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USER'S MANUAL FOR THE TRW GASPIPE 2 PROGRAM

(NASA-CR-114672) USER'S MANUAL FOR THE
TRW GASPIPE 2 PROGRAM: A VAPOR-GAS
FRONT ANALYSIS PROGRAM FOR HEAT PIPES
CONTAINING NON-CONDENSIBLE GAS (TRW
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(A VAPOR-GAS FRONT ANALYSIS PROGRAM FOR
HEAT PIPES CONTAINING NON-CONDENSIBLE GAS)

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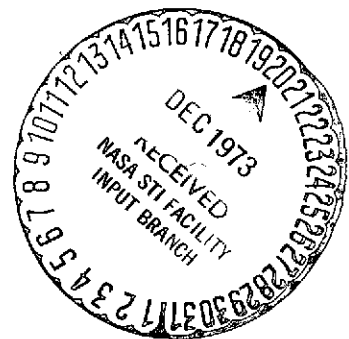
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FORWARD

This manual is a revision of an April 1971 report "User's Manual for the TRW Gaspipe Program". The Gaspipe 2 Program includes a number of changes in logic and operating options which provide it with expanded capability. The program revision was performed under NASA Contract No. NAS2-5503, "Design, Fabrication, and Testing of a Variable Conductance Constant Temperature Heat Pipe.

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The program has been conducted by TRW Systems Group of TRW, Inc., Redondo Beach, California, with Dr. Bruce D. Marcus serving as Program Manager and Principal Investigator. Major contributors to the program were Mr. G. L. Fleischman and Prof. D. K. Edwards.

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1.0 INTRODUCTION

This report describes a digital computer program useful in the design and analysis of heat pipes which contain non-condensable gases; either for temperature control or to aid in start-up from the frozen state. Because the program includes the effects of axial conduction and mass diffusion on the performance of such heat pipes, it represents a significant advance in steady-state design technology over the "flat-front" theory previously found in the literature [1, 2]. It allows one to:

- Calculate the wall temperature profile along a gas-loaded heat pipe.
- Calculate the amount of gas loading necessary to obtain a desired evaporator temperature at a desired heat load.
- Calculate the heat load versus the evaporator temperature for a fixed amount of gas in the pipe.
- Calculate the heat and mass transfer along the pipe, including the vapor-gas front region.
- Calculate the heat leak when the condenser is filled with gas.
- Calculate whether or not freezing occurs in the condenser and, if so, at what rate.
- Determine the information required to size the gas reservoir of gas-controlled heat pipes.

The program contains numerous reservoir options which allow it to be used for hot or cold reservoir passive control as well as heated reservoir active control heat pipes. Additional input options permit its use for parametric studies and off-design performance predictions as well as heat pipe design.

Provision is also made in the program for two condenser sections and an adiabatic section.

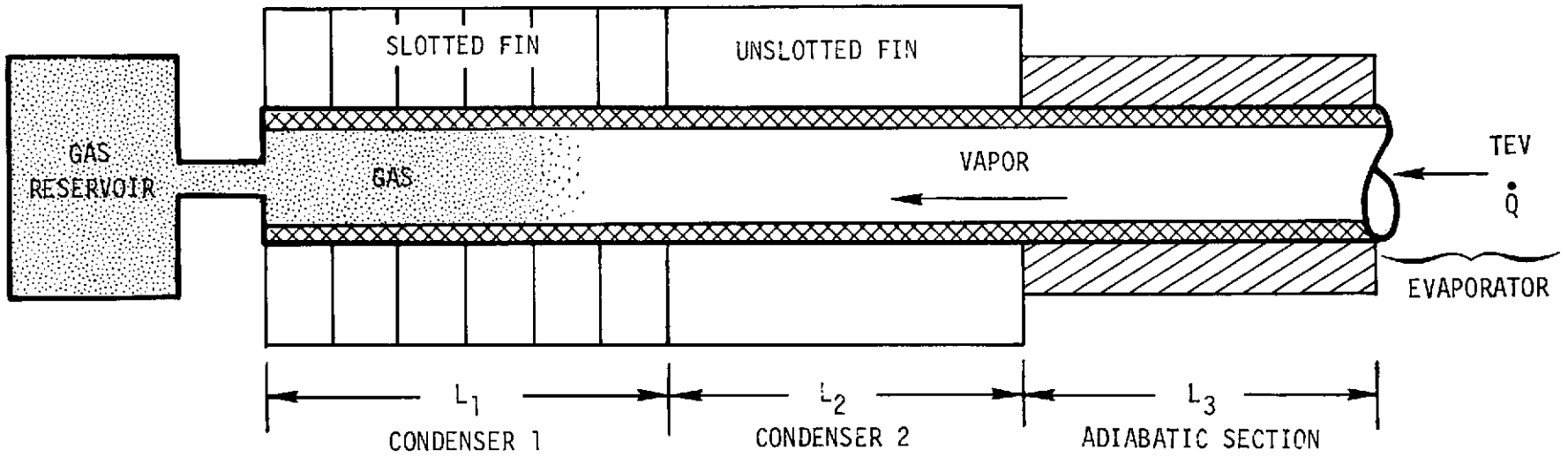
The analysis and formulation of the equations used in the program are presented in Section 2. Basically, a one-dimensional steady state analysis has been used and the equations written assuming small wick resistance and negligible vapor pressure drop along the pipe. The analytical model used is shown in Figs. 1-1 and 1-2. However, the program is not limited to the geometry shown. Non-circular and non-axisymmetric configurations can also be studied by calculating equivalent diameters, thicknesses, etc. consistent with the formulation of the equations.

The numerical technique used to solve the equations is also discussed in Section 2. It involves a fourth-order Runge-Kutta routine to solve two simultaneous equations for (1) a parameter fixing the mole fraction of the non-condensable gas, and (2) the condensable vapor velocity.

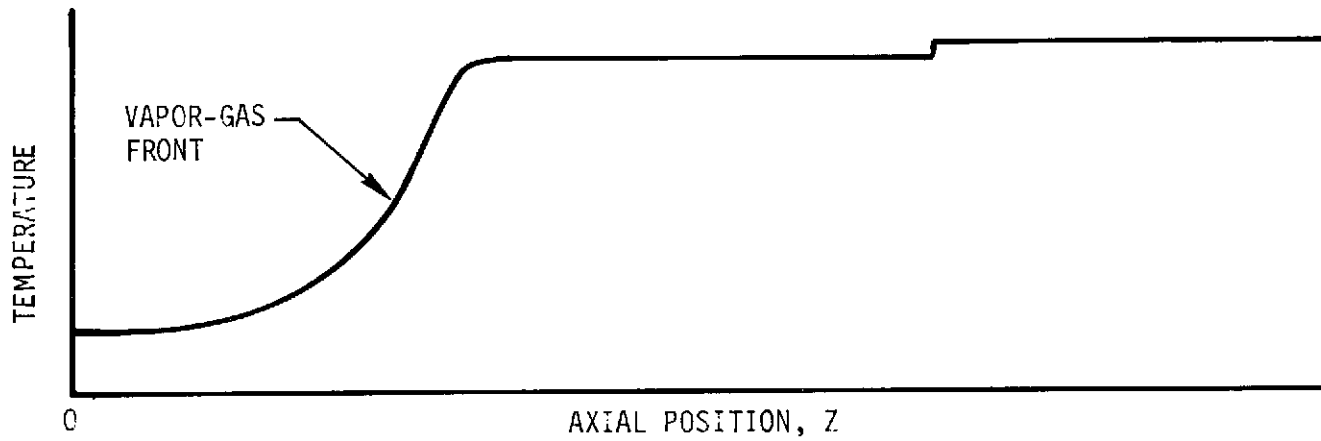
Section 3 discusses the potential uses of the program for research, heat pipe design and performance predictions. The program input requirements are described in Section 4, and the output discussed in Section 5.

Flow diagrams, program listings and sample problems are presented in the appendices.

This manual assumes that the user has a prior understanding of the principles involved in gas-loaded heat pipes. References [2 - 4] can aid in this respect.



a. Schematic Diagram of a Gas-Loaded Heat Pipe



b. Temperature Distribution

FIGURE . Vapor-Gas Front Analytical Model for a Gas Loaded Heat Pipe

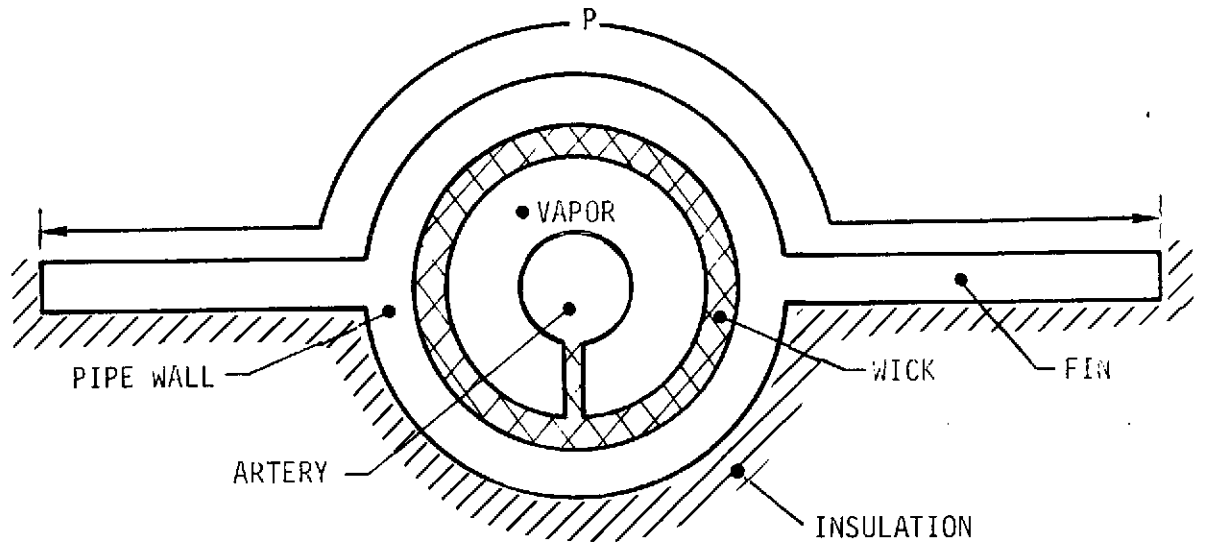


FIGURE 1-2. Cross-section of Condenser

2.0 ANALYSIS

2.1 Formulation

The condensing section of the pipe is assumed to reject heat by radiation and convection from a fin of perimeter P with an effectiveness η as shown in Figure 1-2. The net heat loss from a length of condenser dz is thus taken to be

$$d\dot{Q} = \left[\epsilon\sigma T_w^4 + h(T_w - T_f) - q_{abs} \right] \eta P dz \quad (2-1)$$

where ϵ is total hemispherical emittance, σ the Stefan-Boltzman constant, T_w the wall temperature, h the convective heat transfer coefficient, if any, T_f the external fluid temperature, and q_{abs} is the power absorbed per unit area from the surrounds, αH in the case of irradiation H onto the condenser surface of absorptance α . For simplicity all parameters are taken to be constants, but a step change is allowed between sections of condenser.

In the usual heat pipe application the difference between the wick-vapor interface temperature T_i and the condenser wall temperature T_w is small compared to absolute temperature level. For this reason Eq. (2-1) is written in a linearized form

$$d\dot{Q} = S dz (T_w - T_c) \quad (2-2)$$

where

$$S(z) = \left[4\epsilon\sigma T_i^3 + h \right] \eta P \quad (2-3)$$

and

$$T_c(z) = \frac{3\epsilon\sigma T_i^4 + q_{abs} + hT_f}{4\epsilon\sigma T_i^3 + h} \quad (2-4)$$

We adopt the unusual sign convention that the power \dot{Q} is measured in the negative z direction. Then Fourier's law is written without the usual negative sign. Heat flows into an element of pipe dz long at $z+dz$ and out at z by axial conduction. Heat also flows across the wick by conduction at the rate

$$\frac{2\pi k_e dz}{\ln \frac{D_i + 2\delta}{D_i}} (T_i - T_w) = K dz (T_i - T_w) \quad (2-5)$$

where k_e is the equivalent thermal conductivity of the liquid-filled wick, D_i the inside diameter of the wick, and δ the wick thickness. Eq. (2-5) defines K . The heat balance on an element of condenser is then

$$C \frac{d^2 T_w}{dz^2} + K(T_i - T_w) - S(T_w - T_c) = 0 \quad (2-6)$$

where C is the axial conductivity-area product for the condenser cross section,

$$C = \sum_{n=1}^N k_n A_{c,n} \quad (2-7)$$

In Eq. (2-7) k_n is the effective axial conductivity, allowing for slots or other anisotropies, and $A_{c,n}$ the cross-sectional area of the n th element in the pipe. These elements include the pipe wall, the wick and the fin wall, as shown in Fig. 1-2. When an artery is present, even if it is not in intimate thermal contact with the condenser wall, its axial conductance should also be included in Eq. (2-7), because the temperature gradient in it tends to follow dT_i/dz which in turn tends to follow dT_w/dz , when K is large compared to S , (See Sec. 4.4).

The wick interface temperature T_i is the saturation temperature for the partial pressure of the vapor above the interface, since the net condensation rate is far from the absolute rate of condensation. Other simplifying assumptions introduced, which are reasonable for most applications, are negligible vapor side pressure loss and a simple vapor pressure law derived from the Clausius-Clapeyron relation. The mole fraction of the non-condensable at the interface x_i and the interface temperature T_i are then related in the following way

$$x_i = 1 - \exp \left[-(h_{fg}/RT_{ev})(T_{ev}/T_i - 1) \right] \quad (2-8a)$$

$$T_i = \frac{T_{ev}}{1 + \frac{RT_{ev}}{h_{fg}} \ln \frac{1}{1-x_i}} = \frac{T_{ev}}{1 + \frac{T_{ev}}{T_o} \ln \frac{1}{1-x_i}} \quad (2-8b)$$

Conservation of non-condensable gas requires that the diffusion plus convection in the tube sum to zero [5],

$$-c \frac{dx_s}{dz} - cVx_b = 0 \quad (2-9)$$

where c is the molar concentration, D the diffusion coefficient for the non-condensable diffusing in the vapor, x_s the spatial or area-weighted average mole fraction, V the mole average velocity, and x_b the bulk (area-velocity weighted) average. At least in the region of the condenser which is gas-controlled, the radial velocity rates will be sufficiently low so that the bulk, spatial, and wall values of mole fraction of non-condensable will be nearly the same. This assumption is made for the entire condenser so that the subscripts i , s , and b on x will be dropped in what follows.

To obtain an equation having the grouping $\dot{m} = cVA_c M$, the condensable flow rate, Eq. (2-9) is multiplied by $A_c M$, where M is the molecular weight of the condensable working fluid. In addition, the dependent variable is transformed from mole fraction x to ϕ by introducing

$$\phi = \ln \frac{1}{x}, \quad x = e^{-\phi} \quad (2-10)$$

Equation (2-9) then becomes

$$\dot{m} = A_c M c \frac{d\phi}{dz} \quad (2-11)$$

Conservation of mass shows that increase in mass flow rate with distance from the end of the condenser is equal to the condensation rate which in turn is equal to the product of wick conductance and temperature difference across the wick divided by the latent heat of vaporization or sublimation.

$$\frac{d\dot{m}}{dz} = K(T_i - T_w)/h_{fg} \quad (2-12)$$

Equations (2-6, 2-11 and 2-12) form a set of three simultaneous differential equations in three unknowns: T_w , ϕ , and \dot{m} . The temperature T_i is related to ϕ through the highly non-linear relations, Eqs. (2-10) and (2-8). The coefficient S defined by Eq. (2-3) is also nonlinear. An explicit energy equation for the liquid or vapor is not written, because subcooling of liquid in the wick and superheating of the vapor in the pipe are not considered to be key physical phenomena and are neglected in the present treatment. Equations (2-12) and (2-6) will give an entirely correct energy balance when x_i , x_s and x_b are identical, the wick resistance small, and no freezing occurs.

A boundary condition on (2-6), (2-11) and (2-12) is taken to be

$$\dot{m} = 0 \text{ at } z = 0 \quad (2-13)$$

In addition, either one of two conditions may be prescribed: a total heat rate rejected

$$\dot{Q} = \int_0^L S(T_w - T_c) dz \quad (2-14a)$$

or a total number of moles of non-condensable present

$$\dot{m} = A_c \int_0^L \left[P_i(T_i(z))/R_u T_i \right] dz \quad (2-14b)$$

In computing \dot{m} a more accurate vapor pressure law than Eq. (2-8) must be used. An exponential of a polynomial in the reciprocal of T_i is used.

Strictly speaking, since Eq. (2-6) is second order, two more conditions must be specified, such as a zero CdT_w/dz at $z = 0$ and $z = L$. However, an approximation is made that the first and second derivatives of T_w with respect to z are equal to those of T_i . As is shown in Section 2.2, this approximation reduces the set of equations to two first order ones so that Eqs. (2-13) and (2-14) are sufficient. The condition on CdT_w/dz is met at $z = 0$, and at $z = L$ it is met in practical effect when the evaporator is purged of gas. The approximation regarding the derivatives of T_w and T_i is, of course, exact when the wick resistance is zero.

A review of the features of the analysis and assumptions made are as follows:

1. Radiation and convection from a finned pipe are considered. Absorbed radiation from the surrounds is included. Provision for a step change in condenser properties and ambient conditions is made.
2. The condenser wall temperature T_w is assumed close to the wick interface temperature T_i . The first and second derivatives of T_w and T_i with respect to z are assumed equal, respectively. In essence high wick conductance is assumed.
3. Axial conduction of heat in the pipe wall and fin and one-dimensional axial diffusion of the condensible species, which carries latent heat, are accounted for.
4. Vapor pressure drop in the pipe is neglected. In calculating the shape of the wall temperature and wick temperature distributions, an approximate vapor pressure law derived from Clausius-Clapeyron is used. But in calculating the pressure in the pipe and the amount of non-condensibles present a more accurate expression is used.
5. The condition of zero wall temperature gradient is met at $z = 0$. Either the total number of moles of non-condensibles present in the pipe or the total heat rejected by the pipe is specified.

2.2 Dimensionless Governing Equations

The mass flow rate, mass diffusivity, temperatures, and other parameters were made dimensionless so that orders of magnitudes could be assessed and for convenient numerical solution. The dimensionless quantities are

$$\begin{aligned}
 z^* &= z/D_e \\
 V^* &= \dot{m} h_{fg} / \dot{Q}_{\text{nominal}} \\
 \rho^* &= M(c_{ev} \rho_{ev} / D_e) A_c h_{fg} / \dot{Q}_{\text{nominal}} \\
 T_i^* &= T_i / T_{ev} \\
 T_w^* &= T_w / T_{ev} \\
 T_0^* &= T_0 / T_{ev} \\
 T_c^* &= T_c / T_{ev} \\
 T_R^* &= T_R / T_{ev} \\
 Q_e^* &= \frac{dQ^*}{dz^*} = S^* (T_w^* - T_c^*) \\
 S^* &= F^* (4\epsilon\sigma T_i^{*3} + H^*) \\
 F^* &= \eta P D_e \sigma T_{ev}^4 / \dot{Q}_{\text{nominal}} \\
 H^* &= h / \sigma T_{ev}^3 \\
 C^* &= C T_{ev} / D_e \dot{Q}_{\text{nominal}}
 \end{aligned}$$

where T_{ev} is the evaporator temperature which sets the total pressure in the system, and D_e is an equivalent diameter allowing for the presence of arteries within the pipe,

$$D_e = (4A_c / \pi)^{1/2},$$

where A_c is the cross sectional area available for vapor flow. An exponent E is an empirical factor to account for the temperature variation of the mass diffusivity defined by

$$c = c_{ev} \left(T_i / T_{ev} \right)^E$$

Eqs. (2-6), (2-11), (2-12), and (2-8) written in dimensionless form become

$$C^* \frac{d^2 T_w^*}{dz^{*2}} + K^* (T_i^* - T_w^*) - S^* (T_w^* - T_c^*) = 0 \quad (2-16)$$

$$\frac{d\phi^*}{dz^*} = \frac{V^*}{T_i^* E} \quad (2-17)$$

$$\frac{dV^*}{dz^*} = K^* (T_i^* - T_w^*) \quad (2-18)$$

$$1 - e^{-\phi} = e^{-T_0^* (1/T_i^* - 1)} \quad (2-19)$$

Under approximation 2 Eq. (2-16) is approximated as

$$C^* \frac{d^2 T_i^*}{dz^{*2}} + K^* (T_i^* - T_w^*) - S^* (T_w^* - T_c^*) = 0 \quad (2-16a)$$

The simplifying feature of this approximation is that the second derivative in Eq. (2-16a) can now be eliminated. Eq. (2-19) is differentiated with respect to z^* , and Eq. (2-17) is used to eliminate $d\phi/dz^*$. The result multiplied by C^* is

$$C^* \frac{dT_i^*}{dz^*} = C^* \frac{e^{-\phi} T_i^{*2-E}}{1 - e^{-\phi} T_0^*} V^* \quad (2-21)$$

Eq. (2-21) is differentiated again with respect to z^* , Eq. (2-17) is used again to eliminate $d\phi/dz^*$, and Eq. (2-21) itself is used to eliminate dT_i^*/dz^* .

$$C^* \frac{d^2 T_i^*}{dz^{*2}} = \phi_1 \frac{dV^*}{dz^*} - \phi_1 \phi_2 \phi_3 \quad (2-22)$$

where the functions ϕ_1, ϕ_2, ϕ_3 are

$$\phi_1(\phi) = C^* \frac{e^{-\phi} T_i^{*2-E}}{(1-e^{-\phi}) T_0^*} \quad (2-23)$$

$$\phi_2(\phi) = 1 - (2-E)(T_i^*/T_0^*)e^{-\phi} \quad (2-24)$$

$$\phi_3(\phi, V^*) = V^{*2} / (1-e^{-\phi}) T_i^{*E} \quad (2-25)$$

Equation (2-16a) together with Eqs. (2-18) and (2-22) now can be written

$$\frac{dV^*}{dz^*} = Q_e^* - \phi_1 \phi_4 \quad (2-26)$$

where

$$\phi_4(\phi, V^*) = \frac{Q_e^*(\phi) - \phi_2(\phi) \phi_3(\phi, V^*)}{1 + \phi_1(\phi)} \quad (2-27)$$

The program accounts for a step change in axial conduction between sections 1 and 2 of the condenser, Fig. 1-1, by assuming continuity in the mole fraction, x and ϕ . Because the analysis is one dimensional, this assumption leads to a step change in the vapor velocity, V , when the front forms across the discontinuity. Thus, for a discontinuity in condenser parameters, the mole average velocity, V , is calculated as follows:

$$V_2^* = V_1^* \frac{1 + \frac{C_1^*}{V_1^*} \left(\frac{dT_i^*}{dz^*} \right)_{z^*=z_1^{*-}}}{1 + \frac{C_2^*}{V_2^*} \left(\frac{dT_i^*}{dz^*} \right)_{z^*=z_1^{*+}}} \quad (2-28)$$

where $\frac{C^*}{V^*} \frac{dT_i^*}{dz^*}$ is given by Eq. (2-21).

Eqs. (2-17) and (2-26) together with (2-19) and the definitions of ϕ_j in Eqs. (2-23, 2-24, 2-25 and 2-27) form a set of two simultaneous nonlinear first order ordinary differential equations which can be numerically solved by, say, a fourth-order Runge-Kutta routine. The initial conditions are $V^* = 0$ and $\phi = \phi_0$ at $z = 0$. Values of \dot{m} and \dot{Q} for a length of pipe L can be obtained versus ϕ_0 for a given set of parameters and an evaporator temperature T_{ev} . An iterative routine can be used to find ϕ_0 for a prescribed value of either \dot{m} or \dot{Q} .

2.3 Numerical Solution

Section 2.2 shows how Eqs. (2-6), (2-11) and (2-12) are reduced by virtue of assumption 2 (high wick conductance) to Eqs. (2-17) and (2-26), a set of two simultaneous first order differential equations in ϕ and V^* (a dimensionless velocity or mass flow rate).

In the numerical solution of these equations, an initial value of T_i slightly in excess of the sink temperature is used to fix $\phi(0)$, and a

fourth order Runge-Kutta routine is used to solve for $\phi(z)$ and $V^*(z)$. Either the amount of gas in the pipe or the total heat rejection is then compared with the input value. Depending on the sign of the deviation, the program then either (1) operates in the "long mode" and slides the front up the pipe a certain distance or (2) operates in the "short mode" and increases $\phi(0)$ a prescribed amount, and the integration is repeated. This iteration scheme is repeated until the calculated value of m or \dot{Q} (depending on the option used) agrees within the numerical integration accuracy with the specified value.

3.0 PROGRAM APPLICATION

The program has been found useful in the following areas:

- Research
- Design
- Performance prediction

As a research tool it can be used to study the nature of the vapor-gas interface in gas-loaded heat pipes [Ref. 4]. Using the program for parametric analysis, one can study the relative effects of various boundary conditions, fluid properties, material properties, operating temperatures, etc., on heat and mass transfer. Useful program outputs for purposes of comparison are the temperature, heat transfer and mass transfer profiles, and the diffusion freezeout rates.

Although the computer program is not a design program, per se, it can be extremely useful in this respect. By running the program for minimum and maximum design conditions (evaporator temperature, power and sink conditions) one establishes the variation in condenser gas inventory and uses this information to size the gas reservoir. Also, through variation of design parameters, one can optimize the condenser and radiator design for the desired power and evaporator temperature control range.

Given a particular heat pipe configuration, the program can be used to predict performance at various operating conditions, i.e., run a performance map of \dot{Q} versus T_{ev} for a fixed set of parameters. This is particularly useful in studying heat pipe performance under off-design conditions.

3.1 Minimum Power and Freezeout Rates

It is possible to obtain the heat leakage when the gas completely blocks the condenser by simply reading the value of QSUM at the beginning of an adiabatic section. This heat transfer represents, for example, the heat leak associated with a variable conductance heat pipe in the "full-off" position. Each component of heat transfer can be calculated separately

by multiplying the mass flow at a point (for example, $TI = 0.986$) by the latent heat of vaporization of the working fluid and subtracting from QFLOW. In the example given in Appendix C the total heat transfer across the front is 2.01 Btu/hr, with 0.37 Btu/hr due to diffusion and 1.64 Btu/hr due to conduction.

If the temperature of the gas-blocked portion of the condenser falls below the freezing point of the working fluid, then vapor which diffuses through the gas and freezes on the walls does not return to the evaporator. Given sufficient time, this will deplete the evaporator of fluid and result in heat pipe failure. The rate of fluid loss (diffusion freezeout rate) is given by the mass flow past the point at which the wick falls to the freezing point of the fluid.

3.2 Design

For design applications one most commonly uses the heat input option (MODEQM = 0) and prescribes the required heat input, Q . An example of how the program might be used to size the reservoir of gas-controlled heat pipes is outlined below.

