NASA TECHNICAL NOTE

NASA TN D-5605

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NASA TN D-5605

GAS TURBINE FACE SEAL THERMAL DEFORMATION AND COMPUTER PROGRAM FOR CALCULATION OF AXISYMMETRIC TEMPERATURE FIELD

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • DECEMBER 1969

1. Report No. NASA TN D-5605	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle GAS TURBINE FACE SEAL THERMAL DEFORMATION AND COMPUTER PROGRAM FOR CALCULATION OF AXISYMMETRIC TEMPERATURE FIELD		5. Report Date December 1969
		6. Performing Organization Code
7. Author(s) Terrence E. Russell, Gordon P. Allen, Lawrence P. Ludwig, and Robert L. Johnson		8. Performing Organization Report No. E-4389
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135		10. Work Unit No. 126-15
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Note
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A computer program, which is general and can be applied to a variety of steady-state thermal problems, is presented in detail. The program is written in FORTRAN IV language. Application of the program to a specific mainshaft seal design is illustrated; both computer input and output data are given. A sample problem, having an exact solution, is also given as a means of demonstrating program accuracy.

17. Key Words (Suggested by Author(s)) Seal, Computer program, Heat transfer, Temperature, Steady state, Axisymmetric, Thermal deformation	18. Distribution Statement Unclassified - unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price *
Unclassified	Unclassified	110	$3.00

*For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151

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SUMMARY

The effects of seal deformation on seal balance are pointed out. In particular, divergent sealing faces are shown to be undesirable. As a first step in determining sealing face deformation, a computer program is presented for calculating the temperature field in the arbitrary body of revolution with arbitrary thermal boundary conditions. The program, which is written in FORTRAN IV language for an IBM 7094 digital computer, is general and can be applied to a variety of problems. Application of the program to a specific gas turbine mainshaft seal is demonstrated in detail; both computer input and output data are given. The program is also used to solve an example problem which has an exact solution; thus a partial check on program accuracy is provided.

INTRODUCTION

Face seals in advanced gas turbine engines will be subjected to temperatures, pressures, and sliding surface speeds higher than that of current engine practice. Increases in temperature arise from continuing increases in flight speed and turbine inlet temperature (ref. 1), increases in pressure result from use of higher pressure ratio compressors, and increases in surface speeds are due in part to increases in shaft diameter needed to carry increases in torque. As an example, proposed advanced engines have seal sliding speeds to 500 feet per second (127 m/sec) (ref. 2) as compared to 350 feet per second (88.9 m/sec) in engines in current use. In order to cope with these higher temperatures, pressures, and speeds, the contacting-type face seal may be replaced with noncontacting face seals such as the hydrostatic and hydrodynamic type (ref. 3). However, regardless of the type of face seal used, deformation of the sealing faces, due to thermal gradients, pressures, and centrifugal forces, will have significant effects on seal performance (ref. 4). In particular, deformations due to thermal gradients are a major problem area. The first step in determining thermal deformation is calculation of temperature distribution in the seal assembly. Such calculation by computer program is the subject of this report. The specific objectives of this study were to (1) present in detail a computer program for calculation of temperature distribution in axisymmetric bodies, (2) show how the computer program is applied to mainshaft seal thermal analysis, and (3) demonstrate program accuracy by comparison with a thermal problem having an exact solution.

The computer program for calculation of temperature distribution is written in FORTRAN IV computer language for use on an IBM 7094 digital computer. The program is quite general and can be applied to a variety of axisymmetric body problems. The calculation procedure requires that these bodies be divided into an arbitrary finite number of axisymmetric volume elements or nodes. These nodes need not be equal in cross section. The program will take into account contact resistance at the interface between nodes and will also account for material properties that vary from node to node. Also provisions are made in the program to handle varying gas temperatures along the seal boundaries and internal viscous heat generation within the fluid at the boundaries.

SYMBOLS

A	area, ft^2
A_x	cross section area, ft^2
a	outer radius of rotor or stator, ft
C	thermal conductance, Btu/(sec)(^oF)
C_f	skin friction coefficient
C_M	torque coefficient
C_p	specific heat, Btu/(lbm)(^oF)
D	hydraulic diameter, ft
D_L	characteristic length for liquid film cooling, ft
d	differential
F	function of
f	view factor for radiation
Gr	Grashof number
Gr_D	Grashof number based on diameter, $D_o^3 g_o (T_b - T_s) / \nu_f^2 T_f$
Gr_L	Grashof number based on length, $L^3 g_o (T_b - T_s) / \nu_f^2 T_f$

g_o	gravitational acceleration, ft/sec^2
H	convective conductance, Btu/(sec)(^{o}F)
h	heat transfer coefficient, Btu/(ft^2)(sec)(^{o}F)
K	β/ω
k	thermal conductivity, Btu/(ft)(sec)(^{o}F)
L	length of cylinder or surface, ft
Δl	axial length, in. or ft
N	radiative conductance, Btu/(sec)(^{o}F)
Nu	Nusselt number, hD_L/k
P_w	wetted perimeter, ft
Pr	Prandtl number
Pr_f	Prandtl number of boundary film, $\left[C_p\mu/k\right]_f$
Q	heat flux, Btu/sec
q	internal heat generation, Btu/sec
q_f	fluid internal heat generation, Btu/sec
R	thermal resistance, (sec)(^{o}F)/Btu
R_c	contact resistance, (sec)(^{o}F)/Btu
Re	Reynolds number
Re_c	critical Reynolds number for transition
Re_v	Reynolds number based on total velocity, $\left(\sqrt{\omega^2 r^2 + V_a^2}\right)_s \Big/ \nu_f$
Re_w	Reynolds number based on mass flow, $W_a D/\mu_f$
Re_x	Reynolds number based on flow length, $V_\infty X/\nu_f$
Re_ω	Reynolds number based on rotation, $\omega r^2/\nu_f$
r	radial coordinate, ft
Δr	radial width, in. or ft
r_{av}	average radius of element, in. or ft
r_i	inner radius of annulus between cylinders, ft
r_o	outer radius of annulus between cylinders, ft
s	clearance (e.g., seal gap), ft

T temperature, ^{o}F

T_{av} average (or film) temperature, ^{o}F

T_{in} temperature entering fluid element, ^{o}F

T_{out} temperature leaving fluid element, ^{o}F

T_{∞} bulk fluid temperature, ^{o}F

Ta_f Taylor number of boundary film, $\omega rs^{3/2} / \nu_f^{3/2}$

V_a axial velocity, ft/sec

V_R linear velocity of inner cylinder, ft/sec

V_{tot} total fluid velocity, ft/sec

V_{∞} free stream velocity, ft/sec

W mass flow rate, lbm/sec

W_a mass flow per square foot of cross section, W/A_x, lbm/(ft^2)(sec)

w over-relaxation factor

X flow length, ft

z axial coordinate, ft

α coefficient of thermal expansion

β angular velocity of fluid, rad/sec

∂ partial derivative

Δ difference

ϵ emissivity for radiation

μ absolute viscosity, lbm/(ft)(sec)

ν kinematic viscosity, ft^2/sec

ρ density, lbm/ft^3

τ_t tangential shear stress at wall, lbf/in.^{2}

ω rotor angular velocity, rad/sec

Subscripts:

b at fluid bulk temperature

c convective

e environment

ei between element and environment

es from environment to element

f at boundary film temperature

i element

j neighbor element of i

ji between neighbor and element

k environment "area" affecting element i by radiation

ki between environment "area" k and element

l environment "area" affecting element i by convection

$l$am laminar

li between environment "area" l and element

r radiation

s surface

se from element to environment

tr transition

turb turbulent

DISCUSSION OF THERMAL DEFORMATION IN SEALS

Figure 1 is a schematic drawing of a gas turbine mainshaft seal for bearing sumps. The seal restricts leakage of surrounding high temperature, high pressure gas into the

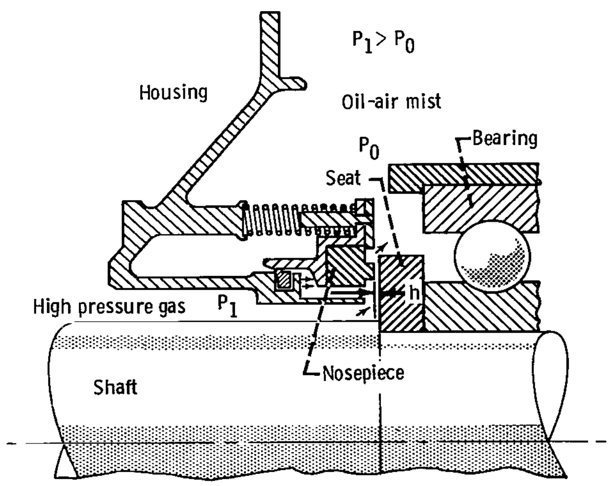


Figure 1. - Mainshaft seal for bearing sump in gas turbine engine.

sump. The gas leakage, through the seal into the sump, acts as a sweep gas which helps prevent oil leakage. However, it is desirable to minimize this gas leakage, since the hot gas degrades the lubricant and adds to the cooling requirements of the lubricant system.

Seal leakage and wear are grossly affected by seal force balance and it has been recognized that deformation of the sealing faces (which form the dam) can have a significant effect on the seal force balance (ref. 5). A discussion of seal force balancing can be found in reference 6. The manner in which the sealing face deformation affects the seal force balance and stability of a conventional face seal is discussed in reference 7. In general, thermal deformations cause the seal faces (dam) to form a nonparallel leakage path, and the pressure within these sealing faces is greatly dependent on the shape (convergent or divergent) of this leakage path; thus the force balance is affected by the thermal deformation.

Thermal gradients usually produce sealing gaps divergent from the dam inside diameter to the outside diameter. Thus, it is usually advantageous to locate the higher pressure at the seal outside diameter since this will result in convergence with respect to the leakage direction. However, many face seals are designed with the higher pressure at

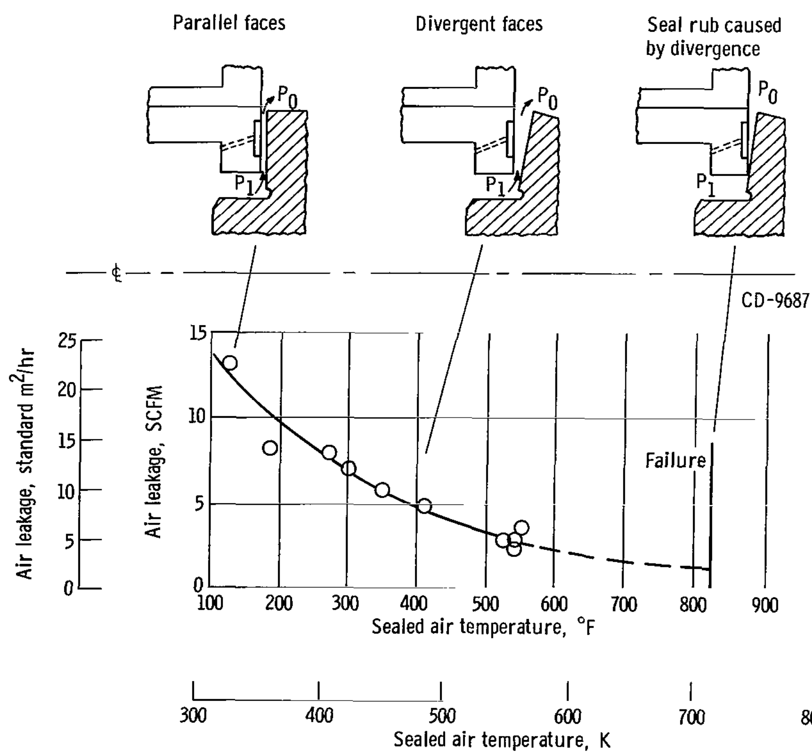


Figure 2. - Effect of thermal deformation on air leakage of orifice compensated hydrostatic seal. Sliding speed, 200 feet per second (61.0 m/sec); pressure differential, 100 pounds per square inch (6.89×10^4 N/m^2). (Data from ref. 4.)

the dam inside diameter and the gas turbine face seal is an example of this construction practice. The advantage of placing the higher pressure gas at the dam inside diameter puts the oil mist at the outside diameter; thus centrifugal force also acts to prevent oil leakage.

Thermal deformation also affects operation of hydrostatic seals. Figure 2, from reference 4, shows the effect of sealing face deformation on leakage through a hydrostatic seal operating at 200 feet per second (61.0 m/sec) and 100 pounds per square inch (6.89×10^4 N/m^2) pressure differential. With a sealed air temperature of 120^o F (322 K), the seal leakage is approximately 13 SCFM (0.0062 standard m^3/sec) and as the air tem-

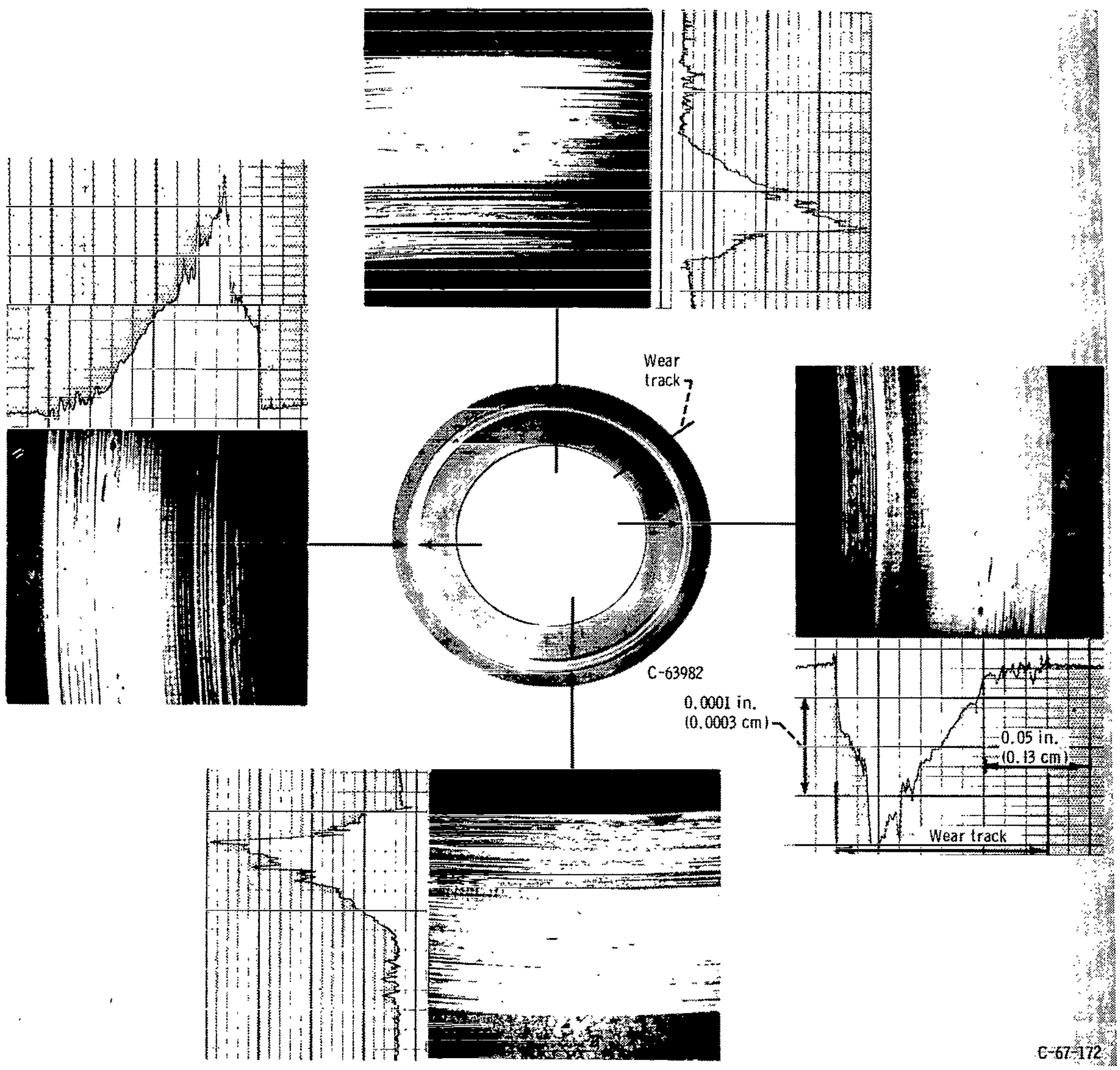


Figure 3'. - Overall wear pattern, surface profile traces, and photomicrographs of tungsten carbide seal seat. Sodium temperature, 1000° F (538° C); operating time, 4 hours; sliding velocity, 79 feet per second (24 m/sec); pressure, 50 pounds per square inch gage (34 N/cm^2 gage). (Data from ref. 6.)

perature is increased, the leakage decreases. This leakage decrease is due to increasing angular deformation of the sealing gap. The result is that the seal runs with closer clearance. Eventually as the air temperature increases still further, the deformation causes the inside diameter of the nosepiece to rub against the seal seat and failure occurs.

Seal thermal deformation effects have also been noticed in other applications. As an example, reference 6 reports that the main problem in sealing liquid sodium with a face contact seal was thermal deformation of the sealing faces. Some results of this study are repeated in figure 3 which shows the wear pattern made by a nosepiece sliding against a seal seat. Surface profile traces have been taken at intervals around the wear track. These profile traces show that the sealing faces were not parallel during operation, the greatest wear occurring at the inside diameter. The slope of the wear pattern suggests a divergence in the range of 0.006 inch per inch (0.006 m/m) of radial distance.

Regardless of the seal type (face contact, hydrostatic, or hydrodynamic), the sealing gap is usually small (0.0001 to 0.0010 in. or 0.00025 to 0.0025 cm for gas film seals) and deformations can easily be of the same magnitude, thus affecting seal performance significantly. These sealing face deformations could arise from temperature, pressure, or centrifugal force effects. Careful design can minimize undesirable effects due to pressure and centrifugal force. Deformations due to temperature gradients are usually difficult to eliminate. Even the heat generated in shearing a thin film of gas within the interface can introduce a significant and undesirable thermal gradient in the seal rings.

The preceding evidence indicates that thermal deformation can significantly affect seal performance. The first step in analysis of these thermal deformations is calculation of the temperature fields in the seal assembly, and the computer program for these calculations is given in the following sections.

