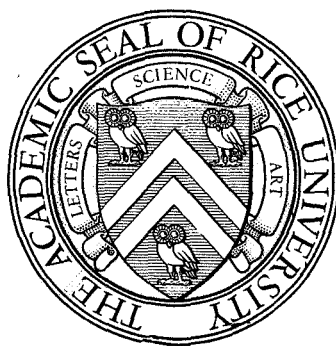


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CONDENSERS AND OR EVAPORATORS
IN CONVECTIVE AND RADIATIVE ENVIRONMENTS

D. B. Mackay, Professor
of Aerospace Engineering

G. R. Brown, Student Assistant
Aerospace Technology Report#5

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Prepared under NASA Grant NGR 44-006-033.

ABSTRACT

Two digital programs, Numbers 5-1 and 5-2, for analyzing steady-state performance of heat exchanger systems, are presented. These programs are restricted to systems where the principal source or sink for the heat is attributable to latent heat of the fluid which passes through ducts located in the exchanger. Extended surfaces (fins) to improve the system performance may be attached to the ducts. Heat is exchanged with the environment by radiation, convection, or both. Fluid pressure drop is calculated (for the two-phase flow) by the Lockhart-Martinelli method.

Program 5-1 is restricted to the analysis of circular ducts having two symmetrically located single section fins. The radiation environment may include the effects of three external bodies. One of these is assumed to be the sun. The others can be of almost any shape or size as long as their effect on heat transfer can be expressed by their view factors, surface temperatures and emissivities. These three factors are assumed constant along the length of the duct and along the length of the fin. Fin performance is established by a Runge-Kutta-Gill numerical integration routine.

Program 5-2 analyzes complicated duct and fin configurations. Pressure drops for irregular duct shapes are calculated assuming an effective diameter equal to four times the hydraulic mean radius. Single or multisection fins can be attached to the external surface of the duct. Each fin can have its individual material properties and environments. However, the fin performance must be fed in as input data to the program. Performance of unsymmetrically spaced fins in a radiative environment will need to be approximated since no known exact solutions are available.

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INTRODUCTION

In the performance analysis of condensers or evaporators two major items that have to be evaluated are (1) the radiative and convective heat exchange with environment and (2) the fluid pressure change within the duct. To handle the overall task it was decided to assemble two complete programs. These are numbered 5-1 and 5-2.

This study is a natural follow-up of the work presented in Refs. 1 and 2 in which programs are presented for calculating the combined effects of radiative and convective heat transfer in heat exchangers and surfaces. Techniques have already been developed for predicting the performance of condensers losing heat solely by radiation, see Ref. 3. This study contains the first programs capable of analyzing both condensers and evaporators in convective and radiative environments.

In radiative and convective cases it was observed that the length of duct required to cool or heat a fluid could be established using equivalent length for the fins and duct system. The equivalent length of a fin is defined as the length of an imaginary strip measured perpendicular to the axis of the duct that would transfer the same amount of heat as the actual strip but would have a constant temperature equal to the root temperature. The equivalent length was observed to be nearly independent of the root temperature and would therefore remain essentially constant along the duct.

Program 5-1 analyzes configurations employing circular tubes and symmetrical fins. The maximum complexity for the radiative environment is as illustrated in Fig. 1. Program 5-2 analyzes complex configurations including multisection fins and non circular ducts. The duct configuration is

specified either by the internal diameter or by the cross-sectional area and perimeter. The later option is used for non-circular ducts. The required fin performance item is the equivalent length which can be evaluated by using programs given in Ref. 2. By separating the fin performance calculations from the duct length calculations, innumerable geometric configurations can be analyzed. The fins can be of single or multisection shapes, of unsymmetrical design, of different materials, and even in different environments.

Heat exchanger performance calculations in purely radiative environments given in Ref. 4 were simplified by using dimensionless parameters to specify the environment and the fin configuration. Curve fitting techniques were subsequently employed to correlate numerically calculated data so that the programs contained only systems of curve fit equations to calculate the fin performance. No comparable set of equations is available for calculating the effectiveness of fins in a combination of radiative and convective environment. Therefore, in these programs, numerical integrations are used, either directly or indirectly, to obtain the fin performance.

The heat transfer coefficient from the fluid to the wall is very high when a mixture of liquid and vapor is present. Under these conditions little temperature difference exists between the fluid and the wall and little error is introduced in the programs by assuming the two temperatures are equal.

Two-phase flow in the tubes of a condenser presents a more difficult pressure drop analysis than does a liquid in a radiator. The flow can be in either laminar or turbulent regimes at the tube entrance. In two-phase flow, one of the phases can be turbulent while the other is laminar. Due to condensation or evaporation of vapor the flow regime for either liquid or vapor can change from one to the other. Since all the variations are possible, these programs have been written to evaluate the regime for each fluid,

for each section and to calculate the pressure drop in the section assuming the no change or regime takes place within the section. To accurately calculate the total pressure drop in the duct it is necessary to divide the length into a number of short sections. The input data for specifying the problems are the normal conditions encountered, such as tube size, fluid flow rate, and fin geometry. The duct lengths and duct section lengths are established by the programs. The input values for temperature (T^*) and pressure (P^*) for the fluid entering the ducts are assumed to be at saturated conditions. As the fluid flows along the duct the static pressure will either rise or fall. In a condenser for low to moderate flow rates the pressure normally rises since the momentum head is larger than the friction pressure drop. At higher rates the friction pressure drop will become the predominant factor. For evaporators, however, there is always a pressure drop. The momentum pressure head for the liquid is less than for the mixture of vapor and liquid. Should the analysis of excessive flow rates be attempted, the calculated increment for the pressure drop will be found to be high. The program was not written to accurately calculate the thermal properties of the fluid when the pressures deviate widely from the inlet conditions. Two tests are provided in the program to avoid meaningless analysis. A particular case is terminated when the calculated pressure is less than zero, or if the section length is negative. Print outs are provided to give the reason for early case termination.

The basic assumptions made for these programs include the following:

1. Steady state conditions have been reached.
2. No heat is transferred from the outer edges of the fins. Corrections can be made for this item in program 5-2 if this feature is applicable and if the user wishes to expend the effort to do so. Normally the accuracy of the problem does not warrant such refinement.

3. No heat is transferred in the direction parallel to the duct.

The temperature gradient in this direction is normally small enough that its effect does not materially degrade the predicted performance.

4. The environment remains constant along a fin and throughout the length of the duct.

5. The heat transfer properties of the duct and fin materials are not affected by temperature or position in the system.

6. The duct wall temperature is assumed equal to the temperature of the vapor.

7. The fin equivalent length remains constant along the duct and in Program 5-1 is calculated at the fluid inlet temperature.

8. The fluid enters the duct at its saturation temperature and pressure. However, the weight percentage of vapor is an input variable which depends upon the desired problem conditions.

NOMENCLATURE

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
A_d	AD	Duct cross sectional area for fluid flow, sq ft/duct
A	A(I), AA(I), AAA(I)	Curve fit equation constants [see Eq. (128), Ref. 3]
A_e		An element of condenser area, sq-ft
α_a	ALPHAA	Absorptivity of surface facing sun, nondimensional
α_b	ALPHAB	Absorptivity of surface away from sun, nondimensional
A_p	AS	Plan form area exchanging heat with the environment. (Heat may be exchanged from both sides of the extended surface), sq ft
B	B(I), BB(I), BBB(I)	Curve fit equation constants [see Eq. (128), Ref. 3]
N	CAPN	Number of ducts in heat exchanger
χ	CHI	Pressure drop function [see Eq.(114), Ref. 3], nondimensional
C_χ	CHIC1	Pressure drop constant [see Eq.(116), Ref. 3]
C	C(I), CC(I), CCC(I)	Curve fit equation constants [see Eq.(128), Ref. 3]
$K_{o,4}$	CKO, CK1, CK4	Heat transfer constants, [see Eqs. (2.15) to (2.17)]
	CM(I)	Subscripted constant in Runge-Kutta-Gill integration routine
$(C_p)_g$	CPG	Specific heat of vapor, Btu/lb R
$(C_p)_L$	CPL	Specific heat of liquid, Btu/lb R
C_1	CL	Radiation constant, $\sigma(\epsilon_a + \epsilon_b)$ Btu/ft ² ·hr R ⁴

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
$C_1(L)$	C1(L)	Radiative constant, C_1 , for fin (L), Btu/hr sq ft R^4
$C_{1d}(I)$	C1D(I)	Radiative constant, C_1 , for duct section (I), Btu/hr sq ft R^4
C_2	C2	Radiative constant, heat received from environment by both surfaces of a unit of fin area, Btu/hr sq ft
$C_{2d}(I)$	C2D(I)	Radiative constant C_2 for duct section (I), Btu/hr sq ft
$C_2(L)$	C2(L)	Radiative constant C_2 for fin (L) (heat to both surfaces), Btu/hr sq ft
C_3	C3	Environmental parameter, $C_2/C_1(T^*)^4$, nondimensional
δ_h	DELTAH	Thickness of root or attachment end of extended surface, ft
dw_L	DELWL	Weight of liquid changing phase in each section, lb/sec
δ_r	DELTAR	Ratio of end to root thickness of fin
D_i	DI	Duct inside diameter (or effective diameter), ft
D	D(I)	R_L curve fit constant [see Eq.(129), Ref 3]
D_o	DO	Tube outside diameter, ft
C_{DP}	DPC1	A constant [see Eq.(99), Ref. 3]
	DPM	Change in momentum pressure from entrance to exit of duct (+ if pressure rise), lb/sq ft
C_{D1}	DPMDW1	A constant [see Eq.(141), Ref. 3]
C_{D2}	DPMDW2	A constant [see Eq.(140), Ref. 3]
C_{D3}	DPMDW3	A constant [see Eq.(142), Ref. 3]
C_{D4}	DPMDW4	A constant [see Eq.(144), Ref.3]

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
C_{D5}	DPMDW5	A constant [see Eq.(145), Ref. 3]
dP_m/dw_L	DPMDWX	Pressure change in the duct due to momentum change in the fluids, lb-sec/ lb-ft ²
	DPSUM	Accumulated sum of pressure change, lb/sq ft
dP_f/dx	DPXF	Friction pressure drop per foot of duct length, lb/ft ³
dL_w	DX	Differential length of duct, ft
DZ0	DZ0	$(dZ/d\omega)_1$ for a previous attempt at convergence where heat transfer was low
DZW	DZW	$(dZ/d\omega)_1$ for a previous attempt at convergence where heat transfer was high
$(dZ/d\omega)_1$	DZ1	Initial value of $(dZ/d\omega)$ to start integration routine, nondimensional
$\frac{d^2 Z}{d\omega^2}$	D2Z	Function statement, nondimensional
Ω_c	EFC1	Flat plate convective effectiveness, nondimensional
E	E(I)	R_L curve fit constant [see Eq.(129), Ref. 3]
	EKEND	Fluid kinetic energy at duct exit, Btu/lb
E_{ks}	EKS	Fluid kinetic energy at duct entrance, Btu/lb
L_c	ELC	Duct width for convective heat transfer, ft
L_e	ELE	Equivalent length of a fin, ft
$L_e(L)$	ELE(L)	Equivalent length for fin (L), ft
L_h	ELH	Actual extended surface width, ft.
L_w	ELW	Duct length, ft
ϵ_a	EMA	Hemispherical emissivity of extended surface facing sun, nondimensional
ϵ_b	EMB	Hemispherical emissivity of extended surface away from sun, nondimensional

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
ϵ_x	EMX	Hemispherical emissivity of external surface x, nondimensional
N	ENT	Number of ducts in heat exchanger
ϵ_a	EPSA	Emissivity of extended surface facing sun, nondimensional
ϵ_b	EPSB	Emissivity of extended surface away from sun, nondimensional
ϵ_m	EPSM	Emissivity of body "m", nondimensional
ϵ_x	EPSX	Emissivity of external body, "x", nondimensional
F_a	FA	Radiative form factor between exchanger and body, "m", for surface facing sun, nondimensional
F_{ah}	FAH	Environmental convective parameter, $[(h_a T_{aa} + h_b T_{ab}) L_h^2 / k_h \delta_h T]$, nondimensional
F_{ax}	FAX	Radiative form factor between the heat exchanger surface facing the sun and a second surface near the exchanger, nondimensional
F_b	FB	Radiative form factor between exchanger and body "m" for surface away from sun, nondimensional
F_{bx}	FBX	Radiative form factor between the exchanger surface away from sun and a second surface near the exchanger, nondimensional
F_e	FE	Variable used in Newton's iteration procedure
F_h	FH	Extended surface convective parameter, $[(h_a + h_b) L_h^2 / k_h \delta_h]$, nondimensional
h_{fg}	FHH	Latent heat of fluid, Btu/lb
F	F(I)	R_L curve fit constant [see Eq.(129), Ref. 3]
L_h	FINLH	Extended surface length of section, ft
δ_c	FINTC	Thickness of extended surface at cold end, ft

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
δ_h	FINTH	Thickness of extended surface at root edge, ft
N_s	FMESH	Number of subsections in which the duct length is divided for calculation purposes, nondimensional
μ_g	FMUG	Viscosity of vapor, lb/sec-ft
μ_L	FMUL	Viscosity of liquid, lb/sec-ft
k	FNK	Thermal conductivity of fin material, Btu/ft-hr $^{\circ}$ R
	FO(I)	Subscripted integration term
f	F2	Fanning friction factor, nondimensional
g	G	Units conversion factor, 32.17, ft/sec 2
gD_i	GDI	Product of g and tube inside diameter, ft 2 /sec 2
$G_{d1,3}$	GD1,...GD3	Heat exchange constants for duct
gJ	GJ	Product of gravity and the mechanical equivalent of heat, 32.17 $\times$ 778 ft 2 -lb/Btu-sec 2
$G_2(L)$	G2(L)	Subscripted constants
$G_3(L)$	G3(L)	Subscripted constants
h_a	HA	Convective heat transfer coefficient on the side facing the sun (if applicable) Btu/hr sq ft R
$h_a(L)$	HA(L)	Convective heat transfer coefficient to the environment for side "a" of fin (L), Btu/hr sq ft R
h_{at}	HAT	Sum of convective terms, ($h_a T_{aa} + h_b T_{ab}$), Btu/hr sq ft
h_b	HB	Convective heat transfer coefficient on the side away from the sun (if applicable), Btu/hr sq ft R

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
$h_b(L)$	HB(L)	Convective heat transfer coefficient to the environment from side "b" of fin (L), Btu/hr sq ft R
$h_d(I)$	HD(I)	Convective heat transfer coefficient to environment from duct section (I), Btu/hr sq ft R
h_L	HG	Enthalpy of liquid, Btu/lb
h_g	HL	Enthalpy of vapor, Btu/lb
h_t	HT	Sum of convective heat transfer coefficients, $(h_a + h_b)$, Btu/hr sq ft R
	ISO	Switch to signal a zero condition has been encountered
	ISW	Switch to signal a wilt condition has been encountered
	ITER	The number of attempts for a starting value of $DZ/d\omega$
ω	OMEGA	Ratio, L/L_h where L represents distance that the heat has traveled along the fin and L_h represents the total length, non-dimensional
	P	Absolute fluid pressure, lb/sq ft
p	PERIM	Duct internal perimeter, ft
φ	PHI	Function [see Eq.(113), Ref. 3]
	PMEND	Fluid momentum pressure of duct exit, lb/sq ft
P_{ms}	PMS	Fluid momentum pressure at duct entrance, lb/sq ft
P^*	PSTAR	Static saturation pressure at duct inlet, lb/ft ²
X^*	QALSTR	Quality of fluid entering duct, weight fraction vapor, nondimensional

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
q	Q	Heat exchanged with environment, Btu/hr per duct
q_d	QDPR	Heat transfer from duct per foot of length, Btu/hr-ft
q	QS	Heat transfer to the environment from a unit of duct length, Btu/sec
q_s	QSUM	System heat exchanged with environment, Btu/hr
R	R	Gas constant, 1544/M, ft-lb/lb-mol
R_{eg}	REGP	Pseudo Reynolds number for vapor in duct, nondimensional
R_e		Reynolds number for a fluid flowing in a duct, nondimensional
R_{eL}	REL P	Pseudo Reynolds number for liquid in the duct, nondimensional
R_g	RGP	Fraction of the duct filled with vapor at the section midpoint, nondimensional
R_L	RLP	Fraction of the duct filled with liquid at the section midpoint, nondimensional
ρ		Fluid density, lb/ft ³
	RHOEND	Fluid density at duct exit, lb/cu ft
ρ_{fs}	RHOF S	Fluid density at duct entrance, lb/cu ft
ρ_g	RHOG	Density of vapor fraction, lb/ft ³
ρ_L	RHOL	Density of condensed liquid, lb/ft ³
ρ_f	RHOFM	Density of fin material, lb/ft ³
ρ_m	RHOM	Reflectivity of environmental surface, nondimensional
ρ_d	RHOTM	Density of tube material, lb/ft ³
ρ_x	RHOX	Reflectivity of second surface, x, nondimensional

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
	RLAFEG	Subroutine used in pressure drop calculations
S_c	SC	Solar heat, Btu/hr sq ft
$S_c(I)$	SC(I)	Peripheral duct length for convective heat transfer from section (I), ft
$S_r(I)$	SR(I)	Effective peripheral duct length for radiative heat transfer from section (I), ft
T	T	Absolute static temperature of vapor and fin root (taken equal), R
T_{aa}	TAA	Ambient fluid temperature on side "a", R
$T_{aa}(L)$	TAA(L)	Ambient environmental temperature for side "a" of fin (L), R
T_{ab}	TAB	Ambient fluid temperature of side "b", R
$T_{ab}(L)$	TAB(L)	Ambient environmental temperature for side "b" of fin (L), R
$T_a(I)$	TA(I)	Ambient environmental temperature for duct section (I), R
T_e	TE	Effective environmental temperature, [see Eqs. (1.14) and (2.20)], R
θ_m	THETAM	Angle between sun's rays and normal to body "m" surface, degrees
θ_p	THETAP	Angle between sun's rays and normal to fin surface, degrees
θ_x	THETAX	Angle between sun's rays and normal to second surface, degrees
T_m	TM	Surface temperature of body "m", R
T^*	TSTAR	Temperature of fluid (must be saturated) and also tube wall at inlet, R

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
T_x	TX	Surface temperature of body "x", R
	T(2)	Existing value of ω , nondimensional
$d\omega$	T(3)	Increment of ω used for calculations, nondimensional
Z	T(4)	Value of T/T^* , nondimensional
$dZ/d\omega$	T(5)	$dZ/d\omega$, nondimensional
U	U	Vapor velocity in duct, ft/sec
	UFEND	Fluid velocity at duct exit, ft/sec
U_{fs}	UFS	Fluid velocity at duct entrance, ft/sec
	UP2	Pseudo velocity of vapor in duct (as if vapor occupied entire volume), ft/sec
U^*	UZERO	Fluid velocity at duct entrance, (equal velocities assumed), ft/sec
u^2	U2	Square of the vapor velocity, ft^2/sec^2
V	V	Liquid velocity in duct, ft/sec
v_f	VF	Specific volume of the liquid, ft^3/lb
v_g	VG	Specific volume of the vapor, ft^3/lb
v_{fg}	VFG	Specific volume increase during evaporation, ft^3/lb
V_f		Fluid velocity in a duct, ft/sec
V^2	V2	Square of the liquid velocity, ft^2/sec^2
w	W	Weight rate in one duct, lb/sec
	WALTH	Tube wall thickness, ft
	WD	Weight of a tube, lb
$\dot{w}$	WDOT	Total weight rate of flow, vapor and liquid, lb/hr
$\dot{w}_d$	WDOTD	Weight flow of fluid in a duct, lb/hr-tube

<u>Equations</u>	<u>Computer Program</u>	<u>Definition</u>
W_d^1	WDPR	Weight of the duct per foot of length, lbs/ft
W_e	WE	Weight of extended surface, lb
	WILT	Value of $(dZ/dw)_1$ used for the previous iteration, nondimensional
w_g	WG	Weight flow rate of vapor in duct, lb/sec
w_L	WL	Weight flow rate of the liquid in duct, lb/sec
W_{Lt}	WLT	Weight of the liquid trapped in the conden- ser, lb
W_q	WQ	Dry condenser weight per unit of heat transfer, lb-hr/Btu
W_t	WT	Total weight of condenser (neglecting fluid), lb
M	WTM	Molecular weight of fluid, lb/mol
y		Heat transfer rate at fin root temperature, Btu/hr sq ft
Y_L		Lockhart-Martinelle Correlation factor
Z	Z	Correction factor, $P/\rho_g RT$, nondimensional also used as a dimensionless ratio, i.e., the temperature in a fin at a given section divided by the hot end temperature
ζ_p	$\begin{cases} \text{ZETAP} \\ \text{ZZ} \end{cases}$	Profile number, $C_1 T_h^3 L_h^2 / k \delta_h$, for rectangular plan extended surface, nondimensional

SUBSCRIPTS

a	Surface facing the sun (if applicable)
b	Surface in shade (if applicable)
(I)	Duct section "I" or φ curve fit for section "I"
(L)	Fin "L"

- 1 Denotes entrance to duct section (if applicable)
- 2 Denotes exit from duct section (if applicable)

PROGRAM 5-1 DESCRIPTION

This program is adapted to systems having the geometry shown in Fig.

1. Much of the work presented is common to the two programs and the overlapping portions will not be repeated.

The heat transfer from an element of fin surface depicted in Fig. 2 in a radiative and convective environment can be written as

$$dq = [C_1 T^4 - C_2 + h_a (T - T_{aa}) + h_b (T - T_{ab})] dA_p. \quad (1.1)$$

The radiative constants C_1 and C_2 are

$$C_1 = (\epsilon_a + \epsilon_b) \sigma = (\epsilon_a + \epsilon_b) 0.1713 \times 10^{-8} \quad (1.2)$$

[Ref. 3, Eq. 2]*

and

$$\begin{aligned} C_2 = & S_c (\alpha_a \cos \theta_p + F_a \alpha_a \rho_m \cos \theta_m + F_{ax} \alpha_a \rho_x \cos \theta_x + F_b \alpha_b \rho_m \cos \theta_m \\ & + F_{bx} \alpha_b \rho_x \cos \theta_x) + 0.1713 \times 10^{-8} \left[(F_a \epsilon_a + F_b \epsilon_b) \epsilon_m T_m^4 \right. \\ & \left. + (F_{ax} \epsilon_x + F_b \epsilon_b) \epsilon_x T_x^4 \right] + 0.01 (\epsilon_a + \epsilon_b). \end{aligned} \quad (1.3)$$

[Ref. 3, Eq. 3]

The heat transfer from an element of fin can be written as

$$dq = y L_e dL = \frac{-k \delta_h T}{L_h} \left(\frac{dZ}{d\omega} \right)_{\perp} dL_w \quad (1.4)$$

*This denotes the source of the equation.

where

$$y = C_1 T^4 - C_2 + T h_t - h_{at} \quad (1.5)$$

$$h_t = h_a + h_b \quad (1.6)$$

and

$$h_{at} = h_a T_{as} + h_b T_{ab} \quad (1.7)$$

Thus y is the heat exchanged per hour per unit area at the wall temperature.

Rearranging Eq.(1.4) and combining with (1.5)

$$L_e = \frac{-L_h \left(\frac{dZ}{d\omega} \right)_1}{\zeta_p (1-C_3) + F_h - F_{ah}} \quad (1.8)$$

[Ref. 1, Eq. (1.8)]

The value of $(dZ/d\omega)_1$ is obtained at the inlet vapor temperature, T^* , by the numerical integration procedures described in Ref. 2, Eqs. (4) through (23).

