\text{ft}^2} = 59.7 \text{ ft/hr} = 0.1661 \text{ ft/sec}$$

$$Re = \frac{m D_H}{A \mu} = \frac{27500 (45/\text{hr}) \times 0.11382 (45)}{0.7986 (45^2) \times 1.0892 (26/\text{ft-sec})}$$

$$= 3598.4$$

$$f = 0.079 Re^{-1/2} \quad (\text{for } Re > 5000)$$

$$f = 16/Re \quad (\text{for } Re \leq 5000)$$

$$f = 16/3598.4 = 4.45 \times 10^{-3}$$

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$$\begin{aligned}
 \Delta P &= \left(4 \times \frac{f}{D} \times \frac{L}{D} + K_c + K_e \right) \frac{\rho V^2}{2} \\
 &= \left(4 \times 4.45 \times 10^{-3} \times \frac{2.333}{0.11372} + 0.5 + 1.0 \right) \times \frac{57.15 \times 0.1661^2}{2 \times 32.2} \\
 &= \underline{0.04988 \text{ PSF}}
 \end{aligned}$$

Pressure drop through the flow openings around the lower tubesheet.

Assumed sharp edged orifice

$$V = \frac{\dot{m}}{\rho A} = \frac{27500}{57.6 \times 0.42} = 1136.74 \text{ ft/hr} = 0.3158 \text{ ft/sec}$$

$$A = \pi D L = \pi \times \frac{19.25}{12} \times \frac{1}{12} = 0.42 \text{ ft}^2$$

$$D_n = \frac{4 \times \pi \times 0.4}{2 \pi D} = 2 \times \frac{1}{12} (\text{in}) = 0.1667 (\text{ft})$$

$$Re = \frac{\rho V D_n}{\mu} = \frac{27500 \times 0.1667}{0.42 \times 10892} = 10021$$

$$K = 2.80 \quad (Re > 10000)$$

$$\begin{aligned}
 \Delta P &= K \frac{\rho V^2}{2} \\
 &= 2.8 \times \frac{57.6 \times 0.3158^2}{2 \times 32.2} = \underline{0.2450 \text{ PSF}}
 \end{aligned}$$

Pressure drop through the opening of the seal area.

3 in. Dia 16 holes.

$$V = \frac{\dot{m}}{\rho A}$$

$$= \frac{27500}{57.6 \times 0.7854}$$

$$= 607.88 \text{ ft/hr} = 0.1689 \text{ ft/sec}$$

$$\begin{aligned}
 A &= \frac{\pi}{4} D^2 \times 16 = \frac{\pi}{4} \left(\frac{3}{12} \right)^2 \times 16 \\
 &= 0.7854 \text{ ft}^2
 \end{aligned}$$

$$\Delta P = K \frac{\rho V^2}{2} = (2.8) \times \frac{57.6 \times (0.1689)^2}{2 \times 32.2}$$

$$= \underline{0.07144 \text{ PSF}}$$

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Pressure drop through the economizer tubes including inlet and exit loss

$$A_{\text{area}} = \frac{\pi}{4} (D^2) \times \text{number of Tubes}$$

$$D = 0.93 \text{ in.}$$

$$A = \frac{\pi}{4} \left(\frac{0.93}{12} \right)^2 \times 91 = 0.4293 \text{ ft}^2$$

$$V = \frac{\dot{m}}{\rho A} = \frac{27500 \text{ (lb/hr)}}{57.6 \text{ (lb/ft}^3\text{)} \times 0.4293 \text{ (ft}^2\text{)}} = 1112 \text{ ft/hr} = 0.3089 \text{ ft/sec}$$

$$Re = \frac{\dot{m} D}{A \mu} = \frac{27500 \text{ (lb/hr)} \times 0.93 \text{ (in)}}{0.4293 \text{ (ft}^2\text{)} \times 1.0822} = 4557.91$$

$$f = 0.079 Re^{-1/2} = 0.079 (4557.91)^{-1/2} = 9.6 \times 10^{-3}$$

$$\Delta P = \left(4f \frac{L}{D} + K_c + K_e \right) \times \frac{\rho V^2}{2g} = \left(4 \times 9.6 \times 10^{-3} \times \frac{3.3333}{0.93/12} + 1.5 \right) \times \frac{57.6 \times (0.3089)^2}{2 \times 32.2} = 0.2689 \text{ PSI}$$

Pressure drop through the inlet and outlet nozzles

Inlet and Outlet nozzle

$$\phi D = 2.875 \text{ in.}$$

$$ID = 2.125 \text{ in.}$$

$$\text{flow area} = \frac{\pi}{4} \left(\frac{2.125}{12} \right)^2 = 0.0246 \text{ in}^2$$

$$V = \frac{\dot{m}}{\rho A} = \frac{27500}{57.6 \times 0.0246} = 19407 \text{ ft/hr} = 5.39 \text{ ft/sec}$$

$$\Delta P = (1 + 0.5) \times 2 \times \frac{\rho V^2}{2g} = (1 + 0.5) \times 2 \times \frac{57.6 \times 5.39^2}{2 \times 32.2} = 77.953 \text{ PSI}$$

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Pressure drop through the flow baffle (Horizontal)

Tube $\phi D = 1.0$ in.

flow passage diameter $1\frac{1}{4}$ in.

number of holes 91

$$\text{flow area} = \frac{\pi}{4} (1.25^2 - 1^2) \times \frac{91}{144} = 0.2792 \text{ ft}^2$$

$$V = \frac{Q}{A} = \frac{27500 (\frac{\text{in}^3}{\text{min}})}{57.6 (\frac{\text{in}^3}{\text{ft}^3}) (0.2792) \text{ ft}^2} = 1710 \frac{\text{ft}^3}{\text{min}} = 0.475 \frac{\text{ft}^3}{\text{sec}}$$

$$Re = \frac{V D}{\mu} = \frac{27500 (\frac{\text{in}^3}{\text{min}}) \times (0.25 \frac{\text{in}}{12})}{0.2792 \text{ ft}^2 \times 1.6892 (\frac{\text{lbm}}{\text{ft} \cdot \text{sec}})} = 1883 \quad (K = 2.7 \text{ for laminar flow})$$

$$\Delta P = K \frac{\rho V^2}{2g} = \frac{2.7 \times 57.6 (\frac{\text{lbm}}{\text{ft}^3}) \times 0.475^2 (\frac{\text{ft}^3}{\text{sec}})}{2 \times 32.2 (\frac{\text{ft}}{\text{sec}^2})} = 0.5449 \frac{\text{lb}}{\text{ft}^2} = 3.32377 \times 10^{-3} \text{ PSI}$$

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Total pressure drop in the cold trap

Sodium flow rate 60 GPM (27500 lb/hr)

- (1) Economizer shell side pressure drop (0.04988 PSF)
- (2) Pressure drop through the shell opening around
the lower tube sheet (0.245 PSF)
- (3) Pressure drop through the tubes including inlet and
exit losses (0.2689 PSF)
- (4) Pressure drop through the inlet and outlet nozzles (77.953 PSF)
- (5) Pressure drop through the opening of the seal area (0.07144 PSF)
- (6) Pressure drop through the flow baffle (3.7838×10^{-3} PSF)
- (7) Pressure drop in the crystallizer mesh (8.197 PSF)

$$\begin{aligned}
 \text{Total pressure drop} &= 0.04988 + 0.245 + 0.07144 \\
 &+ 0.2689 + 77.953 + 3.7838 \times 10^{-3} + 8.197 \\
 &= 86.79 \text{ PSF} \\
 &= \boxed{0.6027 \text{ PSI}}
 \end{aligned}$$

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SODIUM FLOW RATE 80 GPM (33.667 lb/hr)

Pressure drop in the Type II Cold trap crystallizer.

Annulus

$$U = \frac{33.667 (\text{lb}/\text{hr})}{57.6 (\frac{\text{lb}}{\text{ft}^3}) \times (5^2 - 3^2) \times \frac{1}{12} \times \frac{\pi}{2} (\text{ft}^2)}$$

$$= 79.84 \text{ ft}/\text{hr} = 0.0222 \text{ ft}/\text{sec}$$

$$E = 0.96$$

$$\mu = 1.5 \text{ lb}/\text{hr} - \text{ft} = 4.1667 \times 10^{-4} \text{ lb}/\text{ft} - \text{sec}$$

$$Re = \frac{\rho U}{\mu} = \frac{57.6 (\frac{\text{lb}}{\text{ft}^3}) \times 0.0222 (\text{ft}/\text{sec})}{408 (\frac{\text{lb}}{\text{ft}^3}) \times 4.1667 \times 10^{-4} (\text{lb}/\text{ft} - \text{sec})}$$

$$= 7.5218$$

$$\text{from fig. 5} \quad f_c = 1.8$$

$$\Delta P = f_c L \rho U^2 / g_c E^3$$

$$= 1.8 \times 7.6667 (\text{ft}) \times 408 (\frac{\text{lb}}{\text{ft}^3}) \times 57.6 (\frac{\text{lb}}{\text{ft}^3})$$

$$\times 0.0222^2 (\text{ft}^2/\text{sec}^2) / \left\{ 32.2 = \left(\frac{\text{lbm} - \text{ft}}{\text{sec}^2} \right) \times 0.96^3 \right\}$$

$$= 4.3916 \text{ PSI}$$

Cylinder Core.

$$U = \frac{33.667 (\text{lb}/\text{hr})}{57.6 (\frac{\text{lb}}{\text{ft}^3}) \times (\frac{3^2}{12}) \times \frac{\pi}{2} (\text{ft}^2)}$$

$$= 100.964 \text{ ft}/\text{hr} = 0.028 \text{ ft}/\text{sec}$$

$$Re = \frac{\rho U}{\mu} = \frac{57.6 \times 0.028}{408 \times 4.1667 \times 10^{-4}} = 9.5224$$

$$\text{from fig. 5} \quad f_c = 1.8$$

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$$\Delta P = \frac{f}{2} \frac{L \rho U^2}{D} \left(\frac{1}{Re} \right)$$

$$= \frac{1.8 \times 2.6667 (lb) \times 408 \left(\frac{lb}{ft^3} \right) \times 57.6 \left(\frac{lb}{ft^3} \right) \times (0.2214)^2 \left(\frac{ft}{sec} \right)^2}{32.2 \left(\frac{lbm-ft}{lbf-sec^2} \right) \times 0.96^3}$$

$$= 8.925 \text{ PSF}$$

Total pressure drop in the crystallizer

$$= 8.925 + 4.3916$$

$$= 13.3166 \text{ PSF}$$

Economizer Shell Side Pressure Drop.

$$Re = \frac{\rho V D}{\mu} = \frac{m D_H}{F \mu}$$

$$A = 115 \text{ in}^2 = 0.7986 \text{ ft}^2$$

$$\mu = 1.0892 \text{ lbm/ft-sec}$$

$$\rho = 57.6 \text{ lbm/ft}^3$$

$$\dot{m} = 36667 \text{ lb/hr}$$

$$D_H = 0.1138 \text{ ft}$$

$$V = \frac{\dot{m}}{\rho A} = \frac{36667 (lb/hr)}{57.6 (lbm/ft^3) \times 0.7986 \text{ ft}^2}$$

$$= 797.11 \text{ ft/hr} = 0.2214 \text{ ft/sec}$$

$$Re = \frac{\dot{m} D_H}{F \mu} = \frac{36667 (lb/hr) \times 0.1138 (ft)}{0.7986 (ft^2) \times 1.0892 (lbm/ft-sec)}$$

$$= 4797.96$$

$$\frac{f}{2} = 0.079 (4797)^{-0.25}$$

$$= 9.49 \times 10^{-3}$$

$$\Delta P = \left(4 f \frac{L}{D} + K_2 + K_3 \right) \frac{\rho U^2}{2}$$

$$= \left(4 \times 9.49 \times 10^{-3} \times \frac{3.333}{0.1138} + 1.5 \right) \times \frac{57.6 \times 0.2214^2}{2 \times 32.2}$$

$$= 0.1145 \text{ PSF}$$

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Pressure drop through the flow opening around the Lower Tubenut.

$$V = \frac{m}{\rho A} = \frac{36667 \left(\frac{lb}{hr} \right)}{57.6 \left(\frac{lb}{ft^3} \right) \times 0.42 \left(ft^2 \right)} \quad A = \pi D L = \pi \times \frac{1.75}{12} \times \frac{1}{12}$$

$$= 1515.8 \text{ ft/hr}$$

$$= 0.42 \text{ ft/sec}$$

$$D_H = \frac{4 \times \pi \times D \times L}{2 \pi D} = 2 \times \frac{1}{12} = 0.1667 \text{ (ft)}$$

$$Re = \frac{m D_H}{\rho \mu} = \frac{36667 \left(\frac{lb}{hr} \right) \times 0.1667 \text{ (ft)}}{0.42 \left(\frac{lb}{ft^3} \right) \times 1.3892 \left(\frac{lb}{ft \cdot sec} \right)}$$

$$= 13361$$

$$K = 2.8 \quad (Re > 10000)$$

$$\Delta P = K \frac{\rho V^2}{2g} = 2.8 \times \frac{57.6 \times (0.42)^2}{2 \times 32.2}$$

$$= 0.4418 \text{ PSF}$$

Pressure drop through the openings of the seal area.
3 in Dia. 16 holes

$$V = \frac{m}{\rho A} \quad A = \frac{\pi}{4} D^2 \times 16$$

$$= \frac{36667 \left(\frac{lb}{hr} \right)}{57.6 \left(\frac{lb}{ft^3} \right) \times 0.7854 \left(ft^2 \right)} \quad = \frac{\pi}{4} \left(\frac{3}{12} \right)^2 \times 16 = 0.7854 \left(ft^2 \right)$$

$$= 810.52 \text{ ft/hr} = 0.2251 \text{ ft/sec}$$

$$\Delta P = K \frac{\rho V^2}{2g} = (2.8) \times \frac{57.6 \times (0.2251)^2}{2 \times 32.2}$$

$$= 0.127 \text{ PSF}$$

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Pressure drop through the tubes including inlet and exit losses

$$\begin{aligned}
 V &= \frac{\dot{m}}{\rho A} \\
 &= \frac{36667 (lb/hr)}{57.6 (lb/ft^3) \times 0.4293 (ft^2)} \\
 &= 1482.83 \text{ ft/hr} \\
 &= 0.4119 \text{ ft/sec}
 \end{aligned}$$

$$A = \frac{\pi}{4} D^2 \times \text{number of tubes}$$

$$D = 0.93 \text{ in.}$$

$$A = \frac{\pi}{4} \left(\frac{0.93}{12} \right)^2 \times 91$$

$$= 0.4293 \text{ ft}^2$$

$$\begin{aligned}
 Re &= \frac{\dot{m} D}{A \mu} = \frac{36667 (lb/hr) \times (3.0775) \text{ lb}}{0.4293 (ft^2) \times 1.0892 (lb/ft-sec)} \\
 &= 6077.27
 \end{aligned}$$

$$\begin{aligned}
 f &= 0.079 Re^{-1/4} \\
 &= 0.079 (6077)^{-1/4} \\
 &= 8.9475 \times 10^{-3}
 \end{aligned}$$

$$\begin{aligned}
 \Delta P &= \left(4f \frac{L}{D} + K_c + K_e \right) \frac{\rho V^2}{2} \\
 &= \left(4 \times 8.9475 \times 10^{-3} \times \frac{3.3333}{0.93/12} + 1.5 \right) \times \frac{57.6 \times (0.4119)^2}{2 \times 32.2} \\
 &= 0.4612 \text{ PSF}
 \end{aligned}$$

