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STMGEN

"A Computer Code For The Design Of A Steam Generator"

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RELEASED FOR ANNOUNCEMENT

IN NUCLEAR SCIENCE ABSTRACTS

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The STMGEN computer code is described herein as it existed on September 1, 1965. The code has been in continuous development for 1 years and in its presented form has been applied successfully by General Atomic to the kind of problems discussed later in this report. However, the development and improvement of the code are being continued, so that duplication of results (or even close agreement) between problems run with the code as published and the code as it existed either before or after this time is not necessarily to be expected.

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I. SUMMARY

STMGEN is a Computer Code written for the IBM-7044 Digital Computer. It is the first of a series of programs that will be used in a plant optimization program. The code will compute the geometry of each section of a steam generator required to satisfy the design conditions.

II. INTRODUCTION

The problems associated with system and plant optimization have been under consideration at General Atomic for a considerable length of time. During the past year the decision was made to develop a computer program capable of determining the minimum cost of a reactor plant as a function of a large number of independent variables. The problem was divided into two basic sections as follows:

Section I - Design and Cost

Design subroutines must be developed that will compute the cost of each of the major components as a function of a specific set of independent variables.

Section II - Optimization

Develop an optimization subroutine that will systematically vary all of the independent variables and select the combination associated with the minimum cost. The Monte Carlo method is an example of the mathematical technique that might be used in this section of the code.

The steam generator was selected as the first system to be analysed and programmed. The cost of the steam generator is a function of its size, geometry, pressure drop, etc. As a result these quantities must be computed as a function of the independent variables (INPUT). In other words, the steam generator code (STMGEN) must be capable of designing a unique steam generator as a function of its design conditions in sufficient detail to permit the computation of a realistic cost. This report describes the design portion of the steam generator code. The cost analysis will be issued at a later date.

The basic analysis performed by "STMGEN" consists of determining the area of a steam generator section (superheater, reheater, etc.) required to transfer a given amount of heat in accordance with the pressure

drop and maximum tube temperature constraints. Subroutine "AREA" allows the engineer to formulate the method of varying the length and number of passes required to transfer the proper amount of heat for a particular geometry, whereas, the main program, "CONTRL", is used to make the adjustments to the geometry required to satisfy the constraints. CONTRL is also used to specify the interconnections between the various sections of the steam generator. It is hoped that CONTRL and AREA will permit the engineer to design a great variety of steam generators with a comparatively few numbers of Fortran statements.

The heat transfer analysis is capable of handling either cross or parallel helium flow. However, the heat transfer film coefficient and helium pressure drop correlations used by the code are for cross flow only. An appropriate addition can be made to the program to permit the analysis of parallel flow generators.

III. DESCRIPTION

The heat transfer model used in STMGGEN is based on a single pass, subdivided into increments. The problem is analyzed by sequentially computing the heat transferred and the changes in fluid temperatures for each increment of the pass under consideration. The computed helium and steam temperatures are transferred to the next pass in accordance with the physical arrangement of the steam generator section (economizer, boiler, superheater or reheater), being analyzed. The program will determine the number and geometry of the passes required to satisfy the heat transfer and pressure drop requirements of each section; maximum metal temperatures may also be specified. This section describes the basic computation performed by the code; Section 4 explains how the program may be controlled by the engineer.

3.1 Increment Heat Transfer

Two basic options are provided by the code, these are cross flow or parallel flow. The equations for these options are derived below. In both cases the flow may be either plus or minus and the computation may be based on the inlet or outlet conditions of either flow stream. However, the helium and steam conditions must be known at the first pass computed.

3.1.1 Cross Flow

The cross flow situation is the more general one and will be treated first.

Assumptions:

1. The flow streams are orthogonal.
2. The flow streams are mixed in a direction perpendicular to the flow i.e., a constant temperature exists across each flow stream.
3. Material properties can be computed based on the average increment temperature of each stream.

4. The flow direction is positive if the increment inlet conditions are known.
5. An average heat transfer area may be used without introducing a significant error.

Definitions

T = temperature
m = flow rate
Cp = specific heat
L = length
W = width
q = heat transfer rate
L = length
U = Over-all heat transfer coefficient including tube.

Subscripts

1 = hot stream
2 = cold stream
m = average

Figure 1

Consider an increment dy high and L long

Figure 2

$$E_1 - dq = E_2 \text{ ----- (1)}$$

$$E_1 = \frac{FH}{W} \cdot CP_1 \cdot T_1 \cdot dy \text{ ----- (2)}$$

$$E_2 = E_1 + \frac{FH}{W} CP_1 \frac{\partial T_1}{\partial X} \cdot dx \cdot dy \text{ ----- (3)}$$

Substitute Eq. 2 and 3 into 1

$$dq = -\frac{FH}{W} \cdot Cp_1 \cdot \frac{\partial T_1}{\partial x} \cdot dx \cdot dy \text{ ----- (4)}$$

Similarly

$$dq = \frac{FS}{L} \cdot Cp_2 \cdot \frac{\partial T_2}{\partial y} \cdot dy \cdot dx \text{ ----- (5)}$$

Let

$$C_1 = FH \cdot Cp_1 \text{ ----- (6)}$$

$$C_2 = FS \cdot Cp_2 \text{ ----- (7)}$$

dq can also be expressed by

$$dq = U \cdot dx \cdot dy (T_1 - T_2) \text{ ----- (8)}$$

Substitute Eq. 5 into 8 and integrate from 0 to L

$$\int_0^L \frac{C_2}{L} \cdot \frac{\partial T_2}{\partial y} \cdot dy \cdot dx = U \int_0^L (T_1 - T_2) dy \cdot dx \text{ -(9)}$$

$$T_2 \neq f(x)$$

$$\frac{\partial T_2}{\partial y} \cdot dy = dT_2$$

$$C_2 \cdot \frac{dT_2}{dy} = U \int_0^L (T_1 - T_2) dx \text{ ----- (10)}$$

$$T_{lm} = \frac{1}{L} \int_0^L T_1 dx \text{ ----- (11)}$$

$$\frac{dT_2}{dy} = \frac{U \cdot L}{C_2} (T_{lm} - T_2) \text{ ----- (13)}$$

$$T_2 = T_{lm} + A e^{-\frac{U \cdot L}{C_2} y} \text{ -----}$$

$$\bullet \quad y = 0; \quad T_2 = T_{21}$$

∴

$$A = (T_{21} - T_{lm})$$

$$(T_{lm} - T_2) = (T_{lm} - T_{21}) e^{-\frac{U \cdot L}{C_2} y} \text{ ----- (14)}$$

$$\bullet \quad y = w; \quad T_2 = T_{2e}$$

$$(T_{lm} - T_{2e}) = (T_{lm} - T_{21}) e^{-\frac{U \cdot L \cdot W}{C_2}} \text{ ----- (15)}$$

Let

$$\alpha = \frac{U \cdot L \cdot W}{C_2} \text{ ----- (16)}$$

Substitute 16 into 15 and add T_{21} to both sides

$$(T_{2e} - T_{21}) = (T_{lm} - T_{21}) (1 - e^{-\alpha}) \text{ ----- (17)}$$

Consider an element dx wide and W high taken from Figure 1,
 Page 3-3

Figure 3

By performing the same analysis that was used in deriving equation 14 (i.e. equations 1 - 14) the following equation is obtained.

$$(T_1 - T_{2m}) = (T_{1i} - T_{2m}) e^{-\frac{U \cdot W}{C_1} x} \quad \text{-----} \quad (18)$$

$$\text{at } x = L; T_1 = T_{1e}$$

Let

$$\beta = \frac{U \cdot L \cdot W}{C_1} \quad \text{-----} \quad (19)$$

$$(T_{1e} - T_{11}) = (T_{2m} - T_{11}) (1 - e^{-\beta}) \text{ ----- (20)}$$

The total heat transferred over the entire increment can be expressed as

$$q = U \cdot L \cdot W (T_{1m} - T_{2m}) \text{ ----- (21)}$$

$$q = C_2 (T_{2e} - T_{21}) \text{ ----- (22)}$$

$$q = -C_1 (T_{1e} - T_{11}) \text{ ----- (23)}$$

From equation 23 and 21, equation 20 becomes

$$- \frac{U \cdot L \cdot W}{C_1} (T_{1m} - T_{2m}) = (T_{2m} - T_{11}) (1 - e^{-\beta}) \text{ ----- (24)}$$

Substitute 19 into 24 and rearrange.

$$T_{2m} = - \frac{\beta(T_{1m} - T_{2m})}{1 - e^{-\beta}} + T_{11} \text{ ----- (25)}$$

From equation 22, 21 and 16 Equation 17 becomes

$$T_{1m} = \frac{\alpha(T_{1m} - T_{2m})}{1 - e^{-\alpha}} + T_{21} \text{ ----- (26)}$$

Subtract 25 from 26 and collect terms

$$(T_{1m} - T_{2m}) = \frac{(T_{1i} - T_{2i})}{\left(\frac{\alpha}{1 - e^{-\alpha}} + \frac{\beta}{1 - e^{-\beta}} - 1 \right)} \quad (27)$$

The heat transferred may now be computed from equation 21.

These equations are based on the inlet conditions being known. If the outlet conditions of the steam are known the code will make the appropriate flow rate negative and substitute the exit temperature for the inlet (T_{2i} in equation 27). If the helium exit temperatures are known the flow is read into the machine as a negative number (see Section VI Data Group 8).

The properties of both streams are computed as a function of the stream average temperature and the average temperatures are a function of the mean temperature difference (see equation 25 and 26). Since the mean temperature difference is in turn a function of the properties of each stream (see equations 27, 19, 16, 7 and 6), it can easily be seen that an iterative technique is required to determine the average temperature difference.

3.1.2 Parallel Flow

The equations describing the parallel flow situation can be arranged in a manner that will permit the cross flow equations to be used with two simple modifications. These equations are derived in this section.

Assumptions:

1. The flow streams are parallel
2. The flow streams are mixed in a direction perpendicular to the flow i.e. a constant temperature exists across each flow stream.
3. Material properties can be computed based on the average increment temperature of each stream.
4. The flow direction is positive if the increment inlet conditions are known.
5. An average heat transfer area may be used without introducing a significant error.

Definitions:

T = temperature

m = flow rate

C_p = specific heat

L = length

W = width

q = heat transfer rate

L = length

U = Over-all heat transfer coefficient including tube.

Concurrent flow m_2 is positive

Counter flow m_2 is negative and $T_{2i} > T_{2e}$

Fluid No. 1 is the hot fluid.

For Fluid No. 1

$$E_{11} - dq = E_{12} \text{ ----- (28)}$$

$$E_{11} = m_1 C_{p1} T_1 \text{ ----- (29)}$$

$$E_{12} = E_{11} + \frac{\partial}{\partial x} (E_{11}) dx \text{ ----- (30)}$$

Substitute Eqs. 30 and 29 into 28

$$dq = - m_1 \cdot C_{p1} \cdot dT_1 \text{ ----- (31)}$$

Similarly for Fluid No. 2

$$dq = m_2 \cdot C_{p2} \cdot dT_2 \text{ ----- (32)}$$

Let

$$C_1 = m_1 \cdot C_{p1} \text{ ----- (33)}$$

$$C_2 = m_2 \cdot C_{p2} \text{ ----- (34)}$$

dq can also be expressed as

$$dq = U \cdot dx \cdot W(T_1 - T_2) \text{ ----- (35)}$$

which can be written as

$$\int_0^x \frac{dq}{(T_1 - T_2)} = U \cdot W \cdot X \text{ ----- (36)}$$

Equating equations 31 and 32, integrating from $x = 0$ to x and substituting eqs. 33 and 34 to obtain an expression for $(T_1 - T_2)$

$$(T_2 - T_{21}) = \frac{C_1}{C_2} (T_{11} - T_1) \text{ ----- (37)}$$

add T_1 to both sides and collect terms

$$(T_1 - T_2) = (T_{11} - T_{21}) - \frac{C_2 + C_1}{C_2} (T_{11} - T_1) \text{ ----- (38)}$$

Equation 31 and 33 can now be integrated by dividing both sides by $(T_1 - T_2)$ and substituting equation 36 for the left hand side of the equation

$$\int_0^X \frac{dq}{(T_1 - T_2)} = U \cdot W \cdot X = - \int_0^X \frac{C_1 dT_1}{(T_1 - T_2)} \text{ ----- (39)}$$

Substitute eq. 38 into 39 and integrate

$$U \cdot W \cdot X = - C_1 \int_0^X \frac{dT_1}{(T_{11} - T_{21}) - \left(\frac{C_2 + C_1}{C_2}\right) (T_{11} - T_1)} \text{ --(40)}$$

$$-U \cdot W \cdot X = \frac{1}{\left(\frac{1}{C_1} + \frac{1}{C_2}\right)} \ln \left[\frac{(T_{11} - T_{21}) - \left(\frac{C_2 + C_1}{C_2}\right) (T_{11} - T_1)}{(T_{11} - T_{21})} \right] \text{ -- (41)}$$

Substitute Eq. 38 into 41 and rearrange

$$\frac{T_1 - T_2}{T_{11} - T_{21}} = e^{-\left(\frac{1}{C_1} + \frac{1}{C_2}\right) U \cdot W \cdot X}$$

Let

$$\phi = \left(\frac{1}{C_1} + \frac{1}{C_2}\right) U \cdot W$$

$$(T_1 - T_2) = (T_{11} - T_{21}) e^{-\phi \cdot X} \quad \text{-----} \quad (42)$$

Substitute eq. 42 into 38 and solve for T_1

$$\left(\frac{C_2 + C_1}{C_2}\right) (T_{11} - T_1) = (T_{11} - T_{21}) (1 - e^{-\phi \cdot X}) \quad (43)$$

$$T_1 = T_{11} - \left(\frac{C_2}{C_2 + C_1}\right) (T_{11} - T_{21}) (1 - e^{-\phi \cdot X}) \quad \text{--} \quad (44)$$

Substitute $(T_{11} - T_1)$ from eq. 37 into 43

$$T_2 = T_{21} + \left(\frac{C_1}{C_2 + C_1}\right) (T_{11} - T_{21}) (1 - e^{-\phi \cdot X}) \quad \text{--} \quad (45)$$

The average of T_1 and T_2 is found by integrating over X

$$T_{1m} = \frac{1}{L} \int_0^L T_1 \, dx \quad \text{-----} \quad (46)$$

Integrating equations 44 and 45 over X and dividing by L

$$T_{1m} = T_{11} - \left(\frac{C_2}{C_2 + C_1} \right) (T_{11} - T_{21}) \left(1 + \frac{e^{-\phi \cdot L}}{\phi \cdot L} \right) \quad (47)$$

$$T_{2m} = T_{21} + \frac{C_1}{C_2 + C_1} (T_{11} - T_{21}) \left(1 + \frac{e^{-\phi \cdot L}}{\phi \cdot L} \right) \quad (48)$$

Subtract equation 48 from 47

$$(T_{1m} - T_{2m}) = \frac{T_{11} - T_{21}}{\left(\frac{\phi \cdot L}{1 - e^{-\phi \cdot L}} \right)} \quad (49)$$

Compare eq. 49 with 27

If $\frac{\beta}{1 - e^{-\beta}}$ is set equal to 1 and $\phi \cdot L$ substituted for α the same equation may be used for both parallel and cross flow in the code.

NOTE: If a parallel flow problem is to be run the helium film coefficient (subroutine FUN6), the geometry (subroutine GEOMET), and the helium pressure drop (subroutine SECTON) must be changed.

3.2 Tube Geometry

Definitions

Number of passes (I) - Number of times that the steam flow crosses the helium path (maximum of 20). Passes are numbered in the direction of computation.

Section (K) A section is composed of one or more passes. (There are a maximum of 10 sections)

Increment (J) Each pass may be divided into one or more increments (maximum of 20)

The heat transfer computation is based on a single pass composed of "ATNUM(K)" tubes. The individual passes may be arranged into sections of "U" tubes, or of helically or spirally wound tubes. This section describes these arrangements in detail.

3.2.1 Pass Geometry

Figure 5 and 6 give the tube patterns that are permitted in any pass (triangular or rectangular pitch). The pitch spacing, number of tubes, tube diameter and number of increments per pass are constant for any section. The length may be varied for each pass of the section (a spirally wound tube is a typical example of variable length passes). Each pass is divided into axial increments for computational purposes. The heat transfer area is found by computing the area of all the tubes in the pass per increment. As a result the computed steam temperatures are the average temperatures per pass in each axial increment.

$ST(K)$ = Transverse Pitch Spacing
 $SL(K)$ = Longitudinal Pitch Spacing
 $SD(K)$ = Diagonal Pitch Spacing (computed)
 $TROW(K)$ = Number of Rows per Pass.
 $TCOL(K)$ = Number of Columns per Pass
 $WPASS(K)$ = Width of Pass
 $DPASS(K)$ = Depth of Pass
 $TNUM(K)$ = Total Number of Tubes in Pass

TRIANGULAR PITCH SPACING

Figure 5

$ST(K)$ = Transverse Pitch
 $SL(K)$ = Longitudinal Pitch
 $TROW(K)$ = Number of Tube Rows per Pass
 $TCOL(K)$ = Number of Tube Columns per Pass
 $WPASS(K)$ = Width of Pass
 $DPASS(K)$ = Depth of Pass
 $TNUM(K)$ = Total Number of Tubes in Pass

RECTANGULAR PITCH

Figure 6

3.2.2 Increment Geometry

1. Transverse Channels/Row

$$CHT(K) = \frac{TCOL(K)-1}{2} \text{ ----- (50)}$$

2. Diagonal Channels

$$CHD(K) = 2 \cdot CHT(K) \text{ ----- (51)}$$

3. Diagonal Pitch Spacing

If the pitch spacing is rectangular (See Figure 6), the diagonal pitch is meaningless.

$$SD(K) = ((ST(K)/2.0)^2 + SL(K)^2)^{1/2} \text{ ----- (52)}$$

4. Width of Pass

Rectangular Pitch

$$WPASS(K) = TCOL(K) \cdot ST(K) \text{ ----- (53)}$$

Triangular Pitch

$$WPASS(K) = TCOL(K) \cdot SK(K)/2.0 \text{ ----- (54)}$$

5. Helium Flow Path Length per Pass

$$DPASS(K) = TROW(K) \cdot SL(K) \text{ ----- (55)}$$

6. Increment Length

$$TLSEG = TUBE(I,K)/AMSEG(K) \text{ ----- (56)}$$

TUBE(I,J) = Length of pass I in
Section (K)

AMSEG(K) = Number of Axial Increment
in Section K

7. Helium Transverse Flow Area Per Unit Length

$$AFHT = CHT(K) \cdot (ST(K) - DO(K)) \text{-----} (57)$$

(See Figure 5 or 6)

8. Helium Diagonal Flow Area per Unit Length

(for triangular pitch only see Figure 5)

$$AFHD = CHD(K) \cdot (SD(K) - DO(K)) \text{-----} (58)$$

9. Helium Flow Area

The helium flow area is the minimum flow area that the helium must pass through (per increment)

Rectangular Pitch

$$AFHMIN = AFHT \cdot TLSEG \text{-----} (59)$$

Triangular Pitch

$$AFHMIN = \text{Minimum of } (AFHT, AFHD) \cdot TLSEG \text{----} (60)$$

10. Steam Flow Area per Pass

$$ASSEG = TNUM(K) \cdot \pi \cdot DI(K)^2/4.0 \text{-----} (61)$$

11. Void Volume Per Unit Length

$$VOID(K) = DPASS(K) \cdot WPASS - TNUM \cdot \pi DO(K)^2/4.0 \text{--}(62)$$

12. Friction Surface Areas Per Unit Length Per Pass

$$FRSR(K) = TNUM(K) \cdot \pi DO(K) \text{-----} (63)$$

13. Hydraulic Diameters

Steam

$$D = DI(K) \text{-----} (64)$$

Helium

Heat Transfer Film Coefficient

$$D = DO(K) \text{-----} \quad (65)$$

Friction Factor

$$DV(K) = \frac{4 \cdot \text{VOID}(K)}{\text{FRSR}} \quad (66)$$

$DV(K)$ = Void volume hydraulic diameter
(see section 3.4.1, eq. 113)

3.2.3 Section Geometry

A section is formed by connecting the various passes together in a prescribed manner. Many sections can be represented as a series of properly connected straight tubes; these include the U-tube, helical and spiral arrangements.

1. U Tube Section AITUBE = 1.0

Consider the following

Figure 7

This U tube section is divided into six straight passes (see Fig. 7B) with a length equal to the straight portion of each actual pass (see Fig. 7A). The bends are not considered as effective heat transfer surface. The length of each pass need not be the same. Each pass is, however, divided into the same number of equal increments (see Eq. 56 (Section 3.2.2)).

The over-all helium flow may be specified and the code will divide the flow equally into the various increments or the helium flow for each increment may be specified (see Section VI data group 8).

The steam flow starts at Point one (1), it may be positive or negative, and proceeds through tube 1. The code will automatically set the steam conditions at points 2 and 3 equal and the computation proceeds for pass 2. This procedure is repeated for each pass. Refer to section 4.2 for the method of varying the tube length, tube diameter and the number of passes required to satisfy the design conditions.

2. Helical or Spiral Sections

The spiral section will be used as an example. The same procedure is used to convert the helical section into a series of straight passes.

The helium flow path is considered to flow radially in or out of the section (this is not a necessary restriction on the flow pattern). The section is divided into equal segments and unwound.

Figure 9

In this case the code will automatically set the steam conditions at points 2 and 3 equal and the steam conditions at points 4 and 5 equal. See Section 4.1 for the method of computing the length of each pass and the method of determining the total number of passes (coils).

These two types have been used as examples of how various shapes may be converted to equivalent straight tubes. This same procedure may be used on many other arrangements.

3.2.4 Steam Generator Arrangement

The steam generator is composed of a series of sections connected together by the helium and steam flow paths specified by the engineer in

subroutine CONTRL (see Section 4.2). There may be up to 10 sections and they may be connected in any sequence the engineer desires provided the helium and steam conditions are known at the starting point of each section (inlet or outlet).

3.3 The Over-all Heat Transfer Coefficient

The over-all heat transfer coefficient, hereafter represented by U , is composed of the steam and helium film coefficients and an equivalent coefficient for the tube. The code uses U and an equivalent area to compute the heat transferred in each increment (See Eq. 21 Section 3.1).

3.3.1 Equivalent Area

FIG 10

$$q_1 + dq = q_2$$

For No heat generation

$$dq = 0$$

$\therefore$

$$\frac{\partial}{\partial r} (q_1) dr = 0 \text{-----} (67)$$

$$q_1 = -2\pi r dz \frac{kdT}{dr} \text{-----} (68)$$

Sub 68 into 67 and integrate twice assuming constant k for a unit height

$$-2\pi k r \frac{dT}{dr} = C_1 \text{-----} (69)$$

$$T = \frac{-C_1}{2\pi k} \ln r + C_2 \text{-----} (70)$$

Boundary Conditions:

$$\text{at } r = R_I; T = T_{TI}$$

$$\text{at } r = R_O; T = T_{TO}$$

Solving for C_1 in equation 70 and substituting into eq. 69 and 68

$$q = - (TTO - TTI) \frac{2\pi k}{\ln \frac{RO}{RI}} \text{ ----- (71)}$$

The minus sign indicates that q is in the opposite direction to R and may be neglected.

Define

$$q = k \cdot Am \frac{(TTO - TTI)}{(RO - RI)} \text{ ----- (72)}$$

The equivalent area Am from equation 72 and 71 for an increment of length $LSEG$ and a tube of outside diameter DO and inside diameter DI is

$$Am = 2\pi \cdot \frac{(DO - DI)}{2 \ln \frac{DO}{DI}} \cdot LSEG \text{ ----- (73)}$$

Am is used in equation 21 by setting

$$W \cdot L = AM \text{ ----- (74)}$$

$$q = U \cdot Am (T_{lm} - T_{2m}) \text{ ----- (75)}$$

3.3.2 Equation for U

Define:

H_h	=	Helium Film Coefficient
AO	=	Outside tube heat transfer area for the increment
$THAV$	=	Average helium temperature
TTO	=	Average outside tube temperature
TTI	=	Average inside tube temperature
$TSAB$	=	Average steam temperature

HS = Steam film coefficient

AI = Inside tube heat transfer area for the increment

$$(THAV - TTO) = q \frac{1}{H_h \cdot AO} \text{-----} (76)$$

$$(TTO - TTI) = q \frac{(DO - DI)}{2 k A_m} \text{-----} (77)$$

$$(TTI - TSAV) = q \frac{1}{H_{St} \cdot AI} \text{-----} (78)$$

Add Eqs. 76, 77, 78 and set

$$DELTA V = (THAV - TSAV) \text{-----} (79)$$

$$DELTA V = \frac{q}{A_m} \left[\frac{A_m}{H_h \cdot AO} + \frac{DO-DI}{2k} + \frac{A_m}{H_{St} \cdot AI} \right] \text{-----} (80)$$

Note

$$DELTA V = (T_{lm} - T_{2m}) \text{ in Eq. 21, 27, 49.}$$

Define the following resistances

Helium Resistance

$$RH = \frac{A_m}{H_h \cdot AO} \text{-----} (81)$$

Tube Resistance

$$RT = \frac{DO - DI}{2k} \text{-----} (82)$$

Steam Resistance

$$RS = \frac{A_m}{H_{St} \cdot AI} \text{-----} (83)$$

Substitue 81, 82, and 83 into equation 80 and define

$$U = \frac{1}{(R_H + R_T + R_S)} \text{-----} (84)$$

3.3.3 Helium Resistance

The helium resistance is computed in subroutine FUN6. It currently uses the correlations given in Heat Transmissions by McAdams, Vol. III, pages 272-275, to compute the helium film coefficient. These relations may be changed by the Engineer to compute any value of RH desired by rewriting FUN6.

From page 272 McAdams

$$\frac{H_m \cdot D}{HTC} = ATUBE \cdot \left(\frac{Cp \cdot HVIS}{HTC} \right)^{AHE} \cdot \left(\frac{D \cdot HGMAX}{HVIS} \right)^{BHE} \text{-----} (85)$$

Where

H_m = Average film coefficient for flow across 10 tubes
 D = Hydraulic diameter - outside diameter of tubes
 Cp = Specific heat of helium
 $HVIS$ = Viscosity of helium
 $HGMAX$ = Mass flow rate of helium
 HTC = Fluid conductivity
 $ATUBE$ = 0.33 Triangular pitch (Staggered)
 = 0.26 Rectangular (in line)
 AHE = 0.3333
 BHE = 0.6

From Table 10-7 page 10-7 page 275 McAdams Vol. III

$$H_{\infty} = \frac{H_m}{.93} = \frac{ATUBE}{0.93} \cdot \frac{HTC}{DO} (PR)^{AHE} (RE)^{BHE} \text{-----} (86)$$

I th ROW	H/H _∞) _I
1	0.63
2	0.76
3	0.93
4	0.98
5	0.99
6	1.0
7	1.0

$$H_I = (H/H_{\infty})_I \cdot H_{\infty} \text{ ----- (87)}$$

Table 10-7 of McAdams gives the ratio of the film coefficient for tube N vs. the film coefficient for an infinite bank. The actual film coefficient for the tube is computed by multiplying equation 86 by $(H/H_{\infty})_I$. If there are more than one tube in a pass the average for the pass is computed from

$$\frac{H_{AV}}{H_{\infty}} = \sum_{I=a}^N \frac{(H/H_{\infty})_I}{(N-a)+1} \text{ ----- (88)}$$

$$H_{AV} = \left(\frac{H_{AV}}{H_{\infty}} \right) \cdot H_{\infty} \text{ ----- (89)}$$

The helium resistance is computed from

$$R_H = \frac{A_m}{H_H \cdot AO}$$

where

$$H_H = H_I \text{ or } H_{AV} \text{ as the case may be}$$

$$A_0 = \pi D_0 \cdot TLSEG \text{ ----- (90)}$$

$$A_m = \text{See Eq. 73}$$

3.3.4 Tube Resistance

The tube resistance is computed in subroutine FUN5 by Equation 82.

$$R_T = \left(\frac{D_0 - D_I}{2k} \right) \text{ ----- (82)}$$

3.3.5 Steam Resistance

The term "Steam Film Coefficient," as used in this report, is an inclusive term used to refer to the film coefficient on the water side of the steam generator in the subcooled, saturated, superheated or supercritical region. The steam phase diagram is divided into four separate regions for the purpose of computing a film coefficients and subdividing an increment which contains two or more of these regions (see Section 3.6.). These regions are shown in Figure 11.

Figure 11

Notice that the regions are numbered with odd numbers the dividing points are even numbers.

Region 1	subcooled
Region 3	saturated
Region 5	Transition from saturated to superheated
Region 7	Superheated

Supercritical steam is considered to be in region 1

H_2	=	HSATW
H_4	=	HP
H_6	=	HSATS

HP is defined by the following equation

$$HP = QUAL \cdot HSATS + (1.0 - QUAL) \cdot HSATW \text{ ----- (91)}$$

QUAL = Quality at beginning of transition region(input)

Define:

SRe	=	Reynolds No. = $\frac{DI \cdot SGMAX}{SVIS}$
HSAV	=	Average steam enthalpy
STC	=	Steam thermal conductivity
SVIS	=	Steam viscosity
SCALE	=	Scale coefficient
CSI	=	Steam inverse specific heat
Nu	=	Nusselt No. = $(HS \cdot D/k)$
HSATS	=	Enthalpy of saturated steam
HSATW	=	Enthalpy of saturated water
D	=	Hydraulic diameter = DO

1. Subcooled or Supercritical Region 1 (See Figure 11)

The subcooled or supercritical film coefficient is considered constant in the laminar REGION ($RE < 2000$) and is computed as a function of the Reynolds and Prandlt number in the turbulent region ($RE > 15,000$).

The transition REGION ($2,000 < RE < 15,000$) is computed by defining a function ($Nu = a (RE)^b$) that will bridge the gap between the two regions. The coefficient a and exponent b are evaluated from the value of the Nusselt number at a Reynolds Number of 2000.0 and 15,000.0. These computations are performed in subroutine FUN1.