The heat transfer from an element of tube can be obtained by adding the amounts resulting from both radiation and convection. However, in this program each mode of heat transfer is calculated differently. As explained in Ref. 1, the heat transferred by radiation from a fin and tube system can be readily evaluated with excellent accuracy using the projected area of the tube. In this program the heat transferred by convection is assumed to take place from the exposed area of the tube. Using these areas, the heat exchange is

$$dq_d = [D_o (C_1 T^4 - C_2) + L_c (h_t T + h_{at})] dL_w \quad (1.9)$$

[Ref. 1, Eq. (1.9)]

where

$$L_c = \frac{\pi D_o}{2} - \delta_h . \quad (1.10)$$

The total heat from the surface to the environment is obtained by combining equations (1.4) and (1.9). For the element

$$dq = 3600 \bar{q} dL_w \quad (1.11)$$

for the system total

$$q_s = 3600N \sum_{L_w=0}^{L_w} \bar{q} dL_w \quad (1.12)$$

where $\bar{q}$ represents the heat exchanged with the environment per second per foot of tube length or

$$\bar{q} = [2yL_e + D_o (C_1 T_1^h - C_2) + L_c (h_t T - h_{at})] \div 3600. \quad (1.13)$$

The environmental temperature (defined as the one the fluid would reach if the duct were infinitely long) was calculated from Eq. (1.13) by putting $\bar{q} = 0$ and $T_e = T_w$. The value of T_e was obtained using Newton's method in which

$$T_e = T_e' - F_e \left/ \frac{dF_e}{dT_e} \right. \quad (1.14)$$

where

$$F_e = (C_1 T_e^h - C_2)(2L_e + D_o) + (h_t T_e - h_{at})(2L_e + L_c) \quad (1.15)$$

and

$$\frac{dF_e}{dT_e} = 4C_1 T_e^3 (2L_e + D_o) + h_t (2L_e + L_c) \quad (1.16)$$

T^* was used as the first approximation for T_e and T_e was accepted when

$$F_e \leq 0.001. \quad (1.17)$$

When convection is absent

$$h_t = 0, \quad (1.18)$$

$$y = C_1 T_e^4 - C_2, \quad (1.19)$$

$$q_d = D_o (C_1 T_e^4 - C_2), \quad (1.20)$$

and with these substitutions in Eq. (1.13) and rearrangement

$$T_e = \left(\frac{C_2}{C_1} \right)^{\frac{1}{4}}. \quad (1.21)$$

The mixed fluid properties at the tube inlet are calculated assuming the two fluids are traveling at the same velocity. From the continuity equation for each constituent

$$A_L = \frac{w_L}{\rho_L V} \quad (1.22)$$

$$A_g = \frac{w_g}{\rho_{gs} U} \quad (1.23)$$

For equal velocities

$$U_{fs} = U = V \quad (1.24)$$

The duct area is equal to the sum of the areas occupied by the two fractions or

$$A_L + A_g = A_d \quad (1.25)$$

Combining Eqs. (1.23) through (1.25) and rearranging the mixed fluid velocity is

$$U_{fs} = \frac{1}{A_d} \left(\frac{w_L}{\rho_L} + \frac{w_g}{\rho_g} \right) \quad (1.26)$$

The fluid momentum pressure (velocity $\times$ mass/sec) is

$$P_{ms} = \frac{1}{gA_d} (\rho_L A_L V^2 + \rho_g A_g U^2) \quad (1.27)$$

The total flow is the sum for the two fractions or

$$w = w_L + w_g \quad (1.28)$$

Combining Eqs.(1.22), (1.23), (1.24), (1.27) and (1.28)

$$P_{ms} = \frac{w U_{fs}}{g A_d} \quad (1.29)$$

The kinetic energy per pound of fluid at duct entrance is

$$E_{ks} = U_{fs}^2 / 2gJ . \quad (1.30)$$

A similar set of equations is applicable to the fluid leaving the duct. No assumptions need be made for velocity distribution since $w_L =$ zero in an evaporator and $w_g =$ zero in a condenser.

In these programs the size and shape of the system is specified except for the length of tubes needed to condense the vapor or evaporate the liquid. The length of tube and pressure drop along it are determined simultaneously by calculating the pressure drop over an increment of tube length, and then performing a step-by-step numerical integration down the length of

PROGRAM 5-2 DESCRIPTION

This program is set up to handle a variety of duct and fin configurations as illustrated by Fig. 4. In order to make it flexible the number of extended surfaces attached to the duct and the divisions of the duct circumference are specified by the input data. The heat transfer to the extended surface is calculated for each surface from its equivalent length. The heat transfer from the duct is obtained by adding the radiative and convective heat transfer from each of the sections.

When the radiative heat transfer to the environment from a given extended surface is independent of the other extended surfaces, the programs in Ref. 2 can be used to calculate the equivalent length for the surface. Unfortunately, when the extended surfaces are oriented in such a way that they can "see" each other, the heat transfer by radiation to the environment is restricted and no known programs are available for calculating the equivalent length. At present the user will have to approximate the reduction in heat transfer and adjust the values of L_e accordingly. The approximations will be sufficiently accurate if the interfering surfaces are insulated, or if the ambient fluid is opaque to radiation.

The cross sectional flow area for the duct can be calculated by the program when the duct is circular. If not, the area and duct perimeter must be included in the input data. The effective internal diameter used to compute pressure drop for a non-circular duct is

$$D_i = \frac{4A_d}{p} . \quad (2.1)$$

For circular ducts

$$A_d = \frac{\pi D_i^2}{4} . \quad (2.2)$$

and

$$p = \pi D_i . \quad (2.3)$$

To account for the two modes of heat transfer with the environment, the calculations for a section of duct circumference are divided into two parts, convection and radiation. The division is necessary because of the use of projected areas, if applicable, for calculating radiative heat transfer. Also it is assumed that the duct itself might be of a complicated configuration requiring several sections to adequately represent the heat transfer. For an element of any section, the heat transfer can be written as

$$dq(I) = \left\{ S_r(I) \left[C_{1d}(I) T^4 - C_{2d}(I) \right] + S_c(I) h_d(I) \left[T - T_a(I) \right] \right\} dL. \quad (2.4)$$

The effective section lengths $S_r(I)$ and $S_c(I)$ are thus chosen independently. In some cases, for example a duct without fins, equal values for $S_r(I)$ and $S_c(I)$ should be specified. The total heat transfer from an element of duct circumference is the sum of the amount from all sections, or

$$dq_d = (G_{d1} T^4 + G_{d2} T - G_{d3}) dL \quad (2.5)$$

where

$$G_{d1} = \sum_{I=1}^n S_r(I) C_{1d}(I) \quad (2.6)$$

$$G_{d2} = \sum_{I=1}^n S_c(I) h_d(I) \quad (2.7)$$

and

$$G_{d3} = \sum_{I=1}^n \left[S_r(I) C_{2d}(I) + S_c(I) h_d(I) T_a(I) \right] . \quad (2.8)$$

For an extended surface the heat transfer is

$$dq(L) = \left\{ C_1(L) T^4 - C_2(L) + T \left[h_a(L) + h_b(L) \right] - \left[h_a(L) T_{aa}(L) + \right. \right. \\ \left. \left. + h_b(L) T_{ab}(L) \right] \right\} L_e(L) dL. \quad (2.9)$$

setting

$$G_2(L) = h_a(L) + h_b(L) \quad (2.10)$$

and

$$G_3(L) = h_a(L) T_{aa}(L) + h_b(L) T_{ab}(L) + C_2(L), \quad (2.11)$$

$$dq(L) = \left[C_1(L) T^4 + G_2(L) T - G_3(L) \right] L_e(L) dL. \quad (2.12)$$

The heat from an element of duct length can be obtained by adding the heat from the extended surfaces and the duct or

$$dq = 3600 \bar{q} dL_w \quad (2.13)$$

Where

$$\bar{q} = [K_o + K_1 T + K_4 T^4] \quad (2.14)$$

$$K_o = - \left(G_{d3} + \sum_{L=1}^{n'} G_3(L) L_e(L) \right) \quad (2.15)$$

$$K_1 = G_{d2} + \sum_{L=1}^{n'} \left[G_2(L) L_e(L) \right] \quad (2.16)$$

$$K_4 = G_{d1} + \sum_{L=1}^{n'} \left[C_1(L) L_e(L) \right] \quad (2.17)$$

and

n' = number of fins attached to a duct.

Equation (2.14) is used with Newton's method for establishing the effective environmental temperature. Setting, $\bar{q} = 0$ and $T_e' = T$

$$F_e = K_0 + K_1 T_e + K_4 T_e^4 \quad (2.18)$$

$$dF_e / dT_e = K_1 + 4K_4 T_e^3 \quad (2.19)$$

and

$$T_e = T_e' - F_e / \frac{dF_e}{dT_e} \quad (2.20)$$

The inlet fluid temperatures T^* is used as the first approximation for T_e' . The value of T_e is accepted when

$$F_e \leq .001 \quad (2.21)$$

CONCLUSIONS AND RECOMMENDATIONS

These programs can be used to solve a myriad of evaporator and condenser problems. While they have been specifically designed for problems where the heat exchange with the environment is by the combination of convection and radiation, they can be used where the transfer is restricted to

one or the other. Problems involving only convection environments are also solvable by conventional approaches and such a program would be a little bit more economical with machine time.

The rigorous mathematical treatment of the combined effects of radiation and convection heat exchange systems has been avoided in the past because of the difficulties in solving the nonlinear differential equations. These difficulties are made acute by the large number of variables which influence the exchanger performance. Radiative exchange problems have been greatly simplified by the use of dimensionless parameters. Comparable studies with the combined effects of radiation and convection are sorely needed. Performance curves or charts would aid in the understanding of problems and in interpreting the results obtained for a given case. The programs presented herein combined with those of Refs. 1 and 2 should provide interested parties with the basic tools for making such a study.

Inter-radiation effects between fins which "see" each other will introduce errors which are difficult to approximate. Very little work has been done in this field.

Problems involving heating and cooling of gases and mixtures of gases can not be solved with either these programs or those of Ref. 1. The modifications required are not extensive and work in this field is recommended.

REFERENCES

1. Mackay, D. B. and Branner, W. E. "Heat Exchangers for Convective and Radiative Environments," Aerospace Technology Report #4, Rice University, August, 1968.
2. Mackay, D. B. and Branner, W. E. "Radiative and Convective Heat Transfer from Single and Multisection Extended Surfaces," Aerospace Technology Report #2, Rice University, March 1968.
3. Mackay, D. B. and Branner, W. E. "Digital Programs for Establishing Steady-State Space Condenser Performance," Aerospace Technology Report #1, Rice University, Revised April 1969.

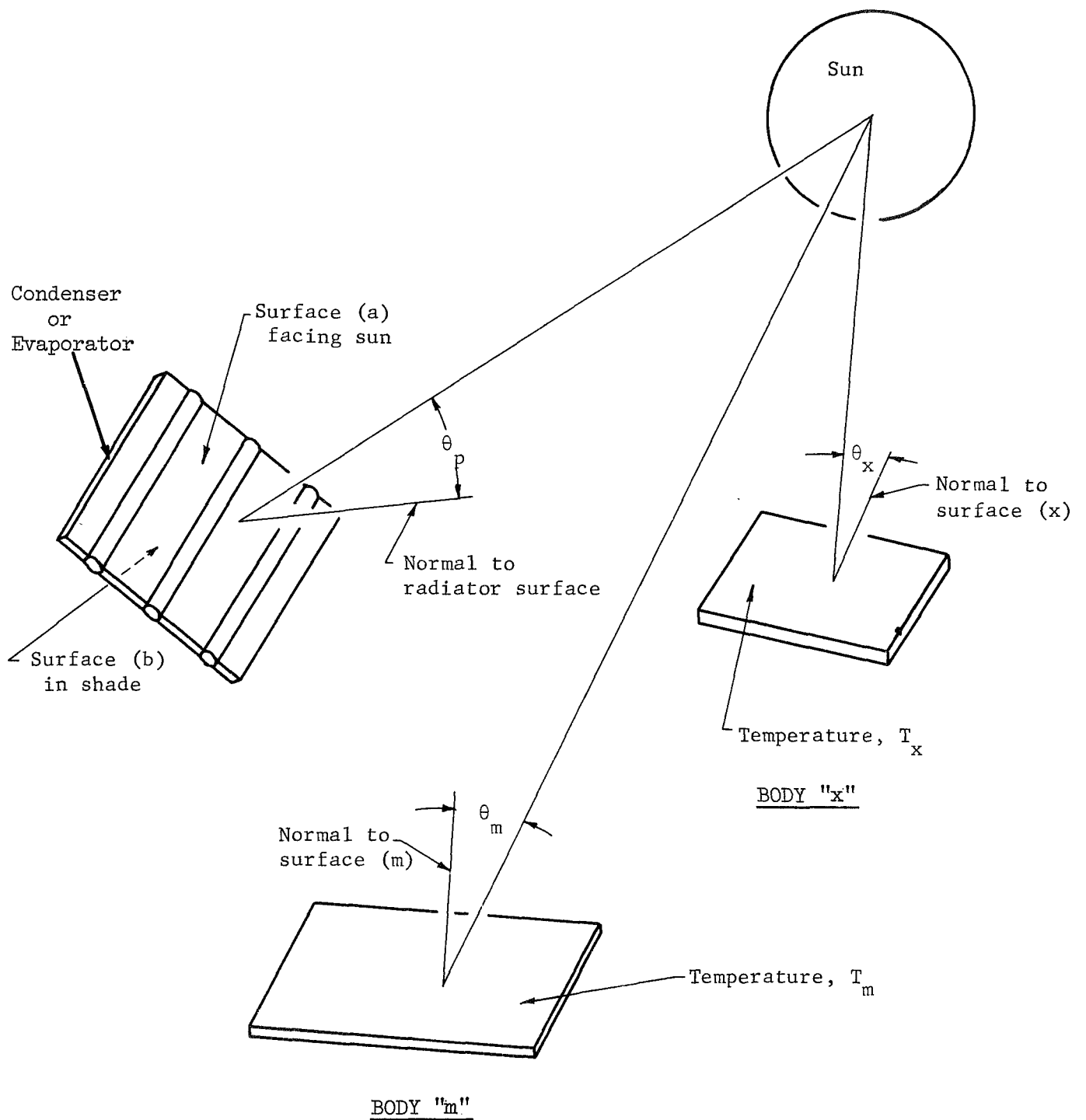


Fig. 1. Program 5.1 Radiative Environment

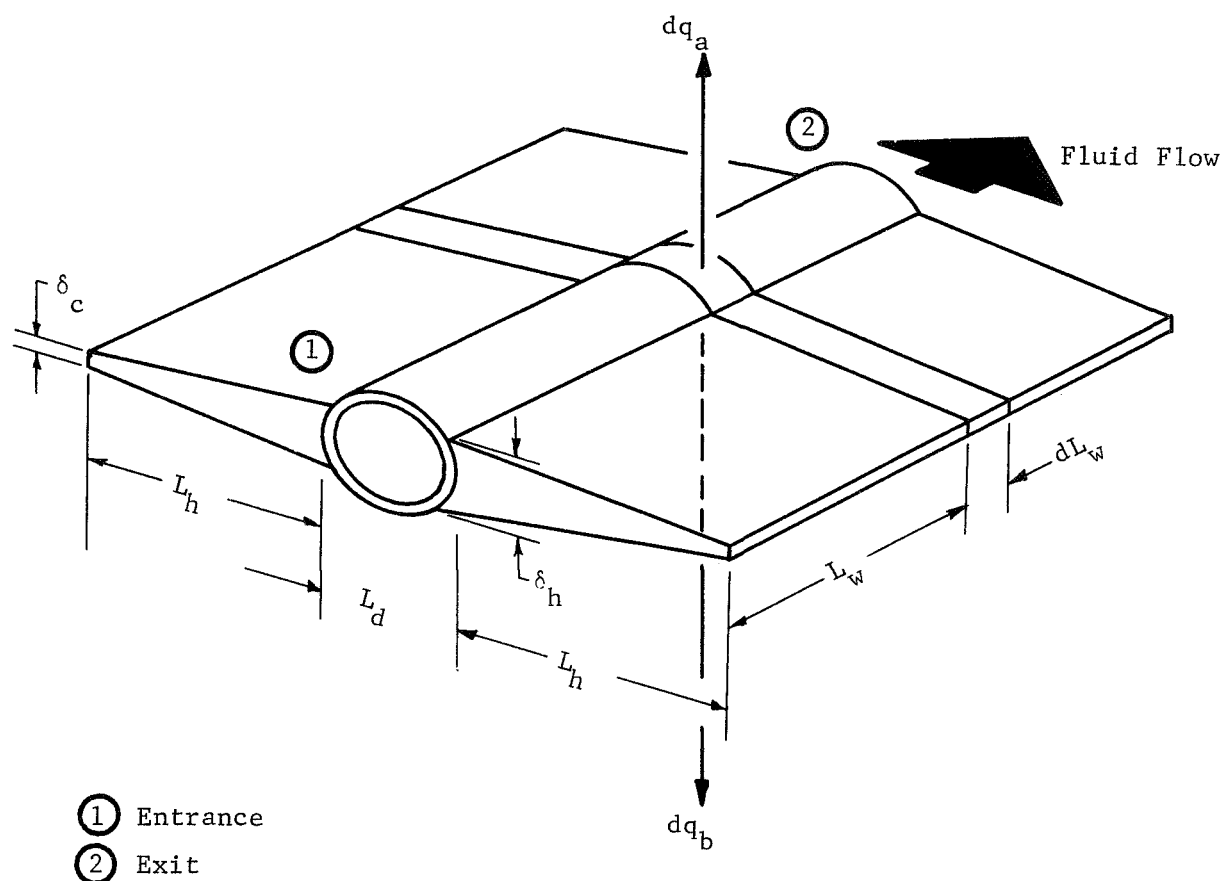


Fig. 2. Typical Configuration (Program 5.1)

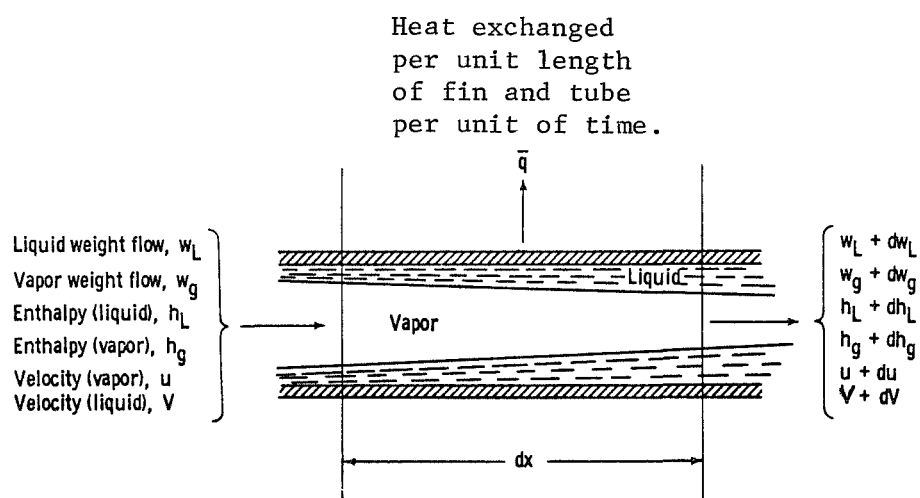


Fig. 3. Condenser Tube Two-Phase Flow Model

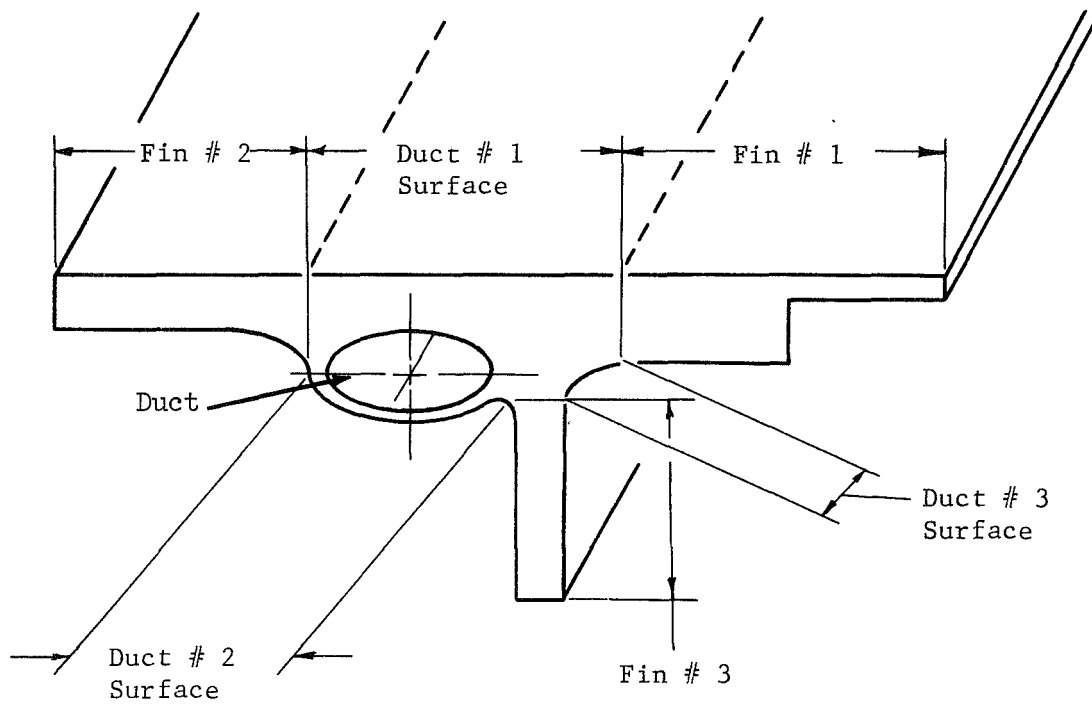


Fig. 4 Representative Configuration (Program 5.2)

APPENDIX APROGRAM INFORMATION

Included in this appendix are deck setups, flow diagrams, compiled listings of the main programs and subroutines, (Figures A-1 to A-5 inclusive), Information for Program Users, and Input Variables for Programs. Subroutines permanent Hollerith listings and a set of input data for sample problems are included along with program listings.