For a given condenser/fin geometry the following conditions determine the amount of gas in the pipe for the "full-on"* and "full-off"* cases.

(1) Condenser Full-on (Maximum Power):

Heat Input
Evaporator Temperature
Sink Conditions

(2) Condenser Full-Off (Minimum Power):

Heat Input
Evaporator Temperature
Sink Conditions

*Note that if the condenser were truly full-on then there would be no gas in the pipe. In reality, however, it is not possible to achieve this condition in a gas loaded pipe because of diffusion, nor is it desirable from a control point of view--especially in passive systems. Similarly, there is always a minimum power (heat leak) in the full-off position.

A run is made for each of these two cases with the reservoir volume set equal to zero ($V_{RES} = 0$) to yield the number of moles of non-condensable gas, m_{max} and m_{min} , in the pipe. These are the final values of MPIPE printed at $z = L_1 + L_2 + L_3$ in each case. Summing the total number of moles-- constant for a closed system--yields two simultaneous equations, which may be solved for the required reservoir volume and gas inventory:

$$\begin{aligned} m &= V_R \left(\frac{P_{gr}}{R_u T_R} \right)_{max} + m_{max} \\ m &= V_R \left(\frac{P_{gr}}{R_u T_R} \right)_{min} + m_{min} \end{aligned} \quad (3-1)$$

where P_{gR} is the partial pressure of non-condensable gas in the reservoir, which may be found by reading the vapor pressure curve at the evaporator and reservoir temperatures ($P_{gR} = P_{ev} - P_{vR}$).

Solving for the reservoir volume:

$$V_R = \frac{R_u (m_{min} - m_{max})}{\left(\frac{P_{gR}}{T_R} \right)_{max} - \left(\frac{P_{gR}}{T_R} \right)_{min}} \quad (3-2)$$

This equation may be expressed in terms of the computer output variables as follows:

$$V_R = \frac{m_{min} - m_{max}}{[x_R c_{ev} \left(\frac{T_{ev}}{T_R} \right)]_{max} - [x_R c_{ev} \left(\frac{T_{ev}}{T_R} \right)]_{min}} \quad (3-3)$$

where

$$c_{ev} = \frac{P_{ev}}{R_u T_{ev}}, \text{ lb-mole/ft}^3$$

T_{ev} = evaporator temperature, °R

P_{ev} = vapor pressure corresponding to evaporator temperature, psf

x_R = mole fraction of non-condensable gas in the control reservoir, $(P_{gR}/P_{ev}) = XSR$

CEV and TEV are direct outputs of the program, but some discretion must be used in defining the reservoir properties, x_R and T_R . Although the reservoir volume was set equal to zero, much information about the reservoir properties may be obtained from the output. The temperature at the end of the condenser ($z=0$) where the reservoir feedtube is attached, for instance, defines the reservoir temperature and the mole fraction in certain cases, Ref. [1]. The temperature at the end of the pipe depends on the length and shape of the front; and the reservoir properties are usually quite sensitive to this temperature. These considerations are summarized in Table 3-I for the usual applications.

Table 3-I

Gas Reservoir Characteristics (Design)

<u>Type of Control</u>	<u>Type of Reservoir</u>	<u>T_R</u>	<u>X_R</u>
Passive	Non-Wicked (Hot)	TEV*	XS @ Z=0
Active	Wicked (Heated)	Independent Variables (determined external to program).	
Passive	Wicked (Insulated)	TWICK @ Z=0**	XS @ Z=0

*Assuming the reservoir temperature is coupled to the evaporator temperature.

**Assuming the reservoir well coupled, thermally, to the end of the condenser and insulated from the surrounds.

It must be emphasized that the preceding is not a fixed design procedure, and the approach may be altered to accommodate other possibilities, such as variable volume reservoirs, or passive wicked reservoirs which are thermally de-coupled from the condenser.

3.3 Performance Prediction

For a given application, the amount of inert gas in the pipe is a known quantity. Thus, in order to predict the performance at various design or off-design conditions, the amount of gas is prescribed and MODEQM

is set equal to one. Note that under this option the gas inventory may be specified in either of two ways:

- (1) ZGAS - the length of condenser filled with gas if a sharp front is assumed (flat-front theory).
- (2) AGAS - the amount of gas in lb-moles, *m*.

The former might be used in parametric analyses to establish similar vapor-gas interface locations for varying conditions without tedious calculation of appropriate molar inventories. It might also be used for specifying the amount of gas in a heat pipe to aid start-up from the frozen state. For example, one might specify that the entire condenser be gas-blocked at an evaporator temperature a few degrees above the freezing point of the working fluid.

But, for performance estimation purposes, the AGAS option is used and the amount of gas is put in directly, in lb-moles. If there is a separate reservoir volume, it is necessary to enter the appropriate control integer (NRES) and reservoir temperature (TRES) in the input. Table 3-II is a summary of the appropriate input values for typical applications. It should be pointed out that the program does not account for heat leakage from an actively heated reservoir into the condenser.

Again, the preceding is not a fixed procedure, but may be modified for other possibilities. The heat load might be more accurately known than the molar inventory, for example, in a certain performance test. In this case one would use the heat input option (MODEQM = 0) rather than specifying the amount of gas. Table 3-II is applicable in either case.

Table 3-II

Gas Reservoir Characteristics (Performance)

<u>Type of Control</u>	<u>Type of Reservoir</u>	<u>NRES</u>	<u>TRES</u>
Passive	Non-wicked (Hot)	0	TEV [*]
Active	Wicked (Heated)	1	Desired Temp
Passive	Wicked (Insulated)	2	Arbitrarv ^{**}

*Assuming the reservoir temperature coupled to the evaporator temperature.

**The program assumes that the reservoir is insulated and takes the temperature at the end of the condenser as the reservoir temperature in this case. Thus, the input value is arbitrary (non-zero).

3.4 Adiabatic Section

In many heat pipe applications an unfinned, insulated section exists between the evaporator and condenser. The heat loss from this section may be negligible. It can then be treated as adiabatic. The computer program has the capability of dealing with such a section in addition to two condenser sections farther from the evaporator.

If an "adiabatic section" is not truly adiabatic but loses heat so that it is not satisfactory to model it so, the program can still be used, but care must be exercised. The way to treat a not-quite adiabatic section with the existing program is to treat that section as a condenser, Section 2. There then remains only one other condenser Section 1 which must model the active condenser of the actual pipe. The program adiabatic section capability is then not made use of, and a value of XLONGA = 0.0 is accordingly input.

4.0 INPUT DESCRIPTION

An input form for the program is reproduced in Fig. 4-1. Each line corresponds to a data card, and the input format is given in the second column. Also shown are the input parameters which cannot be set equal to zero without causing numerical difficulties in operation of the program. The following defines each input variable and gives some of the restrictions and limitations imposed on these variables.

Cards 1 & 2 (72H)

These are title cards which are used to identify the run. Any desired information, such as project, name, date, etc. may be typed on these cards. The only restriction is that column one is used for carriage control. Thus, a "1" is usually punched in the first column of card one to start printout at the top of the page, and the first column of card two is left blank.

4.1 Fluid Characteristics

Card 3 (3F 12.5)

A11, B11, C11: vapor pressure parameters in the least squares fit,

$$\ln P = A11 - \frac{B11}{T} - \frac{C11}{T^2}$$

where the pressure, P, is in psia and the temperature, T, is in °R. See Table 4-I.

Card 4 (5 F 12.5)

XMC: molecular weight of the condensible. See Table 4-I.

DIF: mass diffusivity for the vapor-gas pair at one atmosphere and 460°R (ft²/hr). See Table 4-I.

CARD	FORMAT	DESCRIPTION					
1	72H	1					
2	72H						
		PARAMETERS					
3	3F12.5	A11	B11	C11			
		≠ 0	≠ 0	≠ 0			
4	4F12.5	XMC	DIF	E	HFG		
		≠ 0	≠ 0		≠ 0		
5	6F12.5	PF1	AF1	CF1	EF1	EMIS1	HF1
		≠ 0			≠ 0	NOT BOTH	
6	6F12.5	PF2	AF2	CF2	EF2	EMIS2	HF2
						NOT BOTH	
7	6F12.5	DOUTA	THKWA	CWA	DELA	CWKA	XLONGA
		≠ 0					
8	3F12.5	DOUT	THKW	CW			
		≠ 0					
9	3F12.5	DEL	CONWK	DART			
		≠ 0	≠ 0				
10	3F12.5	TF1	POW1	XLONG1			
			≠ 0	≠ 0			
11	3F12.5	TF2	POW2	XLONG2			
			≠ 0				
12	3F12.5, E12.5	TEV	Q	ZGAS	AGAS	TTRAP	
		≠ 0	≠ 0	NOT BOTH			
13	2F12.5, 2I4, F12.5, I4	VRES	TRES	NRRES	MODEQM	ZPRINT	NRUN
			≠ 0			≠ 0	

FIGURE 4-1. Program Input Form Showing Parameters Which Cannot be Set Equal to Zero

E: exponent used in the following equation to convert mass diffusivity at standard conditions to the value at operating pressure and temperature. See Table 4-I.

$$D_{ev} = \text{DIF} \left(\frac{1}{P_{ev}} \right) \left(\frac{T_{ev}}{460} \right)^{1+E}$$

where T_{ev} = evaporator temperature ($^{\circ}\text{R}$)

P_{ev} = vapor pressure of condensible corresponding to evaporator temperature (atmos).

HFG: latent heat of vaporization of the condensible evaluated at the evaporator temperature (Btu/lb_m). If a freeze-out rate is the primary quantity desired, the latent heat of vaporization plus the latent heat of fusion (the heat of sublimation) at the freezing point should be used.

Table 4-I

Fluid Characteristics

<u>Fluid</u>	<u>A11</u>	<u>B11</u>	<u>C11</u>	<u>XMC</u>	<u>DIF*</u>	<u>E</u>
Ammonia (NH ₃)	13.13	3821.04	296548.2	17.0	0.763	0.81
Methanol (CH ₃ OH)	14.48	6262.17	557386.2	32.0	0.442	0.81
Water (H ₂ O)	14.20	6526.73	810130.7	18.0	0.892	0.81

*Typical values for diffusion in air.

4.2 Condenser Parameters, Section 1, Farthest from Evaporator

Card 5 (6F 12.5)

PF1: fin perimeter perpendicular to the pipe over which heat transfer occurs (inches). Note that if there is no fin (e.g. a tube rejecting heat from its outer diameter) PF1 equals πD_{out} . See Fig. 1-2.

AF1: fin cross-sectional area perpendicular to the pipe (in.^2). When there is no fin AF1 is set equal to zero. AF1 can even have a negative value to account for a reduction in pipe wall thickness with respect to the input value THKW.

CF1: effective thermal conductivity of fin for conduction in the axial direction ($\text{Btu/hr-ft-}^\circ\text{F}$). For a plain fin, the effective conductivity is simply the conductivity of the fin material. However, in many cases the fin might be segmented (slotted) to lower axial conductance. In that case CF1 should reflect the contribution of the segmented fin to overall axial conductance. An approximate approach to this case is as follows:

The total axial resistance is given by:

$$R_T = R_{fin} + R_{gap} \quad (4-1)$$

But,

$$R_T = \frac{N}{\frac{1}{R_{wick}} + \frac{1}{R_{wall}} + \frac{1}{R_{fin}}} + \frac{N-1}{\frac{1}{R_{wick}} + \frac{1}{R_{wall}}} \quad (4-2)$$

Defining the relation for k'_{fin} , the effective conductivity:

$$\begin{aligned}
 R_T &= \frac{L}{(kA)_{\text{wick}} + (kA)_{\text{wall}} + k'_{\text{fin}} (A_c)_{\text{fin}}} \\
 &= \frac{NL_f}{(kA)_{\text{wick}} + (kA)_{\text{wall}} + (kA)_{\text{fin}}} \\
 &+ \frac{(N-1) L_g}{(kA)_{\text{wick}} + (kA)_{\text{wall}}} \tag{4-3}
 \end{aligned}$$

- where
- R_T = overall axial thermal resistance of the condenser section
 - R_{FIN} = thermal resistance in the region where the fins are attached
 - R_{GAP} = thermal resistance of the gaps between the fins
 - R_{wick} = axial thermal resistance of the wick
 - R_{wall} = axial thermal resistance of the pipe wall
 - R_{fin} = axial thermal resistance of a single fin
 - $L = \text{XLONG}$ = overall length of condenser section
 - L_f = length of a single fin in axial direction
 - L_g = gap width
 - N = number of fin segments
 - kA = axial conductivity - area product
 - k'_{fin} = CFI - effective thermal conductivity of the slotted fin
 - $(A_c)_{\text{fin}}$ = AFI - fin cross-sectional area

Equation 4-3 may be solved in detail for k'_{fin} (CF1), but for most applications the conductance of the wick and the first term on the right hand side of Eq. 4-3 are negligible relative to the other terms. Thus, in most cases the effective conductivity may be calculated from the following:

$$k'_{fin} = \frac{(kA)_{wall}}{(A_c)_{fin}} \left[\frac{L}{(N-1)L_g} - 1 \right] \quad (4-4)$$

- EF1: effectiveness of condenser fin, η (dimensionless)
- EMIS1: fin total hemispherical emissivity, ϵ (dimensionless)
Must be consistent with POW1, section 4.6, and must be zero when convection only.
- HF1: fin external convective heat transfer coefficient,
 h_{f_1} (Btu/hr-ft²-°F)
Must be set equal to zero when radiation only.

Note that EF1 and HF1 cannot both be set equal to zero.

4.3 Condenser Parameters, Section 2, Nearest to Evaporator

Card 6 (6F 12.5)

The input variables for card 6 are the same as defined above for condenser section number 1. If there is only one condenser section, then set everything on card 6 identical to card 5. If section number 2 is an adiabatic section, then PF2 is set equal to zero (Paragraph 3.4).

4.4 Adiabatic Section Parameters

Card 7 (6F 12.5)

DOUTA = outside diameter of adiabatic section pipe (inches)

THKWA = wall thickness of adiabatic section (inches)

CWA = thermal conductivity of adiabatic section wall (Btu/hr.ft.°F)

DELA = wick thickness in the adiabatic section (inches)

CWKA = wick thermal conductivity of the wick in the adiabatic section (Btu/hr.ft.°F.)

XLONGA = length of adiabatic section (feet)

4.5 Wall Characteristics

Card 8 (3F 12.5)

DOUT: outside diameter of heat pipe (inches)

THKW: heat pipe wall thickness (inches)

CW: pipe wall thermal conductivity (Btu/hr-ft-°F)

If an artery is present, multiply CW by the ratio

$$[(kA)_{\text{artery}} + (kA)_{\text{wall}}] / (kA)_{\text{wall}}$$

4.6 Wick Characteristics

Card 9 (3F 12.5)

DEL: heat pipe wick thickness, δ (inches)

CONWK: effective thermal conductivity of saturated wick (Btu/hr-ft-°F)

DART: effective diameter of arteries in pipe (inches)

$$DART = (4A_c/\pi)^{1/2} \quad (4-5)$$

where A_c is the total cross-sectional area of arteries in the pipe. See Fig. 1-2.

4.7 Environmental Parameters and Lengths

Card 10 (3F 12.5)

TF1: condenser, section number 1, external fluid or sink temperature for convective heat transfer, T_{f1} , ($^{\circ}$ R). May be set equal to zero if only heat transfer mode is radiation.

POW1: The absorbed power per unit area of the outer fin surface (perimeter times length). The power is both from the back (internal power) and the front (solar absorption, etc.), but the area is the front area only (Btu/hr-ft^2). For the case where the front is surrounded by an effectively black enclosure at a known temperature T_1 and there is no internal heat transfer, POW1 is calculated as follows:

$$\text{POW1} = \alpha_1 \sigma T_1^4 \quad (4-6)$$

where α is the external*total hemispherical absorptivity for source temperature T_1 and surface temperature T_{ev} .* If T_1 is close to T_{ev} both α and ϵ would be the same internal total hemispherical emissivity.

POW1 may be set equal to zero for convection heat transfer only. In other applications POW1 or POW2 may be a very small number, e.g. 0.01, but not zero.

XLONG1: length of condenser, section 1, L_1 (feet).

*See the Journal of Heat Transfer, 91, p. 2, Feb. 1969.

Card 11 (3F 12.5)

The input variables for card 10 are the same as defined above for condenser section number 1. If there is only one condenser section, then set TF2 and POW2 equal to TF1 and POW1, respectively and make the sum of the lengths, XLONG1 + XLONG2 equal to the total length of the condenser. If section 2 is an adiabatic section, then TF2 and POW2 should be input identical to section 1, but XLONG2 is the adiabatic length (see Section 3.4).

4.8 Operating Conditions

Card 12 (3F 12.5, E12.5)

TEV: evaporator temperature, T_{ev} ($^{\circ}R$)

Q: heat pipe power, \dot{Q} (Btu/hr).

When using the heat input option, MODEQM = 0, \dot{Q} is the prescribed heat pipe heat load. If the amount of gas is input, MODEQM = 1, the program calculates the heat pipe power, but it is necessary to put in a nominal value for \dot{Q} , since it is used to non-dimensionalize certain variables. The value of \dot{Q} in this case is arbitrary; it need be correct only within half an order of magnitude. See Table 4-II.

The value of \dot{Q} cannot exceed the heat rejection of an isothermal condenser at T_{ev} , as given by Eq. (4-7); otherwise an error message will print "heat flux too high or pipe too short."

$$\begin{aligned} \dot{Q} < n_1 P_1 L_1 [\epsilon_1 \sigma T_{ev}^4 + h_{f_1} (T_{ev} - T_{f_1}) - POW_1] \\ + n_2 P_2 L_2 [\epsilon_2 \sigma T_{ev}^4 + h_{f_2} (T_{ev} - T_{f_2}) - POW_2] \end{aligned} \quad (4-7)$$

ZGAS: length of condenser filled with gas if a sharp temperature front is assumed (feet). ZGAS is a means of specifying the non-condensable gas inventory when using the gas input option, MODEQM = 1. It is convenient for making parametric runs or estimating the performance of a pipe with gas in it to aid in start-up from the frozen state.

Since ZGAS and AGAS cannot both be zero, ZGAS is set equal to a nominal value when the heat input option is used. See Table 4-II.

AGAS: Amount of non-condensable gas in heat pipe and reservoir. \mathcal{M} (lb-moles). See Table 4-II.

TTRAP: - Temperature of the wick at the entrance to a non-wicked reservoir if different from the temperature of the end of Condenser 1 farthest from the evaporator. If the same as the temperature of the end of the condenser, enter 0.0.

Table 4-II

Operating Conditions

<u>MODEQM</u>	<u>\dot{Q}</u>	<u>ZGAS</u>	<u>AGAS</u>	<u>REMARKS</u>
0	Actual	Nominal*	0	Heat input option
1	Nominal**	0	Actual	Amount of gas input in terms of lb-moles
1	Nominal**	Actual	0	Amount of gas input in terms of gas length

* Not used in calculations, but must be input since ZGAS and AGAS cannot both be zero.

** Used to non-dimensionalize certain variables. Put in a low estimate.

4.9 Reservoir Characteristics

Card 13 (2F 12.5, 2I12, F 12.5, I 12)

- VRES: gas reservoir volume, V_R (in.³). Set equal to zero when a reservoir is not desired.
- TRES: gas reservoir temperature, T_R (°R). When VRES = 0 an arbitrary non-zero value must be put in for TRES. Use TEV. When NRES = 2 the reservoir temperature is determined internally to the program. Thus, an arbitrary non-zero value (e.g., TEV) must also be input for TRES in this case. See Tables 3-I and 3-II.
- NRES: control constant for type of reservoir (0, 1, 2). Refer to Table 3-II.

4.10 Program Control Options

The following variables are included on card 12 although not related to the reservoir characteristics.

- MODEQM: refers to a prescribed heat input (0) or a prescribed amount of gas (1). Refer to paragraphs 3.2, 3.3 and Table 4-II.
- ZPRINT: Indicates the length of condenser in inches between printed output points. This distance should exceed one-quarter of a pipe diameter.
- NRUN: equals 1 if another set of data follows; otherwise leave blank.

5.0 OUTPUT DESCRIPTION

5.1 Input

The input is printed out to document the input parameters and to permit the user to verify that they were read in correctly. The first two lines are the descriptive words used to describe the run.

5.1.1 Vapor Pressure and Fluid Properties

The first two lines of numerical printout are the input vapor pressure parameters and the fluid properties read in on input cards 3 and 4. See Section 4.1.

5.1.2 Fin Properties

The next two lines of numerical printout are the fin properties read in on input cards 5 and 6, Section 4.2.

5.1.3 Adiabatic Section and Pipe Properties

The adiabatic section parameters read in on input card 7 is then printed, followed by the data on input card 8.

5.1.4 Condenser Environments

The condenser environments are next printed out, corresponding to input cards 10 and 11.

5.1.5 Wick, Artery and Reservoir

Input data on card 9 having to do with the wick and artery, and data on input card 13 having to do with the reservoir are next printed in the output.

5.1.6 Operating Conditions

Finally, the remaining data on input cards 12 and 13 are printed out. The quantities XGAS and AMT are computed quantities corresponding to input ZGAS or AGAS which fix the gas in the reservoir. The dimensionless quantity GAS is the amount of gas divided by the normalizing factor COEF, which is also printed.

5.2 Dimensionless Parameters

A number of dimensionless parameters used in the program are printed. These printouts are of no great import, but the user may be interested in some of them. For example, the dimensionless sink temperatures TS1 and TS2 give the fraction of the evaporator absolute temperature which would be achieved under completely gas-blocked conditions with no axial conduction acting.

5.2.1 Dimensionless Temperatures

The quantities TZ, TS1, TS2, TR, and TTRP are as follows:

TZ	T_o^* in Eq. (2-19)
TS1	T_w in Eq. (2-1) when $d\dot{Q} = 0$, Condenser 1
TS2	As above, Condenser 2
TR	T_{res}/T_{ev} , dimensionless reservoir temperature
TTRP	Dimensionless cold trap temperature

5.2.2 Dimensionless Condenser Parameters

For each of the two condenser sections the following quantities are printed:

EMIS	Emissivity
C	C^* in Eq. (2-16)
F	F^* defined in Section 2.2, radiation parameter
H	H^* defined in Section 2.2, convection parameter
XL	L^* length L divided by D_e
XS	x_s , mole fraction of gas corresponding to temperature T_w in Eq. (2-1) when $d\dot{Q} = 0$.

5.2.3 Dimensionless Adiabatic Section Parameters

Quantities are printed as follows:

C3	C^* in Eq. (2-16) for the adiabatic third section
RA	Dimensionless wick resistance, adiabatic section
DIADI	Inside diameter normalized by the condensing section inside diameter D_e
R	Dimensionless wick resistance, condensing section
XL3	Length normalized by D_e

5.3 Debug Information

A number of printed statements give the user clues as to whether or not the program is functioning with the input data given it.

5.3.1 Exits from INPT

In subroutine INPT certain errors in the input data will result in the printing of one or more of the following error messages:

```
CONDENSER SECTION NO. 1 INPUT WRONG
CONDENSER SECTION NO. 2 INPUT WRONG
INPUT ERROR, ZGAS = 0.0 AGAS = 0.0
PIPE EXCEEDS 250 DIAMETERS
```

The first two above result when, for the condenser section in question, the effectiveness, perimeter, or the sum of the emissivity and convective heat transfer coefficient is zero.

The "input error" message results when both the length of gas-blocked condenser and the amount of gas specified are zero. The program is designed to treat heat pipes containing enough non-condensable gas to affect at least a portion of one of the condensers.

If the combined lengths of the three sections exceeds 250 inside diameters D_e , the internally specified incremental length $DZ = 0.25$ will result in over 1000 integration steps along the pipe. This number will then exceed the number of storage locations specified within the program. For heat pipes which exceed 250 diameters in length, it is necessary to increase DZ within the Fortran source program or increase the number of storage locations.

5.3.2 Exits from FIRST

A check is made in subroutine FIRST to determine whether the mole fraction in gas blocked condenser 1 exceeds 0.999999. If it does, a warning message is printed

```
INPUT ERROR, CONDENSER 1 ENVIRONMENT TOO COLD
```

Next a check is made to establish whether the sink conditions for Condenser 1 are colder than those for Condenser 2. If they are not,

a message is printed as follows:

```
INPUT ERROR, CONDENSER 1 ENVIRONMENT HOTTER THAN
      THAT FOR CONDENSER 2
```

Also in subroutine FIRST, depending upon whether MODEQM equals 0 or 1, that is, depending upon whether the heat flux or the amount of gas is meant to be specified, a check is made to see whether the specification is compatible with the other specified parameters, such as evaporator temperature, condenser parameters, and reservoir size. IF they are not compatible the program prints one of the following two messages:

```
INPUT ERROR, HEAT FLUX TOO HIGH OR CONDENSERS TOO SHORT
INPUT ERROR, TOO MUCH GAS FOR PIPE
```

The gas inventory estimate is made using elementary flat-front theory so that it is remotely possible that the user can input too large a gas inventory and still pass the screening test.

5.3.3 Convergence

The program prints messages indicating the subroutines used in the search for an answer satisfying the convergence criterion. One normal message is:

```
ITERATING IN PATCH
```

Subroutine PATCH calls BACK once and then FORWRD and CROSS repeatedly to establish the gas-blocked temperature profile in the first condenser section, based upon the assumption that the second condenser is sufficiently long to achieve a uniform gas-blocked temperature in the region remote from the first. If the quantity DELTEE is not large enough, or if the axial conduction is quite strong, difficulty may be experienced resulting in the prints:

```
1000 STEPS IN BACK
1000 STEPS IN FORWARD
```

Trouble in CROSS may result in the following messages:

```
1000 STEPS IN CROSS
ZERO J2 IN CROSS
```

With none of these troubles the next normal print is:

```
ITER=0  TSTART =      Z1 =      XL1 =
```

This printing is normally repeated with ITER increasing sequentially. Convergence in PATCH occurs when Z1 is within DZ of XL1. Failure to achieve this situation is signalled with the message:

```
FAILED TO CONVERGE IN PATCH
```

After the completion of subroutine PATCH, subroutine LONG calls subroutine START which utilizes PIPE. Trouble in PIPE may be signalled by:

```
TOO MANY STEPS IN PIPE, J = 1001
```

In the normal situation the next print, after successful completion of the iterating in PATCH, will be:

```
ITERATING IN LONG
ITER=0  JSTART = 1  GAS =  QSUM =  JEND =  MOREJ =
```

If the program continues iterating in LONG, additional lines with ITER = 1, 2, etc. will appear. Successful convergence is signalled by MOREJ = 0 and may be verified by QSUM = 1.0 for prescribed power or GAS nearly equalling the value printed under the previous heading AMOUNT OF NONCONDENSIBLE GAS. Failure to achieve this condition results in the message:

```
FAILED TO CONVERGE IN LONG
```

Under some conditions subroutine LONG may call upon subroutine START2. In this case the message:

```
ITERATING IN START2
```

may appear followed by prints of:

```
I =      TSTART =      XSUM =      QSUM =      JEND =      MOREJ =
```

Convergence is again indicated by MOREJ = 0 and an appropriate value of QSUM or XSUM.