ANALYSIS OF TEMPERATURE FIELDS IN AXISYMMETRIC BODIES

Shaft seals are composed of basically axisymmetric bodies. Also, the circumferential temperature gradient approaches zero for most applications. Therefore, the cylindrical coordinate system is used as a basis for analysis. The following restrictions are placed on the thermal analysis:

(1) A steady state must exist.

(2) An axisymmetric temperature field must exist.

Therefore, with internal heat generation, the heat conduction equation in cylindrical coordinates is (ref. 8)

$$\frac{1}{r} \frac{\partial}{\partial r}\left(kr \frac{\partial T}{\partial r}\right) + \frac{\partial}{\partial z}\left(k \frac{\partial T}{\partial z}\right) + q(r, z) = 0 \tag{1}$$

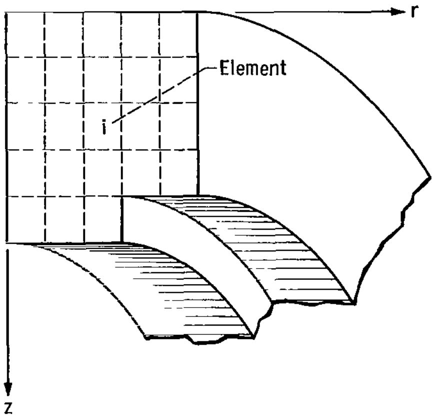


Figure 4. - Seal axisymmetric nosepiece subdivided into finite number of three-dimensional axisymmetric volume elements.

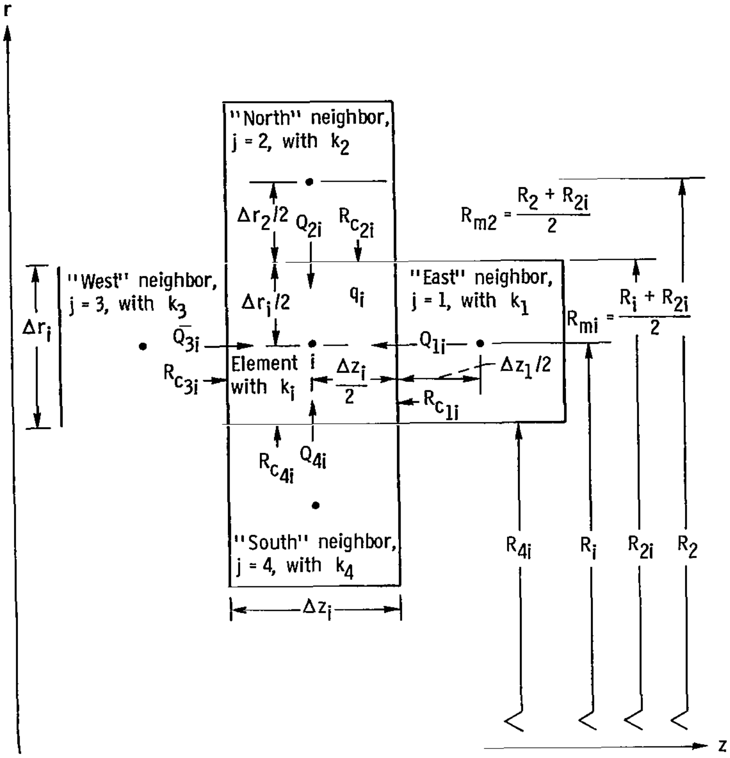


Figure 5. - Typical interior (i^{th}) element and its four neighbor elements.

where r is the radial coordinate, k is thermal conductivity, z is the axial coordinate, T is temperature, and q is internal heat generation.

Equation (1), which makes no restrictions of constant thermal conductivity k, can be approximated by a finite difference numerical approach in which thermal conductivity is held constant over small regions. In this finite difference approach, each of the axisymmetric bodies, which comprise the seal, is subdivided into a finite number of three-dimensional axisymmetric volume elements of rectangular cross section (see fig. 4). These elements need not be equal in cross-sectional area. In general, there will be P elements of which m are elements whose temperature is obtained by solving a heat balance equation and P - m are elements in which the temperature is specified. Figure 4 indicates the position of a typical interior element (i^{th} element). The numbers assigned to the neighboring elements will be determined in the construction of the element pattern, but for the purpose of developing the heat balance equation these neighboring elements are numbered 1, 2, 3, and 4 (see fig. 5).

For the numerical solution, the application of the law of conservation of energy at each volume element allows good generality to be maintained. Referring to figure 5, a heat balance for steady-state conduction at element i results in the following difference equation:

$$Q_{1i} + Q_{2i} + Q_{3i} + Q_{4i} + q_i = 0$$

where the Q_{ji} terms are the heat fluxes from the neighboring elements or

$$C_{1i}(T_1 - T_i) + C_{2i}(T_2 - T_i) + C_{3i}(T_3 - T_i) + C_{4i}(T_4 - T_i) + q_i = 0 \tag{2a}$$

in which the conductances C_{ji} are computed as follows with reference to figure 5:

$$\left.\begin{aligned} R_{1i} &= \frac{1}{C_{1i}} = \frac{\frac{\Delta z_1}{2}}{2\pi R_1 \, \Delta r_1 k_1} + \frac{\frac{\Delta z_i}{2}}{2\pi R_i \, \Delta r_i k_i} + R_{c_{1i}} \\ R_{2i} &= \frac{1}{C_{2i}} \cong \frac{\frac{\Delta R_i}{2}}{2\pi R_{mi} \, \Delta z_i k_i} + \frac{\frac{\Delta R_2}{2}}{2\pi R_{m2} \, \Delta z_2 k_2} + R_{c_{2i}} \end{aligned}\right\} \tag{2b}$$

where R_{ji} is thermal resistance. As an example, for heat conduction from neighbor element 1 to the i^{th} element, the resistance is made up of the resistance of one-half that of the i^{th} element plus one-half that of neighbor element 1 plus the contact resistance $R_{c_{ji}}$. Thus the calculated temperature is that of the element center. However, the thermal conductivity assigned to the whole element volume is the value at the temperature of the element center.

Equation (2a) can be stated concisely as

$$\sum_{j=1}^{4} C_{ji}(T_j - T_i) + q_i = 0 \tag{3}$$

where i is the element under consideration, the j's are its four neighboring elements, and $1 \leq i \leq m$. At the outer surfaces of the axisymmetric bodies, which comprise the seal, the i^{th} element will have less than four solid neighbor elements but will have environmental radiation and convection effects on the external surface (or surfaces) (fig. 6). This means that some of the j neighbors are replaced by environmental regions which are identified as the k^{th} area for radiation and the l^{th} area for convection. It should be noted that an external surface could have both radiation and convection effects. The k^{th} and l^{th} areas would, therefore, be superimposed.

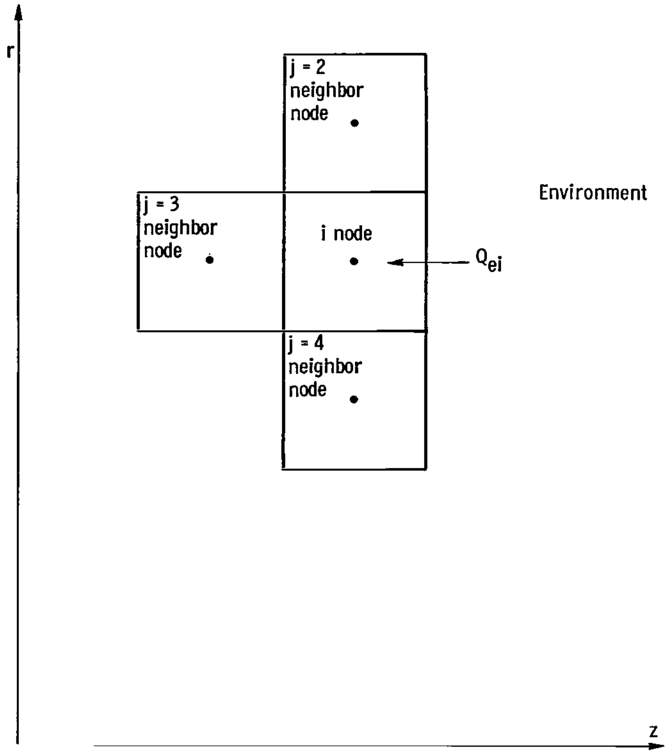


Figure 6. - Typical element with environment convection and/or radiation to one surface.

An i^{th} element could have radiation on more than one face. This radiation heat flux is

$$Q_{ki} = \sum_{k=1}^{4} N_{ki}(T_k - T_i) \tag{4}$$

An i^{th} element could have more than one face with convective effects

$$Q_{li} = \sum_{l=1}^{4} H_{li}(T_l - T_i) \tag{5}$$

Combining equations (3), (4), and (5) results in the difference equation for the heat balance of the i^{th} element:

$$\underbrace{\sum_{j=1}^{4} C_{ji}(T_j - T_i)}_{\text{Conduction}} + \underbrace{\sum_{k=1}^{4} N_{ki}(T_k - T_i)}_{\text{Radiation}} + \underbrace{\sum_{l=1}^{4} H_{li}(T_l - T_i)}_{\text{Convection}} + \underbrace{\dot{q}_i}_{\text{Internal heat generation}} = 0 \qquad (6)$$

It should be noted that equation (6) establishes the convention that heat flowing from an element has a negative value and heat flowing into an element has a positive value.

In addition to the boundary conditions of radiation and convection, two other boundary surface conditions arepossible. The heat flux may be a specified function

$$Q_{ei} \begin{cases} = K_{ei} A \left(\dfrac{\partial T}{\partial r}\right)_i \\ = C_{ei}\left(\dfrac{\partial T}{\partial r}\right) \\ \text{or} \\ = C(r, z) \end{cases} \qquad (7)$$

where $C(r, z) = 0$ for a perfectly insulated surface. Or the heat transfer coefficient may be a specified value such as

$$h_{ei} = f(r, z) \quad (\text{or } H_{ei} = f(r, z)) \qquad (8)$$

Also the temperature of any element may be specified as

$$T_i = f(r, z) \qquad (9)$$

The program has the special feature of calculating varying gas temperatures in flow over a surface or in small passages. In addition, heat generated within a fluid, such as that due to viscous shear in the sealing interfaces, can be accounted for. Referring to figure 7 reveals the heat balance for the center fluid element is

$$WC_p(T_{in} - T_{out}) + h_1A_1(T_{s1} - T_{in}) + h_2A_2(T_{s2} - T_{in}) + q_f = 0 \qquad (10)$$

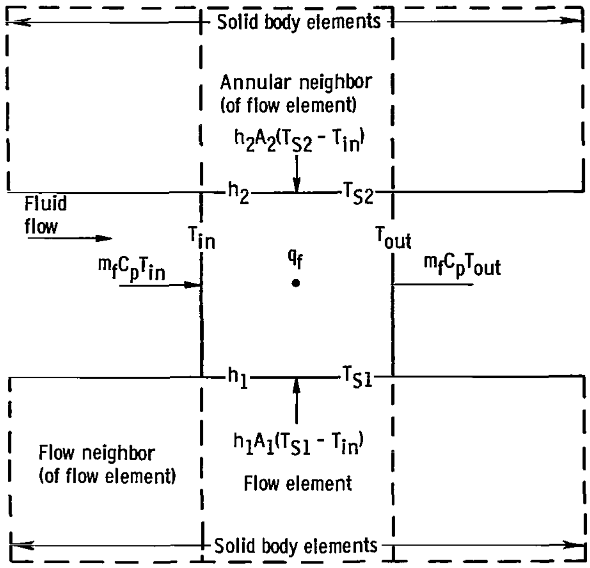


Figure 7. - Fluid volume element for varying temperature forced convection heat transfer.

in which q_f is the internal heat generated. Equation (10) enters into the element heat balance (eq. (6)) only through the determination of the fluid temperature.

Returning to the element heat balance (eq. (6)) matrix notation can be used to express this system of linear equations as follows:

$$\underbrace{-\sum_{j=1}^{4} C_{ji}T_j + \left(\sum_{j=1}^{4} C_{ji} + \sum_{k=1}^{4} N_{ki} + \sum_{l=1}^{4} H_{li}\right)}_{[A]} \underbrace{T_i}_{\{T\}} = \underbrace{\sum_{k=1}^{4} N_{ki}T_k + \sum_{l=1}^{4} H_{li}T_l - q_i}_{\{TL\}} \tag{11}$$

where [A] is the $m \times m$ conductance matrix, {T} is the $m \times 1$ temperature vector, and {TL} is the $m \times 1$ thermal load vector.

In equations (6) and (11) it should be noted that, for interior elements, the N_{ki} and H_{li} terms vanish; also numbers are assigned to the j^{th} elements.

The matrix [A] can be shown to be real, symmetric, and positive definite. The temperatures are obtained using the successive over-relaxation technique. By introducing the over-relaxation factor w, the successive over-relaxation algorithm is given for the temperature at the i^{th} element at the $(K + 1)^{th}$ iteration by:

$$a_{i,i}T_i^{K+1} = a_{i,i}T_i^K + W\left[-\sum_{j=1}^{i-1} a_{i,j}T_j^{K+1} - \sum_{j=i+1}^{m} a_{i,j}T_j^K + (TL)_i - a_{i,i}T_i^K\right]$$

where

$$1 \leq W < 2 \quad \text{and} \quad 1 < i \leq m$$

and

$$a_{i,i} = \left(\sum_{j=1}^{4} C_{ji} + \sum_{k=1}^{4} N_{ki} + \sum_{l=1}^{4} H_{li}\right) \qquad \text{diagonal term of } i^{th} \text{ row in matrix } [A]$$

$$a_{i,j} = -C_{ji} = a_{j,i} \qquad \text{off-diagonal terms of } i^{th} \text{ row in matrix } [A]$$

$$(TL)_i = \sum_{k=1}^{4} N_{ki}T_k + \sum_{l=1}^{4} H_{li}T_l + q_i \qquad i^{th} \text{ thermal load term}$$

This system of m equations is iteratively solved until a specified level of convergence is obtained.

The boundary condition conductances N_{ki} and H_{li} are calculated with the aid of the empirical relations listed in table I and discussed later.

LIMITATIONS AND SCOPE

This program has a present capacity of 400 volume elements, 200 boundary condition elements, 95 varying temperature boundary elements (see Computer Input in appendix A), and 15 different materials. Several minor limitations are discussed in the section on input where the parameters involved are introduced. The program is designed for an IBM 7094 digital computer and is written in FORTRAN IV language.

Provision is made for adding subroutines to calculate additional boundary condition coefficients without interrupting the sequence of statement numbers or altering present statements. Up to four forced convection, five free convection, and two varying tempera-

TABLE I. - BOUNDARY HEAT TRANSFER COEFFICIENTS

Heat transfer type	Geometry and fluid	Regime	Coefficient equation
Forced convection	Duct flow, liquid	Laminar	$h = 1.24 (k_f/D)(Re_w Pr_f D/X)^{1/3}$
		Turbulent	$h = 0.023 (k_f/D) Re_w^{0.8} Pr_f^{0.4} \left[1 + 0.3 (D/X)^{0.7}\right]$
		Transition	$h_{tr} = h_{lam} + (h_{turb} - h_{lam})(Re - 2500)/4500$
	Sides of rotors, liquid or gas	Laminar	$h = 0.574 (k_f/r)(s/r)^{0.1} Re_\omega^{0.5} Pr_f^{1/3} / (\beta/\omega)$
		Turbulent	$h = 0.01826 (k_f/r)(s/r)^{0.1} Re_\omega^{0.8} Pr_f^{1/3} / (\beta/\omega)$
	Radial seal gap, liquid or gas	Laminar	$h = 2 (k_f/s) Pr_f^{1/3}$
		Turbulent	$h = 0.0297 (k_f/r)(r/s)^{1/6} Re_\omega^{3/4} Pr_f^{1/3}$
	Concentric cylinders, liquid or gas	Turbulent	$h = \frac{k}{\Delta r}\left[0.015 Re_d^{0.8} Pr_f^{1/3} \left(\frac{r_o}{r_i}\right)^{0.46} + 0.092 Ta_f^{2/3} Pr_f^{1/3}\right]$
	Flat plate, liquid or gas	Laminar	$h = 0.332 (k/X) Re_x^{1/2} Pr_f^{1/3}$
		Turbulent	$h = 0.0288 (k/X) Re_x^{0.8} Pr_f^{1/3}$
Free convection	Horizontal cylinder, liquid or gas	Laminar	$h = 0.53 (k_f/D_o)(Gr_{D,f} Pr_f)^{1/4}$
		Turbulent	$h = 0.13 (k_f/D_o)(Gr_{D,f} Pr_f)^{1/3}$
	Vertical cylinder or plane	Laminar	$h = 0.44 (k_f/X)(Gr_{D,f} Pr_f)^{1/4}$
		Turbulent	$h = 0.13 (k_f/X)(Gr_{D,f} Pr_f)^{1/3}$
	Liquid film cooling, gravity flow	--------	$h = 2C_p(W/L)/\pi D_l$
Radiation	Any surface	--------	$h_r = \frac{q}{A\,\Delta T} = \frac{\sigma\epsilon_e(1 - \epsilon_s)F_{es}\left(T_e^3 + T_e^2 T_s + T_e T_s^2 + T_s^3\right)}{1 - F_{es}F_{se}(1 - \epsilon_e)(1 - \epsilon_s)}$

ture conditions can be added by writing appropriate subroutines and by adding the required statements in subroutine CQN. The CQN statements required can be deduced from the portions labeled for present coefficients. Changes and some limitations are discussed in more detail in appendix B.

The present coefficient equations are based on properties evaluated at the boundary film temperature (average of bulk fluid and surface temperatures). Unless the initial temperature estimates (required as a starting point) are very close to the final temperatures calculated, the input required will have to be changed and the problem rerun at least once to obtain the best results.

CONCLUDING REMARKS

The program, which is written in FORTRAN IV language for an IBM 7094 digital computer, is general and can be applied to a variety of axisymmetric problems. Various convection and radiation boundary conditions which can be used are given in the mathematical formulation. The program listing and flowcharts for steady-state thermal solution of an axisymmetric solid in cylindrical coordinates are given. Computer program application to a nosepiece assembly is given in detail. Additional demonstration of the program is provided in a comparison of the program solution to the exact solution for a finite cylinder. This comparison shows a maximum error of 15 percent when a coarse mesh is used. Thus a partial check on program accuracy is provided.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, July 10, 1969,
126-15.