Decimal Data
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In Column 1 of
Last Card of
Every Case

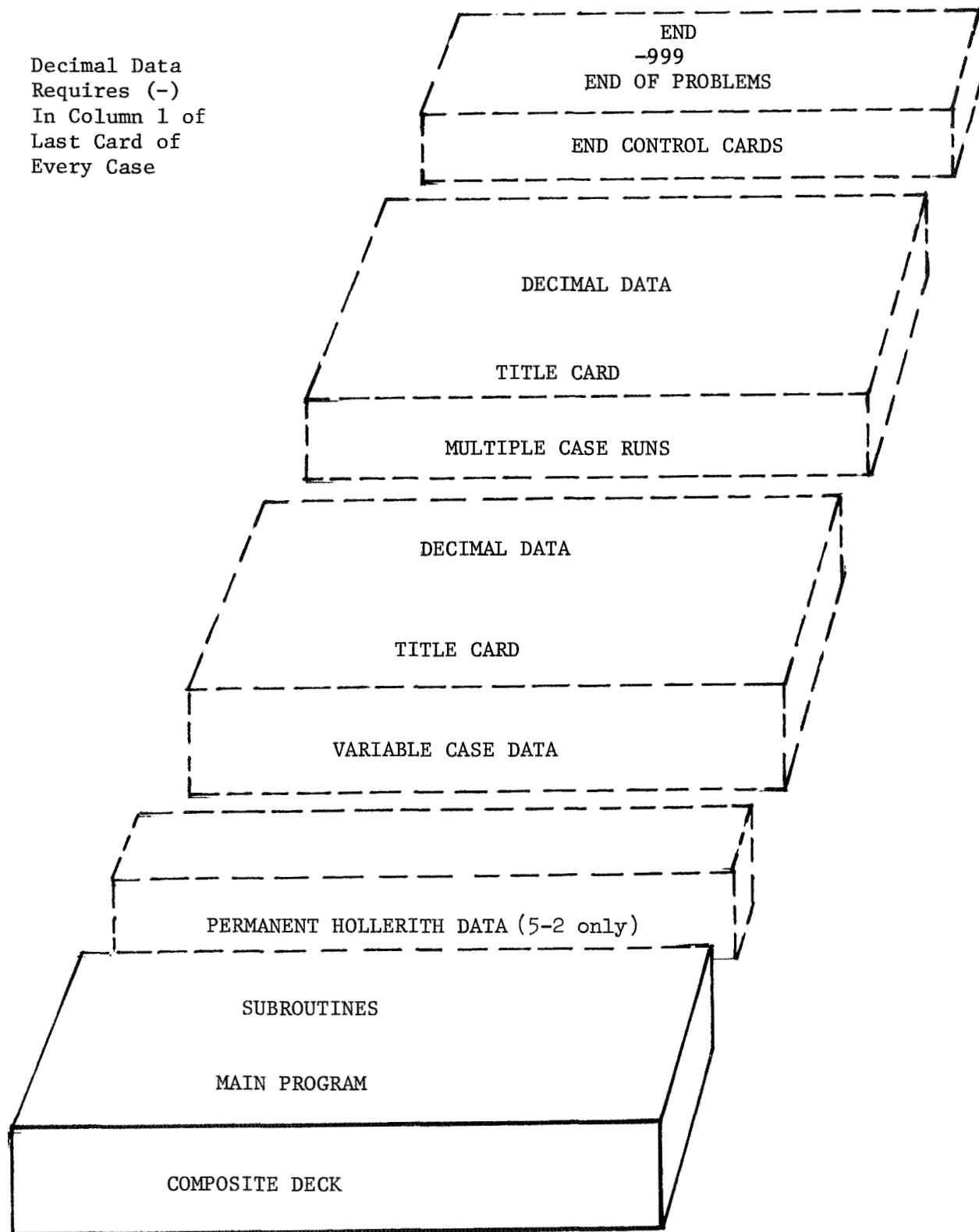


Fig. A-1. Composite Deck Setup

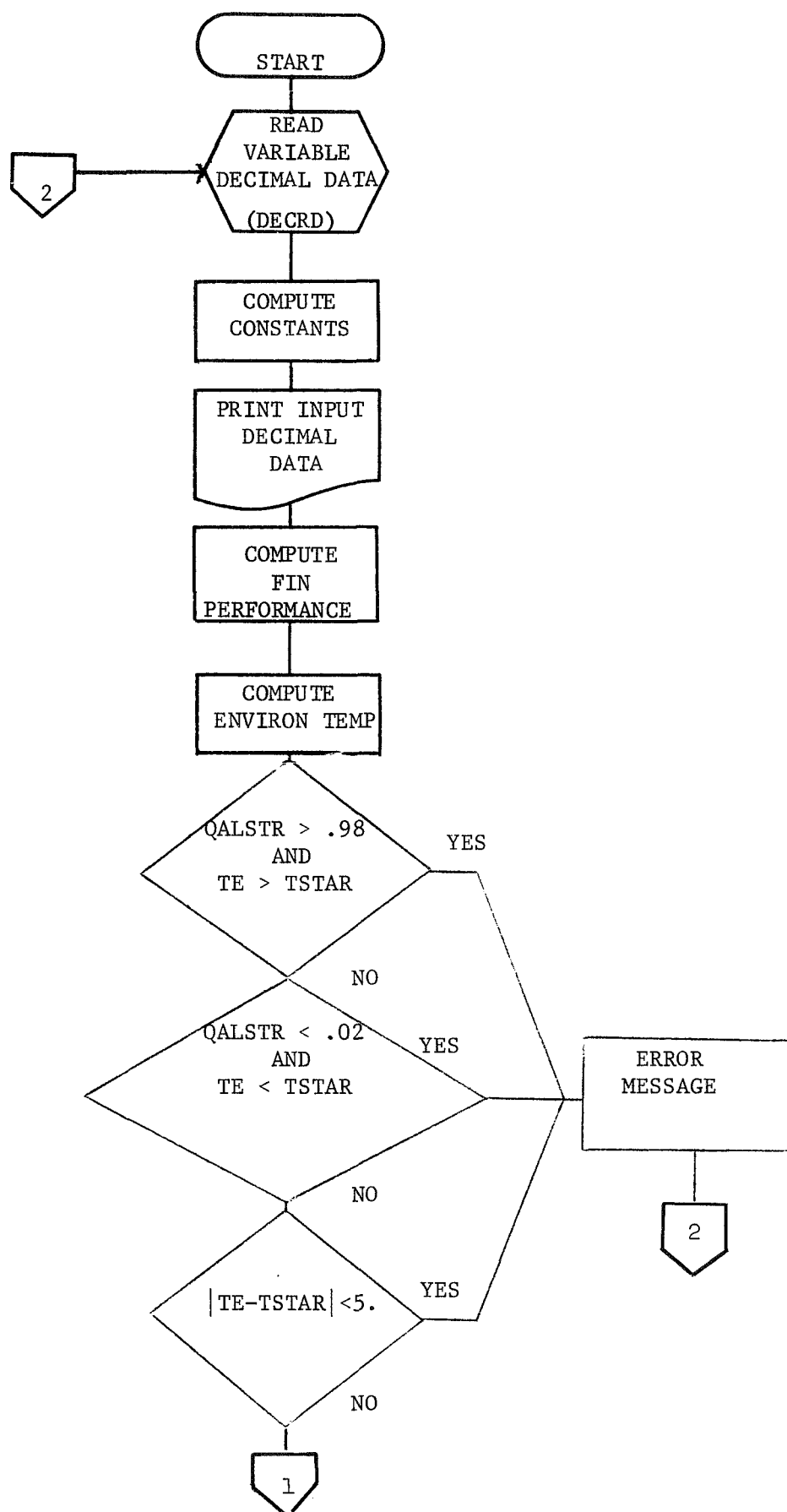


Fig. A-2. Program 5-1. Flow Diagram

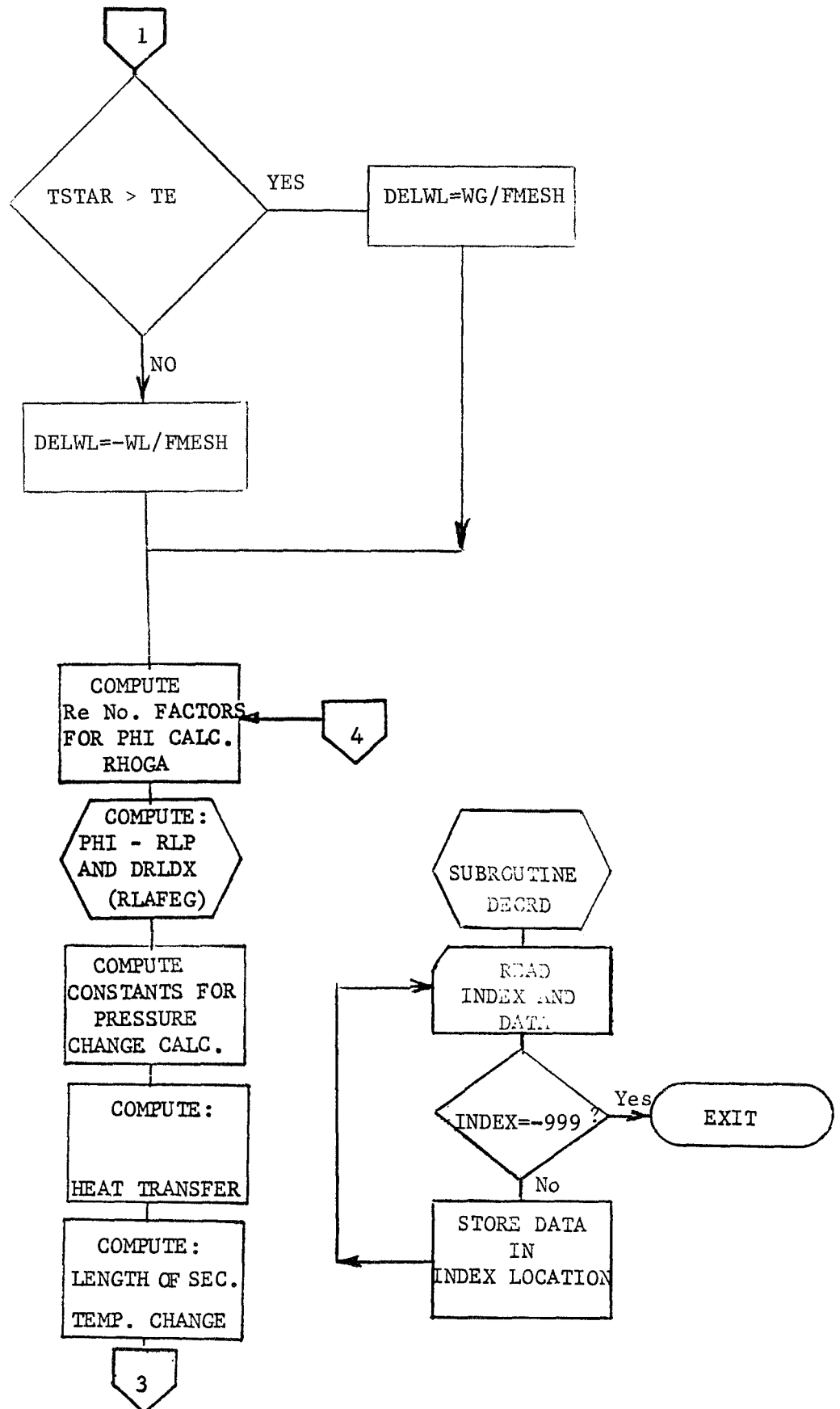


Fig. A-2. Program 5-1 Flow Diagram (cont.)

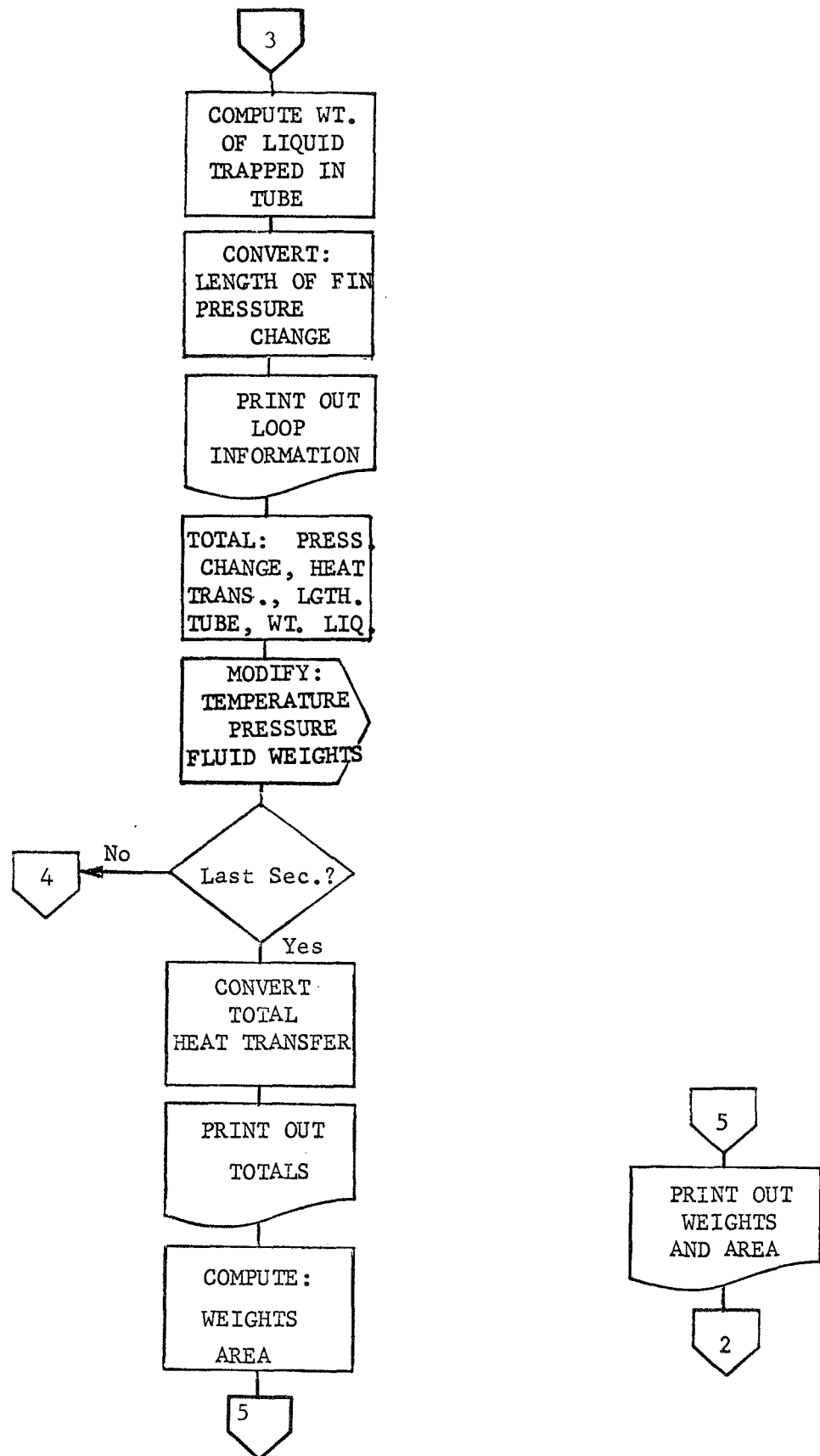


Fig. A-2. Program 5-1 Flow Diagram (cont.)

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PROGRAM 5-1, CONDENSER AND / OR EVAPORATOR ANALYSIS
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DIMENSION DA(50) , CARD(16)
COMMON EMA, EMB, THETAP, FA, ALFAA, RHOM, THETAM, FAX, RHOX,
1THETAX, FB, ALFAB, FBX, TM, LMX, TX, C1, C2, TSTAR, ELH, FNK,
2FINTH, DELTAR, ZZ, CAPN, WDOT, QALSTR, WTM, Z, DO, DI, VF, VG,
3FHH, HA, HB, TAA, TAB, FH, FAH, ELE, C3, PSTAR, CPL, CPG, RHOI,
4FMUG, FMUL, THP, RHOIM

DA(45)=1.0
READ DATA
10 READ 521, CARD
521 FORMAT (16A5)
PRINT 522, CARD
522 FORMAT ("1",16A5/)
CALL DECRO(DA)
ENTER DATA
FMUG=DA(8); FMUL=DA(9); TSTAR=DA(3); QALSTR=DA(10)
WTM=DA(13); C1=DA(35); C2=DA(36); CPG=DA(37); CPL=DA(38)
DO=DA(1); DI=DA(2); WDOT=DA(4); ELH=DA(5); FINTH=DA(6);
VDELTAR=DA(7); FNK=DA(11); FHH=DA(12); HA=DA(14); HB=DA(15);
VTAA=DA(16); TAB=DA(17); ALFAA=DA(18); ALFAB=DA(19);
VEMA=DA(20); EMB=DA(21); EMX=DA(22); FA=DA(23); FAX=DA(24);
VFB=DA(25); FBX=DA(26); RHOM=DA(27); RHOX=DA(28); ZZ=DA(29);
VTHETAM=DA(30); THETAX=DA(31); TM=DA(32); TX=DA(33); EPSM=DA(34);
VFMESH=DA(39); PSTAR=DA(40); INDIC=DA(41); RHOI=DA(42); FH=DA(47);
CAPN=DA(44); Z=DA(45); RHOIM=DA(46); THETAP=DA(43); FAH=DA(48)
CALCULATE SYSTEM CONSTANTS
CALL C1N2(INDIC)
ZZ=C1*TSTAR**3*ELH**2/(FNK*FINTH)
PRINT INPUT DATA
CALL OUT
CALL ENIGRT
COMPUTE ENVIRONMENTAL TEMPERATURE
CALL TEMP(TE)
PRINT 987, ELE, TE
987 FORMAT (6X, "CALCULATED DATA"/F15.5,5X,"EFFECTIVE LENGTH OF FIN,
1FT."/F15.5,5X,"ENVIRONMENTAL TEMPERATURE, DEGREES R"/)
IF (QALSTR .GT. .98 .AND. TE .GT. TSTAR) GO TO 101
IF (QALSTR .LT. .02 .AND. TE .LT. TSTAR) GO TO 102
IF (ABS(TSTAR-TE) .LT. 5.) GO TO 103
SECTION CONSTANTS
PI=3.14159
W=WDOT/(CAPN*3600.)
GJ=778.*32.17
AD=PI*DI**2/4.
GDI=32.17*DI
502 WL=(1.-QALSTR)*W
WG=W-WL
IF (ISTAR .GT. TE) GO TO 1
DELWL=-WL/FMESH ; GO TO 2
1 DELWL=WG/FMESH
2 P=PSTAR
T=ISTAR
PX=P
FJH=778.*FHH
DPSUM=0.0
ELW=0.0
QSUM=0.0
WLTSUM=0.0

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Fig. A-3. Program 5-1, Listing

R=1544./WTM	A-7	62
RHOGS=PSTAR/(TSTAR*R*Z)		63
WL1=WL+DELWL/2.		64
WG1=W-WL1		65
UFS=(WL/RHOL+WG/RHOGS)/AD		66
PRINT 49, JFS		67
49 FORMAT (F15.5,5X,"MIXTURE VELOCITY AT TUBE ENTRANCE, FT/SEC"/)		68
UFS2=UFS**2		69
PMS=W*UFS/(32.17*AD)		70
EKS=UFS2/(2.*GJ)		71
MESH=FMESH		72
SECTION CALCULATIONS		73
DO 27 J=1,MESH		74
QAL=WG1/W		75
RHOGA=P/(R*T*Z)		76
REGP=(4.*WG1)/(PI*DI*FMUG)		77
RELP=(4.*WL1)/(PI*DI*FMUL)		78
IF(REGP-2000.)28,28,29		79
28 IF(RELP-2000.)30,30,31		80
29 IF(RELP-2000.)32,32,33		81
30 CHIC1=(FMUL*RHOGA)/(FMUG*RHOL)		82
CHI=SQRT((WL1*CHIC1)/WG1)		83
DCHI=W*CHI/(2.*WL1*WG1)		84
F=16./REGP		85
GO TO 34		86
31 CHIC1=(.046*4.**.8)/(16.*(PI*DI)**.8)*(RHOGA/RHOL)*(FMUL**2/FMUG)		87
CHI=SQRT((WL1**1.8/WG1)*CHIC1)		88
DCHI=(1.8*WG1+WL1)*CHI/(2.*WG1*WL1)		89
F=16./REGP		90
GO TO 34		91
32 CHIC1=(16.*(PI*DI)**.8)/(.046*4.**.8)*(RHOGA/RHOL)*(FMUL/FMUG**2)		92
CHI=SQRT((WL1/WG1**1.8)*CHIC1)		93
DCHI=((WG1+1.8*WL1)*CHI)/(2.*WG1*WL1)		94
F=.046/REGP**2		95
GO TO 34		96
33 CHIC1=(RHOGA/RHOL)*(FMUL/FMUG)**2		97
CHI=SQRT((WL1/WG1)**1.8*CHIC1)		98
DCHI=(.9*W*CHI)/(WG1*WL1)		99
F=.046/REGP**2		100
34 CALL RLAFEG (CHI,PHI,RLP,DRLDX,REGP,RELP)		101
RGP=1.-RLP		102
V=WL1/(RLP*AD*RHOL)		103
U=WG1/(RGF*AD*RHOGA)		104
V2=V**2		105
U2=U**2		106
UP2=(WG1/(AD*RHOGA))**2		107
U2COEF=1.-((WG1*DCHI*DRLDX)/RGF)		108
V2COEF=1.-((WL1*DCHI*DRLDX)/RLP)		109
DPXF=PHI**2*2.*UP2*RHOGA*F/GDI		110
DPMDW1=DRLDX*DCHI		111
DPMDW2=2.-((DPMDW1*WG1)/RGF)		112
DPMDW3=2.-((DPMDW1*WL1)/RLP)		113
DPMDW4=RHOGA*U2*RGF*DPMDW2/(32.17*WG1)		114
DPMDW5=RHOL*V2*RLP*DPMDW3/(32.17*WL1)		115
DPMDWX=DPMDW4+DPMDW5		116
DPC1=(CPL*WL1+CPG*WG1)*T/(FJH*RHOGA)		117
HT=(HA+HB)		118
HAT=HA*TA4+HB*TAB		119
AREA=(DO*PI-2.*DELTAH)/2.		120
QS2=((C1*2.*ELE+C1*DO)*T**4+(HT*2.*ELE+HT*AREA)*T		121
1+(-C2-HAT)*2.*ELE-C2*DO-HAT*AREA)/3600.		122

Fig. A-3. Program 5-1, Listing (con't)