Pressure drop through the inlet and outlet nozzles.

$$P27E \quad \phi D = 2.875 \text{ in.}$$

$$ID = 2.125 \text{ in.}$$

$$\begin{aligned}
 \text{flow area} &= \frac{\pi}{4} \left(\frac{2.125}{12} \right)^2 \\
 &= 0.0246 \text{ ft}^2
 \end{aligned}$$

$$\begin{aligned}
 Re &= \frac{\dot{m} D}{A \mu} = \frac{36667 \times 2.125/12}{0.0246 \times 1.0892} \\
 &= 242330
 \end{aligned}$$

$$\begin{aligned}
 f &= 0.079 (Re)^{-1/4} \\
 &= 0.079 (242330)^{-0.25} = 3.5606 \times 10^{-3}
 \end{aligned}$$

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$$V = \frac{m}{\rho A} = \frac{36667 \left(\frac{lb}{ft^3} \right)}{57.6 \left(\frac{lb}{ft^3} \right) \times 0.0246}$$

$$= 25870 \text{ ft/hr} = 7.188 \text{ ft/sec}$$

$$\Delta P = (4 \times 3.5606 \times 10^{-3} \times \frac{1.237}{0.177} + 1.5) \times 2 \times \frac{57.6 \times 7.188^2}{2 \times 32.2}$$

$$= 147.83 \text{ PSF} = \underline{1.02 \text{ PSI}}$$

Pressure drop through the flow baffle

Tube OD = 1.0 in.
 flow passage diameter $1\frac{1}{4}$ in
 number of holes 91

$$A = \frac{\pi}{4} (1.25^2 - 1^2) \frac{91}{124} = 0.2792 \text{ ft}^2$$

$$V = \frac{m}{\rho A} = \frac{36667 \left(\frac{lb}{ft^3} \right)}{57.6 \left(\frac{lb}{ft^3} \right) \times 0.2792 \left(\frac{ft^2}{ft^2} \right)} = 2280 \text{ ft/hr}$$

$$Re = \frac{m D_v}{\rho \mu} = \frac{36667 \left(\frac{lb}{ft^3} \right) \times (1.25/12) \text{ ft}}{0.2792 \left(\frac{ft^2}{ft^2} \right) \times 1.0892 \left(\frac{lb}{ft \cdot sec} \right)}$$

$$= 2511.35$$

$K = 2.7$ (for laminar flow)

$$\Delta P = K \frac{\rho V^2}{2g}$$

$$= \frac{2.7 \times 57.6 \left(\frac{lb}{ft^3} \right) \times 0.6334^2 \left(\frac{ft}{sec} \right)^2}{2 \times 32.2 \left(\frac{ft}{sec^2} \right)}$$

$$= \underline{0.9688 \text{ PSF}}$$

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- (1) Economizer shell side pressure drop (0.1145 psf)
- (2) Pressure drop through the shell casing around
the lower tube sheet (0.4418 psf)
- (3) Pressure drop through the opening of the seal area (0.127 psf)
- (4) Pressure drop through the tubes including inlet and
exit losses (0.4612 psf)
- (5) Pressure drop through the inlet and outlet nozzles
(147.83 psf)
- (6) Pressure drop through the flow baffle (0.9688 psf)
- (7) Pressure drop in crystallizer mesh (13.3166 psf)

Total sodium pressure drop in the cold trap.

$$= 0.1145 + 0.4418 + 0.127 + 0.4612 + 147.73$$

$$+ 0.9688 + 13.3166$$

$$= 163.26 \text{ psf}$$

$$= 1.1337 \text{ PSI}$$

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IHTS/EVS GAS SIDE PRESSURE DROP

AIR FLOW RATE 7000 SCFM
180 CARBON STEEL FINS

Pressure drop through the inlet duct (8 duct)

8 in. Dia. 8 ea.

$$V = \frac{7000 \text{ ft}^3/\text{min} \times \frac{1 \text{ (min)}}{60 \text{ (sec)}}}{\frac{\pi}{4} \left(\frac{8}{12}\right)^2 \times 8 \text{ (ft}^2\text{)}}$$

$$= 41.77 \text{ ft/sec}$$

$$\Delta P = (1 + 0.5) \times \frac{2116.8}{53.34 \times (460 + 70)} \times \frac{41.77^2}{2 \times 32.2}$$

$$= 3.04 \text{ PSF}$$

Pressure drop through the fin length

$$\text{Periphery} = \frac{\pi(59.75 + 55.25)}{180} + 2 \times 2 = 6.00 \text{ in.}$$

$$\text{AREA} = \frac{\pi/4 (59.75^2 - 55.25^2)}{180} - 2 \times 0.25 = 1.758 \text{ in}^2$$

$$D_H = \frac{4A}{P} = \frac{4 \times 1.758}{6} = 1.172 \text{ in} = 0.09767 \text{ ft}$$

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$$V = \frac{7000 \frac{\text{ft}^3}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ sec}}}{180 \times 0.01221 \text{ ft}^2}$$

$$= 53.0834 \text{ ft/sec}$$

$$Re = \frac{\rho V D}{\mu} = \frac{0.0667 \times 53.0834 \times 3600 \times 0.0075}{0.0084}$$

$$= 25721$$

$$\rho = 0.0667 \text{ (at } 135^\circ\text{F)}$$

$$\mu = 0.0084 \text{ lbm/ft-sec}$$

$$\frac{f}{Re} = 0.079 Re^{-\frac{1}{4}}$$

$$= 0.079 (25721)^{-\frac{1}{4}}$$

$$= 6.238 \times 10^{-3}$$

$$\Delta P = (4 \times 6.238 \times 10^{-3} \times \frac{12.833}{0.0075} - 1.5) \times \frac{0.0667 \times 53.0834}{2 \times 32.2}$$

$$= 12.45 \text{ psf}$$

Pressure drop through the 4-outlet.

Assuming 9.75 in. Dia sharp edged orifice

$$V = \frac{7000 \frac{\text{ft}^3}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ sec}}}{\frac{\pi}{4} \left(\frac{9.75}{12} \right)^2 \times \pi} = 14.063 \text{ ft/sec}$$

$$\Delta P = (2.8) \times \frac{14.063^2}{2 \times 32.2} \times \frac{2116.8}{53.34 \times (400 + 120)}$$

$$= 0.5883 \text{ psf}$$

Total pressure drop

$$= 3.04 - 12.45 - 0.5883$$

$$= 16.083 \text{ psf}$$

$$= 0.1117 \text{ PSI}$$

$$= 3.09 \text{ in. of water}$$

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NAK PRESSURE DROP IN COOLANT JACKET

Jacket thickness 2.625 in
 Jacket height 45 in
 ID of the coolant jacket 60 in
 Distance between baffles 8.0 in
 NAK inlet pipe 2" pipe sch 40 (2.067" ID)
 NAK inlet Temp. 185°F
 NAK flow 40,000 lb/hr
 Length of the NAK inlet pipe 50 in

NAK MATERIAL PROPERTIES

$K = 13.92 \text{ BTU/hr-ft-}^\circ\text{F}$ (at 300°F)
 $\mu = 1.575 \text{ lb/ft-hr}$ (at 150°F)
 $\rho = 54.06 \text{ lb/ft}^3$ (at 150°F)
 $P_n = 0.01905$ (at 250°F)
 $C_p = 0.2245 \text{ BTU/lb-}^\circ\text{F}$ (at 150°F)

Pressure drop through the inlet and outlet pipes.

$$\text{Pipe flow area} = \frac{\pi}{4} \left(\frac{2.067}{12} \right)^2 = 0.0233 \text{ ft}^2$$

$$\begin{aligned}
 \text{NAK flow velocity} &= \frac{m}{\rho A} \\
 &= \frac{40,000 \text{ (lb/hr)}}{54.06 \text{ (lb/ft}^3\text{)} \times 0.0233 \text{ ft}^2} \\
 &= 31752 \text{ ft/hr} \\
 &= 8.82 \text{ ft/sec}
 \end{aligned}$$

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$$Re = \frac{\dot{m} D}{\mu A} = \frac{40.000 \left(\frac{lb}{ft^3} \right) \times (2.067) \text{ ft}}{1.575 \left(\frac{lb}{ft \cdot sec} \right) \times 0.0233 \text{ ft}^2}$$

$$= 187750$$

$$f = 0.079 Re^{-0.25}$$

$$= 0.079 (187750)^{-0.25}$$

$$= 3.795 \times 10^{-3}$$

$$\Delta P = \left(4 \times f \times \frac{L}{D} + K_e + K_c \right) \frac{\rho V^2}{2g}$$

$$= \left(4 \times 3.795 \times 10^{-3} \times \frac{100}{2.067} + 1.5 \right) \frac{54.6 \times 8.32}{2 \times 32.2}$$

$$= 147.37 \text{ PSI}$$

Pressure drop through the flow channel.

Length of flow channel.

$$= \pi (57.375) \times \frac{45}{\pi} = 10140 \text{ in}$$

$$= 84.5 \text{ ft}$$

Cross sectional area of the channel.

$$= 2.625 \times 8 = 21 \text{ in}^2 = 0.1458 \text{ ft}^2$$

$$NAK \text{ Velocity} = \frac{40.000 \left(\frac{lb}{ft^3} \right)}{54.6 \left(\frac{lb}{ft^3} \right) \times 0.1458 \text{ ft}^2}$$

$$= 5024 \text{ ft}^2/\text{in}$$

$$= 1.3957 \text{ ft/sec}$$

$$D_h = \frac{4 \times 21 \text{ (in}^2\text{)}}{2(2.625 + 8) \text{ (in)}} = 3.9529 \text{ in}$$

$$= 0.329 \text{ ft}$$

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$$Re = \frac{\dot{m} D_n}{\mu A}$$

$$= \frac{40.000 (lb/hr)}{1.575 (lb/ft^2 \cdot hr) \times 0.1458 (ft^2)} = 174200$$

$$f = 0.079 Re^{-0.25}$$

$$= 0.079 (174200)^{-0.25}$$

$$= 3.867 \times 10^{-3}$$

$$\Delta P = \left(4f \frac{L}{D_n} + K_e + K_c \right) \times \frac{\rho V^2}{2g}$$

$$= \left(4 \times 3.867 \times 10^{-3} \times \frac{10.14.0}{3.9529} + 0.5 + 1 \right) \times \frac{57.66 \times 8.22^2}{2 \times 32.2}$$

$$= 357 \text{ PSF}$$

Total pressure drop in coolant jacket.

$$= 357 - 147.37$$

$$= 504.4 \text{ PSF}$$

$$= 3.5 \text{ PSI}$$

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Primary Cold Trap

sodium flow rate 60 GPM (27500 lb/hr)

Pressure drop in the crystallizer mesh.

$$\Delta P = 8.197 \text{ (PSF)} \times \frac{45 \text{ (in)}}{92 \text{ (in)}}$$

$$= \underline{4.009 \text{ PSF}} \quad (60 \text{ GPM})$$

$$\Delta P = 13.3166 \text{ (PSF)} \times \frac{45 \text{ (in)}}{92 \text{ (in)}}$$

$$= \underline{6.5136 \text{ PSF}} \quad (\text{at } 80 \text{ GPM})$$

Total pressure drop in the cold trap.

sodium flow rate 60 GPM (27500 lb/hr)

- (1) Economizer shell side pressure drop (0.04988 PSF)
- (2) Pressure drop through the shell opening around
the lower tubesheet (0.245 PSF)
- (3) Pressure drop through the tubes including inlet and
exit losses (0.2689 PSF)
- (4) Pressure drop through the inlet and outlet nozzles (77.953 PSF)
- (5) Pressure drop through the opening of the seal area (0.07144 PSF)
- (6) Pressure drop through the flow baffle (3.78377×10^{-3} PSF)
- (7) Pressure drop in the crystallizer mesh (4.009 PSF)

$$\text{Total pressure drop} = 0.04988 + 0.245 + 0.2689 + 77.953$$

$$+ 0.07144 + 3.784 \times 10^{-3} + 4.009$$

$$= 82.60 \text{ PSF}$$

$$= \underline{10.5736 \text{ PSI}}$$

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Total pressure drop in the cold trap.

sodium flow rate 80 GPM (36.667 $\frac{lb}{min}$)

- (1) Economizer shell side pressure drop (0.1145 PSF)
- (2) Pressure drop through the shell opening around
the lower tubesheet (0.4418 PSF)
- (3) Pressure drop through the opening of the seal area
(0.127 PSF)
- (4) Pressure drop through the tubes including inlet and
exit losses (0.4612 PSF)
- (5) Pressure drop through the inlet and outlet nozzles
(147.83 PSF)
- (6) Pressure drop through the flow baffle (0.9588 PSF)
- (7) Pressure drop in crystallizer mesh (6.5136 PSF)

Total sodium pressure drop in the cold trap.

$$\begin{aligned}
 &= 0.1145 + 0.4418 + 0.127 + 0.4612 + 147.83 + 0.9588 + 6.5136 \\
 &= 156.46 \text{ PSF} \\
 &= \boxed{1.086 \text{ PSI}}
 \end{aligned}$$

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SODIUM RESIDENCE TIME CALCULATION.