Under other conditions, following the print ITER = 0 from subroutine LONG, the print:

ITERATING IN SHORT

ITER = TSTART = XSUM = QSUM =

appears. Convergence is indicated by an appropriate value of XSUM or QSUM. Lack of convergence is indicated by:

FAILED TO CONVERGE IN SHORT

5.4 Calculated Reservoir Conditions

After completion of the iteration searching process the reservoir conditions are printed:

TRES Reservoir Temperature in °R
 XSR Mole fraction of noncondensable in reservoir
 RESGAS Amount of gas in lb.-moles in reservoir

If the volume of the reservoir is input as Zero, this line of output will not appear.

5.5 Profiles

Profiles of temperature, mass flow, mole fraction and cumulative sums of power lost and gas contained in the reservoir and pipe are printed versus length along the pipe. These profiles are as follows:

J Integration step
 ZIN Distance from end of condenser farthest from
 the evaporator in inches
 Z Dimensionless distance
 V Dimensionless mass flow V^* in Eq. (2-17)
 P Dimensionless gas quantity ϕ in Eq. (2-10)
 TI Dimensionless wick - vapor interface temperatures
 XSUM Dimensionless running sum of gas contained
 QSUM Dimensionless running sum of power lost
 MASS FLOW Vapor flow in the pipe, lb./hr.
 QFLOW Cumulative power lost, BTU/hr.
 XS Mole fraction
 TWICK Wick-vapor interface temperature, °R
 TWALL Wall temperature, °R
 MGAS Cumulative sum of gas contained in the reservoir
 and the pipe, lb.-moles

Missing values of J have been skipped because of the ZPRINT criterion.

5.6 Total Gas and Heat Flow

The final four print statements are as follows:

GAS IN ONE DZ STEP OF GAS-BLOCKED CONDENSER 1 = LB-MOLES.
POWER LOST BY ONE DZ STEP OF FULL-ON CONDENSER 1 = BTU/HR.
TOTAL GAS IN PIPE AND RESERVOIR = LB-MOLES.
TOTAL POWER LOST BY CONDENSERS = BTU/HR.

The first line is the gas contained in a length of Condenser 1 equal to the step size used in the integration. The second line likewise equals the power radiated in an incremental length of full-on condenser. Of the final two lines, one should agree, within the integration precision, with the input value, and the other constitutes an answer of interest to the heat pipe analyst or designer. If ZGAS or AGAS had been input, the gas inventory should agree with that value within the precision indicated, and the power is the answer sought. If Q had been input, the power should agree with that value within the indicated precision, and the gas inventory is the answer sought.

6.0 NOMENCLATURE

A_c	- Cross sectional area
C	- Axial conductivity-area product
D	- Diameter
D	- Diffusion coefficient for noncondensable in condensable
E	- Empirical constant for temperature dependence of D
F^*	- Nondimensional quantity defined in Paragraph 2.2
H	- Irradiation onto condenser surface
K	- Radial wick conductance
L	- Length of condenser
M	- Molecular weight of condensable
m	- Molar inventory of noncondensable
P	- Heat transfer perimeter of fin
P_i	- Partial pressure of noncondensable at temperature T_i
\dot{Q}	- Heat transfer rate
Q_e^*	- Nondimensional quantity defined in Paragraph 2.2
R	- Gas constant for condensable
R_u	- Universal gas constant (1545.4, ft-lb _f /°R-lbmole)
S	- Radial conductance from condenser
T	- Temperature
T_o	- Characteristic temperature of fluid defined by Eq. (2-8b)
V	- Mole average velocity
c	- Molar concentration
h	- Coefficient of heat transfer
h_{fg}	- Latent heat of vaporization
k	- Thermal conductivity
\dot{m}	- Mass flow rate
q	- Heat flux
v	- Void volume
x	- Mole fraction of noncondensable
z	- Axial position

- α - Absorptance of condenser surface
- δ - Wick thickness
- ϵ - Total hemispherical emittance of condenser surface
- ϕ - Dimensional variable defined by Eq. (2-10)
- $\phi_1, \phi_2, \phi_3, \phi_4$ - Dimensionless groupings defined in Paragraph 2.2
- η - Effectiveness of condenser fin
- σ - Stefan-Boltzmann constant

Subscripts:

- abs - Absorbed from surrounds
- b - Bulk average (area-velocity weighted) value
- c - Effective sink conditions
- e - Equivalent value
- ev - Evaporator conditions
- f - External fluid conditions
- i - Wick surface conditions
- min,max - Minimum, maximum
- nominal - Initialized value for numerical solution
- n - Cross-sectional element of pipe
- Res, R - Reservoir conditions
- s - Spatial (area weighted) average
- w - Condenser wall conditions
- 1,2 - Condenser section number 1 and 2, respectively

* - Superscript denotes nondimensional variable

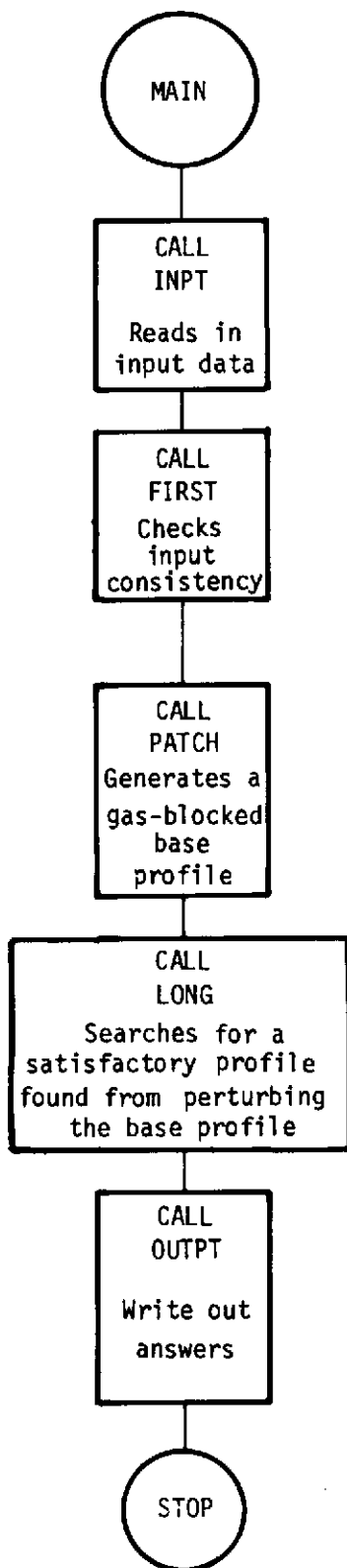
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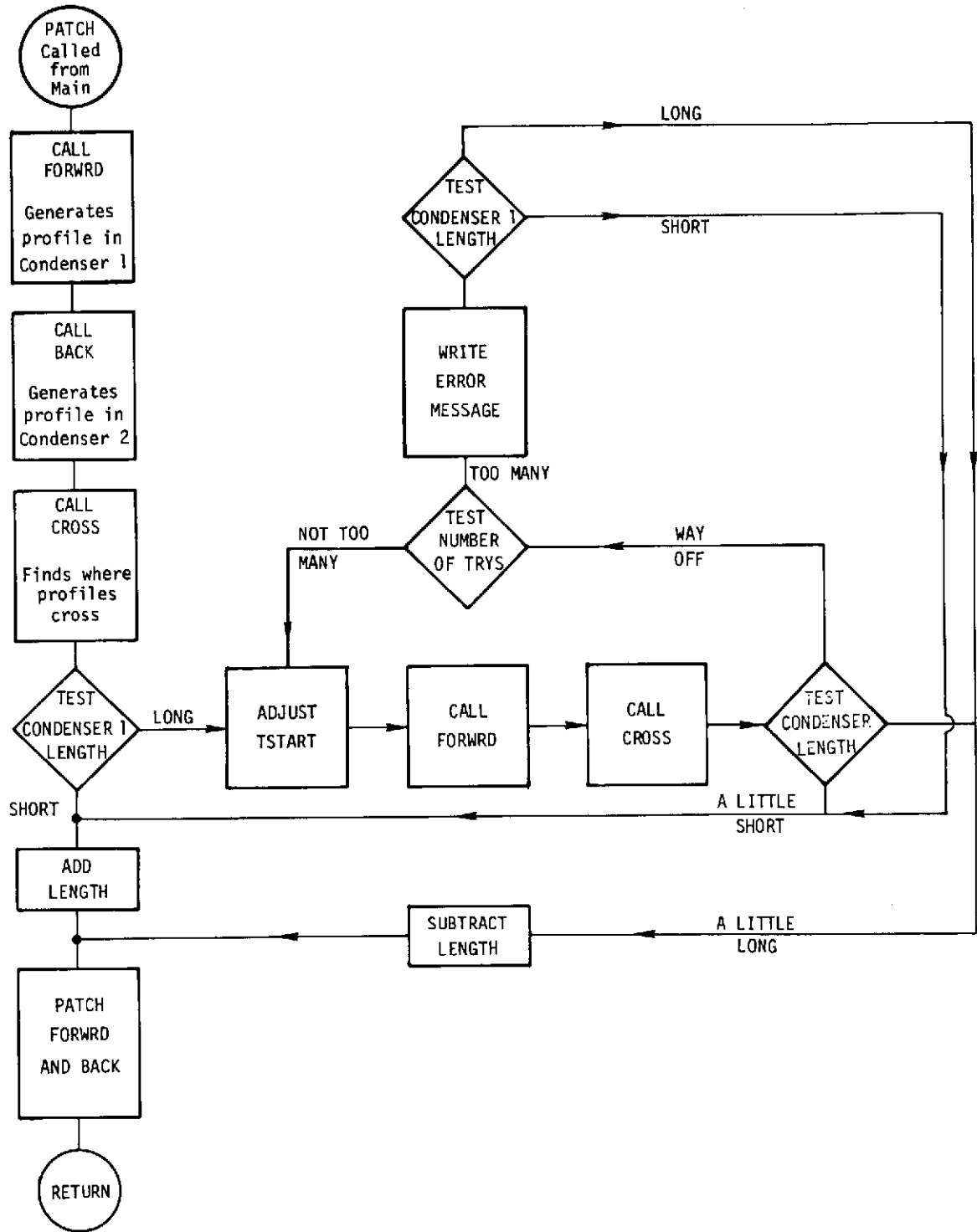
APPENDIX A
FLOW DIAGRAM (TRW-GASPIPE)

The flow diagrams presented in the following pages are included as an aid to understanding the overall program logic.

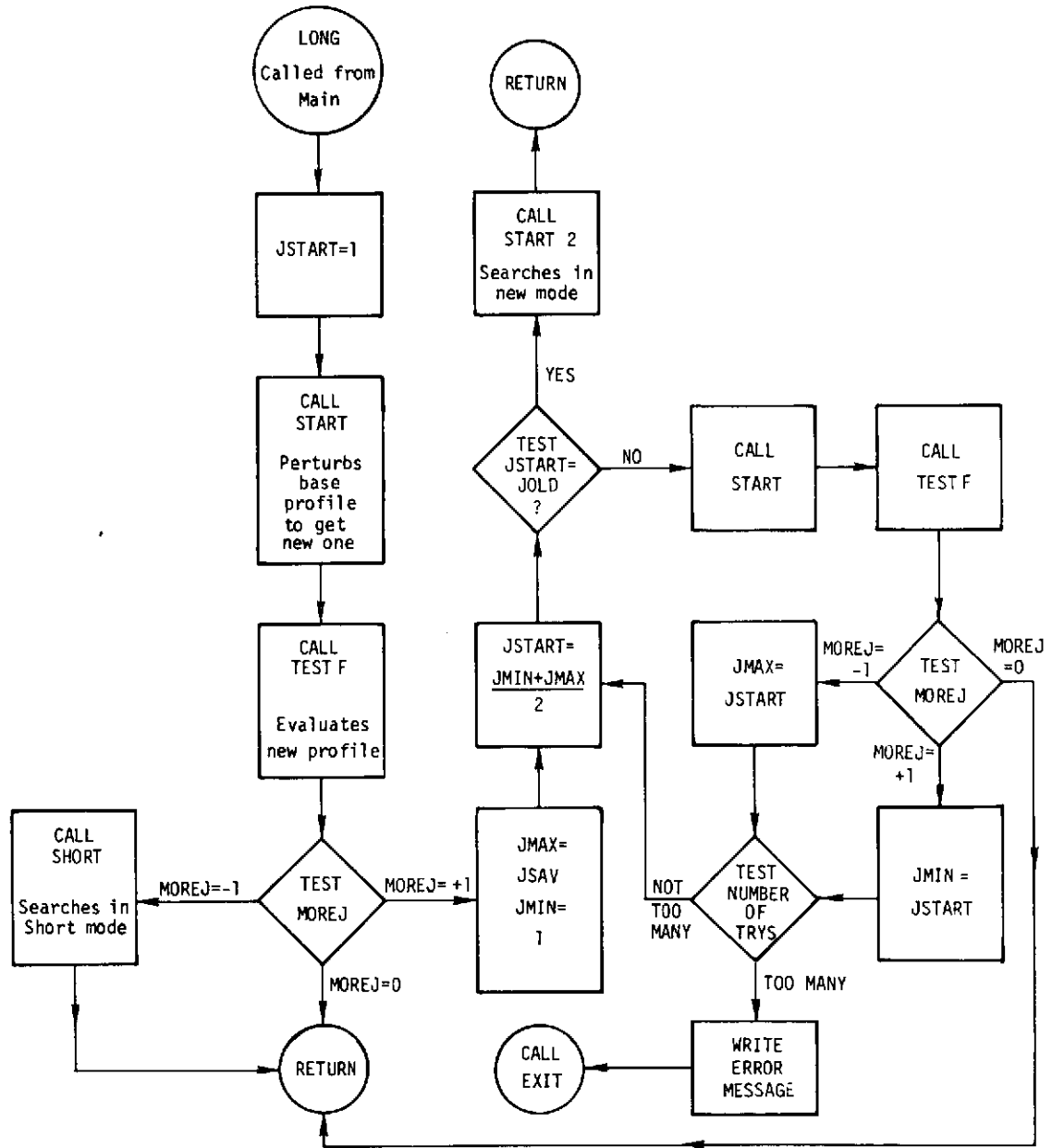
FLOWCHART OF MAIN PROGRAM



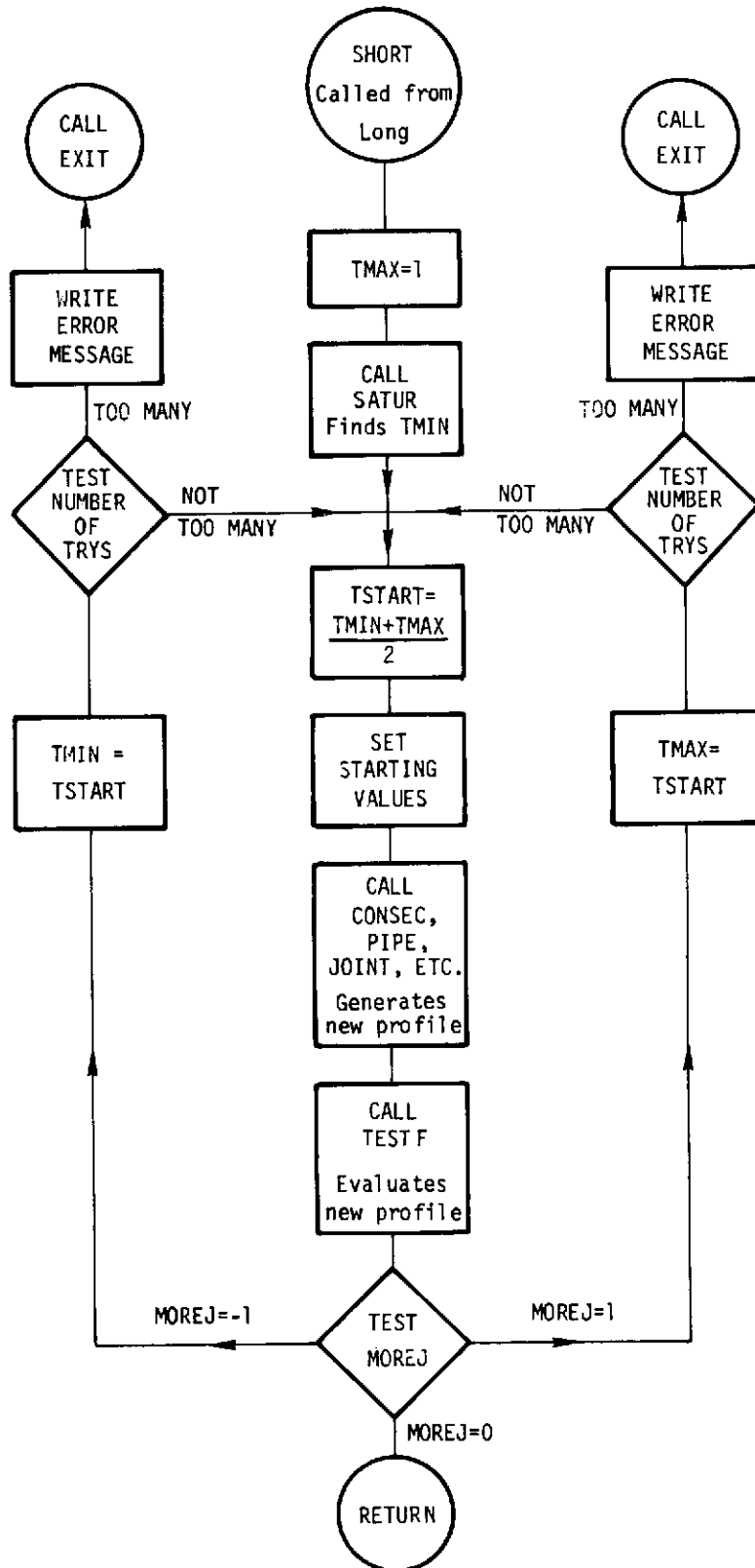
FLOWCHART OF SUBROUTINE PATCH



FLOWCHART OF SUBROUTINE LONG



FLOWCHART OF SUBROUTINE SHORT



APPENDIX B
LISTING (TRW - GASPIPE)

The program listing which is reproduced in the following pages was compiled on a CDC-6500 computer. The program is general and may be used on the IBM 360 or Univac 1108 simply by changing the asterisks in the output format statements to an apostrophe. In addition, the first card of the main program, which defines the input and output tapes, is not required with the IBM and Univac versions.

Storage requirements are on the order of 50,000 words (octal); approximately 15 seconds are required for compilation and from 10 to 60 seconds computation time per run.

PROGRAM GASCON (INPUT=201,TAPE5=INPUT,OUTPUT,TAPE6=OUTPUT)

```

C      MODIFICATION OF GASPIPE TO TREAT TWO GAS-BLOCKED
C      CONDENSERS AND AN ADIABATIC SECTION
000004  COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000004  COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000004  COMMON /ADIA9/ XL3,C3,RA,DIADI
000004  COMMON /WOKK/ XL, TS, C, F, H, EMIS, TMIN, ZF
000004  COMMON /VP7X0/ VV(1000), PP(1000), ZZ(1000), XX(1000), QQ(1000),
000004  1      VB(1000), PB(1000), ZB(1000), YB(1000), QB(1000),
000004  2      VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000004  COMMON /GASDTA/ TZ, D, E, A11, B11, C11, DELTEE, HFG
000004  COMMON /PIPOTA/ TCV, DFT, Q, GAS, TP, VR, VRES, DZ, P, COEF,TTRP
000004  COMMON /INTC/ NRES, MODEQM, ZPRINT, NRUN, NERROP
000004  COMMON /PIPIN/ ZZERO, VZERO, PZERO, XZERO, QZERO, JZERO, XTEST
000004  COMMON /PIPOUT/ XSUM, QSUM, PSUM, XSP, ZFPONT, JEND, PREQ, PREG
000004  COMMON /LNG/ JSTART, JSAY, XL12, XL123
000004  COMMON /CRSS/ Z1,Z2,V1,V2,X1,X2,PCROSS,QCROSS,J1,J1M,J2,J2M,JBAK
000004  REWIND 5
000006  REWIND 6

C
000010  1  NERROR=0
000011  500 CALL INPT
000012  IF (NERROR.EQ.0) GO TO 2
000013  IF (NRUN.EQ.1) GO TO 1
000015  600 CALL EXIT
000016  2  CONTINUE
000016  TMIN=TS1
000020  DELTEE=0.25
000022  CALL FIRST
C      FIRST CHECKS CONSISTENCY OF INPUT Q AND GAS
000023  CALL PATCH
C      PATCH PATCHES TOGETHER THE TEMP. PROFILES AT THE
C      CONDENSER JOINT.
000024  CALL LONG
C      LONG SEARCHES FOR A VALUE OF JSTART FOR WHICH
C      XSUM EQUALS GAS
000025  CALL OUTPT
    
```

MAIN

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13111-6054-R0-00

TRW
RUNX COMPTLR (VER. 25)

10/02/73. 15.05.14.

GASCON

C OUTPUT WRITES OUT THE VPZXQ VARIABLES AND CONVERTS
C SOME OF THEM TO DIMENSIONAL QUANTITIES

000026 C IF (NRUN.EQ.1) GO TO 1

000030 STOP
000032 END

MAIN

B-3

13111-6054-R0-00

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

BACK

```
000060      OM=(P1+P)/2.0
000063      CALL SATUR (PM, TM)
000065      CALL MOLE (TM, YM)
000067      XSUM=XSUM+XM*D7/TM
000073      CALL SURF (TM, S, TC)
000075      QI=S*(TM-TC)/(1.0+S*P)
000104      QSUM=QSUM+QI*D7
000107      PB(J)=P
000112      VB(J)=V
000115      YB(J)=YSUM
000120      QB(J)=QSUM
000123      ZB(J)=Z
000125      IF (ABS(DV).LT.0.015625 .AND. ABS(DZ).LT.0.25) D7=2.0*DZ
000143      CALL SATUR (P, TI)
000145      IF (TI.LE.TS1) GO TO 150
000150      100 CONTINUE
           C
000152      WRITE (6,10)
000156      10  FORMAT (I2Y,*1000 STEPS IN BACK*)
000156      CALL EXIT
           C
000157      150 CONTINUE
000157      DZ=+0.25
000161      JBAK=J
000163      RETURN
000164      END
```

BACK

B-4

13111-6054-RO-00

SUBROUTINE BACK

```

C
000002 COMMON /COND1/ XL1, TS1, C1, F1, M1, EMIS1, XS1
000002 COMMON /COND2/ XL2, TS2, C2, F2, M2, EMIS2, XS2
000002 COMMON /VPZQ/ VV(1000), PP(1000), ZZ(1000), XX(1000), QQ(1000),
000002 1 VR(1000), PB(1000), ZB(1000), XB(1000), OB(1000),
000002 2 VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000002 COMMON /GASDTA/ TZ, D, E, A11, B11, C11, DELTEE, MFG
000002 COMMON /PIPDTA/ TEV, DFT, Q, GAS, TR, VR, VRES, DZ, R, COEF, TTRP
000002 COMMON /MORK/ DUMMY(6), IMIN, ZF
000002 COMMON /CPSS/ Z1, Z2, V1, V2, X1, X2, PCROSS, QCROSS, J1, J1M, J2, J2M, JBAK

C
000002 CALL CONSEC (2)
000004 TSTART=TS2-DELTEE/TEV
000007 PZERO=PHI(TSTART)
000012 DZ=-0.25
000014 V=1.0E-8
000016 P=PZERO
000020 CALL SATUR (P, TI)
000022 CALL MOLE (TI, XS)

C
000024 J=R
000025 XSUM=0.0
000026 OSUM=0.0
000027 Z=0.0
000030 DO 100 I=1,1000
000032 CALL RUNGE (V, P, DV, DP)
000035 IF (ABS(DV).GT.0.0625) GO TO 200
000042 GO TO 400
000043 200 DZ=DZ/2.0
000045 GO TO 100
000046 400 CONTINUE
000046 J=J+1
000050 Z=Z+DZ
000052 P1=P
000054 P=P+DP
000056 V=V+DV

```

BACK

RUNX COMPTER (VER.26)

10/02/73, 15.05.14.

SUBROUTINE CONSEC (NSEC)

```
      C
000003      COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000003      COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000003      COMMON /ADIA1/ XL3, C3, RA, DIAD1
000003      COMMON /WORK/ XL, TS, C, F, H, EMIS, TMIN, 7F
      C
000003      IF (NSEC.NE.1) GO TO 100
000005      XL=XL1
000007      TS=TS1
000011      C=C1
000013      F=F1
000015      H=H1
000017      EMIS=EMIS1
000021      RETURN
      C
000022      100 CONTINUE
000022      IF (NSEC.NE.2) GO TO 200
000024      XL=XL1+XL2
000026      TS=TS2
000030      C=C2
000032      F=F2
000034      H=H2
000036      EMIS=EMIS2
000040      RETURN
000041      200 CONTINUE
000041      XL=XL1+XL2+XL3
000044      TS=TS2
000046      C=C3
000050      F=0.0
000051      H=1.0
000053      EMIS=0.0
000054      RETURN
000055      END
```

CONSEC

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13111-6054-R0-00

SUBROUTINE CROSS

```

C
000002 COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000002 COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000002 COMMON /ADIAB/ XL3, C3, RA, DIADI
000002 COMMON /VPZKO/ VV(1000), PP(1000), ZZ(1000), XX(1000), QQ(1000),
000002 1 VR(1000), PR(1000), ZR(1000), XB(1000), QB(1000),
000002 2 VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000002 COMMON /PIPDTA/ TEV, DFT, Q, GAS, TR, VR, VRES, DZ, R, COEF, TTRP
000002 COMMON /PIPOUT/ XSUM, QSUM, RSUM, XSR, ZFRONT, JEND, PREQ, PREG
000002 COMMON /LNG/ JSTART, JSAV, XL12, XL123
000002 COMMON /CRSS/ Z1, Z2, V1, V2, X1, X2, PCROSS, QCROSS, J1, J1M, J2, J2M, JBAK
C
000002 XL123=XL1+XL2+XL3
000005 XL12=XL1+XL2
000007 J2=JBAK
000011 J1=0
C
000012 P2=PB(J2)
000015 Q2=QB(J2)
000020 DO 100 I=1,1000
000022 J1=J1+1
000024 P1=PP(J1)
000027 Q1=QQ(J1)
000032 IF(P1.LT.P2) GO TO 100
000035 99 J2=J2-1
000037 IF (J2.EQ.0) GO TO 101
000040 P2=PB(J2)
000043 Q2=QB(J2)
000046 IF (P2.LT.P1) GO TO 99
000051 IF (Q2.LT.Q1) GO TO 102
000054 100 CONTINUE
C
000056 WRITE (6,30)
000062 30 FORMAT (/* 1000 STEPS IN CROSS*)
000062 CALL EXIT
C

```

CROSS

PUNX COMPILE (VER.26)

10/02/73. 15:05.14.