DX1=QS2+DPC1*DPXF	123
DX2=FHH-V2*V2COEF/GJ+U2*U2COEF/GJ-DPC1*DPMDWX+(U2-V2)/(2.*GJ)	124
DX=DX2*DELWL/DX1	125
IF(DX)35,35,36	126
35 PRINT 63	127
GO TO 10	128
36 DP= DPMWX*DELWL+DPXF*DX	129
DELT= T*DP/(FJH*RHOGA)	130
WLT=RHOL*AD*RLP*DX*CAPN	131
PRINT 44, J	132
44 FORMAT ("0",5X,"SECTION",I10)	133
PRINT 110, QAL	134
110 FORMAT (F15.5,5X,"QUALITY AT MIDDLE OF SECTION")	135
PRINT 111, V	136
111 FORMAT (F15.5,5X,"LIQUID VELOCITY (FT./SEC.)")	137
PRINT 41, U, QS2, DX, DELT, DP	138
41 FORMAT (F15.5,5X,"VAPOR VELOCITY (FT./SEC.)"/F15.5,5X,	139
1"QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH,(BTU/SEC-FT)"/	140
2F15.5,5X,"DIFFERENTIAL LENGTH OF TUBE, (FT.)"/F15.5,5X,	141
3"CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R"/	142
4F15.5,5X,"CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)")	143
T=1+DELT	144
PX=P	145
WL1=WL1+DELWL	146
WG1=W-WL1	147
DPSUM=DPSUM+DP	148
P=P+DP	149
IF (P,LE. 0.0) GO TO 75	150
ELW=ELW+DX	151
QSUM=QSUM+QS2*DX*CAPN	152
WLTSUM=WLTSUM+WLT	153
27 CONTINUE	154
QSUM=QSUM*3600.	155
PRINT 42, DPSUM, ELW, QSUM, WLTSUM	156
42 FORMAT (// F15.5,5X,"ACCUMULATED SUM OF PRESSURE CHANGE, (PSF)"/	157
1F15.5,5X,"TOTAL TUBE LENGTH, FT."/F15.5,5X,	158
2"ACCUMULATED SUM OF HEAT LOST, BTU/HR"/F15.5,5X,"ACCUMULATED WEIGH	159
3T OF TRAPPED LIQUID, LB.")	160
RHUGE=P/(T*R*Z)	161
WLE=WL1-DELWL/2.	162
WGE=W-WLE	163
UFEND=(WLE/RHOL+WGE/RHUGE)/AD	164
UFE2=UFEND**2	165
PMEND=W*UFEND/(32.17*AD)	166
DPM=PMS-PMEND	167
EKEND=UFE2/(2.*GJ)	168
WD=P1*RHOTM*ELW*(DU**2-DI**2)/4.	169
WE=FINTH*ELH*RHOFM*ELW*(1.+FRTIO)/2.	170
WT=CAPN*(WD+2.*WE)	171
WQ=WT/QSUM	172
AS=(DU+2.*ELH)*ELW*CAPN	173
FINTC=FINTH*FRTIO	174
PRINT 40, WD, WT, WQ, AS	175
40 FORMAT (F15.5,5X,"WEIGHT OF ONE TUBE, LBS"/F15.5,5X,	176
1 "TOTAL WEIGHT OF UNIT, LBS"/F15.5,5X,"WEIGHT PER UNIT OF HEAT TRA	177
2NSFER, LB-HR/BTU"/F15.5,5X,"PLANFORM AREA, SQFT"/)	178
PRINT 81, PMS, EKS, PMEND, EKEND, DPM	179
81 FORMAT (F15.5,5X,"MOMENTUM PRESSURE AT INLET, LBS/SQFT"/	180
1F15.5,5X,"KINETIC ENERGY OF FLUID AT INLET, BTU/LB	181
2F15.5,5X,"MOMENTUM PRESSURE AT END, LBS/SQFT"/F15.5,5X,"KINETIC EN	182
3ERGY OF FLUID AT END, BTU/LB	183

```

4"CHANGE IN MOMENTUM PRESSURE, LBS/SQFT") 184
  GO TO 10 185
75 PRINT 76 186
76 FORMAT (" FLOW RATE EXCESSIVE, PRESSURE DROP GREATER THAN INLET PR 187
  1ESSURE") 188
  GO TO 10 189
101 PRINT 901 190
  GO TO 10 191
901 FORMAT(" TEMPERATURE IS TOO HIGH TO CONDENSE") 192
102 PRINT 902 193
902 FORMAT(" TEMPERATURE IS TOO LOW TO EVAPORATE") 194
  GO TO 10 195
103 PRINT 903 196
903 FORMAT(" FLUID TEMPERATURE TOO CLOSE TO ENVIRONMENTAL TEMPERATURE" 197
  1) 198
  GO TO 10 199
63 FORMAT(38H FLOW RATE EXCESSIVE. GO TO NEXT CASE.) 200
  END 201

SUBROUTINE RLAFEG (CHI,PHI,RLP,DRLOX,REGP,RELPI) 202
  COMMON EMA, EMB, THETAP, FA, ALFAA, RHOM, THETAM, FAX, RHOX, 203
  1THETAX, FB, ALFAB, FBX, TM, EMX, TX, C1, C2, TSTAR, ELH, FNK, 204
  2FINTH, DELTAR, ZZ, CAPN, WDOT, QALSTR, WTM, Z, DO, DI, VF, VG, 205
  3FHH, HA, HB, TAA, IAB, FH, FAH, ELE, C3, PSTAR, CPL, CPG, RHOL, 206
  4FMUG, FMUL, THP, RHOIM 207
  DIMENSION A(5),B(5),C(5),AA(5),BB(5),CC(5),AAA(5),BBB(5),CCC(5), 208
  VD(5),E(5),G(5),DA(100) 209
  DATA (A(I),I=1,5)/.961729, .052676, .17996, .108387, .022224/ 210
  DATA (B(I),I=1,5)/4.28577, .222, .509048, .653052, .81402/ 211
  DATA (C(I),I=1,5)/4.74133, .250008, .409772, .409772, .334969/ 212
  DATA (AA(I),I=1,5)/.957448, .062721, .201257, .138803, .050525/ 213
  DATA (BB(I),I=1,5)/4.29955, .292137, .584971, .530757, .691175/ 214
  DATA (CC(I),I=1,5)/4.82121, .385293, .539591, .539591, .46745/ 215
  DATA (AAA(I),I=1,5)/.0344006, .0728001, .1368, .13, .079999/ 216
  DATA (BBB(I),I=1,5)/.239203, .3784, .4928, .481, .562003/ 217
  DATA (CCC(I),I=1,5)/.448004, .572802, .6232, .631, .600998/ 218
  DATA (D(I),I=1,5)/-.29093, -.28915, -.20092, -.092062, -.075481/ 219
  DATA (E(I),I=1,5)/-.3407, -.060579, .45461, .461834, .456419/ 220
  DATA (G(I),I=1,5)/-1.6256, -1.0725, -.63827, -.63827, -.65665/ 221
  IF(CHI=1.E+2)1,1,2 222
1 ELX=ALOG10(CHI) 223
  IF(.001=CHI)3,3,5 224
5 NA=0.0 225
  GO TO 6 226
3 NA=4.+ELX 227
  GO TO 6 228
2 CHI=99.99 229
  GO TO 1 230
6 IF(NA)/,/,8 231

```

Fig. A-3. Program 5-1, Listing (con't)

7 PHI=1.	235
GO TO 11	236
8 IF(ELGP=2000.)15,15,16	237
15 IF(ELGP=2000.)17,17,18	238
16 IF(ELGP=2000.)18,18,19	239
17 X=ELX*(ELX*A(NA)+B(NA))+C(NA)	240
PHI=10.**X	241
GO TO 11	242
18 X=ELX*(ELX*AA(NA)+BB(NA))+CC(NA)	243
PHI=10.**X	244
GO TO 11	245
19 X=ELX*(ELX*AA4(NA)+BBB(NA))+CCC(NA)	246
PHI=10.**X	247
11 IF(NA)12,12,13	248
12 RLP=10.**ELX	249
DRLDX=10.**ELX/CHI	250
GO TO 14	251
13 RLP=ELX*(ELX*D(NA)+E(NA))+G(NA)	252
RLP=10.**RLP	253
DRLDX=RLP*(2.**ELX*D(NA)+E(NA))/CHI	254
14 RETURN	255
END	256
SUBROUTINE C1N2 (INDIC)	257
IF INDIC=0, C1N2 WILL CALCULATE ALL CONSTANTS	258
IF INCIC=1, C1N2 WILL NOT CALCULATE C1 AND C2	259
IF INDIC=2, C1N2 WILL NOT CALCULATE C1, C2, FH, OR FAH	260
COMMON EMA, EMB, THETAP, FA, ALFAA, RHOM, THETAM, FAX, RHOX,	261
1THETAX, FB, ALFAB, FBX, TM, EMX, TX, C1, C2, TSTAR, ELH, FNK,	262
2FINTH, DELTAR, ZZ, CAPN, WOOT, QALSTR, WTM, Z, DO, DI, VF, VG,	263
3FHH, HA, HB, TAA, TAB, FH, FAH, ELE, C3, PSTAR, CPL, CPG, RHOL,	264
4FMUG, FMUL, THP, RHO TM	265
IF (INDIC .EQ. 1) GO TO 113	266
IF (INDIC .EQ. 2) GO TO 13	267
C1 = .1713E-8 * (EMA+EMB)	268
P = 3.1415926/180.	269
C2 = 443.*(ALPHA A *COS(P*THETAP)+FA*ALPHA A *RHOM *COS(P*THETAM)	270
V +FAX*ALPHA A *RHOX *COS(P*THETAX)+FB*ALPHA B *RHOM *COS(P*THETAM)	271
V +FBX*ALPHA B *RHOX *COS(P*THETAX))	272
V +TM**4*.1713E-8*(FA*EMA+FB*EMB)*EPSM	273
V +EMX*TX**4*.1713E-8*(FAX*EMA+FBX*EMB)	274
V + .01*(EMA+EMB)	275
113 FH=(ELH**2*(HA+HB))/(FNK*FINTH)	276
FAH=(ELH**2*(HA*TAA+HB*TAB))/(FNK*FINTH*TSTAR)	277
13 IF (C1 .NE. 0.0) C3=C2/(C1*TSTAR**4)	278
RETURN	279
END	280
	281
	282
	283

Fig. A-3. Program 5-1, Listing (con't)

```

SUBROUTINE DECRD(DATA)
READS A VARIABLE NUMBER OF ITEMS OF FLOATING-POINT DATA INTO
SPECIFIED ELEMENTS OF AN ARRAY IN BLOCKS OF 5 CONSECUTIVE ITEMS.
ONE OR MORE BLANK FIELDS ON A DATA CARD CAUSE THE VALUES IN CORE
TO REMAIN UNCHANGED
THE FORTRAN INTEGER INDEX IN THE FIRST FIELD OF EACH CARD DEFINES
THE POSITION OF THE ARRAY OF THE FIRST ITEM OF EACH BLOCK OF FIVE.
THE BLOCKS NEED NOT BE SEQUENTIAL NOR CONTINUOUS.
THE INDEX IS PLACED AT THE END OF ITS FIELD. IT MAY NOT BE ZERO
OR BLANK. IT SHALL NOT CONTAIN A DECIMAL POINT.
A DECIMAL POINT MUST ALWAYS BE PLACED IN EACH DATA ITEM, THEREFORE
THE VALUE MAY BE PLACED ANYWHERE IN EACH OF THE FIELDS PER CARD.
THE DECIMAL SCALE, IF ANY, FOR A DATA ITEM MUST BE PLACED AT THE
END OF THE FIELD.
A 0. MUST BE ENTERED TO READ IN A ZERO. A -0. IS THE SAME AS A
BLANK FIELD. THE READING OF DATA IS TERMINATED BY ENTERING A
NEGATIVE INDEX ON THE LAST CARD OF EACH SERIES.
TO USE THE ROUTINE ---- CALL DECRD(DATA)
DIMENSION DRBU (5), DATA (6)
1 READ 2, IND, (DRBU(I), I=1,5)
2 FORMAT(I12, SE12.0)
  IF (IND. EQ. (-999)) STOP
3 J = IABS(IND)
4 DO 7 I=1,5
5 IF(DRBU(I)) 6,10,6
6 DATA(J) = DRBU(I)
7 J = J+1
8 IF(IND) 9,11,1
9 RETURN
10 IF(SIGN(1., DRBU(I))) 7,11,6
11 CALL EXIT
END

SUBROUTINE TEMP (T2)

COMMON EMA, EMB, THETAP, FA, ALFAA, RHOM, THETAM, FAX, RHOX,
1THETAX, FB, ALFAB, FBX, FM, EMX, TX, C1, C2, TSTAR, ELH, FNK,
2FINTH, DELTAR, ZZ, CAPN, WOOT, QALSTR, WTM, Z, DD, DI, VF, VG,
3FHH, HA, HB, TAA, TAB, FH, FAH, ELE, C3, PSTAR, CPL, CPG, RHOL,
4FMUG, FMUL, THP, RHOIM

C1D=C1
C2D=C2
HAT=(HA*TAA+FB*TAB)
PI=3.14159
AREA=(DD*PI-2.*DELTAR)/2.
A=C1*2.*ELE+C1D*DD
B=(FA+HAT)*(2.*ELE+AREA)
C=(-C2-HAT)*2.*ELE-C2D*DD-HAT*AREA
T1=TSTAR
DO 19 I=1,100
T2=T1*(A*T1**4+B*T1+C)/(4.*A*T1**3+B)
IF (ABS(T2-T1) .LT. .001) RETURN
19 T1=T2
PRINT 1
1 FORMAT (' SUBROUTINE TEMP DID NOT CONVERGE')
CALL EXIT
END

```

Fig. A-3. Program 5-1, Listing (con't)

SUBROUTINE OUT	A-12	341
		342
COMMON EMA, EMB, THETAP, FA, ALFAA, RHOM, THETAM, FAX, RHOX,		343
1THETAX, FB, ALFAB, FBX, TM, EMX, TX, C1, C2, TSTAR, ELH, FNK,		344
2FINTH, DELTAR, ZZ, CAPN, WDOT, QALSTR, WTM, Z, DO, DI, VF, VG,		345
3FHH, HA, HB, TAA, TAB, FH, FAH, ELE, C3, PSTAR, CPL, CPG, RHOL,		346
4FMUG, FMUL, THP, RHOTM		347
		348
PRINT 90		349
90 FORMAT (" ",10X,"INPUT DATA"//)		350
PRINT 91, ISTAR, PSTAR, WDOT, QALSTR		351
91 FORMAT (" ",F14.5,5X,"FLUID TEMPERATURE, DEGREES R"/		352
1F15.5,5X,"FLUID ENTRY PRESSURE, LB/SQFT"/		353
2F15.5,5X,"FLOW RATE, LB/HR"/F15.5,5X,"WEIGHT FRACTION OF VAPOR"/)		354
PRINT 92, CPL, FMUL, RHOL, FHH		355
92 FORMAT (F15.5,5X,"SPECIFIC HEAT OF LIQUID, BTU/LB-DEGREES R"/		356
1F15.5,5X,"VISCOSITY OF LIQUID, LB/SEC-FT"/F15.5,5X,		357
2"DENSITY OF LIQUID, LB/CUFT"/F15.5,5X,"LATENT HEAT OF FLUID, BTU/L		358
3B"/)		359
PRINT 94, CPG, FMUG, WTM, Z		360
94 FORMAT (F15.5,5X,"SPECIFIC HEAT OF GAS, BTU/LB-DEGREES R"/		361
1F15.5,5X,"VISCOSITY OF GAS, LB/SEC-FT"/		362
2F15.5,5X,"MOLECULAR WEIGHT OF GAS, LB/MOL"/F15.5,5X,		363
3"CORRECTION FACTOR FOR IDEAL GAS FORMULA"/)		364
PRINT 912, DI, DO, CAPN		365
912 FORMAT (F15.5,5X,"INSIDE DIAMETER OF TUBE, FT"/		366
1F15.5,5X,"OUTSIDE DIAMETER OF TUBE, FT"/F15.5,5X,		367
2"NUMBER OF TUBES"/)		368
PRINT 93, FNK, FA, FB, ALFAA, ALFAB, EMA, EMB		369
93 FORMAT (F15.5,5X,"THERMAL CONDUCTIVITY OF FIN		370
1 MATERIAL (BTU/FT.HR.R)"/F15.5,5X,"FORM FACTOR BETWEEN SIDE A AND		371
2MOON"/F15.5,5X,"FORM FACTOR BETWEEN SIDE B AND MOON"/F15.5,5X,		372
3"ABSORPTIVITY, SIDE A"/F15.5,5X,"ABSORPTIVITY, SIDE B"/		373
4F15.5,5X,"EMISSIVITY, SIDE A"/F15.5,5X,"EMISSIVITY, SIDE B")		374
PRINT 95, FAX, FBX, TX, THETAX, RHOX		375
95 FORMAT (F15.5,5X,"FORM FACTOR BETWEEN SIDE A AND X"/F15.5,5X,		376
1"FORM FACTOR BETWEEN SIDE B AND X"/F15.5,5X,"TEMPERATURE OF X (DEG		377
2REES R)"/F15.5,5X,"ANGLE BETWEEN SUNS RAYS AND NORMAL TO X (DEGREE		378
3S)"/F15.5,5X,"REFLECTIVITY OF X")		379
PRINT 96, TM, THETAM, RHOM		380
96 FORMAT (F15.5,5X,"TEMPERATURE OF MOON (DEGREES R)"/F15.5,5X,		381
1"ANGLE BETWEEN SUNS RAYS AND NORMAL TO MOON SURFACE (DEGREES)"/		382
2F15.5,5X,"REFLECTIVITY OF MOON SURFACE")		383
PRINT 97, IHP, FINTH, DELTAR, ELH		384
97 FORMAT (F15.5,5X,"ANGLE BETWEEN SUNS RAYS AND PLANE OF EXTENDED SU		385
1RFACE"/F15.5,5X,"ROOT THICKNESS, (FEET) "/F15.5,5X,		386
2"RATIO OF END TO ROOT SECTION"/F15.5,5X,"LENGTH OF FIN (FEET)"/)		387
PRINT 98, HA, HB, TAA, TAB		388
98 FORMAT (F15.5,5X,"CONVECTION COEFFICIENT SIDE A (BTU/HR.SQFT.R)"/		389
1F15.5,5X,"CONVECTION COEFFICIENT SIDE B (BTU/HR.SQFT.R)"/F15.5,5X,		390
2"FLUID TEMPERATURE SIDE A (DEGREES R)"/F15.5,5X,"FLUID TEMPERATURE		391
3 SIDE B (DEGREES R)"/)		392
SC1=C1*1.0E08		393
PRINT 99, SC1, C2		394
99 FORMAT (F15.5,5X,"X10E-08",5X,"C1 (BTU/HR.SQFT.R**4)"/F15.5,5X,		395
1"C2 (BTU/HR.SQFT.) "///)		396
PRINT 910		397
910 FORMAT (" NONDIMENSIONAL PARAMETERS"/)		398
PRINT 911, ZZ, C3, FH, FAH		399
911 FORMAT (F15.5,5X,"ZETA P PROFILE NUMBER"/F15.5,5X,"C3 ENVIRONMENT		400

```

1AL PARAMETER"/F15.5,5X,"FH SURFACE CONVECTIVE PARAMETER"/F15.5, 401
25X,"FAH ENVIRONMENT CONVECTIVE PARAMETER"/) 402
RETURN 403
END 404

SUBROUTINE ENTGRI 405

COMMON EMA, EMB, THETAP, FA, ALFAA, RHOM, THETAM, FAX, RHOX, 406
1THETAX, FB, ALFAB, FBX, TM, EMX, TX, C1, C2, TSTAR, ELH, FNK, 407
2FINTH, DELTAR, ZZ, CAPN, WDOT, QALSTR, WTM, Z, DO, DI, VF, VG, 408
3FHH, HA, HB, TAA, TAB, FH, FAH, ELE, C3, PSTAR, CPL, CPG, RHOL, 409
4FMUG, FMUL, THP, RHOTM 410
DIMENSION CM(5),F(5), T(5), A(3), B(3), C(3) 411

DATA (A(I),I=1,3)/ .41199999 , .0053315, .00002362/ 412
DATA (B(I),I=1,3)/-.87831999, -.0962565, -.00405435/ 413
DATA (C(I),I=1,3)/ 1.0, .6246049, .23347166/ 414

DZ(12,T4,T5)=(T5*(1.-DELTAR)+ZETAP*(T4**4-C3)+FH*T4-FAH)/ 415
V(1.-T2*(1.-DELTAR)) 416
ZETAP=ZZ 417
IF (ZETAP=100.) 126, 125, 125 418
125 NA=3 419
GO TO 127 420
126 IF (ZETAP) 123, 129, 128 421
128 NA=2+ALOG10(ZETAP) 422
IF (NA .LT. 1) NA=1 423
127 EFR1=(1.-C3)*(ZETAP*(ZETAP*A(NA)+B(NA))+C(NA)) 424
129 IF (FH .NE. 0.0) EFC1=TANH(SQRT(FH))/SQRT(FH) 425
T(5)=-ZETAP*EFR1-(FH-FAH)*EFC1 426
IF (ZETAP .EQ. 0.0) GO TO 1400 427
ITER = 0 428
ITLT=15. 429
ISU=0 430
ISW=0 431
DZ0=0. 432
DZW=0. 433
DZ1A=T(5) 434
050 WILT = 500. 435
T(4) = 1. 436
061 T(3)=1./25. 437
T(2) = 0. 438
MESH=25. 439
DZ1=T(5) 440
ITER=ITER+1 441
IF (ITLT = ITER) 1125,1130,1130 442
125 PRINT 1500,DZ1A,DZ1 443
500 FORMAT(38H0INTEGRATION CONVERGENCE FAILED. DZ1A=E12.5,5H DZ1= 444
V E12.5) 445
RETURN 446
130 DO 1390 J=1,MESH 447
F(2)=0. 448
F(3)=T(3)/2. 449
F(4)=T(3)/2. 450
F(5)=T(3) 451
CM(1)=0. 452
DO 2 I=2,5 453

```

Fig. A-3. Program 5-1, Listing (con't)

```

      CM(I)=DZ2(T(2)+F0(I),T(4)+F0(I)*T(5),T(5)+F0(I)*CM(I-1))
2  CONTINUE
      T(2)=I(2)+I(3)
      DT4 =T(3)/6.*(CM(2)+CM(3)+CM(4))*T(3)+T(3)*T(5)
      T(4)=I(4)+DT4
      DT5 =T(3)/6.*(CM(2)+2.*CM(3)+2.*CM(4)+CM(5))
      T(5)=I(5)+DT5
1200 IF(ABS(DZ1)+ABS(T(5))-ABS(DZ1+T(5)))1250,1250,1205
1205 IF(ISW)1225,1235,1225
1225 DZ0=DZ1
      T(5)=.5*(DZ0+DZW)
      GO TO 1210
1235 DZ0=DZ1
      T(5)=1.10*DZ1
      IF(ISW)1210,1239,1210
1210 IF((ABS(DZW)-ABS(DZ0))/ABS(T(5))=.0025)1400,1400,1239
1239 IS0=1
      IF(IIIT=ITER) 1125,1125,1050
*** TEST FOR WILT
1250 IF (ABS (WILT)-ABS (T(5))) 1260, 1380,1380
1260 IF(IS0)1278,1277,1278
1277 T(5)=.90*DZ1
      DZW=DZ1
      GO TO 1265
1278 DZW=DZ1
      T(5)=.5*(DZ0+DZW)
1265 IF((ABS(DZW)-ABS(DZ0))/ABS(T(5))=.0025)1400,1400,1270
1270 ISW=1
      IF(IIIT=ITER) 1125,1125,1050
1380 WILT=T(5)
1390 CONTINUE
      GO TO 1260
1400 ELE=-ELH*T(5)/(ZETAP*(1.-C3)+FH-FAH)
      RETURN
      END

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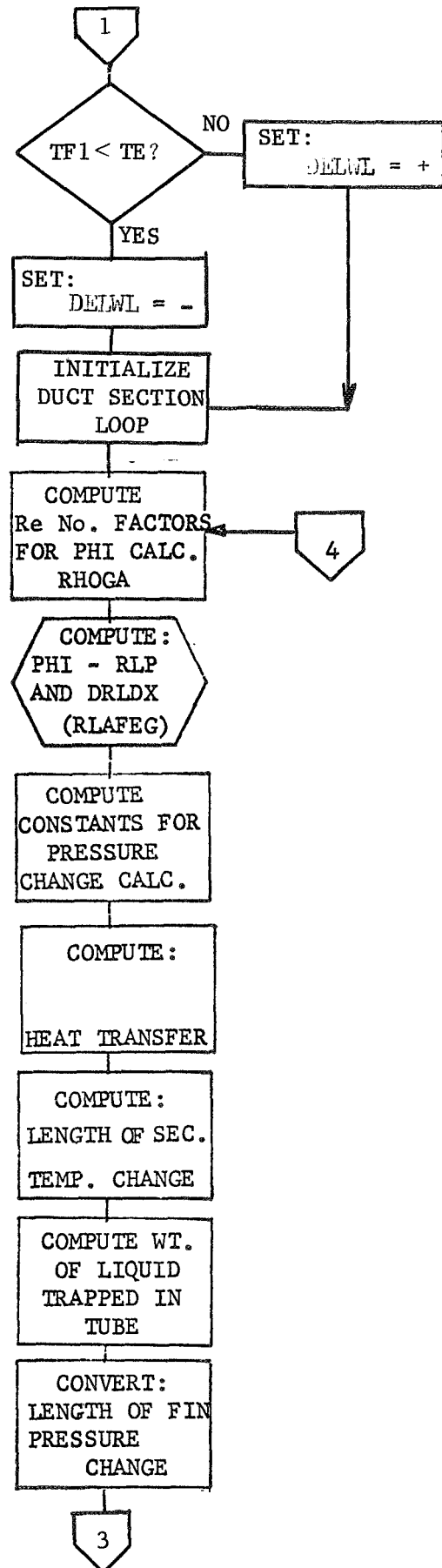
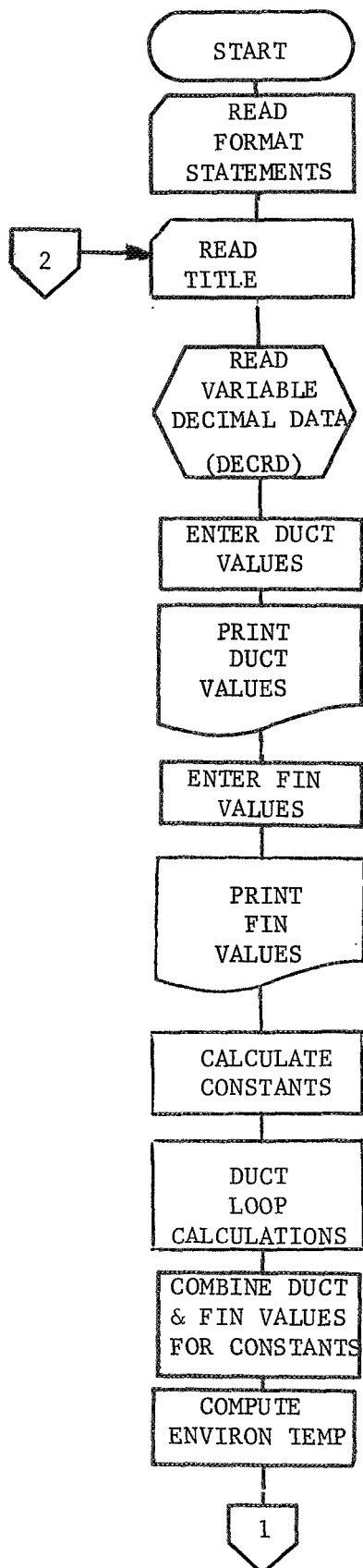
DATA FOR PROBLEMS