APPENDIX A

COMPUTER PROGRAM

Preparation of Input Data

The recommended first step is the preparation of the element pattern. For the seal analyzed in appendix C, a layout of the seal assembly five times actual size was used. There is no restriction on the numbering sequence except the use of consecutive numbers (i.e., every number from 1 to P), but it is preferable to use an orderly system in order to avoid confusion and to expedite assembling the data required for input. The drawing also includes, for convenience, the radial dimension and mean radius of each element row and the axial dimension of each column.

Adjacent elements should have the same common dimension. Slight variations will not cause appreciable errors if a contact resistance is added to compensate for the increased conduction path length of off-center nonmatching elements.

Also, for convenience, the boundary conditions (pressure, temperature, fluid, and so forth, needed to determine the values of required properties) are included. The materials of the various parts are included in a table (on the drawing if room is available).

The items of data required are listed in the following section on computer input. A compact outline of most items can be obtained from the section Program Symbols and Definitions or from table II. The conduction element matrix (TD1) and boundary coefficient lists (TD2) include input data.

TABLE II. - SUMMARY OF TD2 LISTS FOR SUBROUTINES TO CALCULATE COEFFICIENTS

[Parameters in parentheses are calculated in subroutine. Except for TD2(20) of SN3 and VT2 and TD2(11) of FC1 and FC2, parameters after hA are merely to make writing FORTRAN expression for h easier.]

TD2 word or sub-script	Subroutine											
	SN1 (duct flow, liquid)	SN2 (sides of rotors)	SN3 (radial seal gap)	SN4 (concen-tric cyl-inders)	SN5 (flat plate)	FC1 (horizon-tal cylinder)	FC2 (vertical cylinder or plane)	FC3 (liquid film cooling, gravity flow)	RA1 (radia-tion)	SC1 (specified heat transfer coeffi-cient)	VT1 (varying tempera-ture duct flow, liquid)	VT2 (varying tempera-ture radial seal gap)
1	T_b	T_b	T_b	T_b	T_b	T_b	T_b	T_b	T_e	T_b or T_e	T_b	T_b
2	k_f	k_f	k_f	k_f	k_f	k_f	k_f	W/L	f_{es}	h	k_f	k_f
3	$C_{p,f}$	$C_{p,f}$	$C_{p,f}$	$C_{p,f}$	$C_{p,f}$	$C_{p,f}$	$C_{p,f}$	C_p	f_{se}	(hA)	$C_{p,f}$	$C_{p,f}$
4	μ_f	μ_f	μ_f	μ_f	μ_f	μ_f	μ_f	D_L	ϵ_e	--------	μ_f	μ_f
5	W_a	ν_f	ν_f	ν_f	ν_f	ν_f	ν_f	(h)	ϵ_s	--------	W	ν_f
6	D	r_{av}	r_{av}	r_o	X	D	L	(hA)	(h)	--------	D	r_{av}
7	X	s	s	r_i	V_∞	(Pr_f)	(Pr_f)	------	(hA)	--------	X	s
8	---------	ω	ω	ω	(Re_x)	(Gr_D)	(Gr_L)	------	$(1 - \epsilon_e)$	--------	Annular neighbor conduction number	ω
9	---------	a	a	V_a	(Pr_f)	(h_f)	(h_f)	------	$(1 - \epsilon_s)$	--------	Flow neighbor conduction number	a
10	---------	*	----	(Re_v)	(h)	(hA)	(hA)	------	$\left(\frac{T_e^4 - T_s^4}{T_e - T_s}\right)$	--------	Combining flow indicator	Combining flow indicator
11	---------	(Re_ω)	----	$\left(Pr_f^{1/3}\right)$	(hA)	$(Pr_f Gr_D)$	$(Pr_f Gr_D)$	------	--------	--------	Flow initiation indicator	Flow initiation indicator
12	---------	$\left(Pr_f^{1/3}\right)$	----	(h_f)	-----	(ΔT)	(ΔT)	------	--------	--------	A_x	Annular neighbor conduction number
13	(Re_w)	(h_f)	----	(hA)	-----	(T_{av})	(T_{av})	------	--------	--------	(Re_w)	Flow neighbor conduction number
14	(Pr_f)	(hA)	----	(V_R)	-----	(k_f/D)	(k_f/L)	------	--------	--------	(Pr_f)	W
15	(h_f)	(k_f/r_{av})	(Re_ω)	(V_{tot}^2)	-----	--------	--------	------	--------	--------	(h_f)	(Re_ω)
16	(hA)	$\left([s/r_{av}]^{0.1}\right)$	$\left(Pr_f^{1/3}\right)$	(V_{tot})	-----	--------	--------	------	--------	--------	(hA)	$\left(Pr_f^{1/3}\right)$
17	(D/X)	(K)	(Re_c)	(s)	-----	--------	--------	------	--------	--------	(D/X)	(Re_c)
18	(k_f/D)	----------	(h_f)	------	-----	--------	--------	------	--------	--------	(k_f/D)	(h_f)
19	$\left([(D/X)]^{0.7}\right)$	----------	(hA)	------	-----	--------	--------	------	--------	--------	$\left([D/X]^{0.7}\right)$	(hA)
20	---------	----------	(Heat genera-tion factor)	------	-----	--------	--------	------	--------	--------	---------	(Heat generation factor)

*Rotor or stator flag (zero for rotor, nonzero for stator).

Computer Input

The data input of a problem is submitted to the computer on the cards described in this section. Unless specifically stated, no input card may be omitted.

Item 1: Title card (72H)

word 1	columns 1 to 72	Title of problem being run

Item 2: Output control (LD) card (10I6) for obtaining printouts in addition to that listed in the section Computer Output

word 1	columns 1 to 6	A nonzero integer causes printout of the conduction matrix (TD1 table) input
word 2	columns 7 to 12	A nonzero integer causes printout of the boundary conductance matrix (H(NBPT,J),J=1,9)
word 3	columns 13 to 18	A nonzero integer causes printout of the element temperatures for the next to last iteration (unless execution terminated by reaching maximum number of iterations) for comparison with temperatures of last iteration
word 4	columns 19 to 24	Leave blank. This word is set within the program to cause printout of the convergence criterion (Item 5, word 4) and of the temperature change for each element at each N^{th} iteration; N is specified by word 2 of the Run data card (Item 4).
word 5	columns 25 to 30	A nonzero integer causes printout of the boundary condition input matrix (TDA and TD2 lists)
word 6	columns 31 to 36	Not used
word 7	columns 37 to 42	Not used
word 8	columns 43 to 48	A nonzero integer causes the final element temperatures to be punched on cards for use as initial estimates for another run
word 9	columns 49 to 54	A nonzero integer causes thermal expansions to be punched on cards for use in other programs (e.g., a stress analysis)

word 10	columns 55 to 60	A nonzero integer causes printout of element temperatures and heat fluxes after each iteration. Also thermal expansion data (α, T, α ΔT) are printed. This option is meant only for debugging data and should not be included for a standard run.

Item 3: Miscellaneous options (NI) card (5I6)

word 1	columns 1 to 6	Number of cases (designs) to be analyzed. If only one case, this word may be left blank.

No other words now used; leave blank.

Item 4: Run data (RD) card (5F6.0)

word 1	columns 1 to 6	Over-relaxation factor w $(1 \leq w < 2)$
word 2	columns 7 to 12	Reference temperature for thermal expansion (α ΔT)
word 3	columns 13 to 18	The interval N required for word 4 of the LD card (Item 2)

No other words now used.

Item 5: Case data (CD) card (10F6.0)

word 1	columns 1 to 6	Number of elements (400 maximum at present)
word 2	columns 7 to 12	Number of boundary elements (200 maximum at present)
word 3	columns 13 to 18	Maximum number of iterations allowed for a run
word 4	columns 19 to 24	Temperature convergence criterion. The maximum change in temperature of any element from one iteration to the next that is considered an acceptable error.
word 5	columns 25 to 30	Not used
word 6	columns 31 to 36	Starting temperature for varying temperature flow 1 (see varying temperature under boundary condition input (Item 10))
word 7	columns 37 to 42	Starting temperature for varying temperature flow 2

word 8	columns 43 to 48	Not used
word 9	columns 49 to 54	To avoid numerical instability due to low flow rates in the varying temperature calculation, the boundary elements are subdivided. The number of subdivisions is specified between 1 and 100 in this word.
word 10	columns 55 to 60	Not used

Item 6: Thermal conductivity data cards

The thermal conductivity of each material is treated as a power series function of temperature ($k = AT^0 + BT^1 + . . . + NT^m$). Provision is made for curve fitting up to 15 materials. The coefficients required are computed by an auxiliary program (or, of course, by hand) from available data. The degree of fit of a curve is defined as the highest power of temperature appearing in the function. Thus, a linear fit is degree 1; a constant conductivity is degree 0; and so forth.

The auxiliary program is designed to produce fits of all degrees up to 11 from which the best agreement with a set of average values of k is selected as the function to be used. Therefore, words 4 and 5 were included to avoid exceeding the computer capacity when the higher powers of temperature occurred. Later it was somewhat arbitrarily decided to limit the maximum degree of fit to five in view of data scatter due to variation between material lots. The primary reason was to increase the number of materials possible and to save computer storage space.

Card 1 (5F10.0)

word 1	columns 1 to 10	Upper temperature limit of curve fit
word 2	columns 11 to 20	Material code number. Each material must be assigned a number so that the correct properties will be used in the program.
word 3	columns 21 to 30	Degree of fit (0 to 5)
word 4	columns 31 to 40	Thermal conductivity scaling factor. At present, this is 1.
word 5	columns 41 to 50	Temperature scaling factor. At present, this is 1.

Card 2 (6E13.6) - The coefficients of the equation: A in columns 1 to 13, B in columns 14 to 26, and so forth.

Card 3 (blank card) - If less than 15 materials are used, a blank card <u>must</u> be inserted following the last conductivity card in order to terminate the reading of data.

Item 7: Mean coefficient of linear thermal expansion cards

The remarks made about conductivity (see Item 6) also apply to expansion.

Card 1 (5F10.0)

word 1	columns 1 to 10	Upper temperature limit of curve fit
word 2	columns 11 to 20	Material code number
word 3	columns 21 to 30	Degree of fit (0 to 5)
word 4	columns 31 to 40	Thermal expansion scaling factor. At present, this is 1.
word 5	columns 41 to 50	Temperature scaling factor. At present, this is 1.

Card 2 (6E13.6) - The coefficients of the equation as in Item 6.

Card 3 (blank card) - To terminate data read in for less than 15 materials (see Item 6).

Item 8: Conduction matrix data (TD1) card (F4.0, 1X, F7.4, 2F5.3, 1X, 4F4.0, F3.0, 4F7.0) - 1 card per element; element numbers in numerical order

word 1	columns 1 to 4	Element conduction number
word 2	columns 6 to 12	Mean element radius, r_{av}, in.
word 3	columns 13 to 17	Element radial width, Δr, in.
word 4	columns 18 to 22	Element axial length, Δl, in.
word 5	columns 24 to 27	East neighbor conduction number, j_1
word 6	columns 28 to 31	North neighbor conduction number, j_2
word 7	columns 32 to 35	West neighbor conduction number, j_3
word 8	columns 36 to 39	South neighbor conduction number, j_4
word 9	columns 40 to 42	Material code number (see Item 6, word 2)
word 10	columns 43 to 49	East contact resistance, $R_{c_{1,i}}$, (sec)(^{o}F)/Btu
word 11	columns 50 to 56	North contact resistance, $R_{c_{2,i}}$, (sec)(^{o}F)/Btu
word 12	columns 57 to 63	West contact resistance, $R_{c_{3,i}}$, (sec)(^{o}F)/Btu
word 13	columns 64 to 70	South contact resistance, $R_{c_{4,i}}$, (sec)(^{o}F)/Btu

Item 9: Initial temperature cards (16F5.0) - Put 16 initial element temperatures per card.

words 1 to 16	columns 1 to 5, 6 to 10, 11 to 15, and so forth	Initial element temperatures (^{O}F) are listed in sequence from 1 to the total number of elements: elements 1 to 16 on the first card, elements 17 to 32 on the second, and so forth.

Item 10: Boundary heat transfer cards

Each boundary element requires an indicator card. Following the indicator card is a set of one or more cards for each boundary condition associated with the element. A partial outline is presented in table II. This sequence is repeated for each boundary element.

Card 1: Boundary indicator card (3I6) - 1 card per element

word 1	columns 1 to 16	Boundary number of the element. In addition to the comduction numbers which are assigned to the elements, each boundary element is given a boundary number. Any convenient order of numbering can be used. This is for convenience in preparing data.
word 2	columns 7 to 12	Conduction number of the boundary element. Most computation is based on the conduction number.
word 3	columns 13 to 18	Boundary heat transfer type code number for first basic type associated with the element. Code numbers are as follows: (1) Specified heat flux - the net flux for all faces for which it is specified. If this type is associated with a node, it must appear first; but the other types need not appear in any fixed order. (2) Forced convection (3) Free convection (4) Radiation (5) Specified heat transfer coefficient (6) Specified temperature - By definition this will be the only condition for an element; the program considers only its effect on adjacent elements.

Card 2: Index card (for each condition: basic type or subtype)

This card has two forms. Form A is used for specified parameters (types 1 and 7) which require no additional cards. Form B (TDA) is used for the remaining types which do require additional cards.

Form A for specified heat flux (I5,E13.6,I6)

word 1	columns 1 to 5	Conduction number of element
word 2	columns 6 to 18	Heat flux, Btu/sec
word 3	columns 19 to 24	A nonzero integer if other types or subtypes associated with the node follow; blank (or 0) if no types or subtypes follow.

Form A for specified temperature (I5,1X,F6.0)

word 1	columns 1 to 5	Conduction number of element
word 2	columns 7 to 12	Temperature of element, ^{o}F

Form B (6F6.0,F12.0) - These (TDA) cards are the same for all types using them.

word 1	columns 1 to 6	Conduction number of element
word 2	columns 7 to 12	Heat transfer type (2 to 6)
word 3	columns 13 to 18	Heat transfer subtype code number. (For additions or substitutions see limitations and scope.)

Subtype code numbers for type 2 (forced convection) are as follows:

(1) Duct flow, liquid - for explanation see headings under additional cards
(2) Sides of rotors
(3) Radial seal gap
(4) Concentric cylinders
(5) Flat plate
(6) to (9) for additional subtypes

Subtype code numbers for type 3 (free convection) are as follows:

(1) Horizontal cylinder
(2) Vertical cylinder or plane
(3) Liquid film cooling, gravity flow
(4) to (8) for additional subtypes

Subtype code numbers for type 6 (varying temperature forced convection) are as follows:
(1) Duct flow, liquid
(2) Radial seal gap
(3) to (4) for additional subtypes

Types 4 and 5, at present, have no subtypes; so word 3 = 0.

word 4	columns 19 to 24	Nonzero number if other types or subtypes follow
word 5	columns 25 to 30	Number of items to be read from the remaining cards for this condition
word 6	columns 31 to 36	Area indicator code number specifies to which face of the element the condition applies; these numbers are as follows: (1) East face (2) North face (3) West face (4) South face (5) Specified area - used for special cases such as a small duct passing through an element or a boundary at an appreciably nonparallel or nonnormal angle to the axis. Since conductive resistance is assumed to be negligible compared with boundary film resistance, the problem of location does not occur.
word 7	columns 37 to 48	If a specified area (code number 5 in word 6) is used, the value in square feet is placed here; otherwise, this word is left blank.

For types 2 to 6, the following additional cards are needed as shown under types 4 and 5 and the subtypes of types 2, 3, and 6. Card 1 is the indicator card described previously. Card 2 is the TDA card for the type or subtype. The properties are evaluated at the temperature indicated by the equations in table I.

Steady-state forced convection (type 2):

Subtype 1 - Duct flow, liquid

Card 3 (7F11.0)

word 1	columns 1 to 11	Fluid bulk temperature, $^{\circ}F$

word 2	columns 12 to 22	Thermal conductivity, Btu/(ft)(sec)(^{o}F)
word 3	columns 23 to 33	Specific heat, Btu/(lbm)(^{o}F)
word 4	columns 34 to 44	Absolute viscosity, lbm/(ft)(sec)
word 5	columns 45 to 55	Mass flow per square foot of cross section, lbm/(ft^{2})(sec)
word 6	columns 56 to 66	Hydraulic diameter, $4A_x/P_w$, ft
word 7	columns 67 to 77	Flow length (distance from start of duct to center of element), ft

Subtype 2 - Sides of rotors (see Use of Local Coefficients in appendix D)

Card 3 (7F11.0)

word 1	columns 1 to 11	Fluid bulk temperature, ^{o}F
word 2	columns 12 to 22	Thermal conductivity, Btu/(ft)(sec)(^{o}F)
word 3	columns 23 to 33	Specific heat, Btu/(lbm)(^{o}F)
word 4	columns 34 to 44	Absolute viscosity, lbm/(ft)(sec)
word 5	columns 45 to 55	Kinematic viscosity, ft^{2}/sec
word 6	columns 56 to 66	Average radius of element, ft
word 7	columns 67 to 77	Gap between rotor and stator, ft

Card 4 (3F11.0)

word 1	columns 1 to 11	Rotor angular velocity, rad/sec
word 2	columns 12 to 22	Outer radius of rotor or stator, ft
word 3	columns 23 to 33	Rotor or stator flag (zero for rotor, nonzero for stator)

Subtype 3 - Radial seal gap

Card 3 (7F11.0)

word 1	columns 1 to 11	Fluid bulk temperature, ^{o}F
word 2	columns 12 to 22	Thermal conductivity, Btu/(ft)(sec)(^{o}F)
word 3	columns 23 to 33	Specific heat, Btu/(lbm)(^{o}F)
word 4	columns 34 to 44	Absolute viscosity, lbm/(ft)(sec)

word 5	columns 45 to 55	Kinematic viscosity, ft^2/sec
word 6	columns 56 to 66	Average radius of element, ft
word 7	columns 67 to 77	Gap between rotor and stator, ft

Card 4 (2F11.0)

word 1	columns 1 to 11	Rotor angular velocity, rad/sec
word 2	columns 12 to 22	Outer radius of rotor or stator, ft

Subtype 4 - Concentric cylinders (inner cylinder rotating)