CROSS

```
000063 101 WRITE (5,40)
000067 40  FORMAT (/ * ZERO J2 IN CROSS*)
C
000067 102 CONTINUE
000067 J2M=J2+1
000071 Q2M=QB(J2M)
000074 P2M=PB(J2M)
000077 J1M=J1-1
000101 Q1M=QB(J1M)
000104 P1M=PB(J1M)
000107 TERM1=(P1-P1M)*(Q2-Q2M)
000113 TERM2=(Q1-Q1M)*(P2M-P2)
000117 DENOM=TERM1+TERM2
000121 TERM3=(Q1-Q1M)*P1M-(P1-P1M)*Q1M
000130 TERM4=(Q2-Q2M)*P2M+(P2M-P2)*Q2M
000135 XNUM=TERM3*(P2M-P2)+TERM4*(P1-P1M)
000144 PCROSS=XNUM/DENOM
000146 XNUM=(Q1-Q1M)*TERM4-(Q2-Q2M)*TERM3
000154 QCROSS=XNUM/DENOM
000156 IF(P1.NE.P1M) FRAC1=(PCROSS-P1M)/(P1-P1M)
000164 IF(P2.NE.P2M) FRAC2=(PCROSS-P2M)/(P2-P2M)
000172 IF(Q1.NE.Q1M) FRAC1=(QCROSS-Q1M)/(Q1-Q1M)
000200 IF(Q2.NE.Q2M) FRAC2=(QCROSS-Q2M)/(Q2-Q2M)
000206 Z1=ZZ(J1M)+FRAC1*(ZZ(J1)-ZZ(J1M))
000214 Z2=ZB(J2M)+FRAC2*(ZB(J2)-ZB(J2M))
000222 V1=VV(J1M)+FRAC1*(VV(J1)-VV(J1M))
000230 X1=XX(J1M)+FRAC1*(XX(J1)-XX(J1M))
000236 V2=VB(J2M)+FRAC2*(VB(J2)-VB(J2M))
000244 X2=XB(J2M)+FRAC2*(XB(J2)-XB(J2M))
000252 RETURN
000253 END
```

CROSS

B-8

13111-6054-RO-00

```

SUBROUTINE DELTA(V,P,DV,DP)
000007 COMMON /WORK/ XL, TS, C, F, H, EMIS, TMIN, ZF
000007 COMMON /GASDTA/ TZ, D, E, A11, B11, C11, DELTEE, HFG
000007 COMMON /PIPDYA/ TEV, DET, Q, GAS, TP, VR, VPES, DZ, R, COEF, TTRP
000007 CALL SATUR(P,T)
000014 TEE = T**E
000020 XC=FEX(P)
000025 CALL SURF(T,S,TC)
000033 X=EXP(-P)
000041 QI = S*(T-TC)/(1.0+S*R)
000047 TERM1 = C*(X/XC)*(T**2/TEE)/(D*TZ)
000057 DP = DZ*V/(D*TEE)
000062 TERM2 = 1.0-(2.0-E)*(T/TZ)*X
000070 TERM3 = V**2/(D*TEE*XC)
000074 DV=DZ*TERM1*TERM2*TERM3/(1.+TERM1)
000102 IF (QI.EQ.0.) RETURN
000104 DV=(DZ*QI/(1.0+TERM1))*(1.0+TERM1*TERM2*TERM3/QI)
000115 RETURN
000116 END
  
```

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DELTA

10/02/73 15.05.14

RUNX COMPILER (VER.26)

10/02/73 15.05.14

```
FUNCTION FEX(X)
000003 IF(X.LT.0.1) GO TO 100
000006 FEX=1.0
000010 IF (X.GT.30.) RETURN
000014 FEX=1.0-EXP(-X)
000022 RETURN
000024 100 XXX = X
000026 FEX = X
000028 XN = 1.0
000030 F = 1.0
000032 SIGN = 1.0
000034 DO 101 I = 1,7
000036 XN = XN+1.0
000040 SIGN = -SIGN
000041 F = F*XN
000043 XXX = X*XXX
000045 FEX = FEX+SIGN*XXX/F
000051 101 CONTINUE
000053 RETURN
000055 END
```

B-10

FEX

13111-6054-R0-00

10/02/73. 15.05.14.

SUBROUTINE FIRST

```
      C      FIRST CHECKS Q AND GAS
000002      COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000002      COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000002      COMMON /ADTAR/ XL3, C3, RA, DIADI
000002      COMMON /WORK/ XL, TS, C, F, H, EMIS, TMIN, ZF
000002      COMMON /GASDTA/ TZ, D, E, A11, B11, C11, DELTEF, HFG
000002      COMMON /PIPDTA/ TEV, DFT, Q, GAS, TR, VR, VRES, DZ, R, COFF, TTRP
000002      COMMON /INTC/ NRES, MODEQH, ZPRINT, NRUN, NERROR
000002      COMMON /PIPIN/ ZZERO, VZERO, PZERO, XZERO, JZERO, XTEST
000002      COMMON /PIPOUT/ XSUM, QSUM, RSUM, XSR, ZFRONT, JFND, PREQ, PREG

      C
000002      TEST=1.0-XS1
000004      IF(TEST.LT.1.0E-6) WRITE(6,10)
000012      10 FORMAT(/,* INPUT ERROR, CONDENSER 1 ENVIRONMENT TOO COLD*)
000012      IF(TS2.LT.TS1) WRITE(6,11)
000020      11 FORMAT(/,* INPUT ERROR, CONDENSER 1 ENVIRONMENT HOTTER*,
000020      1 * THAN THAT FOR CONDENSER 2*)
000020      DZ=0.25
000022      PREG=DZ*XS1/TS1
000025      TI=1.0
000027      CALL CONSEC(1)
000031      CALL SURF(TI,S1,TC1)
000034      QI1 = S1*(TI-TC1)/(1.0+S1*R)
000042      PREG=DZ*QI1
000044      IF(MODEQH.NE.0) GO TO 98
      C      CHECK FOR Q CONSISTENCY
000045      CALL CONSEC(2)
000047      CALL SURF(TI,S2,TC2)
000052      QI2 = S2*(TI-TC2)/(1.0+S2*R)
000060      VZ = QI1*XL1+QI2*XL2
000064      IF(VZ.GT.1.0) RETURN
000067      WRITE(6,12)
000073      12 FORMAT(/,* INPUT ERROR, HEAT FLUX TOO HIGH OR CONDENSERS*,
000073      1 * TOO SHORT*)
000073      WRITE(6,60) S1,TC1,QI1,XL1,S2,TC2,QI2,XL2,VZ
000121      60 FORMAT(1X,9E12.4)
```

FIRST

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

FIRST

000121 GO TO 999

C

C

CHECK FOR GAS CONSISTENCY

C

000122 98 CONTINUE

000122 TR1=TS1

000124 IF(NRES.EQ.1) TR1=TR

000130 IF(NRES.EQ.2) TR=TR1

000134 IF(NRES.EQ.0.AND.TTRP.NE.0.0) TR1=TTRP

000144 CALL MOLE (TR1,XSR)

000146 RSUM=VR*XSP/TR

000151 GASMAX=RSUM+XS1*XL1/TS1+XS2*(XL2+XL3)/TS2

000162 IF(GASMAX.GT.GAS) RETURN

000165 WRITE(6,13) GAS, GASMAX

000175 13 FORMAT(/,2X,*INPUT ERROR, TOO MUCH GAS FOR PIPE*,4X,

000175 1 *GAS =*,E12.4,4X,*GASMAX =*,E12.4)

000175 999 CALL EXIT

000176 RETURN

000177 END

B-12

FIRST

13111-6054-R0-00

SUBROUTINE FORMPD(TSTART)

```
      C
000003 COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000003 COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000003 COMMON /VPXQ/ VV(1000), PP(1000), ZZ(1000), XX(1000), QQ(1000),
000003 1 VB(1000), PB(1000), ZB(1000), XB(1000), QB(1000),
000003 2 VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000003 COMMON /GASDTA/ TZ, D, E, A11, B11, C11, DELTEE, HFG
000003 COMMON /PIPDTA/ TEV, OFT, Q, GAS, TR, VR, VRES, DZ, R, COEF, TTRP
000003 COMMON /WORK/ DUMMY(6), TMIN, ZF
      C
000003 TMIN=TSTART
000004 PZERO=PHI(TSTART)
000007 TR1=TSTART
000010 IF(NRES.EQ.1) TR1=TR
000014 IF(NRES.EQ.2) TR=TR1
000020 IF(NRES.EQ.0.AND.TTRP.NE.0.0) TR1=TTRP
000030 CALL MOLE (TR1,XSR)
000033 RSUM=VR*XSR/TR
000036 CALL MOLE (TSTART,XSTART)
000041 Z=0.
000042 V=0.
000043 P=PZERO
000045 XSUM=RSUM
000047 QSUM=0.
000050 J=0
000051 DZ=0.25
000053 CALL CONSEC (1)
000056 DO 100 I=1,1000
000060 CALL RUNGE (V,P,DV,DP)
000064 IF(ABS(DV).GT.0.0525) GO TO 200
000071 GO TO 400
000072 200 DZ=DZ/2.
000074 GO TO 100
000075 400 CONTINUE
000075 J=J+1
000077 Z=Z+DZ
```

FORWARD

B-13

13111-6054-R0-00

RUNX COMPILER (VFR.26)

10/02/73. 15.05.14.

FORWRD

```
000101      P1=P
000103      P=P+DP
000105      V=V+DV
000107      PM=(P1+P)/2.
000112      CALL SATUP (PM, TM)
000115      CALL MOLF (TM, XM)
000120      XSUM=XSUM+YM*D7/TM
000124      CALL SURF (TM, S, TC)
000130      QI=S*(TM-TC)/(1.+S*R)
000136      QSUM=QSUM+QI*D7
000141      VV(J)=V
000144      PP(J)=P
000147      ZZ(J)=7
000152      XX(J)=XSUM
000155      QQ(J)=QSUM
000160      IF (ABS(DV).LT.0.015625.AND.ABS(DZ).LT.0.25) DZ=2.*DZ
000173      CALL SATUP (P, TT)
000176      IF (TT.GE.TS2) GO TO 150
000201      100 CONTINUE
000203      WRITE (5, 10)
000210      10 FORMAT (/2X, *1000 STEPS IN FORWRD*)
000210      CALL EXIT
000212      150 CONTINUE
000212      TMIN=TS1
000214      DZ=0.25
000216      RETURN
000217      END
```

FORWRD

SUBROUTINE INPT

```

000002 COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000002 COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000002 COMMON /ACTAB/ YL3,C3,RA,DIADI
000002 COMMON /WORK/ XL, TS, C, F, H, FMIS, TMTN, ZF
000002 COMMON /GASDTA/ TZ, D, E, A11, B11, C11, DELTEE, HFG
000002 COMMON /PIPDYA/ TEV, DFT, Q, GAS, TP, VR, VRES, OZ, R, COEF, TTRP
000002 COMMON /INTC/ NRES, MODEQM, ZPRINT, NRUN, NERROR
000002 COMMON /PIPIN/ ZZERO, VZERO, PZERO, XZERO, QZERO, JZERO, XTEST
000002 COMMON /PIPOUT/ XSUM, OSUM, RSUM, XSR, ZFRONT, JEND, PREQ, PREG
000002 READ (5,5)
000006 5 FORMAT (72H
000006 $ /72H
000006 $ )
000006 WRITE (6,5)
C
C FLUID CHARACTERISTICS
C1
000012 READ (5,10) A11,B11,C11
000024 10 FORMAT (3F12.5)
C A11,B11 AND C11 ARE VAPOR PRESSURE PARAMETERS IN THE LEAST SQUARES
C FIT, P=EXP(A11-B11/T-C11/(T**2)), PSIA, T IN DEG-R.
C2
000024 READ(5,11) XMC,DIF,E,HFG
000040 11 FORMAT(4F12.5)
C XMC IS MOLECULAR WEIGHT OF THE CONDENSIBLE
C DIF IS THE MASS DIFFUSIVITY AT ONE ATMOS AND 460R, FT**2/HR
C E IS THE TEMPERATURE EXPONENT FOR DIFFUSIVITY MINUS ONE
C HFG IS THE LATENT HEAT (BTU/LB) ( AT TEV )
000040 WRITE(6,12)
000044 12 FORMAT(/,26H VAPOR PRESSURE PARAMETERS)
000044 WRITE (6,13) A11,B11,C11
000056 13 FORMAT (/, 6H A11=1PE12.5,7H B11=1PE12.5,7H C11=1PE12.5)
000056 WRITE(6,14)
000062 14 FORMAT(//,17H FLUID PROPERTIES)
000062 WRITE(6,15) HFG,DIF,XMC,E
000076 15 FORMAT(/,6H HFG=F9.4,14H BTU/LB DIF=F9.4,15H FTFT/HR XMC=F9.4

```

INPT

B-14A

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

INPT

000075 § ,10H CD EXP=F9.4)

C

CONDENSER PARAMETERS, SECTION 1, FARTHEST FROM EVAPORATOR

C3

000075 READ(5,16) PF1,AF1,CF1,FF1,EMIS1,HF1

000115 16 FORMAT(6F12.5)

C

PF1 IS FIN PERIMETER PERPENDICULAR TO PIPE (INCHES)

C

AF1 IS FIN CROSS-SECTIONAL AREA (SQ. INCHES)

C

CF1 IS EFFECTIVE THERMAL CONDUCTIVITY OF FIN, ALLOWS FOR SLOTS

C

FF1 IS FIN EFFECTIVENESS (DIMENSIONLESS)

C

EMIS1 IS FIN TOTAL HEMISPHERICAL EMISSIVITY (DIMENSIONLESS)

C

HF1 IS FIN CONVECTIVE HEAT TRANSFER COEFFICIENT (BTU/HR-FT²-R)

000116 WRITE(6,17)

000122 17 FORMAT(//,* FIN PROPERTIES, CONDENSER SECTION NUMBER 1*)

000122 WRITE(6,18) PF1,AF1,CF1,FF1,EMIS1,HF1

000142 18 FORMAT(/,2X,*PF=*,F8.4,* IN*,2X,*AF=*,F8.4,* SQ IN*,2X,

000142 1 *CF=*,F8.4,* BTU/HRFT²*,2X,*EF=*,F6.4,2X,*EMIS=*,F6.4,2X,

000142 2 *HF=*,F9.4,* PTU/HRFT²R*)

000142 TEST=EF1*PF1*(EMIS1+HF1)

000146 IF (TEST.NE.0.) GO TO 996

000147 NERROR=1

000150 WRITE(6,19)

000154 19 FORMAT(/,35H CONDENSER SECTION NO. 1 INPUT WRONG)

000154 996 CONTINUE

C

C

CONDENSER PARAMETERS, SECTION 2, NEAREST TO EVAPORATOR

C4

000154 READ(5,16) PF2,AF2,CF2,FF2,EMIS2,HF2

000174 WRITE(6,20)

000200 20 FORMAT(//,* FIN PROPERTIES, CONDENSER SECTION NUMBER 2*)

000200 WRITE(6,18) PF2,AF2,CF2,FF2,EMIS2,HF2

000220 TEST=EMIS2+HF2

000222 IF (TEST.NE.0.) GO TO 997

000223 NERROR=1

000224 WRITE(6,21)

000230 21 FORMAT(/,35H CONDENSER SECTION NO. 2 INPUT WRONG)

000230 997 CONTINUE

C

INPT

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13111-6054-RO-00

RUNX COMPTER (VER.26)

10/02/73. 15.05.14.

INPT

C ADIABATIC SECTION CHARACTERISTICS
C5

000230 READ (5,22) DOUTA,THKWA,CWA,DELA,CWKA,XLONGA
000250 22 FORMAT(6F12.5)

C DOUTA IS OUTSIDE DIAMETER (INCHES)
C THKWA IS WALL THICKNESS (INCHES)
C CWA IS WALL THERMAL CONDUCTIVITY (BTU/HR-FT-R)
C DELA IS THE WICK THICKNESS IN ADIABATIC SECTION (INCHES)
C CWKA IS EFFECTIVE CONDUCTIVITY OF WICK (BTU/HR-FT-R)
C XLONGA IS THE LENGTH OF THE ADIABATIC SECTION (FT)

000250 WRITE (6,23)

000254 23 FORMAT(//,29H ADIABATIC SECTION PROPERTIES)
000254 WRITE (6,24) DOUTA,THKWA,CWA,DELA,CWKA,XLONGA

000274 24 FORMAT(/,8H DOUTA=F9.4,11H IN, THKWA=F9.4,4H IN, /

000274 1 6H CWA= F9.4,17H BTU/HRFTR DELA=F9.4,
000274 2 6H CWKA= F9.4,19H BTU/HRFTR XLONGA=F9.4,3H FT)

C
C WALL CHARACTERISTICS
C5

000274 READ(5,25) DOUT,THKW,CW

000306 25 FORMAT(3F12.5)
C DOUT IS OUTSIDE DIAMETER OF HEAT PIPE (INCHES)
C THKW IS WALL THICKNESS (INCHES)

C CW IS WALL THERMAL CONDUCTIVITY (BTU/HR-FT-R)
C WRITE(6,26)

000306 26 FORMAT(//,16H PIPE PROPERTIES)

000312 WRITE(6,27) DOUT,THKW,CW

000324 27 FORMAT(/,7H DOUT=F9.4,15H IN WALL THK=F9.4,16H IN WALL COND=
000324 \$ F9.4,13H BTU/HRFTR)

C
C WICK CHARACTERISTICS
C7

000324 READ(5,28) DEL,CONWK,DART

000336 28 FORMAT(3F12.5)
C DEL IS THE HEAT PIPE WICK THICKNESS (INCHES)

C CONWK IS THE EFFECTIVE THERMAL CONDUCTIVITY OF FILLED WICK
C DART IS THE EFFECTIVE DIAMETER OF ARTERIES IN PIPE (INCHES)
C

INPT

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13111-6054-RO-00

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

INPT

C ENVIRONMENTAL PARAMETERS AND LENGTHS

C8

000336 READ(5,29) TF1,POW1,XLONG1

000350 29 FORMAT(3F12.5)

C TF1 IS THE FLUID TEMPERATURE (DEGREES-R)

C POW1 IS THE ABSORBED POWER PER UNIT AREA OF THE OUTER FIN SURFACE

C (PERMETER TIMES LENGTH) THE POWER IS BOTH INSIDE (INTERNAL

C POWER) AND OUTSIDE (SOLAR ABSORPTION, ETC.) BUT THE AREA IS THE

C OUTSIDE AREA ONLY (BTU/HR-FT²)

C XLONG1 IS THE LENGTH OF CONDENSER SECTION NUMBER 1 (FEET)

C9

000350 READ(5,29) TF2,POW2,XLONG2

C XLONG2 IS THE LENGTH OF CONDENSER SECTION NUMBER 2 (FEET)

000362 WRITE(6,30)

000366 30 FORMAT(//,* CONDENSER ENVIRONMENT, SECTION NUMBER 1*)

000366 WRITE(6,31) TF1,POW1,XLONG1

000400 31 FORMAT(//,* TF=* ,0PE12.4,* R POW=* ,0PE12.4,* BTU/HRFTFT XLONG=*

000400 * ,0PE12.4,* FT*)

000400 WRITE(6,32)

000404 32 FORMAT(//,* CONDENSER ENVIRONMENT, SECTION NUMBER 2*)

000404 WRITE(6,31) TF2,POW2,XLONG2

C

C OPERATING CONDITIONS

C10

000416 READ(5,33) TEV,Q,7GAS,AGAS,TTRAP

000434 33 FORMAT(5F12.5)

C TEV IS THE EVAPORATOR TEMPERATURE (DEGREES-R)

C Q IS THE HEAT PIPE POWER (BTU/HR)

C 7GAS IS THE LENGTH OF CONDENSER FILLED WITH GAS IF SHARP FRONT, FT

C AGAS IS THE AMOUNT OF GAS IN LB-MOLES

C ONE, BUT NOT BOTH, OF 7GAS AND AGAS MUST BE EQUAL TO ZERO

C TTRAP IS THE COLD TRAP TEMPERATURE (R). IF THERE IS NO

C ACTIVE COLD TRAP, USE ZERO FOR THE INPUT VALUE.

000434 IF(7GAS.EQ.0.0.AND.AGAS.EQ.0.0) GO TO 998

000442 IF(7GAS.EQ.0.0.OR.AGAS.EQ.0.0) GO TO 200

000450 998 CONTINUE

000450 NERROR=1

000451 WRITE(6,34) 7GAS,AGAS

INPT

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RUNX COMPILER (VER.26)

10/02/73, 15.05.14.

INPT

000461 34 FORMAT(/,* INPUT WRONG, ZGAS=*,DPE12.5,* AGAS=*,DPE12.5)

000461 CALL EXIT

000462 200 CONTINUE

C

C

RESERVOIR CHARACTERISTICS

C11

000462 READ (5,35) VRES,TPFS,NRES,MODEQM,ZPRINT,NRUN

000502 35 FORMAT(2F12.5,2I12,F12.5,I12)

C

VRES IS THE RESERVOIR VOLUME IN CUBIC INCHES

C

TRES IS THE RESERVOIR TEMPERATURE IN DEGREES R

C

NRES REFERS TO A NON-WICKED (0), AN ACTIVE-WICKED (1) OR A

C

PASSIVE-WICKED (2) RESERVOIR.

C

MODEQM REFERS TO A PRESCRIBED Q (0) OR PRESCRIBED MOLES OF GAS (1).

C

IN THE LATTER CASE Q IS SIMPLY A GUESS, HOPEFULLY LOW BUT CORRECT

C

IN ORDER OF MAGNITUDE. IN THE FORMER CASE AGAS IS SET EQUAL TO

C

ZERO AND ZGAS IS A NOMINAL GUESS.

C

NPRINT INDICATES THE NUMBER OF LINES TO BE SKIPPED IN OUTPUT.

C

NRUN EQUALS 1 IF ANOTHER SET OF DATA FOLLOWS. OTHERWISE 0.

000502 WRITE(6,36)

000506 36 FORMAT(//,* WICK PROPERTIES AND RESERVOIR CONDITIONS*)

000506 WRITE(6,37) DEL,CONWK,DART,VRES,TRES,NRES

000526 37 FORMAT(/,2X,*WCK THK=*,F8.4,* IN*,2X,*WCK CON=*,F8.4,

000526 1 * BTU/HRFT²*,2X,*D-ART=*,F7.4,* IN*,2X,*VRES=*,F8.4,* CU IN*,

000526 2 2X,*TPFS=*,F6.1,* R*,2X,*NRES=*,I2)

000526 SIGMA = 0.1714E-8

000530 RU = 1544.0

000532 PT = 3.1415927

000534 IF(EMIS1.EQ.0.0.AND.HF1.EQ.0.0) GO TO 999

000542 GO TO 100

000543 999 CONTINUE

000543 NERROR=1

000544 RETURN

C

C

CALCULATION OF DIMENSIONLESS PARAMETERS

C

000545 100 CONTINUE

000545 IF (NERROR.EQ.1) GO TO 999

000547 CALL SINK(EMIS1,POW1,HF1,TF1,TS1)

INPT

B-18

13111-6023-RO-00

RUNX COMPILE (VER.26)

10/02/73. 15.05.14.

INPT

```
000553      TS2=TS1
000555      IF (PE2.NF.0.) CALL STNK(E4TS2,POW2,HF2,TF2,TS2)
000562      TS1 = TS1/TEV
000564      TS2 = TS2/TEV
000566      B11 = B11/TEV
000570      C11 = C11/TEV**2
000572      CALL MOLF(TS1,XS1)
000574      CALL MOLF(TS2,YS2)
000576      TP = TRES/TEV
000600      TTPP=TTPAP/TEV
000602      PEV=(EXP(A11-B11-C11))*144.0
000611      CFV = PEV/(PIJ*TEV)
000614      TZ=B11+C11*(1.0+1.0/TS1)
000621      PATMOS = PEV/(144.0*14.7)
000623      DEV=(DIF/PATMOS)*((TEV/460.0)**(E+1.0))
000634      CHDH = XMC*DEV*CFV*HFG
000640      DIN = DOUT-2.0*THKW
000643      DI = DIN-2.0*DFL
000646      FTNKA1 = CF1*AF1/144.0
000651      FTNKA2 = CF2*AF2/144.0
000654      WALKA = (PI/576.0)*(DOUT**2-DIN**2)*CW
000662      WICKA = (PI/576.0)*(DIN**2-DI**2)*CONWK
000670      SUMKA1 = FTNKA1+WALKA+WICKA
000673      SUMKA2 = FTNKA2+WALKA+WICKA
000676      DTNA=DOUTA-2.*THKWA
000701      DINWA=DINA-2.*DFLA
000704      ANA=(PI/4.1)*(DOUTA**2-DINA**2)
000711      ANKA=(PI/4.1)*(DTNA**2-DINWA**2)
000716      SUMKA3=(CWA*ANA+CWKA*ANKA)/144.
000723      IF (DT.GF.DART) GO TO 300
000726      WRITE(6,39) DI,DART
000736      39 FORMAT(/,* DART TOO BIG.  DI=*,DPE12.4,*  DART=*,DPE12.4)
000736      NERPOR=1
000737      RETURN
000740      300 DFT = SORT(DI**2-DART**2)/12.0
000747      VP = VRES/((PI/4.0)*1728.0*DFT**3)
000754      XL1 = XLONG1/DFT
000756      XL2 = XLONG2/DFT
```

INPT

RUNX COMPTLR (VER.26)

10/02/73. 15.05.14.

INPT

```

000760      XL3 = XLONGA/DFT
000762      XLIOT=XL1+XL2
000764      IF(XLTOT.LT.250.) GO TO 600
000767      WRITE(6,40)
000773      40  FORMAT(//,27H PIPE EXCEEDS 250 DIAMETERS)
000773      CALL EXIT
000774      600  CONTINUE
000774      C1 = SUMKA1*TEV/(Q*DFT)
001000      C2 = SUMKA2*TEV/(Q*DFT)
001004      C3 = SUMKA3*TEV/(Q*DFT)
001010      XKA=2.*PT*GWKA*DFT*TEV/(Q*ALOG(DINA/DINWA))
001023      RA=1./XKA
001025      DIADI=DINA/DI
001027      XK = 2.0*PT*CONWK*DFT*TEV/(Q*ALOG(DIN/DI))
001042      R = 1.0/XK
001044      D = (PI/4.0)*DFT*CHDH/Q
001051      F1 = EF1*(PF1/12.0)*DFT*SIGMA*TEV**4/Q
001060      F2 = EF2*(PF2/12.0)*DFT*SIGMA*TEV**4/Q
001067      H1 = HF1*TEV/(SIGMA*TEV**4)
001073      H2 = HF2*TEV/(SIGMA*TEV**4)
001077      COEF = 3.1415927*CEV*DFT**3/4.0
001103      GAS = AGAS/COEF
001105      TR1=TS1
001107      IF(NRES.EQ.1) TP1=TR
001113      IF(NRES.EQ.2) TP1=TP1
001117      IF(NRES.EQ.0.AND.TTOP.NE.0.0) TR1=TTRP
001127      CALL MOLE(TR1,XR)
001131      RSUM=XR*VR/TR
001134      IF(ZGAS.EQ.0.0) GO TO 400
001135      GAS = (ZGAS*XS1/(TS1*DFT))+RSUM
001142      IF(ZGAS.LE.XLONG1) GO TO 400
001145      GAS=RSUM+XL1*XS1/TS1+(ZGAS-XLONG1)*XS2/(TS2*DFT)
001157      400  AMT = COFF*GAS
001161      XGAS = DFT*(GAS-RSUM)*TS1/XS1
001166      IF(XGAS.LE.XLONG1) GO TO 500
001171      GAS1=XL1*XS1/TS1
001174      GAS2=(GAS-RSUM)-GAS1
001177      XGAS=DFT*(XL1+(GAS2*TS2/XS2))

```

INPT

PUNX COMPILER (VER.26)

10/02/73, 15,05,14.