```

POTASSIUM CONDENSER  6000 LB/HR  464 TUBES
      6.0083333  .25  1.21E-05  1.0E-04
      120.0  0.0
      39  4.  490.
      3  1620.
      10 .8  51.5  873.  39.1
      35 .3082E-080.0  .21  .183
      1 .05208  .0312  6000.  .16666
      45 .936  494.
      -  41  1.0  43.6  464.
POTASSIUM CONDENSER  6000 LB/HR  120 TUBES
      -  44  120.
POTASSIUM REHEATER  CONVECTIVE ENVIRONMENT
      44  464.
      14  2.  2.  2000.  2000.
      35 .001E-08
      -4  3000.
POTASSIUM REHEATER  CONVECTIVE ENVIRONMENT
      -  16  1622.  1622.
POTASSIUM CONDENSER CONVECTIVE AND RADIATIVE ENVIRONMENT
      -  35 .0500E-08
END OF DATA
      -  999

```

Fig. A-3. Program 5-1, Listing (con't)



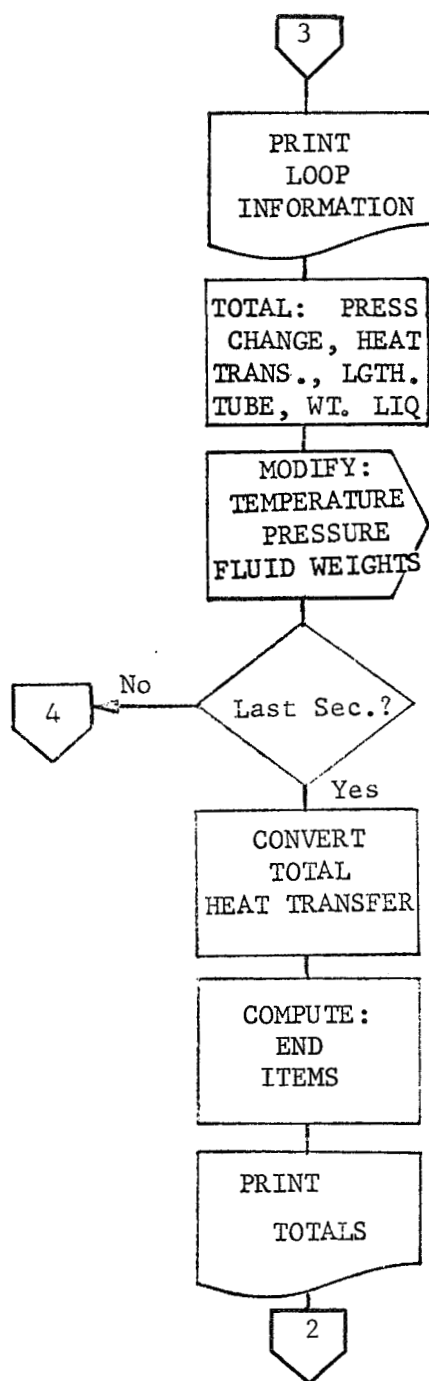


Fig. A-4. Program 5-2 Flow Diagram (cont.)

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C      PROGRAM NO. 5-2 CONDENSER AND/OR EVAPORATOR ANALYSIS
C
      DIMENSION F1(12),F2(12),F3(24),F4(132),F5(24),F6(24),F7(12),F8(12)
      V,F9(24),F10(12),F11(24),F12(12),F13(24),F14(24),F15(12),F16(12),
      VF17(12),F18(24),F19(24),F20(24),F21(60),F22(36),F23(12),TITLE(16)
      DIMENSION DA(300),SR(6),SC(6),C1D(6),C2D(6),HD(6),TA(6),C1(10),
      VC2(10),HA(10),HR(10),TAA(10),TAB(10),FLE(10)
      EQUIVALENCE(DA(1),WDOT),(DA(2),ENT),
      1(DA(8),FMESH),(DA(9),PSTAR),(DA(10),TSTAR),(DA(11),QALSTR),
      2(DA(12),FHH),(DA(13),CPG),(DA(14),FMUG),(DA(15),WTM),(DA(16),7),
      3(DA(17),RHOL),(DA(18),CPL),(DA(19),FMUL)
C
      READ 2,F1,F2,F3,F4,F5,F6,F7,F8,F9,F10,F11,F12,F13,F14,F15,F16,
      VF17,F18,F19,F20,F21,F22,F23
      2 FORMAT (12A6)
      5 READ 2400,TITLE
      2400 FORMAT (16A5)
      CALL DECRD (DA)
C      PRINT CASE DATA
      PRINT 2600,TITLE
      2600 FORMAT (1H1,16A5///)
      PRINT F4,(J,DA(J),J=1,19)
C
C      ENTER AND PRINT DUCT VALUES
      NP=30
      ND=DA(6)
      DO 100 I=1,ND
      SR(I)=DA(NP)
      SC(I)=DA(NP+1)
      C1D(I)=DA(NP+2)
      C2D(I)=DA(NP+3)
      HD(I)=DA(NP+4)
      TA(I)=DA(NP+5)
      100 NP=NP+10
      PRINT F5,(K,SR(K),K=1,ND)
      PRINT F6,(K,SC(K),K=1,ND)
      PRINT F7,(K,C1D(K),K=1,ND)
      PRINT F8,(K,C2D(K),K=1,ND)
      PRINT F9,(K,HD(K),K=1,ND)
      PRINT F10,(K,TA(K),K=1,ND)
C
C      ENTER AND PRINT FTH VALUES
      NF=DA(7)
      IF(NF.LE.0.0) GO TO 250
      N=90
      DO 200 L=1,NF
      C1(L)=DA(N)
      C2(L)=DA(N+1)
      HA(L)=DA(N+2)
      HR(L)=DA(N+3)
      TAA(L)=DA(N+4)
      TAB(L)=DA(N+5)
      ELE(L)=DA(N+6)
      200 N=N+10

```

Fig. A-5. Program 5-2, Listing

```

      PRINT F11,(K,C1(K),K=1,NF)
      PRINT F12,(K,C2(K),K=1,NF)
      PRINT F13,(K,HA(K),K=1,NF)
      PRINT F14,(K,HB(K),K=1,NF)
      PRINT F15,(K,TAA(K),K=1,NF)
      PRINT F16,(K,TAB(K),K=1,NF)
      PRINT F17,(K,ELE(K),K=1,NF)
250  PRINT F19
C
C      CALCULATE SYSTEM CONSTANTS
      PI=3.1415926
      IF(DA(3)) 275,280,275
275  PERIM=DA(3)
      AD=DA(4)
      DT=4.*AD/PERIM
      GO TO 295
280  DI=DA(5)
      AD=PI*DI**2/4.
      PERIM=PI*DI
295  W=WDOT/(ENT*3600.)
      GJ=778.*32.17
      GD1=32.17*DI
      GD1=0.
      GD2=0.
      GD3=0.
      SUM0=0.
      SUM1=0.
      SUM4=0.
      DO 300 I=1,ND
      GD1=GD1+SR(I)*C1D(I)
      GD2=GD2+SC(I)*HD(I)
300  GD3=GD3+(SR(I)*C2D(I)+SC(I)*HD(I)*TA(I))
      IF(NF.LE.0.0) GO TO 550
      DO 500 L=1,NF
      SUM0=SUM0+ELE(L)*(HA(L)*TAA(L)+HB(L)*TAB(L)+C2(L))
      SUM1=SUM1+ELE(L)*(HA(L)+HB(L))
500  SUM4=SUM4+ELE(L)*C1(L)
550  CK0=-(GD3+SUM0)
      CK1=GD2+SUM1
      CK4=GD1+SUM4
C
C      COMPUTE ENVIRONMENT TEMP
      IF(CK1.LE.0.0) GO TO 675
      LC=0
      TE=TSTAR
640  LC=LC+1
      IF (LC=25) 660,660,651
651  PRINT F18,TE,CK0,CK1,CK4
      GO TO 5
660  FE=CK0+CK1*TE+CK4*TE**4
      IF(ABS(FE)=.001)1003,1003,670
670  DFEDTE=CK1+4.*CK4*TE**3
      TE=TE-FE/DFEDTE
      GO TO 640
675  TE=SQRT(SQRT(-CK0/CK4))

```

Fig. A-5. Program 5-2, Listing (con't)

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C
C      SECTION CONSTANTS
1003 IF(QALSTR .GT. .98 .AND. TE .GT. TSTAR) GO TO 701
      IF (QALSTR .LT. .02 .AND. TE.LT. TSTAR) GO TO 702
      IF (ABS(TSTAR-TE) .LT. 5.) GO TO 703
      WL=(1.-QALSTR)*W
      WG=W-WL
      IF (TSTAR .GT. TE) GO TO 801
      DELWL=-WL/FMESH
      GO TO 802
801 DELWL=WG/FMESH
802 P=PTAR
      T=TSTAR
      FJH=778.*FHH
      DPSUM=0.0
      ELW=0.0
      ASUM=0.0
      WLISUM=0.0
      R=1544./41M
      RHOGS=PTAR/(TSTAR*R*Z)
      WL1=WL+DELWL/2.
      UFS=(WL/RHOL+WG/RHOGS)/AD
      UFS2=UFS**2
      RMS=W*UFS/(32.17*AD)
      EKS=UFS2/(2.*GJ)
      WG1=W-WL1
      MESH=FMESH

C
C      SECTION CALCULATIONS
      DO 37 J=1,MESH
      RHOGA=P/(R*T*Z)
      REGP=(4.*WG1)/(PERIM*FMUG)
      RELP=(4.*WL1)/(PERIM*FMUL)
      IF( REGP-2000.)28,28,29
28 IF( RELP-2000.)30,30,31
29 IF( RELP-2000.)32,32,33
30 CHIC1=(FMUL*RHOGA)/(FMUG*RHOL)
      CHI=SQRT((WL1*CHIC1)/WG1)
      DCHI=W*CHI/(2.*WL1*WG1)
      F=16./REGP
      GO TO 34
31 CHIC1=(.046*4.**.8)/(16.*(PERIM)**.8)*(RHOGA/RHOL)*(FMUL**.2/FMUG)
      CHI=SQRT((WL1**1.8/WG1)*CHIC1)
      DCHI=(1.8*WG1+WL1)*CHI/(2.*WG1*WL1)
      F=16./REGP
      GO TO 34
32 CHIC1=(16.*(PERIM)**.8)/(.046*4.**.8)*(RHOGA/RHOL)*(FMUL/FMUG**.2)
      CHI=SQRT((WL1/WG1**1.8)*CHIC1)
      DCHI=((WG1+1.8*WL1)*CHI)/(2.*WG1*WL1)
      F=.046/REGP**.2
      GO TO 34
33 CHIC1=(RHOGA/RHOL)*(FMUL/FMUG)**.2
      CHI=SQRT((WL1/WG1)**1.8*CHIC1)
      DCHI=(.9*W*CHI)/(WG1*WL1)
      F=.046/REGP**.2

```

Fig. A-5. Program 5-2, Listing (con't)

```

34 CALL RLAFEG(CHI,PHI,RLP,DRLDX,REGP,RFLP)
   RGP=1.-RLP
   V=WL1/(RLP*AD*RHOL)
   U=WG1/(RGP*AD*RHOGA)
   V2=V**2
   U2=U**2
   UP2=(WG1/(AD*RHOGA))**2.
   U2COEF=1.-((WG1*DCHI*DRLDX)/RGP)
   V2COEF=1.-((WL1*DCHI*DRLDX)/RLP)
   DPXF=-1.*(PHI**2*((2.*UP2*RHOGA*F)/GJ))
   DPMOW1=DRLDX*DCHI
   DPMOW2=2.-((DPMOW1*WG1)/RGP)
   DPMOW3=2.-((DPMOW1*WL1)/RLP)
   DPMOW4=RHOGA*U2*RGP*DPMOW2/(32.17*WG1)
   DPMOW5=RHOL*V2*RLP*DPMOW3/(32.17*WL1)
   DPMOWX=DPMOW4-DPMOW5
   DPC1=(CPL*WL1+CPG*WG1)*T/(FJH*RHOGA)
   QS=(CK0+CK1*T+CK4*T**4)/3600
   DX1=QS+DPC1*DPXF
   DX2=FHH-V2*V2COEF/GJ+U2*U2COEF/GJ-DPC1*DPMOWX+(U2-V2)/(2.*GJ)
   DX=DX2*DEFLWL/DX1
   IF(DX)35,35,36
35 PRINT F22,DX1,DX2,T,TE,QS,DPC1,DPXF
   GO TO 5
36 DP= DPMOWX+DEFLWL+DPXF*DX
   DELT= T*DP/(FJH*RHOGA)
   WLT=RHOL*AD*RLP*DX*ENT
   PRINT F20,RELP,V,REGP,U,QS,DX,DELT,DP
   T=T+DELT
   WL1=WL1+DEFLWL
   WG1=W-WL1
   DPSUM=DPSUM+DP
   P=P+DP
   IF(P,LE,0.0) GO TO 705
   ELW=ELW+DX
   QSUM=QSUM+QS*DX*ENT
   WLTSUM=WLTSUM+WLT
37 CONTINUE
   QSUM=QSUM*3600.
   RHOGA=P/(1+R*2)
   WLF=WL1+DEFLWL/2.
   WGF=W-WLF
   UFEND=(WLE/RHOL+WGE/RHOGA)/AD
   UFF2=UFEND**2
   PMEND=W*UFEND/(32.17*AD)
   PMS=PMS-PMEND
   EFEND=UFF2/(2.*GJ)
   PRINT F21,DPSUM,PPM,WLTSUM,QSUM,UFFS,UFEND,ELW,PMS,PMEND,TE,EKS,
VEKEND
   GO TO 5
701 PRINT F1,TE,TSTAR
   GO TO 5
702 PRINT F2,TE,TSTAR
   GO TO 5
703 PRINT F3,TE,TSTAR
   GO TO 5
705 PRINT F23,P,DPSUM
   GO TO 5
END

```

Fig. A-5. Program 5-2, Listing (con't)

```

SUBROUTINE RLAFEG (CHI,PHI,RLP,DRLDX,REGP,RFLP)
C
  DIMENSION A(5),B(5),C(5),AA(5),BB(5),CC(5),AAA(5),BBB(5),CCC(5),
  VD(5),E(5),G(5),DA(300)
C
  DATA (A(I),I=1,5)/.961729, .052676, .17996, .108387, .022224/
  DATA (B(I),I=1,5)/4.28577, .222, .509048, .653052, .81402/
  DATA (C(I),I=1,5)/4.74133, .250008, .409772, .409772, .334969/
  DATA (AA(I),I=1,5)/.957448, .062721, .201257, .138803, .050525/
  DATA (BB(I),I=1,5)/4.29955, .292137, .584971, .530757, .691175/
  DATA (CC(I),I=1,5)/4.82121, .385293, .539591, .539591, .46745/
  DATA (AAA(I),I=1,5)/.0344006, .0728001, .1368, .13, .079999/
  DATA (BBB(I),I=1,5)/.239203, .3784, .4928, .481, .562003/
  DATA (CCC(I),I=1,5)/.448004, .572802, .6232, .631, .600998/
  DATA (D(I),I=1,5)/-.29093,-.28915,-.20092,-.092062,-.075481/
  DATA (E(I),I=1,5)/-.3407,-.060579, .45461, .461834, .456419/
  DATA (G(I),I=1,5)/-1.6256,-1.0725,-.63827,-.63827,-.65665/
  IF(CHI=1,F+2)1,1,2
1  ELX=ALOG10(CHI)
  IF(.001=CHI)3,3,5
5  NA=0.0
  GO TO 6
3  NA=4.+ELX
  GO TO 6
2  CHI=99.99
  GO TO 1
6  IF(NA)7,7,8
7  PHI=1.
  GO TO 11
8  IF(REGP=2000.)15,15,16
15 IF(RFLP=2000.)17,17,18
16 IF(RFLP=2000.)18,18,19
17 X=ELX*(ELX*A(NA)+B(NA))+C(NA)
  PHI=10.**X
  GO TO 11
18 X=ELX*(ELX*AA(NA)+BB(NA))+CC(NA)
  PHI=10.**X
  GO TO 11
19 X=ELX*(ELX*AAA(NA)+BBB(NA))+CCC(NA)
  PHI=10.**X
11 IF(NA)12,12,13
12 RLP=10.**ELX
  DRLDX=10.**ELX/CHI
  GO TO 14
13 RLP=ELX*(FLX*D(NA)+E(NA))+G(NA)
  RLP=10.**RLP
  DRLDX=RLP*(2.*ELX*D(NA)+E(NA))/CHI
14 RETURN
  END

```

Fig. A-5. Program 5-2, Listing (con't)

SUBROUTINE DECRD(DATA)

```

C
C   READS A VARIABLE NUMBER OF ITEMS OF FLOATING-POINT DATA INTO
C   SPECIFIED ELEMENTS OF AN ARRAY IN BLOCKS OF 5 CONSECUTIVE ITEMS.
C   ONE OR MORE BLANK FIELDS ON A DATA CARD CAUSE THE VALUES IN CORE
C   TO REMAIN UNCHANGED
C   THE FORTRAN INTEGER INDEX IN THE FIRST FIELD OF EACH CARD OFFINES
C   THE POSITION OF THE ARRAY OF THE FIRST ITEM OF EACH BLOCK OF FIVE.
C   THE BLOCKS NEED NOT BE SEQUENTIAL NOR CONTINUOUS.
C   THE INDEX IS PLACED AT THE END OF ITS FIELD. IT MAY NOT BE ZERO
C   OR BLANK. IT SHALL NOT CONTAIN A DECIMAL POINT.
C   A DECIMAL POINT MUST ALWAYS BE PLACED IN EACH DATA ITEM, THEREFORE,
C   THE VALUE MAY BE PLACED ANYWHERE IN EACH OF THE FIELDS PER CARD.
C   THE DECIMAL SCALE, IF ANY, FOR A DATA ITEM MUST BE PLACED AT THE
C   END OF THE FIELD.
C   A 0. MUST BE ENTERED TO READ IN A ZERO. A -0. IS THE SAME AS A
C   BLANK FIELD. THE READING OF DATA IS TERMINATED BY ENTERING A
C   NEGATIVE INDEX ON THE LAST CARD OF EACH SERIES.
C   TO USE THE ROUTINE ---- CALL DECRD(DATA)
C   DIMENSION DRBU (5), DATA (6)
1  READ 2, IND, (DRBU(I),I=1,5)
2  FORMAT(I12, 5F12.0)
   IF (IND.EQ. (-999)) STOP
3  J = IABS(IND)
4  DO 7 I=1,5
5  IF(DRBU(I)) 6,10,6
6  DATA(J) = DRBU(I)
7  J = J+1
8  IF(IND) 9,11,1
9  RETURN
10 IF(SIGN(1.,DRBU(I))) 7,11,6
11 CALL EXIT
   END
C
C   PERMANENT HOLLERITH DATA
C
(36H TEMPERATURE IS TOO HIGH TO CONDENSE/4H TE=F12.8,7H TSTAR=F12.8)
(36H TEMPERATURE IS TOO LOW TO EVAPORATE/4H TE=E12.8,7H TSTAR=E12.8)
(57H FLUID TEMPERATURE TOO CLOSE TO ENVIRONMENTAL TEMPERATURE/4H TE=F12.
8,7H TSTAR=E12.8)
(11H INPUT DATA/I9,F15.8,26H TOTAL WEIGHT FLOW (LB/HR)/I9,F15.8,13
H NO. OF DUCTS/I9,F15.8,28H DUCT PERIMETER (FT) *OPTION/I9,F15.8,26H DUC
T AREA (SQ FT) *OPTION/I9,F15.8,32H EFFECTIVE DIAMETER (FT) *OPTION/I9,
F15.8,21H NO. OF DUCT SECTIONS/I9,F15.8,12H NO. OF FINS/I9,F15.8,18H NO
OF SUBSECTIONS/I9,F15.8,26H INLET PRESSURE (LB/SQ FT)/I9,F15.8,27H FLUID
TEMP AT ENTRANCE (R)/I9,F15.8,22H WEIGHT FRACTION VAPOR/I9,F15.8,30H LA
TENT HEAT OF FLUID (BTU/LB)/I9,F15.8,34H SPECIFIC HEAT OF VAPOR (BTU/LB
R)/I9,F15.8,31H VISCOSITY OF VAPOR (LB/SEC FT)/I9,F15.8,35H MOLECULAR WE
IGHT OF FLUID (LB/MOL)/I9,F15.8,29H VAPOR COMPRESSIBILITY FACTOR/I9,F15.
8,29H DENSITY OF LIQUID (LB/CU FT)/I9,F15.8,35H SPECIFIC HEAT OF LIQUID
(BTU/LB R)/I9,F15.8,32H VISCOSITY OF LIQUID (LB/SEC FT))
(/18H INPUT DUCT VALUES/      4H SEC5X,43H EFFECT PERIFERAL LENGTH FOR RA
DIATION (FT)/(I3,7X,F15.8))
(      4H SEC5X,44H EFFECT PERIFERAL LENGTH FOR CONVECTION (FT)/(I3,7X,
F15.8))
(      4H SEC5X,42H RADIATION CONSTANT C1 (BTU/HR SQ FT R**4)/(I3,7X,F15.8))
(      4H SEC5X,37H RADIATION CONSTANT C2 (BTU/HR SQ FT)/(I3,7X,F15.8))
(      4H SEC5X,48H CONVECTIVE HEAT TRANSFER COEFF (BTU/HR SQ FT R)/(I3,7X
,F15.8))
(      4H SEC5X,17H AMBIENT TEMP (R)/(I3,7X,F15.8))
(17H INPUT FIN VALUES/      4H FIN5X,42H RADIATION CONSTANT C1 (BTU/HR SQ
FT R**4)/(I3,7X,F15.8))

```