SRe < 2000

$$\frac{H_s \cdot DI}{STC} = 4.0 \text{ ----- (92)}$$

2000 $\leq$ SRe < 15,000

$$\frac{H_s \cdot DI}{STC} = a(SRe)^b \text{ ----- (93)}$$

15,000 < SRe

$$\frac{H_s \cdot DI}{STC} = 0.021 (SRe)^{0.8} (Pr)^{0.4} \text{ ----- (94)}$$

Evaluation of a and b in equation 93

$$\text{at Re} = 2000.0, Nu_1 = 4.0$$

$$\text{at Re} = 15,000.0$$

$$Nu_2 = 0.021 (15,000)^{0.8} (PR)^{0.4}$$

By substituting the above conditions into equation 92 and solve for a and b .

$$b = \ln \left(\frac{Nu_2}{4.0} - 7.5 \right) \text{ ----- (95)}$$

$$a = 4.0 (2,000.0)^{-b} \text{ ----- (96)}$$

Nu_2 is evaluated from equation 93 for Re = 15,000

2. Saturated Region 3

The boiling film coefficient is assumed to be constant and is provided in the input. The coefficient is set in subroutine FUN2

$$H_s = BOLCOE \text{ ----- (97)}$$

3. Superheated Region 7

The equations used in the superheated region are the same as the equations used in the subcooled region. They are computed separately in subroutine FUN4 in order to facilitate change. The equations and procedures are the same as given in Section 3.3.4 Eqs. 92 - 96. The material properties are based on superheated steam.

4. Transition Region 5

The transition region connects the boiling region to the superheated region by a straight line relationship based on enthalpy.

$$H_2 = A + B \cdot \text{HSAV} \text{ ----- (98)}$$

$$\text{HP} \leq \text{HSAV} \leq \text{HSATS}$$

A and B are evaluated by computing H_s at $\text{HSAV} = \text{HP}$ from equation 98 and $\text{HSAV} = \text{HSATS}$ from Equation 92, 93, or 94 evaluated as given in 3.3.4 - 3 above and substituting into equation 98.

Let

$\text{SATSH} =$ Film coefficient computed for superheated steam

at $\text{HSAV} = \text{HSATS}$

$\frac{\text{SATSH} \cdot \text{DI}}{\text{STC}}$ is evaluated by Eq. 92, 93 or 94 at point 6 in Figure 11.

The end point conditions needed to evaluate A and B in Equation 98 are

at $\text{HSAV} = \text{HP}$	$\text{HS} = \text{BOLCOE}$
at $\text{HSAV} = \text{HSATS}$	$\text{HS} = \text{SATSH}$

By substituting the above conditions into equation - 98 and solving for A and B.

$$B = \frac{SATSH - BOLCOE}{HSATS - HP} \text{ ----- (99)}$$

$$A = SATSH - B \text{ ----- (100)}$$

The transition film coefficient is computed in subroutine FUN3.

5. Scale Factor

The steam resistance is the sum of the film resistance ($1/HS$) plus the resistance due to fouling or scaling. The scale film coefficient ($ASCALE(K)$) is included in the input.

The over-all film coefficient is given by

$$\frac{1}{HST} = \frac{1}{HS} + \frac{1}{SCALE} \text{ ----- (101)}$$

The steam resistance is given by

$$RS = \frac{A_m}{HST \cdot AI} \text{ ----- (102)}$$

A_m is computed by Eq. 73

$$AI = \pi DI \cdot TLSEG \text{ ----- (103)}$$

3.4 Pressure Drop

The equation for the pressure drop will be derived from the momentum equation.

Define:

m	=	mass flow
v	=	velocity
P	=	static pressure
A	=	area
ρ	=	density
PF	=	friction perimeter
f	=	friction factor
Z	=	distance
V	=	specific volume
W	=	mg

Consider the increment dz

Figure 12

$$F = f \cdot PF \cdot \frac{v^2}{2g} \cdot \rho \, dZ \text{ ----- (104)}$$

The momentum balance is

$$mv + PA + P \frac{\partial A}{\partial Z} dZ = mv + \frac{\partial}{\partial Z}(PA)dZ + f \cdot PF \cdot \frac{v^2}{2g} \cdot \rho \cdot dZ \quad (105)$$

$$\rho = 1/v$$

$$v = WV/A \quad (106)$$

$$mv = \frac{W^2}{g} \frac{v}{A}$$

$$\frac{\partial}{\partial Z} (PA) = \frac{P \partial A}{\partial Z} + \frac{A \partial P}{\partial Z} \quad (107)$$

Using Eq. 105

$$\frac{\partial}{\partial Z} (mv) = \frac{W^2}{g} \left[\frac{1}{A} \cdot \frac{\partial v}{\partial Z} - \frac{v}{A^2} \cdot \frac{\partial A}{\partial Z} \right] \quad (108)$$

Sub 104-106 into 103 and collect terms and simplify

$$\frac{\partial P}{\partial Z} + \frac{W^2}{2g} \left[\frac{2}{A^2} \cdot \frac{\partial v}{\partial Z} + \frac{f \cdot PF \cdot v}{A^3} - \frac{2v}{A^3} \frac{\partial A}{\partial Z} \right] = 0 \quad (109)$$

This equation is very difficult to solve unless the variables are assumed to be separable. This is not a bad assumption if the pressure changes are small in comparison to the magnitude of the pressure.

Therefore assume separability and integrate.

$$-(P_2 - P_1) = \frac{W^2}{2g} \left[\frac{2}{A^2} \int_{v_1}^{v_2} dv + \frac{f \cdot \overline{PF} \cdot \bar{v}}{A^3} \int_{Z_1}^{Z_3} dZ - 2\bar{v} \int_{A_1}^{A_2} \frac{dA}{A^3} \right] \quad (110)$$

$$\text{Define } D = \frac{4\bar{A}}{\bar{P}F}$$

$$f_m = 4f$$

$$-\Delta P = \left(\frac{W}{\bar{A}}\right)^2 \frac{\bar{V}}{2g} \left[\frac{2(V_2 - V_1)}{V} + \frac{f_m \cdot \Delta Z}{D} + \left(\frac{\bar{A}}{A_2}\right)^2 - \left(\frac{\bar{A}}{A_1}\right)^2 \right] \text{----- (111)}$$

3.4.1 Helium Pressure Drop

Helium may be treated as a perfect gas. The equations defining the friction factor are for cross flow

$$V_1 = \frac{RT_1}{\bar{P}} \text{----- (112)}$$

Let

$$F = \frac{f_m \Delta Z}{D} \text{----- (113)}$$

Equation 111 may be written as

$$\Delta P = \left(\frac{W}{\bar{A}}\right)^2 \frac{RT}{2g\bar{P}} \left[\frac{2(T_2 - T_1)}{\bar{T}} + F + \left(\frac{\bar{A}}{A_2}\right)^2 - \left(\frac{\bar{A}}{A_1}\right)^2 \right] \text{----- (114)}$$

F can be related to the friction pressure drop given in a paper titled "A general correlation of friction factors for various types of cross flow" by A. Y. Gunter and W. A. Shaw published in the ASME transactions of Nov. 1945

The friction pressure drop given in this report is expressed by

$$\Delta P = \left(\frac{W}{\bar{A}}\right)^2 \frac{R \cdot T}{2g \cdot \bar{P}} \left[\frac{f \cdot L}{DV} \left(\frac{\mu_S}{\mu}\right)^{0.14} \left(\frac{DV}{ST}\right)^{0.4} \left(\frac{SD}{ST}\right)^{0.6} \right] \text{----- (115)}$$

where

μ_s = Viscosity evaluated at the average tube temperature

μ = Viscosity evaluated at the average bulk coolant temperature

DV = Void hydraulic diameter

W = FHSEG - helium flow rate

SD = Diagonal pitch (See Sec. 3.2.2 eq. 52)

ST = Transverse pitch (See Figure 5)

f = Friction factor

L = Flow path length (See Sec. 3.2.2 Eq. 55)

A = Minimum helium flow area (see Sec. 3.2.2, Eq. 60)

T = Average helium temperature

P = Average helium pressure

Re = Reynolds Number

$$\mu = AAMU(T)^{ABMU} \text{-----} (116)$$

$$C_p = AAC_p + ABC_p \cdot T \text{-----} (117)$$

CP = Helium specific heat

$$HTC = AAKG(T)^{ABKG} \text{-----} (118)$$

HTC = Helium thermal conductivity

$$HRE = \frac{DV \cdot W}{\mu \cdot A} \text{-----} (119)$$

HRE = Helium Reynolds number

The friction factor f in equation 115 is computed from a function of the Reynolds number

$$\text{HRE} < 200.00$$

$$f = \frac{1800.0}{\text{HRE}} \text{-----} (120)$$

$$\text{HRE} \geq 200.0$$

$$f = \frac{0.196}{\text{HRE}^{0.144}} \text{-----} (121)$$

Compare equation 115 with the friction portion of equation 114. The friction terms are the same if

$$F = \frac{f \cdot L}{DV} \left(\frac{\mu_s}{s} \right)^{0.14} \left(\frac{DV}{ST} \right)^{0.4} \left(\frac{SD}{ST} \right)^{0.6} \text{-----} (122)$$

3.4.2.1 Helium Pressure Drop Options

There are six helium pressure drop options provided for each section. The desired option is specified by the input parameter ADROP(K). (See section VI data group 10) The options are listed below.

OPTION 1 ADROP(K) = 1

Do not compute the helium pressure drop in Section K.

OPTION 2 ADROP(K) = 2

Compute the average helium pressure drop across section K.

OPTION 3 ADROP(K) = 3

Compute the helium section flow FHT(K) that will produce a pressure drop of DPH(K).

OPTION 4 ADROP(K) = 4

Compute the helium pressure drop for each axial increment.

OPTION 5 ADROP(K) = 5

Compute the helium flow in each axial increment that will produce a pressure drop of DPH(K).

OPTION 6 ADROP(K) = 6

Compute the section pressure drop DPH(K) and the flow for each axial increment associated with a total section flow of FHT(K).

The helium pressure drop computations are performed in the latter portion of subroutine SECTION. . If a parallel flow section is to be analyzed, the helium pressure drop computation must be changed.

3.4.2 Steam Pressure Drop

The steam pressure drop is computed in Subroutine DROPS for each increment immediately after the increment has been analysed. A literature search has indicated that the homogeneous model gives satisfactory answers for two phase pressure drop provided that the pressure is above 2000 psia and that the properties are computed as a function of the specific volume or quality in the saturated region.

The homogeneous equation for constant area is

$$-\Delta P = \left(\frac{W}{A} \right)^2 \frac{\bar{V}}{2g} \left(2 \frac{\Delta V}{\bar{V}} + \frac{f_m \Delta Z}{D} \right) \text{-----} (123)$$

See Section 3.4, eqs. 104-111 for the derivation of this equation.

Adding a change in elevation term, and expressing a pressure drop as a positive number with the following definitions.

VOUT	=	increment outlet specific volume
VIN	=	increment inlet specific volume
ΔV	=	VOUT - VIN = Change in specific volume
$\bar{V}$	=	VAV = Average specific volume based on the average enthalpy
$\frac{W}{A}$	=	SGMAX = $\frac{FSSEG}{ASEG}$ = Mass flow rate
DELPS	=	ΔP = Pressure drop
DELH	=	Change in elevation
F_m	=	Moody friction factor
DELZ	=	Increment length
g	=	$32.2 \cdot (3600)^2 \text{ ft/hr}^2$

Equation 123 becomes

$$\text{DELPS} = (\text{SGMAX})^2 \frac{\text{VAV}}{2g} \left[2 \frac{(\text{VOUT}-\text{VIN})}{\text{VAV}} + \frac{\text{FM} \cdot \text{DELZ}}{\text{DI}} \right] + \frac{\text{DELH}}{\text{VAV}} \text{----} (124)$$

This equation is written for a pressure drop being a positive number in the direction of flow.

The change in elevation, DELH, is evaluated as follows:

Figure 13

$$\text{DELH} = \text{SIGNP}(K) \cdot \text{LSEG} \cdot \sin(\text{ANGLE}(K)) \quad \text{-----} \quad (125)$$

where

$\text{SIGNP}(K)$ = 1.0 flow is up the tube
 = -1.0 flow is down the tube

$\text{ANGLE}(K)$ = Angle in radians

The Moody friction factor is computed from

$\text{SRE} < 2000$

$$\text{FM} = 64/\text{SRE} \quad \text{-----} \quad (126)$$

$2000 \leq \text{SRE} < 6000$

$$\text{FM} = .032 \left(\frac{\text{RE}}{2000} \right)^{.10721} \quad \text{-----} \quad (127)$$

$$6000 < RE$$

$$FM = .036 \left(\frac{6000}{RE} \right)^{.25} \text{-----} (128)$$

$$SRE = \frac{DI(K) \cdot SGMAX}{SVIS} \text{-----} (129)$$

3.5 The Basic Computation on a Section

Consider a section composed of either helical or U tubes with cross flow. The object of this particular analysis is to compute the number of passes required to produce the specified helium and steam conditions. The inlet and outlet helium and steam conditions are known. Assume that the unit has counter flow, therefore, the first tube considered will be at the steam outlet and the helium inlet.

The computation will proceed as follows:

Figure 14

1. Set the initial value of the average ΔT equal to $(TH(1,J) - TSOUT(K))$. See Eq. 27, $\overline{\Delta T} = (T_{1m} - T_{2m})$
2. Compute the average temperature of the helium from equation 26.

3. Compute the average enthalpy of the steam

$$HSAV = HIN + \frac{1}{2} \left[\text{Heat transferred} = AMU(T_{1m} - T_{2m}) \right]$$

4. Determine the steam temperature associated with HSAV in the steam table subroutine TEMP (see Section 4.5.7).

5. Compute the over-all film coefficient based on the computed average temperatures (see section 3.3)
6. Compute the average ΔT from Equation 27 and compare with the previous average ΔT . If it is within the convergence criteria go on to step 7, if not return to step 2 and repeat until the convergence is satisfied.
7. Compute the increment inlet steam conditions and the increment exit helium conditions.
8. Compute the steam pressure drop (see section 3.3.4).
9. Go on to next increment. Compute the average ΔT based on film coefficients of previous increment. Return to step 2. If last increment of current pass has been completed go on to step 10.
10. Enter subroutine area and compare the computed steam conditions with the given input steam conditions. If the computed conditions are higher than given values add another pass (see section 4.1) and return to step 2. Repeat this procedure until the computed steam conditions are equal to or less than the specified values, then go on to step 11.
11. Compute the helium pressure drop in accordance with one of the options given in Section 3.4.2.1.

Steps 1 - 11 above outline the basic computation for one section. This computation is used over and over again to satisfy the design conditions of each section.

3.6 Properties of Steam

The properties of steam are evaluated in two different subroutines. The temperature, specific volume (SPVOL) and the inverse specific heat (CSI) are evaluated in subroutine TEMP (see 4.5.6) which contains a complete set of steam tables. The viscosity and thermal conductivity of the steam are computed in subroutine PROPS by the equations listed below.

These equations may be used over the entire range of the saturated, superheated and supercritical range. The equations do not apply in the subcooled region below 400°F.

Steam Viscosity

$$SVIS = 0.001 \cdot \left[18.0 + 0.054 \cdot T + 0.44 \cdot (SPVOL)^{-1.58} \right] \text{ ----- (130)}$$

Steam Conductivity

$$STC = T \cdot (8.691 \times 10^{-9} \cdot T + 2.571 \times 10^{-5}) + 7.97 \times 10^{-3} + 2.67 \times 10^{-3} \cdot (SPVOL)^{-1.24} \text{ ----- (131)}$$

3.7 Properties of Helium

$$PV = RT \text{ -----(132)}$$

Helium Viscosity

$$HVIS = AMU(T)^{BMU} \text{ -----(133)}$$

Helium Conductivity

$$HTC = AKG(T)^{BKG} \text{ -----(134)}$$

Helium Specific Heat

$$Cp = ACP + BCP \cdot T \text{ ----- (135)}$$

Helium Gas Constant

$$R = \frac{1544}{\text{Mol. Weight}}$$

The properties of helium are not computed in a special subroutine, they are computed in the routine that requires the properties.

IV. PROGRAM CONTROL

As indicated in Section 3.5, subroutine AREA is used to determine the number and length of the passes required to satisfy the heat transfer requirements of a particular section. The remaining section design parameters are determined in the main program. (See Fig 16) for an elementary flow diagram). This section describes how the main program CONTRL, and subroutine AREA are used to design a complete steam generator. The following typical steam generator will be used to illustrate the procedures.

1. Each steam generator is composed of a superheater, a reheater, and an economizer-boiler section.
2. The superheater and reheater have the same heat load.
3. The superheater and reheater are in parallel with each other with equal helium flow and equal but unknown helium pressure drops.
4. The steam pressure drop in the superheater must be less than ΔP_s .
5. The maximum permissible surface temperature in the three sections are:

Superheater	-	TMAXS
Reheater	-	TMAXR
Economizer-Boiler	-	TMAXB
6. The inlet and outlet helium and steam conditions are known for each section.

A block diagram is given for the system in Figure 15.

Figure 15

For simplicity the steam flow is not shown.

The superheater is computed first because the steam pressure drop and maximum tube temperature criteria must both be satisfied. The steam pressure drop criteria is satisfied first and then the maximum tube temperature. (This may not be the best sequence in all problems but it is assumed for this example problem). The reheater is then designed such that its helium pressure drop is equal to the superheater drop within acceptable limits. The maximum tube temperature must also be controlled in the reheater. The economizer-boiler is then designed. The only restriction for this unit is the maximum tube temperature.

The design procedure is described in more detail by the example problem flow diagram given in Figure 16. A description of the subroutines used by the code are given below. The subroutines which must be prepared by the engineer (the main program CONTRL and sub. AREA) are discussed first followed by a general discussion of the remaining.

4.1 The Main Program - CONTRL

CONTRL is written by the engineer for each different type of problem analyzed to accomplish the following functions:

1. Over-all control of the subroutines
2. Adjust the pass dimensions in order to satisfy the maximum tube temperature, the helium pressure drop, and the steam pressure drop constraints.
3. Specify the helium and steam interconnections between sections.

The following parameters may be changed in CTRL:

ATROW(K)	-	Number of tube rows per pass
TCOL(K)	-	Number of tube columns per pass
TNUM(K)	-	Number of tubes per pass
ST(K)	-	Transverse pitch spacing - ft
SL(K)	-	Longitudinal pitch spacing - ft
TUBE(1,K)	-	Length of first pass - ft
DO(K)	-	Outside tube diameter - ft
TT(K)	-	Tube thickness

These parameters may be varied to produce the desired metal temperature, steam pressure drop and helium pressure drop. Figure 17 illustrates the general functions that the main program performs. A fortran listing of the statements require in the main program for all problems is given in Appendix A.

EXAMPLE PROBLEM FLOW DIAGRAM FIG. 16

MAIN PROGRAM Fig. 17

4.2 Subroutine AREA

Subroutine AREA is called by subroutine SECTION (see Figure 17 and 18) after each pass is completed to compare the computed steam conditions with the design conditions. If the design conditions are not satisfied subroutine AREA is used to furnish the length of the next pass to be computed. The engineer must program the method of computing or setting the length of subsequent passes for each section to be designed. A convergence flag, IAA, is provided in subroutine AREA. If the required heat has been transferred IAA is set equal to zero. IAA is set equal to one (1) if another pass is required.

4.3 Subroutine SECTION

Subroutine SECTION controls the computations performed on each pass and computes the helium pressure drop for the entire section in accordance with the equations given in Section 3.4.1. This subroutine has been written for cross flow (helium flowing perpendicular to the tubes); if a parallel flow exchanger is to be analyzed this section must be changed. The sequence of operations performed by this code are given in Figure 18.

SUBROUTINE SECTION FIG. 18

4.4

Subroutine HEAT

Subroutine HEAT computes the heat transferred for each increment in accordance with the equations derived in Section 3.1.1 and 3.1.2 for either cross or parallel flow. In addition the subroutine will automatically subdivide an increment if a phase change occurs within the increment. The subroutine does not contain any subscripted design parameters, thus eliminating any dependence on the geometry or arrangement of the various sections. See Figure 19.

SUBROUTINE HEAT FIG. 19

4.5 Auxiliary Subroutines

The auxiliary subroutines are not involved in over-all control of the program nor are they used in the basic heat transfer analysis. Their basic function is to supply data for the main calculation. See Appendix "A" for a fortran listing of each subroutine.

4.5.1 Subroutine DROPS

Subroutine DROPS computes the steam pressure drop for each increment in accordance with the equations in Section 3.4.2. Drops will compute the pressure drop for all phases of subcritical and supercritical water. Care must be exercised to insure that the steam tables included in subroutine TEMP cover the range of pressures anticipated for any problem.

4.5.2 Subroutine GEOMET

Subroutine GEOMET computes the dimensions of the section and pass required to perform the heat transfer and pressure drop computations for cross flow. If a parallel flow exchanger is to be analyzed appropriate changes must be made to this subroutine. See Appendix "A" for the Fortran Listing.

4.5.3 Steam Film Resistance

The steam film resistances are computed in subroutines FUN1 - FUN4. By the equations in Section 3.3.5.

4.5.4 Tube Resistance

The tube resistance is computed in FUN5 (See section 3.3.3)

4.5.5 Helium Film Resistance

The helium film resistance is computed in FUN6 (See Section 3.3.4).

4.5.6 Subroutines PROPS

The thermal conductivity and viscosity of the steam are computed in subroutine PROPS. See Section 3.6.

4.5.7 Subroutine TEMP

Subroutine TEMP is used to find the steam temperature, specific volume, and the inverse specific heat from a set of steam tables as a function of the pressure and enthalpy. This subroutine is a conventional two-dimensional interpolation routine, a description of which is not included here.

4.5.8 Subroutine ERROR

When an error stop is encountered in the code control is shifted to subroutine ERROR. The location and cause of the error are printed out and a core dump is executed. Each error stop is self explanatory.

V. CONVERGENCE

There are two basic categories of convergence criteria used in the code; one is for the helium pressure drop computation in subroutine SECTION. The other is used for the heat transfer analysis in Subroutine HEAT.

5.1 Heat Transfer Convergence

As indicated in Section 3.5. The increment heat transfer is solved by an iterative solution for the average increment temperature difference.

Define

DELT = Average temperature difference from the previous iteration

DELTAV = Average temperature difference from the previous iteration.

DELTAV is considered converged when

$$\frac{\text{DELTAV} - \text{DELT}}{\text{DELT}} < \text{QCONV}$$

QCONV is read into the machine as AQCONV. A value of 1.0×10^{-5} has been found satisfactory. This convergence criteria is also used for the subdivision of an increment. (See 4.4)

5.2 Helium Pressure Drop Convergence

Helium pressure drop options 3 and 5 involve computing a helium flow that will produce a pressure drop with a given tolerance (see 3.4.2.1) This tolerance is specified by the quantity ACONVP provided in the input.

CONVP = ACONVP

Define

DPH(K) - Specified pressure drop

DP - Computed pressure drop

The convergence criteria is satisfied when

$$\frac{DPH(K) - DP}{DPH(K)} < CONV P$$

Helium pressure drop option 6 involves the convergence on a flow rate.

This convergence criteria is specified in the input by the quantity ACONVW.

$$CONV W = ACONV W$$

Define

FHT(K) = Specified flow

FHTOT = Computed flow

Convergence is satisfied when

$$\frac{FHT(K) - FHTOT}{FHT(K)} < CONV W$$

A value of 0.001 for both CONVW and CONV P has been found to be satisfactory.

VI. INPUT

The input is arranged in 16 groups of related data. This grouping permits the engineer to run successive cases with a minimum amount of input repetition.

Three input formats are provided as follows:

- E10.1 A field of 10 columns wide is reserved for a floating point number.
- I2 A field two columns wide is reserved for an integer number which must be written to the extreme right of the field.
- A6 A field six columns wide is reserved for six Alpha-numeric characters that may be printed out in the same form they are written.

6.1 Input Preparation

Each case to be run is preceded with a title. Any combination of Alpha-numeric characters may be written in columns 1 - 72. The title will be printed at the beginning of each case.

The data contained in each data group is preceded with a card containing the data group number written in an I2 format. These identifying cards are referred to as K cards. The last card of every case is a K card with the number 17 written in Columns 1 and 2. Successive cases may be run by providing a title card followed by the complete data groups in which a change is to be made plus the K-17 end card.

COMMENTS and NAMES

Word	1-12	
Column	1-72	
Format	12A6	
Card TITLE	Case title. This card and the end of data card must be included with each case. Successive case include these cards plus the complete data group in which a change is to be made.	
Symbol	AZX (IX)	

Word	1	Constants
Column	1-2	
Format	I2	
Card 1-1	Data group I identification.	
Symbol	KK = 1	

Word	1	2	3	4	5	6	7	See Section 3.3.3 3.3.5 V
Column	1-10	11-20	21-30	31-40	41-50	51-60	61-70	
Format	E10.1	E10.1	E10.1	E10.1	E10.1	E10.1	E10.1	
Card 1-2	Helium Prandlt No Exponent (0.3333)	Helium Reynolds no. expon- ent (0.6)	Boiling Film Coeff. (2000.0) (Btu/hr-ft ² -°F)	Saturated Enthalpy Division (0.8)	Heat Trans. Converg. Criteria (0.0005)	Pressure Drop Converg. Criteria (0.001)	Flow rate Converg. Criteria (0.001)	
Symbol	AAHE	ABHE	ABLCOE	AQUAL	AQCONN	ACONVP	ACONVW	

Word	8	9	10	11	12	13	14	See Section 3.7
Column	1-10	11-20	21-30	31-40	41-40	51-60	61-70	
Format	E10.1	E10.1	E10.1	E10.1	E10.1	E10.1	E10.1	
Card 1-3	Gas Equation Constant (1.242) (Btu/lb.-°F)	Gas Equation Coeff. (0.0)	Gas Conductivity Exponent (.00129) (Btu/hr-ft°F)	Gas Conductivity Exponent (0.674)	Gas Viscosity Coeff. (0.00069) (lbs/hr-ft)	Gas Viscosity Exponent (0.674)	Average Helium Pressure (Psi)	
Symbol	AACP	ABCP	AAKG	ABKG	AAMU	ABMU	APHAY	

Word	15	
Column	1-10	
Format	E10.1	
Card 1-4	Number of Selections	
Symbol	ANSEC	
NS = ANSEC		

Word	1	Tube Bank Geometry
Column	1-2	
Format	I2	
Card 2-1	Data Group 2 Identification Card	
Symbol	KK = 2	

Word	1	2	3	etc.	<div>$1 \leq NS \leq 10$ If NS is larger than 7, two cards will be required See Sec. 3.2.3-1 and 2</div>
Column	1-10	11-20	21-30		
Format	E10.1	E10.1	E10.1		
Card 2-2	Tube Flag =1.0 U Tube =2.0 Helical				
Symbol	AITUBE(1) AITUBE(2) AITUBE(3) - - - - - AITUBE(NS)				

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 2-A	Number of Axial incr. in Sec. 1			
Symbol	AMSEG(1)	AMSEG(2)	AMSEG(3)	- - - - - AMSEG(NS)

$AMSEG(K) \leq 20$

If NS is larger than 7, two cards will be required.

See Sect. 3.2.3

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 2-B	Angle Tubes in Section 1 make with horizontal (RADIANs)			
Symbol	AANGLE(1) AANGLE(2) AANGLE(3) - - - - - AANGLE(NS)			

If NS is larger than 7, two cards will be required.

See Sec. 3.4.2, Eq. 123

Word	1
Column	1-2
Format	I2
Card 3-1	Data Group 3 Identification Card
Symbol	KK = 3

Pass
Geometry

4-9

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 3-2	Number of Tube Rows per pass in Sec.1			
Symbol	ATROW(1) ATROW(2) ATROW(3) - - - - - ATROW(NS)			

If NS is larger than 7, two cards will be required.

See Sec. 3.2 Fig. 5 and 6

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 3-A	Number of Tube Columns Per Pass in Section 1			
Symbol	ATCOL(1) ATCOL(2) ATCOL(3) - - - - - ATCOL(NS)			

If NS is larger than 7, two cards will be required

See Sec. 3.2 Fig. 5 and 6

Word	1	2	3	etc./
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 3-B	Number of Tubes per pass in Sec. 1.			
Symbol	ATNUM(1)	ATNUM(2)	ATNUM(3) - - - - -	ATNUM(NS)

If NS is larger than 7, two cards will be required.

See Sec. 3.2, Fig 5 and 6

Word	1
Column	1-2
Format	I2
Card 4-1	Data Groupe 4 Identification Card
Symbol	KK = 4

PITCH

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 4-2	Pitch Flag =1.0 Rectangular Pitch =2.0 Triangular Pitch			
Symbol	APITCH(1)	APITCH(2)	APITCH(3) - - - - -	APITCH(NS)

If NS is larger than 7, two cards will be required.

See Sec. 3.2 Fig. 5 and 6

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 4-A	Transverse pitch in Sec. 1. (inches)			
Symbol	AST(1)	AST(2)	AST(3) - - - - -	AST(NS)

If NS is larger than 7, two cards will be required.

See Sec. 3.2 Fig. 5 and 6

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 4-B	Longitudinal Pitch in Sec. 1 (Inches)			
Symbol	ASL(1)	ASL(2)	ASL(3)	- - - - - ASL(1)

If NS is larger than 7, two cards will be required.

See Sec. 3.2 Fig. 5 and 6

Word	1
Column	1-2
Format	I2
Card 5-1	Date Group 5 Identification Card
Symbol	KK = 5

TUBE SIZE

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 5-2	Tube length of first tube in Pass 1 (Inches)			
Symbol	ATUBE(1)	ATUBE(2)	ATUBE(3)	- - - - - ATUBE(NS)

If NS is larger than 7, two cards will be required.

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 5-A	Outside Tube Diameter in Sec. 1 (Inches)			
Symbol	ADO(1)	ADO(2)	ADO(3)	- - - - - ADO(NS)

If NS is larger than 7, two cards will be required.