1. IHTS, EVS COLD TRAP

2. ECONOMIZER SHELL SIDE FLOW

$$\text{FLOW AREA} = 115.49 \text{ in}^2$$

$$\begin{aligned} \text{TOTAL FLOW VOLUME} &= 115.49 (\text{in}^2) \times 39 (\text{in}) \\ &= 4504.11 (\text{in}^3) \\ &= 2.6065 (\text{ft}^3) \end{aligned}$$

$$\text{VOLUMETRIC FLOW RATE} = 60 \text{ GPM}$$

$$= 60 \frac{\text{gal}}{\text{min}} \times 231 \frac{\text{in}^3}{\text{gal}} \times \frac{1 \text{ min}}{60 \text{ sec}}$$

$$= 231 \text{ in}^3/\text{sec}$$

$$\text{RESIDENCE TIME} = \frac{\text{FLOW VOLUME}}{\text{VOLUMETRIC FLOW RATE}}$$

$$= \frac{4504.11 (\text{in}^3)}{231 \text{ in}^3/\text{sec}} = 19.49 \text{ sec}$$

6. ECONOMIZER TUBE SIDE FLOW

$$\text{TOTAL FLOW VOLUME}$$

$$= \frac{\pi}{4} (0.93)^2 \times 91 \times 39 = 2410.8 \text{ in}^3$$

$$\text{RESIDENCE TIME} = \frac{2410.8}{231} = 10.44 \text{ sec}$$

C. CRYSTALLIZER.

$$\text{TOTAL FLOW VOLUME}$$

$$= \left[\frac{\pi}{4} (54^2) - \frac{\pi}{4} (38.38^2 - 34.39^2) \right] \times 26.93$$

$$= 179218.3 \text{ in}^3$$

$$\begin{aligned} \text{RESIDENCE TIME} &= \frac{179218.3 (\text{in}^3)}{231 (\text{in}^3/\text{sec})} = 775.8 \text{ sec} \\ &= 12.93 \text{ minutes} \end{aligned}$$

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2. PRIMARY COLD TRAP

a. ECONOMIZER SHELL SIDE FLOW

$$\text{FLOW AREA} = 115.49 \text{ in}^2$$

$$\begin{aligned} \text{TOTAL FLOW VOLUME} &= 115.49 (\text{in}^2) \times 61. (\text{in}) \\ &= 7044.89 \text{ in}^3 \end{aligned}$$

$$\begin{aligned} \text{RESIDENCE TIME} &= \frac{\text{FLOW VOLUME}}{\text{VOLUMETRIC FLOW RATE}} \\ &= \frac{7044.89 (\text{in}^3)}{231 (\text{in}^3/\text{SEC})} \\ &= \underline{30.49 \text{ SEC}} \end{aligned}$$

b. ECONOMIZER TUBE SIDE FLOW

$$\text{TOTAL FLOW VOLUME}$$

$$= \frac{\pi}{4} (0.93)^2 \times 91 \times 61 = 3770.74 \text{ in}^3$$

$$\text{RESIDENCE TIME} = \frac{3770.74 (\text{in}^3)}{231 (\text{in}^3/\text{SEC})} = \underline{16.32 \text{ SEC}}$$

c. CRYSTALLIZER

$$\text{TOTAL FLOW VOLUME}$$

$$\begin{aligned} &= \left[\frac{\pi}{6} (54^3) - \frac{\pi}{6} (38.38^3 - 34.58^3) \right] \times 45 / 3 \\ &= 93041 \text{ in}^3 \end{aligned}$$

$$\begin{aligned} \text{RESIDENCE TIME} &= \frac{93041 (\text{in}^3)}{231 (\text{in}^3/\text{SEC})} = 402.78 \text{ SEC} \\ &= \underline{6.71 \text{ minutes}} \end{aligned}$$

APPENDIX D

Steady State Component Temperatures

FIG. D-1.

INLET NOZZLE AND
ECONOMIZER JUCTION
NODAL MAP

NODE
NUMBER

TEMPERATURES

Node Number	Temperature 1	Temperature 2	Temperature 3	Temperature 4	Temperature 5
1	850.00	850.00	849.99	849.94	849.20
6	844.90	841.03	831.25	826.95	822.69

11	815.68	798.00	798.00	798.00	798.00
16	798.00	798.00	798.00	807.52	808.23
21	604.68	798.00	.0	.0	.0

LOCATIONS 26 THROUGH 30 EQUAL ZERO

31	850.00	850.00	850.00	849.95	849.34
36	846.07	843.87	840.45	837.59	834.77
41	831.48	828.21	826.92	826.28	825.95
46	825.74	825.57	825.32	824.87	821.66
51	813.79	798.00	.0	.0	.0

LOCATIONS 56 THROUGH 60 EQUAL ZERO

61	850.00	850.00	850.00	849.99	849.90
66	849.34	849.04	848.54	848.09	847.65
71	847.15	846.67	846.46	846.36	846.31
76	846.27	846.24	846.20	846.09	845.56
81	844.34	842.25	.0	.0	.0

LOCATIONS 86 THROUGH 90 EQUAL ZERO

91	850.00	850.00	850.00	850.06	849.96
96	849.72	849.61	849.41	849.13	848.79
101	848.34	847.78	848.20	848.20	.0

LOCATIONS 106 THROUGH 110 EQUAL ZERO

111	850.00	850.00	850.00	849.98	849.76
116	848.25	847.49	846.25	844.40	842.25
121	839.28	835.00	835.00	835.00	.0

NODE
NUMBER

TEMPERATURES

131	850.00	850.00	850.00	849.98	849.71
136	847.85	846.82	844.91	841.20	838.84
141	835.00	.0	.0	.0	.0

LOCATIONS 146 THROUGH 200 EQUAL ZERO

201	811.53	809.23	804.81	798.00	799.78
206	799.44	798.81	798.00	798.19	798.15
211	798.09	798.00	798.00	798.00	798.00

216	798.00	.0	.0	.0	.0
221	838.79	837.34	835.00	837.01	836.24
226	835.00	835.51	835.31	835.00	835.20
231	835.12	835.00	835.00	835.00	835.00

LOCATIONS 236 THROUGH 495 EQUAL ZERO

496	.0	.0	798.00	835.00	850.00
-----	----	----	--------	--------	--------

FIG. D-2

UPPER TUBESHEET AND ECONOMIZER HEAD JUNCTION
NODAL MAP

NODE
NUMBER

TEMPERATURES

1	798.00	798.00	798.00	798.00	798.00
6	798.00	808.05	824.39	840.37	850.00
11	850.00	850.00	850.00	850.00	846.63
16	843.53	835.00	835.00	835.00	835.00
21	835.00	835.00	835.00	.0	.0

LOCATIONS 26 THROUGH 30 EQUAL ZERO

31	798.05	798.15	798.52	799.94	803.67
36	806.70	814.03	824.92	835.43	842.29
41	847.37	848.75	849.07	848.64	845.05
46	842.54	838.80	837.04	836.18	835.22
51	835.03	835.00	835.00	.0	.0

LOCATIONS 56 THROUGH 60 EQUAL ZERO

61	798.09	798.27	798.98	801.56	807.73
66	811.60	817.79	825.73	833.19	838.54
71	845.17	847.58	848.21	847.62	844.54
76	842.80	840.59	838.17	836.87	835.35
81	835.04	835.00	835.00	.0	.0

LOCATIONS 86 THROUGH 90 EQUAL ZERO

91	798.13	798.37	799.31	802.72	810.34
96	814.62	820.59	826.88	832.50	836.82
101	843.48	846.53	847.42	846.88	844.56
106	843.51	842.58	.0	.0	.0
111	798.14	798.42	799.48	803.32	811.71
116	816.41	823.46	828.50	832.76	836.23
121	842.26	845.63	846.74	846.35	844.71
126	844.07	843.62	.0	.0	.0
131	828.16	830.67	833.57	836.27	841.43
136	844.89	846.16	845.96	844.85	844.45
141	844.20	.0	.0	.0	.0

LOCATIONS 146 THROUGH 150 EQUAL ZERO

151	832.39	833.42	835.01	836.77	840.63
156	843.99	845.45	845.53	844.98	844.80
161	844.69	.0	.0	.0	.0

NODE
NUMBER

TEMPERATURES

171	834.95	835.47	836.36	837.50	840.21
176	843.28	844.85	845.21	845.01	844.95
181	844.91	.0	.0	.0	.0

LOCATIONS 186 THROUGH 190 EQUAL ZERO

191	836.00	836.35	837.01	837.89	840.08
196	842.96	844.57	845.06	845.01	844.98
201	844.97	.0	.0	.0	.0

LOCATIONS 206 THROUGH 210 EQUAL ZERO

211	798.00	798.00	798.00	798.00	798.00
216	798.00	798.00	783.86	766.23	753.07
221	787.79	850.00	798.00	772.44	731.73
226	674.32	757.92	850.00	798.00	772.10
231	709.80	495.13	722.40	850.00	798.00
236	798.00	798.00	.0	759.24	850.00
241	798.00	813.31	850.00	798.00	822.63
246	850.00	798.00	823.83	850.00	798.00
251	824.00	850.00	798.00	824.11	850.00

LOCATIONS 256 THROUGH 260 EQUAL ZERO

261	850.00	850.00	850.00	850.00	850.00
266	850.00	850.00	850.00	850.00	850.00
271	850.00	850.00	850.00	850.00	850.00
276	850.00	850.00	850.00	.0	.0

FIG. D-3. TUBE AND TUBESHEET NODAL MAP

NODE
NUMBER

TEMPERATURES

1	798.33	799.36	800.23	801.29	802.77
6	805.26	811.63	818.19	818.57	818.58
11	818.58	818.58	818.58	818.58	818.58
16	818.58	818.58	818.58	818.58	.0
21	798.78	802.12	804.68	807.83	812.18
26	819.12	834.09	.0	.0	.0
31	799.26	804.75	808.83	813.65	819.75
36	827.99	845.49	.0	.0	.0
41	799.60	806.55	811.60	817.34	824.09
46	832.25	846.97	.0	.0	.0
51	799.82	807.72	813.35	819.55	826.51
56	834.37	847.45	.0	.0	.0
61	799.95	808.40	814.35	820.77	827.77
66	835.41	847.65	.0	.0	.0
71	800.01	808.71	814.79	821.30	828.31
76	835.83	847.73	.0	.0	.0

LOCATIONS 81 THROUGH 85 EQUAL ZERO

80	.0	.0	834.26	834.45	834.45
91	834.45	834.45	834.45	834.45	834.45
96	834.45	834.45	834.45	834.45	.0
101	850.00	798.00	.0	.0	.0

FIG. D-4 BELLOW SUPPORT AND FLOW DIVIDER
JUNCTION NODAL MAP

**NODE
NUMBER**

TEMPERATURES

1	286.00	286.00	286.00	286.00	286.00
6	286.00	285.99	285.93	285.63	284.03
11	275.52	261.73	249.31	236.88	234.54
16	234.10	234.02	234.00	234.00	234.00
21	286.00	285.96	285.93	285.90	285.87
26	285.86	285.85	285.84	285.83	285.83
31	285.82	285.82	285.81	285.81	285.81
36	285.81	285.80	285.80	285.80	285.80
41	286.00	286.00	286.00	286.00	286.00
46	286.00	286.00	286.00	286.00	286.00
51	286.00	286.00	286.00	286.00	286.00
56	286.00	286.00	286.00	286.00	286.00
61	281.85	260.00	238.15	281.85	260.00
66	238.15	281.85	260.00	238.15	281.85
71	260.00	238.15	281.85	260.00	238.15
76	281.85	260.00	238.15	281.84	260.01
81	238.15	281.82	260.02	238.16	281.69
86	260.08	238.17	280.83	260.35	238.20

REGION NODAL MAP

MODE
TEMPER

TEMPERATURES

1	340.04	348.77	339.56	338.99	329.74
6	329.16	319.88	319.19	310.22	309.69
11	319.46	308.81	309.44	299.79	299.52
16	298.84	296.52	289.84	289.66	280.93
21	348.50	347.05	340.69	337.49	330.32
26	327.63	320.30	317.61	310.45	308.43
31	306.45	304.41	300.15	298.02	296.33
36	293.98	289.02	286.80	286.36	282.12
41	348.22	346.25	340.16	336.78	330.44
46	326.41	320.32	315.91	310.02	307.47
51	305.43	303.01	299.31	296.74	294.39
56	291.43	287.16	283.57	283.45	282.90
61	347.98	345.46	340.03	336.02	330.32
66	326.14	320.15	314.62	308.87	305.87
71	303.34	300.70	297.65	294.78	291.18
76	288.15	283.74	.0	.0	.0
81	.0	.0	349.70	335.49	329.69
86	325.45	319.74	313.18	305.97	302.72
91	300.05	297.46	294.72	291.76	288.29
96	283.71	.0	.0	298.06	296.97
101	295.38	293.49	291.34	288.45	286.29
106	283.36	.0	.0	293.67	292.59
111	291.44	290.11	288.61	286.44	285.13
116	283.23	.0	.0	.0	288.74
121	288.31	287.58	286.65	285.57	284.39
126	283.15	.0	.0	.0	286.73
131	286.48	285.95	285.34	284.64	283.89
136	283.19	.0	.0	.0	.0
141	294.89	284.71	284.40	284.00	283.55
146	283.07	.0	.0	.0	.0
151	294.08	283.99	283.82	283.60	283.33
156	283.94	.0	.0	.0	.0
161	283.68	283.63	283.53	283.38	283.22
166	283.03	.0	.0	.0	.0
171	283.51	283.47	283.49	283.29	283.16
176	283.03	.0	.0	.0	.0

FIG. D-6 TYPE I COLD TRAP
ECONOMIZER SHELL AND CRYSTALLIZER
UPPER HEAD NODAL MAP

NODE
NUMBER

TEMPERATURES

1	315.34	315.28	314.86	302.05	301.60
6	301.16	288.50	288.06	287.84	287.08
11	275.74	275.01	274.92	274.91	274.90
16	274.35	263.35	262.86	262.86	262.86
21	315.19	314.70	312.74	303.61	301.44
26	299.31	290.31	288.19	286.78	284.85
31	279.31	277.63	277.15	277.12	277.24
36	276.86	273.36	273.65	273.71	273.71
41	315.12	314.41	311.80	304.20	301.32
46	298.52	291.08	288.26	286.33	284.28
51	280.69	279.06	278.51	278.54	278.91
56	279.29	279.03	284.33	284.42	284.43
61	315.09	314.24	311.17	304.49	301.21
66	298.03	291.55	288.31	286.08	284.09
71	281.58	280.20	279.72	279.86	280.55
76	281.84	283.70	.0	.0	.0
81	.0	.0	316.78	304.58	301.03
86	297.60	291.94	288.36	285.90	284.01
91	282.46	281.54	281.25	281.60	282.74
96	285.39	.0	.0	.0	283.27
101	283.02	282.66	282.65	283.09	284.11
106	285.81	.0	.0	.0	.0
111	283.70	283.78	283.99	284.42	285.08
116	285.95	.0	.0	.0	.0
121	284.62	284.71	284.91	285.19	285.57
126	286.00	.0	.0	.0	.0
131	.0	285.34	285.44	285.60	285.80
136	286.02	.0	.0	.0	.0
141	.0	285.70	285.74	285.82	285.92
146	286.04	.0	.0	.0	.0
151	.0	.0	285.92	285.95	285.99
156	286.04	.0	.0	.0	.0
161	.0	.0	286.00	286.01	286.02
166	286.05	.0	.0	.0	.0
171	.0	.0	286.02	286.03	286.04
176	286.05	.0	.0	.0	.0
181	.0	.0	286.03	286.04	286.04
186	286.05	.0	.0	.0	.0