INPT

```
001204      500 CONTINUE
001204      WRITE(5,41)
001210      41 FORMAT(//,21H OPERATING CONDITIONS)
001210      WRITE(5,42) TEV,0,MODEQH,CEV,TTRAP
001226      42 FORMAT(/,* TEV=*,0PE12.4,* R Q=*,0PE12.4,* BTU/HR  MODEQH=*,
001226      *T2, * CEV=*,0PE12.4,* LBMOLE/FT3 TTRAP=*,0PE12.4,* R*)
001226      WRITE(5,43)
001232      43 FORMAT(//,29H AMOUNT OF NONCONDENSIBLE GAS)
001232      WRITE(5,44) GAS,ZGAS,AGAS,COEF,AMT,XGAS
001252      44 FORMAT(/,5H GAS=0PE12.4,9H ZGAS=0PE12.4,11H FT AGAS=0PE12.4,
001252      $ 15H LBMOLE COEF=0PE12.4,9H LBMOLE/,5H AMT=0PE12.4,
001252      * 14H LBMOLE XGAS=0PE12.4,3H FT)
001252      WRITE(5,45)
001256      45 FORMAT(//,* DIMENSIONLESS TEMPERATURES*)
001256      WRITE(5,46) T7,TS1,TS2,TR,TTRP
001274      46 FORMAT(/,* T7=*,0PE12.4,* TS1=*,0PE12.4,* TS2=*,0PE12.4,* TR=*,
001274      $ 0PE12.4,* TTRP=*,0PE12.4)
001274      WRITE(5,47)
001300      47 FORMAT(//,* DIMENSIONLESS CONDENSER PARAMETERS, SECTION NO. 1*)
001300      WRITE(5,48) FMIS1,C1,F1,H1,XL1,XS1
001320      48 FORMAT(/,* FMIS=*,0PE12.4,* C=*,0PE12.4,* F=*,0PE12.4,* H=*,
001320      $ 0PE12.4,* XL=*,0PE12.4,* XS=*,0PE12.4)
001320      WRITE(5,49)
001324      49 FORMAT(//,* DIMENSIONLESS CONDENSER PARAMETERS, SECTION NO. 2*)
001324      WRITE(5,48) FMIS2,C2,F2,H2,XL2,XS2
001344      WRITE(5,50)
001350      50 FORMAT(//,* DIMENSIONLESS ADIABATIC SECTION PARAMETERS*)
001350      WRITE(5,51) C3,PA,DIADI,R,XL3
001366      51 FORMAT(/,44 C3=F12.5,5H PA=E12.5,
001366      * 8H DIADI=F12.5,4H P=F12.5,6H XL3= E12.5)
001366      WRITE(5,52)
001372      52 FORMAT(///)
001372      RETURN
001373      END
```

INPT

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13111-6054-R0-00

RUNX COMPTER (VER.26)

10/02/73. 15.05.14.

SUBROUTINE JOINT (NSEC,P,V,VNEW)

```
      C
000007 COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000007 COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000007 COMMON /ADTA9/ XL3,C3,PA,DIADI
000007 COMMON /GASOTA/ TZ, D, E, A11, B11, C11, DELTEE, HFG
      C
000007 CALL SATUP (P,TI)
000014 DTEE=D*TI**E
000021 TERM=(TI**2/DTEE)*EXP(-P)/(FEX(P)*TZ)
000041 IF(NSEC.EQ.2) GO TO 100
000047 VNEW=V*((1.0+C1*TERM)/(1.0+C2*TERM))
000052 RETURN
000053 100 CONTINUE
000053 VNEW=V*((1.0+C2*TERM)/(1.0+C3*TERM))
000052 RETURN
000053 END
```

B-22

JOINT

13111-6054-RO-00

SUBROUTINE LONG

```

C      LONG CALLS START REPEATEDLY TO SEARCH FOR A VALUE
C      OF JSTART FOR WHICH XSU = GAS OR OSUM = 0
000002  COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000002  COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000002  COMMON /ADIAR/ XL3, C3, PA, DIADI
000002  COMMON /WOPK/ XL, TS, C, F, H, EMIS, THIN, ZF
000002  COMMON /PIPDTA/ TEV, DFT, Q, GAS, TR, VR, VRES, DZ, R, COEF, TTRP
000002  COMMON /INTC/ NRES, MODEQM, ZPRINT, NPUN, NFEROP
000002  COMMON /LNG/ JSTART, JSAV, XL12, XL123
000002  COMMON /PIPOUT/ XSUM, OSUM, RSUM, XSR, ZFRONT, JEND, PREQ, PREG
000002  JSAV=JEND
000004  JSTART=1
000005  CALL STAPT
000006  CALL TESTF(MOREJ)
000010  WRITE(6,30)
000014  30 FORMAT(/,2X,*ITERATING IN LONG*)
000014  T=0
000015  WRITE(6,20) T, JSTART, XSUM, OSUM, JEND, MOREJ
000035  IF(MOREJ.EQ.0) RETURN
000037  IF(MOREJ.EQ.1) GO TO 99
000041  CALL SHORT

C
000042  RETURN
000043  99 CONTINUE
000043  JMAX=JSAV
000045  JMIN=1

C
000046  DO 100 T=1,30
000050  JOLD=JSTART
000052  JSTART=(JMAX+JMIN)/2
000055  IF(JSTART.NE.JOLD) GO TO 101
000057  IF(MOREJ.EQ.1) JSTART=JSTART+1
000063  CALL STAPT2
000064  THIN=TS1
000065  RETURN
000067  101 CONTINUE
    
```

LONG

TRIP
RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

LONG

```
000067      CALL START
000070      CALL TEST(MOREJ)
000072      WRITE(6,20) I, JSTART, XSUM, QSUM, JEND, MOREJ
      C
000112      20 FORMAT(2X,*ITER=*,I4,2X,*JSTART=*,I4,2X,
000112          1 *XSUM=*,F12.5,2X,*QSUM=*,E12.5,
000112          2 2X,*JEND=*,I4,2X,*MOREJ=*,T4)
000112      IF(MOREJ.EQ.0) RETURN
000114      IF(MOREJ.EQ.1) GO TO 200
000116      JMAX=JSTART
000120      GO TO 100
      C
000121      200 CONTINUE
000121      JMIN=JSTART
000123      100 CONTINUE
      C
000125      WRITE (6,10)
000131      10  FORMAT (/* FAILED TO CONVERGE IN LONG*)
000131      CALL EXIT
      C
000132      RETURN
000133      END
```

B-24

LONG

13111-6054-R0-00

TRW SYSTEMS

RUNX COMPTER (VER.26)

10/02/73. 15.05.14.

SUBROUTINE MOLE (TI, XS)

```
000005 COMMON /GASDTA/ TZ, D, E, A11, B11, C11, DELTEF, MFG
000005 TERM1 = B11*(1.0/TI-1.0)
000010 TERM2 = C11*(1.0/TI**2-1.0)
000014 ARG = TERM1+TERM2
000016 XS = FEX(ARG)
000022 RETURN
000023 END
```

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MOLE

13111-6054-R0-00

RUNX COMPILER (VER.26)

10/02/73, 15.05.14.

SUBROUTINE OUTPT

```
000002 COMMON /WORK/ XL, TS, C, F, H, EMIS, TMIN, ZF
000002 COMMON /VP7X0/ VV(1000), PP(1000), ZZ(1000), XX(1000), QQ(1000),
000002 1 VB(1000), PR(1000), ZB(1000), XB(1000), QB(1000),
000002 2 VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000002 COMMON /GASDTA/ TZ, D, F, A11, B11, C11, DELTEE, HFG
000002 COMMON /PIPDTA/ TEV, DFT, Q, GAS, TR, VP, VRES, DZ, R, COEF, TTRP
000002 COMMON /PIPOUT/ XSUM, OSUM, PSUM, XSR, ZFRONT, JEND, PREQ, PREG
000002 COMMON /INTC/ MRES, MODEQM, ZPRINT, NRUN, NERROR
```

C

```
000002 V=0.0
000003 Z=0.0
000004 RESGAS=COEF*PSUM
000006 TRFS=TEV*TR
000010 IF(VPES.EQ.0.0) GO TO 98
000011 WRITE(5,10) TRFS,XSR,RESGAS
000023 10 FORMAT(/,2Y,*TRFS =*,E12.4,* DEG R*,4X,*XSR =*,E12.4,10X,
000023 1 *RESGAS =*,F12.4,* LB-MOLFS*)
000023 98 CONTINUE
000023 NSEC=1
000024 CALL CONSEC(NSEC)
000026 IPRINT=1
```

C

```
000027 DO 100 J=1,JEND
000031 V1=V
000033 Z1=Z
000035 Z=Z7(J)
000040 ZET=Z*DFT
000042 ZIN=12.*ZET
000044 IF(J.EQ.1.OR.J.EQ.JEND) GO TO 102
000054 IF(Z.LE.XL) GO TO 99
000057 IF (NSEC.EQ.1) GO TO 101
000061 IF (NSEC.EQ.2) GO TO 103
000063 IF (NSEC.EQ.3) GO TO 200
000065 99 JPRINT=ZIN/ZPRINT
000070 IF(JPRINT.LT.IPRINT) GO TO 100
000073 IPRINT=JPRINT+1
```

OUTPT

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

OUTPT

```
000075      192 CONTINUE
000075      V=VV(J)
000100      P=PP(J)
000103      XSUM=XX(J)
000106      QSUM=QQ(J)
000111      QFLOW=Q*QSUM
000113      CALL SATUP(P,TT)
000115      CALL MOLE(TT,XS)
000117      CALL SURF(TT,S,TC)
000122      TW=(TT+S*R*TC)/(1.0+S*R)
000132      TWICK=TEV*TT
000134      TWALL=TEV*TW
000136      XMOOT=V*Q/HFC
000141      AMT=COEF*XSUM
000143      DTEE=D*(TT**E)
000150      DVOZ=(V-V1)/(Z-71)
000154      ASTN=DVOZ/(15.0*DTEE)
000157      WRITE (6,11) J,7IN,7
000171      11 FORMAT (/ * J = *,I4,6X, *ZIN = *,E12.4, * INCHES*,8X, *Z = *,E12.4)
000171      WRITE (6,12) V,P,TT
000203      12 FORMAT (16X, *V = *,E12.4,15X, *P = *,E12.4,14X, *TI = *,E12.4)
000203      WRITE (6,13) XSUM,QSUM,XMOOT
000215      13 FORMAT (13X, *XSUM = *,E12.4,12X, *QSUM = *,E12.4,8X, *MASSFLOW = *,
000215      1 E12.4, * LB/HR*)
000215      WRITE (6,14) QFLOW,XS,TWICK
000227      14 FORMAT (12X, *QFLOW = *,E12.4, * BTU/HR*,7X, *XS = *,E12.4,
000227      1 11X, *TWICK = *,E12.4, * DEG R*)
000227      WRITE (6,15) TWALL,AMT
000237      15 FORMAT (12X, *TWALL = *,E12.4, * DEG R*,5X, * MGAS = *,E12.4,
000237      1 * LB-MOLES*)
000237      GO TO 100
000240      101 CONTINUE
000240      NSEC=2
000241      CALL CONSEC(NSEC)
000243      GO TO 102
000244      103 CONTINUE
000244      NSEC=3
000245      CALL CONSEC(NSEC)
```

OUTPUT

TRW
UNIX COMPILER (VER.26)

10/02/73. 15.05.14.

OUTPT

```
000247      GO TO 102
000250      100 CONTINUE
000253      200 CONTINUE
           C
000253      DQ=Q*PREF
000255      DG=COEF*PREG
000257      WRITE(6,23) DG
000265      23 FORMAT(/,* GAS IN ONE DZ STEP OF GAS-BLOCKED CONDENSER 1*,
000265      1 4X,*=*,E12.5,* LB-MOLES*)
000265      WRITE(6,24) DQ
000273      24 FORMAT(/,* POWER LOST BY ONE DZ STEP OF FULL-ON*,
000273      1 * CONDENSER 1 =*,E12.5,* BTU/HR*)
000273      WRITE (6,25) AMT
000301      25 FORMAT (/,* TOTAL GAS IN PIPE AND RESERVOIR =*,E12.5,
000301      1 * LB-MOLES*)
000301      WRITE(6,26) QFLOW
000307      RETURN
000310      26 FORMAT(/,* TOTAL POWER LOST BY CONDENSERS =*,E12.5,
000310      1 * BTU/HR*)
000310      END
```

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OUTPT

13111-6054-R0-00

SUBROUTINE PATCH

```

C
000002 COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000002 COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000002 COMMON /ADIAB/ XL3, C3, RA, DIADI
000002 COMMON /VP7X0/ VV(1000), PP(1000), ZZ(1000), XX(1000), QQ(1000),
000002 1 VB(1000), PR(1000), ZB(1000), XB(1000), QB(1000),
000002 2 VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000002 COMMON /GASDTA/ TZ, D, E, A11, B11, C11, DELTEE, MFG
000002 COMMON /PIPODTA/ TEV, DFT, Q, GAS, TR, VR, VRES, DZ, P, COEF, TTRP
000002 COMMON /PIPOHT/ XSUM, QSUM, PSUM, XSR, ZFRONT, JEND, PREQ, PREG
000002 COMMON /LNG/ JSTART, JSV, XL12, XL123
000002 COMMON /CRSS/ Z1, Z2, V1, V2, X1, X2, PCROSS, QCROSS, J1, J1M, J2, J2M, JBAK

C
000002 WRITE(6,10)
000006 10 FORMAT(/,2X,*ITERATING IN PATCH*)

C
000006 TDIF=DELTEE/TFV
000010 TSTART=TS1+TDIF
000012 TMIN=TSTART
000014 TMAX=TS2
000016 CALL FORWRD(TSTART)
000020 CALL RACK
000021 CALL CROSS
000022 T=0
000023 WRITE(6,11) I, TSTART, Z1, XL1
000037 11 FORMAT(2X,*ITER=*,I4,2X,*TSTART=*,F10.5,2X,*Z1=*,
000037 1 F10.5,2X,*XL1=*,F10.5)
000037 IF (Z1.LF.XL1) GO TO 200
000042 DO 100 I=1,30
000044 TSTART=(TMIN+TMAX)/2.
000047 CALL FORWRD(TSTART)
000051 CALL CROSS
000052 WRITE(6,11) I, TSTART, Z1, XL1
000066 TEST=ABS(Z1-XL1)
000071 IF (TEST.LT.0Z) GO TO 101
000074 IF (Z1.GT.XL1) TMIN=TSTART
  
```

PATCH

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

PATCH

```
000100      IF(Z1.LT.XL1) TMAX=TSTART
000104      100 CONTINUE
000106      WRITE(5,12)
000112      12 FORMAT(/,2X,*FAILED TO CONVERGE IN PATCH*)
000112      101 CONTINUE
000112      IF (Z1.LF.XL1) GO TO 200
000115      II=J1
000117      DO 103 I=1,J1
000121      II=II-1
000123      TEST=Z1-ZZ(II)
000126      IF(TEST.GT.XL1) GO TO 104
000132      103 CONTINUE
000135      104 CONTINUE
000135      P=PP(II)
000140      II=II+1
000142      ZDIFF=Z1-XL1
000144      CALL CONSEC(I)
000146      CALL SATUR(P,II)
000150      CALL MOLE(II,XS)
000152      CALL SUPR(II,S,TC)
000155      XDIF=XX(II)+XS*(ZZ(II)-ZDIFF)/(II-XX(1)+XS1*ZZ(1)/TS1
000167      QDIFF=QO(II)-(ZZ(II)-ZDIFF)*S*(II-TC)/(1.+S*R)
000202      JJ=0
000203      DO 105 I=II,J1M
000205      JJ=JJ+1
000207      V=VV(I)
000212      VV(JJ)=V
000215      VSAV(JJ)=V
000220      P=PP(I)
000223      PP(JJ)=P
000226      PSAV(JJ)=P
000231      Z=ZZ(I)-ZDIFF
000234      ZZ(JJ)=Z
000237      ZSAV(JJ)=Z
000242      XSUM=XX(I)-XDIF
000245      XX(JJ)=XSUM
000250      YSAV(JJ)=YSUM
000253      QSUM =QO(I)-QDIFF
```

PATCH

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

PATCH

```
000256      QQ(JJ)=OSUM
000261      OSAV(JJ)=OSUM
000264      105 CONTINUE
000267      GO TO 300
000270      200 CONTINUE
000270      ZDIFF=XL1-71
000272      STEP=ZDIFF/DZ
000274      I1=STEP
000276      STEP=I1
000300      ZDIFF=0Z*STEP
000302      RSUM=XY(I1)-ZZ(I1)*XS1/TS1
000306      Z=XL1-Z1-7DIFF
000311      XSUM=RSUM+Z*YS1/TS1
000315      P=PHI(TS1)
000320      IF(I1.LE.0) GO TO 202
000322      DO 201 I=1,I1
000324      Z=Z+DZ
000326      XSUM=XSUM+0Z*YS1/TS1
000332      VSAV(I)=0.
000334      PSAV(I)=0
000337      ZSAV(I)=Z
000342      XSAV(I)=XSUM
000345      QSAV(I)=0.
000347      201 CONTINUE
000352      202 CONTINUE
000352      DO 203 I=1,J1M
000354      JJ=I1+I
000356      VSAV(JJ)=VV(I)
000362      PSAV(JJ)=PP(I)
000366      ZSAV(JJ)=ZZ(I)
000372      XSAV(JJ)=XY(I)+(XSUM-RSUM)
000400      OSAV(JJ)=OQ(I)
000404      203 CONTINUE
000407      DO 204 I=1,JJ
000411      VV(I)=VSAV(I)
000414      PP(I)=PSAV(I)
000417      ZZ(I)=ZSAV(I)
000422      XX(I)=XSAV(I)
```

PATCH

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

PATCH

```
000425      QQ(I)=QSAV(I)
000430      204 CONTINUE
000433      300 CONTINUE
000433      ZDIFF=XL1-ZZ(JJ)
000436      JJ=JJ+1
000440      7=XL1
000442      CALL SATUP(PCROSS,TCROSS)
000444      CALL MOLE(TCROSS,XSC)
000446      P=PCROSS
000450      V=V1
000452      XSUM=XX(JJ)+ZDIFF*XSC/TCROSS
000457      QSUM=QCROSS
000461      VV(JJ)=V
000464      VSAV(JJ)=V
000467      PP(JJ)=P
000472      PSAV(JJ)=P
000475      ZZ(JJ)=Z
000500      ZSAV(JJ)=Z
000503      XX(JJ)=XSUM
000506      XSAV(JJ)=XSUM
000511      QQ(JJ)=QSUM
000514      QSAV(JJ)=QSUM
000517      XSUMC=XSUM
000521      II=J2
000523      JJJ=J2-1
000525      DO 301 I=1,JJJ
000527      II=II-1
000531      ZDIFF=ZB(II)-Z?
000534      XDIFF=XB(II)-X?
000537      JJ=JJ+1
000541      V=VB(II)
000544      VV(JJ)=V
000547      VSAV(JJ)=V
000552      P=PB(II)
000555      PP(JJ)=P
000560      PSAV(JJ)=P
000563      7=XL1+ZDIFF
000565      ZZ(JJ)=Z
```

PATCH

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

PATCH

```
000571      ZSAV(JJ)=7
000573      XSUM=XSUMC+XDIFC
000575      XX(JJ)=XSUM
000600      XSAV(JJ)=XSUM
000603      QSUM=QB(IT)
000606      QO(JJ)=QSUM
000611      QSAV(JJ)=QSUM
000614      ZDIFF=ZD(IT)-Z2
000617      XDIFC=XX(IT)-X2
000622      JEND=JJ
000624      IF(7.65.XL123) RETURN
000630      301 CONTINUE
000633      ZDIFF=XL123-7
000635      STEP=ZDIFF/07
000637      NSTEP=STEP
000641      NSTEP=NSTEP+1
000643      STEP=NSTEP
000645      DZ=ZDIFF/STEP
000647      V=0.
000650      P=PHI(TS2)
000653      QSUM=0.
000654      XSUM=XX(JJ)
000657      DO 302 I=1,NSTEP
000661      JJ=JJ+1
000663      Z=Z+DZ
000665      XSUM=XSUM+07*X2/TS2
000671      VV(JJ)=V
000674      VSAV(JJ)=V
000677      PP(JJ)=P
000702      PAV(JJ)=P
000705      ZZ(JJ)=7
000710      ZSAV(JJ)=7
000713      XX(JJ)=XSUM
000716      XSAV(JJ)=XSUM
000721      QO(JJ)=QSUM
000724      QSAV(JJ)=QSUM
000727      302 CONTINUE
000732      JEND=JJ
```

PATCH

RUNX COMPILER (VER.26) 10/02/73. 15.05.14. PATCH

000734 0Z=0.25
000735 RETURN
000737 END

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted] PATCH

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13111-6054-R0-00

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

SUBROUTINE PIPE

```
000002 C COMMON /WORK/ XL, TS, G, F, H, EMIS, TMIN, ZF
000002 COMMON /VP7XD/ VV(1000), PP(1000), Z7(1000), XY(1000), QQ(1000),
000002 1 VR(1000), PR(1000), ZR(1000), XB(1000), QR(1000),
000002 2 VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000002 COMMON /PIQDTA/ TEV, DFT, O, GAS, TR, VR, VRES, DZ, P, COFF, ITRP
000002 COMMON /PIPIN/ ZZERO, VZERO, PZERO, XZERO, QZERO, JZERO, XTEST
000002 COMMON /PIQOUT/ XSUM, QSUM, PSUM, XSR, ZFRONT, JEND, PREQ, PREG
000002 C
000002 V=VZERO
000004 P=PZERO
000006 Z=ZZERO
000010 J=JZERO
000012 XSUM=XZERO
000014 QSUM=QZERO
000016 DZ=0.25
000020 C
000020 DO 100 I=1,2000
000022 CALL RUNGE (V,P,DV,DP)
000025 IF (ABS(DV).GT.0.1250) GO TO 200
000032 GO TO 400
000033 200 DZ=DZ/2.0
000035 GO TO 100
000036 400 CONTINUE
000036 J=J+1
000040 IF (J.GT.1000) GO TO 102
000044 Z=Z+DZ
000046 IF (Z.GT.XL) GO TO 150
000052 P1=P
000054 P=P+DP
000056 V=V+DV
000060 PM=(P1+P)/2.0
000063 CALL SATUR (PM,TM)
000065 CALL MOLF (TM,XM)
000067 XSUM=XSUM+XM*DZ/TM
000073 CALL SURF (TM,S,TC)
```

PIPE

B-35

13111-6054-RO-00

TRW SYSTEMS
RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

PIPE

```
000076      QI=S*(TM-TC)/(1.0+S*P)
000104      QSUM=QSUM+QI*07
000107      PP(J)=P
000112      VV(J)=V
000115      ZZ(J)=Z
000120      XX(J)=XSUM
000123      QQ(J)=QSUM
000126      IF (ABS(DV).LT.0.04 .AND. DZ.LT.0.25) DZ=2.0*DZ
000141      100 CONTINUE
000143      102 CONTINUE
000143      WRITE (6,10) J
000151      10  FORMAT (/,* TOO MANY STEPS IN PIPE, J =*,I5)
           C
000151      150  DZ1=Z-XL
000153      ZZ(J)=XL
000156      FRAC=(DZ-DZ1)/DZ
000161      TEST=Z
000163      Z=XL
000165      P1=P
000167      P=P+DP*FRAC
000172      PP(J)=P
000175      V=V+DV*FRAC
000200      VV(J)=V
000203      PM=(P1+P)/2.0
000206      CALL SATUP (PM, TM)
000210      CALL MOLE (TM, XM)
000212      XSUM=XSUM+XM*DZ*FRAC/TM
000217      XX(J)=XSUM
000222      CALL SURF (TM, S, TC)
000225      QI=S*(TM-TC)/(1.0+S*P)
000233      QSUM=QSUM+QI*DZ*FRAC
000237      QQ(J)=QSUM
000242      JEND=J
000244      JZERO=J
000246      PZERO=P
000250      VZERO=V
000252      ZZERO=Z
000254      XZERO=XSUM
```

PIPE

7/29/73
RUNX COMPTLR (VER.26) 10/02/73. 15.05.14. PIPE

000256 QZERO=QSUM
C

000260 RETURN
000261 END

PIPE

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13111-6054-RO-00

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

SUBROUTINE RUNGE (V,P,DV,DP)

```
000007 CALL DELTA(V,P,DV1,DP1)
000014 V1 = V+DV1/2.0
000017 P1 = P+DP1/2.0
000022 CALL DELTA(V1,P1,DV2,DP2)
000030 V1 = V+DV2/2.0
000033 P1 = P+DP2/2.0
000036 CALL DELTA(V1,P1,DV3,DP3)
000044 V1 = V+DV3
000046 P1 = P+DP3
000050 CALL DELTA(V1,P1,DV4,DP4)
000056 DV = (DV1+2.0*DV2+2.0*DV3+DV4)/6.0
000064 DP = (DP1+2.0*DP2+2.0*DP3+DP4)/6.0
000072 RETURN
000073 END
```

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RUNGE

13111-6054-R0-00

RUNY COMPILER (VER.26)

10/02/73, 15.05.14.

```
      SUBROUTINE SATUP(P, TI)
000005 COMMON /WORK/ XL, TS, C, F, H, FMIS, TMIN, ZF
000005 COMMON /CASDTA/ TZ, D, E, A11, B11, C11, DELTEE, HFG
      C FLAT RADIAL PROFILE
000005 IF(P.GT.30.0) GO TO 100
000011 IF(P.LE.0.0) GO TO 101
000013 TI = 1.0/(1.0+(1.0/TZ)*ALOG(1.0/FEX(P)))
000026 IF (TI.LT.TMIN) TI=TMIN
000032 GO TO 102
000033 100 TI = 1.0
000034 GO TO 102
000035 101 TI=TMIN
000036 102 RETURN
000037 END
```