K-6 and 7

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 5-B	Tube Wall Thickness in Sec. 1 (Inches)			
Symbol	ATT(1) ATT(2) ATT(3) - - - - ATT(NS)			

If NS is larger than 7, then two cards will be required.

Word	1
Column	1-2
Format	I2
Card 6-1	Data Group 6 Identification Card
Symbol	KK = 6

Tube Thermal Conductivity

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 6-2	Tube Thermal Conductivity in Section 1. (Btu/hr-ft-°F)			
Symbol	ATTC(1) ATTC(2) ATTC(3) - - - - - ATTC(NS)			

If NS is larger than 7, two cards will be required.

Word	1
Column	1-2
Format	I2
Card 7	Data Group 7 Identification Card
Symbol	KK = 7

FLOW FLAGS

K- 7 and 8

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 7-1	=+1.0 Inlet Helium conditions are known in Section (K) =-1.0 Outlet Helium conditions are known in Section (K)			
Symbol	ASIGNH(1) ASIGNH(2) ASIGNH(3) - - - - - ASIGNH(NS)			

If NS is larger
than 7, two cards
will be required.

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 7-A	= +1.0 Steam flow is up in the first pass of Section (K) = -1.0 Steam flow is down in the first pass of Section (K)			
Symbol	ASIGNP(1) ASIGNP(2) ASIGNP(3) - - - - - ASIGNP(NS)			

If NS is larger
than 7, two cards
will be required.

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 7-B	= +1.0 Co-Current steam flow in Section (K) = -1.0 Counter current steam flow in Section (K)			
Symbol	ASIGNS(1) ASIGNS(2) ASIGNS(3) - - - - - ASIGNS(NS)			

If NS is larger
than 7, two cards
will be required.

Word	1
Column	1-2
Format	I2
Card 8-1	Data Group 8 Identification Card
Symbol	KK = 8

HELIUM FLOW

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card	= 1.0 Total flow for section is given in Section (K)			
8-2	= 2.0 Flow for each axial increment is given in Section (K)			
Symbol	AlFH(1)	AlFH(2)	AlFH(3) - - - - -	AlFH(NS)

Helium Flow Flag.

If NS is larger than 7, two cards will be required.

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card	= 0.0 Parallel gas flow			
8-A	= 1.0 Cross gas flow			
Symbol	CRSPAR(1)	CRSPAR(2)	CRSPAR(3) - - - - -	CRSPAR(NS)

Cross Flow or Parallel Flow Flag.

If NS is larger than 7, two cards will be required.

Start with K = 1 and select either of the following options for each section, depending on the value of AlFH(K)
Provide these cards for Section (K) if AlFH(K) = 1.0

Word	
Column	
Format	
Card	Total helium flow in Section (K) lbs/hr.
8-B	
Symbol	

One card for each section.

Provide these Cards for Section (K) if AlFH(K) = 2.0

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card	Helium flow for each axial increment is Section (K)			
8-C	$M = \text{MSEG}(K) \leq 20$			
Symbol	AFH(1,K)	AFH(2,K)	AFH(3,K) - - - - -	AFH(M,K)

20 increments are permitted in each section.

Word	1	Helium Inlet and Outlet Temperature.
Column	1-2	
Format	I2	
Card 9-1	Data Group 9 Identification Card.	
Symbol	KK = 9	

Word	1	2	3	Helium Temp. Flag If NS is larger than 7, two cards will be required.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 9-2	= 1.0 Average helium inlet and outlet temperatures are specified. = 2.0 Average outlet and increment inlet temperatures are given. = 3.0 Average helium inlet and increment outlet temperatures are given.			
Symbol	AI TH(1)	AI TH(2)	AI TH(3) - - - - -AI TH(NS)	

Start with K = 1 and provide one of the following three options depending on value of AI TH(K)
Provide these cards if AI TH(K) = 1.0

Word	1	2	One card for each section.
Column	1-10	11-20	
Format	E10.1	E10.1	
Card 9-A			
Symbol	ATHISC(K)	ATHOSC(K)	

Provide the following two groups if AI TH(K) = 2.0

Word	1	One card for each section.
Column	1-10	
Format	E10.1	
Card 9-B	Average outlet helium temperature for Section K.	
Symbol	THOSC(K)	

Word	1	2	3	etc.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 9-C	Increment inlet temperature for each axial increment of Section (K).			
Symbol	ATHIN(1,K) ATHIN(2,K) ATHIN(3,K) - - - -ATHIN(M,K) (M < 20)			

If NS is larger than 7, two cards will be required.

Provide the following two groups if ASITH(K) = 3.0

Word	1
Column	1-10
Format	E10.1
Card 9-D	Average inlet helium temperature for Section (K).
Symbol	ATHISC(1)

One card for each section.

ATH(K) = 3.0

Word	1	2	3
Column	1-10	11-20	21-30
Format	E10.1	E10.1	E10.1
Card 9-E	Increment outlet temperature for each axial increment of Section K.		
Symbol	ATHOUT	ATHOUT	ATHOUT ATHOUT(M,K)

If NS is larger than 7, two cards will be required.

Word	1
Column	1-2
Format	I2
Card 10-1	Date Group 10 identification card.
Symbol	KK = 10

Helium pressure

Word	1	2	3
Column	1-10	11-20	21-30
Format	E10.1	E10.1	E10.1
Card 10-A	= 1 Inlet helium pressure is known. = 2 Outlet helium pressure is known.		
Symbol	AIPH(1)	AIPH(2)	AIPH(3) - - - - AIPH(NS) (NS ≤ 10)

Helium Pressure Flag.

If NS is larger than 7, two cards will be required.

Card	1	2
Column	1-10	11-20
Format	E10.1	E10.1
Card 10-B	Inlet helium pressure is given. Inlet helium Specified helium pressure for pressure drop, Sec. 1, psi. psi.	
Symbol	APHIN(K)	ADPH(K)

One card for each section.

Word	1	2
Column	1-10	11-20
Format	E10.1	E10.1
Card	Outlet helium pressure are known. Outlet helium Specified helium 10-C pressure for pressure drop, Sec. 1, psi psi	
Symbol	APHOUT(K)	ADPH(K)

One card for each section.

Word	1	Steam Flow.
Column	1-2	
Format	I2	
Card 11-1	Data Group 11 Identification Card	
Symbol	KK = 11	

Word	1	2	3
Column	1-10	11-20	21-30
Format			
Card 11-2	Steam flow in Sec. 1. lbs/hr		
Symbol	AFS(1)	AFS(2)	AFS(3) - - - - - AFS(NS)

If NS is larger than 7, two cards will be required.

Word	1	Steam Enthalpy.
Column	1-2	
Format	I2	
Card 12-1	Data Group 12 Identification Card	
Symbol	KK = 12	

Word	1	2	3	4
Column	1-10	11-20	21-30	31-40
Format	E10.1	E10.1	E10.1	E10.1
Card 12-2	Inlet steam	Outlet steam		
	Enthalpy Sec.	Enthalpy Sec.		
	1. Btu/lb	1. Btu/lb.		
Symbol	AHSIN(1)	AHSOUT(1)	AHSIN(2)	AHSOUT(2) - - -AHIN(NS) AHSOUT(NS)

More than one card will be required if NS is greater than 3.

Word	1	Steam Pressure. If NS is larger than 7, two cards will be required.
Column	1-2	
Format	I2	
Card 13-1	Data Group 13 Identification Card.	
Symbol	KK = 13	

Word	1	2	3	Helium Pressure Flag. If NS is larger than 7, two cards will be required.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 13-2	=1 Inlet steam pressure is known. =2 Outlet steam pressure is known.			
Symbol	AIPS(1)	AIPS(2)	AIPS(3) - - - - - AIPS(NS)	

Start with Section 1 and provide one of the following groups depending on value of AIPS(K)
Provide the following if AIPS(K) = 1.0

Word	1	2	3	4	More than one card is required if NS is greater than 3.
Column	1-10	11-20	21-30	31-40	
Format	E10.1	E10.1	E10.1	E10.1	
Card 13-A	Inlet Steam Pressure is Known. Inlet steam pressure, psi. Specified steam pres. drop, psi.				
Symbol	APSIN(1)	ADPS(1)	APSIN(2)	ADPS(2) - - - APSIN(NS) ADPS(NS)	

Provide the following if AIPS(K) = 2.0

Word	1	2	3	4	More than one card is required if NS is greater than 3.
Column	1-10	11-20	21-30	31-40	
Format	E10.1	E10.1	E10.1	E10.1	
Card 13-B	Outlet Steam Pressure is Known. Outlet steam pressure, psi. Specified steam pres. drop, psi.				
Symbol	APSOUT(1)	ADPS(1)	APSOUT(2)	ADPS(2) - - - APSOUT(NS) ADPS(NS)	

Word	1	Steam Scale Coefficient.
Column	1-2	
Format	I2	
Card 14-1	Data Group 14 Identification Card.	
Symbol	KK = 14	

Word	1	2	3	etc.	If NS is larger than 7, more than one card is required.
Column	1-10	11-20	21-30		
Format	E10.1	E10.1	E10.1		
Card 14-2	Waterside Scale Coeff. Btu/hr-sq.ft-°F				
Symbol	ASCALE(1) ASCALE(2) ASCALE(3) - - - ASCALE(NS)				

Word	1	Print Indexes.
Column	1-2	
Format	I2	
Card 15-1	Data Group 15 Identification Card.	
Symbol	KK = 15	

Word	1	
Column	1-2	
Format	I2	
Card 15-2	The output is consecutively numbered. IPR is the total number of groups. The output may be expanded to produce 30 groups.	
Symbol	IPR	

Word	1	2	3	
Column	1-2	3-4	5-6	
Format				
Card 15-3	IPRINT(L) = 0 Do not print output Group (L) = 1 Print Output Group (L) = 1 ≤ L ≤ IPR			
Symbol	IPRINT(1)	IPRINT(2)	IPRINT(3) - - - - -	IPRINT(IPR)

Word	1	
Column	1-2	
Format	I2	
Card 16-1	Data Group 16 Identification Card.	
Symbol	KK = 16	

Output Titles.

Word	1	
Column	1-10	
Format	E10.1	
Card 16-2	Each column of output for a two dimensional variable is labbed with a twelve column word read in by this data group. If there are eight titles, these will be given in 16 A6 Holerith words. i.e. XTTL = 8	
Symbol	IPR	

Assume XTTL = 8

Word	1	2	3	4	5	6
Column	1-12	13-24	25-36	37-48	49-60	61-72
Format	2A6	2A6	2A6	2A6	2A6	2A6
Card 16-3	Each word is a title. Notice title is centered by indicating blanks with A().					
Symbol	AFH(I, J)	ATHOUT(I, J)	ATHIN(I, J)	FH(J, K)	THOUT(J, K)	THIN(J, K)

Word	1	2
Column	1-12	13-24
Format	2A6	2A6
Card 16-4		
Symbol	DELPH(J,K)	TUBE(J,K)

Word	1
Column	1-2
Format	I2
Card 17-1	End of data card. This card and a title card must be provided with each case. Successive cases are compose of these two cards plus the complete data group in which a change is to be made.
Symbol	KK = 17

Word	
Column	
Format	
Card	
Symbol	

Word	
Column	
Format	
Card	
Symbol	

VII. NOMENCLATURE

The nomenclature given in the following section is divided into three categories as follows:

INPUT

PROGRAM

DERIVATION

The input variables are generally the program variable preceded with the letter "A", for instance consider the program variable AMU(K) in the input this variable becomes AAMU(K). In certain instances there is also a change in dimensions.

The variables used in the derivations in Section 3 generally contain only one character to simplify the equations.

The input and derivation variables are defined in terms of the program variables.

SYMBOL	SEC/EQ.	DEFINITION	UNITS
AA1		(REYNOLDS NO.):** BHE	
AA5		Frictional velocity heads loss	
AA6		Accelerational velcoity heads loss	
AACP	INPUT	See ACP	BTU/lb-Deg
AAHE	INPUT	See AHE	Unitless
AAKG	INPUT	See AKG	BTU/hr-ft-Deg
AAMU	INPUT	See AMU	Lbs/hr-ft
AANGLE(K)	INPUT	See ANGLE(K)	Radians
ABCP	INPUT	See BCP	1/Deg
ABHE	INPUT	See BHE	Unitless
ABKG	INPUT	See BKG	Unitless
ABLCOE	INPUT	See BOLCO	BTU/hr-sq.ft-Deg
ABMU	INPUT	See BMU	Unitless
ACONVP	INPUT	See CONVP	Unitless
ACONVW	INPUT	See CONVW	Unitless
ACP	INPUT	Constant in helium specific heat equation	BTU/lb-Deg
ADO(K)	INPUT	DO(K)*12	Inches
ADPH(K)	INPUT	DPH(K)*144	Lbs/sq.ft.
ADPS(K)	INPUT	DPS(K) x 144	Lbs/sq.ft.
ADROP(K)	INPUT	See IDROP(K)	Unitless
AFHT(K)	INPUT	See FHT(K)	Lbs/hr
AFH(J,K)	INPUT	See FH(J,K)	Lbs/hr
AFS(K)	INPUT	See FS(K)	Lbs/hr
AHSIN(K)	INPUT	See HSIN(K)	BTU/lb
AHSOUT(K)	INPUT	See HSOUT(K)	BTU/lb
APIITCH(K)	INPUT	See IPITCH(K)	Unitless
AITUBE(K)	INPUT	See ITUBE(K)	Unitless
AMSEG(K)	INPUT	See MSEG(K)	Unitless
ANSEC	INPUT	See NSEC	Unitless
APHAV	INPUT	PHAV * 144.0	Lbs/sq.ft
APHIN(K)	INPUT	PHIN(K) * 144.0	Lbs/sq.ft
APHOUT(K)	INPUT	PHOUT(K) * 144.0	Lbs/sq.ft
APSIN(K)	INPUT	PSIN(K) x 144.0	Lbs/sq.ft

SYMBOL	SEC/EQ.	DEFINITION	UNITS
APSOUT(K)	INPUT	PSOUT(K) x 144.0	Lbs/sq.ft.
AQCONV	INPUT	See QCONV	Unitless
AQUAL	INPUT	See QUAL	
AREA	4.2	Subroutine for computing passes and pass length	
ASCALE(K)	INPUT	SCALE(K)	BTU/hr-sq.ft
ASIGNH(K)	INPUT	SIGNH(K)	Unitless
ASIGNP(K)	INPUT	SIGNP(K)	Unitless
ASIGNS(K)	INPUT	SIGNS(K)	Unitless
ASL(K)	INPUT	SL(K) * 12	Inches
AST(K)	INPUT	ST(K) * 12.0	Inches
ATCOL(K)	INPUT	TCOL(K)	Unitless
ATAIN(J,K)	INPUT	THIN(J,K)	Deg. Fahrenheit
ATHISC(K)	INPUT	THISC(K)	
ATHOSC(K)	INPUT	THOSC(K)	
ATHOUT(J,K)	INPUT	THOUT(J,K)	
ATNUM(K)	INPUT	TNUM(K)	Unitless
ATROW(K)	INPUT	TROW(K)	
ATT(C)	INPUT	TT(C)	Btu/hr-ft-Deg
ATT(K)	INPUT	TT(K) * 12	Inches
ATUBEL(K)	INPUT	TUBE (1,K) * 12	
IPR	INPUT	Number of double subscripted output variables	Unitless
CRSPAR(K)	INPUT	KROPAR	
ACP	Eq. 133	Constant in helium specific heat equation	BTU/lb-deg
AFA1		Minimum flow area per unit height per pass	Sq. ft.
AFHAV		Average helium flow area per increment for the entire section	Sq. ft.
AFHD	Eq. 58	Diagonal helium flow area per unit height per pass	Sq. ft.
AFHMIN	Eq. 59 - 60	Minimum helium flow area per increment	
AFHT	Eq. 57	Transverse helium flow area per unit height per pass	
AFSP(K)		Steam flow area per pass in Section(K)	Unitless

SYMBOL	SEC/EQ.	DEFINITION	UNITS	
AHE	Eq. 85	Prandtl No. Exponent, helium	Unitless	
AHSEG		Helium heat transfer area per increment per pass (AHSEG = FRSR(K)•TLSEG)	Sq ft.	
AI		AI = ASSEG	Sq. ft.	
AIFH(K)		Helium flow flag	Unitless	
AIPH(K)		AIFH(K) = 1	Total flow is given in current increment	Unitless
		AIFH(K) = 2	Increment flow is given	
		Helium pressure flag		
		AIPH(K) = 1	Inlet helium pressure is known	
AIPS(K)		AIPH(K) = 2	Outlet helium pressure is known	
		Steam pressure flag		
		AIPS(K) = 1	Inlet steam pressure is known	
AITH(K)		AIPS(K) = 2	Outlet steam pressure is known	
		Helium temperature flag		
		AITH(K) = 1	Average helium temperature is given	
		AITH(K) = 2	The increment helium inlet temperature is given	
AKG	Eq. 132	AITH(K) = 3	The increment helium outlet temperature is given	BTU/hr-ft-Deg
		Coefficient in helium conductivity equation		
ALPHA		Subdivision flag and fraction of the increment	Unitless	
ALPHAO		Alpha of previous iteration		
ALPHCO		QCONV		
AM	Eq. 73	See ASEG		
AMU	Eq. 131	Coefficient in helium viscosity equation	Lbs/hr-ft	
ANGLE(K)		Tube angle with the horizontal	Radians	
ANU		Nusselt Number	Unitless	
ANUT		Nusselt number at a Reynolds Number of 15,000		

SYMBOL	SEC/EQ.	DEFINITION	UNITS
ASEG	Eq. 73	Heat transfer area of current increment or subdivision (ASEG = A_m)	Sq. ft.
ASEGO		Heat transfer area of previous iteration	
ASSEG	Eq. 61	Steam heat transfer area	
ATUBE	Eq. 85	Helium friction factor equation coefficient	Unitless
		ATUBE = 0.33 staggered tubes	
		ATUBE = 0.26 inclined tubes	
		-B-	
BCP	Eq. 133	Coefficient in helium specific heat equation	1/deg
BHE	Eq. 85	Reynolds No. exponent, helium	Unitless
BKG	Eq. 132	Exponent in helium conductivity equation	
BMU	Eq. 131	Exponent in helium viscosity equation	
BOLCOE		Boiling film coefficient	BTU/hr-sq.ft-Deg.
BOLCO		1/RS1	
		-C-	
CHD(K)	Eq. 51	Number of diagonal helium flow channels	Unitless
CHI		Helium inverse specific heat	Lb-Deg/BTU
CHT(K)	Eq. 50	Number of transverse helium flow channels	Unitless
CONVP		Pressure drop convergence criteria	
CONVW		Flow rate convergence criteria	
CP	Eq. 85	Helium specific heat	BTU/lb-Deg
CSI		Steam inverse specific heat	Lb-Deg/BTU
		-D-	
D1		Hydraulic diameter/conductivity	Sq.ft-hr-Deg/BTU
DELDEL		Convergence ratio for DELTAV	Unitless
DELH	Eq. 123	Vertical height of increment	Ft

SYMBOL	SEC/EQ.	DEFINITION	UNITS
DELPS		Increment pressure loss	Lbs/sq.ft
DELT		DELTAV of last iteration	Deg
DELTAV	Eq. 79	Average temperature difference between gas and steam	
DIT		DI(K)	Ft
DI(K)	Eq. 61	Inside tube diameter in Section (K)	Ft
DOT		Outside tube diameter	
DO(K)	Eq. 62	Outside tube diameter in Section (K)	
DPASS(K)	Eq. 55	Depth of the pass	
DPHSEC(K)		Computed average helium pressure drop for Section K	Lbs/sq.ft
DPH(K)		Specified helium pressure drop for Section K	
DPS(K)		Specified steam pressure drop for Section K	
DROPS		Subroutine used to compute steam pressure drop	Ft
DV(K)	Eq. 66	Volumetric hydraulic diameter	Ft
		-E-	
ERROR		Subroutine for specifying program errors	Ft
		-F-	
F	Eq. 120	Helium friction factor	Unitless
FH(J,K)		Helium flow rate in increment j of Section K	Lbs/hr
FHJ(J)		Helium flow rate and direction in increment J	
FHDA		Helium mass flow rate	Lbs/hr
FHSC(K)		Total helium flow rate for Section K	
FHSEC		Helium flow rate in the section	
FHSEG		Helium flow of current increment or subdivision	
FHSEGO		Helium increment flow for previous iteration	

SYMBOL	SEC/EQ.	DEFINITION	UNIT
FHTOT		Total helium flow rate for entire section	
FHT(K)		Input total helium flow for Section K	
FH(J,K)		Input helium flow rate for increment J of Section K	
FLDR		Flow direction for current pass FLDR = + 1 up flow FLDR = - 1 down flow	Unitless
FM	Eq. 124 - 126	Moody friction factor	
FRSR(K)	Eq. 63	Helium friction surface area per pass per unit height	Sq. ft
FS(K)		Steam flow rate in Section K	Lbs/hr
FSSEG		Steam flow rate for the current increment	
FUN1		Heat transfer resistance for subcooled and supercritical water	
FUN2		Subroutine used to compute heat transfer resistance for boiling water	
FUN3		Subroutine used for computing the heat transfer resistance for transition boiling water	
FUN4		Subroutine used for computing the heat transfer resistance for superheated steam	
FUN5		Subroutine used for computing the heat transfer resistance for the tube	
FUN6		Subroutine used for computing the heat transfer resistance for helium	
		-G-	
GEOMET		Subroutine for computing pass and increment geometry	
		-H-	
HC(IX)		Film coefficient correction factor for cross flow	Unitless
HEAT		Subroutine used to compute increment heat transfer	

SYMBOL	SEC/EQ.	DEFINITION	UNITS
HGMAX	Eq. 85	Maximum helium mass flow rate	
HINF		Film coefficient for an infinite number of tube rows	BTU/hr-sq.ft-Deg
HM	Eq. 85	Film coefficient for ten tubes	
HMOHIF	Eq. 87	Average film coefficient divided by the infinite	
HP		Division enthalpy between boiling and the transition between boiling and superheated steam	BTU/lb
HRE	Eq. 117	Helium Reynolds Number	
HSATS		Enthalpy of saturated water	BTU/lb
HSAV	3.5-3	Increment average enthalpy	
HSAVE		Average steam enthalpy	
HSEXIT		Computed steam enthalpy	
HSLIM		Exit enthalpy of a subdivided increment or zero	
HSIN(K)		Inlet steam enthalpy in Section K	
HSOUT(K)		Outlet steam enthalpy in Section K	
HSSEG		Known steam enthalpy	
HSXX(1)		HSATS	
HSXX(2)		HP	
HSXX(3)		HSATW	
HSX(1)		Helium enthalpy at the segment exit	
HSX(2)		Helium enthalpy at the segment inlet	
HTC	Eq. 132	Helium thermal conductivity	BTU/hr-sq.ft-Deg.
HVIS	Eq. 131	Helium viscosity HVIS = μ	Lbs/hr-ft
IA1		Subroutine Prop Flag, 1 subcooled, 2 superheat, 3 supercritical	Unitless
IDROP(K)	3.4.2.1	Helium pressure drop flag	Unitless
		IDROP(K) = 1 Do not compute helium pressure drop	
		IDROP(K) = 2 Compute average section pressure drop	
		IDROP(K) = 3 Compute section flow that will produce an average pressure drop DPH(K)	

SYMBOL	SEC/EQ.	DEFINITIONS	UNITS
		IDROP(K) = 4 Compute the helium pressure drop for each axial increment	
		IDROP(K) = 5 Compute the helium flow, FH(J,K) that will produce a pressure drop of DPH(K)	
		IDROP(K) = 6 Compute the pressure drop and flow distribution associated with a section flow rate of FHT(K)	Unitless
INPUT		Subroutine used to read in input	
IP		IDROP(K)	Unitless
IPTICH(K)		IPITCH Flag	
		IPITCH(K) = 1 rectangular pitch	
		IPITCH(K) = 2 triangular pitch	
IPOS(M)		Subdivision position (1-49)	
IREGON		Steam region for pressure drop	
		IREGON = 1 Subcooled or supercritical	
		IREGON = 2 Saturated	
		IREGON = 3 Supercritical	
ISIGN		computation flag	Unitless
		SIGN = + 1 start at J = +1	
		ISIGN = - 1 start at J = M	
ITRANS		Subdivision computed Go To	
ITRY1		subdivision iteration number (40 Max)	
ITUBE		Tube configuration flag	Unitless
		ITUBE(K) = 1 U-Tube	
		ITUBE(K) = 2 Helical tube	
		-K-	
K		Section Number	Unitless
KROPAR		Flow flag	
		KROPAR = 0 parallel flow	
		KROPAR = 1 cross flow	
LSEG		LSEG = TLSEG	Ft

SYMBOL	SEC/EQ.	DEFINITIONS	UNITS
-M-			
M		MSEG	Unitless
MSEG(K)	Eq. 56	Number of axial increments in Section K	Unitless
-N-			
N		NPASS(K)	Unitless
NPASS(K)		Number of passes in Section K	
NSEC		Number of Sections	
NSEG(K)		Number of increments in Section K	
-O-			
OUTPUT		Output subroutine	
-P-			
PHAV		Average helium pressure	Lbs/sq.ft.
PHIN(K)		Inlet helium pressure for Section K	
PHOUT(K)		Outlet helium pressure for Section K	
PR	Eq. 92	(Prandlt No.) ** AHE	Unitless
PROPS		Steam conductivity and viscosity subroutine	
PSEXIT		Computed steam pressure	Lbs/sq.ft.
PSIN(K)		Inlet steam pressure for Section K	
PSOUT(K)		Outlet steam pressure for Section K	
PSSEG		Steam pressure for the current increment	
QCONV		Convergence criteria	Unitless
QUAL		Quality at enthalpy hp	
-R-			
R	Eq. 134	Gas constant $1544/\text{mol.wt.}$	
RE		Helium Reynolds number $RE = HRE$	
RH	Eq. 81	Helium film resistance	Hr-sq.ft-Deg

SYMBOL	SEC/EQ.	DEFINITION	UNITS
RS	Eq. 83	Steam Film resistance plus scale resistance	
RS1		Steam and scale resistance at enthalpy HP	
RT	Eq. 82	Tube resistance	
		-S-	
SA		Coefficient in the equation $ANU=SA*SRE**SB$	Unitless
SB		Exponent in the equation $ANU = SA*SRE**SB$	
SCALE(K)		Scale film coefficient	BTU/hr-sq.ft-Deg
SD(K)	Eq. 52	Diagonal pitch spacing	Ft
SECTION		Subroutine used to compute details of section	
SGMAX	Eq. 121	Steam mass flow rate (W/A)	Lbs/hr-sq.ft
SIGNH(K)		Helium flow flag	Unitless
		SIGNH(K) =+1 Inlet helium conditions are known	
		SIGNH(K) =-1 Outlet helium conditions are known	
SIGNP(K)		Steam flow direction flag	Unitless
		SIGNP(K) =+1 Steam flow is up the tube in first tube	
		SIGNP(K) =-1 Steam flow is down the tube in first tube	
SIGNS(K)		Steam Condition Flag	
		SIGNS(K) = +1 Inlet steam conditions are known	Unitless
		SIGNS(K) = -1 Outlet steam conditions are known	
SL(K)	Eq. 52	Longitudinal pitch spacing	Ft
SPVOL		Steam specific volume computed in subroutine temperature	Cu Ft/lb
SRE	Eq. 127	Reynolds Number	Unitless
STC	Eq. 129	Steam thermal conductivity	BTU/hr-ft-Deg.
ST(K)	Eq. 52	Transverse pitch spacing	ft
SVIS	Eq. 128	Steam viscosity	Lbs/hr-ft.

