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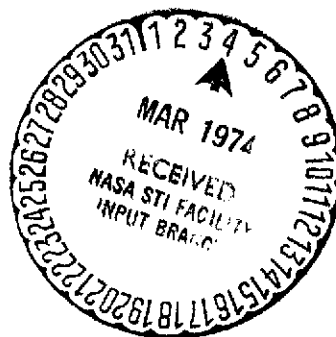
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A Homogeneous Heat Pipe Design Code

A. M. Nakashima

G. M. Kikin

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PREFACE

The work described in this report was performed by the Propulsion Division of the Jet Propulsion Laboratory.

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A HOMOGENEOUS HEAT PIPE DESIGN CODE

A. M. Nakashima and G. M. Kikin

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ABSTRACT

To facilitate parametric performance evaluation of heat pipes in lightweight heat rejection systems, a computer program was developed. This report contains a description of that code along with a user's manual and sample input. It is limited to the analysis and design of homogeneous wick heat pipes, although the annular heat pipe program previously developed is included as part of the heat pipe radiator subroutine in this document.

A HOMOGENEOUS HEAT PIPE ANALYSIS CODE

I. Introduction

Heat pipes have been successfully used in a variety of high and low heat transfer applications and for isothermal operations. They have been suggested for use in thermionic reactor system concepts to achieve highly reliable lightweight heat rejection systems.^{1,2} In order to facilitate evaluation of heat pipes for these concepts and to perform parametric evaluations of alternative heat pipe designs, a computer program was developed to compute heat pipe performance. The code was required for performance predictions for laboratory experiments and to aid in the selection of heat pipe materials and designs for thermionic reactor systems.

This report contains a description of that code along with a user's manual and sample input. A typical heat pipe consists of a closed tube or pipe with an internal wick or screen running the length of the pipe and a small quantity of a liquid working fluid. Heat transfer from the evaporator to the condenser is achieved by vaporization of the working fluid which flows to the condenser of the heat pipe because of the self-induced pressure differential. The fluid condenses and returns from the condenser to the evaporator by capillary pumping in the wick. The heat transferred depends on the fluid circulation rate and latent heat of vaporization. Factors which influence the operation of a heat pipe are the liquid and vapor flow properties of the working fluid, the surface tension of the liquid, the physical dimensions of the vapor and liquid flow spaces, and the geometry of the capillary pumping structure. The performance of most homogeneous heat pipes depends on the capillary pumping capacity of the wick structure and its resistance to liquid flow.

A variety of wick configurations are described elsewhere.³⁻⁵ This report is limited to the analysis and design of homogeneous wick heat pipes. In these designs the capillary wick usually is a screen swaged directly to the inner wall of the heat pipe. In comparison, an annular heat pipe has a thin liquid annulus separating the wick and the heat pipe wall. The annular heat pipe, because it has an open channel for liquid flow, has a much lower liquid pressure drop and, therefore, has a much higher heat transfer capacity. Also, since the wick pore size affects only the pumping power and not the pressure drop, the pore size can be made as small as convenient. An unfortunate characteristic of annular heat pipes is that the pumping power developed by the capillary force in the wick is limited by the largest pore, i.e., this gives the lowest developed pressure head. Thus control of pore size during wick fabrication is critical. This is not true with a homogeneous heat pipe. In a homogeneous pipe an increased pressure drop in the wick is tolerated in order to remove the dependence of pumping pressure head on maximum pore size. The reduced sensitivity of this design to variations in pore size makes fabrication easier and should result in lower heat pipe production costs. Since large numbers of heat pipes must be fabricated for the space radiator applications under consideration, the homogeneous heat pipe is an attractive alternative. A program similar to the one described herein was written to perform analyses of annular heat pipes, and is described in the Thermionic Reactor System Analysis code document.⁶ The annular heat pipe program is included as part of the heat pipe radiator subroutine in this document.

II. Theory

1. Assumptions and Approximations. In order for a heat pipe to function properly the total pumping pressure generated by the wick capillary force must

exceed the sum of the pressure drops in the heat pipe. Thus,

$$\Delta P_{cp} \geq \Delta P_v + \Delta P_\ell + \Delta P_g + \Delta P_m \quad (1)$$

Diagrams of both transverse and longitudinal cross sections of a typical homogeneous heat pipe are shown in Figures 1a and 1b. The equations used to describe the heat pipe performance are given in the following section. The approximations and derivations are indicated where applicable. More complete derivations are given in references 3-5. The equations contained herein are applicable only to heat pipes with a cylindrical cross section.

2. Radial Temperature Drops. The outside evaporator wall temperature is given by T^* as shown in Figure 1. This is the surface temperature; thus any radial film temperature drop to the heat sink must be treated separately. The temperature drop through the cylindrical evaporator wall is

$$\Delta T_{te} = \frac{Q_e \ln \frac{r_{oe}}{r_{ie}}}{2\pi k_{te} L_e F_e} \quad (2)$$

The radial temperature drop through the wick is

$$\Delta T_{we} = \frac{Q_e \ln \frac{r_{ie}}{r_v}}{2\pi k_{we} L_e F_e} \quad (3)$$

The total radial temperature drop for the evaporator is therefore:

$$\Delta T_e = \frac{Q_e}{2\pi L_e F_e} \left[\frac{1}{k_{t_e}} \ln \frac{r_{oe}}{r_{ie}} + \frac{1}{k_{w_e}} \ln \frac{r_{ie}}{r_v} \right] \quad (4)$$

Similarly, the temperature drop through the condenser wall and wick is

$$\Delta T_c = \frac{Q}{2\pi L_c F_c} \left[\frac{1}{k_{t_c}} \ln \frac{r_{oc}}{r_{ic}} + \frac{1}{k_{w_c}} \ln \frac{r_{ic}}{r_v} \right] \quad (5)$$

The vapor temperature in the evaporator is

$$T_{ve} = T^* - \Delta T_e \quad (6)$$

and the rejection temperature at the outer surface of the condenser is

$$T_c = \bar{T}_{vc} - \Delta T_c \quad (7)$$

3. Mass Transport Expressions. The total fluid mass flow rate in the heat pipe is

$$W = \frac{Q}{\lambda} \quad (8)$$

where λ is the heat of vaporization of the working fluid. The mean velocity in the vapor region is

$$\bar{V}_v = \frac{W}{\rho_v \pi r_v^2} \quad (9)$$

The sonic velocity in the heat pipe is determined by the properties and conditions in the heat pipe as

$$V_s = 11,772 \left[\frac{T_v}{M} \right]^{1/2}, \text{ cm/sec} \quad (10)$$

This correlation assumes the ratio of specific heats, K , for the working fluid equals 1.667 for monatomic vapors.

4. Pressure. The static vapor pressure ratio in the evaporator (for points 1 and 2 of Figure 1) is

$$\frac{P_{e1}}{P_{e2}} = 1 + N^2 K \quad (11)$$

where N is the mach number of the vapor. Therefore,

$$P_{e2} = P_{e1} \left[\frac{1}{1.0 + 1.667 (N)^2} \right] \quad (12)$$

5. Acceleration Pressure Drop. The total acceleration pressure drop is

$$\Delta P_m = P_{e1} - P_{e2} \left[\frac{1.667 (N)^2}{1.0 + 1.667 (N)^2} \right] \quad (13)$$

The pressure recovery in the condenser due to decrease in the vapor velocity as a result of condensation of the vapor is estimated to be 40 percent of the acceleration pressure drop in the evaporation.

$$\Delta P_{m-rec} \cong 0.40 \Delta P_m \quad (14)$$

The temperature in the condenser section is obtained from the pressure and the equation of state of the working fluid in the condenser.

6. Vapor Flow Pressure Drop. The pressure drop in the flowing vapor is given by the Fanning equation

$$\Delta P_v = \frac{2fG^2L}{g_c \rho_v^D} \quad (15)$$

The length used in these calculations is an effective length of the heat pipe, L_{eff} , defined as

$$L_{eff} = \frac{L_e + L_c}{2} + L_a \quad (16)$$

This definition is used since heat is added over the entire evaporator length and the vapor flow rate increases linearly until the exit of the evaporator (Pt. 2, Fig. 1b) is reached. Conversely, in the condenser section the flow rate decreases linearly as the heat is extracted and the vapor condenses. The Reynolds number for the vapor flow is

$$Re_v = \frac{D_v}{\mu_v} \frac{W}{\pi r_v^2} = \frac{2W}{\pi r_v \mu_v} \quad (17)$$

If $Re_v \leq 2000$, then a laminar flow correlation for the friction factor is used, resulting in a pressure drop of

$$\Delta P_v = \frac{32G L_{eff}}{D_v^2} \left(\frac{\mu}{\rho} \right)_v \quad (18)$$

With $Re > 2000$, turbulent flow correlations are used and the vapor pressure drop is

$$\Delta P_v = \frac{4f_v L G_v^2}{D_v^2 2\rho_v} = \frac{4}{D_v} \left(\frac{0.0252}{Re^{0.087}} \right) \frac{L_{eff} G^2}{2\rho_v} \quad (19)$$

Finally,

$$\Delta P_v = \frac{(0.08)W^{1.913} \mu_v^{0.087} L_{eff}}{D_v^{4.91} \rho_v} \quad (20)$$

7. Liquid Flow Pressure Drop. The liquid phase pressure drop is obtained from

$$\Delta P_l = \frac{\mu_l L_{eff} W}{\rho_l K_w A_w} \quad (21)$$

where the flow area is the total cross sectional area of the wick

$$A_w = \pi(r_i^2 - r_v^2) \quad (22)$$

8. Average Condenser Section Conditions. The average pressure of the vapor in the condenser is

$$\bar{P}_{Vc} = P_{V2} - \Delta P_V + 0.2(P_{V1} - P_{V2}) \quad (23)$$

The average radiator temperature is

$$\bar{T}_r = \bar{T}_c - \frac{Q_c}{2\pi L_c} \left[\frac{1}{k_t} \ln \frac{r_{ot}}{r_{it}} + \frac{1}{k_w} \ln \frac{r_{it}}{r_v} \right] \quad (24)$$

\bar{T}_c is obtained from (23) and the equation of state of the working fluid.