THERMAL DATA (IHTS COLD TRAP)

1. ECONOMIZER SHELL (FULL LENGTH)

NODE NO	TEMPERATURE (°F)				
801	664.86	TOP OF THE	655.01	645.17	635.33
806	615.64	ECONOMIZER	605.80	595.97	586.13
811	566.45	SHELL	556.62	546.78	536.45
816	517.28		507.45	497.62	487.79
821	468.13		458.30	448.48	438.65
826	419.00		409.17	399.35	389.52
831	369.88		360.05	350.23	341.01
836	301.66		296.76	291.92	287.11
					BOTTOM OF THE ECONOMIZER
					300.00
					282.34

2. ECONOMIZER TUBE

	TEMPERATURE (°F)				
01	644.86	TOP OF A	635.01	625.17	615.32
06	595.63	TUBE	585.79	575.94	566.10
11	546.42		536.58	526.74	516.91
16	497.23		487.40	477.56	467.73
21	448.06		438.23	428.40	418.57
26	398.91		389.08	379.25	369.42
31	349.71		339.94	330.11	320.13
36	300.46		290.75	281.11	271.52
					BOTTOM OF A TUBE
					261.97

3. CRYSTALLIZER TANK WALL

NODE NO	TEMPERATURE (°F)				
501	218.26	218.85	219.44	220.02	220.61
506	221.19	221.78	222.36	210.98	213.38
511	215.79	218.21	220.64	223.09	225.54
516	228.02	230.50	233.00	235.52	238.05
521	240.59	243.16	245.73	248.33	250.94
526	253.58	256.23	258.90	273.56	274.86
531	218.35	218.94	219.53	220.11	220.70
536	221.28	221.87	222.45	210.83	213.22
541	215.63	218.05	220.49	222.93	225.39
546	227.86	230.35	232.85	235.36	237.89
551	240.44	243.00	245.58	248.18	250.79
556	253.43	256.08	258.74	273.56	274.86
561	218.26	218.85	219.44	220.02	220.61
566	221.19	221.78	222.36	210.98	213.38
571	215.79	218.21	220.64	223.09	225.54
576	228.02	230.50	233.00	235.52	238.05
581	240.59	243.16	245.73	248.33	250.94
586	253.58	256.23	258.90	273.56	274.86
591	212.72	213.31	213.90	214.49	215.09
596	215.68	216.27	216.86	189.81	192.30
601	194.79	197.28	199.79	202.30	204.82
606	207.35	209.89	212.44	215.01	217.56
611	220.16	222.76	225.36	227.98	230.62
616	233.27	235.93	238.60	265.95	267.23
621	212.56	213.15	213.75	214.34	214.93
626	215.52	216.11	216.70	186.64	189.13
631	191.64	194.15	196.66	199.19	201.72
636	204.26	206.81	209.36	211.93	214.51
641	217.10	219.70	222.31	224.94	227.57
646	230.22	232.89	235.57	265.97	267.25
651	212.72	213.31	213.90	214.50	215.09
656	215.68	216.27	216.86	189.81	192.30
661	194.79	197.28	199.79	202.30	204.82
666	207.35	209.89	212.45	215.01	217.56
671	220.16	222.76	225.36	227.98	230.62
676	233.27	235.93	238.60	265.95	267.23

4. FIN

NODE NO.	TEMPERATURE (°F)				
686	0.0	0.0	0.0	171.53	174.09
691	176.65	179.22	181.79	184.36	186.94
696	189.52	192.11	194.70	197.31	199.91
701	202.53	205.15	207.79	210.43	213.08
706	215.74	218.42	221.10		
711	165.00	167.30	169.60	171.90	174.20
716	176.50	178.80	181.10	157.44	160.05
721	162.67	165.29	167.90	170.52	173.14
726	175.77	178.39	181.02	183.65	186.29
731	188.93	191.58	194.23	196.89	199.55
736	202.23	204.91	207.60		

5. FLOW BAFFLE

	TEMPERATURE (°F)				
01	228.79	BOTTOM OF	230.23	231.70	233.18
06	216.21	THE FLOW	237.75	239.31	240.90
11	244.13	BAFFLE	245.78	247.44	249.14
16	252.58		254.34	256.12	257.93
21	261.60		262.62	.0	.0

THERMAL DATA (PNTS. COLD TRAP)

1. ECONOMIZER SHELL

NODE NO	TEMPERATURE (°F)				
801	815.37	TOP OF THE	821.13	806.89	792.66
806	764.20	ECONOMIZER	749.98	735.75	721.53
811	693.10	SHELL	678.88	664.67	650.46
816	622.05		607.85	593.64	579.44
821	551.05		536.85	522.66	508.47
826	480.09		465.90	451.72	437.54
831	409.17		394.99	380.81	366.09
836	311.78		304.84	298.01	291.26
					BOTTOM OF
					THE ECONOMIZER
					SHELL
					284.59

2. ECONOMIZER TUBE

	TEMPERATURE (°F)				
01	816.95	TOP OF	802.70	788.46	774.23
06	745.76	A TUBE	731.53	717.30	703.08
11	674.63		660.41	646.20	631.98
16	603.56		589.35	575.14	560.93
21	532.53		518.33	504.13	489.93
26	461.54		447.35	433.16	418.97
31	390.59		376.41	362.22	347.72
36	319.57		305.83	292.27	278.83
					BOTTOM
					OF A TUBE
					265.47

3. FLOW BAFFLE

	TEMPERATURE (°F)				
01	234.01	BOTTOM OF	240.42	241.81	243.17
06	245.82	THE FLOW	247.11	248.38	249.63
11	252.07	BAFFLE	253.26	254.44	255.59
16	257.86		258.98	260.08	261.16
21	263.30		264.35	0	0
			TOP OF		
			THE FLOW BAFFLE		

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PARAMETER CALCULATION FOR THE COMPONENTS

ADMITTANCES

$$K (\text{STAINLESS STEEL}) = 11.6 \text{ } \frac{\text{BTU}}{\text{hr} \cdot \text{ft}^2 \cdot ^\circ\text{F}}$$

$$= 2.6852 \times 10^{-4} \frac{\text{BTU}}{\text{sec} \cdot \text{in}^2 \cdot ^\circ\text{F}}$$

$$Y1 \sim Y3, Y61 \sim Y63, Y91 \sim Y93, Y131 \sim Y133$$

$$= \frac{KA}{X} = \frac{2.6852 \times 10^{-4} \times 0.625}{1.0} = 1.6782 \times 10^{-5} \frac{\text{BTU}}{\text{sec} \cdot ^\circ\text{F}}$$

$$Y31 \sim Y33, Y111 \sim Y113$$

$$= \frac{2.6852 \times 10^{-4} \times 0.25}{1.0} = 6.713 \times 10^{-5} \frac{\text{BTU}}{\text{sec} \cdot ^\circ\text{F}}$$

$$Y4, Y64, Y94, Y134$$

$$= \frac{2.6852 \times 10^{-4} \times 0.625}{0.9} = 1.8647 \times 10^{-5} \frac{\text{BTU}}{\text{sec} \cdot ^\circ\text{F}}$$

$$Y34, Y114$$

$$= \frac{2.6852 \times 10^{-4} \times 0.25}{0.9} = 7.4539 \times 10^{-5} \frac{\text{BTU}}{\text{sec} \cdot ^\circ\text{F}}$$

$$Y5, Y65, Y95, Y135$$

$$= \frac{2.6852 \times 10^{-4} \times 0.625}{0.47} = 3.5707 \times 10^{-5} \frac{\text{BTU}}{\text{sec} \cdot ^\circ\text{F}}$$

$$Y35, Y115$$

$$= \frac{2.6852 \times 10^{-4} \times 0.25}{0.47} = 1.4283 \times 10^{-4} \frac{\text{BTU}}{\text{sec} \cdot ^\circ\text{F}}$$

$$Y6 \sim Y11, Y66 \sim Y71$$

$$= \frac{2.6852 \times 10^{-4} \times 2.1625}{0.15625} = 1.074 \times 10^{-4} \frac{\text{BTU}}{\text{sec} \cdot ^\circ\text{F}}$$

$$Y26 \sim Y41$$

$$= \frac{2.6852 \times 10^{-4} \times 2.25}{0.15625} = 4.2063 \times 10^{-4} \frac{\text{BTU}}{\text{sec} \cdot ^\circ\text{F}}$$

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$\gamma_{12} \sim \gamma_{21}, \quad \gamma_{72} \sim \gamma_{81}$

$$= \frac{2.6852 \times 10^{-4} \times 0.0625}{0.125} = 1.3426 \times 10^{-4} \text{ cm/sec}^{-1}$$

$\gamma_{42} \sim \gamma_{51},$

$$= \frac{2.6852 \times 10^{-4} \times 0.25}{0.125} = 5.3704 \times 10^{-4} \text{ cm/sec}^{-1}$$

$\gamma_{96} \sim \gamma_{101} \quad \gamma_{136} \sim \gamma_{140}.$

$$= \frac{2.6852 \times 10^{-4} \times 0.0625}{0.125} = 1.3426 \times 10^{-4} \text{ cm/sec}^{-1}$$

$\gamma_{116} \sim \gamma_{121}$

$$= \frac{2.6852 \times 10^{-4} \times 0.25}{0.125} = 5.3704 \times 10^{-4} \text{ cm/sec}^{-1}$$

γ_{102}

$$= \frac{2.6852 \times 10^{-4} \times 0.0625}{0.375} = 4.47 \times 10^{-5} \text{ cm/sec}^{-1}$$

γ_{102}

$$= \frac{2.6852 \times 10^{-4} \times 0.25}{0.575} = 1.1791 \times 10^{-4} \text{ cm/sec}^{-1}$$

γ_{103}

$$= \frac{2.6852 \times 10^{-4} \times 0.0625}{0.625} = 2.6852 \times 10^{-5} \text{ cm/sec}^{-1}$$

γ_{123}

$$= \frac{2.6852 \times 10^{-4} \times 0.1875}{0.625} = 8.0556 \times 10^{-5} \text{ cm/sec}^{-1}$$

$\gamma_{201} \sim \gamma_{203},$

$$= \frac{2.6852 \times 10^{-4} \times 0.5}{0.15625} = 8.5926 \times 10^{-4} \text{ cm/sec}^{-1}$$

$\gamma_{205} \sim \gamma_{211}$

$$= \frac{2.6852 \times 10^{-4} \times 1}{0.15625} = 1.71853 \times 10^{-3} \text{ cm/sec}^{-1}$$

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$$Y_{213} \sim Y_{215}$$

$$= \frac{2.6852 \times 10^{-4} \times 0.44}{0.125} = 9.4519 \times 10^{-5} \text{ cm/sec} - \text{?}$$

$$Y_{221} \sim Y_{222} \quad Y_{224} \sim Y_{225}$$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{0.125} = 2.6852 \times 10^{-4} \text{ cm/sec} - \text{?}$$

$$Y_{227} \sim Y_{228}$$

$$= \frac{2.6852 \times 10^{-4} \times 0.35}{0.125} = 5.3704 \times 10^{-4} \text{ cm/sec} - \text{?}$$

$$Y_{230} \sim Y_{232}$$

$$= \frac{2.6852 \times 10^{-4} \times 1}{0.125} = 2.1482 \times 10^{-3} \text{ cm/sec} - \text{?}$$

$$Y_{301} \sim Y_{304}, \quad Y_{331} \sim Y_{334}, \quad Y_{391} \sim Y_{394}, \quad Y_{411} \sim Y_{414},$$

$$= \frac{2.6852 \times 10^{-4} \times 1}{0.0625 + 0.25/2} = 1.4321 \times 10^{-3} \text{ cm/sec} - \text{?}$$

$$Y_{305}, \quad Y_{335}$$

$$= \frac{2.6852 \times 10^{-4} \times 0.7}{0.0625 + 0.25/2} = 1.0025 \times 10^{-3} \text{ cm/sec} - \text{?}$$

$$Y_{306} \sim Y_{307}, \quad Y_{336} \sim Y_{337}$$

$$= \frac{2.6852 \times 10^{-4} \times 2.15625}{0.0625 + 0.25/2} = 2.2577 \times 10^{-3} \text{ cm/sec} - \text{?}$$

$$Y_{308} \sim Y_{311}$$

$$= \frac{2.6852 \times 10^{-4} \times 0.15625}{(0.1275 + 0.25)/2} = 2.2228 \times 10^{-4} \text{ cm/sec} - \text{?}$$

$$Y_{312} \sim Y_{322}$$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{0.1275 + 0.25/2} = 1.3293 \times 10^{-4} \text{ cm/sec} - \text{?}$$

$$Y_{338} \sim Y_{352}$$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{0.0625 + 0.25/2} = 1.79 \times 10^{-4} \text{ cm/sec} - \text{?}$$

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$\gamma 335 \sim \gamma 415$

$$= \frac{2.6852 \times 10^{-4} \times 0.3225}{0.25/2 + 0.0625} = 1.271 \times 10^{-3} \text{ stn/sec-}^{\circ}\text{F}$$

$\gamma 396 \sim \gamma 402, \gamma 416 \sim \gamma 418$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{0.0625 + 0.25/2} = 1.7901 \times 10^{-4} \text{ stn/sec-}^{\circ}\text{F}$$

$\gamma 403 \sim \gamma 404$

$$= \frac{2.6852 \times 10^{-4} \times 0.625}{0.0625 + 0.1875} = 6.713 \times 10^{-4} \text{ stn/sec-}^{\circ}\text{F}$$

$\gamma 419 \sim 421$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{(0.25 - 0.0625)/2} = 2.1282 \times 10^{-4} \text{ stn/sec-}^{\circ}\text{F}$$

$\gamma 521 \sim \gamma 523$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{(0.0625 - 0.125)/2} = 3.5803 \times 10^{-4} \text{ stn/sec-}^{\circ}\text{F}$$