Card 3 (7F11.0)

word 1	columns 1 to 11	Fluid bulk temperature, $^{\circ}F$
word 2	columns 12 to 22	Thermal conductivity, Btu/(ft)(sec)($^{\circ}F$)
word 3	columns 23 to 33	Specific heat, Btu/(lbm)($^{\circ}F$)
word 4	columns 34 to 44	Absolute viscosity, lbm/(ft)(sec)
word 5	columns 45 to 55	Kinematic viscosity, ft^2/sec
word 6	columns 56 to 66	Outer radius of annulus between cylinders, ft
word 7	columns 67 to 77	Inner radius of annulus, ft

Card 4 (2F11.0)

word 1	columns 1 to 11	Rotational velocity of inner cylinder, rad/sec
word 2	columns 12 to 22	Axial flow velocity, ft/sec

Subtype 5 - Flat plate

Card 3 (7F11.0)

word 1	columns 1 to 11	Fluid bulk temperature, $^{\circ}F$
word 2	columns 12 to 22	Thermal conductivity, Btu/(ft)(sec)($^{\circ}F$)
word 3	columns 23 to 33	Specific heat, Btu/(lbm)($^{\circ}F$)
word 4	columns 34 to 44	Absolute viscosity, lbm/(ft)(sec)
word 5	columns 45 to 55	Kinematic viscosity, ft^2/sec
word 6	columns 56 to 66	Flow length (distance from start of plate to center of element), ft
word 7	columns 67 to 77	Velocity of bulk fluid, ft/sec

Free convection (type 3):

Subtype 1 (horizontal cylinder) or 2 (vertical cylinder or plane), gas - identical except for the characteristic length used

Card 3 (6F11.0)

word 1	columns 1 to 11	Fluid bulk temperature, $^{\circ}F$
word 2	columns 12 to 22	Thermal conductivity, Btu/(ft)(sec)($^{\circ}F$)
word 3	columns 23 to 33	Specific heat, Btu/(lbm)($^{\circ}F$)
word 4	columns 34 to 44	Absolute viscosity, lbm/(ft)(sec)
word 5	columns 45 to 55	Kinematic viscosity, ft^2/sec
word 6	columns 56 to 66	Subtype 1: hydraulic diameter, ft Subtype 2: flow length (distance from start of flow to top of surface of which element is a part), ft

Subtype 3 - Liquid film cooling, gravity flow

Card 3 (4F11.0)

word 1	columns 1 to 11	Fluid film temperature, $^{\circ}F$
word 2	columns 12 to 22	Mass flow per unit length (at a right angle to flow direction), lbm/(ft)(sec)
word 3	columns 23 to 33	Specific heat, Btu/(lbm)($^{\circ}F$)
word 4	columns 34 to 44	Flow length (distance from point where flow starts to where it leaves surface (e.g., one-half circumference of horizontal cylinder)), ft

Graybody radiation (type 4):

Card 3 (4F11.0)

word 1	columns 1 to 11	Environmental temperature, $^{\circ}F$
word 2	columns 12 to 22	View factor, environment to surface
word 3	columns 23 to 33	View factor, surface to environment
word 4	columns 34 to 44	Emissivity of environment
word 5	columns 45 to 55	Emissivity of surface

Specified heat transfer coefficient (type 5):

Card 3 (2F11.0)

word 1	columns 1 to 11	Fluid bulk (or environmental) temperature, ^{o}F
word 2	columns 12 to 22	Heat transfer coefficient, Btu/(ft^2)(sec)(^{o}F)

Varying temperature forced convection (type 6):

Subtype 1 - Varying temperature duct flow, liquid

Card 3 (7F11.0)

word 1	columns 1 to 11	Fluid bulk temperature, ^{o}F
word 2	columns 12 to 22	Thermal conductivity, Btu/(ft)(sec)(^{o}F)
word 3	columns 23 to 33	Specific heat, Btu/(lbm)(^{o}F)
word 4	columns 34 to 44	Absolute viscosity, lbm/(ft)(sec)
word 5	columns 45 to 55	Mass flow per square foot of cross section, lbm/(ft^2)(sec)
word 6	columns 56 to 66	Hydraulic diameter, $4A_x/P_w$, ft
word 7	columns 67 to 77	Flow length (distance from start of duct to center of element), ft

Card 4 (4F11.0)

word 1	columns 1 to 11	Conduction number of annular neighbor (element on other boundary of flow if flow is between two elements). If none, leave blank.
word 2	columns 12 to 22	Conduction number of flow neighbor (element upstream of element under consideration). If this is the first element along the flow, leave blank.
word 3	columns 23 to 33	Combined flow indicator (see remarks at end of this subtype)
word 4	columns 34 to 44	Flow initiation indicator (see remarks at end of this subtype)
word 5	columns 45 to 55	Cross section of duct, ft^2

There is provision in the program for varying temperature flows of two starting temperatures. Any number of varying temperature flows can be handled subject to the following additional restrictions. The program will handle only one such boundary condition per element. The number of elements with varying temperature flows cannot exceed half the number of boundary elements (95) at present. There can be no more than five combined flows (explained later).

The flow initiation indicator distinguishes the two starting temperatures. If 1 is used, the starting temperature is word 1, Card 2 of Item 5 (Case data). If 2 is used, the starting temperature is word 2, Card 2 of Item 5.

If two flows (limit of program) combine at a boundary element to form a new flow, this element is a combined flow element. For a combined flow element, the flow initiation indicator must be zero. Five such combinations are permitted by the program. An additional card is then required.

Card 5 (2I6) - only for combined flow elements

word 1	columns 1 to 6	Conduction number of one upstream neighbor element
word 2	columns 7 to 12	Conduction number of other upstream neighbor element

Subtypes - Varying temperature radial seal gap

Card 1 (7F11.0)

word 1	columns 1 to 11	Fluid bulk temperature, ^{o}F
word 2	columns 12 to 22	Thermal conductivity, Btu/(ft)(sec)(^{o}F)
word 3	columns 23 to 33	Specific heat, Btu/(lbm)(^{o}F)
word 4	columns 34 to 44	Absolute viscosity, lbm/(ft)(sec)
word 5	columns 45 to 55	Kinematic viscosity, ft^2/sec
word 6	columns 56 to 66	Average radius of element, ft
word 7	columns 67 to 77	Gap between rotor and stator, ft

Card 2 (7F11.0)

word 1	columns 1 to 11	Rotor angular velocity, rad/sec
word 2	columns 12 to 22	Outer radius of rotor, ft
word 3	columns 23 to 33	Combined flow indicator
word 4	columns 34 to 44	Flow initiation indicator
word 5	columns 45 to 55	Annular neighbor conduction number

word 6	columns 56 to 66	Flow neighbor conduction number
word 7	columns 67 to 77	Mass flow, lbm/sec

Card 5 (2I6) - only for combined flow elements

word 1	columns 1 to 6	Conduction number of one upstream neighbor element
word 2	columns 7 to 12	Conduction number of other upstream neighbor element

Computer Output

Standard output of results. - The standard output of the program is obtained with all list options (Item 2 of Computer Input) set at zero with the possible exception of the punch options (words 8 and 9). This output is as follows:

Item 1: Problem title
Item 2: Printout options (see input Item 2)
Item 3: Miscellaneous options (see input Item 3)
Item 4: Run data (see input Item 4)
Item 5: Case data (see input Item 5)
Item 6: Thermal conductivity curve fit coefficients for each material
Item 7: Thermal expansion curve fit coefficients for each material
Item 8: Element starting temperature estimates
Item 9: Varying temperature boundary element dimensionless coefficient, hA/WC_p
Item 10: Varying temperature boundary element fluid internal heat generation
Item 11: Conduction number and preceding element conduction numbers for each combined flow element
Item 12: Conduction number, varying temperature number, and flow code for varying temperature boundary elements
Item 13: Element steady-state temperatures
Item 14: Boundary element forced convection, free convection, radiation, and varying temperature convection conductances
Item 15: Varying temperature boundary condition fluid temperatures
Item 16: Element thermal conductivities
Item 17: Element heat fluxes to neighbor elements
Item 18: Element conductances to neighbor elements
Item 19: Element boundary conductance sums and boundary heat flux sums
Item 20: Element free thermal expansion, $\alpha \, \Delta T$

An illustration of the output can be found in the listing for the sample problem in appendix C.

Program error messages. - The program includes checks of some of the input to ensure correct relations. First, the conductivity (TD1) cards are checked for numerical order of conduction numbers. Once this has been achieved, a check is made for neighbor agreement. For example, if element 10 has element 11 listed as east neighbor, element 11 must have element 10 as west neighbor, assuming this is the correct relation. When the neighbor agreement is complete, a check is made of boundary index cards to ensure numerical order of boundary numbers. Then a check is made to see that the conduction number(s) on the element boundary index card(s) agree with the conduction number on the indicator card. Also there is a check for agreement of the boundary number corresponding to an element conduction number with the conduction number corresponding to the element boundary number.

Program Symbols and Definitions

AFN(NTF)	conduction number of varying temperature element annular neighbor
ALPHA(15, 11)	thermal expansion curve fit matrix (input Item 6)
CE(NJPTS, 4)	neighbor conductance matrix
GFN(NTF)	conduction number of varying temperature element flow neighbor
H(NBPTS, 9)	boundary conductance matrix
JBNT(JBPT)	boundary number of element JBPT
JBP	conduction number of boundary element (in card check)
JBPT	conduction number of boundary element, NBND(NBP)
JNTF(JVPT)	varying temperature number of element JVPT
JPT	conduction number of element
JVPT	conduction number of varying temperature element, NODE(NTF)
MATL(15, 11)	thermal conductivity curve fit matrix (input Item 5)
NAT(NDR)	conduction number of one adjacent element upstream of NDR
NBDIM	maximum number of boundary elements accepted by program
NBND(NBP)	conduction number of boundary element NBP
NBP	boundary number of boundary element
NBPTS	actual number of boundary elements

NBR(NTR)	flow number (input Item 10, Card 4, word 3) of varying temperature element
NBT(NDR)	conduction number of other adjacent element upstream of NDR
NDIM	maximum number of conduction elements accepted by program
NDR	combination number of combined flow varying temperature element
NITS	maximum number of iterations allowed for analysis
NJPTS	actual number of conduction elements
NM(NDR)	conduction number of combined flow element NDR
NODE(NTF)	conduction number of varying temperature element NTF
NTF	varying temperature number of varying temperature boundary element
NTR	noncombining flow number of varying temperature element
NVDIM	maximum number of varying temperature elements accepted
QF(NTF)	fluid shear heat generation at varying temperature element NTF
Q(JBPT)	sum of boundary heat fluxes of conduction element JBPT
SUMH(NBPT)	sum of boundary conductances of boundary element NBPT
SUMT(NBPT)	sum of boundary heat fluxes of boundary element NBPT
TBND(NTF)	fluid temperature at varying temperature boundary element
TCF(NTF)	dimensionless coefficient of varying temperature element, kA/WC_p
TDA(7)	index card (input Item 10, Card 2) list
TD1(NJPTS,19)	conduction data matrix
TD2(20)	properties cards (input Item 10, Card(s) 3 and those following) list
THEXP(JPT)	element thermal expansion, $\alpha \Delta T$
T(JPT)	initial temperature estimate for element JPT
TS(INC)	fluid temperature calculation by subdivision of boundary element

Conductance matrix CE(NJPTS,4). - The symbols for conductance matrix CE(NJPTS,4) are as follows:

CE(JPT,1)	conductance between conduction element JPT and east neighbor
CE(JPT,2)	conductance between conduction element JPT and north neighbor
CE(JPT,3)	conductance between conduction element JPT and west neighbor
CE(JPT,4)	conductance between conduction element JPT and south neighbor

Boundary conductance matrix H(NBPTS, 9). - The symbols for boundary conductance matrix H(NBPTS, 9) are as follows:

H(NBPT, 1)	specified heat flux
H(NBPT, 2)	sum of forced convection (including specific coefficient) conductances
H(NBPT, 3)	sum of forced convection conductance × fluid temperature
H(NBPT, 4)	sum of free convection conductances
H(NBPT, 5)	sum of free convection conductance × fluid temperature
H(NBPT, 6)	sum of radiation "conductances"
H(NBPT, 7)	sum of radiation "conductance" × environmental temperature
H(NBPT, 8)	sum of varying temperature conductances
H(NBPT, 9)	sum of varying temperature conductance × fluid temperature

Conduction data matrix TD1(NJPTS, 19). - The symbols for conduction data matrix TD1(NJPTS, 19) are as follows:

TD1(JPT, 1)	element conduction number
TD1(JPT, 2)	mean element radius
TD1(JPT, 3)	element radial width, Δr
TD1(JPT, 4)	element axial length, Δl
TD1(JPT, 5)	east neighbor conduction number, j_1
TD1(JPT, 6)	north neighbor conduction number, j_2
TD1(JPT, 7)	west neighbor conduction number, j_3
TD1(JPT, 8)	south neighbor conduction number, j_4
TD1(JPT, 9)	material code number
TD1(JPT, 10)	east contact resistance, $R_{c_{1i}}$
TD1(JPT, 11)	north contact resistance, $R_{c_{2i}}$
TD1(JPT, 12)	west contact resistance, $R_{c_{3i}}$
TD1(JPT, 13)	south contact resistance, $R_{c_{4i}}$
TD1(JPT, 14)	east and west boundary areas (added during run)
TD1(JPT, 15)	north boundary area (added during run)
TD1(JPT, 16)	south boundary area (added during run)
TD1(JPT, 17)	boundary condition type code number (added during run)

TD1(JPT, 18) thermal conductivity (added during run)

TD1(JPT, 19) element temperature (added during run)

TD2 list for subroutine SN1, type 2 (forced convection), subtype 1 (duct flow, liquid). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) boundary film thermal conductivity, k_f

TD2(3) boundary film specific heat, $C_{p,f}$

TD2(4) boundary film absolute viscosity, μ_f

TD2(5) fluid mass flow per square foot of cross section, W_a

TD2(6) duct hydraulic diameter, D

TD2(7) length from start of flow to center of element, X

TD2(8) not used in order to obtain compatability with VT1

TD2(9) not used in order to obtain compatability with VT1

TD2(10) not used in order to obtain compatability with VT1

TD2(11) not used in order to obtain compatability with VT1

TD2(12) not used in order to obtain compatability with VT1

TD2(13) Reynolds number (calculated in subroutine), Re_w

TD2(14) Prandtl number (calculated in subroutine), Pr_f

TD2(15) heat transfer coefficient (calculated in surboutine), h_f

TD2(16) conductance across boundary film (calculated in subroutine), hA

TD2(17) hydraulic diameter/flow length (calculated in subroutine), D/X

TD2(18) conductivity/hydraulic diameter (calculated in subroutine), k_f/D

TD2(19) 0.7 power of TD2(16) (calculated in subroutine), $(D/X)^{0.7}$

TD2 list for subroutine SN2, type 2 (forced convection), subtype 2 (sides of rotors). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) boundary film thermal conductivity, k_f

TD2(3) boundary film specific heat, $C_{p,f}$

TD2(4) boundary film absolute viscosity, μ_f

TD2(5) boundary film kinematic viscosity, ν_f

TD2(6) average radius of element, r_{av}

TD2(7) clearance between rotor and stator, s

TD2(8) rotor angular velocity, ω

TD2(9) outer radius of rotor, a

TD2(10) rotor or stator flag (zero for rotor, nonzero for stator)

TD2(11) Reynolds number (calculated in subroutine), Re_{ω}

TD2(12) cube root of Prandtl number (calculated in subroutine), $Pr_f^{1/3}$

TD2(13) heat transfer coefficient (calculated in subroutine), h_f

TD2(14) conductance across boundary film (calculated in subroutine), hA

TD2(15) conductivity/average radius (calculated in subroutine), k_f/r_{av}

TD2(16) 0.1 power of clearance/average radius (calculated in subroutine), $(s/r_{av})^{0.1}$

TD2(17) fluid angular velocity/rotor angular velocity (calculated in subroutine), K

TD2 list for subroutine SN3, type 2 (forced convection), subtype 3 (radial seal gap). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) boundary film thermal conductivity, k_f

TD2(3) boundary film specific heat, $C_{p,f}$

TD2(4) boundary film absolute viscosity, μ_f

TD2(5) boundary film kinematic viscosity, ν_f

TD2(6) average radius of element, r_{av}

TD2(7) clearance between rotor and stator, s

TD2(8) rotor angular velocity, ω

TD2(9) outer radius of rotor, a

TD2(10) not used to obtain compatability with VT2

TD2(11) not used to obtain compatability with VT2

TD2(12) not used to obtain compatability with VT2

TD2(13) not used to obtain compatability with VT2

TD2(14) not used to obtain compatability with VT2

TD2(15) Reynolds number (calculated in subroutine), Re_{ω}

TD2(16) cube root of Prandtl number (calculated in subroutine), $Pr_f^{1/3}$

TD2(17) critical Reynolds number (calculated in subroutine), Re_c

TD2(18) heat transfer coefficient (calculated in subroutine), h_f

TD2(19) conductance from center of seal gap to surface (calculated in subroutine), hA

TD2(20) heat generation factor (calculated in subroutine)

TD2 list for subroutine SN4, type 2 (forced convection), subtype 4 (concentric cylinders). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) boundary film thermal conductivity, k_f

TD2(3) boundary film specific heat, $C_{p,f}$

TD2(4) boundary film absolute viscosity, μ_f

TD2(5) boundary film kinematic viscosity, ν_f

TD2(6) outer radius of annulus between cylinders, r_o

TD2(7) inner radius of annulus between cylinders, r_i

TD2(8) angular velocity of inner rotating cylinder, ω

TD2(9) axial flow velocity, V_a

TD2(10) Reynolds number (calculated in subroutine), Re_v

TD2(11) cube root of Prandtl number (calculated in subroutine), $Pr_f^{1/3}$.