9. Available Pumping Pressure. The available pumping pressure depends on the capillary wick pore size and surface tension of the working fluid. The total capillary pumping head available is:

$$\Delta P_{cp} = \frac{2\gamma}{r_p} \quad (25)$$

where γ is the liquid surface tension and r_p is the effective pore size in the wick.

10. Empirical Correlations. Several material properties are not available as analytic expressions. These include the permeability, the sintered

thickness of several layers of screen, and the pore size resulting from swaging and sintering of the screen. The data were obtained from tests at JPL. It was found that the data could be conveniently represented by the following expressions:

Wick Permeability

$$\varphi = 0.0371 \left(\frac{1}{S}\right)^{1.6185} \text{ cm}^2 \quad (26)$$

Layer Thickness

$$t = 10.74 \left(\frac{1}{S}\right)^{1.3553} \text{ cm} \quad (27)$$

Pore Size

$$r_p = 1.65 \left(\frac{1}{S}\right)^{1.0945} \text{ cm} \quad (28)$$

In all cases S refers to the screen mesh (available presently only in wires per inch) and the range of validity for the correlation is $50 \leq S \leq 200$.

III. Program Description

1. Method of Solution. The program provides a convenient method of solving the equations in Section II. The heat input to the pipe is defined by the input data. The equations describing operation of the pipe are solved iteratively to obtain the necessary heat rejection area. A Newton-Raphson iteration scheme is used to provide faster convergence than direct substitution. The iteration is necessary since the pressure drops depend on the pipe

dimensions, hence the length and/or diameter of the heat pipe, while the condenser dimensions depend on the temperature of the condenser. The condenser temperature is fixed by the condenser pressure and the equation of state of the working fluid.

In operation the program computes heat fluxes through the evaporator wall and vapor temperature in the evaporator. From the equation of state, the absolute pressure in the evaporator is computed. From the total heat input and the pipe dimensions the flow rate of the working fluid is computed. Pressure drops and total pumping head available from surface tension correlations are computed. If the available pump head is sufficient to circulate the fluid and therefore transfer the heat, the pressure in the condenser determines the average rejection temperature. This approximation holds well when the major pressure drops are in the liquid phase flow; otherwise, pressure drops and recovery in the condenser cause large temperature variations along the condenser. When this occurs the assumption that a single average temperature can be used to represent the rejection temperature of the heat pipe may be less valid.

2. Built-in Data Correlations. Data on material properties of the wall, and wick and working fluid are built into the code. The available options are:

Wall material - Niobium (NC=1)
 Stainless Steel (NC=2)

Working fluid - Potassium (NL=1)
 Sodium (NL=2)

The material properties required and the algebraic form of the equations are shown in Table 1. New coefficients must be incorporated if other materials are desired.

IV. User's Manual

1. Input. A list of the input data required is shown in Table 2. Default values for all parameters are included in the code and are shown in the last column of the table. These default values define a sample problem and the use of a single namelist, \$INP\$, will cause this default case to be run.

2. Output. The output includes an edit of the input data used for the case in NAMELIST format. The output data provided is a list of the input conditions as well as temperatures, pressures, and pressure drops for the three sections of the heat pipe.

Note that temperature variations in the condenser due to pressure variations along the heat pipe were neglected and a single temperature is used to characterize the condenser. A typical runstream is shown as an appendix.

V. Nomenclature

A_w	Cross-section area of wick
D	diameter, cm
f	fanning friction factor
F_e	fraction of evaporator area available for heat transfer
F_c	fraction of condenser area available for heat rejection
G	mass flow rate - grams/cm ² -sec
g_c	dimensional constant
K	ratio of specific heat = (1.667 for monatomic fluid)
k	thermal conductivity, W/cm-K
L	length, cm
L_{eff}	effective length of the heat pipe, cm
M	molecular weight of the working fluid
N	Mach number (V_v/V_s)
n	number of layers of screen
p	static vapor pressure
ΔP_{cp}	pumping pressure generated by capillary wick, N/cm ²
ΔP_g	pressure drop due to gravity head, N/cm ²
ΔP_l	pressure drop in liquid flow, N/cm ²
ΔP_m	pressure drop due to momentum change, N/cm ²
ΔP_{m-rec}	pressure rise in condenser due to vapor momentum recovery
ΔP_v	pressure drop in vapor flow, N/cm ²
Q	total heat carried by pipe, W
Re	Reynolds number
r	radius, cm

r_p pore radius in wick, cm
 r_v radius of vapor region ($= r_{i_w}$ inside radius of wick)
 S screen mesh size (number of wires per inch)
 T temperature, $^{\circ}K$
 T^* outside evaporator wall temperature
 t thickness of one layer of screen, cm
 \overline{V}_v mean vapor velocity, cm/sec
 V_s sonic velocity in the vapor, cm/sec
 W circulating mass flow rate in the heat pipe, gm/sec

 γ liquid surface tension
 λ heat of vaporization of the working fluid, W/gm
 μ viscosity
 ρ fluid density, gm/cm³
 φ_w wick permeability

Subscripts

a adiabatic section
 c condenser section
 cp capillary pumping
 e evaporator section
 i inner
 l liquid
 m momentum
 o outer
 s sonic

t tube wall
v vapor
w wick properties
1 beginning of evaporator
2 exit of evaporator

VI. References

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3. Kemme, J. E., Heat Pipe Design Considerations, LA-4221-MS, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Aug. 1969.
4. Schwartz, H., The Heat Pipe and Its Operation, Internal Report 701-21, Jet Propulsion Laboratory, Pasadena, CA, Jan. 1969.
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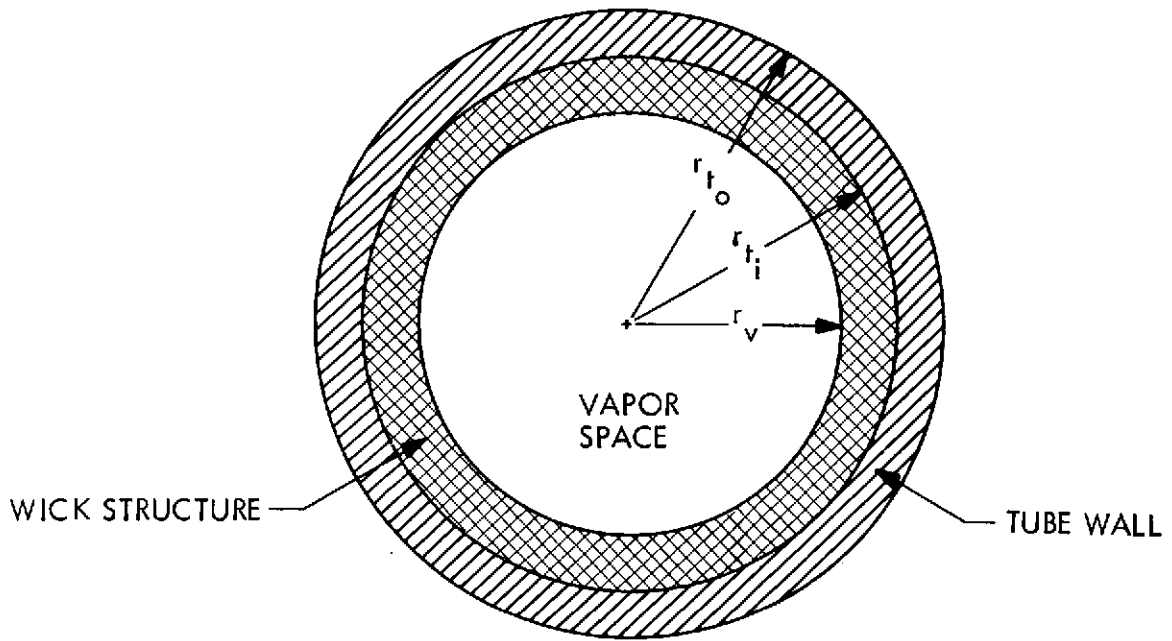
Table 1. Functional data correlations

Symbol	Variable	Form
P(t)	pressure (equation of state)	$P(T) = e^{A_1 - A_2(1/T) - A_3 \log T}$
γ	surface tension	$A_1 - A_2 T$
ρ_e	liquid density	$A_1 + T A_2 + T^2 A_3 + T^4 A_4$
μ_e	liquid viscosity	$A_1 e^{A_2/T}$
k_w	wall thermal conductivity	$A_1 - A_2 T$
k_l	liquid conductivity	tabular data
ρ_v	vapor density at STP	tabular data