$\gamma 524 \sim \gamma 526$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{(0.125 + 0.125)/2} = 2.6852 \times 10^{-4} \text{ stn/sec-}^{\circ}\text{F}$$

$\gamma 527 \sim \gamma 529$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{(0.25 + 0.125)/2} = 1.7901 \times 10^{-4} \text{ stn/sec-}^{\circ}\text{F}$$

$\gamma 530 \sim \gamma 532$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{(1 - 0.25)/2} = 5.3704 \times 10^{-4} \text{ stn/sec-}^{\circ}\text{F}$$

$\gamma 533 \sim \gamma 535$

$$= \frac{2.6852 \times 10^{-4} \times 0.125}{\frac{1}{2}} = 1.67825 \times 10^{-4} \text{ stn/sec-}^{\circ}\text{F}$$

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$\gamma 501 \sim \gamma 504$

$$= \frac{2.6752 \times 10^{-4} \times 0.15625}{(0.5 + 0.1275)/2} = 1.3373 \times 10^{-4} \text{ BTU/sec-}^{\circ}\text{F}$$

$\gamma 505 \sim \gamma 508$

$$= \frac{2.6752 \times 10^{-4} \times 0.15625}{(0.5 + 1)/2} = 5.5942 \times 10^{-5} \text{ BTU/sec-}^{\circ}\text{F}$$

$\gamma 509 \sim \gamma 512$

$$= \frac{2.6752 \times 10^{-4} \times 0.15625}{(1 + 1)/2} = 4.19563 \times 10^{-5} \text{ BTU/sec-}^{\circ}\text{F}$$

$\gamma 513 \sim \gamma 516$

$$= \frac{2.6752 \times 10^{-4} \times 0.125}{(0.44 + 0.1275)/2} = 1.1829 \times 10^{-4} \text{ BTU/sec-}^{\circ}\text{F}$$

CONVECTION AREA

$\gamma 661 \sim \gamma 664, \gamma 691 \sim \gamma 694$

$$= 1 \times 1 = 1.0 \text{ in}^2$$

$\gamma 665$

$$= 0.7 \text{ in}^2$$

$\gamma 666 \sim \gamma 691$

$$= 0.15625 \text{ in}^2$$

$\gamma 692 \sim \gamma 693$

$$= 0.125 \text{ in}^2$$

$\gamma 695 \quad 0.8875 \text{ in}^2$

$\gamma 696 \sim \gamma 702 \quad 0.125 \text{ in}^2$

$\gamma 703 \sim \gamma 704 \quad 0.625 \text{ in}^2$

$\gamma 722 \quad 0.125 \text{ in}^2$

$\gamma 723 \sim \gamma 724 \quad 0.625 \text{ in}^2$

$\gamma 733 \quad 0.125 \text{ in}^2$

$\gamma 736 \quad 0.125 \text{ in}^2$

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Y 739 0.25 in²
 Y 741 0.0625 in²
 Y 742 1 in²
 Y 745 1 in²
 Y 802 - Y 808 0.125 in²
 Y 813 , Y 816 0.565 in²
 Y 814 - Y 815 0.125 in²
 Y 824 0.5 in²
 Y 828 , Y 832 1 in²
 Y 842 0.1275 in²
 Y 844 0.25 in²

INLET NOZZLE

$$\phi D = 2.875 \text{ IN.}$$

$$ID = 2.125 \text{ IN}$$

$$\text{WALL THICKNESS } 0.375 \text{ IN}$$

$$NA \text{ FLOW RATE } 27500 \text{ LB/HR}$$

MATERIAL PROPERTIES OF SODIUM

$$\text{DENSITY} = 57.16 \text{ lbm/ft}^3 \quad P_n = 0.508158$$

$$K = 48.86 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F}$$

$$\mu = 1.3316 \text{ lbm/ft-hr}$$

$$Re = \frac{\phi D}{\mu} = \frac{27500 \times 2.125/12}{\frac{\pi}{4} (2.125/12)^2 \times 1.3316}$$

$$= 148487$$

$$Nu_D = 7 + 0.025 (Re P_n)^{0.8}$$

$$= 7 + 0.025 (148487 \times 0.508158)^{0.8}$$

$$= 14.82$$

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$$Nu_D = \frac{hD}{k} = 14.82$$

$$\begin{aligned}
 h &= \frac{14.82 \times 48.86}{2.125/12} = 4088 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F} \\
 &= 7.8858 \times 10^{-3} \text{ Btu/sec-in}^2\text{-}^\circ\text{F}
 \end{aligned}$$

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PARAMETER CALCULATIONS

JUNCTION OF THE UPPER TUBESHEET AND
THE ECONOMIZER SHELL

ADMITTANCE

CALCULATE ADMITTANCE BASE ONE RADIAN REVOLUTION

$$Y1 \sim Y3 \quad Y11 \sim Y13 \quad Y20 \sim Y22$$

$$AREA = \frac{9.75^2 - 9.625^2}{2} = 1.2109 \text{ in}^2$$

Admittance

$$= \frac{KA}{X} = \frac{2.6852 \times 10^{-4} \times 1.2109}{0.5} = 6.523 \times 10^{-4} \text{ Btu/sec-}^\circ\text{F}$$

Y4, Y14, Y19,

$$= \frac{2.6852 \times 10^{-4} \times 1.2109}{0.3125} = 1.04048 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

Y5, Y15 ~ Y18,

$$= \frac{2.6852 \times 10^{-4} \times 1.2109}{0.125} = 2.6012 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

Y6

$$= \frac{2.6852 \times 10^{-4} \times 1.2109}{0.13585} = 2.3935 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

Y7 ~ Y9

$$= \frac{2.6852 \times 10^{-4} \times 1.2109}{0.1467} = 2.2164 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

Y10

$$= \frac{2.6852 \times 10^{-4} \times 1.2109}{(0.5 + 0.1467)/2} = 1.0056 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

Y31 ~ Y52

$$Area = \frac{R_o^2 - R_i^2}{2} = \frac{9.875^2 - 9.75^2}{2} = 1.2265$$

$$Y31 \sim Y52 = (Y1 \sim Y23) \times \frac{1.2265}{1.2109}$$

$$= (Y1 \sim Y23) \times 1.0129$$

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Y 61 ~ Y 82

$$\text{Area} = \frac{10^2 - 9.175^2}{2} = 1.2422$$

$$\begin{aligned} (Y 61 \sim Y 82) &= (Y 1 \sim Y 22) \times \frac{1.2422}{1.2109} \\ &= (Y 1 \sim Y 22) \times 1.0258 \end{aligned}$$

Y 91 ~ Y 106

$$\text{Area} = \frac{10.125^2 - 10^2}{2} = 1.2578$$

$$\begin{aligned} (Y 91 \sim Y 106) &= (Y 1 \sim Y 16) \times \frac{1.2578}{1.2109} \\ &= (Y 1 \sim Y 16) \times 1.0387 \end{aligned}$$

Y 111 ~ Y 126

$$\text{Area} = \frac{10.25^2 - 10.125^2}{2} = 1.2734$$

$$\begin{aligned} (Y 111 \sim Y 126) &= (Y 1 \sim Y 16) \times \frac{1.2734}{1.2109} \\ &= (Y 1 \sim Y 16) \times 1.0522 \end{aligned}$$

Y 131 ~ Y 140

$$\text{Area} = \frac{10.375^2 - 10.25^2}{2} = 1.2891$$

$$\begin{aligned} (Y 131 \sim Y 140) &= (Y 7 \sim Y 16) \times \frac{1.2891}{1.2109} \\ &= (Y 7 \sim Y 16) \times 1.0645 \end{aligned}$$

Y 151 ~ Y 160

$$\text{Area} = \frac{10.625^2 - 10.375^2}{2} = 2.625$$

$$\begin{aligned} Y 151 \sim Y 160 &= (Y 7 \sim Y 16) \times \frac{2.625}{1.2109} \\ &= (Y 7 \sim Y 16) \times 2.1678 \end{aligned}$$

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Y 171 ~ 180

$$\text{Area} = \frac{10.275^2 - 10.635^2}{2} = 2.6875$$

$$(Y 171 - Y 180) = (Y 7 - Y 16) \times \frac{2.6875}{1.2109}$$

$$= (Y 7 - Y 16) \times 2.2194$$

Y 191 ~ Y 200

$$\text{Area} = \frac{11.125^2 - 10.875^2}{2} = 2.75$$

$$(Y 191 - Y 200) = (Y 7 - Y 16) \times \frac{2.75}{1.2109}$$

$$= (Y 7 - Y 16) \times 2.271$$

Y 211 ~ Y 215

$$\text{Area} = \frac{8.125^2 - 8^2}{2} = 1.0078$$

$$\text{Admittance} = \frac{2.6852 \times 10^{-4} \times 1.0078}{0.1467} = 1.8447 \times 10^{-3} \text{ } \frac{\text{cm}^2}{\text{sec} \cdot \text{cm}^2}$$

Y 217 ~ Y 221

$$\text{Area} = \frac{8.25^2 - 8.125^2}{2} = 1.0234$$

$$(Y 217 - Y 221) = (Y 211 - Y 215) \times \frac{1.0234}{1.0078}$$

$$= (Y 211 - Y 215) \times 1.0155$$

Y 223 ~ Y 227

$$\text{Area} = \frac{8.375^2 - 8.25^2}{2} = 1.0391$$

$$(Y 223 - Y 227) = (Y 211 - Y 215) \times \frac{1.0391}{1.0078}$$

$$= (Y 211 - Y 215) \times 1.031$$

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$Y_{229} \sim Y_{233}$

$$Area = \frac{8.5^2 - 8.315^2}{2} = 1.055$$

$$\begin{aligned} (Y_{229} \sim Y_{233}) &= (Y_{211} \sim Y_{215}) \times \frac{1.055}{1.0078} \\ &= (Y_{211} \sim Y_{215}) \times 1.0465 \end{aligned}$$

$Y_{235} \sim Y_{239}$

$$Area = \frac{8.625^2 - 8.5^2}{2} = 1.0703$$

$$\begin{aligned} (Y_{235} \sim Y_{239}) &= (Y_{211} \sim Y_{215}) \times \frac{1.0703}{1.0078} \\ &= (Y_{211} \sim Y_{215}) \times 1.062 \end{aligned}$$

$Y_{241} \sim Y_{242}$

$$Area = \frac{8.875^2 - 8.625^2}{2} = 2.1875$$

$$\begin{aligned} (Y_{241} \sim Y_{242}) &= (Y_{214} \sim Y_{215}) \times \frac{2.1875}{1.0078} \\ &= (Y_{214} \sim Y_{215}) \times 2.1706 \end{aligned}$$

$Y_{244} \sim Y_{245}$

$$Area = \frac{9.125^2 - 8.875^2}{2} = 2.25$$

$$\begin{aligned} (Y_{244} \sim Y_{245}) &= (Y_{214} \sim Y_{215}) \times \frac{2.25}{1.0078} \\ &= (Y_{214} \sim Y_{215}) \times 2.2326 \end{aligned}$$

$Y_{247} \sim Y_{248}$

$$Area = \frac{9.375^2 - 9.125^2}{2} = 2.3125$$

$$\begin{aligned} (Y_{247} \sim Y_{248}) &= (Y_{214} \sim Y_{215}) \times \frac{2.3125}{1.0078} \\ &= (Y_{214} \sim Y_{215}) \times 2.2946 \end{aligned}$$

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$\gamma_{250} \sim \gamma_{251}$

$$\text{Area} = \frac{9.5^2 - 9.375^2}{2} = 1.1797$$

$$\begin{aligned} (\gamma_{250} \sim \gamma_{251}) &= (\gamma_{214} \sim \gamma_{215}) \times \frac{1.1797}{1.0078} \\ &= (\gamma_{214} \sim \gamma_{215}) \times 1.1706 \end{aligned}$$

$\gamma_{253} \sim \gamma_{254}$

$$\text{Area} = \frac{9.625^2 - 9.5^2}{2} = 1.1953$$

$$\begin{aligned} (\gamma_{253} \sim \gamma_{254}) &= (\gamma_{214} \sim \gamma_{215}) \times \frac{1.1953}{1.0078} \\ &= (\gamma_{214} \sim \gamma_{215}) \times 1.1861 \end{aligned}$$

γ_{261}

$$\text{Area} = 1.0078 (\text{in}^2) \times 1.0155$$

$$X = 0.25$$

$$\begin{aligned} \text{admittance} &= \frac{2.1852 \times 10^{-4} \times 1.0078 \times 1.0155}{0.25} \\ &= 1.099 \times 10^{-3} \text{ cm}^2/\text{sec} - \text{F} \end{aligned}$$

γ_{263}

$$\gamma_{261} \times \frac{1.0391}{1.0234} = \gamma_{261} \times 1.0153$$

γ_{265}

$$\gamma_{261} \times \frac{1.055}{1.0234} = \gamma_{261} \times 1.0309$$

γ_{267}

$$\gamma_{261} \times \frac{1.0703}{1.0234} = \gamma_{261} \times 1.0458$$

γ_{269}

$$\gamma_{261} \times \frac{2.1875}{1.0234} = \gamma_{261} \times 2.1375$$

γ_{271}

$$\gamma_{261} \times \frac{2.25}{1.0234} = \gamma_{261} \times 2.1985$$

γ_{273}

$$\gamma_{261} \times \frac{2.3125}{1.0234} = \gamma_{261} \times 2.2596$$

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Y275

$$Y261 \times \frac{1.1797}{1.0234} = Y261 \times 1.1527$$

Y277

$$Y261 \times \frac{1.1953}{1.0234} = Y261 \times 1.168$$

Y301 ~ Y304

Y320 ~ Y323

$$\frac{2\pi RL}{2\pi} = RL \text{ per radian.}$$

$$\text{Area} = 9.75 \times 0.5 = 4.875 \text{ in}^2$$

$$\text{Admittance} = \frac{2.6852 \times 10^{-4} \times 4.875}{0.125} = 0.0105 \text{ S/m}^2 - F$$

Y305 ~ Y306

$$= \frac{9.75 \times 0.125 \times 2.6852 \times 10^{-4}}{0.125} = 2.6181 \times 10^{-3} \text{ S/m}^2 - F$$

Y307 ~ Y309

$$= \frac{9.75 \times 0.1467 \times 2.6852 \times 10^{-4}}{0.125} = 3.0726 \times 10^{-3} \text{ S/m}^2 - F$$

Y310, Y315 ~ Y319

$$= \frac{9.75 \times 0.125 \times 2.6852 \times 10^{-4}}{0.125} = 2.6161 \times 10^{-3} \text{ S/m}^2 - F$$