TD2(12) heat transfer coefficient (calculated in subroutine), h_f

TD2(13) conductance across boundary film (calculated in subroutine), hA

TD2(14) linear velocity of inner cylinder (calculated in subroutine), V_R

TD2(15) square of total fluid velocity (calculated in subroutine), V_{tot}^2

TD2(16) total fluid velocity (calculated in subroutine), V_{tot}

TD2(17) annular clearance (calculated in subroutine), s

TD2 list for subroutine SN5, type 2 (forced convection), subtype 5 (flat plate). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) boundary film thermal conductivity, k_f

TD2(3) boundary film specific heat, $C_{p,f}$

TD2(4) boundary film absolute viscosity, μ_f

TD2(5) boundary film kinematic viscosity, ν_f

TD2(6) length from start of flow to center of element, X

TD2(7) bulk fluid velocity, V_∞

TD2(8) Reynolds number (calculated in subroutine), Re_x

TD2(9) Prandtl number (calculated in subroutine), Pr_f

TD2(10) heat transfer coefficient (calculated in subroutine), h

TD2(11) conductance across boundary film (calculated in subroutine), hA

TD2 list for subroutine FC1, type 3 (free convection), subtype 1 (horizontal cylinder). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) boundary film thermal conductivity, k_f

TD2(3) boundary film specific heat, $C_{p,f}$

TD2(4) boundary film absolute viscosity, μ_f

TD2(5) boundary film kinematic viscosity, ν_f

TD2(6) diameter of cylinder, D

TD2(7) Prandtl number (calculated in subroutine), Pr_f

TD2(8) Grashof number (calculated in subroutine), Gr_D

TD2(9) heat transfer coefficient (calculated in subroutine), h_f

TD2(10) conductance across boundary film (calculated in subroutine), hA

TD2(11) Prandtl number × Grashof number (calculated in subroutine), $Pr_f Gr_D$

TD2(12) fluid to surface temperature difference (calculated in subroutine), ΔT

TD2(13) average (or film) temperature (calculated in subroutine), T_{av}

TD2(14) conductivity/cylinder outside diameter (calculated in subroutine), k_f/D

TD2 list for subroutine FC2, type 3 (free convection), subtype 2 (vertical cylinder or plane). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) boundary film thermal conductivity, k_f

TD2(3) boundary film specific heat, $C_{p,f}$

TD2(4) boundary film absolute viscosity, μ_f

TD2(5) boundary film kinematic viscosity, ν_f

TD2(6) total height of surface, L

TD2(7) Prandtl number (calculated in subroutine), Pr_f

TD2(8) Grashof number (calculated in subroutine), Gr_L

TD2(9) heat transfer coefficient (calculated in subroutine), h_f

TD2(10) conductance across boundary film (calculated in subroutine), hA

TD2(11) Prandtl number × Grashof number (calculated in subroutine), $Pr_f Gr_D$

TD2(12) fluid to surface temperature difference (calculated in subroutine), ΔT

TD2(13) average temperature (calculated in subroutine), T_{av}

TD2(14) conductivity/surface height (calculated in subroutine), k_f/L

TD2 list for subroutine FC3, type 3 (free convection), subtype 3 (liquid film cooling, gravity flow). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) mass flow of liquid per unit length normal to flow, W/L

TD2(3) fluid specific heat, C_p

TD2(4) flow length (e.g., one-half circumference of horizontal cylinder), D_L

TD2(5) heat transfer coefficient (calculated in subroutine), h

TD2(6) conductance from surface to liquid (calculated in subroutine), hA

TD2 list for subroutine RA1, type 4 (radiation). - The TD2 list is as follows:

TD2(1) environmental temperature, T_e

TD2(2) view factor from environment to element surface, f_{es}

TD2(3) view factor from element surface to environment, f_{se}

TD2(4) emissivity of environment, ϵ_e

TD2(5) emissivity of element surface, ϵ_s

TD2(6) radiation coefficient (calculated in subroutine), h

TD2(7) "conductance" from element surface to environment (calculated in subroutine), hA

TD2(8) reflectivity of environment (calculated in subroutine), $1 - \epsilon_e$

TD2(9) reflectivity of element surface (calculated in subroutine), $1 - \epsilon_s$

TD2(10) difference between fourth powers of temperatures/temperature difference (calculated in subroutine), $\left(T_e^4 - T_s^4\right)/\left(T_e - T_s\right)$

TD2 list for subroutine SC1, type 5 (specified heat transfer coefficient). - The TD2 list is as follows:

TD2(1) fluid bulk (or environmental) temperature, T_b (or T_e)

TD2(2) specified heat transfer coefficient, h

TD2(3) conductance between surface and bulk fluid (calculated in main program), hA

TD2 list for subroutine VT1, type 6 (varying temperature forced convection), subtype 1 (duct flow, liquid). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) boundary film thermal conductivity, k_f

TD2(3) boundary film specific heat, $C_{p,f}$

TD2(4) boundary film absolute viscosity, μ_f

TD2(5) fluid mass flow per square foot of cross section, W_a

TD2(6) duct hydraulic diameter, D

TD2(7) length from start of flow to center of element, X

TD2(8) annular neighbor conduction number

TD2(9) flow neighbor conduction number

TD2(10) combining flow indicator code number

TD2(11) flow initiation indicator code number (must be zero for combined flow element)

TD2(12) duct cross section, A_x

TD2(13) Reynolds number (calculated in subroutine), Re_w

TD2(14) Prandtl number (calculated in subroutine), Pr_f

TD2(15) heat transfer coefficient (calculated in subroutine), h_f

TD2(16) conductance across boundary film (calculated in subroutine), hA

TD2(17) hydraulic diameter/flow length (calculated in subroutine), D/X

TD2(18) conductivity/hydraulic diameter (calculated in subroutine), k_f/D

TD2(19) 0.7 power of TD2(16) (calculated in subroutine), $(D/X)^{0.7}$

TD2 list for subroutine VT2, type 6 (varying temperature forced convection), subtype 2 (radial seal gap). - The TD2 list is as follows:

TD2(1) fluid bulk temperature, T_b

TD2(2) boundary film thermal conductivity, k_f

TD2(3)	boundary film specific heat, $C_{p,f}$
TD2(4)	boundary film absolute viscosity, μ_f
TD2(5)	boundary film kinematic viscosity, ν_f
TD2(6)	average radius of element, r_{av}
TD2(7)	clearance between rotor and stator, s
TD2(8)	rotor angular velocity, ω
TD2(9)	outer radius of rotor, a
TD2(10)	combining flow indicator code number
TD2(11)	flow initiation indicator code number (must be zero for combined flow element)
TD2(12)	annular neighbor conduction number
TD2(13)	flow neighbor conduction number
TD2(14)	fluid mass flow rate, W
TD2(15)	Reynolds number (calculated in subroutine), Re_ω
TD2(16)	cube root of Prandtl number (calculated in subroutine), $Pr_f^{1/3}$
TD2(17)	critical Reynolds number (calculated in subroutine), Re_c
TD2(18)	heat transfer coefficient (calculated in subroutine), h_f
TD2(19)	conductance from center of seal gap to surface (calculated in subroutine), hA
TD2(20)	heat generation factor (calculated in subroutine)