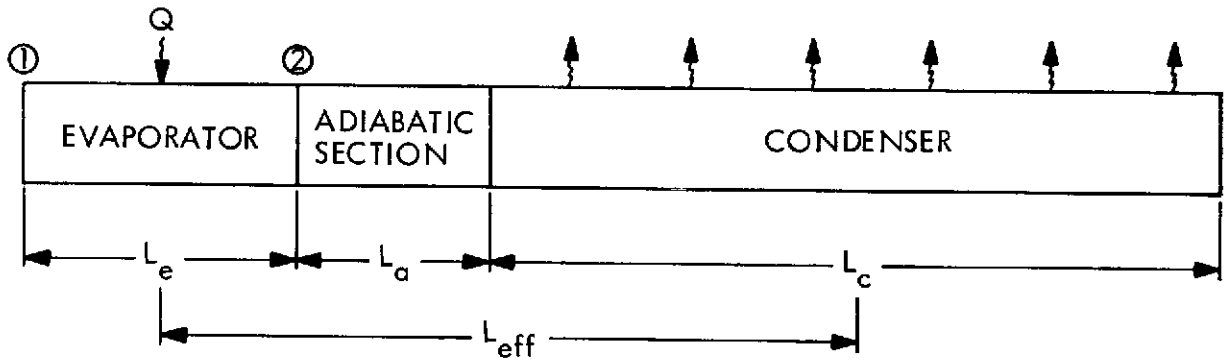
Table 2. Input data for homogeneous heat pipes

Variable	Fortran Name	Definition	Default Value
r_{te}	RTE	outside radius of evaporator	0.5 cm
L_e	LE	length of evaporator section	30.0 cm
Q_{in}	QIN	total heat rejected	700 watts
N_l	NL	working fluid (1 = K, 2 = Na)	1
T_l	TL	liquid thickness	0.0 cm
T_w	TW	wall thickness	0.02 cm
L_a	LA	length of adiabatic section	0.0 cm
T_{ev}	TEVAP	outside surface temperature evaporator	1000°K
r_p	RPST	maximum pore radius*	—
N_c	NC	heat pipe wall material (1 = Nb, 2 = SS)	1
—	MMT	variable FORMAT for output	—
f_e	FDE	fraction of evaporator surface available for heat input	1.0
f_c	FCE	fraction of condenser surface available for heat rejection	1.0
—	IHPT	homogeneous heat pipe flag (1 = homogeneous heat pipe)	1
n_L	NSCL	number of screen layers	1
S	MESH	screen mesh size	100
K	PERMEA	wick permeability*	—
t_{sl}	TSL	thickness of single screen layer*	—

* Computed from correlations if MESH is non zero.



(a) CROSS-SECTION



(b) LONGITUDINAL VIEW

Fig. 1. Heat pipe schematic

APPENDIX

TYPICAL RUNSTREAM AND SAMPLE PROBLEM

QFOR:IS MPD:MPD
FOR S10A-C 06/23/73-16:43:54 (.0)

MAIN PROGRAM

STORAGE USED: CODE(1) 001306; DATA(0) 000705; BLANK COMMON(2) 000025

EXTERNAL REFERENCES (BLOCK, NAME)

0003 HYPE
0004 NINTR
0005 NRNLS
0006 NNDUS
0007 NIOZ
0010 NNLS
0011 NERR2
0012 NIO1
0013 NSTOP

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000002	1L	0001	000044	100L	0001	000203	121L	0001	000262	122L	0001	000355	123L
0001	000450	124L	0001	000543	125L	0001	000636	126L	0001	000731	127L	0001	001024	128L
0001	001117	129L	0001	001212	130L	0001	000222	2026	0001	000241	2146	0001	000242	2166
0001	000277	2326	0001	000327	2466	0001	000337	2506	0001	000372	2646	0001	000422	3006
0001	000432	3026	0001	000465	3166	0001	000515	3326	0001	000525	3346	0001	000560	3506
0001	000610	3646	0001	000620	3666	0001	000653	4026	0001	000302	402L	0001	000375	403L
0001	000470	404L	0001	000563	405L	0001	000656	406L	0001	000751	407L	0001	001044	408L
0001	001137	409L	0001	001232	410L	0001	000703	4166	0001	000713	4206	0001	000746	4346
0001	000776	4506	0001	001006	4526	0001	001041	4666	0001	001071	5026	0001	001101	5046
0001	001134	5206	0001	001164	5346	0001	001174	5366	0001	001227	5526	0001	001257	5666
0001	001267	5706	0000	000733	900F	0000	R 000145	A	0002	R 000000	R	0000	R 000613	FCE
0000	R 000612	FDE	0000	I 000611	I	0000	I 000621	ICNT	0000	I 000614	IHPT	0000	000712	INPP
0000	I 000616	INPRT	0000	000625	INPT	0000	I 000617	ITPRNT	0000	I 000577	I1	0000	I 000610	I1N
0000	I 000600	I2	0000	I 000601	I3	0000	I 000602	I4	0000	I 000603	I5	0000	I 000604	I6
0000	I 000605	I7	0000	I 000606	I8	0000	I 000607	I9	0000	I 000624	J	0000	R 000075	LA
0000	R 000622	LC	0000	R 000013	LE	0000	I 000620	M	0000	R 000000	MESH	0000	I 000574	MMY
0000	I 000133	NC	0000	I 000037	NL	0000	I 000615	NSCL	0000	R 000025	OIN	0000	R 000121	RPST
0000	R 000623	RTC	0000	R 000001	RTE	0000	R 000107	TEVAP	0000	R 000051	TL	0000	R 000063	TW

```

00100 1* C MAIN DRIVER PROGRAM FOR HEAT PIPE COMPUTATIONS
00101 2* COMMON B(21)
00103 3* IMPLICIT REAL (L)
00104 4* REAL MESH
00105 5* DIMENSION RTE(10),LE(10),QIN(10),NL(10),TL(10),TW(10),LA(10),
00106 6* TEVAP(10),RPST(10),NC(10),A(9,31),MMT(3)
00108 7* DATA I1,I2,I3,I4,I5,I6,I7,I8,I9,I10/I0*/
00121 8* DATA (A(I,I),I=1,31)/'RTE','LE','NC','QIN','TL','TW','LA','TEVAP',
00121 9* '1*RPST','NC','LC','RTC','TVAP','TVAPA','TVAPC','TVMIN','TREJ',
00121 10* '2*DPVE','DPVOM','DPVA','DPVC','DPVEK','DPLE','DPLA','DPLC',
00121 11* '3*DPLCON','DPVT','DPLT','DPTOT','DPST','CON'/
00123 12* DATA MMT/(1H,A',6,1P00,'E12.3)'/
00125 13* NAMELIST /INPT,RTE,LE,QIN,NL,TL,TW,LA,TEVAP,RPST,NC,FDE,FCE,
00125 14* I IHPT,NSCL,MESH,INPRT,ITPRNT
00126 15* NAMELIST /INPP,IMPT,NSCL,MESH,FDE,FCE
00126 16* C IHPT 0/1 ANNULAR/HOMOGENEOUS DEFAULT=1
00127 17* DATA IHPT,MESH,NSCL,FDE,FCE /1,100.,1,1.,1./
00135 18* DATA ITPRNT/0/
00135 19* C
00137 20* 1 READ(5,INPT)
00142 21* WRITE (6,900)
00144 22* IF(INPRT.EQ.1) WRITE (6,INPT)
00150 23* IF(INPRT.NE.1) WRITE (6,INPP)
00154 24* WRITE (6,900)
00156 25* INPRT=0
00157 26* M=1
00160 27* ICNT=0
00161 28* 100 CALL HYPEP(RTE(I1),LE(I2),LC,QIN(I3),NL(I4),TL(I5),TW(I6),RTC,
00161 29* 1 LA(I7),TEVAP(I8),RPST(I9),NC(I10),FDE,FCE,IMPT,NSCL,MESH,
00161 30* 2 ITPRNT)
00162 31* WRITE (6,900)
00164 32* ICNT=ICNT+1
00165 33* A(I1+1,1)=RTE(I1)
00166 34* A(I2+1,2)=LE(I2)
00167 35* A(I3+1,3)=NL(I3)
00170 36* A(I4+1,4)=QIN(I4)
00171 37* A(I5+1,5)=TL(I5)
00172 38* A(I6 +1,6)=TW(I6)
00173 39* A(I7 +1,7)=LA(I7)
00174 40* A(I8 +1,8)=TEVAP(I8)
00175 41* A(I9 +1,9)=RPST(I9)
00176 42* A(I10+1,10)=NC(I10)
00177 43* GO TO (121,122,123,124,125,126,127,128,129,130),M
00200 44* 121 I1=I1+1
00201 45* DO 301 I=11,31
00204 46* 301 A(I1,I)=B(I-10)
00206 47* IF(RTE(I1))100,101,100