SYMBOL	SEC/EQ.	DEFINITIONS	UNITS
		-T-	
T_{1m}		$T_{1m} = THAV$	Deg.
T_{2m}		$T_{2m} = TSAV$	Deg.
TCNT		Number of tubes crossed by helium in previous sections	Unitless
TCOL(K)	Eq. 50	Number of tube columns per pass	Unitless
TEMPH		Max. tube temperature for current pass and increment	Deg.
TEMP		Subroutine for computing steam thermodynamic properties	
TEMPH		Maximum tube temperature	Deg.
THAV	Eq. 76	Average helium temperature	
THEXIT		Helium temperature at the increment exit	
THIN(J,K)		Inlet helium temperature for increment J of Section K	
THINSC		Sum of inlet helium temperature for the section	
THINLT		Helium temperature at the increment inlet	
THISC(K)		Average helium inlet temperature for Section K	
THJ(J)		Known helium temperature in increment J	Deg.
THOSC(K)		Average helium outlet temperature for Section K	
THOTSC		Sum of outlet helium temperatures for Section K	
THOUT(J,K)		Outlet helium temperature from increment J of Section K	
THPAV(J)		Average helium temperature in increment (J)	
THSEC		Sum of helium temperature in the section	
THSEG	Eq. 56	Increment inlet helium temperature	
TLSEC		Total length of passes in section	Ft
TLSEG		Length of segment	Ft
TN1		Number of tubes previously crossed by helium flow	Unitless
TNTRAN(K)		Number of rows of tubes crossed	
TNUM(K)		Number of tubes per pass in Section(K)	

SYMBOL	SEC/EQ.	DEFINITION	UNITS
TROW(K)	Eq. 55	Number of tube rows	
TSAV		Average steam temperature for increment or subdivision	Deg.
TSSEG		Increment inlet steam temperature	
TTC(K)		Tube thermal conductivity	BTU/hr-ft-Deg
TTL(K)		Output titles read in with the input	Unitless
TTI	Eq. 77	TTI = TTISEG	Deg
TTISEG	Eq. 77	Inside tube temperature	Ft
TTL(L)		Output titles, six characters each	Unitless
TTO	Eq. 76	TTO = TTOSEG	
TTOSEG	Eq. 76	Outside tube temperature	Deg.
TTPAV(J)		Average tube temperature in increment(J)	Deg.
TTSC(K)		Average tube temperature for section	Deg.
TTSEC		Sum of tube temperature in the section	Deg.
TT(K)		Tube wall thickness in Section (K)	Ft.
TUBE(I,K)	Eq. 56	Length of pass I in Section K	Ft.
TNUM(K)	Eq. 61	Number of tubes per pass	Unitless
-U-			
U	Eq. 84	Over-all heat transfer coefficient	BTU/hr-sq.ft-Deg.
UAA		$-U * ASEG * CHI / FHSEG$	
UAB		$-U * ASEG * CSI / FSSEG$	
UAHE		$UAA / (EXP(UAA) - 1.0)$	
UAST		$UAB / (EXP(UAB) - 1.0)$	
$\bar{V}$	Eq. 121	Average helium specific volume	
VIN	Eq. 122	Specific volume at increment inlet	Cu. Ft/lb
VOID(K)	Eq. 62	Helium void volume per unit height per pass	Cu. ft.
VOUT	Eq. 122	Specific volume at increment outlet	Cu. ft/lb
VSEXIT		Specific volume at computed steam cond.	
VSSEG		Specific volume at known steam conditions	

SYMBOL	SEC/EQ.	DEFINITION	UNITS
		-W-	
WPAS(K)	Eq. 53	Pass width	
		-X-	
X		Parallel flow variable	Unitless
XIORS		FILM Coefficient as a function of enthalpy	BTU/hr sq.ft-Deg.
XM		M	Unitless
XN		N	
XTTL		Number of output titles (six characters ea)	
XTTL		2.0 * IPR	
		-Y-	
Y		ASEG	Unitless

APPENDIX A
FORTRAN LISTING

\$IBFTC CONTRL LIST,DECK,REF

C-----
C CONTRL ER XX...AT STA. XX.
C
C

*****INPUT COMMON*****	*****IPT	1
COMMON/INPT/ AACP ,AAHE ,AAKG ,AAMU ,AANGLE(10) ,ABCP ,ABHE ,IPT		2
1ABKG ,ABLCOE,ABMU , ADD(10), ACONVP, ACONVW ,IPT		3
2ADPH(10) ,ADPS(10) ,ADROP(10) ,AFH(20,10) ,AFHT(10) ,IPT		4
3AFS(10) ,AHSIN(10) ,AHSOUT(10) ,AIFH(10) , APITCH(10) ,IPT		5
4AIPH(10) ,AIPS(10) ,AITH(10) ,AITUBE(10),AMSEG(10),ANSEC, IPT		6
5APHAV ,APHIN(10) ,APHOUT(10) ,APSIN(10) ,APSOUT(10) ,IPT		7
6AQCONV,AQUAL,ASCALE(10) ,ASL(10) ,ASIGNH(10) ,ASIGNP(10) ,IPT		8
7ASIGNS(10) ,AST(10) ,ATCOL(10) ,ATHIN(20,10),ATHISC(10) ,IPT		9
8ATHOSC(10) ,ATHOUT(20,10),ATNUM(10) ,ATROW(10) ,ATT(10) ,IPT		10
9ATT(10) ,ATUBEL(10) ,CRSPAR(10) ,IPT		11
COMMON/CNTL/ AFHAV ,AFHMIN ,AFSP(10) ,CHD(10) ,COM		1
1CHT(10) ,CONVP ,CONVW,DELPH(20,10),DI(10),DO(10) ,COM		2
2DPASS(10) ,DPH(10) ,DPHSEC(10) ,DPS(10) ,DV(10) ,COM		3
3FH(20,10) ,FHJ(10) ,FHT(10) ,FHSC(10) ,COM		4
4FRSR(10) ,FS(10) ,HSIN(10) ,HSOUT(10) ,IDEX ,COM		5
5IDROP(10) ,IFH(10) ,IPITCH(10) ,IPH(10) ,IPS(10) ,COM		6
6ITH(10) ,ITUBE(10) ,I ,IMAX(50) ,ISN ,COM		7
COMMON/CNTL/ IXSIGN ,JMAX(20) ,K ,COM		7A
7M ,MSEG(10) ,N ,NPASS(10),NSEC,PHAV ,COM		8
8PHIN(10) ,PHOUT(10) ,PSIN(10) ,PSOUT(10) ,QCONV ,COM		9
9SD(10) ,SIGNH(10) ,SIGNP(10) ,SIGNS(10) ,COM		10
COMMON/CNTL/ SL(10) ,ST(10) ,TCOL(10) ,TCNT ,COM		11
1THIN(20,10) ,THISC(10) ,THJ(20) ,THOSC(10) ,THOUT(20,10) ,COM		12
2THPAV(20) ,THSC(10) ,TNUM(10) ,TTL(60) ,TT(10) ,COM		13
3TTMAX(20) ,TTPAV(20) ,TTSC(10) ,TUBE(50,10) ,VOID(10) ,COM		14
4WPAS(10) ,XM ,XN ,XTTL ,TROW(10) ,COM		15
COMMON/INCR1/ACP ,AHE ,AHSEG ,AKG ,INCR		1
1ALPHA ,AMU ,ANGLE ,ASEG ,ASSEG ,INCR		2
2ATUBE ,BCP ,BHE ,BKG ,BMU ,INCR		3
3BOLCOE ,BSIGNS ,CHI , DELPS ,INCR		4
4DELPSC ,DELTAV ,DIT ,DOT ,FHSEG ,INCR		5
5FHQA ,FLDR ,FSSEG ,HC(20) ,HGMAX ,INCR		6
6HP ,HSAV ,HSEXIT ,HSLIM ,HSSEG ,INCR		7
7HTC ,HVIS ,IREGON ,KROPAR ,PSEXIT ,INCR		8
8PSSEG ,QCONVA ,QUAL ,RH ,RS ,INCR		9
COMMON/INCR2/RT ,SGMAX ,SCALE ,TEMPH ,INCR2		10
1THAV ,THEXIT ,THSEG ,TLSEG ,TN1 ,INCR2		11
2TROWX ,TSAV ,TSSEG ,TTC ,TTISEG ,INCR2		12
3TTQSEG ,UAST ,UAHE ,INCR2		13
COMMON/CNTRL/ AIPT1 ,AHFD ,ALENGT ,ARMAX ,CNTRL		1
COMMON/CNTRL/ CLEAR ,C100 ,D100 ,DANGLE ,CNTRL		2
COMMON/CNTRL/ D(20) ,DELE ,DELHGT ,DELMIN ,DIAMAXCNTRL		3
COMMON/CNTRL/ DIS(10) ,DOS(10) ,DXS(10) ,DPRH ,DPRS ,CNTRL		4
COMMON/CNTRL/ DPST ,DPSS ,EX ,CNTRL		5

COMMON/CNTRL/	HCONV	,HDELIN	,HEIGHT	CNTRL	6
COMMON/CNTRL/	KE	,KN	,KM	CNTRL	7
COMMON/CNTRL/	PIE	,PRESS(10)	,RBEND	CNTRL	8
COMMON/CNTRL/	SDAV(10)	,SLAV(10)	,SLCONV	,SLL(10)	CNTRL 9
COMMON/CNTRL/	STAV(10)	,STRESS(10)		CNTRL	10
COMMON/CNTRL/		TCONV	,TEMMA	,TMAX	CNTRL 11
COMMON/CNTRL/	X100	,Y100	,Z100	,J100	,K100 CNTRL 12
COMMON/TBLS/	TBL(1)				

C	AKN	=K NUMBER ASSOCIATED WITH THE REHEATER	CN	0
C	ARAMAX	=MAXIMUM NUMBER OF AREA ITERATIONS	CN	0A
C	COLMAX	=MAXIMUM NUMBER OF TIMES TCOL(K) CAN BE CHANGED	CN	0B
C	CSD(L)	=COMPUTED DIAGONAL PITCH	CN	1
C	CSL(L)	=COMPUTED LONGITUDINAL PITCH	CN	2
C	CST(L)	=COMPUTED TRANSVERSE PITCH	CN	3
C	DXS(K)	= DOS(K) IF HELIUM FLOWS FROM OUTSIDE INWARD (AHFD=1.0)	CN	3A
C		= DIS(K) IF HELIUM FLOWS FROM INSIDE OUTWARD (AHFD=-1.0)	CN	3B
C	DIS(K)	=INSIDE DIAMETER OF SECTION K	CN	4
C	DOS(K)	=OUTSIDE DIAMETER OF SECTION K	CN	5
C	DELD	=CHANGE IN DISTANCE BETWEEN PASSES	CN	5A
C	DELMAX	=MAXIMUM DISTANCE BETWEEN PASSES	CN	5B
C	DELMIN	=MINIMUM DISTANCE BETWEEN PASSES	CN	5C
C	DIS(K)	=INSIDE DIAMETER OF PASS K	CN	5D
C	DOS(K)	=OUTSIDE DIAMETER OF PASS K	CN	5E
C	EX	=EXPONENT FOR SECOND GUESS EQUATION	CN	5F
C	IAREA	=NUMBER OF TIMES THE AREA HAS BEEN CHANGED	CN	5G
C	ICOLM	=NUMBER OF TIMES THE NO. OF COLUMNS HAS DECREASED	CN	5H
C	ICOLP	=NUMBER OF TIMES THE NO. OF COLUMNS HAS INCREASED	CN	5I
C	IDLENM	=NUMBER OF TIMES THE LENGTH HAS BEEN DECREASED	CN	5J
C	IDLENP	=NUMBER OF TIMES THE LENGTH HAS BEEN INCREASED	CN	5K
C	IDSLM	=NUMBER OF TIMES SL(K) HAS BEEN SET EQUAL TO (SLO+SLAVE)/2.0	CN	5L
C	IDSLP	=NUMBER OF TIMES SL(K) HAS BEEN SET EQUAL TO (SLO+DO(K))/2.0	CN	5M
C	IDXP	=		
C	ISL	=NUMBER OF ITERATIONS FOR SLAV(K) MAX.	CN	5O
C	ITEMP	=NUMBER OF ITERATIONS FOR THE MAXIMUM TUBE TEMP	CN	5P
C	PASMAX	=NOT ASSIGNED	CN	5Q
C	PHI	=INCLUDED ANGLE BETWEEN COLUMNS	CN	6
C	PRESS(K)	=DESIGN PRESSURE	CN	6A
C	RBEND	=MINIMUM RADIUS OF BEND FOR TUBE THICKNESS EQ.	CN	6B
C	SDAV(K)	=AVERAGE DIAGONAL PITCH	CN	7
C	SLAV(K)	=AVERAGE LONGTUDINAL PITCH	CN	8
C	SL(K)	= FOR THE REHEATER AND SUPERHEATER, THE CHANGE IN	CN	9
C		RADIUS BETWEEN ADJACENT ROWS (INPUT)	CN	10
C	***NOTE*****	SL(K) AND ST(K) ARE ALSO USED AS THE	CN	11
C		AVERAGE VALUES STAV(K) AND SLAV(K) WHEN	CN	12
C		CONTROL IS SHIFTED TO SUBROUTINE SECTON	CN	13
C	SLCONV	=SLAV(K) CONVERGENCE	CN	13A
C	SLD	=CURRENT VALUE OF SL(K)	CN	14
C	ST(K)	=FOR THE SUPERHEATER AND REHEATER THE CIRCUMFERENTIAL	CN	15
C		PITCH OF THE FIRST ROW (INPUT)	CN	16
C	STAV(K)	=AVERAGE TRANSVERSE PITCH	CN	17

C	STRESS(K)=DESIGN TUBE STRESS	CN	17A
C	TCONV =MAXIMUM METAL TEMPERATURE CONVERGENCE CRITERIA	CN	18
-C	TEMMAX=MAXIMUM NUMBER OF TUBE TEMP ITERATIONS	CN	18A
C	TMAX =MAXIMUM METAL TEMPERATURE	CN	19
C	TUBMIN =MINIMUM REHEATER TUBE LENGTH	CN	20
C			
	DPRSMN = 0.	CN	23
	DPRSMX = 0.	CN	24
1	IDEX=0	CN	0025
	TCNT=0.0	CN	0030
	WRITE(6,9999)	CN	0033
9999	FORMAT(1H1)	CN	0036
	CALL INPUT	CN	0040
	NSEC=ANSEC	CN	0050
	DO 2 K=1,NSEC	CN	0060
	MSEG(K)=AMSEG(K)	CN	0070
	TCOL(K)=ATCOL(K)	CN	0080
	TROW(K)=ATROW(K)	CN	0085
	TNUM(K)=ATNUM(K)	CN	0090
	IPITCH(K)=APIITCH(K)	CN	0100
	ST(K)=AST(K)/12.0	CN	0110
	SL(K)=ASL(K)/12.0	CN	0120
	TUBE(1,K)=ATUBEL(K)/12.0	CN	0130
	DO(K)=ADO(K)/12.0	CN	0140
	TT(K)=ATT(K)/12.0	CN	0150
	IFH(K)=AIFH(K)	CN	0160
	FHT(K)=AFHT(K)	CN	0170
	ITH(K)=AITH(K)	CN	0180
	THISC(K)=ATHISC(K)	CN	0190
	THOSC(K)=ATHOSC(K)	CN	0200
	SIGNH(K)=ASIGNH(K)	CN	0210
	SIGNP(K)=ASIGNP(K)	CN	0220
	SIGNS(K)=ASIGNS(K)	CN	0230
	ITUBE(K)=AITUBE(K)	CN	0240
	IDROP(K)=ADROP(K)	CN	0250
	IPH(K)=AIPH(K)	CN	0260
	PHOUT(K)=APHOUT(K)*144.0	CN	0270
	PHIN(K)=APHIN(K)*144.0	CN	0280
	DPH(K)=ADPH(K)*144.0	CN	0290
	FS(K)=AFS(K)	CN	0300
	HSIN(K)=AHSIN(K)	CN	0310
	HSOUT(K)=AHSOUT(K)	CN	0320
	IPS(K)=AIPS(K)	CN	0330
	PSOUT(K)=APSOOUT(K)*144.0	CN	0340
	PSIN(K)=AP SIN(K)*144.0	CN	0350
	DPS(K)=ADPS(K)*144.0	CN	0360
	M=MSEG(K)	CN	0370
	DO 2 J=1,M	CN	0380
	FH(J,K)=AFH(J,K)	CN	0390
	THOUT(J,K)=ATHOUT(J,K)	CN	0400

THIN(J,K)=ATHIN(J,K)
2 CONTINUE
K=0
K=K+1
CALL SECTON
TCNT=TN1
CALL OUTPUT
GO TO 1
END

CN 0410
CN 0420
CW 0430
CW 0440
CW 0450
CW 0460
CW 0470
CW 0480
CW 0490

\$IBFTC INPUT LIST,DECK,REF
SUBROUTINE INPUT

INP 0020

C

COMMON /TITLES/	TTL(60),	IT,	AZX(12)					TITLE	1
COMMON/INPT/	AACP	,AAHE	,AAKG	,AAMU	,AANGLE(10)	,ABCP	,ABHE	,IPT	2
1ABKG	,ABLCOE	,ABMU	,ADO(10),		,ACONVP,		,ACONVW	,IPT	3
2ADPH(10)	,ADPS(10)	,ADROP(10)		,AFH(20,10)	,AFHT(10)			,IPT	4
3AFS(10)	,AHSIN(10)	,AHSOUT(10)		,AIFH(10)	,APITCH(10)			,IPT	5
4AIPH(10)	,AIPS(10)	,AITH(10)		,AITUBE(10),	AMSEG(10),	ANSEC,		IPT	6
5APHAV	,APHIN(10)	,APHOUT(10)		,APSIN(10)	,APSOUT(10)			,IPT	7
6AQCONV,	AQUAL,	ASCALE(10)	,ASL(10)	,ASIGNH(10)	,ASIGNP(10)			,IPT	8
7ASIGNS(10)	,AST(10)	,ATCOL(10)		,ATHIN(20,10),	ATHISC(10)			,IPT	9
8ATHOSC(10)	,ATHOUT(20,10),	ATNUM(10)		,ATROW(10)	,ATT(10)			,IPT	10
9ATT(10)	,ATUBEL(10)	,CRSPAR(10)						IPT	11

C

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C

*****INPUT COMMON*****IPT 1

COMMON/CNTL/	AFHAV	,AFHMIN	,AFSP(10)	,CHD(10)	,COM	1
1CHT(10)	,CONVP	,CONVW,	DELPH(20,10),	DI(10),	DO(10)	,COM 2
2DPASS(10)	,DPH(10)	,DPHSEC(10)	,DPS(10)	,DV(10)	,COM	3
3FH(20,10)	,FHJ(10)	,FHT(10)	,FHSC(10)	,	,COM	4
4FRSR(10)	,FS(10)	,HSIN(10)	,HSOUT(10)	,IDEX	,COM	5
5IDROP(10)	,IFH(10)	,IPITCH(10)	,IPH(10)	,IPS(10)	,COM	6
6ITH(10)	,ITUBE(10)	,I	,IMAX(50)	,ISN	,COM	7
COMMON/CNTL/	IXSIGN	,JMAX(20)	,K	,	,COM	7A
7M	,MSEG(10)	,N	,NPASS(10),	NSEC,	PHAV	,COM 8
8PHIN(10)	,PHOUT(10)	,PSIN(10)	,PSOUT(10)	,QCONV	,COM	9
9SD(10)	,SIGNH(10)	,SIGNP(10)	,SIGNS(10)		,COM	10
COMMON/CNTL/	SL(10)	,ST(10)	,TCOL(10)	,TCNT	,COM	11
1THIN(20,10)	,THISC(10)	,THJ(20)	,THOSC(10)	,THOUT(20,10)	,COM	12
2THPAV(20)	,THSC(10)	,TNUM(10)	,TTL(60)	,TT(10)	,COM	13
3TTMAX(20)	,TTPAV(20)	,TTSC(10)	,TUBE(50,10)	,VOID(10)	,COM	14
4WPAS(10)	,XM	,XN	,XTTL	,TROW(10)	,COM	15

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COMMON/OUTPT/IPRINT(30),IPR IP

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AACP	=	HELIUM EQUATION CONSTANT CP=AACP+ABCP*T	CT
AAHE	=	HELIUM PRANDLT NUMBER EXPONENT=0.33333	CT
AAKG	=	COEFFICIENT IN HELIUM CONDUCTIVITY EQUATION	CT
AAMU	=	EXPONENT IN HELIUM VISCOSITY EQUATION	CT
AANGLE(K)	=	ANGLE TUBE MAKES WITH THE HORIZONTAL	CT
ANSEC	=	NUMBER OF SECTIONS	CT
ABCP	=	COEFFICIENT IN HELIUM SPECIFIC HEAT EQUATION	CT
ABHE	=	HELIUM REYNOLDS NUMBER EXPONENT	CT
ABKG	=	HELIUM CONDUCTIVITY EQUATION EXPONENT	CT
ABLCOE	=	BOILING FILM COEFFICIENT	CT
ABMU	=	EXPONENT IN HELIUM VISCOSITY EQUATION	CT
ADO(K)	=	OUTSIDE TUBE DIAMETER	IP
ACONVP	=	PRESSURE DROP CONVERGENCE CRITERIA	IP
ACONVW	=	FLOW RATE CONVERGENCE CRITERIA	IP

C	ADPH(K)	= SPECIFIED HELIUM PRESSURE DROP FOR SECTION K	IP
C	ADPS(K)	= SPECIFIED STEAM PRESSURE DROP FOR SECTION K	IP
C	ADROP(K)	= HELIUM PRESSURE DROP FLAG	IP
C		ADROP(K)=1 DO NOT COMPUTE HELIUM PRESSURE DROP	CT
C		ADROP(K)=2 COMPUTE AVERAGE SECTION PRESSURE DROP	CT
C		ADROP(K)=3 COMPUTE THE SECTION FLOW THAT WILL	CT
C		PRODUCE AN AVERAGE PRES. DROP DPH(K)	CT
C		ADROP(K)=4 COMPUTE HELIUM PRESSURE DROP FOR	CT
C		EACH AXIAL INCREMENT	CT
C		ADROP(K)=5 COMPUTE THE HELIUM FLOW FH(J,K)	IP
C		THAT WILL PRODUCE A PRES. DROP OF ADPH(K)	IP
C		ADROP(K)=6 COMPUTE THE PRESSURE DROP AND FLOW	CT
C		DISTRIBUTION ASSOCIATED WITH A	CT
C		SECTION FLOW RATE OF FHT(K)	CT
C	AFH(J,K)	= HELIUM FLOW RATE IN INCREMENT J OF SECTION K	IP
C	AFHT(K)	= TOTAL HELIUM FLOW IN SECTION K	IP
C	AFS(K)	= STEAM FLOW RATE	IP
C	AHSIN(K)	= INLET STEAM ENTHALPY FOR SECTION K	IP
C	AHSOUT(K)	= OUTLET STEAM ENTHALPY FOR SECTION K	IP
C	AIFH(K)	= HELIUM FLOW FLAG	
C		AIFH(K)=1 TOTAL FLOW IS GIVEN IN CURRENT	
C		AIFH(K)=2 INCREMENT FLOW IS GIVEN	
C	AIPITCH(K)	= PITCH FLAG	
C		AIPITCH(K)=1 RECTANGULAR PITCH	
C		AIPITCH(K)=2 TRIANGULAR PITCH	
C	AIPH(K)	= HELIUM PRESSURE FLAG	
C		AIPH(K)=1 INLET HELIUM PRESSURE IS KNOWN	
C		AIPH(K)=2 OUTLET HELIUM PRESSURE IS KNOWN	
C	AIPS(K)	= STEAM PRESSURE FLAG	
C		AIPS(K)=1 INLET STEAM PRESSURE IS KNOWN	
C		AIPS(K)=2 OUTLET STEAM PRESSURE IS KNOWN	
C	AITH(K)	= HELIUM TEMPERATURE FLAG	
C		AITH(K)=1 AVERAGE HELIUM TEMPERATURE IS GIVEN	
C		AITH(K)=2 THE INCREMENT HELIUM INLET TEMP. IS GIVEN	IP
C		AITH(K)=3 THE INCREMENT HELIUM OUTLET TEMP IS GIVEN	IP
C	AITUBE(K)	= TUBE FLAG	
C		AITUBE(K)=1.0 UTUBE	
C		AITUBE(K)=2.0 HELICAL	
C	AMSEG(K)	= NUMBER OF AXIAL INCREMENTS IN SECTION K	IP
C	APHAV	= AVERAGE HELIUM PRESSURE	IP
C	APHIN(K)	= INLET HELIUM PRESSURE FOR SECTION K	IP
C	APHOUT(K)	= OUTLET HELIUM PRESSURE FOR SECTION K	IP
C	APSIN(K)	= OUTLET STEAM PRESSURE FOR SECTION K	IP
C	APSOUT(K)	= INLET STEAM PRESSURE FOR SECTION K	IP
C	AQCONV	= CONVERGENCE CRITERIA	
C	AQUAL	= SATURATED ENTHALPY DIVISION	
C	ASCALE(K)	= BOILER SCALE COEFFICIENT BTU/HR-SQFT-DEG	CT
C	ASIGNH(K)	= +1 INLET HELIUM CONDITIONS KNOWN	CT
C		= -1 OUTLET HELIUM CONDITIONS KNOWN	CT
C	ASIGNP(K)	= +1 STEAM FLOW IS UP THE TUBE IN THE FIRST PASS	CT

C		= -1 STEAM FLOW IS DOWN THE TUBE IN THE FIRST PASS	CT
C	ASIGNS(K)	= +1 INLET STEAM CONDITIONS ARE KNOWN	CT
C		= -1 OUTLET STEAM CONDITIONS ARE KNOWN	CT
C	ASL(K)	= LONGITUDINAL PITCH SPACING	IP
C	AST(K)	= TRANSVERSE PITCH SPACING	IP
C	ATCOL(K)	= NUMBER OF TUBE COLUMNS PER PASS	IP
C	ATHIN(J,K)	= INLET HELIUM TEMPERATURE FROM INCREMENT J OF SEC K	IP
C	ATHISC(K)	= AVERAGE HELIUM INLET TEMPERATURE	IP
C	ATHOSC(K)	= AVERAGE HELIUM OUTLET TEMPERATURE	IP
C	ATHOUT(J,K)	= OUTLET HELIUM TEMPERATURE FROM INCREMENT J OF SEC K	IP
C	ATNUM(K)	= NUMBER OF TUBE PER PASS	IP
C	ATROW(K)	= NUMBER OF TUBE ROWS PER PASS IN SECTION K	CT
C	ATTIC(K)	= TUBE THERMAL CONDUCTIVITY IN SECTION K	CT
C	ATT(K)	= TUBE WALL THICKNESS	IP
C	ATUBEL(K)	= TUBE LENGTH IN THE FIRST PASS OF SECTION K	IP
C	CRSPAR(K)	= 0.0 PARALLEL FLOW, =1.0 CROSS FLOW	CT
C	TTL(L)	= OUTPUT TITLES, SIX CHARACTERS EACH	
C	XTTL	= NUMBER OF OUTPUT TITLES (SIX CHARACTERS EACH)	
	2002	FORMAT(12A6)	INP 0030
	2001	FORMAT(I2)	INP 0040
	2000	FORMAT(7E10.1)	INP 0050
	2003	FORMAT(30I2)	IP 0060
C		CASE TITLE	INP 0070
		READ(5,2002)(AZX(IX),IX=1,12)	INP 0080
		WRITE(6,2002)(AZX(IX),IX=1,12)	INP 0090
	1000	READ(5,2001)KK	INP 0100
		GO TO(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17),KK	IP 0110
C		*****CONSTANTS*****	IP 0120
	1	READ(5,2000)AAHE,ABHE,ABLCDE,AQUAL,AQCONV,ACONVP,ACONVW,	IP 0130
		1AACP,ABCP,AAKG,ABKG,AAMU,ABMU,APHAV,ANSEC	IP 0140
		NS=ANSEC	IP 0150
		GO TO 1000	IP 0160
C		*****BANK GEOMETRY*****	IP 0170
	2	READ(5,2000)(ATUBE(K),K=1,NS)	IP 0180
		READ(5,2000)(AMSEG(K),K=1,NS)	IP 0190
		READ(5,2000)(AANGLE(K),K=1,NS)	IP 0200
		GO TO 1000	IP 0210
C		*****PASS GEOMETRY	IP 0220
	3	READ(5,2000)(ATROW(K),K=1,NS)	IP 0230
		READ(5,2000)(ATCOL(K),K=1,NS)	IP 0240
		READ(5,2000)(ATNUM(K),K=1,NS)	IP 0250
		GO TO 1000	IP 0260
C		*****PITCH*****	IP 0270
	4	READ(5,2000)(APITCH(K),K=1,NS)	IP 0280
		READ(5,2000)(AST(K),K=1,NS)	IP 0290
		READ(5,2000)(ASL(K),K=1,NS)	IP 0310
		GO TO 1000	IP 0320
C		*****TUBE SIZE*****	IP 0330
	5	READ(5,2000)(ATUBEL(K),K=1,NS)	IP 0340
		READ(5,2000)(ADO(K),K=1,NS)	IP 0350

	READ(5,2000)(ATT(K),K=1,NS)	IP	0360
	GO TO 1000	IP	0370
- C	TUBE THERMAL CONDUCTIVITY	IP	0380
	6 READ(5,2000)(ATTC(K),K=1,NS)	IP	0390
	GO TO 1000	IP	0400
C	*****FLAGS*****	IP	0410
	7 READ(5,2000)(ASIGNH(K),K=1,NS)	IP	0420
	READ(5,2000)(ASIGNP(K),K=1,NS)	IP	0430
	READ(5,2000)(ASIGNS(K),K=1,NS)	IP	0440
	GO TO 1000	IP	0450
C	*****HELIUM FLOW RATE*****	IP	0460
	8 READ(5,2000)(AIFH(K),K=1,NS)	IP	0470
	READ(5,2000)(CRSPAR(K),K=1,NS)	IP	0480
	DO 8030 K=1,NS	IP	0481
	M=AMSEG(K)	IP	0490
	IF(1.0-AIFH(K))8000,8010,8020	IP	0500
C	INCREMENT HELIUM FLOWRATE	IP	0510
	8000 READ(5,2000)(AFH(J,K),J=1,M)	IP	0520
	AFHT(K)=0.0	IP	0522
	DO 8005 J=1,M	IP	0524
	AFHT(K)=AFH(J,K)+AFHT(K)	IP	0526
	8005 CONTINUE	IP	0528
	GO TO 8030	IP	0530
C	HELIUM FLOW PER SECTION	IP	0540
	8010 READ(5,2000)AFHT(K)	IP	0550
	XM=AMSEG(K)	IP	0552
	AHFL=AFHT(K)/XM	IP	0554
	DO 8015 J=1,M	IP	0556
	AFH(J,K)=AHFL	IP	0558
	8015 CONTINUE	IP	0559
	GO TO 8030	IP	0560
	8020 IR=17	IP	0570
	CALL ERROR(IR)	IP	0580
	8030 CONTINUE	IP	0590
	GO TO 1000	IP	0600
C	*****HELIUM TEMPERATURES*****	IP	0610
	9 READ(5,2000)(AITH(K),K=1,NS)	IP	0620
	DO 9030 K=1,NS	IP	0630
	XM=M	IP	0645
	IF(2.0-AITH(K))9000,9010,9020	IP	0650
C	*****AVERAGE INLET AND INCREMENT OUTLET TEMPERATURES*****	IP	0655
	9000 READ(5,2000)ATHISC(K)	IP	0660
	ATHOSC(K)=0.0	IP	0665
	READ(5,2000)(ATHOUT(J,K),J=1,M)	IP	0670
	DO 9005 J=1,M	IP	0675
	ATHOSC(K)=ATHOSC(K)+ATHOUT(J,K)	IP	0680
	9005 CONTINUE	IP	0685
	ATHOSC(K)=ATHOSC(K)/XM	IP	0690
	GO TO 9030	IP	0695
	*****AVERAGE OUTLET AND INCREMENT INLET TEMPERATURES*****	IP	0700

9010	READ(5,2000)ATHOSC(K)	IP	0705
	ATHISC(K)=0.0	IP	0710
	READ(5,2000){ATHIN(J,K),J=1,M}	IP	0715
	DO 9015 J=1,M	IP	0720
	ATHISC(K)=ATHISC(K)+ATHIN(J,K)	IP	0725
9015	CONTINUE	IP	0730
	ATHISC(K)=ATHISC(K)/XM	IP	0735
	GO TO 9030	IP	0740
C	*****AVERAGE INLET AND OUTLET TEMPERATURES*****	IP	0745
9020	READ(5,2000)ATHISC(K),ATHOSC(K)	IP	0750
	DO 9025 J=1,M	IP	0756
	ATHIN(J,K)=ATHISC(K)	IP	0757
	ATHOUT(J,K)=ATHOSC(K)	IP	0758
9025	CONTINUE	IP	0759
9030	CONTINUE	IP	0755
	GO TO 1000	IP	0760
C	*****HELIUM PRESSURE*****	IP	0770
10	READ(5,2000){ADROP(K),K=1,NS}	IP	0780
	READ(5,2000){AIPH(K),K=1,NS}	IP	0790
	DO 1030 K=1,NS	IP	0800
	IF(1.0-AIPH(K))1005,1010,1020	IP	0810
C	OUTLET HELIUM PRESSURE	IP	0820
1005	READ(5,2000)APHOUT(K),ADPH(K)	IP	0830
	GO TO 1030	IP	0840
C	INLET HELIUM CONDITIONS ARE KNOWN	IP	0850
1010	READ(5,2000)APHIN(K),ADPH(K)	IP	0860
	GO TO 1030	IP	0870
1020	IR=19	IP	0880
	CALL ERROR(IR)	IP	0890
1030	CONTINUE	IP	0900
	GO TO 1000	IP	0910
C	*****STEAM FLOW*****	IP	0920
11	READ(5,2000){AFS(K),K=1,NS}	IP	0930
	GO TO 1000	IP	0940
C	*****STEAM ENTHALPY*****	IP	0950
12	READ(5,2000){AHSIN(K),AHSOUT(K),K=1,NS}	IP	0960
	GO TO 1000	IP	0970
C	*****STEAM PRESSURE*****	IP	0980
13	READ(5,2000){AIPS(K),K=1,NS}	IP	0990
	DO 1330 K=1,NS	IP	1000
	M=AMSEG(K)	IP	1010
	IF(1.0-AIPS(K))1300,1310,1320	IP	1020
C	OUTLET STEAM PRESSURE IS KNOWN	IP	1030
1300	READ(5,2000) APSOUT(K),ADPS(K)	IP	1040
	GO TO 1330	IP	1050
C	INLET STEAM PRESSURE IS KNOWN	IP	1060
1310	READ(5,2000) APSIN(K),ADPS(K)	IP	1070
	GO TO 1330	IP	1080
1320	IR=20	IP	1090
	CALL ERROR(IR)	IP	1100

1330	CONTINUE	IP	1110
	GO TO 1000	IP	1120
C	*****STEAM SIDE SCALE COEFFICIENT*****	IP	1130
14	READ(5,2000)(ASCALE(K),K=1,NS)	IP	1140
	GO TO 1000	IP	1150
C	*****PRINT INDEXES*****	IP	1160
15	READ(5,2003)IPR	IP	1170
	READ(5,2003)(IPRINT(L),L=1,IPR)	IP	1180
	GO TO 1000	IP	1190
C	*****OUTPUT FORMAT*****	IP	1199
16	READ(5,2000)XTTL	IP	1200
	IT=XTTL	IP	1210
	READ(5,2002)(TTL(L),L=1,IT)	IP	1220
	GO TO 1000	IP	1230
17	CONTINUE	IP	1240
C	*****END OF INPUT*****	XXXX	
	RETURN	XXXXX	
	END	XXXXX	

\$IBFTC SECTION LIST,REF
SUBROUTINE SECTION

C
C SECTION ER 1...SIGNH(K) = 0.0 AT STA. 6.
C SECTION ER 2...SIGNH(K) = 0.0 AT STA. 102.
C SECTION ER 3...SIGNH(K) = 0.0 AT STA. 14.
C SECTION ER 4...ISIGN = 0 AT STA. 20
C SECTION ER 5...SIGNH(K) = 0.0 AT STA. 40
C SECTION ER 6...INDEX IP IS 1 OR 4 AT STA. 54.
C SECTION ER 7...IP IS LESS THAN 4 AT STA. 66.
C SECTION ER 8...IP IS 4 OR LESS AT STA. 76.