```

C      4H FIN5X,37H RADIATION CONSTANT C2 (BTU/HR SQ FT)/(I3,7X,F15.8))
C      4H FIN5X,55H CONVECTIVE HEAT TRANSFER COEFF SIDE A (BTU/HR SQ FT R)
/(I3,7X,F15.8))
C      4H FIN5X,55H CONVECTIVE HEAT TRANSFER COEFF SIDE B (BTU/HR SQ FT R)
/(I3,7X,F15.8))
C      4H FIN5X,24H AMBIENT TEMP SIDE A (R)/(I3,7X,F15.8))
C      4H FIN5X,24H AMBIENT TEMP SIDE B (R)/(I3,7X,F15.8))
C      4H FIN5X,19H EFFECT LENGTH (FT)/(I3,7X,F15.8))
(28H ENVIRON TEMP CONVERG FAILED/4H TE=F12.8,5H CK0=F12.8,5H CK1=F12.8,5
H CK4=E12.8)
C//12H OUTPUT DATA/1H0,12HREL= (LIQ),1X,9HV= FT/SEC,4X,12HREGP= (VAP)
,1X,9HU= FT/SEC,4X,11HQ5=BTU/SCFT,2X,6HDX= FT,7X,7HDEL= R,6X,7HDP= PSF)
(1H ,F12.5,1X,F12.5,1X,E12.5,1X,E12.5,1X,E12.5,1X,E12.5,1X,E12.5,1X,E12.
5,1X,E12.5)
(1H0,6HDP5UM=E12.5,9H LB/SQ FT,2X,5H DPM=E12.5,9H LB/SQ FT,2X,8H WLTSUM=
E11.5,3H LB/6H QSUM=E12.5,7H BTU/HR5X5H UFS=F12.5,9H FEET/SEC3X,6HUFEND=
E12.5,9H FEET/SEC/5H ELW=E12.5,5H FEET8X,5H PMS=E12.5,9H LB/SQ FT, 2X,7
H PMEND=E12.5,9H LB/SQ FT/,4H TE=E13.5,2H R11X,5H KFS=E12.5,7H BTU/LB,4X
,7H KEEND=F12.5,7H BTU/LB)
(16H FLOW EXCESSIVE,/5H DX1=E12.5,9H BTU/SCFT, 5H DX2=E12.5,7H BTU/LB,3H
T=E12.5,2H R/4H TE=E12.5,2H R,4H QS=E12.5,9H BTU/SCFT,6H DPC1=F12.5,9H
BTU/SCFT/6H DPXF=E12.5,9H BTU/SCFT)
(21H FLOW RATE EXCESSIVE,/3H P=E12.5,4H PSF/7H DPSUM=F12.5,4H PSF)

```

C

C DATA FOR PROBLEMS

CONDENSER WITH NONCIRCULAR DUCT-2 LB/HR FLOW RATE

12.	1.	.0518	.000111	0.00
61.	2.	10.	1659.74	660.
111.	977.9	.35	.8493E-0518.	
161.	60.3	1.005	.0002052	
30.0304	.0365		.1456E-0888.61	0.
350.				
90	.1456E-0888.61	0.	0.	0.
950.	.1559			
100	.1456E-0888.61	0.	0.	0.
1050.	.1559			

CONDENSER WITH NONCIRCULAR DUCT 1.5 LB/HR FLOW RATE

11.5	1.	.0518	.000111	0.00
------	----	-------	---------	------

MULTI FIN FREON CONDENSER 75 LB/HR FLOW RATE

175.	1.	0.	0.	.0375
63.	3.	10.	3157.9	600.
111.	61.31	.161	.00000746	187.39
16.95	92.33	.218	.00029702	
30.03375	.03375		.1456E-08146.1	7.0
35530.				
400.	0.	0.	0.	0.
450.				
50.03375	.03375	0.	0.	12.
55500.				
90	.1456E-08146.1	7.	12.	530.
95500.	.186			
100	.1456E-08146.1	7.	0.	530.
1050.	.349			
1100.	0.	12.	0.	500.
1150.	.2952			

-

C

C

END CONTROL CARDS

C

END OF PROBLEMS

-999

INFORMATION FOR PROGRAM USERS

DECRD (DECIMAL READ SUBROUTINE)

Description

This routine provides the facility for reading a variable number of pieces of floating point data into specified elements of an array; these elements may be either in sequential or in nonconsecutive locations. Only the information specified is actually read into storage.

The fixed point number (index) in the first field on each card defines the position of the first piece of data on the card. If the index is 1, the first piece of data will be stored in the first location reserved for the array; if it is 16, the first work will be placed in the 16th position, etc. The remaining fields on each card contain information for the successive locations of the array. If one or more fields are left blank, no information is read into the locations corresponding to these fields; the information already in these locations is unaltered.

Use

The decimal data will be read into storage by means of the FORTRAN statement, CALL DECRD (Name of array to be read).

The data are written in decimal data form which has 6 fields of width, 12 card-columns each.

- a. The index or location number must be written to the extreme right of the first field; it may not be zero or blank.
- b. The floating point data may be written in two ways on the data sheets:

1. With a decimal point: 42.62 may be positioned anywhere in the field of width 12.
 2. With the E. type Format and the decimal point: .243 E02, where the exponent specification is written to the extreme right of the field.
- c. Reading data are concluded by placing a negative sign in the first field of the last card to be read.

Restrictions

If any negative zero or ".0" is written as a piece of data, it will be recognized as a blank by FORTRAN. Zero should be designated by "0."

Error Indication

If a zero or blank index appears in the first field of a card, an error message is printed and the job is terminated.

Program Termination

Two cards are used to terminate a program. The first is a card with a title such as "End of Problems", the second has a -999 punched in columns 9 to 12. A test is provided in DECRD to terminate the program when these numbers appear.

NOTES ON PROGRAMS

1. Data numbers for the input variables are shown on pages 27, 28 and 29.
2. Data options are provided in both programs. In program 5-1 an

index (DA 41) is used to specify the option to be taken. If all radiation constants and convection parameters are to be calculated a "0" is entered. If C1 and C2 are entered in DA 35 and DA 36 a "1" is placed in DA 41. If pure parametric studies are to be made C1, C2, FH, and FAH are entered as input data in DA 35, 36, 47, and 48 respectively, and a "2" is entered in DA 41. In program 5-2 if non circular ducts are to be analyzed the duct perimeter and duct area must be entered in DA 3 and DA 4 respectively. If circular ducts are analyzed the internal diameter can be entered in DA 5 or the duct perimeter and area can be entered as for non circular ducts.

INPUT VARIABLES FOR PROGRAMS

DA	Program (5-1)	Program (5-2)
1	DO (outside diameter ft)	$\dot{w}$ (total weight flow, lb/hr)
2	DI (inside diameter ft)	ENT (no. of tubes)
3	T^* (inlet temp, R)	P (duct perimeter, ft)
4	$\dot{w}$ (total weight flow, lb/hr)	AD (duct area, sq ft)
5	ELH (fin length, ft)	DI (effective dia., ft)
6	FINTH (fin root th., ft)	ND (no of duct sect.)
7	DELTAR (thickness ratio)	NF (no of fins)
8	FMUG (gas viscosity, lb/ft-sec)	FMESH (no. of sub. sect.)
9	FMUL (liq. viscosity, lb/ft-sec)	P^* (inlet pressure, lb/ft ²)
10	QALSTR (inlet quality)	T^* (inlet temp, R)
11	FNK (fin k, Btu/hr-ft-R)	QALSTR (inlet quality)
12	FHH (latent heat, Btu/lb)	FHH (latent heat, Btu/lb)
13	WTM (mol wt, lb/mol)	CPG (spec. ht. of vap., Btu/lb)
14	HA (con. h.t. coef., Btu/hr ft ² R)	FMUG (gas viscosity, lb/ft-sec)
15	HB (con. h.t. coef., Btu/hr ft ² R)	WTM (mol. wt., lb/mol)
16	TAA (con. ambient temp, R)	Z (compressibility fac.)
17	TAB (con. ambient temp., R)	RHOL (liq. density lb/ft ³)
18	ALFAA (absorptivity side A)	CPL (spec. ht. of liq., Btu/lb R)
19	ALFAB (absorptivity side B)	FMUL (liq. viscosity lb/ft-sec)
20	EMA (emissivity side A)	
21	EMB (emissivity side B)	
22	EMX (emissivity body x)	

23 FA (view factor to m)
 24 FAX (view factor to x)
 25 FB (view factor to m)
 26 FBX (view factor to x)
 27 RHOM (reflectivity of m)
 28 RHOX (reflectivity of x)
 29 ZZ (profile no.)
 30 THETAM (sun angle to m) (see listing below)
 31 THEATX (sun angle to x)
 32 TM (temp. of m, R)
 33 TX (temp. of x, R)
 34 EPSM (emissivity of m)
 35 C1 (rad. const., Btu/hr ft² R⁴)
 36 C2 (rad. from env. Btu/hr ft²)
 37 CPG (spec. ht. of vap., Btu/lb R)
 38 CPL (spec. ht. of liq., Btu/lb R)
 39 FMESH (no. of sub. sec.)
 40 PSTAR (inlet pres., lb/ft²)
 41 INDIC* (OPTION IND.)
 42 RHOL (liq. density lb/ft³)
 43 THETAP (sun angle θ_p , deg.)
 44 CAPN (no. of tubes)
 45 Z (compressibility fact.)
 46 RHOTM (density of tube, lb/ft³)
 47 FH (convective parameter)
 48 FAH (convective parameter)

NP = 30, I = 0,5

NP + I

NP + I + 1

NP + I + 2

NP + I + 3

NP + I + 4

NP + I + 5

SR(I) (duct width for rad., ft.)

SC(I) (duct width for conv., ft)

ClD(I) (duct rad., Btu/hr ft²R⁴)

C2D(I) (duct rad. from env., Btu/hr ft²)

HD(I) (conv. h.t. coef., Btu/hr ft²R)

TA(I) (conv. ambient temp, R)

N = 90, L = 0,20

N + L

N + L + 1

N + L + 2

N + L + 3

N + L + 4

N + L + 5

N + L + 6

Cl(L) (rad. const., Btu/hr ft²R⁴)

C2(L) (rad. from env., Btu/hr ft²)

HA(L) (conv. h.t. coef., Btu/hr ft²R)

HB(L) (conv. h.t. coef., Btu/hr ft²R)

TAA(L) (conv. amb. temp, R)

TAB(L) (conv. amb. temp., R)

ELE(L) (equivalent length, ft)

APPENDIX B

SAMPLE PROBLEMS

Several sample problems are presented to demonstrate the capabilities and limitations of the programs. These problems are also useful for checkout should the program deck be reproduced or modified for use on another computer.

Three fluids, water, "Freon 113" and potassium were used in the problems. Some of them are reruns of those presented in Ref. 3 and some employ the configurations used in Ref. 1. This will permit the interested reader to make comparisons.

Problem 1: Potassium Space Powerplant Condenser

Two of the problems of Ref. 3 have been rerun as well as two cases with reduced numbers of tubes. Both programs 5-1 and 5-2 have been used for this example. A 6000 lb/hr case was run on program 5-1 and a 3000 lb/hr case was run on 5-2, however, when employing 5-1 the number of sections was reduced to four. The input and output for the 6000 lb/hr case is shown in Figs. B-1 and B-2 respectively. The 3000 lb/hr case is shown in Figs. B-3 and B-4. The calculated data using these programs agree closely with those of Ref. 3; the greatest discrepancy is in the value for the effective length, ELE. The value given in this report is considered to be the more accurate since it was obtained directly from a numerical integration procedure while the one in Ref. 3 was calculated from curve fit data. The difference is approximately two percent. The pressure for both cases is shown to increase as the fluid passes through the tubes. This is due to the fact that the momentum pressure rise is larger than the

friction pressure drop. This may be surprising considering the fact that the fluid enters at a velocity of 459.31196 ft/sec for the 6000 lb/hr case. In spite of this high inlet velocity the tube length is still only 1.8459 feet. This short length demonstrates one of the big problems in designing a satisfactory space power plant condenser.

The results of using 120 and 100 tubes for the 6000 lb/hr case is shown in Fig. B-5. Reducing the number of tubes increases the fluid velocity and the associated pressure drop. It was impossible to completely analyze either of these cases. Calculations terminated after the second section for the case employing 120 tubes and after the first section for the 100 tubes. The reasons for the terminations are different. Pressure fell below zero for 120 tubes and the calculated section length was negative for 100 tubes. Both situations are impossible and both tests are needed in the programs to terminate useless calculations

Problem 2: Potassium Reheater

This problem uses much of the data of Problem 1 except that pure convective environments were selected. Two environments were chosen. In the first an ambient fluid at 2000°R was assumed. This is above the fluid inlet temperature of 1620. The inlet quality was held at 80 percent as in Problem 1. The input and output data are shown in Figs. B-6 and B-7. When the ambient was reduced to 1622 the output data was

CALCULATED DATA

0.15363	EFFECTIVE LENGTH OF FIN, FT.
1622.00000	ENVIRONMENTAL TEMPERATURE, DEGREES R

FLUID TEMPERATURE TOO CLOSE TO ENVIRONMENTAL TEMPERATURE

This check is provided in the program since the integration routine may get into difficulty if the temperatures of fluid and environment are nearly equal.

Problem 3: Potassium Condenser in Convective and Radiative Environments

This problem was chosen to test the ability of program (5-2) to handle an unusual situation. A low value was chosen for the radiation constant C_1 and an ambient convective temperature was chosen which was slightly above the fluid inlet temperature. As shown by Figs. B-8 and B-9, heat transfer by radiation outweighs the convection and heat is lost from the system. The reduced radiation coefficient C_1 accounts for the longer tube length required by this problem.

Problem 4: Tubular Heat Exchanger

Water is to be evaporated as it passes through a 3/8 inch O.D. tube. A low pressure gas having a low convective heat transfer coefficient surrounds the tube but high gas and wall temperatures are present. It is required to find the conditions in the evaporator, as the water passes through tube of sufficient length to completely evaporate the water.

In using Program 5-2 the values of the radiative and environmental parameters C_1 and C_2 are required. The problem conditions used to calculate these parameters are:

$$\epsilon_a = 0.6, \epsilon_x = 1.0, T_x = 1000 \text{ R and } F_{ax} = 1.0$$

Using these values in Eqs. (1.2) and (1.3)

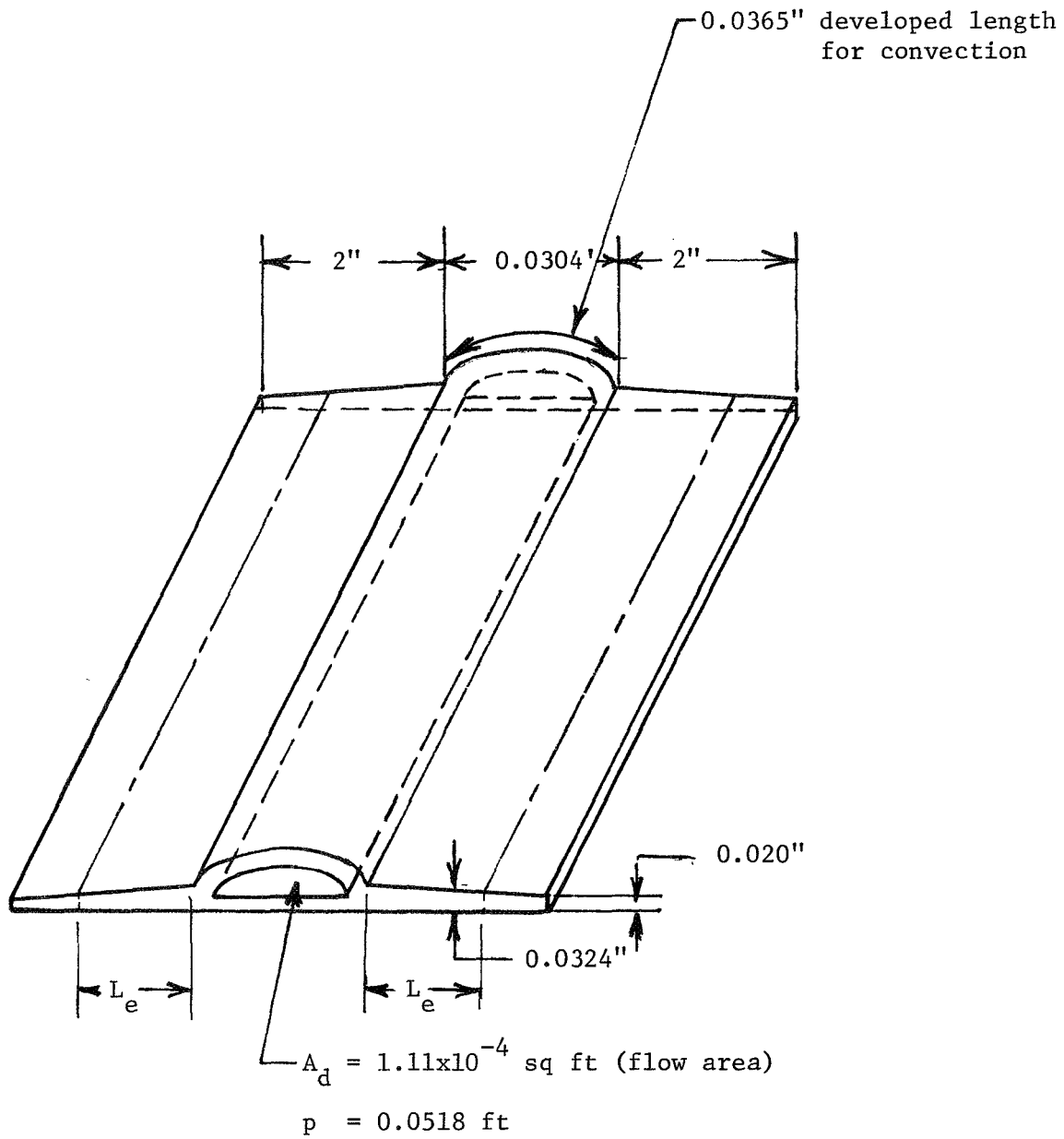
$$C_1 = \epsilon_a \sigma = (0.6)(0.1713)(10^{-8})$$

$$C_2 = 0.1713(10^{-8})(1000^4)(1.0)(0.6) = 1028$$

Two flow rates, 2.5 and 10 lb/hr, were chosen for this illustration. The remaining input items are shown in Fig. B-10. While the output for the two cases is shown in Fig. B-11. The analysis was successful for the 2.5 lb/hr flow rate, but the program ran into difficulty with the higher flow rate. The calculated pressure in the tube at the end of the eighth section was -1521.5 lb/sq. ft. and the program stopped the analysis. Fluid pressure drop in the turbulent regime is substantially higher than in the laminar region. The Reynolds numbers for vapor are shown to be in the turbulent region for all but the first section. Pressure drop for two phase flow is high when compared with single phase flow for either liquid or vapor. It is therefore easy to underestimate the actual pressure drop. In this case the final Reynold's number was 12,975--a value well in the turbulent region but not impossible in many flow problems. Observe also the impossible predicted temperature drop of 2136.9 degrees R in the last section analyzed. This is far from the expected range of only a few degrees of deviation from the inlet temperature. Lowering the flow rate to 2.5 lb/hr reduces the pressure drop to 73.382 lb/sq ft. This drop is only 2.3 percent of the calculated drop associated with approximately 80% of the heat transfer at the higher rate. One should remember that a portion of this difference is due to the difference in tube lengths. The duct length is approximately proportional to the flow rate and the pressure drop is approximately proportional to the length. The higher rate being four times the lower would indicate approximately four times the amount of heat exchange and four times the amount of duct length.

Problem 5: Condenser with Noncircular Duct

Problem 5, illustrated in Sketch 1, also uses Program 5.2.



Fluid - 2 lb/hr of steam

Material - Aluminum - $k = 118$ Btu/hr ft R

$T_{f1} = 660$ R

$L_e = 0.1559'$ (calculated by Program 2-1 and shown in Figs. B-6 and B-7 of Ref. 1)

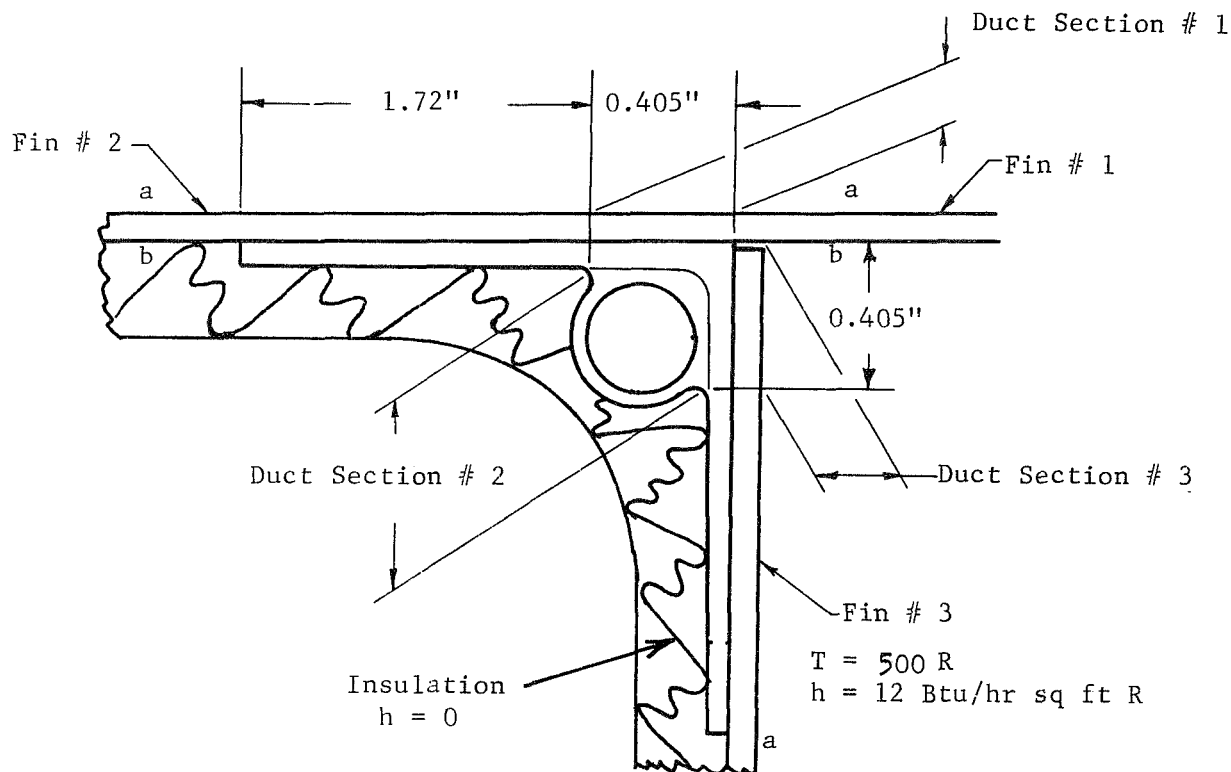
Sketch 1

The input and output data for this problem are shown in Figs. B-12 and B-13. Two flow rates were considered, 1.5 and 2 lb/hr. However, the later flow was excessive and the analysis was stopped after seven of the ten sections had been analyzed. For the lower flow rate, the pressure drop in the first five sections is shown to be considerably higher than in the last five sections. This is due to the turbulent Reynold's number's calculated for the vapor. Even with the lower flow rate the pressure drop is quite high (477.25 lb/sq ft). With the uncertainties involved in using equivalent diameter for calculating two phase flow pressure drop, and since the program ignores the entrance losses that come with any design, the acceptance of this flow rate should be questioned unless actual testing proves otherwise.

Problem 6: Multi Fin Freon Condenser