```

```

00211  98*   101 MMT(2)=MMT(2)+I1-1
00212  99*   WRITE(6,MMT)((A(J,I),J=1,I1),I=1,31)
00223  50*   MMT(2)=MMT(2)-I1+1
00224  51*   I1=1
00225  52*   M=2
00226  53*   122 I2=I2+1
00227  54*   IF(I2.LE.2)GO TO #02
00231  55*   DO 302 I=11,31
00234  56*   302 A(I2,I)=B(I-10)
00236  57*   #02 CONTINUE
00237  58*   IF(LE(I2))100,102,100
00242  59*   102 MMT(2)=MMT(2)+I2-1
00243  60*   IF(I2.GT.2)WRITE(6,MMT)((A(J,I),J=1,I2),I=1,31)
00255  61*   MMT(2)=MMT(2)-I2+1
00256  62*   M=3
00257  63*   I2 =1
00260  64*   123 I3=I3+1
00261  65*   IF(I3.LE.2)GO TO #03
00263  66*   DO 303 I=11,31
00266  67*   303 A(I3,I)=B(I-10)
00270  68*   #03 CONTINUE
00271  69*   IF(BIN(I3))100,103,100
00274  70*   103 MMT(2)=MMT(2)+I3-1
00275  71*   IF(I3.GT.2)WRITE(6,MMT)((A(J,I),J=1,I3),I=1,31)
00307  72*   MMT(2)=MMT(2)-I3+1
00310  73*   M=4
00311  74*   I3 =1
00312  75*   124 I4=I4+1
00313  76*   IF(I4.LE.2)GO TO #04
00315  77*   DO 304 I=11,31
00320  78*   304 A(I4,I)=B(I-10)
00322  79*   #04 CONTINUE
00323  80*   IF(NL(I4))100,104,100
00326  81*   104 MMT(2)=MMT(2)+I4-1
00327  82*   IF(I4.GT.2)WRITE(6,MMT)((A(J,I),J=1,I4),I=1,31)
00341  83*   MMT(2)=MMT(2)-I4+1
00342  84*   M=5
00343  85*   I4 =1
00344  86*   125 I5=I5+1
00345  87*   IF(I5.LE.2)GO TO #05
00347  88*   DO 305 I=11,31
00352  89*   305 A(I5,I)=B(I-10)
00354  90*   #05 CONTINUE
00355  91*   IF(TL(I5))100,105,100
00360  92*   105 MMT(2)=MMT(2)+I5-1
00361  93*   IF(I5.GT.2)WRITE(6,MMT)((A(J,I),J=1,I5),I=1,31)
00373  94*   MMT(2)=MMT(2)-I5+1
00374  95*   M=6
00375  96*   I5 =1
00376  97*   126 I6=I6+1
00377  98*   IF(I6.LE.2)GO TO #06
00401  99*   DO 306 I=11,31
00404  100*  306 A(I6,I)=B(I-10)
00406  101*  #06 CONTINUE
00407  102*   IF(TW(I6))100,106,100
00412  103*  106 MMT(2)=MMT(2)+I6-1
00413  104*   IF(I6.GT.2)WRITE(6,MMT)((A(J,I),J=1,I6),I=1,31)
00423  105*   MMT(2)=MMT(2)-I6+1
00426  106*   M=7
00427  107*   I6 =1
00430  108*  127 I7=I7+1
00431  109*   IF(I7.LE.2)GO TO #07
00433  110*   DO 307 I=11,31
00436  111*  307 A(I7,I)=B(I-10)
00440  112*  #07 CONTINUE
00441  113*   IF(LA(I7))100,107,100
00444  114*  107 MMT(2)=MMT(2)+I7-1
00445  115*   IF(I7.GT.2)WRITE(6,MMT)((A(J,I),J=1,I7),I=1,31)
00457  116*   MMT(2)=MMT(2)-I7+1
00460  117*   M=8
00461  118*   I7 =1
00462  119*  128 I8=I8+1
00463  120*   IF(I8.LE.2)GO TO #08
00465  121*   DO 308 I=11,31
00470  122*  308 A(I8,I)=B(I-10)
00472  123*  #08 CONTINUE
00473  124*   IF(TEVAP(I8))100,108,100
00476  125*  108 MMT(2)=MMT(2)+I8-1
00477  126*   IF(I8.GT.2)WRITE(6,MMT)((A(J,I),J=1,I8),I=1,31)
00511  127*   MMT(2)=MMT(2)-I8+1
00512  128*   M=9
00513  129*   I8 =1
00514  130*  129 I9=I9+1
00515  131*   IF(I9.LE.2)GO TO #09
00517  132*   DO 309 I=11,31
00522  133*  309 A(I9,I)=B(I-10)
00524  134*  #09 CONTINUE
00525  135*   IF(RPST(I9))100,109,100
00530  136*  109 MMT(2)=MMT(2)+I9-1
00531  137*   IF(I9.GT.2)WRITE(6,MMT)((A(J,I),J=1,I9),I=1,31)
00543  138*   MMT(2)=MMT(2)-I9+1
00544  139*   M=10
00545  140*   I9 =1
00546  141*  130 I10=I10+1
00547  142*   IF(I10.LE.2)GO TO #10
00551  143*   DO 310 I=11,31
00554  144*  310 A(I10,I)=B(I-10)
00556  145*  #10 CONTINUE
00557  146*   IF(NC(I10))100,110,100

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00562 147*      110 MMT(2)=MMT(2)+I10-1
00563 148*      IF(I10.GT.2)WRITE(6,MMT)((A(J,I),J=1,I10),I=1,31)
00575 149*      MMT(2)=MMT(2)-I10+1
00576 150*      I10=1
00577 151*      GO TO 1
00600 152*      900 FORMAT (1H1)
00601 153*      END

```

END OF COMPILATION! NO DIAGNOSTICS.

#FOR:IS SEARCH,SEARCH
FOR S10A-C 06/23/73-18:44:00 (,0)

SUBROUTINE SEARCH ENTRY POINT 000202

STORAGE USED: CODE(1) 000240; DATA(0) 000022; BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NERR35

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000170	12L	0001	000040	2L	0001	000113	21L	0001	000125	22L	0001	000104	23L	
0001	000117	24L	0001	000031	4L	0001	000023	5L	0000	000012	INJP5	0000	I	000005	M
0000	I	000007	N	0000	R	000000	P	0000	R	000006	S	0000	R	000002	X
												0000	R	000004	X6

```

00101 1*      SUBROUTINE SEARCH(PR,PC, XX,XU,XL,R,E,K)
00101 2*      CSEARCH
00103 3*      DIMENSION P(2),X(2)
00104 4*      IF(K.NE.0) GO TO 2
00106 5*      K=1
00107 6*      X6=XX
00110 7*      M=1
00111 8*      X(1)=X6
00112 9*      P(1)=PR-PC
00113 10*     IF(P(1).GT.0.)GO TO 4
00115 11*     XL=X6
00116 12*     X6=X6*(1.+R)
00117 13*     5 X(2)=X6
00120 14*     XX=X6
00121 15*     RETURN
00122 16*     4 XU=X6
00123 17*     X6=X6/(1.+R)
00124 18*     GO TO 5
00125 19*     2 M=M+1
00126 20*     IF(M.GE.15) K=(10-M)/5
00130 21*     P(2)=PR-PC
00131 22*     S=(X(2)-X(1))/(P(2)-P(1))
00132 23*     N=0
00133 24*     IF(S.GT.0.)N=1
00135 25*     IF(P(2).GT.0.)GO TO 21
00137 26*     IF(N.GT.0)GO TO 24
00141 27*     23 XU=AMINI(XU,X(2))
00142 28*     GO TO 22
00143 29*     21 IF(N.GT.0)GO TO 23
00145 30*     24 XL=AMAX1(XL,X(2))
00146 31*     22 X6=X(2)-P(2)*S
00147 32*     IF(ABS(1.-PC/PR).LT.E)GO TO 12
00151 33*     X(1)=X(2)
00152 34*     IF(X6.GT.XU.OR.X6.LT.XL)X6=(XU+XL)*.5
00154 35*     P(1)=P(2)
00155 36*     GO TO 5
00156 37*     12 K=2
00157 38*     GO TO 5
00160 39*     END

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END OF COMPILATION! NO DIAGNOSTICS.

#FOR:IS ENTP,ENTP
FOR S10A-C 06/23/73-18:44:02 (,0)

FUNCTION ENTP ENTRY POINT 000263
ENTRP ENTRY POINT 000302
ENTRP1 ENTRY POINT 000307
ENT ENTRY POINT 000312

STORAGE USED: CODE(1) 000317; DATA(0) 000045; BLANK COMMON(2) 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 EXIT
 0004 NPR1\$
 0005 NIO1\$
 0006 NIO2\$
 0007 NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000143	1L	0001	000011	10L	0001	000140	11L	0001	000005	12L	0001	000050	1236
0001	000072	3L	0001	000206	4L	0000	000005	5F	0001	000201	6L	0000	000012	7F
0000	R	000000	ENTP	0000	I	000001	I	0000	000017	INJP\$	0000	I	000002	J
0000	R	000004	S											

```

00100      1*      CENS          INTERP FUNCTION FOR SYSTEM STUDY  COS  NTP0          ENT00100
00101      2*          FUNCTION ENTP(Y,X,N,A,M,K)          ENT00200
00103      3*          DIMENSION Y(1),X(1)          ENT00300
00104      4*          INTEGER I          ENT00400
00105      5*          ENTRY ENTRP(A)          ENT00500
00107      6*          ENTRY ENTRP1(Z)          ENT00600
00111      7*          IF(N.GE.2) GO TO 10          ENT00700
00113      8*          12 ENTP=Y(1)          ENT00800
00114      9*          GO TO 11          ENT00900
00115     10*          10 I=1          ENT01000
00116     11*          IF(K.GT.0)I=N          ENT01100
00120     12*          IF(A.LT.X(I))GO TO 1          ENT01200
00122     13*          DO 2 J=2,N          ENT01300
00125     14*          I=J          ENT01400
00126     15*          IF(K.GT.0)I=N+I-J          ENT01500
00130     16*          2 IF(A.LE.X(I))GO TO 3          ENT01600
00133     17*          GO TO 4          ENT01700
00134     18*          3 K1=I-1          ENT01800
00135     19*          IF(K.GT.0)K1=I+1          ENT01900
00137     20*          S=(A-X(K1))/(X(I)-X(K1))          ENT02000
00140     21*          ENTRY ENTP(Y)          ENT02100
00142     22*          IF(N.LT.2)GO TO 12          ENT02200
00144     23*          ENTP=Y(K1)*(Y(I)-Y(K1))*S          ENT02300
00145     24*          11 RETURN          ENT02400
00146     25*          1 IF(M.EQ.0)          ENT02500
00146     26*          1PRINT 5,A,X(I),Y(I)          ENT02600
00154     27*          5 FORMAT(13H0***** ENTP1,1P3E14.3)          ENT02700
00155     28*          I=2          ENT02800
00156     29*          IF(K.GT.0)I=N-1          ENT02900
00160     30*          6 IF(M.EQ.0)CALL EXIT          ENT03000
00162     31*          GO TO 3          ENT03100
00163     32*          4 IF(M.EQ.0)          ENT03200
00163     33*          1PRINT 7,A,X(I),Y(I)          ENT03300
00171     34*          7 FORMAT(13H0***** ENTPH,1P3E14.3)          ENT03400
00172     35*          GO TO 6          ENT03500
00173     36*          END          ENT03600
    
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END OF COMPILATION: NO DIAGNOSTICS.