B-39

SATUP

13111-6054-R0-00

SUBROUTINE SHORT

```

000002 COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000002 COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000002 COMMON /ADIAB/ XL3, C3, PA, DIADI
000002 COMMON /WORK/ XL, TS, C, F, H, EMIS, DUMM, ZF
000002 COMMON /VP7X0/ VV(1000), PP(1000), ZZ(1000), XX(1000), QQ(1000),
000002 1 VR(1000), PB(1000), ZB(1000), XB(1000), QB(1000),
000002 2 VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000002 COMMON /GASDTA/ YZ, D, F, A11, B11, C11, DELTEF, HFG
000002 COMMON /PIPOTA/ TEV, DET, Q, GAS, TR, VR, VRES, DZ, R, COEF, TTRP
000002 COMMON /INTC/ NRES, MODEQM, ZPRINT, NPUN, NERPOP
000002 COMMON /PIPIN/ ZZERO, VZERO, PZERO, XZERO, QZERO, JZERO, XTEST
000002 COMMON /PIPOUT/ XSUM, RSUM, XSR, ZFRONT, JFND, PREQ, PREG
000002 COMMON /LNG/ JSTART, JSAV, XL12, XL123
000002 WRITE(6,10)
000006 10 FORMAT(/,2Y,*ITERATING IN SHORT*)
000006 TMAX=1.
000010 CALL SATUP(PSAV(1),TMIN)
000012 DO 100 I=1,30
000014 TSTART=(TMIN+TMAX)/2.
000017 DUMM=TSTART
000021 JZERO=0
000022 PZERO=PHI(TSTART)
000025 VZERO=0.
000026 ZZERO=0.
000027 TR1=TSTART
000031 IF(NRES.EQ.1) TR1=TR
000035 IF(NRES.EQ.2) TR1=TR1
000041 IF(NRES.EQ.0.AND.TTRP.NE.0.0) TR1=TTRP
000051 CALL MOLE(TR1,YSP)
000053 RSUM=VR*XSR/TR
000056 XZERO=RSUM
000060 QZERO=0.
000061 CALL CONSEC(1)
000063 CALL PIPE
000064 CALL JOINT(1,PZERO,VZERO,VZFPO)
000067 CALL CONSEC(2)
  
```

SHORT

TRIP
RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

SHORT

```
000071      CALL PIPE
000072      CALL JOINT(2,PZERO,VZERO,VZERO)
000075      CALL CONFC(3)
000077      CALL PIPE
000100      CALL TESTF(MOREJ)
000102      IF(MOREJ.EQ.1) GO TO 200
000104      TMIN=TSTART
000106      WRITE(6,11) I,TSTART,XSUM,OSUM
000122      IF(MOREJ.EQ.0) RETURN
          C
000124      GO TO 100
000125      200 CONTINUE
000125      TMAX=TSTART
000127      WRITE(6,11) I,TSTART,XSUM,OSUM
000143      11 FORMAT(2Y,*ITER=*,I4,2X,*TSTART=*,F10.5,2X,
000143      1  *XSUM=*,E12.5,2X,*OSUM=*,E12.5)
000143      100 CONTINUE
000145      WRITE(6,12)
000151      12 FORMAT(/,2X,*FAILED TO CONVERGE IN SHORT*)
000151      CALL EXIT
000152      END
```

B-41

SHORT

13111-6054-R0-00

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

```

SUBROUTINE SINK(EMIS,POW,HF,TF,TS)
000010      SIGMA = 0.1714E-8
000012      TS = TF
000013      IF(EMIS.EQ.0.0) GO TO 102
000014      TS = SQRT(SQRT(POW/(EMIS*SIGMA)))
000031      IF(HF.EQ.0.0) GO TO 102
000032      IF(TS.EQ.TF) GO TO 102
000034      TM = (TF+TS)/2.0
000037      DO 101 I = 1,10
000041      HR = 4.0*EMIS*SIGMA*TM**3
000045      TS2 = (POW+HF*TF+3.0*EMIS*SIGMA*TM**4)/(HF+HR)
000057      TS = (TS+TS2)/2.0
000062      TM = TS
000063      101 CONTINUE
000065      102 RETURN
000066      END
```

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SINK

13111-6054-R0-00

RUNX COMPTER (VER.26)

10/02/73, 15.05.14.

SUBROUTINE START

```
000002 COMMON /COND1/ YL1, TS1, C1, F1, H1, EMIS1, XS1
000002 COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000002 COMMON /ADTAR/ XL3,C3,RA,DIADT
000002 COMMON /WORK/ YL, TS, C, F, H, EMIS, TMIN, ZF
000002 COMMON /WP7X0/ VV(1000), PP(1000), ZZ(1000), XX(1000), QQ(1000),
000002 1 VR(1000), PR(1000), ZR(1000), XB(1000), OB(1000),
000002 2 VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000002 COMMON /GASOTA/ TZ, D, E, A11, B11, C11, DELTEE, HFG
000002 COMMON /PTPOTAZ/ TEV, DET, Q, GAS, TP, VR, VRES, DZ, R, GCOF, TTRP
000002 COMMON /INTC/ PRES, MODEQM, ZPPINT, NPUN, NERROR
000002 COMMON /PTPTN/ ZZERO, VZERO, PZERO, XZERO, QZERO, XTEST
000002 COMMON /PTPOUT/ XSUM, QSUM, RSUM, XSR, ZFRONT, JEND, PREF, PREFG
000002 COMMON /LNG/ JSTART, JSAV, XL12, XL123
000002 C DO 100 I=1, JSTART
000004 VV(I)=VSAV(I)
000007 PP(I)=PSAV(I)
000012 ZZ(I)=ZSAV(I)
000015 XX(I)=XSAV(I)
000020 QQ(I)=QSAV(I)
000023 100 CONTINUE
000026 JZERO=JSTART
000030 VZERO=(VSAV(JSTART)+1.0E-4)*1.001
000034 ZZERO=ZSAV(JSTART)
000037 XZERO=XSAV(JSTART)
000042 QZERO=QSAV(JSTART)
000045 P=PSAV(JSTART)
000050 CALL SATUR(P, TI)
000052 TSTART=TI+DELTEE/TEV
000055 TMIN=JSTART
000057 PZERO=PHI(TSTART)
000062 IF (ZZERO.EQ.XL1) CALL JOINT(1, PZERO, VZERO, VZERO)
000067 IF (ZZERO.GE.XL1) GO TO 200
000072 CALL CONSEC(1)
000074 CALL PIPE
000075 CALL JOINT(1, PZERO, VZERO, VZERO)
```

START

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13111-6054-RO-00

TRW
RUNX COMPILER (VER.26) 10/02/73. 15.05.14. START

000100 200 CONTINUE
000100 IF(ZZERO.EQ.XL12) CALL JOINT(2,PZERO,VZERO,VZERO)
000105 IF(ZZERO.GE.XL12) GO TO 300
000110 CALL CONSEC(2)
000112 CALL PIPE
000113 CALL JOINT(2,PZERO,VZERO,VZERO)
000116 300 CALL CONSEC(3)
000120 CALL PIPE
000121 TMIN=TS1
000123 RETURN
000124 END

[Empty lines]

START

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13111-6023-R0-0

```

SUBROUTINE START2
000002 COMMON /COND1/ XL1, TS1, C1, F1, H1, EMIS1, XS1
000002 COMMON /COND2/ XL2, TS2, C2, F2, H2, EMIS2, XS2
000002 COMMON /ADIAB/ XL3, C3, RA, DIADI
000002 COMMON /HOPK/ XL, TS, C, F, H, FMIS, TMIN, 7F
000002 COMMON /VPZXQ/ VV(1000), PP(1000), ZZ(1000), XX(1000), QQ(1000),
000002 1 VR(1000), P9(1000), Z9(1000), X9(1000), Q9(1000),
000002 2 VSAV(1000), PSAV(1000), ZSAV(1000), XSAV(1000), QSAV(1000)
000002 COMMON /GASDTA/ TZ, D, E, A11, B11, C11, DELTEE, HFG
000002 COMMON /PIPOYA/ IEV, DET, Q, GAS, TR, V9, VRES, DZ, R, COEF, TTRP
000002 COMMON /TNTC/ NRES, MODEQM, ZPRINT, NPUN, NERROR
000002 COMMON /PIPTN/ ZZERO, VZERO, PZERO, XZERO, QZERO, JZERO, XTEST
000002 COMMON /PIPOUT/ XSUM, QSUM, RSUM, XSR, ZFRONT, JFND, PREG, PREG
000002 COMMON /LNG/ JSTART, JSAV, XL12, XL123
C
000002 WRITE(6,10)
000005 10 FORMAT(/,2X,*ITERATING IN START2*)
000006 I9=0
000007 MOREJ=-1
000010 DO 100 I=1,JSTART
000012 VV(I)=VSAV(I)
000015 PP(I)=PSAV(I)
000020 ZZ(I)=ZSAV(I)
000023 VV(I)=VSAV(I)
000026 QQ(I)=QSAV(I)
000031 100 CONTINUE
000034 VSTART=VSAV(JSTART)
000037 ZSTART=ZSAV(JSTART)
000042 XSTART=XSAV(JSTART)
000045 QSTART=QSAV(JSTART)
000050 P=PSAV(JSTART)
000053 CALL SATUP(P,TSTART)
000055 TDIFF=DELTEE/(2.*TEV)
000060 DO 101 J=1,30
000062 IF (IB.EQ.0) TDIFF=2.*TDIFF
000065 IF (IB.EQ.1) TDIFF=TDIFF/2.
000071 SIGN=-MOREJ
  
```

START 2

Unclass

N74-13663

(NASA CR 114872) USER'S MANUAL FOR THE TRW GASPIPE 2 PROGRAM:
A VAPOR-GAS FRONT ANALYSIS PROGRAM FOR HEAT PIPES CONTAINING
NON-CONDENSIBLE GAS. D.K. Edwards, et al (TRW Systems Group) Oct.
1973. 128 p. GSCL 20M

33

GS

RUNX COMPILED (VER.26)

10/02/73. 15.05.14.

START2

```

000073      TSTART=TSTART+SIGN*TDIFF
000076      TMIN=TSTART
000100      VZERO=VSTART
000102      PZERO=PHI(TSTART)
000105      ZZERO=ZSTART
000107      XZERO=XSTART
000111      QZERO=QSTART
000113      JZERO=JSTART
000115      IF(ZZERO.EQ.XL1) CALL JOINT(1,PZERO,VZERO,VZERO)
000122      IF(ZZERO.GE.XL1) GO TO 200
000125      CALL CONSEC(1)
000127      CALL PIPE
000130      CALL JOINT(1,PZERO,VZERO,VZERO)
000133      200 CONTINUE
000133      IF(ZZERO.EQ.XL12) CALL JOINT(2,PZERO,VZERO,VZERO)
000140      IF(ZZERO.GE.XL12) GO TO 300
000143      CALL CONSEC(2)
000145      CALL PIPE
000146      CALL JOINT(2,PZERO,VZERO,VZERO)
000151      300 CONTINUE
000151      CALL CONSEC(3)
000153      CALL PIPE
000154      CALL TESTE(MOREJ)
000155      WRITE(6,15) T,TSTART,XSUM,QSUM,JEND,MOREJ
000176      15 FORMAT(/,5X,*I=*,I4,2X,*TSTART=*,F10.5,2X,
000176      1 *GAS,I.E.,XSUM=*,E12.5,2X,*QSUM=*E12.5,
000176      2 2X,*JEND=*,I4,2X,*MOREJ=*,I4)
000176      IF(MOREJ.EQ.0) RETURN
000200      IF(MOREJ.GT.0) IS=1
000203      101 CONTINUE
000205      WRITE(6,20)
000211      20 FORMAT(/,2X,*FAILED TO CONVERGE IN START2*)
000211      CALL EXIT
000212      END

```

START 2

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13111-6054-R0-00

RUNX COMPILER (VER.26)

10/02/73. 15.05.14.

SUBROUTINE SURF(TI,S,TC)

```
000006 COMMON /WORK/ XL, TS, C, F, H, EMIS, TMIN, ZF
000006 DENOM = 4.0*EMIS*TI**3+H
000012 S = F/DENOM
000014 TC = (EMIS*TS**4+4*TS+3.0*EMIS*TI**4)/DENOM
000025 RETURN
000026 END
```

SURF

TRIP
RUNX COMPILER (VER.26)

10/02/73, 15.05.14.

SUBROUTINE TESTF(MOREJ)

```
C      TESTF TESTS TO FIND WHETHER QSUM OR XSUM
C      IS ALL RIGHT OR NEEDS MORE OR LESS GAS CONTROL
000003  COMMON /PIPDTA/ TEV, DFT, Q, GAS, TR, VR, VPRES, QZ, P, COEF, ITRP
000003  COMMON /INTC/  NPRES, MODEQM, ZPRINT, NRUN, NERROR
000003  COMMON /PIPOUT/ XSUM, QSUM, RSUM, XSR, ZFRONT, JEND, PREQ, PREG
000003  IF(MODEQM.EQ.1) GO TO 100
C      PRESCRIBED Q HERE
000005  TEST=QSUM-Q
000007  MOREJ=0
000010  IF(ABS(TEST).LT.PREQ) RETURN
000014  MOREJ=1
000015  IF(TEST.GT.0.) RETURN
000017  MOREJ=-1
000020  RETURN
000021  100 CONTINUE
C      PRESCRIBED GAS HERE
000021  TEST=XSUM-GAS
000023  MOREJ=0
000024  IF(ABS(TEST).LT.PREG) RETURN
000030  MOREJ=1
000031  IF(TEST.LT.0.) RETURN
000033  MOREJ=-1
000034  RETURN
000035  END
```

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TESTF

13111-6054-R0-00

APPENDIX C
SAMPLE PROBLEM

One sample problem consists of a performance run for a variable conductance heat pipe for temperature control of NASA's Lunar Surface Magnetometer (LSM). The function of the LSM heat pipe, illustrated in Figure C-1, is to supplement heat rejection during the lunar day while shutting down during the night. It is a passive, gas controlled heat pipe utilizing a cold, wicked gas reservoir. The design details are summarized in Table C-1.

At the "full-on" condition the boundary conditions were stated as follows:

Heat Rejection	> 4 Btu/hr
Evaporator Temperature	≤ 530°R
Effective Sink Temperature	= 495°R

The gas front will form in the cold trap region of the radiator at the end of the condenser, and may extend into the main radiator. Thus, Section 1 of the condenser (cards 5 and 10) consists of the cold trap region, and the main radiator will comprise Section 2 (cards 6 and 11). Note that, in terms of the model, the condenser is visualized as a straight tube with no bends; i.e., the radiator is considered one-half its actual width and twice the actual length. There is some error in this approach if the front extends into the main radiator, in that the bend section offers additional resistance to axial conduction, but the results will be conservative. There is negligible error in not using the actual condenser length, for the control gas occupies only a small portion of the entire length.

An input form for the sample run is shown in Figure C-2. The fluid properties were obtained from Table 4-1. Note that the fin width (PF1) is slightly less than the actual radiator width in the cold trap region to account for the reduced area due to gaps between the fin segments. Using the approximation discussed in Section 4-3 (Eq. 4-4) the effective axial conductivity of the cold trap is calculated as follows:*

*This approach neglects the axial conductance due to the axial metal felt wick inside the heat pipe.

$$(A_c)_{\text{fin}} = AF1 = (3.18) (0.016) = 0.0509 \text{ in}^2$$

$$A_{\text{wall}} = \frac{\pi}{4} (0.25^2 - 0.21^2) = 0.0145 \text{ in}^2$$

$$CF1 = \frac{9.3 (0.0145)}{0.0509} \left[\frac{4.5}{8 (0.2)} - 1 \right] = 4.80 \frac{\text{Btu}}{\text{hr-ft-}^\circ\text{F}}$$

The effective conductivity of the main radiator is simply the thermal conductivity of aluminum since there are no fin segments. Also,

$$AF2 = (3.5) (0.016) = 0.056 \text{ in}^2$$

Because the circumferential grooves offer negligible radial heat transfer resistance, a wick thickness of 0.001 in. was input, which roughly corresponds to the average groove depth. For this reason the wick conductivity was assumed to be the conductivity of the working fluid. The axial wick was treated as an artery.

$$(A_c)_{\text{wick}} = (0.02) (0.21) = 0.0042 \text{ in}^2$$

$$\begin{aligned} \text{DART} &= \left(\frac{4 (0.0042)}{\pi} \right)^{\frac{1}{2}} \\ &= 0.073 \text{ in.} \end{aligned}$$

The effective sink temperature was input as follows:

$$\begin{aligned} \text{POW1} = \text{POW2} &= (0.1712 \times 10^{-8}) (0.85) (495)^4 \\ &= 87.5 \text{ Btu/hr-ft}^2 \end{aligned}$$

Finally, the nominal value for the heat input was estimated using Eq. (4-7).

$$\begin{aligned} \dot{Q} &< \frac{(0.959)(3.18)(4.5)}{144} [(0.85)(0.1712 \times 10^{-8})(530)^4 - 87.5] \\ &+ \frac{(0.959)(3.5)(7.5)}{144} [(0.85)(0.1712 \times 10^{-8})(530)^4 - 87.5] \end{aligned}$$

$$\dot{Q} < 7.44 \text{ Btu/hr}$$

TABLE C-I
HEAT PIPE DESIGN DETAILS

Pipe:

Material: 321 stainless steel
 Outside Diameter = 0.250 in.
 Wall Thickness = 0.020 in.
 Evaporator Length = 2.0 in.
 Condenser Length = 13.5 in.
 Adiabatic Length = 3.5 in.

Radiator:

Material: 6061 aluminum sheet (0.016 in. thick)
 Cold Trap: N = 9 fin segments
 L = 4.5 in.
 L_f = 0.30 in.
 L_g = 0.2 in.

Wick Structure:

Material: Stainless steel
 Description: Metal felt axial wick (0.21 in. X 0.02 in.)
 with circumferential grooves in the tube
 wall.

Reservoir:

Type: Cold, wicked
 Volume: 0.79 in.

Working Fluid: Methanol

Control Gas: Nitrogen (1.26×10^{-7} lb-moles)

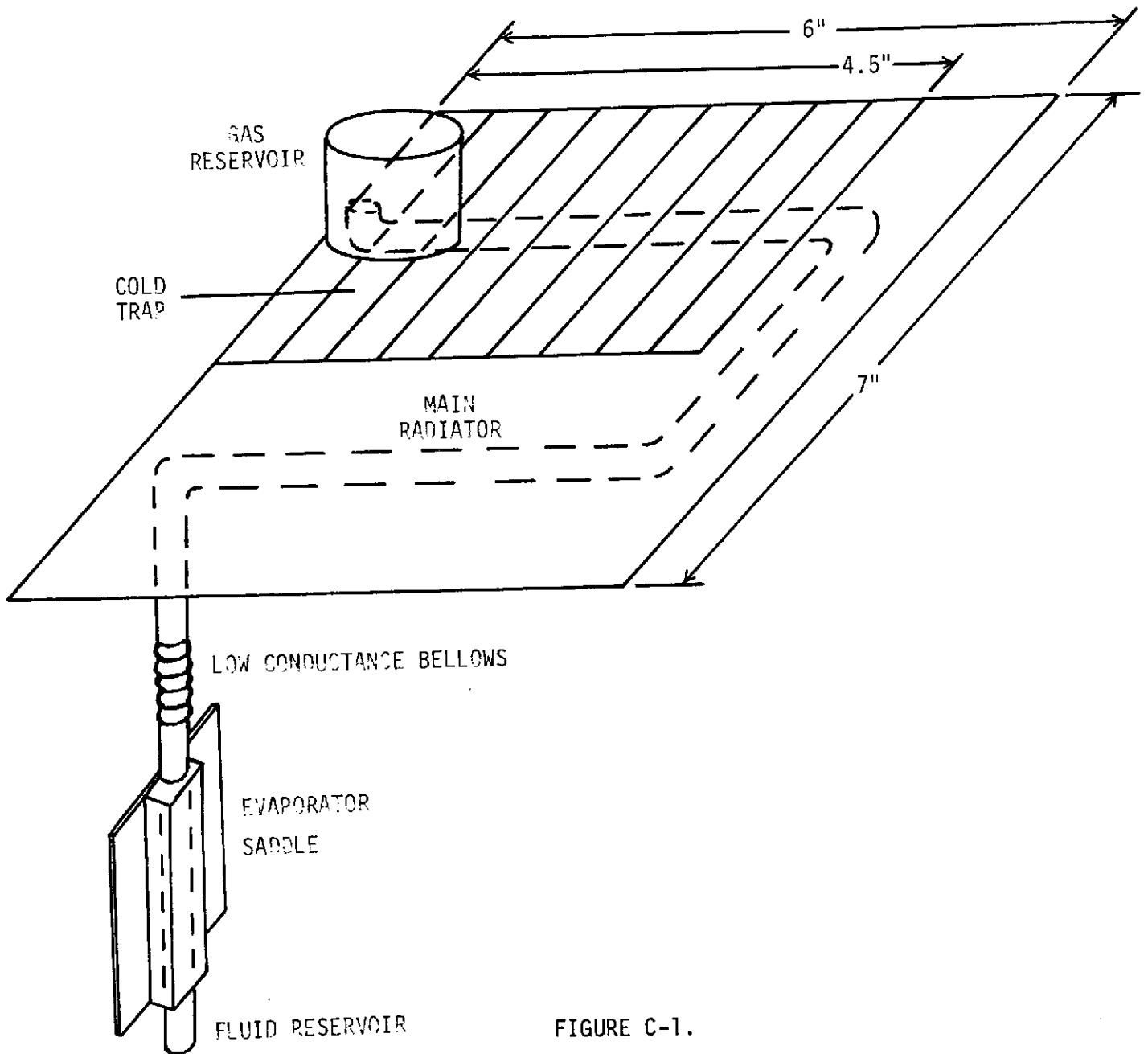


FIGURE C-1.
LUNAR SURFACE MAGNETOMETER HEAT PIPE

CARD	FORMAT	DESCRIPTION					
1	72H	1 SAMPLE PROBLEM 1					
2	72H	A SHORT HEAT PIPE					
		PARAMETERS					
3	3F12.5	A11	B11	C11			
		14.48	6262.17	557386.2			
4	4F12.5	XMC	DIF	E	HFG		
		32.0	0.442	0.81	501.0		
5	6F12.5	PF1	AF1	CF1	EF1	EMIS1	HF1
		3.18	0.051	4.8	0.96	0.85	0.0
6	6F12.5	PF2	AF2	CF2	EF2	EMIS2	HF2
		3.50	0.056	104.0	0.96	0.85	
7	6F12.5	DOUTA	THKWA	CWA	DELA	CWKA	XLINGA
		0.250	0.020	9.30	0.0010	0.120	0.500
8	3F12.5	DOUT	THKW	CW			
		0.25	0.02	9.3			
9	3F12.5	DEL	CONWK	DART			
		0.001	0.12	0.073			
10	3F12.5	TF1	POW1	XLONG1			
		0.	87.5	0.375			
11	3F12.5	TF2	POW2	XLONG2			
		0.	87.5	0.625			
12	3F12.5 E12.5	TEV	Q	ZGAS	AGAS		
		530.	5.0	0.	1.26E-07		
13	2F12.5 2I4, F12.5, I4	VRES	TRES	NRES	MODEQM	PRINT	NRUN
		0.79	495.0	2	1	0.50	

FIGURE C-2. Sample Input, LSM Heat Pipe

The second sample problem consists of a prediction for the AHPE (Ames Heat Pipe Experiment). The pipe, illustrated in Figure C-3, flew on board OAO-C (Orbiting Astronomical Observatory, Configuration C) launched in August 1972. The pipe provides temperature control for the spacecraft's OBP (On Board Processor) platform, keeping it at $60 \pm 5^\circ\text{F}$ despite large variations in environmental conditions and power dissipation loads. It utilizes a hot, nonwicked reservoir containing helium to control the heat rejection by the methanol working fluid. Axial conductivity was minimized by slots in the radiator fins as shown in the figure.

Figure C-4 shows the input data for the sample run, and the output follows.