C *****INPUT COMMON*****IPT 1
C COMMON/INPT/ AACP ,AAHE ,AAKG ,AAMU ,AANGLE(10) ,ABCP ,ABHE ,IPT 2
C 1ABKG ,ABLCOE,ABMU , ADO(10), ACONVP, ACONVW ,IPT 3
C 2ADPH(10) ,ADPS(10) ,ADROP(10) ,AFH(20,10) ,AFHT(10) ,IPT 4
C 3AFS(10) ,AHSIN(10) ,AHSOUT(10) ,AIFH(10) , APITCH(10) ,IPT 5
C 4AIPH(10) ,AIPS(10) ,AITH(10) ,AITUBE(10),AMSEG(10),ANSEC, IPT 6
C 5APHAV ,APHIN(10) ,APHOUT(10) ,APSIN(10) ,APSOUT(10) ,IPT 7
C 6AQCONV,AQUAL,ASCALE(10) ,ASL(10) ,ASIGNH(10) ,ASIGNP(10) ,IPT 8
C 7ASIGNS(10) ,AST(10) ,ATCOL(10) ,ATHIN(20,10),ATHISC(10) ,IPT 9
C 8ATHOSC(10) ,ATHOUT(20,10),ATNUM(10) ,ATROW(10) ,ATT(10) ,IPT 10
C 9ATT(10) ,ATUBEL(10) ,CRSPAR(10) ,IPT 11
C COMMON/CNTL/ AFHAV ,AFHMIN ,AFSP(10) ,CHD(10) ,COM 1
C 1CHT(10) ,CONVP ,CONVW,DELPH(20,10),DI(10),DO(10) ,COM 2
C 2DPASS(10) ,DPH(10) ,DPHSEC(10) ,DPS(10) ,DV(10) ,COM 3
C 3FH(20,10) ,FHJ(10) ,FHT(10) ,FHSC(10) , , COM 4
C 4FRSR(10) ,FS(10) ,HSIN(10) ,HSOUT(10) ,IDEX ,COM 5
C 5IDROP(10) ,IFH(10) ,IPITCH(10) ,IPH(10) ,IPS(10) ,COM 6
C 6ITH(10) ,ITUBE(10) ,I ,IMAX(50) ,ISN ,COM 7
C COMMON/CNTL/ IXSIGN ,JMAX(20) ,K , , COM 7A
C 7M ,MSEG(10) ,N ,NPASS(10),NSEC,PHAV ,COM 8
C 8PHIN(10) ,PHOUT(10) ,PSIN(10) ,PSOUT(10) ,QCONV ,COM 9
C 9SD(10) ,SIGNH(10) ,SIGNP(10) ,SIGNS(10) , , COM 10
C COMMON/CNTL/ SL(10) ,ST(10) ,TCOL(10) ,TCNT ,COM 11
C 1THIN(20,10) ,THISC(10) ,THJ(20) ,THOSC(10) ,THOUT(20,10) ,COM 12
C 2THPAV(20) ,THSC(10) ,TNUM(10) ,TTL(60) ,TT(10) ,COM 13
C 3TTMAX(20) ,TTPAV(20) ,TTSC(10) ,TUBE(50,10) ,VOID(10) ,COM 14
C 4WPAS(10) ,XM ,XN ,XTTL ,TROW(10) ,COM 15
C COMMON/INCR1/ACP ,AHE ,AHSEG ,AKG ,INCR 1
C 1ALPHA ,AMU ,ANGLE ,ASEG ,ASEG ,INCR 2
C 2ATUBE ,BCP ,BHE ,BKG ,BMU ,INCR 3
C 3BOLCOE ,BSIGNS ,CHI , , DELPS ,INCR 4
C 4DELPSC ,DELTAV ,DIT ,DOT ,FHSEG ,INCR 5
C 5FHOA ,FLDR ,FSSEG ,HC(20) ,HGMAX ,INCR 6
C 6HP ,HSAV ,HSEXIT ,HSLIM ,HSSEG ,INCR 7
C 7HTC ,HVIS ,IREGON ,KROPAR ,PSEXIT ,INCR 8
C 8PSSEG ,QCONVA ,QUAL ,RH ,RS ,INCR 9
C COMMON/INCR2/RT ,SGMAX ,SCALE ,TEMPH ,INCR2 10
C 1THAV ,THEXIT ,THSEG ,TLSEG ,TN1 ,INCR2 11

	2TROWX	,TSAV	,TSSEG	,TTC	,TTISEG	,INCR2 12
	3TTTOSEG	,UAST	,UAHE			INCR2 13
	DIMENSION THOUTR(20),THINR(20),THPAVR(20),TTPAVR(20)					DIM SEC
C	AA5	=	FRICTIONAL VELOCITY HEADS LOSS			SC
C	AA6	=	ACCELERATIONAL VELOCITY HEADS LOSS			SC
C	AFHAV	=	AVERAGE HELIUM FLOW AREA PER INCREMENT			SC
C	*AFHMIN	=	MINIMUM HELIUM FLOW AREA			SC
C	*AMU	=	HELIUM VISCOSITY COEFFICIENT			SC
C	*AFSP(K)	=	STEAM FLOW AREA PER PASS			SC
C	*BMU	=	HELIUM VISCOSITY EXPONENT			SC
C	CONVP	=	PRESSURE DROP CONVERGENCE CRITERIA			SC
C	*DI(K)	=	INSIDE TUBE DIAMETER			SC
C	DIT	=	DI(K)			SC
C	*DO(K)	=	OUTSIDE TUBE DIAMETER			SC
C	DOT	=	DO(K)			SC
C	*DPH(K)	=	SPECIFIED HELIUM PRESSURE DROP FOR SECTION K			SC
C	DPHSEC(K)	=	COMPUTED AVERAGE HELIUM PRESSURE DROP FOR SECTION K			SC
C	*DV(K)	=	VOLUMETRIC HYDRAULIC DIAMETER			SC
C	F	=	FRICTION FACTOR			SC
C	*FH(J,K)	=	INPUT HELIUM FLOW RATE			SC
C	FHJ(J)	=	HELIUM FLOW RATE AND DIRECTION IN INCREMENT J			SC
C	FHOA	=	HELIUM MASS FLOW RATE			SC
C	FHSC(K)	=	TOTAL HELIUM FLOW RATE FOR SECTION K			SC
C	FHSEC	=	HELIUM FLOW RATE IN THE SECTION			SC
C	FHT(K)	=	INPUT TOTAL HELIUM FLOW FOR SECTION			SC
C	FHTOT	=	TOTAL HELIUM FLOW RATE FOR ENTIRE SECTION			SC
C	FLDR	=	FLOW DIRECTION FOR CURRENT PASS			SC
C			FLDR = +1 UP FLOW			SC
C			FLDR = -1 DOWN FLOW			SC
C	FSSEG	=	STEAM FLOW RATE FOR THE CURRENT INCREMENT			SC
C	HC(IX)	=	FILM COEFFICIENT CORRECTION FACTOR			SC
C	HGMAX	=	MAXIMUM HELIUM MASS FLOW RATE			SC
C	*HSEXIT	=	STEAM EXIT ENTHALPY FOR CURRENT PASS AND INCREMENT			SC
C	HSSEG	=	HELIUM FLOW RATE FOR THE CURRENT INCREMENT			SC
C	HVIS	=	HELIUM VISCOSITY			SC
C	IDROP(K)	=	HELIUM PRESSURE DROP FLAG			SC
C			IDROP(K) = 1 DO NOT COMPUTE HELIUM PRESSURE DROP			SC
C			IDROP(K) = 2 COMPUTE AVERAGE SECTION PRESSURE DROP			SC
C			IDROP(K) = 3 COMPUTE SECTION FLOW THAT WILL PRODUCE			SC
C			AN AVERAGE PRESSURE DROP DPH(K)			SC
C			IDROP(K) = 4 COMPUTE THE HELIUM PRESSURE DROP FOR			SC
C			EACH AXIAL INCREMENT			SC
C			IDROP(K) = 5 COMPUTE THE HELIUM FLOW, FH(J,K) THAT			SC
C			WILL PRODUCE A PRESSURE DROP OF DPH(K)			SC
C			IDROP(K) = 6 COMPUTE THE PRESSURE DROP AND FLOW			SC
C			DISTRIBUTION ASSOCIATED WITH A SECTION			SC
C			FLOW RATE OF FHT(K)			SC
C	IFH	=	1 COMPUTE INCREMENT PRESSURE DROP			SC
C		=	2 COMPUTE FLOW DISTRIBUTION			SC
C	IK	=	PRESSURE DROP FLAG			SC

C		=1 COMPUTE AVERAGE PRESSURE DROP	SC
C		=2 COMPUTE INCREMENT PRESSURE DROP	SC
C	IP	= IDROP(K)	SC
C	*ISIGN	= +1 START AT J=+1,=-1 START AT J=M	SC
C	*ITUBE(K)	= +1 UTUBE,= 2 HELICAL TUBE	SC
C	*K	= SECTION NUMBER	SC
C	*LSEG	= INCREMENT LENGTH FOR CURRENT PASS	SC
C	LTSEC	= TOTAL LENGTH OF TUBES IN SECTION(HEAT TRANSFER)	SC
C	*TUBE(I,K)	= LENGTH OF PASS I OF SECTION K	SC
C	M	= MSEG	SC
C	N	= NPASS(K)	SC
C	*NPASS(K)	= NUMBER OF PASSES IN SECTION K	SC
C	*NSEG(K)	= NUMBER OF INCREMENTS IN SECTION K	SC
C	PHAV	= AVERAGE HELIUM PRESSURE	SC
C	*PSEXIT	= STEAM EXIT PRES. FOR CURRENT PASS AND INCREMENT	SC
C	PSSEG	= STEAM PRESSURE FOR THE CURRENT INCREMENT	SC
C	RE	= HELIUM REYNOLDS NUMBER	SC
C	SD(K)	= DIAGONAL PITCH SPACING	SC
C	SGMAX	= STEAM MASS FLOW RATE	SC
C	*SIGNH(K)	= +1 INLET HELIUM CONDITIONS ARE KNOWN	SC
C		= -1 OUTLET HELIUM CONDITIONS ARE KNOWN	SC
C	*SIGNP(K)	= +1 STEAM FLOW IS UP THE TUBE IN FIRST TUBE	SC
C		= -1 STEAM FLOW IS DOWN THE TUBE IN FIRST TUBE	SC
C	*SIGNS(K)	= +1 INLET STEAM CONDITIONS ARE KNOWN	SC
C		= -1 OUTLET STEAM CONDITIONS ARE KNOWN	SC
C	ST(K)	= TRANSVERSE PITCH SPACING	SC
C	TCNT	= NUMBER OF TUBES CROSSED BY HELIUM IN PREVIOUS	SC
C		SECTIONS	SC
C	*TEMPH	= MAX. TUBE TEMP. FOR CURRENT PASS AND INCREMENT	SC
C	*THAV	= AVE HELIUM TEMP. FOR CURRENT PASS AND INCREMENT	SC
C	*THEXIT	= HELIUM EXIT TEMP FOR CURRENT PASS AND INCREMENT	SC
C	*THIN(J,K)	= INLET HELIUM TEMPERATURE	SC
C	THINSC	= SUM OF INLET HELIUM TEMPERATURES FOR THE SECTION	SC
C	THISC(K)	= AVERAGE HELIUM INLET TEMPERATURE FOR THE SECTION	SC
C	THJ(J)	= KNOWN HELIUM TEMPERATURE IN INCREMENT J	SC
C	THOSC(K)	= AVERAGE HELIUM OUTLET TEMPERATURE FOR THE SECTION	SC
C	THOTSC	= SUM OF OUTLET HELIUM TEMPERATURES FOR THE SECTION	SC
C	*THOUT(J,K)	= OUTLET HELIUM TEMPERATURE	SC
C	THPAV(J)	= AVERAGE HELIUM TEMPERATURE IN INCREMENT(J)	SC
C	THSC(K)	= AVERAGE HELIUM TEMPERATURE FOR THE SECTION	SC
C	THSEC	= SUM OF HELIUM TEMPERATURE IN THE SECTION	SC
C	TN1	= NUMBER OF TUBES PREVIOUSLY CROSSED BY HELIUM FLOW	SC
C	TTPAV(J)	= AVERAGE TUBE TEMPERATURE IN INCREMENT(J)	SC
C	TTSC(K)	= AVERAGE TUBE TEMPERATURE FOR THE SECTION	SC
C	TTSEC	= SUM OF TUBE TEMPERATURE IN THE SECTION	SC
C	XM	= M	SC
C	XN	= N	SC
C	IF(IDEX)1500,1500,1550		SC 0016
1500	IDEX=1		SC 0017
	HC(1)=0.63		SC 0018

HC(2)=0.76	SC	0019
HC(3)=0.93	SC	0020
HC(4)=0.98	SC	0021
HC(5)=0.99	SC	0022
DO 1525 IB=6,20	SC	0023
HC(IB)=1.0	SC	0024
1525 CONTINUE	SC	0025
AHE=AAHE	SC	0026
BHE=ABHE	SC	0028
BOLCOE=ABLCOE	SC	0030
QUAL=AQUAL	SC	0032
QCONV=AQCONV	SC	0034
QCONVA=AQCONV	SC	0035
CONVP=ACONVP	SC	0036
CONVW=ACONVW	SC	0038
ACP=AACP	SC	0040
BCP=ABCP	SC	0042
AKG=AAKG	SC	0044
BKG=ABKG	SC	0046
AMU=AAMU	SC	0048
BMU=ABMU	SC	0050
PHAV=APHAV*144.0	SC	0052
NSEC=ANSEC	SC	0054
TOG=8.3462E08	SC	0056
GAS=1544.0/(TOG*PHAV*4.003)	SC	0058
1550 SCALE=ASCALE(K)	SC	0060
TTC=ATTIC(K)	SC	0062
TROWX= TROW(K)	SC	0064
ANGLE=AANGLE(K)	SC	0056
BSIGNS=SIGNS(K)	SC	0058
KROPAR=CRSPAR(K)	SC	0070
IPRESS=0	SC	0072
IGEO=1	SC	0074
CALL GEOMET(IGEO,AXB1)	SC	0078
AFH1=AXB1	SC	0079
DOT=DO(K)	SC	0078
DIT=DI(K)	SC	0080
SGMAX=FS(K)/AFSP(K)	SC	0085
1000 FHTOT=0.0	SC	0090
IF(1 -ITUBE(K))1,2,2	SC	0100
1 ISN=1	SC	0110
GO TO 3	SC	0120
2 ISN=-1	SC	0130
3 FLDR=SIGNP(K)	SC	0135
IXSIGN=SIGNP(K)*SIGNS(K)	SC	0140
IF(SIGNS(K)-0.0)4,6,8	SC	0150
4 FSSEG=-FS(K)	SC	0160
HSSEG=HSOUT(K)	SC	0170
PSSEG=PSOUT(K)	SC	0180
GO TO 10	SC	0190

6	IR=1	SC	0200
	GO TO 2000	SC	0210
8	FSSEG=FS(K)	SC	0220
	HSSEG=HSIN(K)	SC	0230
	PSSEG=PSIN(K)	SC	0235
10	FHSC(K)=0.0	SC	0240
	DO 106 J=1,M	SC	0245
	IF(SIGNH(K)-0.0)100,102,104	SC	0250
100	THJ(J)=THOLT(J,K)	SC	0270
	GO TO 105	SC	0280
102	IR=2	SC	0290
	GO TO 2000	SC	0300
104	THJ(J)=THIN(J,K)	SC	0310
105	FHJ(J)=FH(J,K)	SC	0320
	FHSC(K)=FHSC(K)+FH(J,K)	SC	0325
106	CONTINUE	SC	0330
	M=MSEG(K)	SC	0370
	XM=M	SC	0380
	AFHAV=0.0	SC	0410
	DO 11 J=1,M	SC	0420
	TTPAV(J)=0.0	SC	0430
11	THPAV(J)=0.0	SC	0440
	THSEC=0.0	SC	0450
	TTSEC=0.0	SC	0460
	FHSEC=0.0	SC	0470
	THINSC=0.0	SC	0480
	THOTSC=0.0	SC	0490
	TLSEC=0.0	SC	0500
	I=0	SC	0505
	TN1=TCNT	SC	0510
C	BEGINING OF LOOP TO COMPUTE EACH PASS OF SECTION K (EXTENDS	SC	0515
	UAHE=1.0	SC	0517
	UAST=1.0	SC	0518
C	TO STATEMENT NUMBER 36	SC	0520
	TTMAX(K)=0.0	SC	0521
12	I=I+1	SC	0525
	IF(1-I)120,122,122	SC	0530
120	TN1=TN1+TROW(K)	SC	0535
122	IGEO=2	SC	0590
	CALL GEOMET(IGEO,AXB1)	SC	0600
	J=M+1	SC	0610
C	BEGINNING OF INCREMENT DO LOOP. IT ENDS AT CARD SC 0820.	SC	0620
	DO 36 JJ=1,M	SC	0630
	IF(IXSIGN-0)18,20,22	SC	0640
18	J=JJ	SC	0650
	GO TO 24	SC	0660
20	IR=4	SC	0670
	GO TO 2000	SC	0680
22	J=J-1	SC	0690
24	FHSEG=FHJ(J)	SC	0710

THSEG=THJ(J)	SC 0720
HGMAX=HSEG/AFHMIN	SC 0730
CALL HEAT	SC 0740
TOMAX=AMAX1(TTMAX(K),TEMPH)	SC 0742
IF(TTMAX(K)-TOMAX)340,342,342	SC 0744
340 TTMAX(K)=TOMAX	SC 0746
IMAX(K)=I	SC 0748
JMAX(K)=J	SC 0749
342 THJ(J)=THEXIT	SC 0750
PSSEG=PSEXIT	SC 0760
HSSEG=HSEXIT	SC 0770
TTPAV(J)=TTPAV(J)+TEMPH	SC 0780
THPAV(J)=THPAV(J)+THAV	SC 0790
TTSEC=TTSEC+TEMPH*TLSEG	SC 0800
36 CONTINUE	SC 0810
C END OF INCREMENT DO LOOP. IT STARTED AT STATEMENT 17	SC 0820
IXSIGN=ISN*IXSIGN	SC 0830
XSN=ISN	SC 0834
FLDR=XSN*SIGNP(K)	SC 0835
TLSEC=TLSEC+TUBE(I,K)	SC 0840
CALL AREA(IAA)	SC 0845
IA=IAA	SC 0848
IF(IA)38,38,12	SC 0850
C END OF PASS LOOP(STARTED AT STATEMENT NUMBER 12)	SC 0855
38 NPASS(K)=I	SC 0857
N=I	SC 0858
XN=N	SC 0859
AFHAV=AFHAV/XN	SC 0860
AFHSEC=XM*AFHAV	SC 0870
TTSC(K)=TTSEC/TLSEC	SC 0880
TTSCR=TTSC(K)+460.0	SC 0885
IF(SIGNS(K)-0.0)380,380,382	SC 0886
380 HSIN(K)=HSSEG	SC 0888
PSIN(K)=PSSEG	SC 0890
GO TO 384	SC 0892
382 HSOUT(K)=HSSEG	SC 0894
PSOUT(K)=PSSEG	SC 0896
384 DPS(K)=PSIN(K)-PSOUT(K)	SC 0898
DO 42 J=1,M	SC 0899
IF(0.0-SIGNH(K))39,40,41	SC 0900
39 THOUT(J,K)=THJ(J)	SC 0910
GO TO 410	SC 0920
40 IR=5	SC 0930
GO TO 2000	SC 0940
41 THIN(J,K)=THJ(J)	SC 0950
410 THOUTR(J)=THOUT(J,K)+460.0	SC 0955
THINR(J)=THIN(J,K)+460.0	SC 0960
TTPAV(J)=TTPAV(J)/XN	SC 0990
THPAV(J)=THPAV(J)/XN	SC 1000
THSEC=THPAV(J)*FH(J,K)+THSEC	SC 0965

	THINSC=THINSC+THIN(J,K)*FH(J,K)	SC	0970
	THOTSC=THOTSC+THOUT(J,K)*FH(J,K)	SC	0980
	THPAVR(J)=THPAV(J)+460.0	SC	1004
	TTPAVR(J)=TTPAV(J)+460.0	SC	1006
42	CONTINUE	SC	1010
	THSC(K)=THSEC/FHSC(K)	SC	1020
	THOSC(K)=THCTSC/FHSC(K)	SC	1030
	THISC(K)=THINSC/FHSC(K)	SC	1040
	THSCR=THSC(K)+460.0	SC	1042
	THOSCR=THOSC(K)+460.0	SC	1046
	THISCR=THISC(K)+460.0	SC	1048
	IP=IDROP(K)	SC	1050
	XBMU=0.14*BMU	SC	1060
	AA2=(DV(K)/ST(K))*0.4	SC	1070
	AA3=(SD(K)/ST(K))*0.6	SC	1080
	GO TO(80,44,44,64,64,43),IP	SC	1090
43	IF(IPRESS-1)44,64,64	SC	1100
C	COMPUTE THE AVERAGE SECTION HELIUM PRESSURE DROP	SC	1110
44	IPRESS=IPRESS+1	SC	1120
	FHOA=FHSC(K)/AFHSEC	SC	1130
	FHOA=ABS(FHCA)	SC	1131
	AAVOA2=(AFHSEC/(AFH1*TUBE(N,K)))*2	SC	1132
	AAVOA1=(AFHSEC/(AFH1*TUBE(1,K)))*2	SC	1134
	AA1=(TTSCR/THSCR)**XBMU	SC	1140
	HVIS=AMU*THSCR**BMU	SC	1150
	RE=DV(K)*FHCA/HVIS	SC	1160
	AA6=2.0*(THOSCR-THISCR)/THSCR+AAVOA2-AAVOA1	SC	1170
	IF(200.0-RE)48,48,50	SC	1190
48	AA4=RE**0.144	SC	1200
	F=1.92/AA4	SC	1210
	GO TO 51	SC	1220
50	F=180.0/RE	SC	1230
51	AA5=F*DPASS(K)*XN*AA1*AA2*AA3/DV(K)	SC	1240
	DPHSEC(K)=FHOA**2*GAS*THSCR*(AA6+AA5)	SC	1250
	GO TO(54,53,56,54,54,62),IP	SC	1260
53	DPH(K)=DPHSEC(K)	SC	1270
	GO TO 80	SC	1278
54	IR=6	SC	1280
C	COMPUTE THE AVERAGE HELIUM FLOW THAT WILL PRODUCE A	SC	1300
C	PRESSURE DROP OF DPH(K)	SC	1310
56	AP1=(DPH(K)-DPHSEC(K))/DPH(K)	SC	1320
	IF(CONVP-ABS(AP1))58,58,61	SC	1330
58	FHSC(K)=FHSC(K)*(DPH(K)/DPHSEC(K))**WNEW	SC	1340
	AA7=FHSC(K)/XM	SC	1350
	DO 60 J=1,M	SC	1360
	FH(J,K)=AA7	SC	1370
60	CONTINUE	SC	
	GO TO 1000	SC	1380
61	FHT(K)=FHSC(K)	SC	
	GO TO 80	SC	1390

C	COMPUTE THE HELIUM PRESSURE FOR EACH AXIAL INCREMENT	SC	1410
62	DPH(K)=DPHSEC(K)	SC	1420
64	IPRESS=IPRESS+1	SC	1425
	IFHX=1	SC	1430
	DO 74 J=1,M	SC	1440
	FHOA=FH(J,K)/AFHAV	SC	1450
	FHOA=ABS(FHCA)	SC	1451
	AAVOA2=(AFHAV/(AFH1*TUBE(N,K)/XM))**2	SC	1452
	AAVOA1=(AFHAV/(AFH1*TUBE(1,K)/XM))**2	SC	1454
	AA1=(TTPAVR(J)/THPAVR(J))**XBMU	SC	1460
	AA6=2.0*(THOUTR(J)-THINR(J))/THPAVR(J)+AAVOA2-AAVOA1	SC	1470
	HVIS=AMU*THPAVR(J)**BMU	SC	1480
	RE=DV(K)*FHCA/HVIS	SC	1490
	IF(200.0-RE)650,650,652	SC	1495
650	AA4=RE**0.144	SC	1500
	F=1.92/AA4	SC	1505
	GO TO 654	SC	1510
652	F=180.0/RE	SC	1514
654	AA5=F*DPASS(K)*XN*AA1*AA2*AA3/DV(K)	SC	1518
	DELPH(J,K)=FHOA**2*GAS*THPAVR(J)*(AA6+AA5)	SC	1520
	GO TO(69,69,69,74,68,68),IP	SC	1530
C	COMPUTE THE AVERAGE HELIUM FLOW FH(J,K) THAT WILL	SC	1540
C	PRODUCE A PRESSURE DROP OF DPH(K)	SC	1550
68	AP2=(DPH(K)-DELPH(J,K))/DPH(K)	SC	1560
	IF(CONVP-ABS(AP2))70,70,72	SC	1570
69	IR=7	SC	1574
	GO TO 2000	SC	1578
70	FH(J,K)=FH(J,K)*(DPH(K)/DELPH(J,K))**WNEW	SC	1580
	IFHX=2	SC	1590
72	FHTOT=FHTOT+FH(J,K)	SC	1600
74	CONTINUE	SC	1610
	IF(4-IP)75,80,770	SC	1615
75	IF(IFHX-1)76,76,1000	SC	1620
76	IF(IP-5)770,80,77	SC	1623
770	IR=8	SC	1626
	GO TO 2000	SC	1629
C	COMPUTE THE FLOW DISTRIBUTION AND PRESSURE DROP	SC	1630
C	ASSOCIATED WITH A TOTAL FLOW OF FHT(K)	SC	1640
77	AF1=(FHT(K)-FHTOT)/FHT(K)	SC	1650
	IF(CONVW-ABS(AF1))78,78,80	SC	1660
78	DPH(K)=DPH(K)*(FHT(K)/FHTOT)**PNEW	SC	1670
	GO TO 1000	SC	1680
2000	WRITE(6,2010)IR		
2010	FORMAT(14H1 SECTION ERROR,I4)		
80	RETURN	SC	1690
	END		