Flow Charts and Program Listing

The flow charts for the main routine (SEAL2) and subroutines CQN and QT are presented in figures 8, 9, and 10. A listing of the program is as follows:

```
$IBFTC SEAL2
C
C      STEADY STATE HEAT TRANSFER ANALYSIS OF AXISYMMETRIC SYSTEMS TO
C      INCLUDE VARYING FLUID TEMPERATURES ALONG BOUNDARIES APPLIED TO
C      ADVANCED AIR BREATHING ENGINE SEAL DESIGN
C
       DIMENSION TD1(400,19),T(400),CE(400,4),Q(400),THEXP(400),TD2(20)
       DIMENSION H(200,9),SUMH(200),SUMT(200),NBND(200),TBND(95)
       DIMENSION LD(10),NI(5),RD(5),CD(10),TDA(7),MATL(15,11),NODE(95)
       DIMENSION ALPHA(15,11),JNTF(400)
       COMMON/BLK1/JBNT(400),KAN(200),NTF,NDR,NTR,QF(95),NQR
       COMMON/BLK2/TCF(95),GFN(95),AFN(95),NBR(95),NM(5),NAT(5),NBT(5)
       REAL MATL
C
   101 FORMAT(1H1)
   102 FORMAT(F4.0,1X,F7.4,2F5.3,1X,4F4.0,F3.0,4F7.0)
   103 FORMAT(1H0,10X,43HCONDUCTION (TD1) CARD ORDER ERROR, CARD NO.,I3,2
      2X,5HWRONG)
   104 FORMAT(1H0,10X,23HNABOR ERROR FOR ELEMENT,I4,3X,6HAND/OR,I4)
   105 FORMAT(1H0,45X,30HCONDUCTION ELEMENT TABLE (TD1)//(5X,I4,2X,7(2X,I
      22,1H,,1PE11.4)/10X,6(2X,I2,1H,,1PE11.4)//))
   106 FORMAT(16F5.0)
   107 FORMAT(1H1,50X,29HELEMENT STARTING TEMPERATURES//)
   108 FORMAT(10(2X,I3,1X,F6.1))
   109 FORMAT(25X,74HBOUNDARY COEFFICIENT MATRIX -(H*A)BTU/F.SEC AND (H*A
      2*T-B) OR W*C-P BTU/SEC//1X,11HBNDRY COND.,2X,10HFIXED FLUX,6X,17HF
      3ORCED CONVECTION,10X,15HFREE CONVECTION,14X,9HRADIATION,12X,19HVAR
      4.TEMP.CONVECTION/1X,11HELEM. ELEM.,6X,1HW,11X,3HH*A,8X,7HH*A*T-B,8
      5X,3HH*A,8X,7HH*A*T-B,8X,3HH*A,8X,7HH*A*T-E,8X,3HH*A,8X,5HW*C-P//(1
      6X,2(I4,1X),1X,9(1X,E12.5)))
   110 FORMAT(1H0,30X,58HVAR.TEMP.CONVECTION DIMENSIONLESS COEFFICIENTS (
      2H*A/W*C-P)//(6(1X,2I4,1H,,1PE11.4)))
   111 FORMAT(1H0,45X,36HFLUID SHEAR HEAT GENERATION, BTU/SEC//(6(1X,2I4,
      21H,,1PE11.4)))
   112 FORMAT(1H0,2X,10HDATA TIME=,F7.4,2X,7HMINUTES)
   113 FORMAT(1H1,20X,61HTEMPERATURES (F) AND HEAT FLUXES (BTU/SEC) FOR E
      2ACH ITERATION)
   114 FORMAT(3(4X,I3,1H,,1PE14.7,2X,1PE14.7))
   115 FORMAT(1H1,30X,32HCONVERGENCE CRITERIA, ITERATION=,I4//23X,8HCOND.
      2NO.,6X,9HNEW TEMP.,10X,9HOLD TEMP.,9X,10HDIFFERENCE,8X,9HMAX.DIFF.
      3//)
   116 FORMAT(1H0,2X,42HCONVERGENCE CRITERION NOT MET, ITERATIONS=,I6)
   117 FORMAT(1H0,2X,43HCONVERGENCE CRITERION ACHEIVED, ITERATIONS=,I6)
   118 FORMAT(1H1,20X,56HELEMENT(AT CENTER) TEMPERATURES (DEGREES F), ITE
      2RATIONS=,I6//)
   119 FORMAT(6(2X,I4,1H,,1PE14.7))
   120 FORMAT(1H1,9X,102HELEMENT FORCED CONVECTION, FREE CONVECT., RADIAT
      2ION AND VAR.TEMP.CONVECT. CONDUCTANCES(H*A)   BTU/HR.F//)
   121 FORMAT(16X,2I6,4E19.7)
   122 FORMAT(1H1,45X,38HVAR.TEMP.CONVECTION BOUNDARY TEMPS.(F)//(6(1X,2I
      24,1H,,1PE11.4)))
   123 FORMAT(1H1,42X,43HELEMENT THERMAL CONDUCTIVITIES   BTU/HR.FT.F//)
```

```
  124 FORMAT(3X,35HELEMENT ENWS CONDUCTION HEAT FLUXES,2X,I3,4(2X,E14.7)
     2,2X,6HBTU/HR)
  125 FORMAT(15X,45HELEMENT ENWS CONDUCTANCES TO NABORS(BTU/HR.F)//(10X,
     2I4,4(2X,E14.7)))
  126 FORMAT(1H0,10X,104HELEMENT BOUNDARY NO, CONDUCTION NO, BNDRY CONDU
     2CTANCE(H*A) SUM(BTU/HR.F) AND BNDRY HEAT FLUX SUM(BTU/HR)//(3(3X,2
     3I4,2X,E14.7,2X,E14.7)))
  127 FORMAT(1H1,40X,43HELEMENT FREE THERMAL EXPANSION,ALPHA*(T-TO)///)
  128 FORMAT(6E13.6)
C
C
      CALL TIME 1 (START)
C
C     READ RUN PARAMETERS
   60 DO 1 J=1,10
      LD(J)=0
    1 CD(J)=0.
      DO 2 J=1,5
      NI(J)=0
    2 RD(J)=0.
      DO 3 J=1,15
      DO 3 K=1,11
      MATL(J,K)=0.
    3 ALPHA(J,K)=0.
      NK=0
      CALL CDA(LD,NI,RD,CD,MATL,ALPHA)
      IF (NK.NE.0) GO TO 99
C
      NDIM=400
      NBDIM=200
      NVDIM=95
      NJPTS=CD(1)
      NBPTS=CD(2)
      NITS=CD(3)
      NK=0
C
C     ZERO COMMON STORAGE
      DO 5 JPT=1,NJPTS
      T(JPT)=0.0
      Q(JPT)=0.0
      JBNT(JPT)=0
      JNTF(JPT)=0
      THEXP(JPT)=0.0
      DO 4 J=1,4
    4 CE(JPT,J)=0.0
      DO 5 J=1,19
    5 TD1(JPT,J)=0.0
C
      DO 6 NBPT=1,NBPTS
      NBND(NBPT)=0
      SUMH(NBPT)=0.0
      SUMT(NBPT)=0.0
      DO 6 J=1,9
    6 H(NBPT,J)=0.0
C
      DO 7 K=1,NVDIM
```

```
      QF(K)=0.0
      TCF(K)=0.0
      GFN(K)=0.0
      AFN(K)=0.0
      NBR(K)=0
      NODE(K)=0
      TEND(K)=0.0
C
      DO 8 K=1,5
      NM(K)=0
      NAT(K)=0
    8 NPT(K)=0
C
C     READ ELEMENT GEOMETRY DATA, CHECK CARD ORDER
      DO 10 JPT=1,NJPTS
      READ(5,102) (TD1(JPT,J),J=1,13)
C
      NPC=TD1(JPT,1)
      IF (JPT-NPC) 9,10,9
    9 WRITE(6,103) JPT
      NK=1
   10 CONTINUE
      IF (NK.NE.0) GO TO 99
C
C     CHECK FOR CONDUCTANCE NABOR ERRORS
      NK=0
      DO 15 JPT=1,NJPTS
      DO 15 J=5,8
      N=TD1(JPT,J)
      IF (N) 14,15,11
   11 IF (JPT-N) 12,14,12
   12 RJPT=JPT
      JN=J-4
      GO TO (13,213,313,413),JN
   13 IF (RJPT-TD1(N,7)) 14,15,14
  213 IF (RJPT-TD1(N,8)) 14,15,14
  313 IF (RJPT-TD1(N,5)) 14,15,14
  413 IF (RJPT-TD1(N,6)) 14,15,14
   14 WRITE(6,104) JPT,N
      NK=1
   15 CONTINUE
      IF (NK.NE.0) GO TO 99
C
      IF (LD(1).EQ.0) GO TO 16
      WRITE(6,101)
      WRITE(6,105) (JPT,(J,TD1(JPT,J),J=1,13),JPT=1,NJPTS)
C
C     COMPUTE ELEMENT BOUNDARY AREAS, CONVERT TD1 DATA TO FEET
   16 DO 17 JPT=1,NJPTS
      RO=TD1(JPT,2)+TD1(JPT,3)/2.
      RI=TD1(JPT,2)-TD1(JPT,3)/2.
      TD1(JPT,14)=.04363323*TD1(JPT,2)*TD1(JPT,3)
      TD1(JPT,15)=.04363323*TD1(JPT,4)*RO
      TD1(JPT,16)=.04363323*TD1(JPT,4)*RI
      TD1(JPT,2)=TD1(JPT,2)/12.
      TD1(JPT,3)=TD1(JPT,3)/12.
```

```
   17 TD1(JPT,4)=TD1(JPT,4)/12.
C
C     READ INITIAL TEMPERATURE GUESSES, CURVE FIT CONDUCTIVITIES
      READ(5,106) (T(JPT),JPT=1,NJPTS)
      WRITE(6,107)
      WRITE(6,108) (JPT,T(JPT),JPT=1,NJPTS)
      DO 18 JPT=1,NJPTS
      TD1(JPT,19)=T(JPT)
   18 CALL FIT(TD1,JPT,NDIM,MATL)
C
C     READ BOUNDARY CONDITION DATA AND COMPUTE COEFFICIENTS
      IF (LD(5).NE.0) WRITE(6,101)
      NK=0
      NTF=0
      NCR=0
      NTR=0
      DO 19 NBPT=1,NBPTS
   19 CALL CON(NBPT,NBDIM,H,NBND,TBND,TD1,TDA,TD2,NDIM,T,LD,NK,NVDIM,NOD
     1E,JNTF)
      IF (NK.NE.0) GO TO 99
C
C     CON PRINTOUT
      IF (LD(2).EQ.0) GO TO 20
      WRITE(6,101)
      WRITE(6,109) (NBPT,NBND(NBPT),(H(NBPT,J),J=1,9),NBPT=1,NBPTS)
   20 IF (NTF.EQ.0) GO TO 21
      WRITE(6,101)
      WRITE(6,110) (J,NODE(J),TCF(J),J=1,NTF)
      WRITE(6,111) (J,NODE(J),QF(J),J=1,NTF)
C
C     PERFORM ITERATIVE ANALYSIS
   21 CALL TIME 1 (TEX)
      TDAT=(TEX-START)/3600.
      WRITE(6,112) TDAT
      NCC=0
      NPRT=RD(3)
C
      DO 29 NIT=1,NITS
      NK=0
      NCR=0
      NTF=0
      NDR=1
      NTR=0
      NCC=NCC+1
      LD(4)=0
      DO 22 NBPT=1,NBPTS
   22 KAN(NBPT)=0
C
C     BOUNDARY CONDITION ITERATION
      DO 23 NBPT=1,NBPTS
      JBPT=NBND(NBPT)
      CALL QT(NBPT,NBDIM,NDIM,JBPT,H,SUMT,SUMH,TD1,TBND,T,CD,NVDIM,NIT,N
     1ODE,JNTF)
   23 Q(JBPT)=SUMT(NBPT)
C
C     OVER-RELAXATION
```

```
      NCR=0
      DO 24 JPT=1,NJPTS
   24 CALL TATS(TD1,JPT,NDIM,NBND,NBDIM,Q,T,H,RD,LD,CE,NK)
      IF (NK.NE.0) GO TO 99
C
      IF (LD(10).EQ.0) GO TO 25
      WRITE(6,113)
      WRITE(6,114) (JPT,T(JPT),Q(JPT),JPT=1,NJPTS)
C
C     CHECK FOR CONVERGENCE, CORRECTION OF TD1 TEMPERATURES
   25 ERR=CD(4)
      IF (NIT.EQ.NITS) GO TO 30
      IF (NCC.NE.NPRT) GO TO 26
      NCC=0
      LD(4)=1
      WRITE(6,115) NIT
   26 DO 27 JPT=1,NJPTS
   27 CALL CONCHK(JPT,NDIM,TD1,ERR,LD,NK,T)
      IF (NK) 28,31,28
C
C     RECALC. K FROM NEWEST TEMP.
   28 DO 29 JPT=1,NJPTS
      TD1(JPT,19)=T(JPT)
   29 CALL FIT(TD1,JPT,NDIM,MATL)
C
   30 WRITE(6,116) NIT
      GO TO 33
   31 WRITE(6,117) NIT
C
C     TEMPERATURE PRINTOUT
      IF (LD(3)) 32,33,32
   32 NITM1=NIT-1
      WRITE(6,118) NITM1
      WRITE(6,119) (JPT,TD1(JPT,19),JPT=1,NJPTS)
   33 WRITE(6,118) NIT
      WRITE(6,119) (JPT,T(JPT),JPT=1,NJPTS)
      IF (LD(8).NE.0) PUNCH 106, (T(JPT),JPT=1,NJPTS)
C
C     CONVERT FROM SEC.TO HRS.
      DO 34 NBPT=1,NBPTS
      SUMT(NBPT)=SUMT(NBPT)*3600.
      SUMH(NBPT)=SUMH(NBPT)*3600.
      DO 34 J=2,8,2
   34 H(NBPT,J)=H(NBPT,J)*3600.
C
C     PRINT OUT BOUNDARY CONDUCTANCES(H*A)
      WRITE(6,120)
      WRITE(6,121) (NBPT,NBND(NBPT),(H(NBPT,J),J=2,8,2),NBPT=1,NBPTS)
C
C     PRINT OUT VAR.TEMP.BOUNDARY TEMPS.
      IF (NTF.NE.0) WRITE(6,122) (J,NODE(J),TBND(J),J=1,NTF)
C
C     PRINT OUT ELEMENT THERMAL CONDUCTIVITIES
      DO 35 JPT=1,NJPTS
   35 TD1(JPT,18)=TD1(JPT,18)*3600.
      WRITE(6,123)
```

```
      WRITE(6,119) (JPT,TD1(JPT,18),JPT=1,NJPTS)
C
C     COMPUTE AND WRITE HEAT FLUXES
      DO 36 JPT=1,NJPTS
      DO 36 K=1,4
   36 CE(JPT,K)=CE(JPT,K)*3600.
C
      WRITE(6,101)
      DO 48 JPT=1,NJPTS
      NE=TD1(JPT,5)
      IF (NE) 38,37,38
   37 QJE=0.0
      GO TO 39
   38 QJE=CE(JPT,1)*(T(NE)-T(JPT))
   39 NN=TD1(JPT,6)
      IF (NN) 41,40,41
   40 QJN=0.0
      GO TO 42
   41 QJN=CE(JPT,2)*(T(NN)-T(JPT))
   42 NW=TD1(JPT,7)
      IF (NW) 44,43,44
   43 QJW=0.0
      GO TO 45
   44 QJW=CE(JPT,3)*(T(NW)-T(JPT))
   45 NS=TD1(JPT,8)
      IF (NS) 47,46,47
   46 QJS=0.0
      GO TO 48
   47 QJS=CE(JPT,4)*(T(NS)-T(JPT))
   48 WRITE(6,124) JPT,QJE,QJN,QJW,QJS
C
      WRITE(6,101)
      WRITE(6,125) (JPT,(CE(JPT,J),J=1,4),JPT=1,NJPTS)
C
C     PRINT OUT BOUNDARY CONDUCTANCE SUMS AND HEAT FLUX SUMS
      WRITE(6,101)
      WRITE(6,126) (NBPT,NBND(NBPT),SUMH(NBPT),SUMT(NBPT),NBPT=1,NBPTS)
C
C     THERMAL EXPANSION CALCN. AND PRINTOUT
      IF (LD(10).NE.0) WRITE(6,101)
      DO 49 JPT=1,NJPTS
      CALL FIT2(TD1,NDIM,JPT,ALPHA,THEXP)
   49 CALL DEFORM(JPT,NDIM,TD1,RD,LD,THEXP)
      WRITE(6,127)
      WRITE(6,119) (JPT,THEXP(JPT),JPT=1,NJPTS)
      IF (LD(9).NE.0) PUNCH 128,(THEXP(JPT),JPT=1,NJPTS)
C
C     CHECK FOR ADDTL.CASES
      IF (NI(1)-1) 99,99,50
   50 GO TO 60
C
   99 CALL EXIT
      STOP
      END
```

```
$IBFTC CDAM
      SUBROUTINE CDA(LD,NI,RD,CD,MATL,ALPHA,NK)
C
C     PROBLEM PARAMETER INPUT, CONDUCTIVITY AND EXPANSION INPUT
C
      DIMENSION LD(10),NI(5),RD(5),CD(10),MATL(15,11),ALPHA(15,11)
      DIMENSION FILE(11),WCOM(12)
      REAL MATL
C
  101 FORMAT(12A6)
  102 FORMAT(1H1,29X,12A6//)
  103 FORMAT(10I6)
  104 FORMAT(1H0,13X,3HLD=,10(3X,I2,1H,I3))
  105 FORMAT(1H0,13X,3HNI=,5(3X,I2,1H,I3))
  106 FORMAT(10F6.0)
  107 FORMAT(1H0,13X,3HRD=,5(3X,I2,1H,1PE13.6))
  108 FORMAT(1H0,13X,3HCD=,5(3X,I2,1H,1PE13.6)/16X,5(3X,I2,1H,1PE13.6))
  109 FORMAT(1H0,2X,58HNO.CONDUCTION OR BOUNDARY ELEMENTS EXCEEDS ALLOTE
     2D STORAGE)
  110 FORMAT(5F10.0)
  111 FORMAT(6E13.6)
  112 FORMAT(1H0,59X,11HDATA FOR K./(17X,6(2X,I2,1PE14.7)))
  113 FORMAT(1H0,59X,15HDATA FOR ALPHA./(17X,6(2X,I2,1PE14.7)))
C
      READ(5,101) WCOM
      WRITE(6,102) WCOM
C
C     GENERAL DATA
      READ(5,103) (LD(J),J=1,10)
      WRITE(6,104) (J,LD(J),J=1,10)
      READ(5,103) (NI(I),I=1,5)
      WRITE(6,105) (I,NI(I),I=1,5)
      READ(5,106) (RD(I),I=1,5)
      WRITE(6,107) (I,RD(I),I=1,5)
      READ(5,106) (CD(J),J=1,10)
      WRITE(6,108) (J,CD(J),J=1,10)
      IF (400.-CD(1)) 2,1,1
    1 IF (200.-CD(2)) 2,3,3
    2 WRITE(6,109)
      NK=1
      GO TO 11
C
C     CONDUCTIVITY DATA
    3 DO 6 L=1,15
      READ(5,110) (FILE(NCQ),NCQ=1,5)
      IF (FILE(1)) 4,7,4
    4 MN=FILE(2)
      NP6=FILE(3)+6.
      READ(5,111) (FILE(NCQ),NCQ=6,NP6)
      DO 5 NCQ=1,NP6
    5 MATL(MN,NCQ)=FILE(NCQ)
```

```
    6 WRITE(6,112) (NCQ,FILE(NCQ),NCQ=1,NP6)
C
C     EXPANSION DATA
    7 DO 10 I=1,15
      READ(5,110) (FILE(NCQ),NCQ=1,5)
      IF (FILE(1)) 8,11,8
    8 MN=FILE(2)
      NP6=FILE(3)+6.
      READ(5,111) (FILE(NCQ),NCQ=6,NP6)
      DO 9 NCQ=1,NP6
    9 ALPHA(MN,NCQ)=FILE(NCQ)
   10 WRITE(6,112) (NCQ,FILE(NCQ),NCQ=1,NP6)
   11 RETURN
      END
```

```
$IBFTC FITM
      SUBROUTINE FIT(TD1,JPT,NDIM,MATL)
C
C     FIT CONDUCTIVITY (K) FROM POLYNOMINAL CURVE
C
      DIMENSION TD1(NDIM,19),COS(5),CALC(6),MATL(15,11)
      REAL MATL
C
  101 FORMAT(1H0,20X,41HTEMPERATURE EXCEEDS CURVE FIT LIMIT FOR K)
C
      TEMP= TD1(JPT,19)
      MAN = TD1(JPT,9)
      DO 1 NCQ=1,5
    1 COS(NCQ)= MATL(MAN,NCQ)
      IF(TEMP-COS(1)) 3,3,2
    2 WRITE(6,101)
      GO TO 9
    3 NOP = COS(3)
      NOP1=NOP+1
      DO 4 NCQ=1,NOP1
      LC = 5+NCQ
    4 CALC(NCQ)= MATL(MAN,LC)
      IF(COS(3)) 6,5,6
    5 Y= CALC(1)*COS(4)
      GO TO 8
    6 Y = CALC(NOP1)
      TEM1 = TEMP*COS(5)
      DO 7 NPY=1,NOP
      J2 = NOP1-NPY
    7 Y= CALC(J2)+Y*TEM1
      Y = Y*COS(4)
    8 TD1(JPT,18)=Y
C
    9 RETURN
      END
```

```
$IBFTC CQNM
      SUBROUTINE CQN(NBPT,NBDIM,H,NBND,TBND,TD1,TDA,TD2,NDIM,T,LD,NK,NVD