AMES HEAT PIPE EXPERIMENT (AMPE) VARIABLE CONDUCTANCE

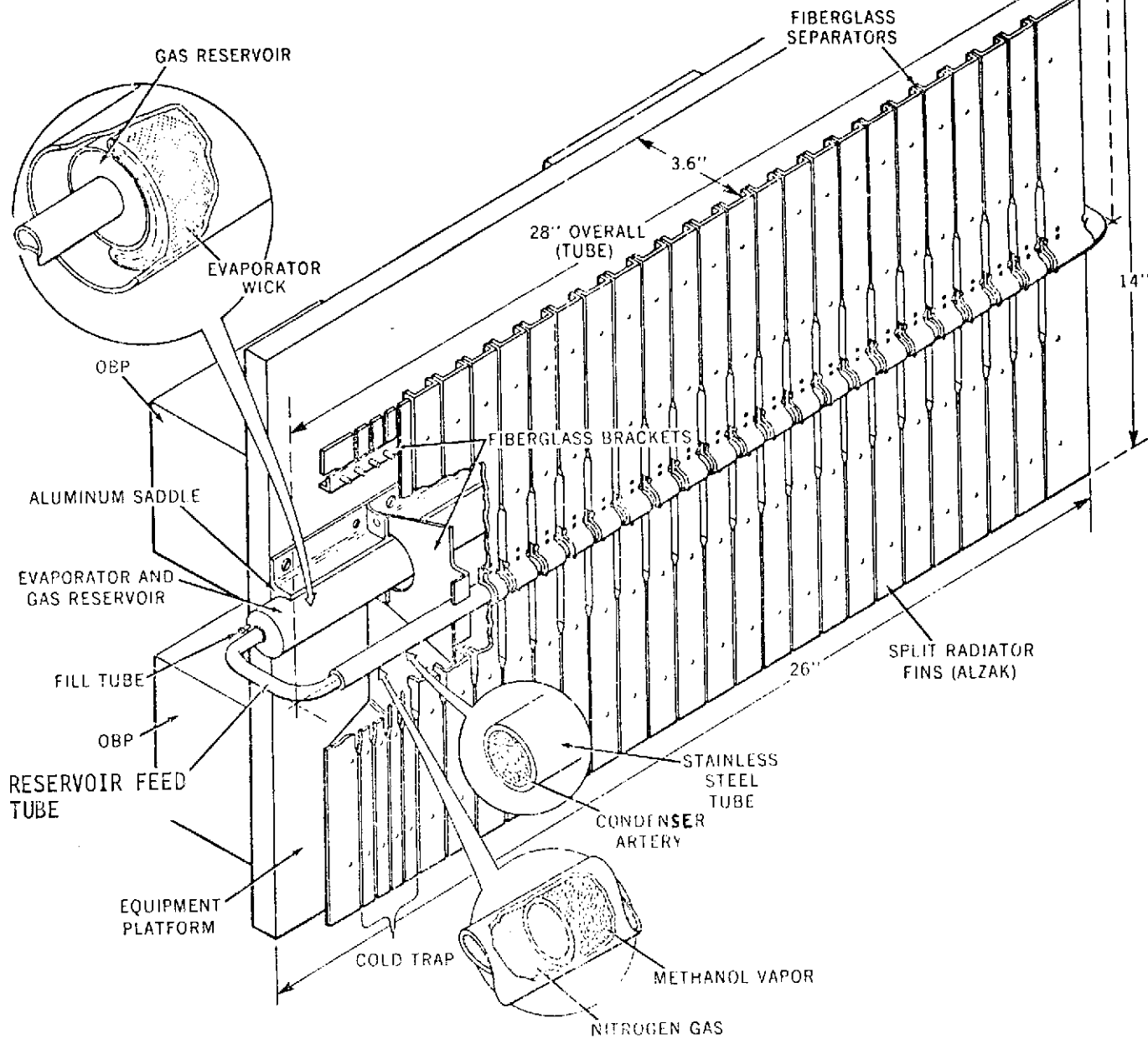


Figure C-3

C-7

CARD	FORMAT	DESCRIPTION					
1	72H	1 SAMPLE PROBLEM 2					
2	72H	A LONG HEAT PIPE					
3	3F12.5	A11	B11	C11			
		14.48	6262.17	557386.2			
4	4F12.5	XMC	DIF	E	HFG		
		32.0	1.77	.91	501.		
5	6F12.5	PF1	AF1	CF1	EF1	EMIS1	HF1
		14.3	0.458	0.545	0.85	0.75	
6	6F12.5	PF2	AF2	CF2	EF2	EMIS2	HF2
		14.3	0.458	1.1	0.89	0.75	0.48
7	6F12.5	DOUTA	THKWA	CWA	DELA	CWKA	XLONGA
		0.437	0.035	6.51	0.0052	0.09	0.30
8	3F12.5	DOUT	THKW	CW			
		0.437	0.035	6.51			
9	3F12.5	DEL	CONWK	DART			
		0.0052	0.09	0.205			
10	3F12.5	TF1	POW1	XLONG1			
		0.0	42.3	0.25			
11	3F12.5	TF2	POW2	XLONG2			
		544.0	42.3	1.960			
12	3F12.5 E12.5	TEV	Q	ZGAS			
		539.0	5.0	1.0			
13	2F12.5 2I4, F12.5, I4	VRES	TRES	NRES	MODEQM	ZPRINT	NRUN
		13.2	539.0	0	1	0.500	

FIGURE C-4. Sample Input, AHPE Heat Pipe

SAMPLE PROBLEM 1
A SHORT HEAT PIPE

VAPOR PRESSURE PARAMETERS

A11=14.49000E+00 B11=62.62170E+02 C11=55.73862E+04

FLUID PROPERTIES

HFG= 501.0000 BTU/LB DTF= .4420 FTFT/HR XMC= 32.0000 CD EXP= .8100

FIN PROPERTIES, CONDENSER SECTION NUMBER 1

PF= 3.1800 IN AF= .0510 SQ IN CF= 4.8000 BTU/HRFT² EF= .9600 EMIS= .8500 HF= -0.0000 BTU/HRFT²R

FIN PROPERTIES, CONDENSER SECTION NUMBER 2

PF= 3.5000 IN AF= .0560 SQ IN CF=104.0000 BTU/HRFT² EF= .9600 EMIS= .8500 HF= -0.0000 BTU/HRFT²R

ADIABATIC SECTION PROPERTIES

DOUTA= .2500 IN. THKWA= .0200 IN.
CHA= 9.3000 BTU/HRFT² DELA= .0010 CWKA= .1200 BTU/HRFT² XLONGA= .5000 FT

PIPE PROPERTIES

DOUT= .2500 IN WALL THK= .0200 IN WALL COND= 9.3000 BTU/HRFT²

CONDENSER ENVIRONMENT, SECTION NUMBER 1

TF= 0. R POW= 4.3700E+01 BTU/HRFT² XLONG= 3.7500E-01 FT

CONDENSER ENVIRONMENT, SECTION NUMBER 2

TF= 0. R POW= 8.7500E+01 BTU/HRFT² XLONG= 6.2500E-01 FT

EXAMPLE 1

WICK PROPERTIES AND RESERVOIR CONDITIONS

WCK THK= .0019 IN WCK CON= .1200 BTU/HRFT D-ART= .0730 IN VRES= .7900 CU IN TRES= 495.0 R NRES= 2

OPERATING CONDITIONS

TEV= 5.3000E+02 R Q= 5.0000E+00 BTU/HR MODFQM= 1 CEV= 3.4745E-04 LBMOL/FT3 TTRAP= -0. R

AMOUNT OF NONCONDENSIBLE GAS

GAS= 1.7216E+02 ZGAS= 1.0000E-02 FT AGAS= -0. LBMOLF COEF= 1.1668E-09 LBMOLF
AMT= 2.0088E-07 LBMOLF XGAS= 1.0000E-02 FT

DIMENSIONLESS TEMPERATURES

TZ= 1.6327E+01 TS1= 7.2521E-01 TS2= 9.3406E-01 TP= 7.9521E-01 TTRP= 0.

DIMENSIONLESS CONDENSER PARAMETERS, SECTION NO. 1

EMIS= 9.5000E-01 C= 1.7201E+01 F= 1.1159E-01 H= 0. XL= 2.3104E+01 XS= 9.8851E-01

DIMENSIONLESS CONDENSER PARAMETERS, SECTION NO. 2

EMIS= 8.5000E-01 C= 2.7023E+02 F= 1.2293E-01 H= 0. XL= 3.8507E+01 XS= 6.7515E-01

DIMENSIONLESS ADIABATIC SECTION PARAMETERS

C3= 6.09988E+00 PA= 7.37702E-03 DIA01= 1.00962E+00 R= 7.37702E-03 XL3= 3.08057E+01

ITERATING IN PATCH

C-10

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ITER= 0	TSTART= .78588	Z1= 59.93265	XL1= 23.10428
ITER= 1	TSTART= .85987	Z1= 10.13391	XL1= 23.10428
ITER= 2	TSTART= .82277	Z1= 17.25290	XL1= 23.10428
ITER= 3	TSTART= .80423	Z1= 24.00287	XL1= 23.10428
ITER= 4	TSTART= .81350	Z1= 20.08438	XL1= 23.10428
ITER= 5	TSTART= .80887	Z1= 21.85655	XL1= 23.10428
ITER= 6	TSTART= .80655	Z1= 22.87404	XL1= 23.10428

ITERATING IN LONG

ITER= 0 JSTART= 1 XSUM= 1.88245E+02 QSUM= 1.59521E+00 JEND= 374 MOPEJ= -1

ITERATING IN SHORT

ITER= 1	TSTART= .90328	XSUM= 1.30764E+02	QSUM= 2.07965E+00
ITER= 2	TSTART= .85402	YSUM= 1.63910E+02	QSUM= 1.79534E+00
ITER= 3	TSTART= .83074	YSUM= 1.77305E+02	QSUM= 1.55440E+00
ITER= 4	TSTART= .84283	XSUM= 1.70100E+02	QSUM= 1.68818E+00
ITER= 5	TSTART= .83678	XSUM= 1.73666E+02	QSUM= 1.62534E+00
ITER= 6	TSTART= .83980	XSUM= 1.71877E+02	QSUM= 1.65767E+00

TRES = 4.4510E+02 DEG R XCR = 9.5418E-01 RESGAS = 1.8048E-07 LB-MOLES

J = 1	ZIN = 4.8692E-02 INCHES	Z = 2.5000E-01	TI = 8.3982E-01
	V = 9.0850E-06	P = 4.5442E-02	MASSFLOW = 9.0668E-08 LB/HR
	XSUM = 1.5496E+02	QSUM = 2.7790E-03	TWICK = 4.4511E+02 DEG R
	QFLOW = 1.3895E-02 BTU/HR	XS = 9.5416E-01	
	TWALL = 4.4506E+02 DEG R	MGAS = 1.8081E-07 LB-MOLES	

J = 11	ZIN = 5.3562E-01 INCHES	Z = 2.7500E+00	TI = 8.4226E-01
	V = 1.0734E-04	P = 4.8133E-02	MASSFLOW = 1.0713E-06 LB/HR
	XSUM = 1.5789E+02	QSUM = 3.1069E-02	TWICK = 4.4640E+02 DEG R
	QFLOW = 1.5535E-01 BTU/HR	XS = 9.5148E-01	
	TWALL = 4.4635E+02 DEG R	MGAS = 1.8412E-07 LB-MOLES	

J = 21	ZIN = 1.0225E+00 INCHES	Z = 5.2500E+00	TI = 8.4894E-01
	V = 2.4882E-04	P = 5.6301E-02	MASSFLOW = 2.4833E-06 LB/HR
	XSUM = 1.6060E+02	QSUM = 6.1935E-02	TWICK = 4.4994E+02 DEG R
	QFLOW = 3.0967E-01 BTU/HR	XS = 9.4338E-01	
	TWALL = 4.4989E+02 DEG R	MGAS = 1.8739E-07 LB-MOLES	

J = 31	ZIN = 1.5095E+00 INCHES	Z = 7.7500E+00	TI = 8.6044E-01
	V = 5.0925E-04	P = 7.3405E-02	MASSFLOW = 5.0823E-06 LB/HR
	XSUM = 1.6334E+02	QSUM = 9.8956E-02	

OFLOW = 4.9028E-01 BTU/HR XS = 9.2664E-01 TWICK = 4.5603E+02 DEG R
 TWALL = 4.5607E+02 DEG R MGAS = 1.9050E-07 LB-MOLES

J = 42 ZIN = 2.0451E+00 INCHES Z = 1.0500E+01 TI = 8.7980E-01
 V = 1.1795E-03 P = 1.1368E-01 MASSFLOW = 1.1772E-05 LB/HR
 XSUM = 1.6622E+02 QSUM = 1.4796E-01 TWICK = 4.6629E+02 DEG R
 OFLOW = 7.3981E-01 BTU/HR XS = 8.8848E-01
 TWALL = 4.6621E+02 DEG R MGAS = 1.9394E-07 LB-MOLES

J = 52 ZIN = 2.5320E+00 INCHES Z = 1.3000E+01 TI = 9.0516E-01
 V = 2.9189E-03 P = 1.9938E-01 MASSFLOW = 2.9111E-05 LB/HR
 XSUM = 1.6862E+02 QSUM = 2.0780E-01 TWICK = 4.7974E+02 DEG R
 OFLOW = 1.0390E+00 BTU/HR XS = 8.1279E-01
 TWALL = 4.7963E+02 DEG R MGAS = 1.9674E-07 LB-MOLES

J = 62 ZIN = 3.0189E+00 INCHES Z = 1.5500E+01 TI = 9.4015E-01
 V = 9.4322E-03 P = 4.3650E-01 MASSFLOW = 9.4134E-05 LB/HR
 XSUM = 1.7062E+02 QSUM = 2.8888E-01 TWICK = 4.9828E+02 DEG R
 OFLOW = 1.4444E+00 BTU/HR XS = 6.3679E-01
 TWALL = 4.9813E+02 DEG R MGAS = 1.9908E-07 LB-MOLES

J = 72 ZIN = 3.5058E+00 INCHES Z = 1.8000E+01 TI = 9.8599E-01
 V = 7.3376E-02 P = 1.5747E+00 MASSFLOW = 7.3230E-04 LB/HR
 XSUM = 1.7179E+02 QSUM = 4.0226E-01 TWICK = 5.2257E+02 DEG R
 OFLOW = 2.0113E+00 BTU/HR XS = 2.0125E-01
 TWALL = 5.2236E+02 DEG R MGAS = 2.0045E-07 LB-MOLES

J = 83 ZIN = 4.0415E+00 INCHES Z = 2.0750E+01 TI = 1.0000E+00
 V = 5.6118E-01 P = 1.9487E+01 MASSFLOW = 5.6005E-03 LB/HR
 XSUM = 1.7189E+02 QSUM = 5.6150E-01 TWICK = 5.3000E+02 DEG R
 OFLOW = 2.8075E+00 BTU/HR XS = 3.3408E-09
 TWALL = 5.2977E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 94 ZIN = 4.5487E+00 INCHES Z = 2.3354E+01 TI = 1.0000E+00
 V = 7.0555E-01 P = 4.6968E+01 MASSFLOW = 7.0414E-03 LB/HR
 XSUM = 1.7188E+02 QSUM = 7.0587E-01 TWICK = 5.3000E+02 DEG R
 OFLOW = 3.5293E+00 BTU/HR XS = 0.
 TWALL = 5.2900E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 95 ZIN = 4.5974E+00 INCHES Z = 2.3604E+01 TI = 1.0000E+00
 V = 7.1177E-01 P = 4.9902E+01 MASSFLOW = 7.1035E-03 LB/HR
 XSUM = 1.7188E+02 QSUM = 7.1209E-01

OFLOW = 3.5604E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.2990E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 104 ZIN = 5.0356E+00 INCHES Z = 2.5854E+01
 V = 7.6775E-01 P = 7.7463E+01 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 7.6807E-01 MASSFLOW = 7.6621E-03 LB/HR
 OFLOW = 3.8403E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.2990E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 114 ZIN = 5.5225E+00 INCHES Z = 2.8354E+01
 V = 8.2994E-01 P = 1.1053E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 8.3026E-01 MASSFLOW = 8.2829E-03 LB/HR
 OFLOW = 4.1513E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.2990E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 124 ZIN = 6.0095E+00 INCHES Z = 3.0854E+01
 V = 8.9214E-01 P = 1.4618E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 8.9246E-01 MASSFLOW = 8.9036E-03 LB/HR
 OFLOW = 4.4623E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.2990E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 135 ZIN = 6.5451E+00 INCHES Z = 3.3604E+01
 V = 9.6056E-01 P = 1.8836E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 9.6088E-01 MASSFLOW = 9.5864E-03 LB/HR
 OFLOW = 4.8044E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.2990E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 145 ZIN = 7.0720E+00 INCHES Z = 3.6104E+01
 V = 1.0223E+00 P = 2.2941E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.0231E+00 MASSFLOW = 1.0207E-02 LB/HR
 OFLOW = 5.1154E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.2990E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 155 ZIN = 7.5189E+00 INCHES Z = 3.8604E+01
 V = 1.0850E+00 P = 2.7304E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.0853E+00 MASSFLOW = 1.0828E-02 LB/HR
 OFLOW = 5.4264E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.2990E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 165 ZIN = 8.0058E+00 INCHES Z = 4.1104E+01
 V = 1.1472E+00 P = 3.1924E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.1475E+00 MASSFLOW = 1.1449E-02 LB/HR

	QFLOW = 5.7374E+00 BTU/HR	XS = 0.	TWICK = 5.3000E+02 DEG R
	TWALL = 5.2990E+02 DEG R	MGAS = 2.0755E-07 LB-MOLES	
J = 176	ZIN = 8.5415E+00 INCHES	Z = 4.3854E+01	
	V = 1.2156E+00	P = 3.7303E+02	TI = 1.0000E+00
	XSUM = 1.7188E+02	OSUM = 1.2159E+00	MASSFLOW = 1.2131E-02 LB/HR
	QFLOW = 6.0794E+00 BTU/HR	XS = 0.	TWICK = 5.3000E+02 DEG R
	TWALL = 5.2990E+02 DEG R	MGAS = 2.0055E-07 LB-MOLES	
J = 186	ZIN = 9.0284E+00 INCHES	Z = 4.6354E+01	
	V = 1.2778E+00	P = 4.2464E+02	TI = 1.0000E+00
	XSUM = 1.7188E+02	OSUM = 1.2781E+00	MASSFLOW = 1.2752E-02 LB/HR
	QFLOW = 6.3904E+00 BTU/HR	XS = 0.	TWICK = 5.3000E+02 DEG R
	TWALL = 5.2990E+02 DEG R	MGAS = 2.0055E-07 LB-MOLES	
J = 196	ZIN = 9.5153E+00 INCHES	Z = 4.8854E+01	
	V = 1.3400E+00	P = 4.7883E+02	TI = 1.0000E+00
	XSUM = 1.7188E+02	OSUM = 1.3403E+00	MASSFLOW = 1.3373E-02 LB/HR
	QFLOW = 6.7014E+00 BTU/HR	XS = 0.	TWICK = 5.3000E+02 DEG R
	TWALL = 5.2990E+02 DEG R	MGAS = 2.0055E-07 LB-MOLES	
J = 206	ZIN = 1.0002E+01 INCHES	Z = 5.1354E+01	
	V = 1.4022E+00	P = 5.3558E+02	TI = 1.0000E+00
	XSUM = 1.7188E+02	OSUM = 1.4025E+00	MASSFLOW = 1.3994E-02 LB/HR
	QFLOW = 7.0124E+00 BTU/HR	XS = 0.	TWICK = 5.3000E+02 DEG R
	TWALL = 5.2990E+02 DEG R	MGAS = 2.0055E-07 LB-MOLES	
J = 217	ZIN = 1.0538E+01 INCHES	Z = 5.4104E+01	
	V = 1.4706E+00	P = 6.0099E+02	TI = 1.0000E+00
	XSUM = 1.7188E+02	OSUM = 1.4709E+00	MASSFLOW = 1.4676E-02 LB/HR
	QFLOW = 7.3545E+00 BTU/HR	XS = 0.	TWICK = 5.3000E+02 DEG R
	TWALL = 5.2990E+02 DEG R	MGAS = 2.0055E-07 LB-MOLES	
J = 227	ZIN = 1.1025E+01 INCHES	Z = 5.6604E+01	
	V = 1.5328E+00	P = 6.6315E+02	TI = 1.0000E+00
	XSUM = 1.7188E+02	OSUM = 1.5331E+00	MASSFLOW = 1.5297E-02 LB/HR
	QFLOW = 7.6655E+00 BTU/HR	XS = 0.	TWICK = 5.3000E+02 DEG R
	TWALL = 5.2990E+02 DEG R	MGAS = 2.0055E-07 LB-MOLES	
J = 237	ZIN = 1.1512E+01 INCHES	Z = 5.9104E+01	
	V = 1.5950E+00	P = 7.2789E+02	TI = 1.0000E+00
	XSUM = 1.7188E+02	OSUM = 1.5953E+00	MASSFLOW = 1.5918E-02 LB/HR

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OFLOW = 7.9765E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.2900E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 249 ZIN = 1.2049E+01 INCHES Z = 6.1961E+01
 V = 1.6574E+00 P = 8.0227E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 250 ZIN = 1.2097E+01 INCHES Z = 6.2111E+01
 V = 1.6574E+00 P = 8.0913E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 259 ZIN = 1.2536E+01 INCHES Z = 6.4361E+01
 V = 1.6574E+00 P = 8.7087E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 269 ZIN = 1.3023E+01 INCHES Z = 6.6861E+01
 V = 1.6574E+00 P = 9.3948E+02 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 279 ZIN = 1.3509E+01 INCHES Z = 6.9361E+01
 V = 1.6574E+00 P = 1.0081E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 290 ZIN = 1.4046E+01 INCHES Z = 7.2111E+01
 V = 1.6574E+00 P = 1.0836E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 300 ZIN = 1.4532E+01 INCHES Z = 7.4611E+01
 V = 1.6574E+00 P = 1.1522E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR

OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 310 ZIN = 1.5019E+01 INCHES Z = 7.7111E+01
 V = 1.6574E+00 P = 1.2208E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 320 ZIN = 1.5506E+01 INCHES Z = 7.9611E+01
 V = 1.6574E+00 P = 1.2894E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 331 ZIN = 1.6041E+01 INCHES Z = 8.2361E+01
 V = 1.6574E+00 P = 1.3649E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 341 ZIN = 1.6528E+01 INCHES Z = 8.4961E+01
 V = 1.6574E+00 P = 1.4335E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 351 ZIN = 1.7015E+01 INCHES Z = 8.7361E+01
 V = 1.6574E+00 P = 1.5021E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 361 ZIN = 1.7502E+01 INCHES Z = 8.9861E+01
 V = 1.6574E+00 P = 1.5707E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR
 OFLOW = 8.2883E+00 BTU/HR XS = 0. TWICK = 5.3000E+02 DEG R
 TWALL = 5.3000E+02 DEG R MGAS = 2.0055E-07 LB-MOLES

J = 372 ZIN = 1.8000E+01 INCHES Z = 9.2417E+01
 V = 1.6574E+00 P = 1.6408E+03 TI = 1.0000E+00
 XSUM = 1.7188E+02 QSUM = 1.6577E+00 MASSFLOW = 1.6540E-02 LB/HR

QFLOW = 8.2883E+00 BTU/HR

XS = 0.

THICK = 5.3000E+02 DEG R

TWALL = 5.3000E+02 DEG R

MGAS = 2.0055E-07 LB-MOLES

GAS IN ONE DZ STEP OF GAS-BLOCKED CONDENSER 1 = 3.67221E-10 LB-MOLES

POWER LCST BY ONE DZ STEP OF FULL-ON CONDENSER 1 = 7.33508E-02 BTU/HR

TOTAL GAS IN PIPE AND RESERVOIR = 2.00545E-07 LB-MOLES

TOTAL POWER LOST BY CONDENSERS = 8.28835E+00 BTU/HR

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SAMPLE PROBLEM 2
A LONG HEAT PIPE

VAPOR PRESSURE PARAMETERS

A11=14.48000E+00 B11=62.62170E+02 C11=55.73862E+04

FLUID PROPERTIES

HFG= 501.0000 BTU/LB DTF= 1.7700 FT/HR XMC= 32.0000 CD EXP= .9100

FIN PROPERTIES, CONDENSER SECTION NUMBER 1

PF= 14.3000 IN AF= .4580 SQ IN CF= .5450 BTU/HPFTR EF= .9500 EMIS= .7500 HF= -0.0000 BTU/HRFT2R

FIN PROPERTIES, CONDENSER SECTION NUMBER 2

PF= 14.3000 IN AF= .4580 SQ IN CF= 1.1000 BTU/HPFTR EF= .9900 EMIS= .7500 HF= .4800 BTU/HRFT2R

ADIABATIC SECTION PROPERTIES

DOUTA= .4370 IN. THKWA= .0350 IN.
CWA= 6.5100 BTU/HRFTP DFLA= .0052 CWKA= .0900 BTU/HRFTYR XLONGA= .3000 FT

PIPE PROPERTIES

DOUT= .4370 IN WALL THK= .0350 IN WALL COND= 6.5100 BTU/HPFTR

CONDENSER ENVIRONMENT, SECTION NUMBER 1

TF= 0. R POW= 4.2300E+01 BTU/HRFTFT XLONG= 2.5000E-01 FT

CONDENSER ENVIRONMENT, SECTION NUMBER 2

TF= 5.4400E+02 R POW= 4.2300E+01 BTU/HRFTFT XLONG= 1.9600E+00 FT

EXAMPLE 2

WICK PROPERTIES AND RESERVOIR CONDITIONS

WCK THK= .0052 IN WCK CON= .0900 BTU/HRFTP D-ART= .2050 IN VRES= 13.2000 CU IN TRES= 539.0 R NRES= 0

OPERATING CONDITIONS

TEV= 5.3000E+02 P Q= 5.0000E+00 PTU/HR MONEQM= 1 QEV= 4.4442E-04 LBMOLE/FT3 TTRAP= -0. R

AMOUNT OF NONCONDENSIBLE GAS

GAS= 7.0804E+02 ZGAS= 1.0000E+00 FT AGAS= -0. LBMOLE COEF= 5.0180E-09 LBMOLE
AMT= 3.5530E-06 LBMOLE XGAS= 1.0000E+00 FT

DIMENSIONLESS TEMPERATURES

TZ= 1.5965E+01 TS1= 7.9018E-01 TS2= 8.9883E-01 TP= 1.0000E+00 TTRP= 0.