\$IBFTC GEOMET LIST,DECK,REF

SUBROUTINE GEOMET(I3,AFH1)

COMMON	AFHAV	,AFHMIN	,AFSP(10)	,CHD(10)	,COM	1
1CHT(10)	,CONVP	,CONVW,DELPH(20,10),DI(10),DO(10)			,COM	2
2DPASS(10)	,DPH(10)	,DPHSEC(10)	,DPS(10)	,DV(10)	,COM	3
3FH(20,10)	,FHJ(10)	,FHT(10)	,FHSC(10)	,	COM	4
4FRSR(10)	,FS(10)	,HSIN(10)	,HSOUT(10)	,IDEX	,COM	5
5IDROP(10)	,IFH(10)	,IPITCH(10)	,IPH(10)	,IPS(10)	,COM	6
6ITH(10)	,ITUBE(10)	,I	,IMAX(50)	,ISN	COM	7
COMMON	IXSIGN	,JMAX(20)	,K	,	COM	7A
7M	,MSEG(10)	,N	,NPASS(10),NSEC	,PHAV	,COM	8
8PHIN(10)	,PHOUT(10)	,PSIN(10)	,PSOUT(10)	,QCONV	,COM	9
9SD(10)	,SIGNH(10)	,SIGNP(10)	,SIGNS(10)		COM	10
COMMON	SL(10)	,ST(10)	,TCOL(10)	,TCNT	,COM	11
1THIN(20,10)	,THISC(10)	,THJ(20)	,THOSC(10)	,THOUT(20,10)	,COM	12
2THPAV(20)	,THSC(10)	,TNUM(10)	,TTL(60)	,TT(10)	,COM	13
3TTMAX(20)	,TTPAV(20)	,TTSC(10)	,TUBE(50,10)	,VOID(10)	,COM	14
4WPAS(10)	,XM	,XN	,XTTL	,TROW(10)	COM	15
COMMON/INCR1/ACP	,AHE	,AHSEG	,AKG		,INCR	1
1ALPHA	,AMU	,ANGLE	,ASEG	,ASSEG	,INCR	2
2ATUBE	,BCP	,BHE	,BKG	,BMU	,INCR	3
3BOLCOE	,BSIGNS	,CHI	,	DELPS	,INCR	4
4DELPSC	,DELTAV	,DIT	,DOT	,FHSEG	,INCR	5
5FHQA	,FLDR	,FSSEG	,HC(20)	,HGMAX	,INCR	6
6HP	,HSAV	,HSEXIT	,HSLIM	,HSSEG	,INCR	7
7HTC	,HVIS	,IREGON	,KROPAR	,PSEXIT	,INCR	8
8PSSEG	,QCONVA	,QUAL	,RH	,RS	INCR	9
COMMON/INCR2/RT	,SGMAX	,SCALE	,TEMPH		,INCR2	10
1THAV	,THEXIT	,THSEG	,TLSEG	,TN1	,INCR2	11
2TROWX	,TSAV	,TSSEG	,TTC	,TTISEG	,INCR2	12
3TTOSEG	,UAST	,UAHE			INCR2	13
COMMON /PRP/	CSI	,HSATS	,HSATW	,SPVOL	CPRP	1
C	AFA1	= MINIMUM FLOW AREA PER UNIT HEIGHT PER PASS			GE	
C	AFHAV	= AVERAGE HELIUM FLOW AREA PER INCREMENT FOR THE			GE	
C		ENTIRE SECTION			GE	
C	AFHD1	= DIAGONAL HELIUM FLOW AREA PER UNIT HEIGHT PER PASS			GE	
C	AFHT1	= TRANSVERSE HELIUM FLOW AREA PER UNIT HEIGHT PER PASS			GE	
C	AFSP(K)	= STEAM FLOW AREA PER PASS IN SECTION(K)			GE	
C	AHSEG	= HELIUM HEAT TRANSFER AREA			GE	
C	ASEG	= AVERAGE TUBE HEAT TRANSFER AREA			GE	
C	ASSEG	= STEAM HEAT TRANSFER AREA			GE	
C	ATUBE	= HELIUM FRICTION FACTOR COEFFICIENT			GE	
C		=0.33 STAGGERED TUBES			GE	
C		=0.26 INCLINED TUBES			GE	
C	CHD(K)	= NUMBER OF DIAGONAL HELIUM FLOW CHANNELS			GE	
C	CHT(K)	= NUMBER OF TRANSVERSE HELIUM FLOW CHANNELS			GE	
C	DI(K)	= INSIDE TUBE DIAMETER IN SECTION(K)			GE	
C	DO(K)	= OUTSIDE TUBE DIAMETER IN SECTION(K)			GE	
C	DV(K)	= VOLUMETRIC HYDRAULIC DIAMETER			GE	
C	FRSR(K)	= HELIUM FRICTION SURFACE AREA PER PASS PER UNIT HEIGHT			GE	

C	IPITCH(K)= 1 RECTANGULAR PITCH	GE	
C	= 2 TRIANGULAR PITCH	GE	
C	MSEG(K) = NUMBER OF AXIAL INCREMENTS IN SECTION(K)	GE	
C	PSDP(K) = DEPTH OF EACH PASS	GE	
C	SD(K) = DIAGONAL PITCH SPACING	GE	
C	SL(K) = LONGITUDINAL PITCH SPACING	GE	
C	ST(K) = TRANSVERSE PITCH	GE	
C	TCOL(K) = NUMBER OF TUBE COLUMNS PER PASS	GE	
C	TLSEG = LENGTH OF THE INCREMENT	GE	
C	TNUM(K) = NUMBER OF TUBES PER PASS IN SECTION(K)	GE	
C	TUBE(I,K)= LENGTH OF PASS I IN SECTION(K)	GE	
C	TROW(K) = NUMBER OF TUBE ROWS	GE	
C	TT(K) = TUBE WALL THICKNESS IN SECTION(K)	GE	
C	VOID(K) = HELIUM VOID VOLUME PER UNIT HEIGHT PER PASS	GE	
C	WPAS(K) = PASS WIDTH	GE	
	PHI=3.14159	GE	0040
	A11=TNUM(K)*PHI	GE	0060
	IGEO=13	GE	0070
	IF(IGEO-1)1,1,10	GE	0080
C	SECTION GEOMETRY	GE	0090
1	DI(K)=DO(K)-2.0*TT(K)	GE	0100
C	STEAM FLOW AREA AND MASS FLOW RATE PER PASS	GE	0110
	A1=A11*DI(K)	GE	0120
	A2=A11*DO(K)	GE	0130
	AFSP(K)=A1*DI(K)/4.0	GE	0140
C	TRANSVERSE CHANNELS	GE	0150
	CHT(K) = TCOL(K)/2.0	GE	0160
C	DIAGONAL CHANNELS	GE	0170
	CHD(K)=2.0*CHT(K)	GE	0180
C	DIAGONAL PITCH	GE	0190
	A3=(ST(K)/2.0)**2+SL(K)**2	GE	0200
	SD(K)=A3**.5	GE	0210
	AFHT1=CHT(K)*{(ST(K)-DO(K))	GE	0220
	IF(IPITCH(K)-1)4,4,5	GE	0230
C	RECTANGULAR PITCH, WIDTH OF PASS	GE	0240
4	WPAS(K)=(TCOL(K))*ST(K)	GE	0250
	ATUBE=0.26	GE	0255
	SD(K)=ST(K)	GE	0260
	AFHD1=10.0*AFHT1	GE	0270
	GO TO 8	GE	0280
C	TRIANGULAR PITCH, WIDTH OF PASS	GE	0290
5	WPAS(K)=(TCOL(K))*ST(K)/2.0	GE	0300
	ATUBE=0.33	GE	0305
	AFHD1=CHD(K)*{(SD(K)-DO(K))	GE	0310
8	DPASS(K)=(TROW(K))*SL(K)	GE	0320
C	VOID VOLUME PER UNIT HEIGHT PER PASS	GE	0330
	VOID(K)=DPASS(K)*WPAS(K)-A2*DO(K)/4.0	GE	0340
	AFH1=AMIN1(AFHT1,AFHD1)	GE	0350
	FRICTION SURFACE AREA PER UNIT HEIGHT PER PASS	GE	0360
	FRSR(K)=A2	GE	0370

	A4=ALOG(DO(K)/DI(K))	GE	0380
	ASEG1=A11*(DO(K)-DI(K))/A4	GE	0390
C	VOLUMETRIC HYDRAULIC DIAMETER	GE	0400
	DV(K)=4.0*VOID(K)/FRSR(K)	GE	0410
	GO TO 12	GE	0420
C	PASS GEOMETRY	GE	0430
10	XMSEG=MSEG(K)	GE	0435
	TLSEG=TUBE(I,K)/XMSEG	GE	0440
	ASSEG=A1*TLSEG	GE	0450
	AFHMIN=AFH1*TLSEG	GE	0460
	AFHAV=AFHAV+AFHMIN	GE	0470
	AHSEG=A2*TLSEG	GE	0480
	ASEG=ASEG1*TLSEG	GE	0490
12	RETURN	GE	0500
	END	GE	0510

\$IBFTC HEAT LIST,DECK,REF
SUBROUTINE HEAT

HT 0020

C
C HEAT ER 1...ASEG IS NEGATIVE AT STA. 2.
C HEAT ER 2...DELTAV ITERATIONS EXCEEDED 40.
C
C HEAT ER 3...HSLIM IS NEGATIVE AT STA. 57.

COMMON/INCR1/ACP	,AHE	,AHSEG	,AKG	,INCR	1
1ALPHA	,AMU	,ANGLE	,ASEG	,INCR	2
2ATUBE	,BCP	,BHE	,BKG	,INCR	3
3BOLCOE	,BSIGNS	,CHI		,INCR	4
4DELPS	,DELTAV	,DIT	,DOT	,INCR	5
5FHOA	,FLDR	,FSSEG	,HC(20)	,INCR	6
6HP	,HSAV	,HSEXIT	,HSLIM	,INCR	7
7HTC	,HVIS	,IREGON	,KROPAR	,INCR	8
8PSSEG	,QCONVA	,QUAL	,RH	,INCR	9
COMMON/INCR2/RT	,SGMAX	,SCALE	,TEMPH	,INCR2	10
1THAV	,THEXIT	,THSEG	,TLSEG	,INCR2	11
2TROWX	,TSAV	,TSSEG	,TTC	,INCR2	12
3TTSE	,UAST	,UAHE		,INCR2	13

COMMON /PRP/ CSI ,HSATS ,HSATW ,SPVOL
DIMENSION HSXX(3),HSX(3),IPOS(3)

C	ALPHA	= SUBDIVISION FLAG AND FRACTION OF THE INCREMENT	HT	0030
C	ALPHA0	= ALPHA OF PREVIOUS ITERATION	HT	0040
C	ALPHCO	= QCONV	HT	0050
C	ASEG	= HEAT TRANSFER AREA OF CURRENT SEGMENT	HT	0060
C	ASEGO	= HEAT TRANSFER AREA OF PREVIOUS ITERATION	HT	0070
C	CHI	= HELIUM INVERSE SPECIFIC HEAT	HT	0080
C	CSI	= STEAM INVERSE SPECIFIC HEAT	HT	0090
C	DELDEL	= CONVERGENCE RATIO FOR DELTAV	HT	0100
C	DELT	= DELTAV OF LAST ITERATION	HT	0110
C	DELTAV	= AVERAGE TEMPERATURE DIFFERENCE BETWEEN GAS AND STEAM	HT	0120
C	FHSEG	= HELIUM FLOW OF CURRENT SEGMENT	HT	0130
C	FHSEGO	= HELIUM FLOW FOR PREVIOUS ITERATION	HT	0140
C	FSSEG	= STEAM FLOW	HT	0150
C	FUN1	= HEAT TRANSFER RESISTANCE FOR SUBCOOLED AND SUPERCRITICAL WATER	HT	0160
C	FUN2	= HEAT TRANSFER RESISTANCE FOR BOILING WATER	HT	0170
C	FUN3	= HEAT TRANSFER RESISTANCE FOR TRANSITION BOILING WATER	HT	0180
C	FUN4	= HEAT TRANSFER RESISTANCE FOR SUPERHEATED STEAM	HT	0190
C	FUN5	= HEAT TRANSFER RESISTANCE FOR THE TUBE	HT	0200
C	FUN6	= HEAT TRANSFER RESISTANCE FOR HELIUM	HT	0210
C	HP	= DIVISION ENTHALPY BETWEEN BOILING AND THE TRANSITION BETWEEN BOILING AND SUPERHEATED STEAM	HT	0220
C	HSLIM	= EXIT ENTHALPY OF A SUBDIVIDED INCREMENT OR ZERO	HT	0230
C	HSATS	= ENTHALPY OF SATURATED WATER	HT	0240
C	HSAV	= INCREMENT AVERAGE ENTHALPY	HT	0250
C	HSSEG	= INLET ENTHALPY OF CURRENT SEGEMENT	HT	0260
C	HSXX(1)	= HSATS	HT	0270
C	HSXX(2)	= HP	HT	0280

C	HSXX(3)	= HSATW	HT	0310
C	HSX(1)	= HELIUM ENTHALPY AT THE SEGMENT EXIT	HT	0320
C	HSX(2)	= HELIUM ENTHALPY AT THE SEGMENT INLET	HT	0330
C	HSEXIT	= STEAM ENTHALPY AT THE SEGMENT EXIT	HT	0340
C	IPOS(M)	= SUBDIVISION POSTION(1-49)	HT	0350
C	IREGON	= STEAM REGION FOR PRESSURE DROP	HT	
C		IREGON = 1 SUBCOOLED OR SUPERCRITICAL	HT	
C		IREGON = 2 SATURATED	HT	
C		IREGON = 3 SUPERHEATED	HT	
C	ITRANS	= SUBDIVISION COMPUTED GO TO	HT	0360
C	ITRY1	= SUBDIVISION ITERATION NUMBER (40MAX)	HT	0370
C	KROPAR	= 0 PARALLEL FLOW,=1 CROSSFLOW	HT	0380
C	PSEXIT	= COMPUTED STEAM PRESSURE	HT	
C	PSSEG	= AVERAGE SEGMENT PRESSURE	HT	0390
C	QCONV	= CONVERGENCE CRITERIA	HT	0400
C	QUAL	= QUALITY AT ENTHALPY HP	HT	0410
C	RH	= HELIUM RESISTANCE	HT	0420
C	RS	= STEAM RESISTANCE	HT	0430
C	RT	= TUBE RESISTANCE	HT	0440
C	TEMP	= SUBROUTINE FOR COMPUTING STEAM THERMODYNAMIC	HT	0450
C		PROPERTIES	HT	0455
C	THSEG	= INCREMENT INLET HELIUM TEMPERATURE	HT	0470
C	THEXIT	= HELIUM TEMPERATURE AT THE INCREMENT EXIT	HT	0480
C	THINLT	= HELIUM TEMPERATURE AT THE INCREMENT INLET	HT	0490
C	TSAV	= AVERAGE STEAM TEMPERATURE	HT	0500
C	TSSEG	= INCREMENT INLET STEAM TEMPERATURE	HT	0510
C	TTISEG	= INSIDE TUBE TEMPERATURE	HT	0520
C	TEMPH	= MAXIMUM TUBE TEMPERATURE	HT	0530
C	TTOSEG	= OUTSIDE TUBE TEMPERATURE	HT	0540
C	U	= OVERALL HEAT TRANSFER COEFFICIENT	HT	0550
C	UAA	= $-U*ASEG*CHI/FHSEG$	HT	0560
C	UAB	= $-U*ASEG*CSI/FSSEG$	HT	0570
C	UAHE	= $UAA/(EXP(UAA)-1.0)$	HT	0580
C	UAST	= $UAB/(EXP(UAB)-1.0)$	HT	0590
C	X	= PARALLEL FLOW VARIABLE	HT	0600
C	Y	= ASEG	HT	0610
	HCP	= $ACP+BCP*THSEG$	HT	0614
	CHI	= $1.0/HCP$	HT	0616
	ARSRAT	= $ASEG/ASSEG$	HT	0617
	ARHRAT	= $ASEG/AHSEG$	HT	0618
	QCONV	= QCONVA	HT	0620
	ASEGO	= ASEG	HT	0622
	ASEGIN	= ASEG	HT	0624
	TLSEGO	= TLSEG	HT	0626
	TLSGIN	= TLSEG	HT	0628
	THINLT	= THSEG	HT	0630
	HSINLT	= HSSEG	HT	0640
	FHINLT	= FHSEG	HT	0650
	FHSEGO	= FHSEG	HT	0654
	PSINLT	= PSSEG	HT	0658

	UAB LIM= (QCONV/.2)**.5	HT	0690
	ALPHCO=QCONV	HT	0700
	ALPHA0=1.0	HT	0710
	ITRY1=0	HT	0720
C	STEAM TEMPERATURE, INVERSE SPECIFIC HEAT AND LIMITING VALUES OF	HT	0730
C	HSATS AND HSATW ARE NOW COMPUTED (MUST BE IN COMMON)	HT	0740
C	-----	HT	0750
	CALL TEMP(HSSEG,PSSEG,TSSEG)	HT	0760
	IF(ASEG)2,3,4	HT	0770
2	IR=1	HT	0780
	GO TO 2000	HT	0790
3	ALPHA=1.0	HT	0800
	HSLIM=0.0	HT	0810
	GO TO 54	HT	0820
4	CONTINUE	HT	0830
C	INTERMEDIATE ENTHALPY	HT	0840
	HP=QUAL*HSATS+(1.0-QUAL)*HSATW	HT	0850
	HSXX(1)=HSATS	HT	0860
	HSXX(2)=HP	HT	0870
	HSXX(3)=HSATW	HT	0880
	ALPHA=1.0	HT	0890
C	CONVERGED SUBDIVISION ITERATION RETURN POINT(STATEMENT 66)	HT	0894
C	KNOWN INCREMENT ENTHALPY	HT	0896
600	HSX(2)=HSSEG	HT	0900
	CALL TEMP(HSSEG,PSSEG,TSSEG)	HT	0910
C	AVERAGE TEMPERATURE DIFFERENCE	HT	0920
C	SUBDIVISION ITERATION RETURN	HT	0930
C	SUBDIVISION ITERATION RETURN POINT(STATEMENT 61)	HT	0935
601	DELTAV=(THSEG-TSSEG)/(UAHE+UAST-1.0)	HT	0940
C	DELTAV ITERATION RETURN POINT(STATEMENT 52)	HT	0975
C	DELTAV ITERATION RETURN POINT	HT	0970
610	IF(KROPAR)7,7,11	HT	0980
C	PARALLEL FLOW-	HT	0990
7	UAB=-U*ASEG*(CHI/FHSEG+CSI/FSSEG)	HT	1000
	IF(ABS(UAB)-UAB LIM)8,9,9	HT	1010
8	X=-U*ASEG*(THSEG-TSSEG)*(3.0+UAB)/6.0	HT	1020
	GO TO 10	HT	1030
9	X=U*ASEG*DELTAV*(UAST-1.0)/UAB	HT	1040
C	AVERAGE HELIUM TEMPERATURE	HT	1050
10	THAV=THSEG+X*CHI/FHSEG	HT	1060
C	AVERAGE STEAM ENTHALPY	HT	1070
	HSXAV=HSSEG-X/FSSEG	HT	1080
	GO TO 14	HT	1090
C	CROSS FLOW	HT	1100
C	AVERAGE HELIUM TEMPERATURE	HT	1110
11	THAV=(THSEG*UAST+TSSEG*(UAHE-1.0))/(UAHE+UAST-1.0)	HT	1120
C	HELIUM RESISTANCE	HT	1130
	UAB=-U*ASEG*CSI/FSSEG	HT	1160
	IF(CSI)12,12,13	HT	1170
	AVERAGE STEAM ENTHALPY FOR AN UNSUBDIVIDED INCREMENT	HT	1180

12	HSAV=HSSEG+.5*U*ASEG*DELTAV/FSSEG	HT	1190
	GO TO 14	HT	1200
13	HSAV=HSSEG+DELTAV*(UAST-1.0)/CSI	HT	1210
14	CONTINUE	HT	1220
C	HELIUM SIDE TUBE TEMPERATURE	HT	1230
	TTASEG=THAV-RH*U*DELTAV	HT	1240
C	STEAM SIDE TUBE TEMPERATURE	HT	1250
	TTISEG=THAV-(RH+RT)*U*DELTAV	HT	1260
C	INCREMENT EXIT STEAM ENTHALPY	HT	1270
C	COMPUTED ENTHALPY	HT	1275
	HSX(1)=HSSEG+U*ASEG*DELTAV/FSSEG	HT	1280
C	CHECK FOR SUPERCRITICAL PRESSURE	HT	1290
	IF(PSSSEG-4.61693E+05)18,18,26	HT	1300
C	DETERMINATION OF POSITION HSX(1),HSX(2)	HT	1310
18	DO 22 M=1,2	HT	1320
	DO 21 N=1,3	HT	1330
	IF(HSXX(N)-HSX(M))19,20,21	HT	1340
19	IPOS(M)=9-N-N	HT	1350
	GO TO 22	HT	1360
20	IPOS(M)=8-N-N	HT	1370
	GO TO 22	HT	1380
21	CONTINUE	HT	1390
	IPOS(M)=1	HT	1400
22	CONTINUE	HT	1410
	ITRANS=(IPOS(2)-1)*7+IPOS(1)	HT	1420
	IF(ALPHA-1.0)221,220,220	HT	1430
220	HSLIM=0.0	HT	1440
221	IF(ABS(UAB)-UABLIM)23,24,24	HT	1450
23	GO TO(36,36,35,35,35,35,35,36,36,39,39,38,38,38,37,39,39,39,38,38,	HT	1460
	138,37,39,39,39,42,42,40,41,41,41,42,42,42,40,41,41,41,42,42,44,44,	HT	1470
	243,43,43,43,43,44,44),ITRANS	HT	1480
24	GO TO(26,26,25,25,25,25,25,26,26,29,29,27,27,27,28,29,29,29,27,27,	HT	1490
	127,28,29,29,29,32,32,30,31,31,31,32,32,32,30,31,31,31,32,32,34,34,	HT	1500
	233,33,33,33,33,34,34),ITRANS	HT	1510
25	HSAV=HSSEG-(UAST-1.0)*(HSATW-HSSEG)/UAB	HT	1520
	HSLIM=HSXX(3)	HT	1530
26	CALL TEMP(HSAV,PSSEG,TSAV)	HT	1540
C	STEAM SIDE RESISTANCE WATER	HT	1550
	CALL FUN1	HT	1560
	IREGON=1	HT	1565
	GO TO 45	HT	1570
27	HSAV=HSSEG-(UAST-1.0)*(HP-HSSEG)/UAB	HT	1580
	HSLIM=HSXX(2)	HT	1590
	GO TO 29	HT	1600
28	HSAV=HSSEG-(UAST-1.0)*(HSATW-HSSEG)/UAB	HT	1610
	HSLIM=HSXX(3)	HT	1620
29	CALL TEMP(HSAV,PSSEG,TSAV)	HT	1630
C	STEAM SIDE RESISTANCE, 2 PHASE, BELOW HP	HT	1640
	CALL FUN2	HT	1650
	IREGON=2	HT	1655

	GO TO 45	HT	1660
	30 HSAV=HSSEG-(UAST-1.0)*{HSATS-HSSEG)	HT	1670
	HSLIM=HSXX(1)	HT	1680
	GO TO 32	HT	1690
	31 HSAV=HSSEG-{UAST-1.0)*{HP-HSSEG)	HT	1700
	HSLIM=HSXX(2)	HT	1710
	32 CALL TEMP(HSAV,PSSEG,TSAV)	HT	1720
C	STEAM SIDE RESISTANCE, 2 PHASE, ABOVE HP	HT	1730
	CALL FUN3	HT	1740
	IREGON=2	HT	1745
	GO TO 45	HT	1750
	33 HSAV=HSSEG-{UAST-1.0)*{HSATS-HSSEG)/UAB	HT	1760
	HSLIM=HSXX(1)	HT	1770
	34 CALL TEMP(HSAV,PSSEG,TSAV)	HT	1780
C	STEAM SIDE RESISTANCE, STEAM	HT	1790
	CALL FUN4	HT	1800
	IREGON=3	HT	1805
	GO TO 45	HT	1810
	35 HSAV=HSSEG+UAST*(3.0+UAB)*{HSATW-HSSEG)/6.0	HT	1820
	HSLIM=HSXX(3)	HT	1830
	36 CALL TEMP(HSAV,PSSEG,TSAV)	HT	1840
C	STEAM SIDE RESISTANCE, WATER	HT	1850
	CALL FUN1	HT	1860
	IREGON=1	HT	1865
	GO TO 45	HT	1870
	37 HSAV=HSSEG+UAST*(3.0+UAB)*{HSATW-HSSEG)/6.0	HT	1880
	HSLIM=HSXX(3)	HT	1890
	GO TO 39	HT	1900
	38 HSAV=HSSEG+UAST*(3.0+UAB)*{HP-HSSEG)/6.0	HT	1910
	HSLIM=HSXX(2)	HT	1920
	39 CALL TEMP(HSAV,PSSEG,TSAV)	HT	1930
C	STEAM SIDE RESISTANCE, 2 PHASE, BELOW HP	HT	1940
	CALL FUN2	HT	1950
	IREGON=2	HT	1955
	GO TO 45	HT	1960
	40 HSAV=HSSEG+UAST*(3.0+UAB)*{HSATS-HSSEG)/6.0	HT	1970
	HSLIM=HSXX(1)	HT	1980
	GO TO 42	HT	1990
	41 HSAV=HSSEG+UAST*(3.0+UAB)*{HP-HSSEG)/6.0	HT	2000
	HSLIM=HSXX(2)	HT	2010
	42 CALL TEMP(HSAV,PSSEG,TSAV)	HT	2020
C	STEAM SIDE RESISTANCE, 2 PHASE, ABOVE HP	HT	2030
	CALL FUN3	HT	2040
	IREGON=2	HT	2045
	GO TO 45	HT	2050
	43 HSAV=HSSEG+UAST*(3.0+UAB)*{HSATS-HSSEG)/6.0	HT	2060
	HSLIM=HSXX(1)	HT	2070
	44 CALL TEMP(HSAV,PSSEG,TSAV)	HT	2080
	STEAM SIDE RESISTANCE STEAM	HT	2090
	CALL FUN4	HT	2100

	IREGON=3	HT	2110
C	OVER ALL RESISTANCE	HT	2120
C	TUBE RESISTANCE AND HELIUM RESISTANCE	HT	2124
45	CALL FUN5	HT	2125
	CALL FUN6	HT	2130
	RSA=RS*ARSRAT	HT	2132
	RHA=ARHRAT*RH	HT	2134
	U=1.0/(RHA+RSA+RT)	HT	2135
C	COMPUTATION OF SEGMENT HEAT TRANSFER EFFECTIVENESS.	HT	2140
	IF(KROPAR)46,46,47	HT	2150
C	PARALLEL FLOW	HT	2160
46	UAA=0.0	HT	2170
	UAHE=1.0	HT	2180
	UAB=-U*ASEG*(CHI/FHSEG+CSI/FSSEG)	HT	2190
	GO TO 50	HT	2200
C	CROSS FLOW	HT	2210
47	UAA=-U*ASEG*CHI/FHSEG	HT	2220
	UAB=-U*ASEG*CSI/FSSEG	HT	2230
	IF(ABS(UAA)-UAB LIM)48,49,49	HT	2240
48	UAHE=1.0-.5*UAA	HT	2250
	GO TO 50	HT	2260
49	UAHE=UAA/(EXP(UAA)-1.0)	HT	2270
50	IF(ABS(UAB)-UAB LIM)500,501,501	HT	2280
500	UAST=1.0-.5*UAB	HT	2290
	GO TO 502	HT	2300
501	UAST=UAB/(EXP(UAB)-1.0)	HT	2310
502	CONTINUE	HT	2320
C	COMPUTATION OF AVERAGE TEMPERATURE DIFFERENCE	HT	2330
51	DELT=DELTAV	HT	2340
	DELTAV=(THSEG-TSSEG)/(UAHE+UAST-1.0)	HT	2350
	DELDEL=(DELTAV-DELT)/DELT	HT	2360
	IF(ABS(DELDEL)-QCONV)54,52,52	HT	2370
52	ITRY1=ITRY1+1	HT	2380
	IF(ITRY1-40)610,610,53	HT	2390
53	IR=2	HT	2400
	GO TO 2000	HT	2410
C	ENTHALPY OF EXIT STEAM FROM SEGMENT	HT	2420
54	HSEXIT=HSSEG+U*ASEG*DELTAV/FSSEG	HT	2430
C	TUBE TEMPERATURE OF SEGMENT	HT	2440
	TEMPH=AMAX1(TT0SEG,TTISEG)	HT	2450
C	DECIDE IF SEGMENT IS ALREADY SUBDIVIDED	HT	2460
541	IF(ALPHA-1.0)58,56,55	HT	2470
55	TEMPH=TSV	HT	2480
56	IF(HSLIM)57,66,58	HT	2490
57	IR=3	HT	2500
	GO TO 2000	HT	2510
58	ALPHA=ABS(FSSEG*(HSLIM-HSSEG)*(UAHE+UAST-1.0)/U/	HT	2520
	1ASEGO/(THSEG-TSSEG))	HT	2530
	ALPHA CONVERGENCE	HT	2540
	IF(ABS(ALPHA-ALPHA0)-ALPHCO)62,59,59	HT	2550