QFOR,IS HOPIPE,HOPIPE
 FOR S10A-C 06/23/73-18:44:04 (+0)

SUBROUTINE MYPE ENTRY POINT 001706

STORAGE USED: CODE(1) 002066) DATA(0) 001441) BLANK COMMON(2) 000022

EXTERNAL REFERENCES (BLOCK, NAME)

0003 ENTP
 0004 NEXP6\$
 0005 ALO6
 0006 EXP
 0007 SORT
 0010 NMDUS
 0011 NIO2\$
 0012 NERR3\$

STORAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	000331	1F	0001	000331	100L	0001	000030	110L	0001	001364	130L	0001	000760	131L		
0001	001464	140L	0001	001504	150L	0000	000353	160F	0000	000343	2F	0001	000517	2376		
0001	000720	2656	0001	000700	331L	0001	001323	3346	0001	001477	500L	0001	001732	520L		
0001	001741	521L	0001	000030	70L	0000	000363	90F	0000	000365	901F	0000	000533	902F		
0000	000701	903F	0000	001047	904F	0000	001227	905F	0000	R	000152	AA	0000	R	000167	ALC
0000	R	000166	ALE	0000	R	000171	AR	0000	R	000123	AW	0000	R	000115	COM	
0000	R	000132	DENSL	0000	R	000131	DENV	0000	R	000201	DPLC	0000	R	000172	DPLCON	
0000	R	000202	DPLCT	0000	R	000143	DPLE	0000	R	000013	DPLT	0000	R	000015	DPVOT	
0000	R	000010	DPVA	0000	R	000011	DPVC	0000	R	000204	DPVCT	0000	R	000147	DPVET	
0000	R	000012	DPVEX	0000	R	000007	DPVWOM	0000	R	000203	DPVREC	0000	R	000014	DPVY	
0000	R	000175	DTFC	0000	R	000127	DYS	0000	R	000173	DYSC	0000	R	000120	DTW	
0000	R	000177	DTWC	0003	R	000000	ENTP	0000	R	000146	F	0001	R	001751	FF	
0000	R	000024	GAM	0000	I	000153	I	0000	001376	INJP\$	0000	R	000111	K		

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0000 R 000062 KL          0000 R 000100 KSS          0000 R 000133 LAMBDA          0000 R 000076 M          0000 R 000142 MDOT
0000 R 000042 MUL          0000 R 000096 MUV          0000 I 000105 NKL          0000 I 000104 NMLV          0000 I 000162 NS
0000 R 000211 OUTP          0000 R 000116 PERMEA          0000 R 000113 PI          0000 R 000016 PT          0000 R 000130 PVAP
0000 R 000155 PVAPA          0000 R 000161 PVAPC          0000 R 000151 PVMIN          0000 R 000137 QA          0000 R 000135 QACRIT
0000 R 000136 QCRIT          0000 R 000160 GENT          0000 R 000157 GENTR          0000 R 000112 R          0000 R 000145 REVAP
0000 R 000030 RHOL          0000 R 000040 RHOV          0000 R 000126 RSCI          0000 R 000140 RSCIC          0000 R 000163 RSCICC
0000 R 000165 RTCI          0000 R 000206 RTCL          0000 R 000205 RTCU          0000 R 000141 RTEC          0000 R 000117 RTEI
0000 R 000122 RTFI          0000 R 000164 RTFIC          0000 R 000106 SIGMA          0000 R 000121 TFL          0000 R 000174 TFLC
0000 R 000072 TKL          0000 R 000056 TMUV          0000 R 000005 TREJ          0000 R 000207 TREJI          0000 R 000107 TS
0000 R 000125 TSC          0000 R 000114 TSL          0000 R 000001 TVAP          0000 R 000002 TVAPA          0000 R 000003 TVAPC
0000 R 000200 TVM          0000 R 000004 TVMIN          0000 R 000176 TWC          0000 R 000110 TWOPI          0000 R 000170 VLE
0000 R 000134 VS          0000 R 000156 VVA          0000 R 000144 VVAP

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00000 *DIAGNOSTIC* THE VARIABLE, RTCU, IS REFERENCED IN THIS PROGRAM, BUT IS NOWHERE ASSIGNED A VALUE.
00000 *DIAGNOSTIC* THE VARIABLE, RTCL, IS REFERENCED IN THIS PROGRAM, BUT IS NOWHERE ASSIGNED A VALUE.
00101 1* SUBROUTINE HTPIPE(RTE,LE,LC,GIN,NL,TL,TW,RTC,LA,TEVAP,RPST,NC,
00101 2* 1 FDE,FCE,(HPT,NSCL,MESH,ITPRINT)
00103 3* IMPLICIT REAL(L,M,K)
00104 4* COMMON B(18)
00105 5* NAMELIST /OUTP,RTE,LE,GIN,NL,TL,TW,LA,TEVAP,RPST,NC,DPST,
00105 6* 1 LC,RTC,TVAP,TVAPA,TVAPC,TVMIN,TREJ,DPVE,DPVMOM,
00105 7* IDPVA,DPVC,DPVEX,DPCL,DPVT,DPTOT
00106 8* DIMENSION PT(3,2),GAM(2,2),RHOL(4,2),RHOV(2),MUL(2,2),MUV(4,2),
00106 9* 1TMUV(4),KL(4,2),TKL(4),M(2),KSS(2,2)
00107 10* DATA PT/16.11149,10398.4,0.53299,17.69932,12767.8,0.61344/
00111 11* DATA GAM/1.388E-3,6.5E-7,2.283E-3,1.E-6/
00113 12* DATA RHOL/0.89862, 0.20132E-3, 0.3084E-7, 4.65E-12,0.1164,
00113 13* 10.2205E-5, 0.1923E-7,5.64E-12/
00115 14* DATA RHOV/0.4689,0.2765/
00117 15* DATA MUL/0.00657,712.7,0.00614,836./
00121 16* DATA MUV,TMUV/9.5E-5,1.14E-4,1.48E-4,2.42E-4,7.2E-5,9.E-5,1.22E-5,
00121 17* 12.3E-5,300.,600.,900.,1500./,NMUV/4/
00125 18* DATA KL,TKL/51.,445.,37.,23.,91.,79.,665.,425,300.,500.,800.,
00125 19* 11500./,NKL/4/
00131 20* DATA M/39.,23./,SIGMA/5.6687E-12/
00134 21* DATA TS/.02/,TWOPI/6.2831853/,K/1.667/,R/8.317/,PI/3.14159265/
00142 22* DATA KSS/0.472,0.1127E-3,0.086,0.157E-3/
00144 23* P(I,1)=EXP(PT(1,I))-PT(2,I)/T-PT(3,I)*ALOG(T))
00145 24* GAMMA(T,I)=GAM(1,I)-GAM(2,I)*T
00146 25* DENL(T,I)=RHOL(1,I)+T*(-RHOL(2,I))+T*(-RHOL(3,I))+T*RHOL(4,I))
00147 26* VISL(T,I)=MUL(1,I)*EXP(MUL(2,I)/T)
00150 27* KWALL(T,I)=KSS(1,I)-KSS(2,I)*T
00151 28* DATA TSL/0.02/
00153 29* CON=0.
00153 30* C HOMOGENEOUS HEAT PIPE PROPERTIES (IHPT=1)
00154 31* IF(MESH.EQ.0) GO TO 70
00156 32* RPST=0.825*(1./MESH)**1.0945
00157 33* PERMEA=0.0371*(1./MESH)**1.6185
00160 34* TSL=11.7446*(1./MESH)**1.3553
00161 35* 70 CONTINUE
00161 36* C EVAPORATOR SECTION
00162 37* 110 RTEI=RTTE-TM
00163 38* TS=TSL*NSCL
00164 39* DTW=GIN*ALOG(RTE/RTTE)/(KWALL(TEVAP,NC)*TWOPI*LE)/FDE
00165 40* TFL=TEVAP-OTM
00166 41* RTFI=RTTE-TL
00167 42* AW=PI*TS*(2.*RTEI-TS)
00170 43* DTF=GIN*ALOG(RTEI/RTFI)/(ENTP(KL(1,NL),TKL,NKL,TFL,0,0)*TWOPI*LE)
00170 44* A /FDE
00171 45* TSC=TFL-DTF
00172 46* RSCI=RTFI-TS
00173 47* DTS=GIN*ALOG(RTFI/RSCI)/(KWALL(TSC,NC)*TWOPI*LE)/FDE
00174 48* TVAP=TSC-DTS
00175 49* PVAP=P(TVAP,NL)
00176 50* DENV=RHOV(NL)*PVAP/TVAP
00177 51* DENSL=DENL(TVAP,NL)
00200 52* LAMBDA=0.01*PVAP*(PT(2,NL)/TVAP-PT(3,NL))*(1./DENV-1./DENSL)
00201 53* VS=SQRT(K*R*TVAP/M(NL))*3162.27
00202 54* QACRIT=DENV*VS*LAMBDA/SQRT(2.*(K+1.))
00203 55* QCRIT=QACRIT*PI*RSCI**2
00204 56* QA=GIN/(PI*RSCI**2)
00205 57* IF(QA.LE.0.6*QACRIT)GO TO 100
00207 58* RSCIC=SQRT(GIN/PI*0.59*QACRIT))
00210 59* RTEC=RSCIC*TS*TL*TM
00211 60* WRITE(6,1)RTEC
00214 61* 1 FORMAT('OCRITICAL HEAT FLUX EXCEEDED. RTE INCREASED TO ',F10.4)
00215 62* RTE=RTEC
00216 63* GO TO 110
00217 64* 100 MDOT=GIN/LAMBDA
00220 65* DPLE = VISL(TVAP,NL)*MDOT*(LE/2.)/(PERMEA*AW*DENSL)*1.E-5
00221 66* VVAP=MDOT/(DENV*PI*RSCI**2)
00222 67* DPVMOM=PVAP*(1.-1./((1.+VVAP/VS)**2*K))
00223 68* REVAP=2.*MDOT/(PI*RSCI*ENTP(MUV(1,NL),TMUV,NMUV,TVAP,0,0))
00224 69* F=FFIREVAP)
00225 70* DPVE=DENV *F*LE*VVAP**2/(2.*RSCI)*1.E-5
00226 71* DPVET=DPVE*DPVMOM
00227 72* DTVET=TVAP*DPVET/(PVAP*(PT(2,NL)/TVAP-PT(3,NL)))
00230 73* TVAPA=TVAP-DTVET
00231 74* DPST=2.*GAMMA(TVAPA,NL)/RPST
00232 75* TVMIN=TVAPA
00233 76* PVMIN=PVAP*DPST
00234 77* TVMIN=AMAX1(PVMIN,.01)
00235 78* AA=ALOG(PVMIN)
00236 79* DO 432 I=1,3
00241 80* 432 TVMIN=TVMIN*(1.+(AA-PT(1,NL)+PT(2,NL)/TVMIN+PT(3,NL)*ALOG(TVMIN))
00241 81* 1/(PT(2,NL)/TVMIN-PT(3,NL)))