Y331 ~ Y353

$$= (Y301 \sim Y323) \times \frac{9.875}{9.75}$$

$$= (Y301 \sim Y323) \times 1.0128$$

Y351 ~ Y377

$$= (Y301 \sim Y317) \times \frac{10.0}{9.75}$$

$$= (Y301 \sim Y317) \times 1.0256$$

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$\gamma 391 \sim \gamma 407$

$$= (\gamma 301 \sim \gamma 317) \times \frac{10.125}{9.75}$$

$$= (\gamma 301 \sim \gamma 317) \times 1.0385$$

$\gamma 417 \sim \gamma 427$

$$= (\gamma 307 \sim \gamma 317) \times \frac{12.35}{9.75}$$

$$= (\gamma 307 \sim \gamma 317) \times 1.0513$$

$\gamma 431$

$$= \frac{2.6852 \times 10^{-4} \times 10.4375 \times 0.1467}{0.1875}$$

$$= 2.1928 \times 10^{-3}$$

$\gamma 432 \sim \gamma 441$

$$= (\gamma 308 \sim \gamma 317) \times \frac{2.1928 \times 10^{-3}}{3.0726 \times 10^{-3}}$$

$$= (\gamma 308 \sim \gamma 317) \times 0.7137$$

$\gamma 451$

$$= \frac{2.6852 \times 10^{-4} \times 10.625 \times 0.1467}{0.25} = 1.6742 \times 10^{-3} \text{ cm}^2/\text{sec} \sim 1.7$$

$\gamma 452 \sim \gamma 461$

$$= (\gamma 308 \sim \gamma 317) \times \frac{1.6742 \times 10^{-3}}{3.0726 \times 10^{-3}}$$

$$= (\gamma 308 \sim \gamma 317) \times 0.5449$$

$\gamma 471 \sim \gamma 481$

$$= (\gamma 451 \sim \gamma 461) \times \frac{10.875}{10.625}$$

$$= (\gamma 451 \sim \gamma 461) \times 1.0235$$

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$\gamma 511 \sim \gamma 516$

$$= \frac{2.6852 \times 10^{-4} \times 8.125 \times 0.1467}{0.125} = 2.5405 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

$\gamma 517 \sim \gamma 522$

$$= (\gamma 511 \sim \gamma 516) \times \frac{8.25}{8.125}$$

$$= (\gamma 511 \sim \gamma 516) \times 1.0154$$

$\gamma 523 \sim \gamma 528$

$$= (\gamma 511 \sim \gamma 516) \times \frac{8.375}{8.125}$$

$$= (\gamma 511 \sim \gamma 516) \times 1.0308$$

$\gamma 529 \sim \gamma 534$

$$= (\gamma 511 \sim \gamma 516) \times \frac{8.5}{8.125}$$

$$= (\gamma 511 \sim \gamma 516) \times 1.046$$

$\gamma 538 \sim \gamma 540$

$$= \frac{2.6852 \times 10^{-4} \times 8.6875 \times 0.1467}{0.1875}$$

$$= 1.8252 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

$\gamma 541 \sim \gamma 543$

$$= \frac{2.6852 \times 10^{-4} \times 8.875 \times 0.1467}{0.25} = 1.3984 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

$\gamma 544 \sim \gamma 546$

$$= \frac{2.6852 \times 10^{-4} \times 9.125 \times 0.1467}{0.25} = 1.4378 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

$\gamma 547 \sim \gamma 549$

$$= \frac{2.6852 \times 10^{-4} \times 9.375 \times 0.1467}{0.1875} = 1.9696 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

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$$\gamma 550 \sim \gamma 552$$

$$= \frac{2.6752 \times 10^{-4} \times 9.635 \times 0.1467}{0.125} = 2.9938 \times 10^{-3} \quad \text{3.42/42-12}$$

$$\gamma 553 \sim \gamma 555$$

$$= \frac{2.6752 \times 10^{-4} \times 9.635 \times 0.1467}{0.125} = 3.0338 \times 10^{-3} \quad \text{3.42/42-12}$$

$$\gamma 561 \sim \gamma 562$$

$$= (\gamma 521) \times \frac{0.125}{0.1467} = \gamma(521) \times 0.8521$$

$$\gamma 563 \sim \gamma 564$$

$$= (\gamma 527) \times 0.8521$$

$$\gamma 565 \sim \gamma 566$$

$$= (\gamma 534) \times 0.8521$$

$$\gamma 567 \sim \gamma 568$$

$$= (\gamma 539) \times 0.8521$$

$$\gamma 569 \sim \gamma 570$$

$$= (\gamma 542) \times 0.8521$$

$$\gamma 571 \sim \gamma 572$$

$$= (\gamma 545) \times 0.8521$$

$$\gamma 573 \sim \gamma 574$$

$$= (\gamma 547) \times 0.8521$$

$$\gamma 575 \sim \gamma 576$$

$$= (\gamma 551) \times 0.8521$$

$$\gamma 577 \sim \gamma 578$$

$$= (\gamma 554) \times 0.8521$$

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TUBE AND TUBESHEET

One radian revolution on the axis of the axial center line.

Y1 ~ Y7

$$R_o = 0.5 \text{ in.}$$

$$R_i = 0.465 \text{ in.}$$

$$\text{Area} = \frac{0.5^2 - 0.465^2}{2} = 0.01639 \text{ in}^2$$

$$X = 0.125 \text{ in.}$$

$$\begin{aligned} \text{Admittance} &= \frac{2.6852 \times 10^{-4} \times 0.01639}{0.125} \\ &= 3.6282 \times 10^{-5} \text{ cm}^2/\text{sec} \cdot \text{in}^2 \end{aligned}$$

Y8 ~ Y19

$$1.8141 \times 10^{-5} \text{ cm}^2/\text{sec} \cdot \text{in}^2$$

Y21, Y26

$$\text{Area} = \frac{0.625^2 - 0.5^2}{2} = 0.0703 \text{ in}^2$$

$$\text{Admittance} = \frac{2.6852 \times 10^{-4} \times 0.0703}{0.1875} = 1.007 \times 10^{-4} \text{ cm}^2/\text{sec} \cdot \text{in}^2$$

Y22 ~ Y25

$$\text{Admittance} = \frac{2.6852 \times 10^{-4} \times 0.0703}{0.125} = 1.51043 \times 10^{-4} \text{ cm}^2/\text{sec} \cdot \text{in}^2$$

Y31 ~ Y36

$$\text{Area} = \frac{0.75^2 - 0.625^2}{2} = 0.08594 \text{ in}^2$$

$$(Y31 \sim Y36) = (Y21 \sim Y26) \times \frac{0.08594}{0.0703}$$

$$= (Y21 \sim Y26) \times 1.2224$$

Y41 ~ Y46

$$\text{Area} = \frac{0.875^2 - 0.75^2}{2} = 0.1016 \text{ in}^2$$

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$$(Y_{41} - Y_{46}) = (Y_{21} - Y_{26}) \times \frac{0.1016}{0.0703}$$

$$= (Y_{21} - Y_{26}) \times 1.4447$$

*Y*₅₁ ~ *Y*₅₆

$$Area = \frac{1.0^2 - 0.875^2}{2} = 0.1172$$

$$(Y_{51} - Y_{57}) = (Y_{21} - Y_{27}) \times \frac{0.1172}{0.0703}$$

$$= (Y_{21} - Y_{27}) \times 1.6669$$

*Y*₆₁ ~ *Y*₆₆

$$Area = \frac{1.125^2 - 1^2}{2} = 0.1328 \text{ in}^2$$

$$(Y_{61} - Y_{67}) = (Y_{21} - Y_{27}) \times \frac{0.1328}{0.0703}$$

$$= (Y_{21} - Y_{27}) \times 1.8892$$

*Y*₇₁ ~ *Y*₇₆

$$Area = \frac{1.25^2 - 1.125^2}{2} = 0.1484$$

$$(Y_{71} - Y_{77}) = (Y_{21} - Y_{27}) \times \frac{0.1484}{0.0703}$$

$$= (Y_{21} - Y_{27}) \times 2.1115$$

*Y*₁₀₁ ~ *Y*₁₀₇

$$Area = RL = 0.51375 \times 0.125$$

$$= 0.0642 \text{ in}^2$$

$$Admittance = \frac{2.685 \times 10^{-4} \times 0.0642}{0.0975} = 1.768 \times 10^{-3} \text{ in}^2/\text{sec}^2$$

*Y*₁₀₈ ~ *Y*₁₁₉

$$R_i = 0.465 \text{ in}$$

$$R_o = 0.5 \text{ in}$$

$$Area = 0.4825 \times 0.125 = 0.0603 \text{ in}^2$$

$$Admittance = \frac{2.685 \times 10^{-4} \times 0.0603}{0.025} = 4.622 \times 10^{-4} \text{ in}^2/\text{sec}^2$$

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Y 121 ~ Y 127

$$\text{Area} = 0.625 \times 0.125 = 0.078125$$

$$\begin{aligned} \text{Admittance} &= \frac{2.6752 \times 10^{-4} \times 0.078125}{0.125} \\ &= 1.6782 \times 10^{-4} \text{ Btu/sec-}^{\circ}\text{F} \end{aligned}$$

Y 131 ~ Y 137

$$\begin{aligned} (Y 131 \sim Y 137) &= (Y 121 \sim Y 127) \times \frac{0.75}{0.525} \\ &= (Y 121 \sim Y 127) \times 1.2 \end{aligned}$$

Y 141 ~ Y 147

$$\begin{aligned} (Y 141 \sim Y 147) &= (Y 121 \sim Y 127) \times \frac{0.875}{0.525} \\ &= (Y 121 \sim Y 127) \times 1.4 \end{aligned}$$

Y 151 ~ Y 157

$$\begin{aligned} (Y 151 \sim Y 157) &= (Y 121 \sim Y 127) \times \frac{1}{0.525} \\ &= (Y 121 \sim Y 127) \times 1.6 \end{aligned}$$

Y 161 ~ Y 167

$$\begin{aligned} (Y 161 \sim Y 167) &= (Y 121 \sim Y 127) \times \frac{1.125}{0.525} \\ &= (Y 121 \sim Y 127) \times 1.8 \end{aligned}$$

CONVECTION AREA

Y 201 ~ Y 219

$$\begin{aligned} \text{Area} &= 0.465 \times 0.125 \\ &= 0.058125 \text{ in}^2 \end{aligned}$$

Y 221, Y 227,

$$\text{Area} = \frac{0.625^2 - 0.5^2}{2} = 0.0703 \text{ in}^2$$

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Y231, Y237.

$$Area = \frac{0.15^2 - 0.625^2}{2} = 0.0859 \text{ in}^2$$

Y241, Y247.

$$Area = \frac{0.875^2 - 0.75^2}{2} = 0.10156 \text{ in}^2$$

Y251, Y257.

$$AREA = \frac{1^2 - 0.875^2}{2} = 0.1172 \text{ in}^2$$

Y261, Y267.

$$Area = \frac{1.125^2 - 1^2}{2} = 0.1328 \text{ in}^2$$

Y271, Y277.

$$Area = \frac{1.25^2 - 1.125^2}{2} = 0.14844 \text{ in}^2$$

Y288 ~ Y299

$$Area = 0.5 \times 0.125 = 0.0625 \text{ in}^2$$

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BELOW SUPPORT AND FLOW DIVIDER

ADMITTANCE

One radian revolution along the axis of the axial center line.

Y1 ~ Y3

$$AREA = \frac{17.315^2 - 17.19^2}{2} = 2.1566 \text{ in}^2$$

$$ADMITTANCE = \frac{2.6852 \times 10^{-4} \times 2.156}{0.5} = 1.1581 \times 10^{-3} \text{ Stm/sec-in}^2$$

Y4, Y19

$$Admittance = \frac{2.6852 \times 10^{-4} \times 2.156}{0.375} = 1.5438 \times 10^{-3} \text{ Stm/sec-in}^2$$

Y5, Y18

$$= \frac{2.6852 \times 10^{-4} \times 2.156}{0.25} = 2.3157 \times 10^{-3} \text{ Stm/sec-in}^2$$

$$Y6, Y17, = \frac{2.6852 \times 10^{-4} \times 2.156}{0.1875} = 3.0876 \times 10^{-3} \text{ Stm/sec-in}^2$$

Y7 ~ Y16

$$= \frac{2.6852 \times 10^{-4} \times 2.156}{0.125} = 4.5314 \times 10^{-3} \text{ Stm/sec-in}^2$$

Y21 ~ Y39

$$Area = \frac{17.44^2 - 17.315^2}{2} = 2.1722$$

$$(Y21 \sim Y39) = (Y1 \sim Y19) \times \frac{2.1722}{2.1566}$$

$$= (Y1 \sim Y19) \times 1.007228$$

Y41 ~ Y59

$$Area = \frac{17.565^2 - 17.44^2}{2} = 2.1878$$

$$(Y41 \sim Y59) = (Y1 \sim Y19) \times \frac{2.1878}{2.1566}$$

$$= (Y1 \sim Y19) \times 1.0145$$

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Y61 ~ Y62

$$R_o = 14.69 \text{ in}$$

$$R_i = 14.19 \text{ in}$$

$$\text{Area} = \frac{14.69^2 - 14.19^2}{2} = 7.22 \text{ in}^2$$

$$\text{Admittance} = \frac{2.6852 \times 10^{-4} \times 7.22}{0.1875} = 0.01034 \text{ 37.1/sec} = 1.034$$

Y64 ~ Y65

$$\text{Area} = \frac{15.19^2 - 14.69^2}{2} = 7.47$$

$$\begin{aligned} (Y64 \sim Y65) &= (Y61 \sim 62) \times \frac{7.47}{7.22} \\ &= (Y61 \sim 62) \times 1.035 \end{aligned}$$

Y67 ~ Y68

$$\text{Area} = \frac{15.69^2 - 15.19^2}{2} = 7.72 \text{ in}^2$$

$$\begin{aligned} (Y64 \sim Y65) &= (Y61 \sim Y62) \times \frac{7.72}{7.22} \\ &= (Y61 \sim Y62) \times 1.069 \end{aligned}$$

Y70 ~ Y71

$$\text{Area} = \frac{16.19^2 - 15.69^2}{2} = 7.97$$

$$\begin{aligned} Y70 \sim Y71 &= (Y61 \sim Y62) \times \frac{7.97}{7.22} \\ &= (Y61 \sim Y62) \times 1.1039 \end{aligned}$$

Y73 ~ Y74

$$\text{Area} = \frac{16.44^2 - 16.19^2}{2} = 4.0788 \text{ in}^2$$

$$\begin{aligned} Y73 \sim Y74 &= (Y61 \sim Y62) \times \frac{4.0788}{7.22} \\ &= (Y61 \sim Y62) \times 0.5649 \end{aligned}$$