C	ALPHA HAS NOT CONVERGED	HT	2560
C	COMPUTE SUBDIVIDED HEAT TRANSFER AREA	HT	2565
59	ASEG=ALPHA*ASEGO	HT	2570
	IF(KROPAR)61,61,60	HT	2580
C	CROSS FLOW	HT	2590
C	COMPUTE SUBDIVIDED HELIUM FLOW RATE	HT	2595
60	FHSEG=ALPHA*FHSEGO	HT	2600
C	PARALLEL FLOW	HT	2610
61	ALPHA0=ALPHA	HT	2620
	GO TO 601	HT	2630
C	ALPHA IS CONVERGED	HT	2640
C	COMPUTE SUBDIVIDED SEGMENT LENGTH	HT	2644
62	TLSEG=TLSEGC*ALPHA	HT	2650
	CALL DROPS	HT	2654
	PSSEG=PSSEG-DELPS	HT	2656
	AA1=(1.0-ALPHA)	HT	2660
	ASEG=AA1*ASEGO	HT	2662
	ASEGO=ASEG	HT	2664
	TLSEG=TLSEGO*AA1	HT	2666
	TLSEGO=TLSEG	HT	2668
	IF(KROPAR)63,63,64	HT	2670
C	PARALLEL FLOW	HT	2680
63	THSEG=THSEG-CHI*FSSEG*(HSLIM-HSSEG)/FHSEG	HT	2690
	GO TO 65	HT	2700
C	CROSS FLOW	HT	2710
64	FHSEG=(1.0-ALPHA)*FHSEGO	HT	2720
	FHSEGO=FHSEG	HT	2730
65	HSSEG=HSLIM	HT	2740
	ALPHA0=1.0	HT	2750
	ALPHA=2.0	HT	2760
	GO TO 600	HT	2770
66	CALL DROPS	HT	2780
	PSEXIT=PSSEG-DELPS	HT	2782
	DELPSC=PSINLT-PSEXIT	HT	2784
	ASEG=ASEGIN	HT	2786
	THSEG=THINLT	HT	2788
	TLSEG=TLSGIN	HT	2789
	FHSEG=FHINLT	HT	2790
	HSSEG=HSINLT	HT	2800
	THEXIT=THSEG-CHI*(HSEXIT-HSSEG)/FHSEG*FSSEG	HT	2810
	RETURN	HT	2820
2000	CALL ERROR(6HHEAT , IR)	HT	2825
	END	HT	2830

\$IBFTC FUN1 LIST,DECK,REF

	SUBROUTINE FUN 1				FN1 0020
	COMMON/INCR1/ACP	,AHE	,AHSEG	,AKG	,INCR 1
	1ALPHA	,AMU	,ANGLE	,ASEG	,INCR 2
	2ATUBE	,BCP	,BHE	,BKG	,INCR 3
	3BOLCOE	,BSIGNS	,CHI	,DELPS	,INCR 4
	4DELPSC	,DELTAV	,DIT	,DOT	,INCR 5
	5FHQA	,FLDR	,FSSEG	,HC(20)	,INCR 6
	6HP	,HSAV	,HSEXIT	,HSLIM	,INCR 7
	7HTC	,HVIS	,IREGON	,KROPAR	,INCR 8
	8PSSEG	,QCONVA	,QUAL	,RH	,INCR 9
	COMMON/INCR2/RT	,SGMAX	,SCALE	,TEMPH	,INCR2 10
	1THAV	,THEXIT	,THSEG	,TLSEG	,INCR2 11
	2TROWX	,TSAV	,TSSEG	,TTC	,INCR2 12
	3TTISEG	,UAST	,UAHE		,INCR2 13
	COMMON /PRP/ CSI ,HSATS ,HSATW ,SPVOL				CPRP 1
C	SUBCOOLED OR SUPERCRITICAL H2O FILM RESISTANCE				FN1 0030
C	ANU	= NUSSELT NUMBER			FN1 0040
C	ANUT	= NUSSELT NUMBER AT A REYNOLDS NUMBER OF 15000			FN1 0050
C	CSI	= STEAM INVERSE SPECIFIC HEAT			FN1 0060
C	D1	= HYDRAULIC DIAMETER/CONDUCTIVITY			FN1 0070
C	IA1	= SUBROUTINEPROPFLAG,1SUBCOOLED,2SUPERHEAT,3SUPERCRITIC			FN1 0080
C	PR	= (PRANDLT NO.)*0.4			FN1 0090
C	RS	= STEAM FILM PLUS SCALE RESISTANCE			FN1 0100
C	SA	= COEFFICIENT IN THE EQUATION ANU=SA*SRE**SB			FN1 0110
C	SB	= EXPONENT IN THE EQUATION ANU=SA*SRE**SB			FN1 0120
C	SRE	= REYNOLDS NUMBER			FN1 0130
C	SVIS	= STEAM VISCOSITY			FN1 0140
C	STC	= STEAM THERMAL CONDUCTIVITY			FN1 0150
C	SUBROUTINE PROPS COMPUTES THE VISCOSITY AND CONDUCTIVITY				FN1 0180
C	OF WATER AND STEAM				FN1 0190
4	CALL PROPS(PSEG,IREGON,TSAV,HSAV,A1,A2)				FN1 0200
	STC=A1				FN1 0210
	SVIS=A2				FN1 0220
	SRE=DIT*SGMAX/SVIS				FN1 0230
	D1=DIT/STC				FN1 0240
	IF(SRE-2000.0)6,8,8				FN1 0250
6	RS=D1/4.0+1.0/SCALE				FN1 0260
	GO TO 14				FN1 0270
8	PR=(SVIS/(CSI*STC))*0.4				FN1 0280
	IF(15000.0-SRE)10,10,12				FN1 0290
10	ANU=0.021*SRE**0.8*PR				FN1 0300
	RS=D1/ANU+1.0/SCALE				FN1 0310
	GO TO 14				FN1 0320
12	ANUT=0.021*PR*15000.0**0.8/4.0				FN1 0330
	SB=ALOG(ANUT)/ALOG(7.5)				FN1 0340
	SA=4.0/(2000.0)**SB				FN1 0350
	ANU=SA*SRE**SB				FN1 0360
	RS=D1/ANU+1.0/SCALE				FN1 0370
14	RETURN				FN1 0390

END

FN1 0390

\$IBFTC FUN2 LIST,DECK,REF

SUBROUTINE FUN2

COMMON/INCR1/ACP

1ALPHA ,AMU
2ATUBE ,BCP
3BOLCOE ,BSIGNS
4DELPSC ,DELTAV
5FHDA ,FLDR
6HP ,HSAV
7HTC ,HVIS
8PSSEG ,QCONVA
COMMON/INCR2/RT
1THAV ,THEXIT
2TROWX ,TSAV
3TTDSEG ,UAST

,AHE ,AHSEG
,ANGLE ,ASEG
,BHE ,BKG
,CHI ,
,DIT ,DOT
,FSSEG ,HC(20)
,HSEXIT ,HSLIM
,IREGON ,KROPAR
,QUAL ,RH
,SGMAX ,SCALE
,THSEG ,TLSEG
,TSSEG ,TTC
,UAHE

,AKG
,ASSEG
,BMU
DELPS
,FHSEG
,HGMAX
,HSSEG
,PSEXIT
,RS
,TEMPH
,TN1
,TTISEG

FN2 0020

,INCR 1

,INCR 2

,INCR 3

,INCR 4

,INCR 5

,INCR 6

,INCR 7

,INCR 8

INCR 9

,INCR2 10

,INCR2 11

,INCR2 12

INCR2 13

COMMON /PRP/ CSI ,HSATS ,HSATW ,SPVOL

CPRP 1

BOILING REGION BELOW HP FILM RESISTANCE

FN2 0030

BOLCOE = BOILING FILM COEFFICIENT

FN2 0040

RS = STEAM FILM RESISTANCE PLUS SCALE RESISTANCE

FN2 0050

SCALE(K) = SCALE FILM COEFFICIENT

FN2 0060

RS=1.0/BOLCOE+1.0/SCALE

FN2 0070

RETURN

FN2 0080

END

FN2 0090

\$IBFTC FUN3 LIST,DECK,REF

SUBROUTINE FUN3

COMMON/INCR1/ACP

1ALPHA ,AMU
2ATUBE ,BCP
3BOLCOE ,BSIGNS
4DELPSC ,DELTAV
5FHOA ,FLDR
6HP ,HSAV
7HTC ,HVIS
8PSSEG ,QCONVA
COMMON/INCR2/RT
1THAV ,THEXIT
2TROWX ,TSAV
3TTOSEG ,UAST

,AHE ,AHSEG
,ANGLE ,ASEG
,BHE ,BKG
,CHI ,
,DIT ,DOT
,FSSEG ,HC(20)
,HSEXIT ,HSLIM
,IREGON ,KROPAR
,QUAL ,RH
,SGMAX ,SCALE
,THSEG ,TLSEG
,TSSEG ,TTC
,UAHE

,AKG
,ASSEG
,BMU
DELPS
,FHSEG
,HGMAX
,HSSEG
,PSEXIT
,RS
,TEMPH
,TN1
,TTISEG

FN3 0020
, INCR 1
, INCR 2
, INCR 3
, INCR 4
, INCR 5
, INCR 6
, INCR 7
, INCR 8
, INCR 9
, INCR2 10
, INCR2 11
, INCR2 12
INCR2 13
CPRP 1
FN3 028
FN3 030
FN3 035
FN3 040
FN3 050
FN3 060
FN3 090
FN3 100
FN3 110
FN3 120
FN3 130

COMMON /PRP/ CSI ,HSATS ,HSATW ,SPVOL

X = HSATS + QCONVA*(HSATS-HP)

HSAV1 = HSAV

HSAV=X

CALL FUN4

HSAV = HSAV1

CALL TEMP(HSAV,PSSEG,T1)

X = RS

RS=1.0/300.0

RS = RS + (X-RS)*(HSAV-HP)/(HSATS-HP)

RETURN

END

\$IBFTC FUN4 LIST,DECK,REF

SUBROUTINE FUN 4

COMMON/INCR1/ACP

1ALPHA	,AMU	,AHE	,AHSEG	,AKG
2ATUBE	,BCP	,ANGLE	,ASEG	,ASSEG
3BOLCOE	,BSIGNS	,BHE	,BKG	,BMU
4DELPSC	,DELTAV	,CHI	,	DELPS
5FHOA	,FLDR	,DIT	,DOT	,FHSEG
6HP	,HSAV	,FSSEG	,HC(20)	,HGMAX
7HTC	,HVIS	,HSEXIT	,HSLIM	,HSSEG
8PSSEG	,QCONVA	,IREGON	,KROPAR	,PSEXIT
		,QUAL	,RH	,RS
		,SGMAX	,SCALE	,TEMPH
1THAV	,THEXIT	,THSEG	,TLSEG	,TN1
2TROWX	,TSAV	,TSSEG	,TTC	,TTISEG
3TTTOSEG	,UAST	,UAHE		

COMMON /PRP/ CSI ,HSATS ,HSATW ,SPVOL

SUPERHEATED STEAM FILM RESISTANCE

C	ANU	= NUSSELT NUMBER	FN4 0020
C	ANUT	= NUSSELT NUMBER AT A REYNOLDS NUMBER OF 15000	FN4 0030
C	CSI	= STEAM INVERSE SPECIFIC HEAT	FN4 0040
C	D1	= HYDRAULIC DIAMETER/CONDUCTIVITY	FN4 0050
C	IA1	= SUBROUTINEPROPFLAG,1SUBCOOLED,2SUPERHEAT,3SUPERCRITIC	FN4 0060
C	PR	= (PRANDLT NO.)**0.4	FN4 0070
C	RS	= STEAM FILM PLUS SCALE RESISTANCE	FN4 0080
C	SA	= COEFFICIENT IN THE EQUATION ANU=SA*SRE**SB	FN4 0090
C	SB	= EXPONENT IN THE EQUATION ANU=SA*SRE**SB	FN4 0100
C	SRE	= REYNOLDS NUMBER	FN4 0110
C	SVIS	= STEAM VISCOSITY	FN4 0120
C	STC	= STEAM THERMAL CONDUCTIVITY	FN4 0130
	CALL PROPS(PSSSEG,IREGON,TSAV,HSAV,A1,A2)		FN4 0140
	STC=A1		FN4 0150
	SVIS=A2		FN4 0160
	SRE=DIT*SGMAX/SVIS		FN4 0170
	D1=DIT /STC		FN4 0180
	IF(SRE-2000.0)1,2,2		FN4 0190
1	RS=D1/4.0+1.0/SCALE		FN4 0200
	GO TO 8		FN4 0210
2	PR=(SVIS/(CSI*STC))**0.4		FN4 0220
	IF(15000.0-SRE)4,4,6		FN4 0230
4	ANU=0.023*SRE**0.8*PR		FN4 0240
	RS=D1/ANU+1.0/SCALE		FN4 0250
	GO TO 8		FN4 0260
6	ANUT=0.023*PR*15000.0**0.8/4.0		FN4 0270
	SB=ALOG(ANUT)/ALOG(7.5)		FN4 0280
	SA=4.0/(2000.0)**SB		FN4 0290
	ANU=SA*SRE**SB		FN4 0300
	RS=D1/ANU+1.0/SCALE		FN4 0310
8	RETURN		FN4 0320
	END		FN4 0340

\$IBFTC FUN5 LIST,DECK,REF

SUBROUTINE FUN5

COMMON/INCR1/ACP

1ALPHA ,AMU
2ATUBE ,BCP
3BOLCOE ,BSIGNS
4DELPSC ,DELTAV
5FHOA ,FLDR
6HP ,HSAV
7HTC ,HVIS
8PSSEG ,QCONVA
COMMON/INCR2/RT
1THAV ,THEXIT
2TROWX ,TSAV
3TTISEG ,UAST

,AHE ,AHSEG
,ANGLE ,ASEG
,BHE ,BKG
,CHI ,
,DIT ,DOT
,FSSEG ,HC(20)
,HSEXIT ,HSLIM
,IREGON ,KROPAR
,QUAL ,RH
,SGMAX ,SCALE
,THSEG ,TLSEG
,TSSEG ,TTC
,UAHE

,AKG
,ASSEG
,BMU
DELPS
,FHSEG
,HGMAX
,HSSEG
,PSEXIT
,RS
,TEMPH
,TN1
,TTISEG

FN5 0020

,INCR 1
,INCR 2
,INCR 3
,INCR 4
,INCR 5
,INCR 6
,INCR 7
,INCR 8
,INCR 9
,INCR2 10
,INCR2 11
,INCR2 12
INCR2 13
CPRP 1
FN5 0030
FN5 0070
FN5 0080
FN5 0115
FN5 0120
FN5 0130

COMMON /PRP/ CSI ,HSATS ,HSATW ,SPVOL

TUBE RESISTANCE

RT = TUBE RESISTANCE

TTC(K) = TUBE THERMAL CONDUCTIVITY

RT=(DOT-DIT)/(2.0*TTC)

RETURN

END

C
C
C

\$IBFTC FUN6 LIST,DECK,REF

SUBROUTINE FUN6

COMMON/INCR1/ACP

1ALPHA	,AMU	,AHE	,AHSEG	,AKG
2ATUBE	,BCP	,ANGLE	,ASEG	,ASSEG
3BOLCOE	,BSIGNS	,BHE	,BKG	,BMU
4DELPSC	,DELTAV	,CHI	,	DELPS
5FHOA	,FLDR	,DIT	,DOT	,FHSEG
6HP	,HSAV	,FSSEG	,HC(20)	,HGMAX
7HTC	,HVIS	,HSEXIT	,HSLIM	,HSSEG
8PSSEG	,QCONVA	,IREGON	,KROPAR	,PSEXIT
		,QUAL	,RH	,RS
COMMON/INCR2/RT		,SGMAX	,SCALE	,TEMPH
1THAV	,THEXIT	,THSEG	,TLSEG	,TN1
2TROWX	,TSAV	,TSSEG	,TTC	,TTISEG
3TTOSEG	,UAST	,UAHE		

COMMON /PRP/ CSI ,HSATS ,HSATW ,SPVOL

HELIUM RESISTANCE

C	AA1	= (REYNOLDS NO)**BHE	FN6 0030
C	ACP	= CONSTANT IN HELIUM SPECIFIC HEAT EQUATION	FN6 0040
C	AHE	= PRANDLT NO. EXPONENT,HELIUM	FN6 0050
C	AKG	= COEFFICIENT IN HELIUM CONDUCTIVITY EQUATION	FN6 0060
C	AMU	= COEFFICIENT IN HELIUM VISCOSITY EQUATION	FN6 0070
C	BCP	= COEFFICIENT IN HELIUM SPECIFIC HEAT EQUATION	FN6 0080
C	BHE	= REYNOLDS NO EXPONENT,HELIUM	FN6 0090
C	BKG	= EXPONENT IN HELIUM CONDUCTIVITY EQUATION	FN6 0100
C	BMU	= EXPONENT IN HELIUM VISCOSITY EQUATION	FN6 0110
C	CP	= HELIUM SPECIFIC HEAT	FN6 0120
C	DOT	= OUTSIDE TUBE DIAMETER	FN6 0130
C	HGMAX	= MAXIMUM HELIUM MASS FLOW RATE LBS/HR-SQFT	FN6 0140
C	HINF	= FILM COEFFICIENT FOR AN INFINIT NUMBER OF TUBE ROWS	FN6 0150
C	HMOHIF	= CORRECTION FOR TNTRAN(K) TUBE ROWS	FN6 0160
C	HTC	= HELIUM THERMAL CONDUCTIVITY	FN6 0170
C	HVIS	= HELIUM VISCOSITY	FN6 0180
C	PR	= (PRANDLT NO)**AHE	FN6 0190
C	RH	= HELIUM FILM RESISTANCE	FN6 0200
C	THAV	= AVERAGE HELIUM TEMPERATURE	FN6 0210
C	TNTRAN(K)	= NUMBER OF ROWS OF TUBES	FN6 0220
	T	=(THAV+TTOSEG)*0.5+460.0	FN6 0230
	HTC	=AKG*T**BKG	FN6 0240
	HVIS	=AMU*T**BMU	FN6 0250
	CP	=ACP+BCP*T	FN6 0260
	PR	=(CP*HVIS/HTC)**AHE	FN6 0270
	AA1	=(DOT*HGMAX/HVIS)**BHE	FN6 0280
	HINF	=ATUBE*AA1*PR*HTC/(DOT*0.93)	FN6 0290
	IF(FHSEG)	6,6,1	FN6 0300
1	IF(TN1-5.0)	2,2,6	FN6 0310
2	IA1	=TN1+1.0	FN6 0320
	X11	=IA1	FN6 0330
	IA2	=X11+TROWX-1.0	FN6 0340
	HAV	=0.0	FN6 0350

DO 4 IB=IA1,IA2
HAY=HAY+HC(IB)
4 CONTINUE
HOHINF=HAY/TROWX
GO TO 8
6 HOHINF=1.0
8 RH=1.0/(HINF*HOHINF)
RETURN
END

FN6 0360
FN6 0370
FN6 0380
FN6 0400
FN6 0400
FN6 0410
FN6 0420
FN6 0430
FUN60440

\$IBFTC AREA LIST,DECK,REF
SUBROUTINE AREA(IAA)

AR 0020

C

C*****STMGEN---VERSION 1A -- PER D. LUDWIG, 2/5/65 *****

C

C AREA ER XX...AT STA. XX.

C

C	*****INPUT COMMON*****	*****IPT	1
	COMMON/INPT/ AACP ,AAHE ,AAKG ,AAMU ,AANGLE(10) ,ABCP ,ABHE ,IPT		2
	1ABKG ,ABLCOE,ABMU , ADO(10), ACONVP, ACONVW ,IPT		3
	2ADPH(10) ,ADPS(10) ,ADROP(10) ,AFH(20,10) ,AFHT(10) ,IPT		4
	3AFS(10) ,AHSIN(10) ,AHSOUT(10) ,AIFH(10) , APITCH(10) ,IPT		5
	4AIPH(10) ,AIPS(10) ,AITH(10) ,AITUBE(10) ,AMSEG(10) ,ANSEC, IPT		6
	5APHAV ,APHIN(10) ,APHOUT(10) ,APSIN(10) ,APSOUT(10) ,IPT		7
	6AQCONV,AQUAL,ASCALE(10) ,ASL(10) ,ASIGNH(10) ,ASIGNP(10) ,IPT		8
	7ASIGNS(10) ,AST(10) ,ATCOL(10) ,ATHIN(20,10) ,ATHISC(10) ,IPT		9
	8ATHOSC(10) ,ATHOUT(20,10) ,ATNUM(10) ,ATROW(10) ,ATT(10) ,IPT		10
	9ATT(10) ,ATUBEL(10) ,CRSPAR(10) ,IPT		11
	COMMON/CNTL/ AFHAV ,AFHMIN ,AFSP(10) ,CHD(10) ,COM		1
	1CHT(10) ,CONVP ,CONVW,DELPH(20,10) ,DI(10) ,DO(10) ,COM		2
	2DPASS(10) ,DPH(10) ,DPHSEC(10) ,DPS(10) ,DV(10) ,COM		3
	3FH(20,10) ,FHJ(10) ,FHT(10) ,FHSC(10) ,COM		4
	4FRSR(10) ,FS(10) ,HSIN(10) ,HSOUT(10) ,IDEX ,COM		5
	5IDROP(10) ,IFH(10) ,IPITCH(10) ,IPH(10) ,IPS(10) ,COM		6
	6ITH(10) ,ITUBE(10) ,I ,IMAX(50) ,ISN ,COM		7
	COMMON/CNTL/ IXSIGN ,JMAX(20) ,K ,COM		7A
	7M ,MSEG(10) ,N ,NPASS(10) ,NSEC,PHAV ,COM		8
	8PHIN(10) ,PHOUT(10) ,PSIN(10) ,PSOUT(10) ,QCONV ,COM		9
	9SD(10) ,SIGNH(10) ,SIGNP(10) ,SIGNS(10) ,COM		10
	COMMON/CNTL/ SL(10) ,ST(10) ,TCOL(10) ,TCNT ,COM		11
	1THIN(20,10) ,THISC(10) ,THJ(20) ,THOSC(10) ,THOUT(20,10) ,COM		12
	2THPAV(20) ,THSC(10) ,TNUM(10) ,TTL(60) ,TT(10) ,COM		13
	3TTMAX(20) ,TTPAV(20) ,TTSC(10) ,TUBE(50,10) ,VOID(10) ,COM		14
	4WPAS(10) ,XM ,XN ,XTTL ,TROW(10) ,COM		15
	COMMON/INCR1/ACP ,AHE ,AHSEG ,AKG ,INCR		1
	1ALPHA ,AMU ,ANGLE ,ASEG ,ASSEG ,INCR		2
	2ATUBE ,BCP ,BHE ,BKG ,BMU ,INCR		3
	3BOLCOE ,BSIGNS ,CHI ,DELPS ,INCR		4
	4DELPSC ,DELTAV ,DIT ,DOT ,FHSEG ,INCR		5
	5FHQA ,FLDR ,FSSEG ,HC(20) ,HGMAX ,INCR		6
	6HP ,HSAV ,HSEXIT ,HSLIM ,HSSEG ,INCR		7
	7HTC ,HVIS ,IREGON ,KROPAR ,PSEXIT ,INCR		8
	8PSSEG ,QCONVA ,QUAL ,RH ,RS ,INCR		9
	COMMON/INCR2/RT ,SGMAX ,SCALE ,TEMPH ,INCR2		10
	1THAV ,THEXIT ,THSEG ,TLSEG ,TN1 ,INCR2		11
	2TROWX ,TSAV ,TSSEG ,TTC ,TTISEG ,INCR2		12
	3TTOSEG ,UAST ,UAHE ,INCR2		13
	COMMON/CNTRL/ AIPT1 ,AHFD ,ALENGT ,ARMAX ,CNTRL		1
	COMMON/CNTRL/ CLEAR ,C100 ,D100 ,DANGLE ,CNTRL		2
	COMMON/CNTRL/ D(20) ,DELE ,DELHGT ,DELMIN ,DIAMAXCNTRL		3

COMMON/CNTRL/	DIS(10)	,DOS(10)	,DXS(10)	,DPRH	,DPRS	CNTRL	4
COMMON/CNTRL/	DPSH	,DPSS	,EX			CNTRL	5
COMMON/CNTRL/	HCONV	,HDELIN	,HEIGHT			CNTRL	6
COMMON/CNTRL/	KE	,KN	,KM			CNTRL	7
COMMON/CNTRL/	PIE	,PRESS(10)	,RBEND			CNTRL	8
COMMON/CNTRL/	SDAV(10)	,SLAV(10)	,SLCONV	,SLL(10)		CNTRL	9
COMMON/CNTRL/	STAV(10)	,STRESS(10)				CNTRL	10
COMMON/CNTRL/		TCNV	,TEMMA	,TMAX		CNTRL	11
COMMON/CNTRL/	X100	,DPRSMN	,DPRSMX	,J100	,K100	CNTRL	12
IAA=0						AR	0030
RETURN						AR	0040
END						AR	0050

\$IBFTC DROPS LIST,DECK,REF
SUBROUTINE DROPS

DP 0020

C
C DROPS ER 1...SIGNS(K) = 0.0 AT STA. 4.
C

COMMON/INCR1/ACP	,AHE	,AHSEG	,AKG	,INCR	1
1ALPHA	,AMU	,ANGLE	,ASEG	,INCR	2
2ATUBE	,BCP	,BHE	,BKG	,INCR	3
3BOLCOE	,BSIGNS	,CHI	,DELPS	,INCR	4
4DELPSC	,DELTAV	,DIT	,FHSEG	,INCR	5
5FHQA	,FLDR	,FSSEG	,HC(20)	,INCR	6
6HP	,HSAV	,HSEXIT	,HSLIM	,INCR	7
7HTC	,HVIS	,IREGON	,KROPAR	,INCR	8
8PSSEG	,QCONVA	,QUAL	,RH	,INCR	9
COMMON/INCR2/RT	,SGMAX	,SCALE	,TEMPH	,INCR2	10
1THAV	,THEXIT	,THSEG	,TLSEG	,INCR2	11
2TROWX	,TSAV	,TSSEG	,TTISEG	,INCR2	12
3TTOSEG	,UAST	,UAHE		,INCR2	13

COMMON /PRP/ CSI ,HSATS ,HSATW ,SPVOL CPRP 1

C	ANGLE(K) = TUBE ANGLE WITH THE HORIZONTAL	DR
C	DELH = VERTICAL HEIGHT OF INCREMENT	DR
C	DELPS = INCREMENT PRESSURE LOSS	DR
C	DIT = INSIDE TUBE DIAMETER	DR
C	F = FRICTION FACTOR	DR
C	FLDR = FLOW DIRECTION	DR
C	FLDR = +1 UPFLOW	DR
C	FLDR = -1 DOWNFLOW	DR
C	HSAVE = AVERAGE STEAM ENTHALPY	DR
C	HSEXIT = COMPUTED STEAM ENTHALPY	DR
C	HSSEG = KNOWN STEAM ENTHALPY	DR
C	IREGON = STEAM PRESSURE DROP REGION	DR
C	IREGON = 1 SUBCOOLED OR SUPERCRITICAL	DR
C	IREGON = 2 SATURATED	DR
C	IREGON = 3 SUPERHEATED	DR
C	SGMAX = STEAM MASS FLOW RATE	DR
C	SIGNS(K) = STEAM FLOW FLAG	DR
C	SIGNS(K) = +1 INLET STEAM CONDITIONS KNOWN	DR
C	SIGNS(K) = 2 OUTLET STEAM CONDITIONS KNOWN	DR
C	SPVOL = STEAM SPECIFIC VOLUME COMPUTED IN SUBROUTINE DROP	DR
C	SRE = STEAM REYNOLDS NUMBER	DR
C	SVIS = STEAM SPECIFIC VOLUME	DR
C	TLSEG = LENGTH OF SEGMENT	DR
C	TSAV = AVERAGE STEAM TEMPERATURE	DR
C	VIN = SPECIFIC VOLUME AT INCREMENT INLET	DR
C	VOUT = SPECIFIC VOLUME AT INCREMENT OUTLET	DR
C	VSEXIT = SPECIFIC VOLUME AT COMPUTED STEAM CONDITIONS	DR
C	VSSEG = SPECIFIC VOLUME AT KNOWN STEAM CONDITIONS	DR

TOG=8.34624E+08 DP 0035

CALL TEMP(HSSEG,PSSEG,AT) DP 0030

VSSEG=SPVOL DP 0040

CALL TEMP(HSEXIT,PSSEG,AT)	DP 0050
VSEXIT=SPVOL	DP 0060
CALL TEMP(HSAV,PSSEG,AT)	DP 0062
VAV=SPVOL	DP 0064
CALL PROPS(PSSEG,IREGON,AT,HSAV,A1,A2)	DP 0070
SVIS=A2	DP 0080
IF(BSIGNS-0.0)2,4,6	DP 0090
2 VOUT=VSSEG	DP 0100
VIN=VSEXIT	DP 0110
GO TO 7	DP 0120
4 CALL ERROR(6HDROPS , IR)	DP 0130
6 VOUT=VSEXIT	DP 0150
VIN=VSSEG	DP 0160
7 DELH=FLDR*TLSEG*SIN(ANGLE)/VAV	DP 0180
SRE=DIT*SGMAX/SVIS	DP 0190
IF(6000.0-SRE)8,10,10	DP 0200
8 FM=0.036*(6000.0/SRE)**0.25	DP 0210
GO TO 16	DP 0220
10 IF(2000.0-SRE)12,12,14	DP 0230
12 FM=0.032*(SRE/2000.0)**0.10721	DP 0240
GO TO 16	DP 0250
14 FM=64.0/SRE	DP 0260
16 AA2=SGMAX**2*(VAV/TOG)*(2.0*(VOUT-VIN)/VAV+FM*TLSEG/DIT)	DR 0270
DELPS=BSIGNS*(AA2+DELH)	DP 0280
RETURN	DR 0290
END	DR 0300