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00241 82* C ADIABATIC SECTION
00243 83* DENSL=DENL(TVAPA,NL)
00244 84* DPLA=VISL(TVAPA,NL)*MDO*(LA+64.,*TL)/(PERMEA*AW*DENSL)*1.E-5
00245 85* PVAPA=PVAP-DPVET
00246 86* DENVRHOV(NL)*PVAPA/TVAPA
00247 87* VVA=MDO*(DENV*PI*RSCI **2)
00250 88* REVAP=2.*MDO*(PI*RSCI *ENTP(MUV(1,NL),TMUV,NMUV,TVAPA,0,0))
00251 89* F=FF(REVAP)
00252 90* DPVA=DENV*F*(LA+64.*RSCI )*VVA **2/RSCI *1.E-5
00253 91* GENTH=LAMBDA*SQR(TPI*0.5*DENV*DPST)*316.227
00254 92* GENTR=GENTR*PI*RSCI**2
00255 93* IF (LA.GT.0.2) GO TO 331
00257 94* DPVA=0.
00260 95* DPLA=0.
00261 96* 331 PVAPC=PVAP-DPVET-DPVA
00262 97* AA=ALOG(PVAPC)
00263 98* TVAPC=TVAPA
00264 99* DO 332 I=1,3
00267 100* 332 TVAPC=TVAPC*(1.+(AA-PT(1,NL)+PT(2,NL)/TVAPC+PT(3,NL)*ALOG(TVAPC))
00267 101* 1/(PT(2,NL)/TVAPC-PT(3,NL)))
00267 102* C CONDENSER SECTION
00271 103* NS=0
00272 104* TREJ=0.5*(TVMIN+TVAPC)
00273 105* LC=QIN/(1.8*RTC*TREJ**4*SIGMA)
00274 106* RSCICC=RSCI
00275 107* 131 RTFIC=RSCICC+TS
00276 108* RTCI=RTFIC+TL
00277 109* RTC=RTCI+TW
00300 110* DPVEX=DENV*VVA **2*0.5*(1.-(RSCI/RSCICC)**2)**2*1.E-5
00300 111* C ALE=PI*TL*(RTFI+RTEI)
00301 112* ALE=PI*TSL*(RTFI+RTEI)
00301 113* C ALC=PI*TL*(RTFIC+RTCI)
00302 114* ALC=PI*TSL*(RTFIC+RTCI)
00303 115* VLE=MDO*(ALE*DENSL)
00304 116* AR=ALE/ALC
00305 117* OPLCON=DENSL*VLE**2*0.2*(1.-AR)*1.E-5
00306 118* DTSC=QIN*ALOG(RTFIC/RSCICC)/(KWALL(TVAPC,NC)*TWOPI*LC)
00307 119* TFLC=TVAPC-DTSC
00310 120* DTFC=QIN*ALOG(RTCI/RTFIC)/(ENTP(KL(1,NL),TKL,NKL,TFLC,0,0)*TWOPI*
00310 121* ILC)
00311 122* TW=DTFC-DTFC
00312 123* DTWC=QIN*ALOG(RTC/RTCI)/(KWALL(TWC,NL)*TWOPI*LC)
00313 124* TVM=TVMIN
00314 125* TREJ= TVAPC -DTSC-DTFC-DTWC
00315 126* LC=QIN/(1.8*RTC*TREJ**4*SIGMA)
00316 127* DENSL=DENL(TVAPC,NL)
00317 128* DPLC=VISL(TVAPC,NL)*MDO*(LC/2.)/(PERMEA*AW*DENSL)*1.E-5
00320 129* DPLCT=DPLC+DPLCON
00321 130* DENVRHOV(NL)*PVAPC/TVAPC
00322 131* VVAP=MDO*(DENV*PI*RSCICC**2)
00323 132* REVAP=2.*MDO*(PI*RSCICC*ENTP(MUV(1,NL),TMUV,NMUV,TVAPC,0,0))
00324 133* F=FF(REVAP)
00325 134* DPVC=DENV*F*LC*VVAP**2/RSCICC*5.E-6
00326 135* DPVREC=0.4*DPVMOM
00327 136* DPVCT=DPVC+DPVEX -DPVREC
00330 137* OPTOT=DPVET+DPVA+DPVCT+DPLE+DPLA+DPLCT
00331 138* PVAPC=PVAP-DPVET-DPVA-0.5*DPVCT
00332 139* AA=ALOG(PVAPC)
00333 140* DO 334 I=1,3
00336 141* 334 TVAPC=TVAPC*(1.+(AA-PT(1,NL)+PT(2,NL)/TVAPC+PT(3,NL)*ALOG(TVAPC))
00336 142* 1/(PT(2,NL)/TVAPC-PT(3,NL)))
00340 143* DPVET=DPVET+DPVA+DPVCT
00341 144* DPLT=DPLE +DPLA+DPLCT
00342 145* NS=NS+1
00343 146* IF(NS.GT.20) GO TO 140
00345 147* GO TO 130
00346 148* 130 CONTINUE
00347 149* IF(ITPRNT.NE.0)
00347 150* AWRITE(6,90)DPOT,DPST,RTCU,RTCL,RSCICC,DPVC,F,REVAP,VVAP,DENV
00347 151* A ,DPLC,DENSL,LC,TREJ,DTWC,DTFC,DTSC,TVAPC,TVM,TVMIN
00347 152* A ,PVAPC,DPLCT,DPVCT,DPLCON,AR,VLE,ALC,ALE,DPVEX,DPVA
00347 153* A ,PVAPA,DPLA,RTC,PVMIN,PVAP,DPLE,DPVE,DPVMOM,RTC ,DPVREC
00347 154* A ,QIN,MDO,AW,TS,GACRIT,QA,GENTR
00431 155* A IF(ABS(TREJ-TREJ1).LT. 0.1) GO TO 500
00433 156* TREJ1=TREJ
00434 157* GO TO 131
00435 158* 140 WRITE(6,2)DPOT,DPST,RSCICC
00442 159* 2 FORMAT('0CANNOT CONVERGE ON PORE SIZE ',5E15.4)
00443 160* CON=1.
00444 161* GO TO 150
00445 162* 500 WRITE(6,160)
00447 163* 160 FORMAT('0PUMPING SUFFICIENT. RTC MAINTAINED.')
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00556 182*      B(13)=DPLE
00557 183*      B(14)=DPLA
00560 184*      B(15)=DPLC
00561 185*      B(16)=DPLCON
00562 186*      B(17)=DPVT
00563 187*      B(18)=DPLT
00564 188*      B(19)=DPTOT
00565 189*      B(20)=DPST
00566 190*      B(21)=CON
00567 191*      RETURN
00567 192*      C *** FORMATS
00570 193*      90 FORMAT(1P10E12,4)
00571 194*      901 FORMAT (' ,5X,'TOTAL PRESURE DROP IN PIPE',10X,'DPTOT',E14.6/
00571 195*      1      ' ,5X,'TOTAL AVAILABLE PRESSURE ',10X,'DPST ',E14.6/
00571 196*      2      ' ,5X,' ',10X,'RTCU ',E14.6/
00571 197*      3      ' ,5X,' ',10X,'RTCL ',E14.6/
00571 198*      4      ' ,5X,' ',10X,'RSCICC',E14.6/
00571 199*      5      ' ,5X,'V PRESSURE DROP CONDENSER ',10X,'DPVC ',E14.6/
00571 200*      5      ' ,5X,'FRICTION FACTOR ',10X,' F ',E14.6/
00571 201*      6      ' ,5X,'REYNOLDS NUMBER VAPOR ',10X,' REVP',E14.6/
00571 202*      7      ' ,5X,'VELOCITY VAPOR ',10X,'VVAP ',E14.6/
00571 203*      8      ' ,5X,'VAPOR DENSITY ',10X,'DENV ',E14.6/
00572 204*      902 FORMAT (' ,5X,'LIQUID PRESSURE DROP CONDE',10X,'DPLC ',E14.6/
00572 205*      1      ' ,5X,'LIQUID DENSITY ',10X,'DENSL ',E14.6/
00572 206*      2      ' ,5X,'CONDENSER LENGTH ',10X,'LC ',E14.6/
00572 207*      3      ' ,5X,'AVG REJECTION TEMPERATURE ',10X,'TREFJ ',E14.6/
00572 208*      4      ' ,5X,'DT CONDENSER WALL ',10X,'DTWC ',E14.6/
00572 209*      5      ' ,5X,'DT CONDENSER FILM ',10X,'DTFC ',E14.6/
00572 210*      6      ' ,5X,'DT CONDENSER SCREEN ',10X,'DISC ',E14.6/
00572 211*      7      ' ,5X,'VAPOR TEMP CONDENSER ',10X,'TVAPC ',E14.6/
00572 212*      8      ' ,5X,' ',10X,'TVM ',E14.6/
00572 213*      9      ' ,5X,' ',10X,'TVMIN',E14.6)
00573 214*      903 FORMAT (' ,5X,'PRESSURE IN CONDENSER ',10X,'PVAPC ',E14.6/
00573 215*      1      ' ,5X,'TOT L PRESSURE DROP COND ',10X,'DPLCT ',E14.6/
00573 216*      2      ' ,5X,'TOT V PRESSURE DROP ',10X,'DPV ',E14.6/
00573 217*      3      ' ,5X,'CONTRACT PRESSURE DROP ',10X,'DPLCON',E14.6/
00573 218*      4      ' ,5X,'AREA RATIO ',10X,'AR ',E14.6/
00573 219*      5      ' ,5X,'LIQUID VELOCITY ',10X,'VLE ',E14.6/
00573 220*      6      ' ,5X,'AREA L FLOW COND ',10X,'ALC ',E14.6/
00573 221*      7      ' ,5X,'AREA L FLOW EVAP ',10X,'ALE ',E14.6/
00573 222*      8      ' ,5X,'PRESSURE DROP EXPA N ',10X,'DPVEX ',E14.6/
00573 223*      9      ' ,5X,'V PRESSURE DROP ADIABATIC ',10X,'DPVA ',E14.6/
00574 224*      904 FORMAT (' ,5X,'PRESSURE IN ADIABATIC SEC ',10X,'PVAPA ',E14.6/
00574 225*      1      ' ,5X,'L PRESS DROP ADIAB ',10X,'DPLA ',E14.6/
00574 226*      2      ' ,5X,' ',10X,'RIC ',E14.6/
00574 227*      3      ' ,5X,'PRESSURE RECOVERED ',10X,'DPVREC',E14.6/
00574 228*      4      ' ,5X,'MIN V PRESSURE ',10X,'PVMIN ',E14.6/
00574 229*      5      ' ,5X,'V PRESSURE CONDENSER ',10X,'PVAP ',E14.6/
00574 230*      6      ' ,5X,' ',10X,' ',E14.6/
00574 231*      7      ' ,5X,'DP V EVAPORATOR ',10X,'DPVE ',E14.6/
00574 232*      8      ' ,5X,'DP V MOMENTUM ',10X,'DPVMOM',E14.6/
00574 233*      9      ' ,5X,'MP RADIUS EVAPORATOR ',10X,'RTE ',E14.6/
00574 234*      A      ' ,5X,'PRESSURE RECOVERED ',10X,'DPVREE',E14.6)
00575 235*      905 FORMAT (' ,5X,'TOTAL HEAT TRANSFERRED ',10X,'QIN ',E14.6/
00575 236*      1      ' ,5X,'MASS FLOWRATE ',10X,'MDOY ',E14.6/
00575 237*      2      ' ,5X,' ',10X,'AW ',E14.6/
00575 238*      3      ' ,5X,' ',10X,'TS ',E14.6/
00575 239*      4      ' ,5X,'CRITICAL HEAT FLUX ',10X,'QACRIT',E14.6/
00575 240*      4      ' ,5X,'ACTUAL HEAT FLUX ',10X,'QA ',E14.6/
00575 241*      6      ' ,5X,'ENTRAINMENT LIMIT ',10X,'QENTR ',E14.6)
00575 242*      C
00575 243*      C
00576 244*      FUNCTION FF(REVAP)
00601 245*      IF(REVAP.GT.2000) GO TO 520
00603 246*      FF=16./REVAP
00604 247*      GO TO 521
00605 248*      520 FF=0.0146/(REVAP)**0.088
00606 249*      521 RETURN
00607 250*      END