DIMENSIONLESS CONDENSER PARAMETERS, SECTION NO. 1

EMIS= 7.5000E-01 C= 1.6561E+01 F= 7.1261E-01 H= 0. XL= 1.0282E+01 XS= 9.8558E-01

DIMENSIONLESS CONDENSER PARAMETERS, SECTION NO. 2

EMIS= 7.5000E-01 C= 2.4386E+01 F= 7.4614E-01 H= 1.7884E+00 XL= 8.0607E+01 XS= 8.2861E-01

DIMENSIONLESS ADIABATIC SECTION PARAMETERS

C3= 8.87568E+00 RA= 1.93942E-02 DIADI= 1.02916E+00 R= 1.93942E-02 XL3= 1.23378E+01

ITERATING IN PATCH

ITER=	0	TSTART=	.79065	Z1=	22.87307	XL1=	10.28154
ITER=	1	TSTART=	.84474	Z1=	3.48817	XL1=	10.28154
ITER=	2	TSTART=	.81769	Z1=	6.38581	XL1=	10.28154
ITER=	3	TSTART=	.80417	Z1=	9.15265	XL1=	10.28154
ITER=	4	TSTART=	.79741	Z1=	11.84004	XL1=	10.28154
ITER=	5	TSTART=	.80079	Z1=	10.28317	XL1=	10.28154

ITERATING IN LONG

ITER=	0	JSTART=	1	XSUM=	6.79337E+02	QSUM=	2.39200E+01	JEND=	423	MOREJ=	1
ITER=	1	JSTART=	207	XSUM=	7.29072E+02	QSUM=	7.54485E+00	JEND=	422	MOREJ=	-1
ITER=	2	JSTART=	104	XSUM=	7.05382E+02	QSUM=	1.54601E+01	JEND=	422	MOREJ=	1
ITER=	3	JSTART=	155	XSUM=	7.17112E+02	QSUM=	1.15409E+01	JEND=	422	MOREJ=	-1
ITER=	4	JSTART=	129	XSUM=	7.11132E+02	QSUM=	1.35389E+01	JEND=	422	MOREJ=	-1
ITER=	5	JSTART=	116	XSUM=	7.08142E+02	QSUM=	1.45379E+01	JEND=	422	MOREJ=	0

TRES = 5.3900E+02 DEG R XSX = 9.8558E-01 RESGAS = 3.3459E-06 LB-MOLES

J =	1	ZIN =	7.2478E-02 INCHES	Z =	2.4437E-01	TI =	8.0081E-01
		V =	2.4409E-05	P =	1.9035E-02		
		XSUM =	6.6337E+02	QSUM =	9.1593E-15	MASSFLOW =	2.4360E-07 LB/HR
		OFLOW =	4.5797E-15 BTU/HR	XS =	9.8099E-01	THICK =	4.3164E+02 DEG R
		THALL =	4.3152E+02 DEG R	MGAS =	3.3288E-06 LB-MOLES		

J =	7	ZIN =	5.1015E-01 INCHES	Z =	1.7484E+00	TI =	8.0183E-01
		V =	1.8074E-04	P =	1.9529E-02		
		XSUM =	6.6521E+02	QSUM =	1.7418E-02	MASSFLOW =	1.8038E-06 LB/HR
		OFLOW =	8.7089E-02 BTU/HR	XS =	9.8049E-01	THICK =	4.3219E+02 DEG R
		THALL =	4.3205E+02 DEG R	MGAS =	3.3380E-06 LB-MOLES		

J =	14	ZIN =	1.0208E+00 INCHES	Z =	3.4984E+00	TI =	8.0516E-01
		V =	4.3048E-04	P =	2.1224E-02		
		XSUM =	6.6734E+02	QSUM =	4.1702E-02	MASSFLOW =	4.2962E-06 LB/HR
		OFLOW =	2.0851E-01 BTU/HR	XS =	9.7977E-01	THICK =	4.3398E+02 DEG R
		THALL =	4.3382E+02 DEG R	MGAS =	3.3487E-06 LB-MOLES		

J =	21	ZIN =	1.5314E+00 INCHES	Z =	5.2484E+00	TI =	8.1145E-01
		V =	8.7251E-04	P =	2.4794E-02		
		XSUM =	6.6946E+02	QSUM =	7.5051E-02	MASSFLOW =	8.7077E-06 LB/HR
		OFLOW =	3.7526E-01 BTU/HR	XS =	9.7515E-01	THICK =	4.3737E+02 DEG R
		THALL =	4.3713E+02 DEG R	MGAS =	3.3594E-06 LB-MOLES		

J =	28	ZIN =	2.0420E+00 INCHES	Z =	6.9984E+00		
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	V = 1.8187E-03	P = 3.2009E-02	TI = 8.2197E-01
	XSUM = 6.7154E+02	OSUM = 1.2462E-01	MASSFLOW = 1.8151E-05 LB/HR
	QFLOW = 6.2399E-01 BTU/HR	XS = 9.6785E-01	TWICK = 4.4304E+02 DEG R
	TWALL = 4.4268E+02 DEG R	MGAS = 3.3698E-06 LB-MOLES	
J = 35	ZIN = 2.5526E+00 INCHES	Z = 8.7484E+00	
	V = 4.2618E-03	P = 4.7729E-02	TI = 8.3889E-01
	XSUM = 6.7357E+02	OSUM = 2.0170E-01	MASSFLOW = 4.2533E-05 LB/HR
	QFLOW = 1.0085E+00 BTU/HR	XS = 9.5211E-01	TWICK = 4.5216E+02 DEG R
	TWALL = 4.5159E+02 DEG R	MGAS = 3.3800E-06 LB-MOLES	
J = 42	ZIN = 3.1023E+00 INCHES	Z = 1.0632E+01	
	V = 7.0463E-03	P = 8.7844E-02	TI = 8.6574E-01
	XSUM = 6.7653E+02	OSUM = 2.7560E-01	MASSFLOW = 7.0322E-05 LB/HR
	QFLOW = 1.3780E+00 BTU/HR	XS = 9.1309E-01	TWICK = 4.6663E+02 DEG R
	TWALL = 4.6758E+02 DEG R	MGAS = 3.3948E-06 LB-MOLES	
J = 43	ZIN = 3.1753E+00 INCHES	Z = 1.0882E+01	
	V = 6.8701E-03	P = 9.3154E-02	TI = 8.6839E-01
	XSUM = 6.7679E+02	OSUM = 2.5394E-01	MASSFLOW = 6.8564E-05 LB/HR
	QFLOW = 1.2697E+00 BTU/HR	XS = 9.0906E-01	TWICK = 4.6806E+02 DEG R
	TWALL = 4.6893E+02 DEG R	MGAS = 3.3961E-06 LB-MOLES	
J = 48	ZIN = 3.5400E+00 INCHES	Z = 1.2132E+01	
	V = 5.6842E-03	P = 1.1705E-01	TI = 8.7873E-01
	XSUM = 6.7807E+02	OSUM = 1.6852E-01	MASSFLOW = 5.5728E-05 LB/HR
	QFLOW = 8.4258E-01 BTU/HR	XS = 8.8575E-01	TWICK = 4.7364E+02 DEG R
	TWALL = 4.7422E+02 DEG R	MGAS = 3.4026E-06 LB-MOLES	
J = 55	ZIN = 4.0506E+00 INCHES	Z = 1.3882E+01	
	V = 3.8565E-03	P = 1.4201E-01	TI = 8.8759E-01
	XSUM = 6.7980E+02	OSUM = 9.4749E-02	MASSFLOW = 3.8488E-05 LB/HR
	QFLOW = 4.7374E-01 BTU/HR	XS = 8.6307E-01	TWICK = 4.7841E+02 DEG R
	TWALL = 4.7873E+02 DEG R	MGAS = 3.4113E-06 LB-MOLES	
J = 62	ZIN = 4.5612E+00 INCHES	Z = 1.5632E+01	
	V = 2.4044E-03	P = 1.5812E-01	TI = 8.9253E-01
	XSUM = 5.8148E+02	OSUM = 5.3191E-02	MASSFLOW = 2.3996E-05 LB/HR
	QFLOW = 2.6595E-01 BTU/HR	XS = 8.4876E-01	TWICK = 4.8107E+02 DEG R
	TWALL = 4.8125E+02 DEG R	MGAS = 3.4197E-06 LB-MOLES	
J = 69	ZIN = 5.0719E+00 INCHES	Z = 1.7382E+01	

	V = 1.4278E-03		P = 1.6789E-01		TI = 8.9529E-01
	XSUM = 6.8714E+02		QSUM = 2.9786E-02		MASSFLOW = 1.4250E-05 LB/HR
	QFLOW = 1.4893E-01 BTU/HR		XS = 8.4021E-01		TWICK = 4.8256E+02 DEG R
	TWALL = 4.8265E+02 DEG R		MGAS = 3.4280E-06 LB-MOLES		
J = 75	ZIN = 5.5095E+00 INCHES		Z = 1.8892E+01		TI = 8.9666E-01
	V = 8.8983E-04		P = 1.7295E-01		
	XSUM = 6.8454E+02		QSUM = 1.8030E-02		MASSFLOW = 8.8806E-06 LB/HR
	QFLOW = 9.0150E-02 BTU/HR		XS = 8.3581E-01		TWICK = 4.8330E+02 DEG R
	TWALL = 4.8336E+02 DEG R		MGAS = 3.4350E-06 LB-MOLES		
J = 82	ZIN = 5.0202E+00 INCHES		Z = 2.0632E+01		TI = 8.9758E-01
	V = 4.9651E-04		P = 1.7645E-01		
	XSUM = 6.8616E+02		QSUM = 9.8642E-03		MASSFLOW = 4.9552E-06 LB/HR
	QFLOW = 4.9321E-02 BTU/HR		XS = 8.3279E-01		TWICK = 4.8380E+02 DEG R
	TWALL = 4.8383E+02 DEG R		MGAS = 3.4432E-06 LB-MOLES		
J = 89	ZIN = 6.5708E+00 INCHES		Z = 2.2382E+01		TI = 8.9808E-01
	V = 2.5825E-04		P = 1.7835E-01		
	XSUM = 6.8779E+02		QSUM = 5.0767E-03		MASSFLOW = 2.5773E-06 LB/HR
	QFLOW = 2.5384E-02 BTU/HR		XS = 8.3115E-01		TWICK = 4.8406E+02 DEG R
	TWALL = 4.8409E+02 DEG R		MGAS = 3.4513E-06 LB-MOLES		
J = 96	ZIN = 7.0414E+00 INCHES		Z = 2.4132E+01		TI = 8.9831E-01
	V = 1.0370E-04		P = 1.7927E-01		
	XSUM = 6.8949E+02		QSUM = 2.0284E-03		MASSFLOW = 1.0350E-06 LB/HR
	QFLOW = 1.0142E-02 BTU/HR		XS = 8.3036E-01		TWICK = 4.8419E+02 DEG R
	TWALL = 4.8421E+02 DEG R		MGAS = 3.4594E-06 LB-MOLES		
J = 103	ZIN = 7.5517E+00 INCHES		Z = 2.5881E+01		TI = 8.9883E-01
	V = 0.		P = 1.8130E-01		
	XSUM = 6.9102E+02		QSUM = 0.		MASSFLOW = 0. LB/HR
	QFLOW = 0. BTU/HR		XS = 8.2861E-01		TWICK = 4.8447E+02 DEG R
	TWALL = 4.8447E+02 DEG R		MGAS = 3.4675E-06 LB-MOLES		
J = 110	ZIN = 8.0613E+00 INCHES		Z = 2.7628E+01		TI = 8.9883E-01
	V = 0.		P = 1.8130E-01		
	XSUM = 6.9263E+02		QSUM = 0.		MASSFLOW = 0. LB/HR
	QFLOW = 0. BTU/HR		XS = 8.2861E-01		TWICK = 4.8447E+02 DEG R
	TWALL = 4.8447E+02 DEG R		MGAS = 3.4756E-06 LB-MOLES		
J = 117	ZIN = 8.5711E+00 INCHES		Z = 2.9375E+01		

	V = 1.1747E-04	P = 1.8322E-01	TI = 8.9932E-01
	XSUM = 6.9424E+02	QSUM = 3.3179E-04	MASSFLOW = 1.1724E-06 LB/HR
	QFLOW = 1.6589E-03 BTU/HR	XS = 8.2697E-01	TWICK = 4.8473E+02 DEG R
	TWALL = 4.8477E+02 DEG R	MGAS = 3.4837E-06 LB-MOLES	
J = 123	ZIN = 9.0088E+00 INCHES	Z = 3.0875E+01	TI = 8.9952E-01
	V = 2.4382E-04	P = 1.8400E-01	
	XSUM = 6.9562E+02	QSUM = 2.7314E-03	MASSFLOW = 2.4334E-06 LB/HR
	QFLOW = 1.3657E-02 BTU/HR	XS = 8.2630E-01	TWICK = 4.8484E+02 DEG R
	TWALL = 4.8482E+02 DEG R	MGAS = 3.4906E-06 LB-MOLES	
J = 130	ZIN = 9.5194E+00 INCHES	Z = 3.2625E+01	TI = 8.9997E-01
	V = 4.7522E-04	P = 1.8580E-01	
	XSUM = 6.9722E+02	QSUM = 7.0565E-03	MASSFLOW = 4.7427E-06 LB/HR
	QFLOW = 3.5283E-02 BTU/HR	XS = 8.2476E-01	TWICK = 4.8508E+02 DEG R
	TWALL = 4.8505E+02 DEG R	MGAS = 3.4987E-06 LB-MOLES	
J = 137	ZIN = 1.0030E+01 INCHES	Z = 3.4375E+01	TI = 9.0080E-01
	V = 8.8284E-04	P = 1.8920E-01	
	XSUM = 6.9883E+02	QSUM = 1.4459E-02	MASSFLOW = 8.8108E-06 LB/HR
	QFLOW = 7.2295E-02 BTU/HR	XS = 8.2186E-01	TWICK = 4.8553E+02 DEG R
	TWALL = 4.8548E+02 DEG R	MGAS = 3.5067E-06 LB-MOLES	
J = 144	ZIN = 1.0541E+01 INCHES	Z = 3.6125E+01	TI = 9.0231E-01
	V = 1.6367E-03	P = 1.9549E-01	
	XSUM = 7.0042E+02	QSUM = 2.7480E-02	MASSFLOW = 1.6334E-05 LB/HR
	QFLOW = 1.3740E-01 BTU/HR	XS = 8.1653E-01	TWICK = 4.8635E+02 DEG R
	TWALL = 4.8624E+02 DEG R	MGAS = 3.5147E-06 LB-MOLES	
J = 151	ZIN = 1.1051E+01 INCHES	Z = 3.7875E+01	TI = 9.0501E-01
	V = 3.0969E-03	P = 2.0724E-01	
	XSUM = 7.0199E+02	QSUM = 5.0592E-02	MASSFLOW = 3.0907E-05 LB/HR
	QFLOW = 2.5296E-01 BTU/HR	XS = 8.0668E-01	TWICK = 4.8780E+02 DEG R
	TWALL = 4.8762E+02 DEG R	MGAS = 3.5226E-06 LB-MOLES	
J = 158	ZIN = 1.1562E+01 INCHES	Z = 3.9625E+01	TI = 9.0979E-01
	V = 6.1223E-03	P = 2.2987E-01	
	XSUM = 7.0353E+02	QSUM = 9.1749E-02	MASSFLOW = .6.1100E-05 LB/HR
	QFLOW = 4.5875E-01 BTU/HR	XS = 7.9803E-01	TWICK = 4.9038E+02 DEG R
	TWALL = 4.9005E+02 DEG R	MGAS = 3.5303E-06 LB-MOLES	
J = 165	ZIN = 1.2073E+01 INCHES	Z = 4.1375E+01	

	V = 1.3115E-02		P = 2.7517E-01		TI = 9.1823E-01
	XSUM = 7.0501E+02		OSUM = 1.5513E-01	MASSFLOW = 1.3089E-04 LB/HR	
	QFLOW = 8.2564E-01 BTU/HR		XS = 7.5129E-01	TWICK = 4.9493E+02 DEG R	
	TWALL = 4.9435E+02 DEG R		MGAS = 3.5377E-06 LB-MOLFS		
J = 171	ZIN = 1.2510E+01 INCHES		Z = 4.2875E+01		TI = 9.3032E-01
	V = 2.8176E-02		P = 3.6026E-01		
	XSUM = 7.0618E+02		OSUM = 2.7231E-01	MASSFLOW = 2.8120E-04 LB/HR	
	QFLOW = 1.3616E+00 BTU/HR		XS = 6.8909E-01	TWICK = 5.0144E+02 DEG R	
	TWALL = 5.0090E+02 DEG R		MGAS = 3.5436E-06 LB-MOLES		
J = 178	ZIN = 1.3021E+01 INCHES		Z = 4.4625E+01		TI = 9.5328E-01
	V = 8.6856E-02		P = 6.1122E-01		
	XSUM = 7.0734E+02		OSUM = 4.8594E-01	MASSFLOW = 8.6682E-04 LB/HR	
	QFLOW = 2.4298E+00 BTU/HR		XS = 5.3328E-01	TWICK = 5.1382E+02 DEG R	
	TWALL = 5.1215E+02 DEG R		MGAS = 3.5494E-06 LB-MOLES		
J = 185	ZIN = 1.3531E+01 INCHES		Z = 4.6375E+01		TI = 9.8580E-01
	V = 4.1771E-01		P = 1.5823E+00		
	XSUM = 7.0803E+02		OSUM = 8.5246E-01	MASSFLOW = 4.1688E-03 LB/HR	
	QFLOW = 4.2623E+00 BTU/HR		XS = 1.9996E-01	TWICK = 5.3134E+02 DEG R	
	TWALL = 5.2861E+02 DEG R		MGAS = 3.5529E-06 LB-MOLES		
J = 197	ZIN = 1.4006E+01 INCHES		Z = 4.8000E+01		TI = 9.9972E-01
	V = 1.3047E+00		P = 5.4091E+00		
	XSUM = 7.0814E+02		OSUM = 1.3283E+00	MASSFLOW = 1.3021E-02 LB/HR	
	QFLOW = 6.6413E+00 BTU/HR		XS = 4.3333E-03	TWICK = 5.3885E+02 DEG R	
	TWALL = 5.3564E+02 DEG R		MGAS = 3.5535E-06 LB-MOLES		
J = 207	ZIN = 1.4516E+01 INCHES		Z = 4.9750E+01		TI = 1.0000E+00
	V = 1.8675E+00		P = 1.2886E+01		
	XSUM = 7.0814E+02		OSUM = 1.8670E+00	MASSFLOW = 1.8637E-02 LB/HR	
	QFLOW = 9.3350E+00 BTU/HR		XS = 2.4535E-06	TWICK = 5.3900E+02 DEG R	
	TWALL = 5.3578E+02 DEG R		MGAS = 3.5535E-06 LB-MOLES		
J = 214	ZIN = 1.5027E+01 INCHES		Z = 5.1500E+01		TI = 1.0000E+00
	V = 2.4065E+00		P = 2.2908E+01		
	XSUM = 7.0814E+02		OSUM = 2.4060E+00	MASSFLOW = 2.4017E-02 LB/HR	
	QFLOW = 1.2030E+01 BTU/HR		XS = 1.0894E-10	TWICK = 5.3900E+02 DEG R	
	TWALL = 5.3579E+02 DEG R		MGAS = 3.5535E-06 LB-MOLES		
J = 221	ZIN = 1.5537E+01 INCHES		Z = 5.3250E+01		

	V = 2.9455E+00	P = 3.5458E+01	TI = 1.0000E+00
	XSUM = 7.0814E+02	OSUM = 2.9450E+00	MASSFLOW = 2.9396E-02 LB/HR
	QFLOW = 1.4725E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG P	MGAS = 3.5535E-06 LB-MOLES	
J = 228	ZIN = 1.6048E+01 INCHES	Z = 5.5000E+01	TI = 1.0000E+00
	V = 3.4845E+00	P = 5.0536E+01	
	XSUM = 7.0814E+02	OSUM = 3.4840E+00	MASSFLOW = 3.4775E-02 LB/HR
	QFLOW = 1.7420E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 235	ZIN = 1.6559E+01 INCHES	Z = 5.6750E+01	TI = 1.0000E+00
	V = 4.0235E+00	P = 6.8142E+01	
	XSUM = 7.0814E+02	OSUM = 4.0230E+00	MASSFLOW = 4.0155E-02 LB/HR
	QFLOW = 2.0115E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG P	MGAS = 3.5535E-06 LB-MOLES	
J = 242	ZIN = 1.7069E+01 INCHES	Z = 5.8500E+01	TI = 1.0000E+00
	V = 4.5625E+00	P = 8.8276E+01	
	XSUM = 7.0814E+02	OSUM = 4.5620E+00	MASSFLOW = 4.5534E-02 LB/HR
	QFLOW = 2.2810E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG P	MGAS = 3.5535E-06 LB-MOLES	
J = 248	ZIN = 1.7507E+01 INCHES	Z = 6.0000E+01	TI = 1.0000E+00
	V = 5.0245E+00	P = 1.0755E+02	
	XSUM = 7.0814E+02	OSUM = 5.0240E+00	MASSFLOW = 5.0145E-02 LB/HR
	QFLOW = 2.5120E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG P	MGAS = 3.5535E-06 LB-MOLES	
J = 255	ZIN = 1.8018E+01 INCHES	Z = 6.1750E+01	TI = 1.0000E+00
	V = 5.5635E+00	P = 1.3237E+02	
	XSUM = 7.0814E+02	OSUM = 5.5630E+00	MASSFLOW = 5.5524E-02 LB/HR
	QFLOW = 2.7815E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG P	MGAS = 3.5535E-06 LB-MOLES	
J = 262	ZIN = 1.8528E+01 INCHES	Z = 6.3500E+01	TI = 1.0000E+00
	V = 6.1025E+00	P = 1.5973E+02	
	XSUM = 7.0814E+02	OSUM = 6.1020E+00	MASSFLOW = 6.0903E-02 LB/HR
	QFLOW = 3.0510E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG P	MGAS = 3.5535E-06 LB-MOLES	
J = 269	ZIN = 1.9039E+01 INCHES	Z = 6.5250E+01	

	V = 6.6415E+00	P = 1.8961E+02	TI = 1.0000E+00
	XSUM = 7.0814E+02	OSUM = 6.6410E+00	MASSFLOW = 6.6262E-02 LB/HR
	QFLOW = 3.3205E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 276	ZIN = 1.9550E+01 INCHES	Z = 6.7000E+01	TI = 1.0000E+00
	V = 7.1805E+00	P = 2.2203E+02	MASSFLOW = 7.1662E-02 LB/HR
	XSUM = 7.0814E+02	OSUM = 7.1900E+00	TWICK = 5.3900E+02 DEG R
	QFLOW = 3.5900E+01 BTU/HR	XS = 0.	
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 283	ZIN = 2.0060E+01 INCHES	Z = 6.8750E+01	TI = 1.0000E+00
	V = 7.7195E+00	P = 2.5697E+02	MASSFLOW = 7.7041E-02 LB/HR
	XSUM = 7.0814E+02	OSUM = 7.7190E+00	TWICK = 5.3900E+02 DEG R
	QFLOW = 3.8595E+01 BTU/HR	XS = 0.	
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 290	ZIN = 2.0571E+01 INCHES	Z = 7.0500E+01	TI = 1.0000E+00
	V = 8.2585E+00	P = 2.9443E+02	MASSFLOW = 8.2420E-02 LB/HR
	XSUM = 7.0814E+02	OSUM = 8.2580E+00	TWICK = 5.3900E+02 DEG R
	QFLOW = 4.1290E+01 BTU/HR	XS = 0.	
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 296	ZIN = 2.1008E+01 INCHES	Z = 7.2000E+01	TI = 1.0000E+00
	V = 8.7205E+00	P = 3.2856E+02	MASSFLOW = 8.7031E-02 LB/HR
	XSUM = 7.0814E+02	OSUM = 8.7200E+00	TWICK = 5.3900E+02 DEG R
	QFLOW = 4.3600E+01 BTU/HR	XS = 0.	
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 303	ZIN = 2.1519E+01 INCHES	Z = 7.3750E+01	TI = 1.0000E+00
	V = 9.2595E+00	P = 3.7072E+02	MASSFLOW = 9.2410E-02 LB/HR
	XSUM = 7.0814E+02	OSUM = 9.2590E+00	TWICK = 5.3900E+02 DEG R
	QFLOW = 4.6295E+01 BTU/HR	XS = 0.	
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 310	ZIN = 2.2030E+01 INCHES	Z = 7.5500E+01	TI = 1.0000E+00
	V = 9.7985E+00	P = 4.1541E+02	MASSFLOW = 9.7790E-02 LB/HR
	XSUM = 7.0814E+02	OSUM = 9.7980E+00	TWICK = 5.3900E+02 DEG R
	QFLOW = 4.8990E+01 BTU/HR	XS = 0.	
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 317	ZIN = 2.2540E+01 INCHES	Z = 7.7250E+01	

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	V = 1.0338E+01	P = 4.6263E+02	TI = 1.0000E+00
	XSUM = 7.0814E+02	QSUM = 1.0337E+01	MASSFLOW = 1.0317E-01 LB/HR
	QFLOW = 5.1685E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 324	ZIN = 2.3051E+01 INCHES	Z = 7.9000E+01	TI = 1.0000E+00
	V = 1.0877E+01	P = 5.1238E+02	
	XSUM = 7.0814E+02	QSUM = 1.0876E+01	MASSFLOW = 1.0855E-01 LB/HR
	QFLOW = 5.4380E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 331	ZIN = 2.3562E+01 INCHES	Z = 8.0750E+01	TI = 1.0000E+00
	V = 1.1416E+01	P = 5.6465E+02	
	XSUM = 7.0814E+02	QSUM = 1.1415E+01	MASSFLOW = 1.1393E-01 LB/HR
	QFLOW = 5.7075E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 338	ZIN = 2.4072E+01 INCHES	Z = 8.2500E+01	TI = 1.0000E+00
	V = 1.1955E+01	P = 6.1945E+02	
	XSUM = 7.0814E+02	QSUM = 1.1954E+01	MASSFLOW = 1.1931E-01 LB/HR
	QFLOW = 5.9770E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 344	ZIN = 2.4510E+01 INCHES	Z = 8.4000E+01	TI = 1.0000E+00
	V = 1.2417E+01	P = 6.6844E+02	
	XSUM = 7.0814E+02	QSUM = 1.2416E+01	MASSFLOW = 1.2392E-01 LB/HR
	QFLOW = 6.2080E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 351	ZIN = 2.5020E+01 INCHES	Z = 8.5750E+01	TI = 1.0000E+00
	V = 1.2956E+01	P = 7.2793E+02	
	XSUM = 7.0814E+02	QSUM = 1.2955E+01	MASSFLOW = 1.2930E-01 LB/HR
	QFLOW = 6.4775E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 358	ZIN = 2.5531E+01 INCHES	Z = 8.7500E+01	TI = 1.0000E+00
	V = 1.3495E+01	P = 7.8996E+02	
	XSUM = 7.0814E+02	QSUM = 1.3494E+01	MASSFLOW = 1.3468E-01 LB/HR
	QFLOW = 6.7470E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	
J = 365	ZIN = 2.6042E+01 INCHES	Z = 8.9250E+01	

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V = 1.4034E+01	P = 8.5451E+02	TI = 1.0000E+00
XSUM = 7.0814E+02	QSUM = 1.4033E+01	MASSFLOW = 1.4006E-01 LB/HR
OFLOW = 7.0165E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 372	ZIN = 2.6520E+01 INCHES	Z = 9.0889E+01	TI = 1.0000E+00
	V = 1.4538E+01	P = 9.1727E+02	
	XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
	OFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3578E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 373	ZIN = 2.6593E+01 INCHES	Z = 9.1139E+01	TI = 1.0000E+00
	V = 1.4538E+01	P = 9.2701E+02	
	XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
	OFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3900E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 379	ZIN = 2.7031E+01 INCHES	Z = 9.2639E+01	TI = 1.0000E+00
	V = 1.4538E+01	P = 9.8545E+02	
	XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
	OFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3900E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 386	ZIN = 2.7541E+01 INCHES	Z = 9.4389E+01	TI = 1.0000E+00
	V = 1.4538E+01	P = 1.0536E+03	
	XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
	OFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3900E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 393	ZIN = 2.8052E+01 INCHES	Z = 9.6139E+01	TI = 1.0000E+00
	V = 1.4538E+01	P = 1.1218E+03	
	XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
	OFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3900E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 400	ZIN = 2.8562E+01 INCHES	Z = 9.7889E+01	TI = 1.0000E+00
	V = 1.4538E+01	P = 1.1900E+03	
	XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
	OFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3900E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 406	ZIN = 2.9000E+01 INCHES	Z = 9.9389E+01	
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V = 1.4538E+01	P = 1.2484E+03	TI = 1.0000E+00
XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
QFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
TWALL = 5.3900E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 413	ZIN = 2.9511E+01 INCHES	Z = 1.0114E+02	TI = 1.0000E+00
	V = 1.4538E+01	P = 1.3166E+03	
	XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
	QFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3900E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 420	ZIN = 3.0021E+01 INCHES	Z = 1.0289E+02	TI = 1.0000E+00
	V = 1.4538E+01	P = 1.3848E+03	
	XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
	QFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3900E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

J = 422	ZIN = 3.0120E+01 INCHES	Z = 1.0323E+02	TI = 1.0000E+00
	V = 1.4538E+01	P = 1.3980E+03	
	XSUM = 7.0814E+02	QSUM = 1.4538E+01	MASSFLOW = 1.4509E-01 LB/HR
	QFLOW = 7.2690E+01 BTU/HR	XS = 0.	TWICK = 5.3900E+02 DEG R
	TWALL = 5.3900E+02 DEG R	MGAS = 3.5535E-06 LB-MOLES	

GAS IN ONE DZ STEP OF GAS-BLOCKED CONDENSER 1 = 1.56471E-09 LB-MOLES

POWER LOST BY ONE DZ STEP OF FULL-ON CONDENSER 1 = 3.91387E-01 BTU/HR

TOTAL GAS IN PIPE AND RESERVOIR = 3.55346E-06 LB-MOLES

TOTAL POWER LOST BY CONDENSERS = 7.26895E+01 BTU/HR