Y76 ~ Y77

$$\text{Area} = \frac{16.69^2 - 16.44^2}{2} = 4.1425$$

$$\begin{aligned} Y76 \sim Y77 &= (Y61 \sim Y62) \times \frac{4.1425}{7.22} \\ &= (Y61 \sim Y62) \times 0.5736 \end{aligned}$$

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Y 77 ~ Y 80

$$\text{Area} = \frac{16.815^2 - 16.62^2}{2} = 2.074 \text{ in}^2$$

$$\begin{aligned} Y 77 \sim Y 80 &= (Y 61 - Y 62) \times \frac{2.074}{7.22} \\ &= (Y 61 - Y 62) \times 0.29 \end{aligned}$$

Y 82 ~ Y 83

$$\text{Area} = \frac{16.94^2 - 16.715^2}{2} = 2.1597 \text{ in}^2$$

$$\begin{aligned} (Y 82 - Y 83) &= (Y 61 - Y 62) \times \frac{2.1597}{7.22} \\ &= (Y 61 - Y 62) \times 0.2922 \end{aligned}$$

Y 85 ~ Y 86

$$\text{Area} = \frac{17.065^2 - 16.94^2}{2} = 2.1253 \text{ in}^2$$

$$\begin{aligned} (Y 85 - Y 86) &= (Y 61 - Y 62) \times \frac{2.1253}{7.22} \\ &= (Y 61 - Y 62) \times 0.2944 \end{aligned}$$

Y 88 ~ Y 89

$$\text{Area} = \frac{17.19^2 - 17.065^2}{2} = 2.1409$$

$$\begin{aligned} Y 88 \sim Y 89 &= (Y 61 - Y 62) \times \frac{2.1409}{7.22} \\ &= (Y 61 - Y 62) \times 0.2965 \end{aligned}$$

Y 101 ~ Y 104 , Y 120 .

$$\text{Area} = 17.315 \times 0.5 = 8.6575$$

$$\text{Admittance} = \frac{2.6852 \times 10^{-4} \times 8.6575}{0.1875} = 0.0124 \text{ cm}^2/\text{sec}^{-1}$$

Y 105 ~ Y 106, Y 118 ~ Y 119,

$$= \frac{17.315 \times 0.25 \times 2.6852 \times 10^{-4}}{0.1875} = 6.1992 \times 10^{-3} \text{ cm}^2/\text{sec}^{-1}$$

Y 107 ~ Y 117

$$= \frac{17.315 \times 0.125 \times 2.6852 \times 10^{-4}}{0.1875} = 3.0996 \times 10^{-3} \text{ cm}^2/\text{sec}^{-1}$$

$$Y 121 \sim Y 140 \quad (Y 121 \sim 140) = (Y 101 - Y 120) \times \frac{17.44}{17.315} = (Y 101 - Y 120) \times 1.0072$$

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Y 161 ~ Y 163

$$\text{Area} = 14.69 \times 0.125 = 1.83625 \text{ in}^2$$

$$\text{Admittance} = \frac{2.6852 \times 10^{-4} \times 1.83625}{0.5} = 9.7614 \times 10^{-4} / 120 =$$

Y 164 ~ Y 166

$$\begin{aligned} (Y_{164} \sim Y_{166}) &= (Y_{161} \sim Y_{163}) \times \frac{15.19}{14.69} \\ &= (Y_{161} \sim Y_{163}) \times 1.034 \end{aligned}$$

Y 167 ~ Y 169

$$\begin{aligned} (Y_{167} \sim Y_{169}) &= (Y_{161} \sim Y_{163}) \times \frac{15.69}{14.69} \\ &= (Y_{161} \sim Y_{163}) \times 1.0691 \end{aligned}$$

Y 170 ~ Y 172

$$\begin{aligned} (Y_{170} \sim Y_{172}) &= (Y_{161} \sim Y_{163}) \times \frac{16.065}{14.69} \times \frac{0.5}{0.375} \\ &= (Y_{161} \sim Y_{163}) \times 1.4581 \end{aligned}$$

Y 173 ~ Y 175

$$\begin{aligned} (Y_{173} \sim Y_{175}) &= (Y_{161} \sim Y_{163}) \times \frac{16.44}{14.69} \times \frac{0.5}{0.25} \\ &= (Y_{161} \sim Y_{163}) \times 2.2383 \end{aligned}$$

Y 176 ~ Y 178

$$\begin{aligned} (Y_{176} \sim Y_{178}) &= (Y_{161} \sim Y_{163}) \times \frac{16.5025}{14.69} \times \frac{0.5}{0.125} \\ &= (Y_{161} \sim Y_{163}) \times 4.4935 \end{aligned}$$

Y 179 ~ Y 181

$$\begin{aligned} (Y_{179} \sim Y_{181}) &= (Y_{161} \sim Y_{163}) \times \frac{16.815}{14.69} \times \frac{0.5}{0.125} \\ &= (Y_{161} \sim Y_{163}) \times 4.5726 \end{aligned}$$

Y 182 ~ Y 184

$$\begin{aligned} (Y_{182} \sim Y_{184}) &= (Y_{161} \sim Y_{163}) \times \frac{16.94}{14.69} \times \frac{0.5}{0.125} \\ &= (Y_{161} \sim Y_{163}) \times 4.6127 \end{aligned}$$

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Y 185 ~ Y 187

$$(Y185 - Y187) = (Y161 - Y163) \times \frac{17.19}{14.69} \times \frac{0.5}{0.125}$$

$$= (Y161 - Y163) \times 4.5457$$

Y 188 ~ Y 190

$$(Y188 - Y190) = (Y161 - Y163) \times \frac{17.19}{14.69} \times \frac{0.5}{0.125}$$

$$= (Y161 - Y163) \times 4.5807$$

CONVECTION AREA

Y 201 ~ Y 204

Y 220

$$AREA = 17.19 \times 0.5 = 8.595 \text{ in}^2$$

$$Y205 \sim Y206, Y218 \sim Y219, 17.19 \times 0.25 = 4.2975 \text{ in}^2$$

Y 207 ~ Y 210, Y 214 ~ Y 217

$$= 17.19 \times 0.125 = 2.14875 \text{ in}^2$$

Y 241 ~ Y 244, Y 260,

$$17.565 \times 0.5 = 8.7825 \text{ in}^2$$

Y 245 ~ Y 246, Y 258 ~ Y 259

$$17.565 \times 0.25 = 4.39125 \text{ in}^2$$

Y 247 ~ Y 257

$$17.565 \times 0.125 = 2.1956 \text{ in}^2$$

Y 261, Y 263

$$AREA = \frac{14.69^2 - 14.19^2}{2} = 7.22 \text{ in}^2$$

Y 264, Y 266

$$7.47 \text{ in}^2$$

Y 267, Y 269

$$7.72 \text{ in}^2$$

Y 270, Y 272

$$7.97 \text{ in}^2$$

Y 273, Y 275

$$8.2788 \text{ in}^2$$

Y 276, Y 278

$$8.58125 \text{ in}^2$$

Y 279, Y 281

$$8.884 \text{ in}^2$$

Y 282, Y 284

$$9.1877 \text{ in}^2$$

$$Y285, Y287, 2.1253 \text{ in}^2$$

$$Y288 \sim Y290, 2.1407 \text{ in}^2$$

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INTS/EVS COLD TRAP.

ECONOMIZER SHELL AND CRYSTALLIZER UPPER HEAD

ADMITTANCE

ONE RADIAN REVOLUTION OF THE FIGURE ABOUT THE
LONGITUDINAL CENTER LINE.

$$K = 2.1760 \times 10^{-4} \text{ STU/SEC-IN}^2$$

Y1 ~ Y7 Y19

$$AREA = \frac{9.75^2 - 9.605^2}{2} = 1.2109 \text{ in}^2$$

$$ADMITTANCE = \frac{2.1760 \times 10^{-4} \times 1.2109}{0.5} = 5.2697 \times 10^{-4} \text{ STU/SEC-IN}^2$$

Y8, Y17

$$= \frac{2.1760 \times 10^{-4} \times 1.2109}{0.375} = 7.0264 \times 10^{-4} \text{ STU/SEC-IN}^2$$

Y9 ~ Y16

$$= \frac{2.1760 \times 10^{-4} \times 1.2109}{0.25} = 1.054 \times 10^{-3} \text{ STU/SEC-IN}^2$$

Y21 ~ Y39.

$$AREA = \frac{9.875^2 - 9.75^2}{2} = 1.2266 \text{ in}^2$$

$$\begin{aligned} (Y21 \sim Y39) &= (Y1 \sim Y19) \times \frac{1.2266}{1.2109} \\ &= (Y1 \sim Y19) \times 1.0129 \end{aligned}$$

Y41 ~ Y59

$$AREA = \frac{10^2 - 9.975^2}{2} = 1.2422$$

$$\begin{aligned} (Y41 \sim Y59) &= (Y1 \sim Y19) \times \frac{1.2422}{1.2109} \\ &= (Y1 \sim Y19) \times 1.0258 \end{aligned}$$

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Y 62 ~ Y 76

$$AREA = \frac{10.25^2 - 10.0^2}{2} = 2.53125 \text{ in}^2$$

$$(Y 62 \sim Y 76) = (Y 2 \sim Y 15) \times \frac{2.53125}{1.2109}$$

$$= (Y 2 \sim Y 15) \times 2.09038$$

Y 61

$$Y 61 = Y 62 \times 0.5$$

Y 85 ~ Y 95

$$AREA = \frac{10.625^2 - 10.25^2}{2} = 3.9141 \text{ in}^2$$

$$(Y 85 \sim Y 95) = (Y 5 \sim Y 15) \times \frac{3.9141}{1.2109}$$

$$= (Y 5 \sim Y 15) \times 3.2324$$

Y 84

$$Y 84 = Y 85 \times 0.5$$

Y 83

$$Y 83 = Y 85 \times 0.33$$

Y 99 ~ Y 105

$$AREA = \frac{11.125^2 - 10.625^2}{2} = 5.4375 \text{ in}^2$$

$$(Y 99 \sim Y 105) = (Y 9 \sim Y 15) \times \frac{5.4375}{1.2109}$$

$$= (Y 9 \sim Y 15) \times 4.4905$$

Y 109 ~ Y 115

$$AREA = \frac{11.625^2 - 11.125^2}{2} = 5.6875 \text{ in}^2$$

$$(Y 109 \sim Y 115) = (Y 9 \sim Y 15) \times \frac{5.6875}{1.2109}$$

$$= (Y 9 \sim Y 15) \times 4.6959$$

Y 120 ~ Y 125

$$AREA = \frac{12.125^2 - 11.625^2}{2} = 5.9375 \text{ in}^2$$

$$(Y 120 \sim Y 125) = (Y 10 \sim Y 15) \times \frac{5.9375}{1.2109}$$

$$= (Y 10 \sim Y 15) \times 4.9034$$

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Y131 ~ Y135

$$AREA = \frac{12.625^2 - 12.125^2}{2} = 6.1875 \text{ in}^2$$

$$Y131 \sim Y135 = (Y11 \sim Y15) \times \frac{6.1875}{1.2125^2}$$

$$= (Y11 \sim Y15) \times 5.1098$$

Y130

$$Y130 = Y131 \times 2.0$$

Y141 ~ Y145

$$AREA = \left(\frac{13.125^2 - 12.625^2}{2} \right) \times 1.035 = 6.6645$$

$$ADMITTANCE = \frac{2.176 \times 10^{-4} \times 6.6645}{0.25} = 5.7009 \times 10^{-3} \text{ Ets/sec}^{-1}$$

Y151 ~ Y155

$$AREA = \left(\frac{13.625^2 - 13.125^2}{2} \right) \times 1.035 = 6.9216 \text{ in}^2$$

$$(Y151 \sim Y155) = (Y141 \sim Y145) \times \frac{6.9216}{6.6645}$$

$$= (Y141 \sim Y145) \times 1.0386$$

Y161 ~ Y165

$$AREA = \left(\frac{14.125^2 - 13.625^2}{2} \right) \times 1.035 = 6.9375$$

$$(Y161 \sim Y165) = (Y141 \sim Y145) \times \frac{6.9375}{6.6645}$$

$$= (Y141 \sim Y145) \times 1.041$$

Y171 ~ Y175

$$AREA = \frac{14.625^2 - 14.125^2}{2} \times 1.035 = 7.1875 \text{ in}^2$$

$$(Y171 \sim Y175) = (Y141 \sim Y145) \times \frac{7.1875}{6.6645}$$

$$= (Y141 \sim Y145) \times 1.0785$$

Y201 ~ Y208 Y218 ~ Y220

$$AREA = 9.750 \times 0.5 = 4.875 \text{ in}^2$$

$$ADMITTANCE = \frac{2.176 \times 10^{-4} \times 4.875}{(0.125 + 0.125/2)} = 5.6576 \times 10^{-3} \text{ Ets/sec}^{-1}$$

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Y209 ~ Y217.

$$AREA = 9.750 \times 0.25 = 2.4375 \text{ in}^2$$

$$ADMITTANCE = \frac{2.176 \times 10^{-4} \times 2.4375}{0.1875} = 2.8288 \times 10^{-3} \text{ cm}^2/\text{sec} - \text{in}^2$$

Y221 ~ 237

$$AREA = 9.875 \times 1.5 = 4.9375 \text{ in}^2$$

$$(Y221 \sim 237) = (Y201 \sim Y217) \times \frac{4.9375}{4.875} \times \frac{0.125}{0.125}$$

$$= (Y201 \sim Y217) \times 1.5192$$

Y238 ~ Y240

$$(Y238 \sim Y240) = (Y218 \sim Y220) \times \frac{4.9375}{4.875}$$

$$= (Y218 \sim Y220) \times 1.0128$$

Y241 ~ Y257

$$AREA = \frac{(9.875 + 10.25)}{2} \times 0.5 = 5.03125 \text{ in}^2$$

$$Y241 \sim Y257 = (Y221 \sim Y237) \times \frac{5.03125}{4.9375} \times \frac{0.125}{0.1875}$$

$$= (Y221 \sim Y237) \times 0.6793$$

Y265 ~ Y276

$$AREA = \frac{(10.625 + 10)}{2} \times 0.5 = 5.15625 \text{ in}^2$$

$$(Y265 \sim Y276) = (Y225 \sim Y236) \times \frac{5.15625}{4.9375} \times \frac{0.125}{0.3125}$$

$$= (Y225 \sim Y236) \times 0.4177$$

Y263

$$Y263 = Y265 \times 2.0$$

Y264

$$Y264 = Y265 \times 1.33$$

Y289 ~ Y296

$$AREA = \left(\frac{11.125 + 10.25}{2} \right) \times 0.25 = 2.6718 \text{ in}^2$$

$$Admittance = \frac{2.176 \times 10^{-4} \times 2.6718}{0.4375} = 1.3289 \times 10^{-3} \text{ cm}^2/\text{sec} - \text{in}^2$$