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END OF COMPILATION: 2 DIAGNOSTICS.

QMAP:IS HP:HP
MAP 23-D 06/23/73 18:44:10 (0) HP

1. IN HPD
2. IN HOPIPE
3. IN SEARCH
4. IN ENTP

ADDRESS LIMITS 001000 020414 040000 047142
STARTING ADDRESS 014242
WORDS DECIMAL 7949 IBANK 3683 OBANK

SEGMENT MAIN	001000	020414	040000	047142
NSWTC\$/FOR	1	001000	001021	
NRBLK\$/FOR	1	001022	001044	
NRNND\$/FOR	1	001045	001126	2 040000 040011
NWFE\$/FOR	1	001127	001312	2 040012 040031
NFTCH\$/FOR	1	001313	001627	2 040032 040057
NINPT\$/FOR	1	001630	002514	2 040060 040103
NCLOS\$/FOR	1	002515	002705	2 040104 040134
NMBLK\$/FOR	1	002706	003017	
NBSBL\$/FOR	1	003020	003060	
NUPDA\$/FOR	1	003061	003116	
NBF00\$/FOR				2 040135 042336
NFTVS\$/FOR	1	003117	003141	
NBDCV\$/FOR	1	003142	003267	2 042337 042401
NCNVT\$/FOR	1	003270	003511	2 042402 042476
NININ\$/FOR	1	003512	003702	2 042477 042502
NOTIN\$/FOR	1	003703	004205	2 042503 042514
UTIN\$V (COMMON BLOCK)				042515 042517
NFCHK\$/FOR	1	004206	005174	2 042520 042673
	3	UTIN\$V		4 042674 042745
NIOER\$/FOR	1	005175	005413	2 042746 043116
NOUT\$/FOR	1	005414	006472	2 043117 043152
NFMT\$/FOR	1	006473	007350	2 043153 043227
NTAB\$/FOR				2 043230 043404
ERUS				
NLOUT\$/FOR	1	007351	010432	2 043405 043442
NLINP\$/FOR	1	010433	012236	2 043443 043627
NINTR\$/FOR-JPL	1	012237	012461	2 043630 043714
NOBUF\$/FOR	1	012462	012523	2 043715 043715
SGRT\$/FOR-JPL	1	012524	012562	2 043716 043722
EXPS\$/FOR	1	012563	012652	2 043723 043743
ALOG\$/FOR	1	012653	012772	2 043744 044004
NEXPS\$/FOR	1	012773	013167	2 044005 044056
NERR\$/FOR	1	013170	013565	2 044057 044257
NIER\$/FOR	1	013566	013737	2 044260 044377
NOSYM\$/FOR	1	013740	014201	2 044400 044404
NSTOP\$/FOR	1	014202	014241	2 044405 044420
BLANK\$COMMON (COMMON BLOCK)				044421 044445
HPD	1	014242	015547	0 044446 045412
				2 BLANK\$COMMON
HOPIPE	1	015550	017635	0 045413 047053
				2 BLANK\$COMMON
SEARCB	1	017636	020075	0 047054 047075
				2 BLANK\$COMMON
ENTP	1	020076	020414	0 047076 047142
				2 BLANK\$COMMON