A coil carrying "Freon 113" is brazed into a tank structure as shown with much of the data in the Sketch 2. The coil itself has a 1/2" outside diameter, and a 0.025" thick wall.

The fin input and output data approximating the problem conditions is shown in Figs. B-10, B-11 and B-12 of Ref 1. The final input and output problem data from program 5-2 is shown in Figs. B-14 and B-15. For this problem two flow rates of 75 and 225 lb/hr were chosen.



System

$$T_{f_1} = 600 \text{ R "Freon 113"}$$

$$L_e = 0.186 \text{ ft. (fin 1)}$$

$$= 0.349 \text{ ft. (fin 2)}$$

$$= 0.2952 \text{ ft. (fin 3)}$$

Fin #1 and Fin#2

$$T_m = T_a = 530 \text{ R}$$

$$h_a = 7 \text{ Btu/hr sq ft R}$$

$$C_1 = 0.1456 \times 10^{-8}$$

$$C_2 = 146.1 \text{ Btu/hr sq ft}$$

Sketch 2

The problem demonstrates the wide capabilities of the program, the manner in which the data might be examined, and the configurations chosen to attain a suitable performance compromise.

Interesting data is printed out for section 9 and 10 for the 75 lb/hr

flow rate. The pressure drop for section 9 is negative while all other sections are positive. In a condenser the vapor velocity decreases as more liquid is formed. This would appear to steadily lower the pressure drop from duct inlet to outlet. The fluid momentum goes down as the vapor condenses. This factor gives a pressure increase to the fluid. For the first eight sections the momentum rise is higher than the friction pressure drop and each section has a positive value for ΔP . In the ninth section the liquid Reynold's number exceeded 2000 and the flow was considered turbulent by the program. The turbulent-turbulent combination produced a higher pressure drop. In the tenth section, however, the friction pressure drop was again reduced in value and the momentum force was again predominant and gave a slight pressure rise. The overall pressure rise for the duct is shown to be 1.837 lb/sq. ft.

POTASSIUM CONDENSER 6000 LB/HR 464 TUBES

INPUT DATA

1620.00000	FLUID TEMPERATURE, DEGREES R
490.00000	FLUID ENTRY PRESSURE, LB/SQFT
6000.00000	FLOW RATE, LB/HR
0.80000	WEIGHT FRACTION OF VAPOR
0.18300	SPECIFIC HEAT OF LIQUID, BTU/LB-DEGREES R
0.00010	VISCOSITY OF LIQUID, LB/SEC-FT
43.60000	DENSITY OF LIQUID, LB/CUFT
873.00000	LATENT HEAT OF FLUID, BTU/LB
0.21000	SPECIFIC HEAT OF GAS, BTU/LB-DEGREES R
0.00001	VISCOSITY OF GAS, LB/SEC-FT
39.10000	MOLECULAR WEIGHT OF GAS, LB/MOL
0.93600	CORRECTION FACTOR FOR IDEAL GAS FORMULA
0.03120	INSIDE DIAMETER OF TUBE, FT
0.05208	OUTSIDE DIAMETER OF TUBE, FT
464.00000	NUMBER OF TUBES
51.50000	THERMAL CONDUCTIVITY OF FIN MATERIAL (BTU/FT.HR.R)
0.00000	FORM FACTOR BETWEEN SIDE A AND MOON
0.00000	FORM FACTOR BETWEEN SIDE B AND MOON
0.00000	ABSORBTIVITY, SIDE A
0.00000	ABSORBTIVITY, SIDE B
0.00000	EMISSIVITY, SIDE A
0.00000	EMISSIVITY, SIDE B
0.00000	FORM FACTOR BETWEEN SIDE A AND X
0.00000	FORM FACTOR BETWEEN SIDE B AND X
0.00000	TEMPERATURE OF X (DEGREES R)
0.00000	ANGLE BETWEEN SUNS RAYS AND NORMAL TO X (DEGREES)
0.00000	REFLECTIVITY OF X
0.00000	TEMPERATURE OF MOON (DEGREES R)
0.00000	ANGLE BETWEEN SUNS RAYS AND NORMAL TO MOON SURFACE (DEGREES)
0.00000	REFLECTIVITY OF MOON SURFACE
0.00000	ANGLE BETWEEN SUNS RAYS AND PLANE OF EXTENDED SURFACE
0.00833	ROOT THICKNESS, (FEET)
0.25000	RATIO OF END TO ROOT SECTION
0.16666	LENGTH OF FIN (FEET)
0.00000	CONVECTION COEFFICIENT SIDE A (BTU/HR.SQFT.R)
0.00000	CONVECTION COEFFICIENT SIDE B (BTU/HR.SQFT.R)
0.00000	FLUID TEMPERATURE SIDE A (DEGREES R)
0.00000	FLUID TEMPERATURE SIDE B (DEGREES R)
0.30820	X10E=08 C1 (BTU/HR.SQFT.R**4)
0.00000	C2 (BTU/HR.SQFT.)

NONDIMENSIONAL PARAMETERS

0.84804	ZETA P PROFILE NUMBER
0.00000	C3 ENVIRONMENTAL PARAMETER
0.00000	FH SURFACE CONVECTIVE PARAMETER
0.00000	FAH ENVIRONMENT CONVECTIVE PARAMETER

Fig. B-1. Problem 1, Input Data

CALCULATED DATA

0.08824	EFFECTIVE LENGTH OF FIN, FT.
0.00290	ENVIRONMENTAL TEMPERATURE, DEGREES R
459.31196	MIXTURE VELOCITY AT TUBE ENTRANCE, FT/SEC
SECTION 1	
0.70000	QUALITY AT MIDDLE OF SECTION
3.16053	LIQUID VELOCITY (FT./SEC.)
406.03216	VAPOR VELOCITY (FT./SEC.)
1.34772	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-F
0.46882	DIFFERENTIAL LENGTH OF TUBE, (FT.)
3.33020	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
11.42571	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
SECTION 2	
0.50000	QUALITY AT MIDDLE OF SECTION
3.05028	LIQUID VELOCITY (FT./SEC.)
286.14649	VAPOR VELOCITY (FT./SEC.)
1.35884	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-F
0.46270	DIFFERENTIAL LENGTH OF TUBE, (FT.)
2.75045	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
9.61710	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
SECTION 3	
0.30000	QUALITY AT MIDDLE OF SECTION
2.55109	LIQUID VELOCITY (FT./SEC.)
170.81236	VAPOR VELOCITY (FT./SEC.)
1.36807	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-F
0.45839	DIFFERENTIAL LENGTH OF TUBE, (FT.)
1.90459	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
6.76430	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
SECTION 4	
0.10000	QUALITY AT MIDDLE OF SECTION
1.62361	LIQUID VELOCITY (FT./SEC.)
58.06430	VAPOR VELOCITY (FT./SEC.)
1.37449	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-F
0.45601	DIFFERENTIAL LENGTH OF TUBE, (FT.)
0.78596	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
2.82173	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
30.62884	ACCUMULATED SUM OF PRESSURE CHANGE, (PSF)
1.84591	TOTAL TUBE LENGTH, FT.
4200147.64539	ACCUMULATED SUM OF HEAT LOST, BTU/HR
0.83150	ACCUMULATED WEIGHT OF TRAPPED LIQUID, LB.
1.24537	WEIGHT OF ONE TUBE, LBS
577.85264	TOTAL WEIGHT OF UNIT, LBS
0.00014	WEIGHT PER UNIT OF HEAT TRANSFER, LB-HR/BTU
330.09666	PLANFORM AREA, SQFT
67.07934	MOMENTUM PRESSURE AT INLET, LBS/SQFT
4.21459	KINETIC ENERGY OF FLUID AT INLET, BTU/LB
0.01574	MOMENTUM PRESSURE AT END, LBS/SQFT
0.00000	KINETIC ENERGY OF FLUID AT END, BTU/LB
67.06360	CHANGE IN MOMENTUM PRESSURE, LBS/SQFT

Fig. B-2. Problem 1, Output Data (464 tubes)

POTASSIUM CONDENSER FOR SPACE POWERPLANT

INPUT DATA

1	3000.00000001	TOTAL WEIGHT FLOW (LB/HR)
2	464.00000000	NO. OF DUCTS
3	0.00000000	DUCT PERIMETER (FT) *OPTION
4	0.00000000	DUCT AREA (SQ FT) *OPTION
5	0.03120000	EFFECTIVE DIAMETER (FT) *OPTION
6	2.00000000	NO. OF DUCT SECTIONS
7	2.00000000	NO. OF FINS
8	10.00000000	NO OF SUBSECTIONS
9	490.00000000	INLET PRESSURE (LB/SQ FT)
10	1620.00000001	FLUID TEMP AT ENTRANCE (R)
11	0.80000000	WEIGHT FRACTION VAPOR
12	873.00000001	LATENT HEAT OF FLUID (BTU/LB)
13	0.21000000	SPECIFIC HEAT OF VAPOR (BTU/LB R)
14	0.00001210	VISCOSITY OF VAPOR (LB/SEC FT)
15	39.10000000	MOLECULAR WEIGHT OF FLUID (LB/MOL)
16	0.93600000	VAPOR COMPRESSIBILITY FACTOR
17	43.60000000	DENSITY OF LIQUID (LB/CU FT)
18	0.18300000	SPECIFIC HEAT OF LIQUID (BTU/LB R)
19	0.00010000	VISCOSITY OF LIQUID (LB/SEC FT)

INPUT DUCT VALUES

INPUT DATA NO.

SEC	EFFECT PERIFERAL LENGTH FOR RADIATION (FT)	
1	0.05208000	30
2	0.05208000	40
SEC	EFFECT PERIFERAL LENGTH FOR CONVECTION (FT)	
1	0.00000000	31
2	0.00000000	41
SEC	RADIATION CONSTANT C1 (BTU/HR SQ FT R**4)	
1	.15410000E+08	32
2	.15410000E+08	42
SEC	RADIATION CONSTANT C2 (BTU/HR SQ FT)	
1	0.00000000	33
2	0.00000000	43
SEC	CONVECTIVE HEAT TRANSFER COEFF (BTU/HR SQ FT R)	
1	0.00000000	34
2	0.00000000	44
SEC	AMBIENT TEMP (R)	
1	0.00000000	35
2	0.00000000	45

Fig. B-3. Problem 1, Input Data (Program 5-2)

TRANSISTION CONDENSER FOR SPACE POWERPLANT

INPUT FIN VALUES		INPUT DATA NO.
FIN	RADIATION CONSTANT C1 (BTU/HR SQ FT R**4)	
1	.30820000E-08	90
2	.30820000E-08	100
FIN	RADIATION CONSTANT C2 (BTU/HR SQ FT)	
1	0.00000000	91
2	0.00000000	101
FIN	CONVECTIVE HEAT TRANSFER COEFF SIDE A (BTU/HR SQ FT R)	
1	0.00000000	92
2	0.00000000	102
FIN	CONVECTIVE HEAT TRANSFER COEFF SIDE B (BTU/HR SQ FT R)	
1	0.00000000	93
2	0.00000000	103
FIN	AMBIENT TEMP SIDE A (R)	
1	0.00000000	94
2	0.00000000	104
FIN	AMBIENT TEMP SIDE B (R)	
1	0.00000000	95
2	0.00000000	105
FIN	EFFECT LENGTH (FT)	
1	0.08738520	96
2	0.08738520	106

OUTPUT DATA

RELPE= (LIQ)	V= FT/SEC	REGP= (VAP)	U= FT/SEC	QS=BTU/SCFT	DX= FT	DELT= R	DP= PSF
.17590E 03	.11513E 01	.46035E 04	.22064E 03	.13376E 01	.93943E-01	.50029E 00	.17165E 01
.23453E 03	.12073E 01	.41189E 04	.19740E 03	.13393E 01	.93779E-01	.45918E 00	.15800E 01
.29317E 03	.12265E 01	.36343E 04	.17425E 03	.13408E 01	.93631E-01	.41611E 00	.14355E 01
.35180E 03	.12160E 01	.31497E 04	.15118E 03	.13422E 01	.93501E-01	.37100E 00	.12830E 01
.41043E 03	.11798E 01	.26652E 04	.12819E 03	.13434E 01	.93388E-01	.32369E 00	.11218E 01
.46907E 03	.11201E 01	.21806E 04	.10523E 03	.13445E 01	.93294E-01	.27393E 00	.95108E 00
.52770E 03	.10060E 01	.16960E 04	.82361E 02	.13454E 01	.93214E-01	.23824E 00	.82846E 00
.58634E 03	.97787E 00	.12114E 04	.59079F 02	.13462E 01	.93156E-01	.16992E 00	.59172E 00
.64497E 03	.87635E 00	.72686E 03	.35785E 02	.13467E 01	.93120E-01	.10394E 00	.36231E 00
.70360E 03	.59768E 00	.24229E 03	.12344E 02	.13471E 01	.93105E-01	.40798E-01	.14229E 00

DPSUM=	.10013E 02	LR/SQ FT	DPM=	.16766E 02	LR/SQ FT	WLISUM=	.49625E 00	LB
QSUM=	.20960E 07	BTU/HR	UFS=	.22966E 03	FEET/SEC	UFEND=	.53878E-01	FEET/SEC
ELW=	.93413E 00	FEET	PMS=	.16770E 02	LR/SQ FT	PMEND=	.39343E-02	LR/SQ FT
TE=	0.	R	KES=	.10536E 01	BTU/LB	KEEND=	.57992E-07	BTU/LB

Fig. B-4. Problem 1, Input and Output Data (Program 5-2)

CALCULATED DATA 120 TUBES

0.08824 EFFECTIVE LENGTH OF FIN, FT.
 0.00290 ENVIRONMENTAL TEMPERATURE, DEGREES R
 1776.00624 MIXTURE VELOCITY AT TUBE ENTRANCE, FT/SEC

SECTION

1

0.70000 QUALITY AT MIDDLE OF SECTION
 20.49243 LIQUID VELOCITY (FT./SEC.)
 1563.46928 VAPOR VELOCITY (FT./SEC.)
 1.34772 QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-FT)
 2.20429 DIFFERENTIAL LENGTH OF TUBE, (FT.)
 -49.53293 CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R)
 -169.94465 CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)

SECTION

2

0.50000 QUALITY AT MIDDLE OF SECTION
 18.38761 LIQUID VELOCITY (FT./SEC.)
 1665.73463 VAPOR VELOCITY (FT./SEC.)
 1.19030 QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-FT)
 2.98780 DIFFERENTIAL LENGTH OF TUBE, (FT.)
 -245.31483 CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R)
 -584.97684 CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
 LOW RATE EXCESSIVE, PRESSURE DROP GREATER THAN INLET PRESSURE

CALCULATED DATA 100 TUBES

0.08824 EFFECTIVE LENGTH OF FIN, FT.
 0.00290 ENVIRONMENTAL TEMPERATURE, DEGREES R
 2131.20749 MIXTURE VELOCITY AT TUBE ENTRANCE, FT/SEC

SECTION

1

0.76000 QUALITY AT MIDDLE OF SECTION
 25.00642 LIQUID VELOCITY (FT./SEC.)
 2034.31417 VAPOR VELOCITY (FT./SEC.)
 1.34772 QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-FT)
 1.28358 DIFFERENTIAL LENGTH OF TUBE, (FT.)
 -69.35513 CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R)
 -237.95349 CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
 LOW RATE EXCESSIVE. GO TO NEXT CASE.

Fig. B-5. Problem 1, Output Data (100 and 120 tubes)

POTASSIUM REHEATER CONVECTIVE ENVIRONMENT

INPUT DATA

1620.00000	FLUID TEMPERATURE, DEGREES R
490.00000	FLUID ENTRY PRESSURE, LB/SQFT
3000.00000	FLOW RATE, LB/HR
0.80000	WEIGHT FRACTION OF VAPOR
0.18300	SPECIFIC HEAT OF LIQUID, BTU/LB-DEGREES R
0.00010	VISCOSITY OF LIQUID, LB/SEC-FT
43.60000	DENSITY OF LIQUID, LB/CUFT
873.00000	LATENT HEAT OF FLUID, BTU/LB
0.21000	SPECIFIC HEAT OF GAS, BTU/LB-DEGREES R
0.00001	VISCOSITY OF GAS, LB/SEC-FT
39.10000	MOLECULAR WEIGHT OF GAS, LB/MOL
0.93600	CORRECTION FACTOR FOR IDEAL GAS FORMULA
0.03120	INSIDE DIAMETER OF TUBE, FT
0.05208	OUTSIDE DIAMETER OF TUBE, FT
464.00000	NUMBER OF TUBES
51.50000	THERMAL CONDUCTIVITY OF FIN MATERIAL (BTU/FT.HR.R)
0.00000	FORM FACTOR BETWEEN SIDE A AND MOON
0.00000	FORM FACTOR BETWEEN SIDE B AND MOON
0.00000	ABSORPTIVITY, SIDE A
0.00000	ABSORPTIVITY, SIDE B
0.00000	EMISSIVITY, SIDE A
0.00000	EMISSIVITY, SIDE B
0.00000	FORM FACTOR BETWEEN SIDE A AND X
0.00000	FORM FACTOR BETWEEN SIDE B AND X
0.00000	TEMPERATURE OF X (DEGREES R)
0.00000	ANGLE BETWEEN SUNS RAYS AND NORMAL TO X (DEGREES)
0.00000	REFLECTIVITY OF X
0.00000	TEMPERATURE OF MOON (DEGREES R)
0.00000	ANGLE BETWEEN SUNS RAYS AND NORMAL TO MOON SURFACE (DEGREES)
0.00000	REFLECTIVITY OF MOON SURFACE
0.00000	ANGLE BETWEEN SUNS RAYS AND PLANE OF EXTENDED SURFACE
0.00833	ROOT THICKNESS, (FEET)
0.25000	RATIO OF END TO ROOT SECTION
0.16666	LENGTH OF FIN (FEET)
2.00000	CONVECTION COEFFICIENT SIDE A (BTU/HR.SQFT.R)
2.00000	CONVECTION COEFFICIENT SIDE B (BTU/HR.SQFT.R)
2000.00000	FLUID TEMPERATURE SIDE A (DEGREES R)
2000.00000	FLUID TEMPERATURE SIDE B (DEGREES R)
0.00000	X10E=08 C1 (BTU/HR.SQFT.R**4)
0.00000	C2 (BTU/HR.SQFT.)

ONDIMENSIONAL PARAMETERS

0.00000	ZETA P PROFILE NUMBER
0.00000	C3 ENVIRONMENTAL PARAMETER
0.25888	FM SURFACE CONVECTIVE PARAMETER
0.31960	FAH ENVIRONMENT CONVECTIVE PARAMETER

Fig. B-6. Problem 2, Input Data

CALCULATED DATA

0.15363	EFFECTIVE LENGTH OF FIN, FT.
2000.00000	ENVIRONMENTAL TEMPERATURE, DEGREES R
229.65598	MIXTURE VELOCITY AT TUBE ENTRANCE, FT/SEC
SECTION 1	
0.82500	QUALITY AT MIDDLE OF SECTION
1.06786	LIQUID VELOCITY (FT./SEC.)
238.93127	VAPOR VELOCITY (FT./SEC.)
-0.16427	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-1
0.47491	DIFFERENTIAL LENGTH OF TUBE, (FT.)
-1.86657	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
-6.40409	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
SECTION 2	
0.87500	QUALITY AT MIDDLE OF SECTION
0.94874	LIQUID VELOCITY (FT./SEC.)
256.02486	VAPOR VELOCITY (FT./SEC.)
-0.16508	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-1
0.47268	DIFFERENTIAL LENGTH OF TUBE, (FT.)
-1.93483	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
-6.56664	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
SECTION 3	
0.72500	QUALITY AT MIDDLE OF SECTION
0.75141	LIQUID VELOCITY (FT./SEC.)
273.57835	VAPOR VELOCITY (FT./SEC.)
-0.16591	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-1
0.47058	DIFFERENTIAL LENGTH OF TUBE, (FT.)
-1.93280	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
-6.48621	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
SECTION 4	
0.97500	QUALITY AT MIDDLE OF SECTION
0.45949	LIQUID VELOCITY (FT./SEC.)
291.27534	VAPOR VELOCITY (FT./SEC.)
-0.16675	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC-1
0.46746	DIFFERENTIAL LENGTH OF TUBE, (FT.)
-2.39970	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
-7.96258	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
-27.41952	ACCUMULATED SUM OF PRESSURE CHANGE, (PSF)
1.88564	TOTAL TUBE LENGTH, FT.
-521276.30831	ACCUMULATED SUM OF HEAT LOST, BTU/HR
0.17709	ACCUMULATED WEIGHT OF TRAPPED LIQUID, LB.
1.27217	WEIGHT OF ONE TUBE, LBS
590.28833	TOTAL WEIGHT OF UNIT, LBS
-0.00113	WEIGHT PER UNIT OF HEAT TRANSFER, LB-HR/BTU
337.20052	PLANFORM AREA, SQFT
16.76983	MOMENTUM PRESSURE AT INLET, LBS/SQFT
1.05365	KINETIC ENERGY OF FLUID AT INLET, BTU/LB
22.09231	MOMENTUM PRESSURE AT END, LBS/SQFT
1.82860	KINETIC ENERGY OF FLUID AT END, BTU/LB
-5.32248	CHANGE IN MOMENTUM PRESSURE, LBS/SQFT

Fig. B-7. Problem 2, Output Data

POTASSIUM CONDENSER CONVECTIVE AND RADIATIVE ENVIRONMENT

INPUT DATA

1620.00000	FLUID TEMPERATURE, DEGREES R
490.00000	FLUID ENTRY PRESSURE, LB/SQFT
3000.00000	FLOW RATE, LB/HR
0.80000	WEIGHT FRACTION OF VAPOR
0.18300	SPECIFIC HEAT OF LIQUID, BTU/LB-DEGREES R
0.00010	VISCOSITY OF LIQUID, LB/SEC-FT
43.60000	DENSITY OF LIQUID, LB/CUFT
873.00000	LATENT HEAT OF FLUID, BTU/LB
0.21000	SPECIFIC HEAT OF GAS, BTU/LB-DEGREES R
0.00001	VISCOSITY OF GAS, LB/SEC-FT
39.10000	MOLECULAR WEIGHT OF GAS, LB/MOL
0.93600	CORRECTION FACTOR FOR IDEAL GAS FORMULA
0.03120	INSIDE DIAMETER OF TUBE, FT
0.05208	OUTSIDE DIAMETER OF TUBE, FT