     1IM,NODE,JNTF)
C
C     COMPUTE HEAT TRANSFER COEFFICIENTS
C
      DIMENSION H(NBDIM,9),NBND(NBDIM),TBND(NVDIM),TDA(7),TD2(20)
      DIMENSION TD1(NDIM,19),T(NDIM),LD(10),NODE(NVDIM),JNTF(NDIM)
      COMMON/BLK1/JBNT(400),KAN(200),NTF,NDR,NTR,QF(95),NQR
      COMMON/BLK2/TCF(95),GFN(95),AFN(95),NBR(95),NM(5),NAT(5),NBT(5)
C
  101 FORMAT(3I6)
  102 FORMAT(1H0,15X,60HBOUNDARY INDICATOR CARD ORDER ERROR,   BOUNDARY
     2ELEMENT NO.=,I4,11H CARD READS,I4)
  103 FORMAT(I5,1X,F6.0)
  104 FORMAT(1H0,10X,71HBOUNDARY INDEX (TYPE 1 OR 7) CARD ORDER ERROR,
     2CONDUCTION ELEMENT NO.=,I4,11H CARD READS,I4)
  105 FORMAT(I5,E13.6,I6)
  106 FORMAT(6F6.0,F12.0)
  107 FORMAT(7F11.0)
  108 FORMAT(1H0,10X,71HBOUNDARY INDEX (TYPE 2 TO 6) CARD ORDER ERROR,
     2CONDUCTION ELEMENT NO.=,I4,11H CARD READS,I4)
  109 FORMAT(1H0,2X,8HELEMENT=,F4.0,2X,5HTYPE=,F2.0,2X,8HSUBTYPE=,F2.0,2
     2X,5HNEXT=,F2.0,2X,11HITEMS READ=,F3.0,3X,10HAREA CODE=,F2.0,2X,13H
     3SPECIAL AREA=,E12.5,1X,7HSQ.FEET)
  110 FORMAT(1H0,2X,17HDUCT FLOW, LIQUID/2X,4HT-B=,F5.0,2X,4HK-F=,E11.4,
     22X,4HC-P=,E11.4,2X,3HMU=,E11.4,2X,10HMASS FLOW=,E11.4,2X,7HD-HYDR=
     3,E11.4,2X,7HL-FLOW=,E11.4/2X,3HRE=,E11.4,2X,3HPR=,E11.4,9X,8HH COE
     4FF=,E14.7,2X,11HCOEFF*AREA=,E14.7)
  111 FORMAT(1H0,2X,15HSIDES OF ROTORS/2X,4HT-B=,F5.0,2X,4HK-F=,E11.4,2X
     2,4HC-P=,E11.4,2X,3HMU=,E11.4,2X,3HNU=,E11.4,2X,5HR-AV=,E11.4,2X,4H
     3GAP=,E11.4,2X,6HOMEGA=,F6.0/4HR-O=,E11.4,2X,5HFLAG=,F2.0,9X,3HRE=,
     4E11.4,2X,8HPR**1/3=,E11.4,2X,8HH COEFF=,E14.7,2X,11HCOEFF*AREA=,E1
     54.7)
  112 FORMAT(1H0,2X,15HRADIAL SEAL GAP/2X,4HT-B=,F5.0,2X,4HK-F=,E11.4,2X
     2,4HC-P=,E11.4,2X,3HMU=,E11.4,2X,3HNU=,E11.4,2X,5HR-AV=,E11.4,2X,4H
     3GAP=,E11.4,2X,6HOMEGA=,F6.0/2X,4HR-O=,E11.4,15X,3HRE=,E11.4,2X,8HP
     4R**1/3=,E11.4,2X,5HRE-C=,E11.4/2X,8HH COEFF=,E14.7,2X,11HCOEFF*ARE
     5A=,E14.7)
  113 FORMAT(1H0,2X,20HCONCENTRIC CYLINDERS/2X,4HT-B=,F5.0,2X,4HK-F=,E11
     2.4,2X,4HC-P=,E11.4,2X,3HMU=,E11.4,2X,3HNU=,E11.4,2X,4HR-O=,E11.4,2
     3X,4HR-I=,E11.4,2X,6HOMEGA=,F6.0/2X,5HV-AX=,E11.4,15X,3HRE=,E11.4,2
     4X,8HPR**1/3=,E11.4,2X,8HH COEFF=,E14.7,9X,11HCOEFF*AREA=,E14.7)
  114 FORMAT(1H0,2X,10HFLAT PLATE/2X,4HT-B=,F5.0,2X,4HK-F=,E11.4,2X,4HC-
     2P=,E11.4,2X,3HMU=,E11.4,2X,3HNU=,E11.4,2X,7HL-FLOW=,E11.4,2X,7HV-F
     3LOW=,E11.4/2X,3HRE=,E11.4,2X,3HPR=,E11.4,9X,3HH COEFF=,E14.7,2X,11
     4HCOEFF*AREA=,E14.7)
C
C     FUTURE FORCED CONVEC.COEFF.FORMATS (115-8)
  119 FORMAT(1H0,2X,39HHORIZONTAL CYLINDER OR VERTICAL SURFACE/2X,4HT-B=
     2,F5.0,2X,4HK-F=,E11.4,2X,4HC-P=,E11.4,2X,3HMU=,E11.4,2X,3HNU=,E11.
```

```
     34,2X,17HL-FLOW OR D-HYDR=,E11.4/2X,3HPR=,E11.4,2X,3HGR=,E11.4,9X,8
     4HH COEFF=,E14.7,2X,11HCOEFF*AREA=,E14.7)
 120 FORMAT(1H0,2X,19HLIQUID FILM COOLING/2X,4HT-B=,F5.0,2X,4HW/L=,E11.
     24,2X,4HC-P=,E11.4,2X,7HL-FLOW=,E11.4,10X,8HH COEFF=,E14.7,2X,11HCO
     3EFF*AREA=,E14.7)
C
C     FUTURE FREE CONVEC.COEFF.FORMATS (121-5)
 126 FORMAT(1H0,2X,9HRADIATION/2X,4HT-E=,F5.0,2X,10HFACTOR-SE=,E11.4,2X
     2,10HFACTOR-ES,E11.4,2X,8HEMIS.-E=,E11.4,2X,8HEMIS.-S=,E11.4/2X,8HH
     3 COEFF=,E14.7,2X,11HCOEFF*AREA=,E14.7)
 127 FORMAT(1H0,2X,21HSPECIFIED COEFFICIENT/2X,4HT-B=,F5.0,2X,8HH COEFF
     2=,E14.7,5X,11HCOEFF*AREA=,E14.7)
 128 FORMAT(1H0,2X,26HVAR.TEMP.DUCT FLOW, LIQUID/2X,4HT-B=,F5.0,2X,4HK-
     2F=,E11.4,2X,4HC-P=,E11.4,2X,3HMU=,E11.4,2X,10HMASS FLOW=,E11.4,2X,
     37HD-HYDR=,E11.4,2X,7HL-FLOW=,E11.4/2X,9HANN.NBR.=,F4.0,2X,9HFLOW N
     4BR=,F4.0,2X,7HFLAG-C=,F2.0,2X,7HFLAG-I=,F2.0,2X,6HX-SEC=,E11.4/2X,
     53HRE=,E11.4,2X,3HPR=,E11.4,6X,8HH COEFF=,E14.7,2X,11HCOEFF*AREA=,E
     614.7)
 129 FORMAT(1H0,2X,24HVAR.TEMP.RADIAL SEAL GAP/2X,4HT-B=,F5.0,2X,4HK-F=
     2,E11.4,2X,4HC-P=,E11.4,2X,3HMU=,E11.4,2X,3HNU=,E11.4,2X,5HR-AV=,E1
     31.4,2X,4HGAP=,E11.4,2X,6HOMEGA=,F6.0/2X,4HR-O=,E11.4,2X,7HFLAG-C=,
     4F2.0,2X,7HFLAG-I=,F2.0,2X,9HANN.NBR.=,F4.0,2X,9HFLO.NBR.=,F4.0,2X,
     510HMASS FLOW=,E11.4/2X,3HRE=,E11.4,2X,8HPR**1/3=,E11.4,2X,5HRE-C=,
     6E11.4,9X,8HH COEFF=,E14.7,2X,11HCOEFF*AREA=,E14.7/2X,14HHT.GEN.FAC
     7TOR=,E12.5)
C
C     FUTURE VAR.TEMP.COEFF.FORMATS (130-1)
 132 FORMAT(1H0,2X,38HCOMBINED FLOW ELEMENT, CONDUCTION NO.=,I4,2X,24HF
     2LOW FROM COND.ELEMENTS ,I3,4HAND ,I4)
C
C     FUTURE COEFF.SUBPROGR.FORMATS (115-8(FORCED),121-5(FREE),130-1
C     (VAR.TEMP.)
C
C     READ INDICATOR CARD, CHECK ORDER
      READ(5,101) NBP,NBND(NBP),INDB
      IF (NBPT-NBP) 1,2,1
    1 WRITE(6,102) NBPT,NBP
      NK=1
C
C     SET PARAMETERS
    2 JBPT=NBND(NBP)
      JBNT(JBPT)=NBPT
      TD1(JBPT,17)=INDB
C
C     SPECIFIED TEMPERATURE
      IF (INDB.NE.7) GO TO 4
      READ(5,103) JBP,T(JBP)
      IF (JBP.NE.JBPT) GO TO 3
      TD1(JBPT,19)=T(JBP)
      GO TO 99
    3 WRITE(6,104) JBPT,JBP
      NK=1
      GO TO 99
C
    4 GO TO (5,7,7,7,7,7),INDB
C
```

```
C       SPECIFIED HEAT FLUX
      5 READ(5,105) JBP,H(NBPT,1),IADDQ
        IF (JBP.EQ.JBPT) GO TO 6
        WRITE(6,104) JBPT,JBP
        NK=1
      6 IF (IADDQ.EQ.0) GO TO 99
C
C       BOUNDARY AREAS
      7 AE=TD1(JBPT,14)
        AN=TD1(JBPT,15)
        AS=TD1(JBPT,16)
C
C       READ DATA FOR TYPES 2 TO 6
     90 READ(5,106) (TDA(J),J=1,7)
        NITM=TDA(5)
        READ(5,107) (TD2(J),J=1,NITM)
C
C       CHECK CONDUCTION NO.MATCH
        JBP=TDA(1)
        IF (JBP-JBPT) 8,9,8
      8 WRITE(6,108) JBPT,JBP
        NK=1
      9 IF (NK.NE.0) GO TO 99
C
        ITYPE=TDA(2)
        GO TO (99,10,29,46,48,55),ITYPE
C
C       FORCED CONVECTION
     10 ISTYPE=TDA(3)
        GO TO (11,13,15,17,19),ISTYPE
C
C       DUCT FLOW, LIQUID
     11 CALL SN1(TDA,TD2,AE,AN,AS)
        H(NBPT,2)=H(NBPT,2)+TD2(16)
        H(NBPT,3)=H(NBPT,3)+TD2(16)*TD2(1)
        IF (LD(5).EQ.0) GO TO 12
        WRITE(6,109) (TDA(J),J=1,7)
        WRITE(6,110) (TD2(J),J=1,7),(TD2(K),K=13,16)
     12 IF (TDA(4)) 90,99,90
C
C       SIDES OF ROTORS
     13 CALL SN2(TDA,TD2,AE,AN,AS)
        H(NBPT,2)=H(NBPT,2)+TD2(14)
        H(NBPT,3)=H(NBPT,3)+TD2(14)*TD2(1)
        IF (LD(5).EQ.0) GO TO 14
        WRITE(6,109) (TDA(J),J=1,7)
        WRITE(6,111) (TD2(J),J=1,14)
     14 IF (TDA(4)) 90,99,90
C
C       RADIAL SEAL GAP
     15 CALL SN3(TDA,TD2,AE,AN,AS)
        H(NBPT,2)=H(NBPT,2)+TD2(19)
        H(NBPT,3)=H(NBPT,3)+TD2(19)*TD2(1)
        IF (LD(5).EQ.0) GO TO 16
        WRITE(6,109) (TDA(J),J=1,7)
        WRITE(6,112) (TD2(J),J=1,9),(TD2(K),K=15,19)
```

```
   16 IF (TDA(4)) 90,99,90
C
C     CONCENTRIC CYLINDERS
   17 CALL SN4(TDA,TD2,AE,AN,AS)
      H(NBPT,2)=H(NBPT,2)+TD2(13)
      H(NBPT,3)=H(NBPT,3)+TD2(13)*TD2(1)
      IF (LD(5).EQ.0) GO TO 18
      WRITE(6,109) (TDA(J),J=1,7)
      WRITE(6,113) (TD2(J),J=1,13)
   18 IF (TDA(4)) 90,99,90
C
C     FLAT PLATE
   19 CALL SN5(TDA,TD2,AE,AN,AS)
      H(NBPT,2)=H(NBPT,2)+TD2(11)
      H(NBPT,3)=H(NBPT,3)+TD2(11)*TD2(1)
      IF (LD(5).EQ.0) GO TO 20
      WRITE(6,109) (TDA(J),J=1,7)
      WRITE(6,114) (TD2(J),J=1,11)
   20 IF (TDA(4)) 90,99,90
C
C     FOR FUTURE SUBROUTINES (4 MORE) (STATEM. NOS 21-2,23-4,25-6,27-8)
C
C     FREE CONVECTION
   29 ISTYPE=TDA(3)
      GO TO (30,32,34),ISTYPE
C
C     HORIZONTAL CYLINDER
   30 CALL FC1(TDA,TD2,AE,AN,AS,T,JBPT,NDIM)
      H(NBPT,4)=H(NBPT,4)+TD2(10)
      H(NBPT,5)=H(NBPT,5)+TD2(10)*TD2(1)
      IF (LD(5).EQ.0) GO TO 31
      WRITE(6,109) (TDA(J),J=1,7)
      WRITE(6,119) (TD2(J),J=1,10)
   31 IF (TDA(4)) 90,99,90
C
C     VERTICAL PLANE OR CYLINDER
   32 CALL FC2(TDA,TD2,AE,AN,AS,T,JBPT,NDIM)
      H(NBPT,4)=H(NBPT,4)+TD2(10)
      H(NBPT,5)=H(NBPT,5)+TD2(10)*TD2(1)
      IF (LD(5).EQ.0) GO TO 33
      WRITE(6,109) (TDA(J),J=1,7)
      WRITE(6,119) (TD2(J),J=1,10)
   33 IF (TDA(4)) 90,99,90
C
C     LIQUID FILM COOLING, GRAVITY FLOW
   34 CALL FC3(TDA,TD2,AE,AN,AS)
      H(NBPT,4)=H(NBPT,4)+TD2(6)
      H(NBPT,5)=H(NBPT,5)+TD2(6)*TD2(1)
      IF (LD(5).EQ.0) GO TO 35
      WRITE(6,109) (TDA(J),J=1,7)
      WRITE(6,120) (TD2(J),J=1,6)
   35 IF (TDA(4)) 90,99,90
C
C     FOR FUTURE SUBROUTINES (5 MORE) (STATEM. 36-7,38-9,40-1,42-3,44-5)
C
C     RADIATION
```

```
   46 CALL RA1(TDA,TD2,AE,AN,AS,T,JBPT,NDIM)
      H(NBPT,6)=H(NBPT,6)+TD2(7)
      H(NBPT,7)=H(NBPT,7)+TD2(7)*TD2(1)
      IF (LD(5).EQ.0) GO TO 47
      WRITE(6,109) (TDA(J),J=1,7)
      WRITE(6,126) (TD2(J),J=1,7)
   47 IF (TDA(4)) 90,99,90
C
C     SPECIFIED COEFFICIENT
   48 NCR=TDA(6)
      GO TO (49,50,49,51,52),NCR
   49 AF=AE
      GO TO 53
   50 AF=AN
      GO TO 53
   51 AF=AS
      GO TO 53
   52 AF=TDA(7)
   53 TD2(3)=TD2(2)*AF
      H(NBPT,2)=H(NBPT,2)+TD2(3)
      H(NBPT,3)=H(NBPT,3)+TD2(3)*TD2(1)
      IF (LD(5).EQ.0) GO TO 54
      WRITE(6,109) (TDA(J),J=1,7)
      WRITE(6,127) (TD2(J),J=1,3)
   54 IF (TDA(4)) 90,99,90
C
C     VARIABLE TEMPERATURE FORCED CONVECTION
   55 NTF=NTF+1
      ISTYPE=TDA(3)
      GO TO (56,57),ISTYPE
C
C     VAR.TEMP.DUCT FLOW, LIQUID
   56 CALL SN1(TDA,TD2,AE,AN,AS)
      H(NBPT,8)=TD2(16)
      H(NBPT,9)=TD2(5)*TD2(3)*TD2(12)
      TBND(NTF)=TD2(1)
      TCF(NTF)=H(NBPT,8)/H(NBPT,9)
      AFN(NTF)=TD2(8)
      GFN(NTF)=TD2(9)
      NODE(NTF)=JBPT
      JXPT=NODE(NTF)
      JNTF(JXPT)=NTF
      IF (LD(5).EQ.0) GO TO 60
      WRITE(6,109) (TDA(J),J=1,7)
      WRITE(6,128) (TD2(J),J=1,16)
      GO TO 60
C
C     VAR.TEMP.RADIAL SEAL GAP
   57 CALL SN3(TDA,TD2,AE,AN,AS)
      TBND(NTF)=TD2(1)
      H(NBPT,8)=TD2(19)
      H(NBPT,9)=TD2(14)*TD2(3)
      TCF(NTF)=H(NBPT,8)/H(NBPT,9)
      AFN(NTF)=TD2(12)
      GFN(NTF)=TD2(13)
      NODE(NTF)=JBPT
```

```
      JXPT=NODE(NTF)
      JNTF(JXPT)=NTF
C
C     FLUID SHEAR HEAT GENERATION
      OMRP=TD2(8)*TD2(8)*TD1(JBPT,2)*TD1(JBPT,2)
      QF(NTF)=TD2(20)*.0000399416*TD2(4)*OMRP*TD1(JBPT,14)/TD2(7)
C
      IF (LD(5).EQ.0) GO TO 60
      WRITE(6,109) (TDA(J),J=1,7)
      WRITE(6,129) (TD2(J),J=1,20)
      GO TO 60
C
C     FOR FUTURE SUBROUTINES (2 MORE) (STATEMENTS 58,59)
C
C     FLOW INITIATION ELEMENT
   60 IF (TD2(11).EQ.0.) GO TO 61
      NTR=NTR+1
      NBR(NTR)=TD2(11)
      GO TO 62
C
C     COMBINED FLOW ELEMENT
   61 IF (TD2(10).EQ.0.) GO TO 62
      NDR=NDR+1
      READ(5,101) NAT(NDR),NBT(NDR)
      WRITE(6,132) JBPT,NAT(NDR),NBT(NDR)
      NM(NDR)=JBPT
   62 IF (TDA(4)) 90,99,90
C
   99 RETURN
      END
```

```
$IBFTC SN1M
      SUBROUTINE SN1(TDA,TD2,AE,AN,AS)
C
C     HEAT TRANSFER COEFFICIENTS FOR LIQUIDS IN DUCTS
C
      DIMENSION TD2(20),TDA(7)
C
C     COMPUTE REYNOLDS AND PRANDTL NUMBERS
      TD2(13)=TD2(5)*TD2(6)/TD2(4)
      TD2(14)=TD2(3)*TD2(4)/TD2(2)
C
C     LAMINAR OR TURBULENT COEFFICIENT
      TD2(17)=TD2(6)/TD2(7)
      TD2(18)=TD2(2)/TD2(6)
      TD2(19)=TD2(17)**.7
      IF (TD2(13)-2500.) 1,1,2
    1 TD2(15)=1.24*TD2(18)*(TD2(13)*TD2(14)*TD2(17))**(1./3.)
      GO TO 5
    2 IF (TD2(13)-7000.) 4,3,3
    3 TD2(15)=.023*TD2(18)*(TD2(13)**.8)*(TD2(14)**.4)*(1.+.3*TD2(19))
      GO TO 5
    4 TD2(15)=.5*((7000.-TD2(13))/4500.)*1.24*(TD2(13)*TD2(14)*TD2(17))*
     2*(1./3.)+.5*((TD2(13)-2500.)/4500.)*.023*TD2(18)*(TD2(13)**.8)*(TD
     32(14)**.4)*(1.+.3*TD2(19))
C
C     COEFFICIENT*AREA
    5 NCR=TDA(6)
      GO TO (6,7,6,8,9),NCR
    6 AF=AE
      GO TO 10
    7 AF=AN
      GO TO 10
    8 AF=AS
      GO TO 10
    9 AF=TDA(7)
   10 TD2(16)=AF*TD2(15)
      RETURN
      END
```

```
$IBFTC SN2M
      SUBROUTINE SN2(TDA,TD2,AF,AN,AS)
C
C     HEAT TRANSFER COEFFICIENTS FOR FLUID MOVING RELATIVE TO RADIAL
C     SURFACE   SEPERATE BOUNDARY LAYERS
C
      DIMENSION TD2(20),TDA(7)
C
C     REYNOLDS AND PRANDTL NUMBERS
      TD2(11)=TD2(8)*TD2(6)*TD2(6)/TD2(5)
      TD2(12)=(TD2(3)*TD2(4)/TD2(2))**(1./3.)
C
C     LAMINAR OR TURBULENT COEFFICIENT
      TD2(15)=TD2(2)/TD2(6)
      TD2(16)=(TD2(7)/TD2(6))**.1
      IF (TD2(11)-158000.) 1,1,4
C
C     LAMINAR
    1 IF (TD2(10).EQ.0.) GO TO 2
      TD2(17)=.50185-.6508*TD2(7)/TD2(9)
      GO TO 3
    2 TD2(17)=.49815+.6508*TD2(7)/TD2(9)
    3 TD2(13)=.574*TD2(15)*TD2(16)*(TD2(11)**.5)*TD2(12)/TD2(17)
      GO TO 7
C
C     TURBULENT
    4 IF (TD2(10).EQ.0.) GO TO 5
      TD2(17)=.48558-.35778*TD2(7)/TD2(9)
      GO TO 6
    5 TD2(17)=.51442+.35778*TD2(7)/TD2(9)
    6 TD2(13)=.01826*TD2(15)*TD2(16)*(TD2(11)**.8)*TD2(12)/TD2(17)
C
C     COEFFICIENT*AREA
    7 NCR=TDA(6)
      GO TO (8,9,9,10,11),NCR
    8 AF=AF
      GO TO 12
    9 AF=AN
      GO TO 12
   10 AF=AS
      GO TO 12
   11 AF=TDA(7)
   12 TD2(14)=AF*TD2(13)
      RETURN
      END
```

```
$IBFTC SN3M
      SUBROUTINE SN3(TDA,TD2,AF,AN,AS)