SYSS\$RLIB\$. LEVEL 68 02
 END OF COLLECTION - TIME 1.450 SECONDS

QXGT HP

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$INPP
IHPT = +1
NSCL = +2
MESH = .10000000E+03
FDE = .10000000E+01
FCE = .10000000E+01
$END

```

PUMPING SUFFICIENT. RTC MAINTAINED.

TOTAL PRESSURE DROP IN PIPE	DPTOT	.220647+00
TOTAL AVAILABLE PRESSURE	DPST	.276054+00
	RTCU	.000000
	RTCL	.000000
V PRESSURE DROP CONDENSER	RSCICC	.434263+00
FRICTION FACTOR	DPVC	.141929-01
REYNOLDS NUMBER VAPOR	F	.994367-02
VELOCITY VAPOR	REVAP	.298626+04
VAPOR DENSITY	VVAP	.159531+04
LIQUID PRESSURE DROP CONDE	DENV	.352173-03
LIQUID DENSITY	OPLC	.162729+00
CONDENSER LENGTH	DENSL	.671531+00
AVG REJECTION TEMPERATURE	LC	.136312+03
DT CONDENSER WALL	TREJ	.997994+03
DT CONDENSER FILM	DTWC	.914876-01
DT CONDENSER SCREEN	DTFC	.000000
VAPOR TEMP CONDENSER	DISC	.224434+00
	TVAPC	.998310+03
	TVM	.994765+03
	TVMIN	.994765+03
PRESSURE IN CONDENSER	PVAPC	.749792+01
TOT L PRESSURE DROP COND	OPLCT	.162729+00
TOT V PRESSURE DROP	DPV	.106193-01
CONTRACT PRESSURE DROP	DPLCON	.000000
AREA RATIO	AR	.100000+01

LIQUID VELOCITY	VLE	.718693+01
AREA L FLOW COND	ALC	.689699-01
AREA L FLOW EVAP	ALE	.689699-01
PRESSURE DROP EXPA N	DPVEX	.000000
V PRESSURE DROP ADIABATIC	DPVA	.000000
PRESSURE IN ADIABATIC SEC	PVAPA	.750323+01
L PRESS DROP ADIAB	DPLA	.000000
	RIC	.500000+00
PRESSURE RECOVERED	DPVREC	.723838+01
MIN V PRESSURE	PVMIN	.751524+01
V PRESSURE CONDENSER	PVAP	.352932-01
		.307212-02
DP V EVAPORATOR	DPVE	.893411-02
DP V MOMENTUM	DPVMOM	.500000+00
HP RADIUS EVAPORATOR	RTE	.357364-02
PRESSURE RECOVERED	DPVREE	
TOTAL HEAT TRANSFERRED	QIN	.700000+03
MASS FLOWRATE	MDOT	.332857+00
	AM	.131368+00
	TS	.457371-01
CRITICAL HEAT FLUX	GACRIT	.191457+05
ACTUAL HEAT FLUX	GA	.118152+04
ENTRAINMENT LIMIT	GENTR	.823268+04

PUMPING SUFFICIENT, RTC MAINTAINED.

TOTAL PRESURE DROP IN PIPE	DPTOT	.147678+00
TOTAL AVAILABLE PRESSURE	DPST	.276768+00
	RTCU	.000000
	RTCL	.000000
	RSCICC	.534263+00
	DPVC	.421640-02
V PRESSURE DROP CONDENSER		.100433-01
FRICTION FACTOR	F	
REYNOLDS NUMBER VAPOR	REVAP	.242640+04
VELOCITY VAPOR	VVAP	.105022+04
VAPOR DENSITY	DENV	.353446-03
LIQUID PRESSURE DROP CONDE	DPLC	.111071+00
LIQUID DENSITY	DENSL	.671430+00
CONDENSER LENGTH	LC	.115071+03
AVG REJECTION TEMPERATURE	TREJ	.998403+03
DT CONDENSER WALL	DTWC	.913152-01
DT CONDENSER FILM	DTFC	.000000
DT CONDENSER SCREEN	DISC	.221263+00
VAPOR TEMP CONDENSER	TVAPC	.998716+03
	TVM	.995031+03
	TVMIN	.995031+03
PRESSURE IN CONSENSER	PVAPC	.752808+01
TOT L PRESSURE DROP COND	DPLCT	.111071+00
TOT V PRESSURE DROP	DPV	.265892-02
CONTRACT PRESSURE DROP	DPLCOM	.000000
AREA RATIO	AR	.100000+01
LIQUID VELOCITY	VLE	.594867+01
AREA L FLOW COND	ALC	.833386-01
AREA L FLOW EVAP	ALE	.833386-01
PRESSURE DROP EXPA N	DPVEX	.000000
V PRESSURE DROP ADIABATIC	DPVA	.000000
PRESSURE IN ADIABATIC SEC	PVAPA	.752941+01
L PRESS DROP ADIAB	OPLA	.000000
	RIC	.600000+00
PRESSURE RECOVERED	DPVREC	.725764+01
MIN V PRESSURE	PVMIN	.753440+01
V PRESSURE CONDENSER	PVAP	.289563-01
		.109842-02
DP V EVAPORATOR	DPVE	.389368-02
DP V MOMENTUM	DPVMOM	.600000+00
HP RADIUS EVAPORATOR	RTE	.155747-02
PRESSURE RECOVERED	DPVREE	
TOTAL HEAT TRANSFERRED	QIN	.700000+03
MASS FLOWRATE	MDOT	.332862+00
	AM	.160105+00
	TS	.457371-01
CRITICAL HEAT FLUX	GACRIT	.191918+05
ACTUAL HEAT FLUX	GA	.780617+03
ENTRAINMENT LIMIT	GENTR	.824417+04

PUMPING SUFFICIENT, RTC MAINTAINED.

TOTAL PRESURE DROP IN PIPE	DPTOT	.108369+00
TOTAL AVAILABLE PRESSURE	DPST	.276716+00
	RTCU	.000000
	RTCL	.000000
	RSCICC	.634263+00
	DPVC	.154076-02
V PRESSURE DROP CONDENSER		.101284-01
FRICTION FACTOR	F	
REYNOLDS NUMBER VAPOR	REVAP	.204342+04
VELOCITY VAPOR	VVAP	.743669+03
VAPOR DENSITY	DENV	.354161-03
LIQUID PRESSURE DROP CONDE	DPLC	.806363-01
LIQUID DENSITY	DENSL	.671373+00
CONDENSER LENGTH	LC	.985418+02
AVG REJECTION TEMPERATURE	TREJ	.998633+03
DT CONDENSER WALL	DTWC	.911780-01
DT CONDENSER FILM	DTFC	.000000
DT CONDENSER SCREEN	DISC	.219028+00
VAPOR TEMP CONDENSER	TVAPC	.998943+03
	TVM	.995217+03
	TVMIN	.995217+03

PRESSURE IN CONSENSER	PVAPC	.754503+01
TOT L PRESSURE DROP COND	DPLCT	.806363-01
TOT V PRESSURE DROP	DPV	.757738-03
CONTRACT PRESSURE DROP	DPLCON	.000000
AREA RATIO	AR	.100000+01
LIQUID VELOCITY	VLE	.507432+01
AREA L FLOW COND	ALC	.977073-01
AREA L FLOW EVAP	ALE	.977073-01
PRESSURE DROP EXPA N	DPVEX	.000000
V PRESSURE DROP ADIABATIC	DPVA	.000000
PRESSURE IN ADIABATIC SEC	PVAPA	.754541+01
L PRESS DROP ADIAB	DPLA	.000000
	RIC	.700000+00
PRESSURE RECOVERED	DPVREC	.727112+01
MIN V PRESSURE	PVMIN	.754783+01
V PRESSURE CONDENSER	PVAP	.245486-01
		.468914-03
DP V EVAPORATOR	DPVE	.195757-02
DP V MOMENTUM	DPVMOM	.700000+00
HP RADIUS EVAPORATOR	RTE	.783026-03
PRESSURE RECOVERED	DPVREE	
TOTAL HEAT TRANSFERRED	QIN	.700000+03
MASS FLOWRATE	MDOY	.332865+00
	AW	.188843+00
	TS	.457371-01
CRITICAL HEAT FLUX	QACRIT	.192240+05
ACTUAL HEAT FLUX	QA	.553872+03
ENTRAINMENT LIMIT	QENTR	.625117+04

RTE	5.000-01	6.000-01	7.000-01
LE	3.000+01	0.000	0.000
NC	1.000+00	0.000	0.000
QIN	7.000+02	0.000	0.000
TL	0.000	0.000	0.000
TW	2.000+02	0.000	0.000
LA	1.000-01	0.000	0.000
TEVAP	1.000+03	0.000	0.000
RPST	5.339-03	0.000	0.000
NC	1.000+00	0.000	0.000
LC	1.383+02	1.151+02	9.854+01
RTC	5.000-01	6.000-01	7.000-01
TVAP	9.985+02	9.988+02	9.990+02
TVAPA	9.984+02	9.987+02	9.989+02
TVAPC	9.983+02	9.987+02	9.989+02
TVMIN	9.948+02	9.950+02	9.952+02
TREJ	9.980+02	9.984+02	9.986+02
DPVE	3.072-03	1.098-03	4.689-04
DPVMOM	8.934-03	3.894-03	1.958-03
DPVA	0.000	0.000	0.000
DPVC	1.419-02	4.216-03	1.541-03
DPVEX	0.000	0.000	0.000
DPLE	3.529+02	2.896-02	2.455-02
DPLA	0.000	0.000	0.000
DPLC	1.627-01	1.111-01	8.064-02
DPLCON	0.000	0.000	0.000
DPVT	2.263-02	7.651-03	3.184-03
DPLT	1.980-01	1.400-01	1.052-01
DPTOT	2.206-01	1.477-01	1.064-01
DPST	2.769-01	2.768-01	2.767-01
CON	0.000	0.000	0.000