464.00000	NUMBER OF TUBES
51.50000	THERMAL CONDUCTIVITY OF FIN MATERIAL (BTU/FT.HR.R)
0.00000	FORM FACTOR BETWEEN SIDE A AND MOON
0.00000	FORM FACTOR BETWEEN SIDE B AND MOON
0.00000	ABSORPTIVITY, SIDE A
0.00000	ABSORPTIVITY, SIDE B
0.00000	EMISSIVITY, SIDE A
0.00000	EMISSIVITY, SIDE B
0.00000	FORM FACTOR BETWEEN SIDE A AND X
0.00000	FORM FACTOR BETWEEN SIDE B AND X
0.00000	TEMPERATURE OF X (DEGREES R)
0.00000	ANGLE BETWEEN SUNS RAYS AND NORMAL TO X (DEGREES)
0.00000	REFLECTIVITY OF X
0.00000	TEMPERATURE OF MOON (DEGREES R)
0.00000	ANGLE BETWEEN SUNS RAYS AND NORMAL TO MOON SURFACE (DEGREES)
0.00000	REFLECTIVITY OF MOON SURFACE
0.00000	ANGLE BETWEEN SUNS RAYS AND PLANE OF EXTENDED SURFACE
0.00833	ROOT THICKNESS, (FEET)
0.25000	RATIO OF END TO ROOT SECTION
0.16666	LENGTH OF FIN (FEET)
2.00000	CONVECTION COEFFICIENT SIDE A (BTU/HR.SQFT.R)
2.00000	CONVECTION COEFFICIENT SIDE B (BTU/HR.SQFT.R)
1622.00000	FLUID TEMPERATURE SIDE A (DEGREES R)
1622.00000	FLUID TEMPERATURE SIDE B (DEGREES R)
0.05000	X10E=08 C1 (BTU/HR.SQFT.R**4)
0.00000	C2 (BTU/HR.SQFT.)

ONDIMENSIONAL PARAMETERS

0.13758	ZETA P PROFILE NUMBER
0.00000	C3 ENVIRONMENTAL PARAMETER
0.25883	FH SURFACE CONVECTIVE PARAMETER
0.25920	FAH ENVIRONMENT CONVECTIVE PARAMETER

CALCULATED DATA

0.12773	EFFECTIVE LENGTH OF FIN, FT.
1298.22747	ENVIRONMENTAL TEMPERATURE, DEGREES R
229.65598	MIXTURE VELOCITY AT TUBE ENTRANCE, FT/SEC
SECTION 1	
0.70000	QUALITY AT MIDDLE OF SECTION
1.19854	LIQUID VELOCITY (FT./SEC.)
203.68647	VAPOR VELOCITY (FT./SEC.)
0.29343	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC=F
1.07253	DIFFERENTIAL LENGTH OF TUBE, (FT.)
-0.67686	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
-2.32228	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
SECTION 2	
0.50000	QUALITY AT MIDDLE OF SECTION
1.21605	LIQUID VELOCITY (FT./SEC.)
147.41722	VAPOR VELOCITY (FT./SEC.)
0.29269	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC=F
1.07321	DIFFERENTIAL LENGTH OF TUBE, (FT.)
-0.20394	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
-0.69698	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
SECTION 3	
0.30000	QUALITY AT MIDDLE OF SECTION
1.01556	LIQUID VELOCITY (FT./SEC.)
89.94401	VAPOR VELOCITY (FT./SEC.)
0.29246	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC=F
1.07241	DIFFERENTIAL LENGTH OF TUBE, (FT.)
0.32276	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
1.10173	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
SECTION 4	
0.10000	QUALITY AT MIDDLE OF SECTION
0.83005	LIQUID VELOCITY (FT./SEC.)
30.59588	VAPOR VELOCITY (FT./SEC.)
0.29282	QUANTITIES OF HEAT REJECTED PER FOOT OF TUBE LENGTH, (BTU/SEC=F
-1.07086	DIFFERENTIAL LENGTH OF TUBE, (FT.)
0.08361	CHANGE IN TEMPERATURE PER DIFFERENTIAL LENGTH, (DEGREES R
0.28594	CHANGE IN PRESSURE PER DIFFERENTIAL LENGTH, (PSF)
-1.63158	ACCUMULATED SUM OF PRESSURE CHANGE, (PSF)
4.28901	TOTAL TUBE LENGTH, FT.
2098096.33713	ACCUMULATED SUM OF HEAT LOST, BTU/HR
2.17501	ACCUMULATED WEIGHT OF TRAPPED LIQUID, LB.
2.89364	WEIGHT OF ONE TUBE, LBS
1342.64905	TOTAL WEIGHT OF UNIT, LBS
0.00064	WEIGHT PER UNIT OF HEAT TRANSFER, LB-HR/RTU
766.98442	PLANFORM AREA, SQFT
16.76983	MOMENTUM PRESSURE AT INLET, LBS/SQFT
1.05365	KINETIC ENERGY OF FLUID AT INLET, BTU/LB
0.00393	MOMENTUM PRESSURE AT END, LBS/SQFT
0.00000	KINETIC ENERGY OF FLUID AT END, BTU/LB
16.76590	CHANGE IN MOMENTUM PRESSURE, LBS/SQFT

Fig. B-9. Problem 3, Output Data

TUBULAR EVAPORATOR

INPUT DATA

1	2.50000000	TOTAL WEIGHT FLOW (LB/HR)
2	1.00000000	NO. OF DUCTS
3	0.00000000	DUCT PERIMETER (FT) *OPTION
4	0.00000000	DUCT AREA (SQ FT) *OPTION
5	0.01925000	EFFECTIVE DIAMETER (FT) *OPTION
6	1.00000000	NO. OF DUCT SECTIONS
7	0.00000000	NO. OF FINS
8	10.00000000	NO OF SUBSECTIONS
9	1659.74000001	INLET PRESSURE (LB/SQ FT)
10	660.00000000	FLUID TEMP AT ENTRANCE (R)
11	0.00000000	WEIGHT FRACTION VAPOR
12	977.90000001	LATENT HEAT OF FLUID (BTU/LB)
13	0.35000000	SPECIFIC HEAT OF VAPOR (BTU/LB R)
14	0.00000849	VISCOSITY OF VAPOR (LB/SEC FT)
15	18.00000000	MOLECULAR WEIGHT OF FLUID (LB/MOL)
16	1.00000000	VAPOR COMPRESSIBILITY FACTOR
17	60.30000000	DENSITY OF LIQUID (LB/CU FT)
18	1.00500000	SPECIFIC HEAT OF LIQUID (BTU/LB R)
19	0.00020520	VISCOSITY OF LIQUID (LB/SEC FT)

INPUT DUCT VALUES

SEC	INPUT DATA NO.
1	30
1	31
1	32
1	33
1	34
1	35

Fig. B-10. Problem 4, Input Data

TUBULAR EVAPORATOR

2.5 LB/HR FLOW RATE

OUTPUT DATA

REL P=	(LIQ)	V=	FT/SEC	REG P=	(VAP)	U=	FT/SEC	Q S=	BTU/SCFT	DX=	FT	DEL T=	R	DP=	PSF
.21265E	03	.24139E	00	.27041E	03	.48201E	01	.30339E	01	.22379E	01	.22894E	01	.77369E	00
.19026E	03	.31780E	00	.81124E	03	.13659E	02	.30340E	01	.22373E	01	.46693E	01	.15774E	01
.16788E	03	.35255E	00	.13521E	04	.22247E	02	.30344E	01	.22368E	01	.66794E	01	.22546E	01
.14550E	03	.36747E	00	.18929E	04	.30709E	02	.30349E	01	.22362E	01	.85130E	01	.28702E	01
.12311E	03	.43855E	00	.24337E	04	.38699E	02	.30356E	01	.22343E	01	.18367E	00	.61833E	01
.10073E	03	.41998E	00	.29745E	04	.47105E	02	.30370E	01	.22328E	01	.24080E	00	.80807E	01
.78344E	02	.38895E	00	.35154E	04	.55530F	02	.30389E	01	.22311E	01	.30127E	00	.10068E	02
.55960E	02	.34270E	00	.40562E	04	.63992E	02	.30413E	01	.22292E	01	.36348E	00	.12083E	02
.33576E	02	.27516E	00	.45970E	04	.72482E	02	.30441E	01	.22272E	01	.42410E	00	.14009E	02
.11192E	02	.16654E	00	.51378E	04	.80864E	02	.30474E	01	.22251E	01	.47221E	00	.15483E	02

DPSUM=	.73382E	02	LB/SQ	FT	DPM=	.62919E	01	LB/SQ	FT	WLTSUM=	.23761E	01	LB	
QSUM=	.24421E	04	BTU/HR		UFS=	.39570E	01	FEET/SEC		UFEND=	.84869E	02	FEET/SEC	
ELW=	.22328E	02	FEET		PMS=	.29350E	02	LB/SQ	FT	PMEND=	.62948E	01	LB/SQ	FT
TE=	.92942E	03	R		KES=	.31281E	07	RTU/LB		KEEND=	.14389E	00	BTU/LB	

10 LB/HR FLOW RATE

OUTPUT DATA

REL P=	(LIQ)	V=	FT/SEC	REG P=	(VAP)	U=	FT/SEC	Q S=	BTU/SCFT	DX=	FT	DEL T=	R	DP=	PSF
.85060E	03	.96556E	00	.10816E	04	.19280E	02	.30339E	01	.89213E	01	.36518E	00	.12341E	02
.76106E	03	.15898E	01	.32449E	04	.53718E	02	.30367E	01	.88134E	01	.16069E	01	.53960E	02
.67152E	03	.21479E	01	.54082E	04	.89467E	02	.30493E	01	.86677E	01	.31951E	01	.10429E	03
.58199E	03	.24415E	01	.75715E	04	.13155E	03	.30741E	01	.84533E	01	.55961E	01	.17237E	03
.49245E	03	.26136E	01	.97348E	04	.18790E	03	.31171E	01	.81322E	01	.94909E	01	.26297E	03
.40291E	03	.28382E	01	.11898E	05	.28039F	03	.31887E	01	.75867E	01	.17309E	02	.39530E	03
.31338E	03	.33627E	01	.14061E	05	.51142E	03	.33151E	01	.62914E	01	.41853E	02	.63096E	03
.22384E	03	.14669E	02	.16225E	05	.12975E	05	.35999E	01	.31883E	00	.21369E	04	.15490E	04

FLOW RATE EXCESSIVE.
P= .15215E 04 PSF
DPSUM= .31812E 04 PSF

Fig. B-11. Problem 4, Output Data

INPUT DATA

1	1.50000000	TOTAL WEIGHT FLOW (LB/HR)
2	1.00000000	NO. OF DUCTS
3	0.05180000	DUCT PERIMETER (FT) *OPTION
4	0.00011100	DUCT AREA (SQ FT) *OPTION
5	0.00000000	EFFECTIVE DIAMETER (FT) *OPTION
6	1.00000000	NO. OF DUCT SECTIONS
7	2.00000000	NO. OF FINS
8	10.00000000	NO OF SUBSECTIONS
9	1559.74000001	INLET PRESSURE (LB/SQ FT)
10	660.00000000	FLUID TEMP AT ENTRANCE (R)
11	1.00000000	WEIGHT FRACTION VAPOR
12	977.90000001	LATENT HEAT OF FLUID (BTU/LB)
13	0.35000000	SPECIFIC HEAT OF VAPOR (BTU/LB R)
14	0.00000849	VISCOSITY OF VAPOR (LB/SEC FT)
15	18.00000000	MOLECULAR WEIGHT OF FLUID (LB/MOL)
16	1.00000000	VAPOR COMPRESSIBILITY FACTOR
17	60.30000000	DENSITY OF LIQUID (LB/CU FT)
18	1.00500000	SPECIFIC HEAT OF LIQUID (BTU/LB R)
19	0.00020520	VISCOSITY OF LIQUID (LB/SEC FT)

INPUT DUCT VALUES

INPUT DATA NO.

SEC	EFFECT PERIFERAL LENGTH FOR RADIATION (FT)	
1	0.03040000	30
SEC	EFFECT PERIFERAL LENGTH FOR CONVECTION (FT)	
1	0.03650000	31
SEC	RADIATION CONSTANT C1 (BTU/HR SQ FT R**4)	
1	.14560000E+08	32
SEC	RADIATION CONSTANT C2 (BTU/HR SQ FT)	
1	88.61000000	33
SEC	CONVECTIVE HEAT TRANSFER COEFF (BTU/HR SQ FT R)	
1	0.00000000	34
SEC	AMBIENT TEMP (R)	
1	0.00000000	35

INPUT FIN VALUES

FIN	RADIATION CONSTANT C1 (BTU/HR SQ FT R**4)	
1	.14560000E+08	90
2	.14560000E+08	100
FIN	RADIATION CONSTANT C2 (BTU/HR SQ FT)	
1	88.61000000	91
2	88.61000000	101
FIN	CONVECTIVE HEAT TRANSFER COEFF SIDE A (BTU/HR SQ FT R)	
1	0.00000000	92
2	0.00000000	102
FIN	CONVECTIVE HEAT TRANSFER COEFF SIDE B (BTU/HR SQ FT R)	
1	0.00000000	93
2	0.00000000	103
FIN	AMBIENT TEMP SIDE A (R)	
1	0.00000000	94
2	0.00000000	104
FIN	AMBIENT TEMP SIDE B (R)	
1	0.00000000	95
2	0.00000000	105
FIN	EFFECT LENGTH (FT)	
1	0.15590000	96
2	0.15590000	106

Fig. B-12. Problem 5, Input Data

CONDENSER WITH NONCIRCULAR DUCT

1.5 LB/HR FLOW RATE

OUTPUT DATA

REL P=	(LIQ)	V=	FT/SEC	REGP=	(VAP)	U=	FT/SEC	QS=	BTU/SCFT	DX=	FT	DEL T=	R	DP=	PSF
.78399E 01		.22441E 00		.35990E 04		.12335E 03		.17838E 01		.23087E 01		.25222E 01		.85237E 02	
.23520E 02		.38927E 00		.32202E 04		.11710E 03		.17439E 01		.23661E 01		.25976E 01		.83919E 02	
.39200E 02		.50089E 00		.28413E 04		.10950E 03		.17033E 01		.24257E 01		.25356E 01		.78165E 02	
.54879E 02		.58316E 00		.24625E 04		.10042E 03		.16641E 01		.24844E 01		.23719E 01		.69823E 02	
.70559E 02		.64243E 00		.20836E 04		.89643E 02		.16278E 01		.25391E 01		.21118E 01		.59525E 02	
.86239E 02		.63916E 00		.17048E 04		.77303E 02		.15959E 01		.25748E 01		.11157E 01		.30251E 02	
.10192E 03		.64103E 00		.13259E 04		.62097E 02		.15791E 01		.26010E 01		.98384E 00		.26136E 02	
.11760E 03		.61661E 00		.94710E 03		.45848E 02		.15644E 01		.26230E 01		.81335E 00		.21221E 02	
.13328E 03		.55493E 00		.56826E 03		.28564E 02		.15523E 01		.26394E 01		.59508E 00		.15296E 02	
.14896E 03		.41652E 00		.18942E 03		.10159E 02		.15435E 01		.26478E 01		.30193E 00		.76765E 01	

DPSUM=	.47725E 03	LB/SQ FT	DPM=	.14933E 02	LB/SQ FT	WLISUM=	.10013E 01	LH
QSUM=	.14813E 04	BTU/HR	UFS=	.12804E 03	FEET/SEC	UFEND=	.62251E 01	FEET/SEC
ELW=	.25210E 02	FEET	PMS=	.14940E 02	LB/SQ FT	PMEND=	.72638E 02	LB/SQ FT
TE=	.49668E 03	R	KES=	.32751E 00	BTU/LB	KEEND=	.77417E 07	BTU/LB

2 LB/HR FLOW RATE

OUTPUT DATA

REL P=	(LIQ)	V=	FT/SEC	REGP=	(VAP)	U=	FT/SEC	QS=	BTU/SCFT	DX=	FT	DEL T=	R	DP=	PSF
.10453E 02		.33453E 00		.47987E 04		.16422E 03		.17838E 01		.31177E 01		.56621E 01		.19135E 03	
.31360E 02		.58550E 00		.42935E 04		.16615E 03		.16949E 01		.33098E 01		.67534E 01		.20543E 03	
.52266E 02		.76943E 00		.37884E 04		.16968E 03		.15917E 01		.35643E 01		.81075E 01		.21656E 03	
.73173E 02		.92381E 00		.32833E 04		.17607E 03		.14721E 01		.39196E 01		.10168E 02		.23078E 03	
.94079E 02		.10644E 01		.27782E 04		.18881E 03		.13284E 01		.44779E 01		.14072E 02		.25705E 03	
.11499E 03		.12161E 01		.22731E 04		.22109E 03		.11406E 01		.56568E 01		.25437E 02		.33293E 03	
.13589E 03		.14916E 01		.17679E 04		.40751E 03		.83249E 02		.13651E 02		.13636E 03		.78451E 03	

FLOW RATE EXCESSIVE.
P= .55887E 03 PSF
DPSUM= .22186E 04 PSF

Fig. B-13. Problem 5, Output Data

MULTI FIN FREON CONDENSER

INPUT DATA

1	75.00000000	TOTAL WEIGHT FLOW (LB/HR)
2	1.00000000	NO. OF DUCTS
3	0.00000000	DUCT PERIMETER (FT) *OPTION
4	0.00000000	DUCT AREA (SQ FT) *OPTION
5	0.03750000	EFFECTIVE DIAMETER (FT) *OPTION
6	3.00000000	NO. OF DUCT SECTIONS
7	3.00000000	NO. OF FINS
8	10.00000000	NO OF SUBSECTIONS
9	3157.90000001	INLET PRESSURE (LB/SQ FT)
10	600.00000000	FLUID TEMP AT ENTRANCE (R)
11	1.00000000	WEIGHT FRACTION VAPOR
12	61.31000000	LATENT HEAT OF FLUID (BTU/LB)
13	0.16100000	SPECIFIC HEAT OF VAPOR (BTU/LB R)
14	0.00000746	VISCOSITY OF VAPOR (LB/SEC FT)
15	187.39000000	MOLECULAR WEIGHT OF FLUID (LB/MOL)
16	0.95000000	VAPOR COMPRESSIBILITY FACTOR
17	92.33000000	DENSITY OF LIQUID (LB/CU FT)
18	0.21800000	SPECIFIC HEAT OF LIQUID (BTU/LB R)
19	0.00029702	VISCOSITY OF LIQUID (LB/SEC FT)

INPUT DUCT VALUES

SEC	EFFECT PERIFERAL LENGTH FOR RADIATION (FT)	INPUT DATA NO.
1	0.03375000	30
2	0.00000000	40
3	0.03375000	50
SEC	EFFECT PERIFERAL LENGTH FOR CONVECTION (FT)	
1	0.03375000	31
2	0.00000000	41
3	0.03375000	51
SEC	RADIATION CONSTANT C1 (BTU/HR SQ FT R**4)	
1	.14560000E-08	32
2	0.	42
3	0.	52
SEC	RADIATION CONSTANT C2 (BTU/HR SQ FT)	
1	146.10000000	33
2	0.00000000	43
3	0.00000000	53
SEC	CONVECTIVE HEAT TRANSFER COEFF (BTU/HR SQ FT R)	
1	7.00000000	34
2	0.00000000	44
3	12.00000000	54
SEC	AMBIENT TEMP (R)	
1	530.00000000	35
2	0.00000000	45
3	500.00000000	55

Fig. B-14. Problem 6, Input Data

MULTI FIN FREON CONDENSER

INPUT FIN VALUES		INPUT DATA NO.
FIN	RADIATION CONSTANT C1 (BTU/HR SQ FT R**4)	
1	.14560000E-08	90
2	.14560000E-08	100
3	0.	110
FIN	RADIATION CONSTANT C2 (BTU/HR SQ FT)	
1	146.10000000	91
2	146.10000000	101
3	0.00000000	111
FIN	CONVECTIVE HEAT TRANSFER COEFF SIDE A (BTU/HR SQ FT R)	
1	7.00000000	92
2	7.00000000	102
3	12.00000000	112
FIN	CONVECTIVE HEAT TRANSFER COEFF SIDE B (BTU/HR SQ FT R)	
1	12.00000000	93
2	0.00000000	103
3	0.00000000	113
FIN	AMBIENT TEMP SIDE A (R)	
1	530.00000000	94
2	530.00000000	104
3	500.00000000	114
FIN	AMBIENT TEMP SIDE B (R)	
1	500.00000000	95
2	0.00000000	105
3	0.00000000	115
FIN	EFFECT LENGTH (FT)	
1	0.18600000	96
2	0.34900000	106
3	0.29520000	116

Fig. B-14. Problem 6, Input Data (con't)

MULTI FIN FREON CONDENSER

75 LB/HR FLOW RATE

OUTPUT DATA

REL P=	(LIQ)	V=	FT/SEC	REG P=	(VAP)	U=	FT/SEC	Q S=	BTU/SCFT	D X=	FT	DEL T=	R	DP=	PSF
.11908E	03	.55195E	00	.90079E	05	.27153E	02	.25579E	00	.49961E	00	.40505E	-02	.21652E	00
.35723E	03	.98849E	00	.80597E	05	.24607E	02	.25581E	00	.49955E	00	.35088E	-02	.18757E	00
.59538E	03	.12890E	01	.71115E	05	.21905E	02	.25582E	00	.49948E	00	.34675E	-02	.18537E	00
.83353E	03	.15177E	01	.61633E	05	.19133E	02	.25583E	00	.49940E	00	.38266E	-02	.20458E	00
.10717E	04	.15745E	01	.52151E	05	.16382E	02	.25584E	00	.49931E	00	.44581E	-02	.23835E	00
.13098E	04	.15356E	01	.42669E	05	.13617E	02	.25585E	00	.49924E	00	.48097E	-02	.25717E	00
.15480E	04	.14378E	01	.33187E	05	.10814E	02	.25587E	00	.49918E	00	.48604E	-02	.25989E	00
.17861E	04	.12804E	01	.23705E	05	.79632E	01	.25588E	00	.49913E	00	.46399E	-02	.24812E	00
.20243E	04	.98526E	00	.14223E	05	.51057E	01	.25589E	00	.49919E	00	-.16282E	-02	-.87072E	-01
.22624E	04	.66044E	00	.47410E	04	.19854E	01	.25589E	00	.49912E	00	.23800E	-02	.12728E	00

DPSUM=	.18378E	01	LB/SQ FT	DPM=	.16329E	02	LB/SQ FT	WLTSUM=	.48360E	-01	LB
QSUM=	.45990E	04	BTU/HR	UFS=	.28053E	02	FEET/SEC	UFEND=	.20430E	00	FEET/SEC
ELW=	.49932E	01	FEET	PMS=	.16449E	02	LB/SQ FT	PMEND=	.11979E	00	LB/SQ FT
TE=	.51423E	03	R	KES=	.15722E	-01	RTU/LB	KEEND=	.83381E	-06	BTU/LB

225 LB/HR FLOW RATE

OUTPUT DATA

REL P=	(LIQ)	V=	FT/SEC	REG P=	(VAP)	U=	FT/SEC	Q S=	BTU/SCFT	D X=	FT	DEL T=	R	DP=	PSF
.35723E	03	.24930E	01	.27024E	06	.80947E	02	.25579E	00	.15282E	01	-.53517E	00	-.28607E	02
.10717E	04	.41701E	01	.24179E	06	.73751E	02	.25418E	00	.15360E	01	-.49815E	00	-.26434E	02
.17861E	04	.52342E	01	.21334E	06	.66063E	02	.25267E	00	.15415E	01	-.43211E	00	-.22774E	02
.25006E	04	.52498E	01	.18490E	06	.58332E	02	.25137E	00	.15677E	01	-.85454E	00	-.44772E	02
.32150E	04	.53723E	01	.15645E	06	.50567E	02	.24879E	00	.15802E	01	-.77636E	00	-.40199E	02
.39295E	04	.49010E	01	.12801E	06	.42658E	02	.24644E	00	.15896E	01	-.65869E	00	-.33742E	02
.46439E	04	.43675E	01	.99561E	05	.34347E	02	.24446E	00	.15958E	01	-.52462E	00	-.26630E	02
.53584E	04	.37514E	01	.71115E	05	.25617E	02	.24287E	00	.15985E	01	-.37857E	00	-.19077E	02
.60728E	04	.30154E	01	.42669E	05	.16400E	02	.24173E	00	.15978E	01	-.22556E	00	-.11307E	02
.67873E	04	.20131E	01	.14223E	05	.63848E	01	.24105E	00	.15932E	01	-.62511E	-01	-.31239E	01

DPSUM=	-.25667E	03	LB/SQ FT	DPM=	.14696E	03	LB/SQ FT	WLTSUM=	.14588E	00	LB
QSUM=	.14034E	05	BTU/HR	UFS=	.84160E	02	FEET/SEC	UFEND=	.61289E	00	FEET/SEC
ELW=	.15729E	02	FEET	PMS=	.14804E	03	LB/SQ FT	PMEND=	.10781E	01	LB/SQ FT
TE=	.51423E	03	R	KES=	.14150E	00	RTU/LB	KEEND=	.75043E	-05	BTU/LB

Fig. B-15. Problem 6, Output Data