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Y 299 ~ Y 306

$$AREA = 11.125 \times 0.25 = 2.78125$$

$$ADMITTANCE = \frac{2.176 \times 10^{-4} \times 2.78125}{0.5} = 1.2104 \times 10^{-3} \text{ BTU/deg-}^2$$

Y 310 ~ Y 316

$$AREA = 11.625 \times 0.25 = 2.90625 \text{ in}^2$$

$$Y 310 \sim Y 316 = (Y 300 \sim Y 306) \times \frac{2.90625}{2.78125}$$

$$= (Y 300 \sim Y 306) \times 1.045$$

Y 320 ~ Y 326

$$AREA = 12.125 \times 0.25 = 3.03125 \text{ in}^2$$

$$Y 320 \sim Y 326 = (Y 300 \sim Y 306) \times \frac{3.03125}{2.78125}$$

$$= (Y 300 \sim Y 306) \times 1.0899$$

Y 331 ~ Y 336

$$AREA = 12.625 \times 0.25 = 3.15625 \text{ in}^2/\text{rad}$$

$$Y 331 \sim Y 336 = (Y 301 \sim Y 306) \times \frac{3.15625}{2.78125}$$

$$= (Y 301 \sim Y 306) \times 1.1348$$

Y 341 ~ Y 346

$$AREA = 13.125 \times 0.25 = 3.28125 \text{ in}^2$$

$$Y 341 \sim Y 346 = \frac{2.176 \times 10^{-4} \times 3.28125 \text{ in}^2}{0.5 \times 1.03}$$

$$= 1.3793 \times 10^{-3} \text{ BTU/deg-}^2$$

Y 351 ~ Y 356

$$AREA = 13.625 \times 0.25 = 3.40625 \text{ in}^2$$

$$Y 351 \sim Y 356 = (Y 341 \sim Y 346) \times \frac{3.40625}{3.28125}$$

$$= (Y 341 \sim Y 346) \times 1.0381$$

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Y361 ~ Y366

$$AREA = 14.125 \times 0.25 = 3.53125 \text{ in}^2$$

$$Y361 \sim Y366 = (Y341 \sim Y346) \times \frac{3.53125}{3.28125}$$

$$= (Y341 \sim Y346) \times 1.0762$$

CONVECTION AREA

Y401 ~ 408 , Y418 ~ Y420

$$AREA = 9.625 \times 0.5 = 4.8125 \text{ in}^2$$

Y409 ~ Y417 .

$$AREA = 9.625 \times 0.25 = 2.40625 \text{ in}^2$$

Y458 ~ Y460

$$AREA = 10 \times 0.5 = 5 \text{ in}^2$$

Y477

$$AREA = \frac{10.25^2 - 10^2}{2} \times 1.4142 = 3.5799 \text{ in}^2$$

Y496

$$3.9141 \text{ in}^2$$

Y506

$$5.4375 \text{ in}^2$$

Y516

$$5.6875 \text{ in}^2$$

Y526

$$5.9375 \text{ in}^2$$

Y536

$$6.1875 \text{ in}^2$$

Y546

$$6.6645 \text{ in}^2$$

Y556

$$6.9216 \text{ in}^2$$

Y566

$$6.9375 \text{ in}^2$$

Y576

$$7.1875 \text{ in}^2$$

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PRIMARY COLD TRAP

ECONOMIZER SHELL AND CRYSTALLIZER UPPER HEAD

Y1 - Y59. SAME AS C-75 COLD TRAP.

Y61 - Y76

$$AREA = \frac{10.125^2 - 10^2}{2} = 1.2578 \text{ in}^2$$

$$(Y61 - Y76) = (Y1 - Y15) \times \frac{1.2578}{1.2109}$$

$$= (Y1 - Y15) \times 1.03874$$

Y95 - Y95

$$AREA = \frac{10.375^2 - 10.125^2}{2} = 2.5625 \text{ in}^2$$

$$Y85 - Y95 = (Y5 - Y15) \times \frac{2.5625}{1.2109}$$

$$= (Y5 - Y15) \times 2.1162$$

Y84

$$Y84 = Y85 \times 0.7$$

Y83

$$Y83 = Y95 \times 0.5$$

Y101 - Y105

$$AREA = \frac{10.625^2 - 10.375^2}{2} = 2.625 \text{ in}^2$$

$$(Y101 - Y105) = (Y11 - Y15) \times \frac{2.625}{1.2109}$$

$$= (Y11 - Y15) \times 2.16781$$

Y100

$$Y100 = (Y101) \times 1.7$$

Y111 - Y115. AREA = 5.4375 in².

$$(Y111 - Y115) = (Y11 - Y15) \times \frac{5.4375}{1.2109}$$

$$= (Y11 - Y15) \times 4.4925$$

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 $\gamma_{122} - \gamma_{125}$

$$\gamma_{122} - \gamma_{125} = (\gamma_{12} - \gamma_{15}) \times 4.6959$$

 γ_{121}

$$\gamma_{121} = \gamma_{122} \times 1.5$$

 $\gamma_{132} - \gamma_{135}$

$$\gamma_{132} - \gamma_{135} = (\gamma_{12} - \gamma_{15}) \times 4.9034$$

 $\gamma_{143} - \gamma_{145}$

$$\gamma_{143} - \gamma_{145} = (\gamma_{12} - \gamma_{15}) \times 5.1538$$

 γ_{142}

$$\gamma_{142} = \gamma_{143} \times 1.5$$

 $\gamma_{153} - \gamma_{155}$

$$5.8009 \times 10^{-3} \text{ Btu/sec-}^\circ\text{F}$$

 $\gamma_{163} - \gamma_{165}$

$$(\gamma_{163} - \gamma_{165}) = (\gamma_{153} - \gamma_{155}) \times 1.0326$$

 $\gamma_{173} - \gamma_{175}$

$$(\gamma_{173} - \gamma_{175}) = (\gamma_{153} - \gamma_{155}) \times 1.041$$

 $\gamma_{183} - \gamma_{185}$

$$(\gamma_{183} - \gamma_{185}) = (\gamma_{153} - \gamma_{155}) \times 1.0575$$

 $\gamma_{201} - \gamma_{220}$

SAME AS HTS COLD TRAP MODEL

 $\gamma_{241} - \gamma_{257}$

$$\text{AREA} = \frac{2.875 + 10.125}{2} \times 0.5 = 5 \text{ in}^2$$

$$\gamma_{241} - \gamma_{257} = (\gamma_{221} - \gamma_{237}) \times \frac{5}{4.9375}$$

$$= (\gamma_{221} - \gamma_{237}) \times 1.0127$$

 $\gamma_{265} - \gamma_{276}$

$$\text{AREA} = \frac{10.375 + 10}{2} \times 0.5 = 5.09375 \text{ in}^2$$

$$\gamma_{265} - \gamma_{276} = (\gamma_{225} - \gamma_{236}) \times \frac{5.09375}{4.9375} \times \frac{0.125}{0.1875}$$

$$= (\gamma_{225} - \gamma_{236}) \times 0.6909$$

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 γ_{263}

$$\gamma_{263} = \gamma_{265} \times 1.5$$

 γ_{264}

$$\gamma_{264} = \gamma_{265} \times 1.3$$

 $\gamma_{291} - \gamma_{296}$

$$\gamma_{291} - \gamma_{296} = (\gamma_{231} - \gamma_{236}) \times \frac{10.375}{9.875} \times \frac{0.125}{0.25}$$

$$= (\gamma_{231} - \gamma_{236}) \times 0.5253$$

 γ_{292}

$$\gamma_{292} = \gamma_{291} \times 0.6$$

 $\gamma_{301} - \gamma_{306}$

$$\gamma_{301} - \gamma_{306} = (\gamma_{231} - \gamma_{236}) \times \frac{10.75}{9.875} \times \frac{0.125}{0.375}$$

$$= (\gamma_{231} - \gamma_{236}) \times 0.3629$$

 $\gamma_{312} - \gamma_{316}$

$$1.2104 \times 10^{-3} \text{ BTU/SEC-}^{\circ}\text{F}$$

 γ_{311}

$$\gamma_{311} = \gamma_{312} \times 0.6$$

 $\gamma_{322} - \gamma_{326}$

$$(\gamma_{322} - \gamma_{326}) = (\gamma_{312} - \gamma_{316}) \times 1.045$$

 $\gamma_{333} - \gamma_{336}$

$$(\gamma_{333} - \gamma_{336}) = (\gamma_{313} - \gamma_{316}) \times 1.0899$$

 γ_{332}

$$\gamma_{332} = \gamma_{333} \times 0.6$$

 $\gamma_{343} - \gamma_{346}$

$$(\gamma_{343} - \gamma_{346}) = (\gamma_{313} - \gamma_{316}) \times 1.1548$$

 $\gamma_{353} - \gamma_{356}$

$$1.3793 \times 10^{-3} \text{ BTU/SEC-}^{\circ}\text{F}$$

 $\gamma_{363} - \gamma_{366}$

$$(\gamma_{363} - \gamma_{366}) = (\gamma_{353} - \gamma_{356}) \times 1.0381$$

 $\gamma_{373} - \gamma_{376}$

$$(\gamma_{373} - \gamma_{376}) = (\gamma_{353} - \gamma_{356}) \times 1.0762$$

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CONVECTION AREA

Y 477

$$AREA = \frac{10.125^2 - 10^2}{2} = 1.2578 \text{ in}^2$$

Y 496

$$AREA = \left(\frac{10.375^2 - 10.125^2}{2} \right) \times 1.2 = 3.275 \text{ in}^2$$

Y 506

$$\frac{10.625^2 - 10.375^2}{2} = 2.625 \text{ in}^2$$

Y 516

$$5.4375 \text{ in}^2$$

Y 526

$$5.6875 \text{ in}^2$$

Y 536

$$5.9375 \text{ in}^2$$

Y 546

$$6.1875 \text{ in}^2$$

Y 556

$$6.6645 \text{ in}^2$$

Y 566

$$6.9216 \text{ in}^2$$

Y 576

$$6.7375 \text{ in}^2$$

Y 586

$$7.1875 \text{ in}^2$$

1. LISTING DIMENSIONS TBD
2. SEE SHEET 1 FOR GENERAL NOTES

DESIGN DATA

WORKING FLUID: SULFUR
PRESSURE: 325 PSIG
TEMPERATURE: 775°F
DESIGN EQUIPMENT SPEC. NO. 100000000, PARA 2.1.1.2 (1000)
NOZZLE PREPARATION (IN G.N.) PER ANSI B16.25
WEIGHT
C.G.
NOZZLE LOADS } SEE LOAD & SPAN & TABLES

1. LISTING DIMENSIONS TBD	
NO. 1	NO. 2
NO. 3	NO. 4
NO. 5	NO. 6
NO. 7	NO. 8
NO. 9	NO. 10
NO. 11	NO. 12
NO. 13	NO. 14
NO. 15	NO. 16
NO. 17	NO. 18
NO. 19	NO. 20
NO. 21	NO. 22
NO. 23	NO. 24
NO. 25	NO. 26
NO. 27	NO. 28
NO. 29	NO. 30
NO. 31	NO. 32
NO. 33	NO. 34
NO. 35	NO. 36
NO. 37	NO. 38
NO. 39	NO. 40
NO. 41	NO. 42
NO. 43	NO. 44
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NO. 47	NO. 48
NO. 49	NO. 50
NO. 51	NO. 52
NO. 53	NO. 54
NO. 55	NO. 56
NO. 57	NO. 58
NO. 59	NO. 60
NO. 61	NO. 62
NO. 63	NO. 64
NO. 65	NO. 66
NO. 67	NO. 68
NO. 69	NO. 70
NO. 71	NO. 72
NO. 73	NO. 74
NO. 75	NO. 76
NO. 77	NO. 78
NO. 79	NO. 80
NO. 81	NO. 82
NO. 83	NO. 84
NO. 85	NO. 86
NO. 87	NO. 88
NO. 89	NO. 90
NO. 91	NO. 92
NO. 93	NO. 94
NO. 95	NO. 96
NO. 97	NO. 98
NO. 99	NO. 100

2 1/2" DIA HOLE
THRU WALL
TYP. INLET &
OUTLET SECTION

FIG. 2 TYPE I COLD TRAP LAYOUT

NO.	REVISION
1	INITIAL
2	11-7
3	11-7
4	11-7
5	11-7

REVISIONS
1. 11/1/78
2. 11/1/78
3. 11/1/78
4. 11/1/78
5. 11/1/78
6. 11/1/78
7. 11/1/78
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93. 11/1/78
94. 11/1/78
95. 11/1/78
96. 11/1/78
97. 11/1/78
98. 11/1/78
99. 11/1/78
100. 11/1/78

DESIGN DATA

WATER FLUID
PRESSURE 100 PSIG
TEMPERATURE 400°F
COR. FACT. 1.0
PRESSURE 100 PSIG
TEMPERATURE 400°F

NOZZLE PREPARATION (SEE INSTRUCTIONS)
WEIGHT
NOZZLE LOADS

NOZZLE	LOADS	WEIGHT	WEIGHT
N1	1000	1000	1000
N2	1000	1000	1000
N3	1000	1000	1000
N4	1000	1000	1000

SECTION	WEIGHT	WEIGHT	WEIGHT
SECTION	1000	1000	1000
SECTION	1000	1000	1000
SECTION	1000	1000	1000

WEIGHT 47.85
MAX 50.0

CHECKING PRINT

NO.	DATE	BY	CHKD	APP'D
1	10/1/50	J. H. H.	J. H. H.	J. H. H.
2	10/1/50	J. H. H.	J. H. H.	J. H. H.
3	10/1/50	J. H. H.	J. H. H.	J. H. H.
4	10/1/50	J. H. H.	J. H. H.	J. H. H.
5	10/1/50	J. H. H.	J. H. H.	J. H. H.
6	10/1/50	J. H. H.	J. H. H.	J. H. H.
7	10/1/50	J. H. H.	J. H. H.	J. H. H.
8	10/1/50	J. H. H.	J. H. H.	J. H. H.
9	10/1/50	J. H. H.	J. H. H.	J. H. H.
10	10/1/50	J. H. H.	J. H. H.	J. H. H.

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