\$IBFTC PROPS LIST,DECK,REF

SUBROUTINE PROPS(AA1,IA2,AA3,AA4,STC,SVIS)

COMMON/PRP/CSI,HSATS,HSATW,SPVOL

C H =STEAM ENTHALPY

C I =STEAM REGION

C I=1 SUBCOOLED

C I=2 SATURATED

C I=3 SUPERHEATED

C P =STEAM PRESSURE PSIA

C SVIS =STEAM VISCOSITY

C STC =STEAM THERMAL CONDUCTIVITY

C T =STEAM TEMPERATURE

1 P=AA1/144.0

P1=AA1

I=IA2

T=AA3

H=AA4

CALL TEMP(H,P1,AA5)

T =AA5

SVIS=(18.0+0.054*T+0.44*SPVOL**(-1.58))*0.001

STC=T*(8.691E-09*T+2.571E-05)+7.97E-03+2.67E-03*SPVOL**(-1.24)

RETURN

END

PR 0020

PR 0030

PR 0040

PR 0050

PR 0060

PR 0070

PR 0080

PR 0090

PR 0100

PR 0110

PR 0120

PR 0130

PR 0135

PR 0140

PR 0150

PR 0160

PR 0170

PR 0180

PR 0190

PR 0200

PR 0210

PR 0220

\$IBFTC TEMP	LIST,DECK,REF	
	SUBROUTINE TEMP(HS1,XPS1,TS1)	TEMP0010
C	TEMP ER 1...PRESS EXCEEDED TABLE LIMIT.	
C	TEMP ER 2...PRESS BELOW TABLE LIMIT.	
	COMMON/PHTV/P(35),H(42,35),T(42,35),V(42,35)	TEMP
	COMMON /PRP/ CSI ,HSATS ,HSATW ,SPVOL	CPRP 1
C	THIS SUBROUTINE DOES DOUBLE INTERPOLATION OF	TEMP0020
C	ENTHALPY AND PRESSURE TO PRODUCE TEMPERATURE---	TEMP0030
C	INVERSE SPECIFIC HEAT (CSI) AND CRITICAL VALUES	TEMP0040
C	(HSATW,HSATS) ARE ALSO PRODUCED (STORED IN COMMON)	TEMP0050
C	ALONG WITH VSI (SPECIFIC VOLUME)	TEMP0060
C	USES TABLES P,T,H,V	TEMP0070
C	HS1 ENTHALPY IN BTU/LB.	TEMP0140
C	PS1 PRESSURE IN PSIA	TEMP0150
C	TS1 TEMPERATURE IN DEGREES F	TEMP0160
	BAR(Q000FL,Q001FL)=Q000FL+PC*(Q001FL-Q000FL)	TEMP0170
C	INITIALIZES VALUES FOR SEARCHING	TEMP0180
	PS1=XPS1/144.0	TEMP0185
	IF(KQ)1,1,2	TEMP0190
1	KQ=35	TEMP0200
	JQ=39	TEMP0210
	KA=1	TEMP0220
	JA=1	TEMP0230
C	SEARCHES FOR PRESSURE VALUES THAT BRACKET PS1	TEMP0240
2	IF(P(KA+1)-PS1)3,5,5	TEMP0250
3	KA=KA+1	TEMP0260
	IF(KA-KQ)2,4,4	TEMP0270
C	PRESSURE ABOVE STEAM TABLE ERROR	TEMP0280
4	IR=1	TEMP0290
	GO TO 2000	TEMP0300
5	IF(P(KA)-PS1)8,6,6	TEMP0310
6	KA=KA-1	TEMP0320
	IF(KA)7,7,5	TEMP0330
7	IR=2	TEMP0350
	GO TO 2000	TEMP0360
C	COMPUTE INTERMEDIATE VALUE FOR INTERPOLATION	TEMP0370
8	PC=(PS1-P(KA))/(P(KA+1)-P(KA))	TEMP0380
C	SEARCHES FOR ENTHALPY THAT BRACKETS HS1	TEMP0390
9	IF(H(JA+1,KA)-HS1)10,12,12	TEMP0400
10	JA=JA+1	TEMP0410
	IF(JA-JQ)9,11,11	TEMP0420
C	ENTHALPY GREATER THAN TABLE ERROR	TEMP0430
11	CSI=1.667	TEMP0440
	TS1=1.667*HS1-1252.5	TEMP0450
	VSI=.7467*TS1/PS1	TEMP0460
	JA=30	TEMP0470
	GO TO 26	TEMP0480
12	IF(H(JA,KA)-HS1)15,15,13	TEMP0490
13	JA=JA-1	TEMP0500
	IF(JA)14,14,12	TEMP0510

C	ENTHALPY LESS THAN TABLE ERROR	TEMP0520
14	CSI=1.0	TEMP0530
	TS1=32.0+HS1-0.003*PS1	TEMP0540
	VSI=.0155	TEMP0550
	JA=5	TEMP0560
	GO TO 26	TEMP0570
15	H1=BAR(H(JA,KA),H(JA,KA+1))	TEMP0580
	T1=BAR(T(JA,KA),T(JA,KA+1))	TEMP0590
	V1=BAR(V(JA,KA),V(JA,KA+1))	TEMP0600
17	H2=BAR(H(JA+1,KA),H(JA+1,KA+1))	TEMP0610
	T2=BAR(T(JA+1,KA),T(JA+1,KA+1))	TEMP0620
	V2=BAR(V(JA+1,KA),V(JA+1,KA+1))	TEMP0630
18	IF(H2-HS1)19,21,21	TEMP0640
19	H1=H2	TEMP0650
	T1=T2	TEMP0660
	V1=V2	TEMP0670
	JA=JA+1	TEMP0680
	IF(JA-JQ)17,11,11	TEMP0690
21	IF(H1-HS1)25,22,22	TEMP0700
22	H2=H1	TEMP0710
	T2=T1	TEMP0720
	V2=V1	TEMP0730
	JA=JA-1	TEMP0740
	IF(JA)14,14,24	TEMP0750
24	H1=BAR(H(JA,KA),H(JA,KA+1))	TEMP0760
	T1=BAR(T(JA,KA),T(JA,KA+1))	TEMP0770
	V1=BAR(V(JA,KA),V(JA,KA+1))	TEMP0780
	GO TO 18	TEMP0790
C	COMPUTE INVERSE SPECIFIC HEAT AND OTHERS	TEMP0800
25	IF(JA-13)249,253,249	TEMP0810
249	HCHK=(HS1-H1)/(H2-H1)	TEMP0820
	IF(HCHK-.5)250,253,251	TEMP0830
250	IF(JA-1)2505,2505,2500	TEMP0840
2500	T3=BAR(T(JA-1,KA),T(JA-1,KA+1))	TEMP0850
	H3=BAR(H(JA-1,KA),H(JA-1,KA+1))	TEMP0860
2501	CSI=((HS1-(H1+H3)/2.0)/((H1+H2)/2.0-(H3+H1)/2.0))*	TEMP0870
1	((T2-T1)/(H2-H1)-(T1-T3)/(H1-H3))+((T1-T3)/(H1-H3))	TEMP0880
	GO TO 252	TEMP0890
251	IF(JA-39)2505,2500,2500	TEMP0900
2505	T3=BAR(T(JA+2,KA),T(JA+2,KA+1))	TEMP0910
	H3=BAR(H(JA+2,KA),H(JA+2,KA+1))	TEMP0920
	IF(H3-H(14,KA))2511,2510,2511	TEMP0930
2510	IF(HCHK-.999999)2511,2511,2513	TEMP0940
2513	CSI=0.0	TEMP0950
	TS1=T2	TEMP0960
	GO TO 26	TEMP0970
2511	CSI=((HS1-(H1+H2)/2.0)/((H2+H3)/2.0-(H1+H2)/2.0))*	TEMP0980
1	((T3-T2)/(H3-H2)-(T2-T1)/(H2-H1))+((T2-T1)/(H2-H1))	TEMP0990
252	TS1=T1+(HS1-H1)*((T2-T1)/(H2-H1))	TEMP1000
	VSI=V1+(HS1-H1)*((V2-V1)/(H2-H1))	TEMP1010

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GO TO 26
253 CSI=(T2-T1)/(H2-H1)
    TS1=T1+(HS1-H1)*CSI
    VSI=V1+(HS1-H1)*(V2-V1)/(H2-H1)
26 HSATS=BAR(H(14,KA),H(14,KA+1))
    HSATW=BAR(H(13,KA),H(13,KA+1))
    SPVOL=VSI
    RETURN
2000 CALL ERROR(6HTEMP , IR)
END

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TEMP1020
TEMP1030
TEMP1040
TEMP1050
TEMP1060
TEMP1070
TEMP1075
TEMP1076
TEMP1078
TEMP1090

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\$IBFTC OUTPUT LIST,REF
SUBROUTINE OUTPUT

OP 0020

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C
C   TTL(L)      =OUTPUT TITLES,SIX CHARACTERS EACH
C   XTTL        =NUMBER OF OUTPUT TITLES (SIX CHARACTERS EACH)
C
C   COMMON /INPT/ ***** 040
      COMMON/INPT/ AACP ,AAHE ,AAKG ,AAMU ,AANGLE(10) ,ABCP ,ABHE ,IPT 2
      1ABKG ,ABLCOE,ABMU ,      ADO(10),      ACONVP,      ACONVW ,IPT 3
      2ADPH(10) ,ADPS(10) ,ADROP(10) ,AFH(20,10) ,AFHT(10) ,IPT 4
      3AFS(10) ,AHSIN(10) ,AHSOUT(10) ,AIFH(10) , APITCH(10) ,IPT 5
      4AIPH(10) ,AIPS(10) ,AITH(10) ,AITUBE(10),AMSEG(10),ANSEC,IPT 6
      5APHAV ,APHIN(10) ,APHOUT(10) ,APSIN(10) ,APSOUT(10) ,IPT 7
      6AQCONV,AQUAL,ASCALE(10) ,ASL(10) ,ASIGNH(10) ,ASIGNP(10) ,IPT 8
      7ASIGNS(10) ,AST(10) ,ATCOL(10) ,ATHIN(20,10),ATHISC(10) ,IPT 9
      8ATHOSC(10) ,ATHOUT(20,10),ATNUM(10) ,ATROW(10) ,ATTC(10) ,IPT 10
      9ATT(10) ,ATUBEL(10) ,CRSPAR(10) IPT 11
C
C   COMMON /CNTL/ ***** 160
      COMMON/CNTL/ AFHAV ,AFHMIN ,AFSP(10) ,CHD(10) ,COM 1
      1CHT(10) ,CONVP ,CONVW,DELPH(20,10),DI(10),DO(10) ,COM 2
      2DPASS(10) ,DPH(10) ,DPHSEC(10) ,DPS(10) ,DV(10) ,COM 3
      3FH(20,10) ,FHJ(10) ,FHT(10) ,FHSC(10) , ,COM 4
      4FRSR(10) ,FS(10) ,HSIN(10) ,HSOUT(10) ,IDEX ,COM 5
      5IDROP(10) ,IFH(10) ,IPITCH(10) ,IPH(10) ,IPS(10) ,COM 6
      6ITH(10) ,ITUBE(10) ,I ,IMAX(50) ,ISN ,COM 7
      COMMON/CNTL/ IXSIGN ,JMAX(20) ,K ,COM 7A
      7M ,MSEG(10) ,N ,NPASS(10),NSEC,PHAV ,COM 8
      8PHIN(10) ,PHOUT(10) ,PSIN(10) ,PSOUT(10) ,QCONV ,COM 9
      9SD(10) ,SIGNH(10) ,SIGNP(10) ,SIGNS(10) ,COM 10
      COMMON/CNTL/ SL(10) ,ST(10) ,TCOL(10) ,TCNT ,COM 11
      1THIN(20,10) ,THISC(10) ,THJ(20) ,THOSC(10) ,THOUT(20,10) ,COM 12
      2THPAV(20) ,THSC(10) ,TNUM(10) ,TTL(60) ,TT(10) ,COM 13
      3TTMAX(20) ,TTPAV(20) ,TTSC(10) ,TUBE(50,10) ,VOID(10) ,COM 14
      4WPAS(10) ,XM ,XN ,XTTL ,TROW(10) COM 15
C
C   COMMON /OUTPT/ ***** 340
      COMMON/OUTPT/IPRINT(30),IPR 350
C
C   COMMON /TITLES/ 360
      COMMON /TITLES/ TTL(60), IT, AZX(12) 370
C
C   DIMENSION AREAS(10),ANPASS(10),XIMAX(50),XJMAX(20) OP 0010
C
C   100 FORMAT(5X,1P7E16.6) OP 0020
C   110 FORMAT(15,1P7E16.6) OP 0030
C   120 FORMAT(7I16) OP 0035
C
C   WRITE (6,2002) (AZX(IX), IX=1,12) OP 0037

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2002 FORMAT (1H0 12A6)

OP 0038

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C
C *****PRINT THE INPUT*****OP 0040
C *****CONSTANTS*****OP 0050
WRITE(6,1010)OP 0060
WRITE(6,100)AAHE,ABHE,ABLCOE,AQUAL,AQCONV,ACONVP,OP 0070
1ACONVWOP 0080
WRITE(6,1020)OP 0090
WRITE(6,100)AACP,ABCP,AAKG,ABKG,AAMU,ABMU,APHAVOP 0100
WRITE(6,1030)OP 0110
WRITE(6,100)ANSECOP 0120
C *****DIMENSIONED INPUT*****OP 0130
WRITE(6,1040)OP 0140
DO 2 K=1,NSECOP 0150
WRITE(6,110)K,AITUBE(K),AMSEG(K),AANGLE(K),ATROW(K),ATCOL(K),OP 0160
1ATNUM(K),APITCH(K)OP 0170
2 CONTINUEOP 0180
WRITE(6,1050)OP 0200
DO 4 K=1,NSECOP 0210
WRITE(6,110)K,AST(K),ASL(K),ATUBEL(K),ADO(K),ATT(K),ATTG(K),OP 0220
1AIFH(K)OP 0230
4 CONTINUEOP 0240
WRITE(6,1060)OP 0250
DO 6 K=1,NSECOP 0260
WRITE(6,110)K,CRSPAR(K),AFHT(K),AITH(K),ATHISC(K),ATHOSC(K),OP 0270
1ASIGNH(K),ASIGNP(K)OP 0280
6 CONTINUEOP 0290
WRITE(6,1070)OP 0300
DO 8 K=1,NSECOP 0310
WRITE(6,110)K,ASIGNS(K),ADROP(K),AIPH(K),APHOUT(K),ADPH(K),OP 0320
1APHIN(K),AFS(K)OP 0330
8 CONTINUEOP 0340
WRITE(6,1080)OP 0350
DO 10 K=1,NSECOP 0360
WRITE(6,110)K,AHSIN(K),AHSOUT(K),AIPS(K),APSOUT(K),ADPS(K),OP 0370
1APSIN(K)OP 0380
10 CONTINUEOP 0390
WRITE(6,2000)OP 0400
DO 12 K=1,NSECOP 0410
WRITE(6,110)K,ASCALE(K)OP 0420
12 CONTINUEOP 0430
BMAX=0.0OP 0435
AMAX=0.0OP 0440
DO 140 K=1,NSECOP 0450
XPASS=NPASS(K)OP 0455
AA=AMAX1(AMAX,AMSEG(K))OP 0460
BB=AMAX1(BMAX,XPASS)OP 0465
AMAX=AAOP 0470
BMAX=BBOP 0475
140 CONTINUEOP 0480
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	N1=BMAX	OP	0485
	M1=AMAX	OP	0490
C	*****TWO DIMENSIONAL INPUT*****	OP	0500
13	IA1=1	OP	0510
14	IA2=IA1+6	OP	0520
	IF(NSEC-IA2)16,18,18	OP	0530
16	IA2=NSEC	OP	0540
18	WRITE(6,2010)(TTL(1),TTL(2),K=IA1,IA2)	OP	0550
	WRITE(6,120)(K,K=IA1,IA2)	OP	0560
	DO 20 J=1,M1	OP	0570
	WRITE(6,110)J,(AFH(J,K),K=IA1,IA2)	OP	0580
20	CONTINUE	OP	0590
	IA1=IA2+1	OP	0600
	IF(NSEC-IA1)23,14,14	OP	0610
23	IA1=1	OP	0620
24	IA2=IA1+6	OP	0630
	IF(NSEC-IA2)26,28,28	OP	0640
26	IA2=NSEC	OP	0650
28	WRITE(6,2010)(TTL(3),TTL(4),K=IA1,IA2)	OP	0660
	WRITE(6,120)(K,K=IA1,IA2)	OP	0670
	DO 30 J=1,M1	OP	0680
	WRITE(6,110)J,(ATHOUT(J,K),K=IA1,IA2)	OP	0690
30	CONTINUE	OP	0700
	IA1=IA2+1	OP	0710
	IF(NSEC-IA1)32,24,24	OP	0720
32	IA1=1	OP	0730
34	IA2=IA1+6	OP	0740
	IF(NSEC-IA2)36,38,38	OP	0750
36	IA2=NSEC	OP	0760
38	WRITE(6,2010)(TTL(5),TTL(6),K=IA1,IA2)	OP	0770
	WRITE(6,120)(K,K=IA1,IA2)	OP	0780
	DO 40 J=1,M1	OP	0790
	WRITE(6,110)J,(ATHIN(J,K),K=IA1,IA2)	OP	0800
40	CONTINUE	OP	0810
	IA1=IA2+1	OP	0820
	IF(NSEC-IA1)42,34,34	OP	0830
C	*****END PRINTING INPUT*****	OP	0840
C	*****CONVERT THE OUTPUT UNITS*****	OP	0850
42	DO 58 K=1,NSEC	OP	0860
	DI(K)=DI(K)*12.0	OP	0870
	DO(K)=DO(K)*12.0	OP	0880
	WPAS(K) = WPAS(K)*12.0	OP	0890
	DPASS(K)=DPASS(K)*12.0	OP	0900
	SD(K)=SD(K)*12.0	OP	0920
	SL(K)=SL(K)*12.0	OP	0930
	ST(K)=ST(K)*12.0	OP	0940
	DV(K)=DV(K)*12.0	OP	0950
	DPHSEC(K)=DPHSEC(K)/144.0	OP	0960
	DPH(K)=DPH(K)/144.0	OP	0970
	PSIN(K)=PSIN(K)/144.0	OP	0980

	PSOUT(K)=PSCUT(K)/144.0	OP	0990
	DPS(K)=DPS(K)/144.0	OP	1000
	M=AMSEG(K)	OP	1010
	N=NPASS(K)	OP	1020
	IF(IPRINT(4))48,48,44	OP	1030
44	DO 46 J=1,M	OP	1040
	DELPH(J,K)=DELPH(J,K)/144.0	OP	1050
46	CONTINUE	OP	1060
C	*****COMPUTE TOTAL H.T. AREA PER SECTION*****	OP	1070
48	AREAS(K)=0.0	OP	1080
	DO 50 I=1,N	OP	1090
	AREAS(K)=FRSR(K)*TUBE(I,K)+AREAS(K)	OP	1100
50	CONTINUE	OP	1110
52	IF(IPRINT(5))58,58,54	OP	1120
54	DO 56 I=1,N	OP	1130
	TUBE(I,K)=TUBE(I,K)*12.0	OP	1140
56	CONTINUE	OP	1150
C	*****END OUTPUT CONVERSION*****	OP	1160
58	CONTINUE	OP	1170
C	-----PRINT THE OUTPUT-----	OP	1180
C	*****SECTION DIMENSIONS*****	OP	1190
	WRITE(6,2020)	OP	1200
	DO 60 K = 1,NSEC	OP	1210
	XNPASS = NPASS(K)	OP	1212
	DEPTH = DPASS(K)*XNPASS	OP	1214
	WRITE(6,110)K,AREAS(K),TROW(K),TNUM(K),XNPASS,WPAS(K),DEPTH,	OP	1220
1	VOID(K)	OP	1221
60	CONTINUE	OP	1230
	WRITE(6,2030)	OP	1240
	DO 62 K = 1,NSEC	OP	1250
	CLEAR1 = ST(K) - DO(K)	OP	1252
	CLEAR2 = SD(K) - DO(K)	OP	1254
	CLEAR = AMIN1(CLEAR1,CLEAR2)	OP	1256
	WRITE(6,110)K,DO(K),DI(K),CLEAR,SD(K),ST(K),SL(K),DV(K)	OP	1260
62	CONTINUE	OP	1280
C	*****HELIUM*****	OP	1290
	WRITE(6,2040)	OP	1300
	DO 64 K=1,NSEC	OP	1310
	XIMAX(K)=IMAX(K)	OP	1315
	XJMAX(K)=JMAX(K)	OP	1320
	WRITE(6,110)K,THOSC(K),THISC(K),FHT(K),DPH(K),TTMAX(K),XIMAX(K),	OP	1325
1	XJMAX(K)	OP	1330
64	CONTINUE	OP	1340
	WRITE(6,2050)	OP	1350
	DO 66 K=1,NSEC	OP	1360
	WRITE(6,110)K,PSIN(K),PSOUT(K),HSIN(K),HSOUT(K),DPS(K),TTSC(K),	OP	1370
1	THSC(K)	OP	1375
66	CONTINUE	OP	1380
	IF(IPRINT(1))77,77,68	OP	1390
	*****HELIUM INCREMENT FLOWS*****	OP	1400

68	IA1=1	OP	1430
70	IA2=IA1+6	OP	1440
	IF(NSEC-IA2)72,74,74	OP	1450
72	IA2=NSEC	OP	1460
74	WRITE(6,2010){TTL(7),TTL(8),K=IA1,IA2}	OP	1470
	WRITE(6,120){K,K=IA1,IA2}	OP	1480
	DO 76 J=1,M1	OP	1490
	WRITE(6,110)J,{FH(J,K),K=IA1,IA2}	OP	1500
76	CONTINUE	OP	1510
	IA1=IA2+1	OP	1520
	IF(NSEC-IA1)77,70,70	OP	1530
C	*****HELIUM OUTLET TEMPERATURES*****	OP	1540
77	IF(IPRINT(2))87,87,78	OP	1550
78	IA1=1	OP	1580
80	IA2=IA1+6	OP	1590
	IF(NSEC-IA2)82,84,84	OP	1600
82	IA2=NSEC	OP	1610
84	WRITE(6,2010){TTL(9),TTL(10),K=IA1,IA2}	OP	1620
	WRITE(6,120){K,K=IA1,IA2}	OP	1630
	DO 86 J=1,M1	OP	1640
	WRITE(6,110)J,{THOUT(J,K),K=IA1,IA2}	OP	1650
86	CONTINUE	OP	1660
	IA1=IA2+1	OP	1670
	IF(NSEC-IA1)87,80,80	OP	1680
C	*****HELIUM INLET TEMPERATURES	OP	1690
87	IF(IPRINT(3))97,97,88	OP	1700
88	IA1=1	OP	1730
90	IA2=IA1+6	OP	1740
	IF(NSEC-IA2)92,94,94	OP	1750
92	IA2=NSEC	OP	1760
94	WRITE(6,2010){TTL(11),TTL(12),K=IA1,IA2}	OP	1770
	WRITE(6,120){K,K=IA1,IA2}	OP	1780
	DO 96 J=1,M1	OP	1790
	WRITE(6,110)J,{THIN(J,K),K=IA1,IA2}	OP	1800
96	CONTINUE	OP	1810
	IA1=IA2+1	OP	1820
	IF(NSEC-IA1)97,90,90	OP	1830
C	*****INCREMENT PRESSURE DROP*****	OP	1840
97	IF(IPRINT(4))207,207,98	OP	1850
98	IA1=1	OP	1880
200	IA2=IA1+6	OP	1890
	IF(NSEC-IA2)202,204,204	OP	1900
202	IA2=NSEC	OP	1910
204	WRITE(6,2010){TTL(13),TTL(14),K=IA1,IA2}	OP	1920
	WRITE(6,120){K,K=IA1,IA2}	OP	1930
	DO 206 J=1,M1	OP	1940
	WRITE(6,110)J,{DELPH(J,K),K=IA1,IA2}	OP	1950
206	CONTINUE	OP	1960
	IA1=IA2+1	OP	1970
	IF(NSEC-IA1)207,200,200	OP	1980

C	*****TUBE LENGTH PER PASS*****	OP	1990
207	IF(IPRINT(5))217,217,208	OP	2000
208	IA1=1	OP	2030
210	IA2=IA1+6	OP	2040
	IF(NSEC-IA2)212,214,214	OP	2050
212	IA2=NSEC	OP	2060
214	WRITE(6,2060)(TTL(15),TTL(16),K=IA1,IA2)	OP	2070
	WRITE(6,120)(K,K=IA1,IA2)	OP	2080
	DO 216 I=1,N1	OP	2090
	WRITE(6,110)I,(TUBE(I,K),K=IA1,IA2)	OP	2100
216	CONTINUE	OP	2110
	IA1=IA2+1	OP	2120
	IF(NSEC-IA1)217,210,210	OP	2130
C	*****END OUTPUT*****	OP	2140
217	RETURN	OP	2150
1010	FORMAT(5H0 ,8X,5H AAHE,11X,5H ABHE,10X,7H ABLCOE,10X,6H AQUAL,9OP	2000	
	1X,7H AQCONV,9X,7H ACONVP,9X,7H ACONVW)	OP	2010
1020	FORMAT(5H0 ,8X,5H AACP,11X,5H ABCP,11X,5H AAKG,11X,5H ABKG,11X,OP	2020	
	15H AAMU,11X,5H ABMU,11X,6H APHAV)	OP	2030
1030	FORMAT(5H0 ,8X,6H ANSEC)	OP	2040
1040	FORMAT(5H1 K,6X,10H AITUBE(K),6X,9H AMSEG(K),7X,10H AANGLE(K),6XOP	2050	
	19H ATROW(K),7X,9H ATCOL(K),7X,9H ATNUM(K),7X,10H APITCH(K))	OP	2060
1050	FORMAT(5H0 K,7X,7H AST(K),9X,7H ASL(K),8X,10H ATUBEL(K),7X,7H ADOP	2070	
	10(K),9X,7H ATT(K),9X,8H ATTC(K),8X,8H AIFH(K))	OP	2080
1060	FORMAT(5H0 K,6X,10H CRSPAR(K),7X,8H AFHT(K),8X,8H AITH(K),7X,10HOP	2090	
	1 ATHISC(K),6X,10H ATHOSC(K),6X,10H ASIGNH(K),6X,10H ASIGNP(K))	OP	2100
1070	FORMAT(5H1 K,6X,10H ASIGNS(K),6X,9H ADROP(K),8X,8H AIPH(K),7X,10OP	2110	
	1H APHOUT(K),7X,8H ADPH(K),7X,9H APHIN(K),8X,7H AFS(K))	OP	2120
1080	FORMAT(5H0 K,6X,9H AHSIN(K),7X,10H AHSOUT(K),7X,8H AIPS(K),7X,10OP	2130	
	1H APSOUT(K),7X,8H ADPS(K),7X,9H APSIN(K))	OP	2140
2000	FORMAT(5H0 K,6X,10H ASCALE(K))	OP	2150
2010	FORMAT(6H1 J ,7(4X,2A6))	OP	2160
2020	FORMAT(5H1 K ,6X,10H AREAS(K) ,6X,10H TROW(K) , 6X,	OP	2170
1	10H TNUM(K) ,6X,10H NPASS(K) ,6X,10H WPASS(K) ,6X,	OP	2171
2	10H DEPTH(K) ,6X,10H VOID(K))	OP	2172
2030	FORMAT(5H0 K ,6X,10H DO(K) ,6X,10H DI(K) , 6X	OP	2180
1	10H CLEAR(K) ,6X,10H SD(K) ,6X,10H ST(K) ,6X,	OP	2181
2	10H SL(K) ,6X,10H DV(K))	OP	2182
2040	FORMAT(5H1 K,6X,9H THOSC(K),7X,9H THISC(K),8X,7H FHT(K),9X,7H DPOP	2210	
	1H(K),8X,9H TTMAX(K),8X,8H IMAX(K),8X,8H JMAX(K))	OP	2220
2050	FORMAT(5H0 K,6X,8H PSIN(K),8X,9H PSOUT(K),7X,8H HSIN(K),8X,9H HSOP	2230	
	1OUT(K),8X,7H DPS(K),9X,8H TTSC(K),7X,8H THSC(K))	OP	2240
2060	FORMAT(6H1 I ,7(4X,2A6))	OP	2250
	END	OP	2155

\$IBFTC ERROR LIST,REF

C FOR DEBUG

SUBROUTINE ERROR(NAME, IR)

C VERSION 2F

WRITE (6,10) NAME, IR

10 FORMAT (1H0 A6, 3H ER I4)

CALL OUTPT

CALL DUMP

RETURN

END

ERROR A

ERROR B

ERROR C

ERROR E

ERROR F

Word	1	Steam Pressure If NS is larger than 7, two cards will be required.
Column	1-2	
Format	12	
Card 13-1	Data Group 13 identification card.	
Symbol	KK = 13	

Word	1	2	3	Steam Pressure Flag. If NS is larger than 7, two cards will required.
Column	1-10	11-20	21-30	
Format	E10.1	E10.1	E10.1	
Card 13-2	= 1.0 Inlet steam pressure is known. = 2.0 Outlet steam pressure is known.			
Symbol	AIPS(1)	AIPS(2)	AIPS(3) - - - - -AIPS(NS)	

Start with Section 1 and provide one of the following groups depending on value of AIPS(K)
Provide the following if AIPS(K) = 1.0

Word	1	2
Column	1-10	11-20
Format	E10.1	E10.1
Card	Inlet steam pressure is known.	
13-A	Inlet steam pressure, psi	Specified steam pressure drop, psi.
Symbol	APSIN(1)	ADPS(1)

One card for each section.

Provide the following if AIPS(K) = 2.0

Word	1	2	One card for each section.
Column	1-10	11-20	
Format	E10.1	E10.1	
Card	Outlet steam pressure is known.		
13-B	Outlet steam pressure, psi.	Specified steam pressure drop, psi.	
Symbol	APSOUT(1)	ADPS(1)	