C
C     HEAT TRANSFER COEFFICIENTS FOR ROTOR AND STATOR WITH SMALL
C     CLEARANCE   MERGED BOUNDARY LAYERS
C
      DIMENSION TD2(20),TDA(7)
C
C     REYNOLDS AND PRANDTL NUMBERS
      TD2(15)=TD2(8)*TD2(6)*TD2(6)/TD2(5)
      TD2(16)=(TD2(3)*TD2(4)/TD2(2))**(1./3.)
C
C     LAMINAR OR TURBULENT COEFFICIENT
      TD2(17)=366.34*((TD2(9)/TD2(7))**(10./9.))
      IF (TD2(15)-TD2(17)) 1,1,2
    1 TD2(18)=2.*TD2(2)*TD2(16)/TD2(7)
      TD2(20)=1.
      GO TO 3
    2 TD2(18)=.0297*(TD2(2)/TD2(6))*((TD2(6)/TD2(7))**(1./6.))*TD2(16)*(
     1TD2(15)**.8)
      TD2(20)=.0002286*(TD2(17)**1.5)*((TD2(7)/TD2(6))**(5./3.))
C
C     COEFFICIENT*AREA
    3 NCR=TDA(6)
      GO TO (4,5,4,6,7),NCR
    4 AF=AF
      GO TO 8
    5 AF=AN
      GO TO 8
    6 AF=AS
      GO TO 8
    7 AF=TDA(7)
    8 TD2(19)=AF*TD2(18)
      RETURN
      END
```

```
$IBFTC SN4M
      SUBROUTINE SN4(TDA,TD2,AE,AN,AS)
C
C     HEAT TRANSFER COEFFICIENTS FOR FLOW BETWEEN CONCENTRIC CYLINDERS
C     INNER ROTATING, NO AXIAL FLOW EFFECT ON BOUNDARY LAYERS
C
      DIMENSION TD2(20),TDA(7)
C
C     TURBULENT COEFFICIENT
      TD2(11)=(TD2(3)*TD2(4)/TD2(2))**(1./3.)
      TD2(14)=TD2(8)*.5*(TD2(6)+TD2(7))
      TD2(15)=TD2(14)*TD2(14)+TD2(9)*TD2(9)
      TD2(16)=SQRT(TD2(15))
      TD2(17)=TD2(6)-TD2(7)
      TD2(10)=2.*TD2(17)*TD2(16)/TD2(5)
      TD2(12)=(TD2(2)/TD2(17))*(.015*(TD2(10)**.8)*TD2(11)*((TD2(6)/TD2(
     17))**.46)+.052*(TD2(14)**(2./3.))*TD2(17)*TD2(11)/TD2(5))
C
C     COEFFICIENT*AREA
      NCR=TDA(6)
      GO TO (1,2,1,3,4),NCR
    1 AF=AE
      GO TO 5
    2 AF=AN
      GO TO 5
    3 AF=AS
      GO TO 5
    4 AF=TDA(7)
    5 TD2(13)=AF*TD2(12)
      RETURN
      END
```

```
$IBFTC SN5M
      SUBROUTINE SN5(TDA,TD2,AE,AN,AS)
C
C     HEAT TRANSFER COEFFICIENTS FOR FLOW OVER FLAT PLATES
C
      DIMENSION TD2(20),TDA(7)
C
C     REYNOLDS AND PRANDTL NUMBERS
      TD2(8)=TD2(7)*TD2(6)/TD2(5)
      TD2(9)=(TD2(3)*TD2(4)/TD2(2))**(1./3.)
C
C     LAMINAR OR TURBULENT COEFFICIENT
      IF(TD2(8)-500000.) 1,1,2
    1 TD2(10)=.332*TD2(2)*(TD2(8)**.5)*TD2(9)/TD2(6)
      GO TO 3
    2 TD2(10)=.0288*TD2(2)*(TD2(8)**.8)*TD2(9)/TD2(6)
C
C     COEFFICIENT*AREA
    3 NCR=TDA(6)
      GO TO (4,5,4,6,7),NCR
    4 AF=AE
      GO TO 8
    5 AF=AN
      GO TO 8
    6 AF=AS
      GO TO 8
    7 AF=TDA(7)
    8 TD2(11)=AF*TD2(10)
      RETURN
      END
```

```
$IBFTC FC1M
      SUBROUTINE FC1(TDA,TD2,AE,AN,AS,T,JBPT,NDIM)
C
C     HEAT TRANSFER COEFFICIENTS FOR HORIZ.CYLINDER FREE CONVECTION
C
      DIMENSION TDA(7),TD2(20),T(NDIM)
C
      TD2(12)=ABS(TD2(1)-T(JBPT))
      TD2(13)=.5*(TD2(1)+T(JBPT))+459.7
      TD2(14)=TD2(2)/TD2(6)
C
C     PRANDTL AND GRASHOF NUMBERS
      TD2(7)=TD2(3)*TD2(4)/TD2(2)
      TD2(8)=TD2(6)*TD2(6)*TD2(6)*32.174*TD2(12)/(TD2(5)*TD2(5)*TD2(13))
      TD2(11)=TD2(7)*TD2(8)
C
C     LAMINAR OR TURBULANT COEFFICIENT
      IF (TD2(11)-.1E+10) 1,1,2
    1 TD2(9)=.53*TD2(14)*TD2(11)**(1./4.)
      GO TO 3
    2 TD2(9)=.13*TD2(14)*TD2(11)**(1./3.)
C
C     COEFFICIENT*AREA
    3 NCR=TDA(6)
      GO TO (4,5,4,6,7),NCR
    4 AF=AE
      GO TO 8
    5 AF=AN
      GO TO 8
    6 AF=AS
      GO TO 8
    7 AF=TDA(7)
    8 TD2(10)=AF*TD2(9)
      RETURN
      END
```

```
$IBFTC FC2M
      SUBROUTINE FC2(TDA,TD2,AE,AN,AS,T,JBPT,NDIM)
C
C     HEAT TRANSFER COEFFICIENTS FOR VERT. SURFACE FREE CONVECTION
C
      DIMENSION TDA(7),TD2(20),T(NDIM)
C
      TD2(12)=ABS(TD2(1)-T(JBPT))
      TD2(13)=.5*(TD2(1)+T(JBPT))+459.7
      TD2(14)=TD2(2)/TD2(6)
C
C     PRANDTL AND GRASHOF NUMBERS
      TD2(7)=TD2(3)*TD2(4)/TD2(2)
      TD2(8)=TD2(6)*TD2(6)*TD2(6)*32.174*TD2(12)/(TD2(5)*TD2(5)*TD2(13))
      TD2(11)=TD2(7)*TD2(8)
C
C     LAMINAR OR TURBULANT COEFFICIENT
      IF (TD2(11)-.1E+10) 1,1,2
    1 TD2(9)=.44*TD2(14)*TD2(11)**(1./4.)
      GO TO 3
    2 TD2(9)=.13*TD2(14)*TD2(11)**(1./3.)
C
C     COEFFICIENT*AREA
    3 NCR=TDA(6)
      GO TO (4,5,4,6,7),NCR
    4 AF=AE
      GO TO 8
    5 AF=AN
      GO TO 8
    6 AF=AS
      GO TO 8
    7 AF=TDA(7)
    8 TD2(10)=AF*TD2(9)
      RETURN
      END
```

```
$IBFTC FC3M
      SUBROUTINE FC3(TDA,TD2,AE,AN,AS)
C
C     HEAT TRANSFER COEFFICIENTS FROM HORIZONTAL CYLINDER TO LIQUID
C     FILM (GRAVITY FLOW)
C
      DIMENSION TD2(20),TDA(7)
C
      TD2(5)=TD2(2)*TD2(3)/TD2(4)
      NCR=TDA(6)
      GO TO (1,2,1,3,4),NCR
    1 AF=AE
      GO TO 5
    2 AF=AN
      GO TO 5
    3 AF=AS
      GO TO 5
    4 AF=TDA(7)
    5 TD2(6)=AF*TD2(5)
      RETURN
      END
```

```
$IBFTC RA1M
      SUBROUTINE RA1(TDA,TD2,AE,AN,AS,T,JBPT,NDIM)
C
C     RADIATION(THERMAL)-GRAY BODY
C
      DIMENSION TDA(7),TD2(20),T(NDIM)
C
      TAE=TD2(1)
      TAS=T(JBPT)
      TD2(8)=1.-TD2(4)
      TD2(9)=1.-TD2(5)
      TD2(10)=TAE*TAE*TAE+TAE*TAE*TAS+TAE*TAS*TAS+TAS*TAS*TAS
      TD2(6)=4.83E-13*TD2(4)*TD2(9)*TD2(2)*TD2(10)/(1.-(TD2(2)*TD2(3)*TD
     12(8)*TD2(9)))
      NCR=TDA(6)
      GO TO (1,2,1,3,4),NCR
    1 AF=AE
      GO TO 5
    2 AF=AN
      GO TO 5
    3 AF=AS
      GO TO 5
    4 AF=TDA(7)
    5 TD2(7)=AF*TD2(6)
      RETURN
      END
```

```
$IBFTC QTM
      SUBROUTINE QT(NBPT,NBDIM,NDIM,JBPT,H,SUMT,SUMH,TD1,TBND,T,CD,NVDIM
     1,NIT,NODE,JNTF)
C
C     COMPUTE BOUNDARY HEAT FLUXES
C
      DIMENSION H(NBDIM,9),SUMT(NBDIM),SUMH(NBDIM),TD1(NDIM,19)
      DIMENSION TBND(NVDIM),T(NDIM),CD(10),TS(100),JNTF(NDIM)
      COMMON/BLK1/JBNT(400),KAN(200),NTF,NDR,NTR,QF(95),NQR
      COMMON/BLK2/TCF(95),GFN(95),AFN(95),NBR(95),NM(5),NAT(5),NBT(5)
C
  101 FORMAT(1H0,2X,39HCOMBINED FLOWS ELEMENT, COMBINATION NO.,I2,3X,12H
     2CONDUCT.NO.=,I3,3X,10HBNDRY.NO.=,I3,3X,31HPREVIOUS ELEMENT VAR.TEM
     3P.NOS.=,I3,2X,3HAND,I4)
  102 FORMAT(1H0,2X,19HCONDUCT.ELEMENT NO.,I4,3X,20HVAR.TEMP.ELEMENT NO.
     2,I4,3X,10HFLOW CODE=,I2)
C
      SUMT(NBPT)=0.0
      SUMH(NBPT)=0.0
      ITYPE=TD1(JBPT,17)
      IF (ITYPE.NE.7) GO TO 1
      GO TO 99
C
C     SPECIFIED FLUX
    1 IF (H(NBPT,1).EQ.0.) GO TO 2
      SUMT(NBPT)=H(NBPT,1)
C
C     FORCED CONVECTION (INCL.SPECIFIED COEFF.)
    2 IF (H(NBPT,2).EQ.0.) GO TO 3
      SUMH(NBPT)=H(NBPT,2)
      SUMT(NBPT)=SUMT(NBPT)+H(NBPT,3)-H(NBPT,2)*T(JBPT)
C
C     FREE CONVECTION
    3 IF (H(NBPT,4).EQ.0.) GO TO 4
      SUMH(NBPT)=SUMH(NBPT)+H(NBPT,4)
      SUMT(NBPT)=SUMT(NBPT)+H(NBPT,5)-H(NBPT,4)*T(JBPT)
C
C     RADIATION
    4 IF (H(NBPT,6).EQ.0.) GO TO 5
      SUMH(NBPT)=SUMH(NBPT)+H(NBPT,6)
      SUMT(NBPT)=SUMT(NBPT)+H(NBPT,7)-H(NBPT,6)*T(JBPT)
C
C     VARYING TEMPERATURE
    5 IF (H(NBPT,8).EQ.0.) GO TO 99
      NTF=NTF+1
      NPT=0
      LHN=0
      QF1=0.
      SUMH(NBPT)=SUMH(NBPT)+H(NBPT,8)
      IF (KAN(NBPT).EQ.0) GO TO 6
      SUMT(NBPT)=SUMT(NBPT)+H(NBPT,8)*(TBND(NTF)-T(JBPT))
```

```
C
    6 JNPT=AFN(NTF)
      JLHN=GFN(NTF)
      TS=0.
      IF (JNPT.EQ.0) GO TO 7
      NPT=JBNT(JNPT)
    7 IF (JLHN.EQ.0) GO TO 8
      LHN=JNTF(JLHN)
    8 IF (NM(NDR)-JBPT) 14,9,14
C
C     COMBINED FLOWS
    9 JNFR=NAT(NDR)
      JNFS=NBT(NDR)
      IF (JNFR.EQ.0) GO TO 10
      NFR=JBNT(JNFR)
      JAT=JNTF(JNFR)
      GO TO 11
   10 NFR=0
      TBND(NFR)=0.
      H(NFR,9)=0.
   11 IF (JNFS.EQ.0) GO TO 12
      NFS=JBNT(JNFS)
      JBT=JNTF(JNFS)
      GO TO 13
   12 NFS=0
      TBND(NFS)=0.
      H(NFS,9)=0.
   13 IF ((NIT-1).EQ.0) WRITE(6,101) NDR,JBPT,NTF,JAT,JBT
C
C     STARTING TEMP.FOR COMBINED FLOWS ELEMENT TEMP.CALC.
      COMBF=H(NFR,9)+H(NFS,9)
      PNFR=H(NFR,9)*TBND(NFR)/COMBF
      PNFS=H(NFS,9)*TBND(NFS)/COMBF
      STEMP=PNFR+PNFS
      NDR=NDR+1
      GO TO 18
C
C     STARTING TEMP.ORDINARY FLOW ELEMENT
   14 NTR=NTR+1
      NER=NBR(NTR)
      IF ((NIT-1).EQ.0) WRITE(6,102) JBPT,NTR,NBR(NTR)
      IF (LHN.NE.0) GO TO 17
      GO TO (15,16),NER
   15 STEMP=CD(6)
      GO TO 18
   16 STEMP=CD(7)
      GO TO 18
   17 STEMP=TBND(LHN)
C
   18 IF (KAN(NBPT).NE.0) GO TO 99
C
C     CALC.TEMP.CHANGE
      HINC=TCF(NTF)/CD(9)
      IF (QF(NTF).EQ.0.) GO TO 19
      QF1=QF(NTF)/(H(NBPT,9)*CD(9))
   19 NCD=CD(9)
```

```
      IF (NPT.NE.0) GO TO 22
C
C     TEMP.CHANGE-NO ANN.NABOR
      DO 21 INC=1,NCO
      IF (INC.NE.1) GO TO 20
      TS(INC)=STEMP+HINC*(T(JBPT)-STEMP)+QF1
      GO TO 21
   20 TS(INC)=TS(INC-1)+HINC*(T(JBPT)-TS(INC-1))+QF1
   21 CONTINUE
      TBND(NTF)=TS(INC)
      GO TO 25
C
C     TEMP.CHANGE-ANNULAR NABOR
   22 HANC=H(NPT,8)/(H(NPT,9)*CD(9))
      DO 24 INC=1,NCO
      IF (INC.NE.1) GO TO 23
      TS(INC)=STEMP+HINC*(T(JBPT)-STEMP)+HANC*(T(JNPT)-STEMP)+QF1
      GO TO 24
   23 TS(INC)=TS(INC-1)+HINC*(T(JBPT)-TS(INC-1))+HANC*(T(JNPT)-TS(INC-1)
     1)+QF1
   24 CONTINUE
      TBND(NTF)=TS(INC)
      TBND(NPT)=TBND(NTF)
      KAN(NPT)=1
   25 SUMT(NBPT)=SUMT(NBPT)+H(NBPT,8)*(TBND(NTF)-T(JBPT))
   99 RETURN
      END
```

```
$IBFTC TATSM
      SUBROUTINE TATS(TD1,JPT,NDIM,NBND,NBDIM,Q,T,H,RD,LD,CE,NK)
C
C     OVER-RELAXATION AND NEW TEMPERATURE CALCULATION
C
      DIMENSION TD1(NDIM,19),CE(NDIM,4),LD(10),RD(5)
      DIMENSION NBND(NBDIM),Q(NDIM),T(NDIM),H(NBDIM,9)
      COMMON/BLK1/JBNT(390),KAN(190),NTE,NDR,NTR,QF(95),NQR
C
  101 FORMAT(1H0,5X,58HERROR IN BNDRY AND COND.NO CORRESP.(TATS CHECK OF
     2ITERATION,I6,13H)COND.ELEMENT,I4,25HGIVES BNDRY NO OF ELEMENT,I4)
C
      HSUM=0.
C
C     EAST CONDUCTANCE
      NE= TD1(JPT,5)
      IF (NE) 2,1,2
    1 CE(JPT,1)=0.0
      GO TO 3
    2 CE(JPT,1)=1./(TD1(JPT,4)/(2.*TD1(JPT,14)*TD1(JPT,18))+TD1(NE,4)/(2
     1.*TD1(NE,14)*TD1(NE,18))+TD1(JPT,10))
*C
C     NORTH CONDUCTANCE
    3 NN=TD1(JPT,6)
      IF (NN) 5,4,5
    4 CE(JPT,2)=0.0
      GO TO 6
    5 CE(JPT,2)=1./(2.*TD1(JPT,3)/(TD1(JPT,18)*(3.*TD1(JPT,15)+TD1(JPT,1
     16)))+2.*TD1(NN,3)/(TD1(NN,18)*(3.*TD1(NN,16)+TD1(NN,15)))+TD1(JPT,
     211))
C
C     WEST CONDUCTANCE
    6 NW=TD1(JPT,7)
      IF (NW) 8,7,8
    7 CE(JPT,3)=0.0
      GO TO 9
    8 CE(JPT,3)=1./(TD1(JPT,4)/(2.*TD1(JPT,14)*TD1(JPT,18))+TD1(NW,4)/(2
     1.*TD1(NW,14)*TD1(NW,18))+TD1(JPT,12))
*C
C     SOUTH CONDUCTANCE
    9 NS= TD1(JPT,8)
      IF (NS) 11,10,11
   10 CE(JPT,4)=0.0
      GO TO 12
   11 CE(JPT,4)=1./(2.*TD1(JPT,3)/(TD1(JPT,18)*(3.*TD1(JPT,16)+TD1(JPT,1
     15)))+2.*TD1(NS,3)/(TD1(NS,18)*(3.*TD1(NS,15)+TD1(NS,16)))+TD1(JPT,
     213))
C
   12 NTD=TD1(JPT,17)
      IF(NTD.EQ.7) GO TO 99
C
```

```
C      COMPUTE RESIDUAL, OVER-RELAX
       RES=CE(JPT,1)*(T(NE)-T(JPT))+CE(JPT,2)*(T(NN)-T(JPT))+CE(JPT,3)*(T
      1(NW)-T(JPT))+CE(JPT,4)*(T(NS)-T(JPT))+Q(JPT)
       CSUM=CE(JPT,1)+CE(JPT,2)+CE(JPT,3)+CE(JPT,4)
C
       WRES=RD(1)*RES
C
C      COMPUTE NEW TEMPERATURE
       IF (Q(JPT)) 13,15,13
   13 NBPT=JBNT(JPT)
       JBPT=NBND(NBPT)
       IF (JBPT.EQ.JPT) GO TO 14
       WRITE(6,101) NIT,JPT,JBPT
       NK=1
       GO TO 99
   14 HSUM=H(NBPT,2)+H(NBPT,4)+H(NBPT,6)+H(NBPT,8)
   15 T(JPT)=T(JPT)+WRES/(CSUM+HSUM)
C
   99 RETURN
       END
```

```
$IBFTC FITA
      SUBROUTINE FIT2(TD1,NDIM,JPT,ALPHA,THEXP)
C
C     FIT EXPANSION COEFFICIENT FROM POLYNOMINAL CURVE
C
      DIMENSION TD1(NDIM,19),COS(5),CALC(6),ALPHA(15,11),THEXP(NDIM)
C
  101 FORMAT(1H0,20X,45HTEMPERATURE EXCEEDS CURVE FIT LIMIT FOR ALPHA)
C
      TEMP= TD1(JPT,19)
      MAN = TD1(JPT,9)
      DO 1 NCO=1,5
    1 COS(NCO)= ALPHA(MAN,NCO)
      IF(TEMP-COS( 1)) 3,3,2
    2 WRITE(6,101)
      GO TO 9
    3 NOP = COS(3)
      NOP1=NOP+1
      DO 4 NCO=1,NOP1
      LC = 5+NCO
    4 CALC(NCO)= ALPHA(MAN,LC)
      IF(COS(3)) 6,5,6
    5 Y= CALC(1)*COS(4)
      GO TO 8
    6 Y = CALC(NOP1)
      TEM1 = TEMP*COS(5)
      DO 7 NPY=1,NOP
      J2 = NOP1-NPY
    7 Y= CALC(J2)+Y*TEM1
      Y = Y*COS(4)
    8 THEXP(JPT)=Y
C
    9 RETURN
      END
```

```
$IBFTC CONCHC
      SUBROUTINE CONCHK(JPT,NDIM,TD1,ERR,LD,NK,T)
C
C     CHECK FOR CONVERGENCE OF OVER-RELAXATION CALC.
C
      DIMENSION TD1(NDIM,19),LD(10),T(NDIM)
C
  101 FORMAT(24X,I4,4(5X,E14.7))
C
      DIFF=T(JPT)-TD1(JPT,19)
      IF (ABS(DIFF).LE.ERR) GO TO 1
      NK=1
    1 IF (LD(4).EQ.0) GO TO 9
      WRITE(6,101) JPT,T(JPT),TD1(JPT,19),DIFF,ERR
C
    9 RETURN
      END
```

```
$IBFTC DEFRMM
      SUBROUTINE DEFORM(JPT,NDIM,TD1,RD,LD,THEXP)
C
C     COMPUTE FREE THERMAL EXPANSION  ALPHA*DELTA TEMP
C
      DIMENSION TD1(NDIM,19),THEXP(NDIM),RD(5),LD(10)
C
  101 FORMAT(1H0,10X,16HELEMENT COND.NO=,I4,3X,6HALPHA=,E13.6,3X,5HTEMP=
     2,F12.5,3X,14HALPHA*(T1-T0)=,E13.6)
C
      TIN=RD(2)
      DELTEM=TD1(JPT,19)-TIN
      A=THEXP(JPT)
      ACT=THEXP(JPT)*DELTEM
      THEXP(JPT)=ACT
      IF (LD(10).EQ.0) GO TO 99
      WRITE(6,101) JPT,A,TD1(JPT,19),THEXP(JPT)
C
   99 RETURN
      END
```

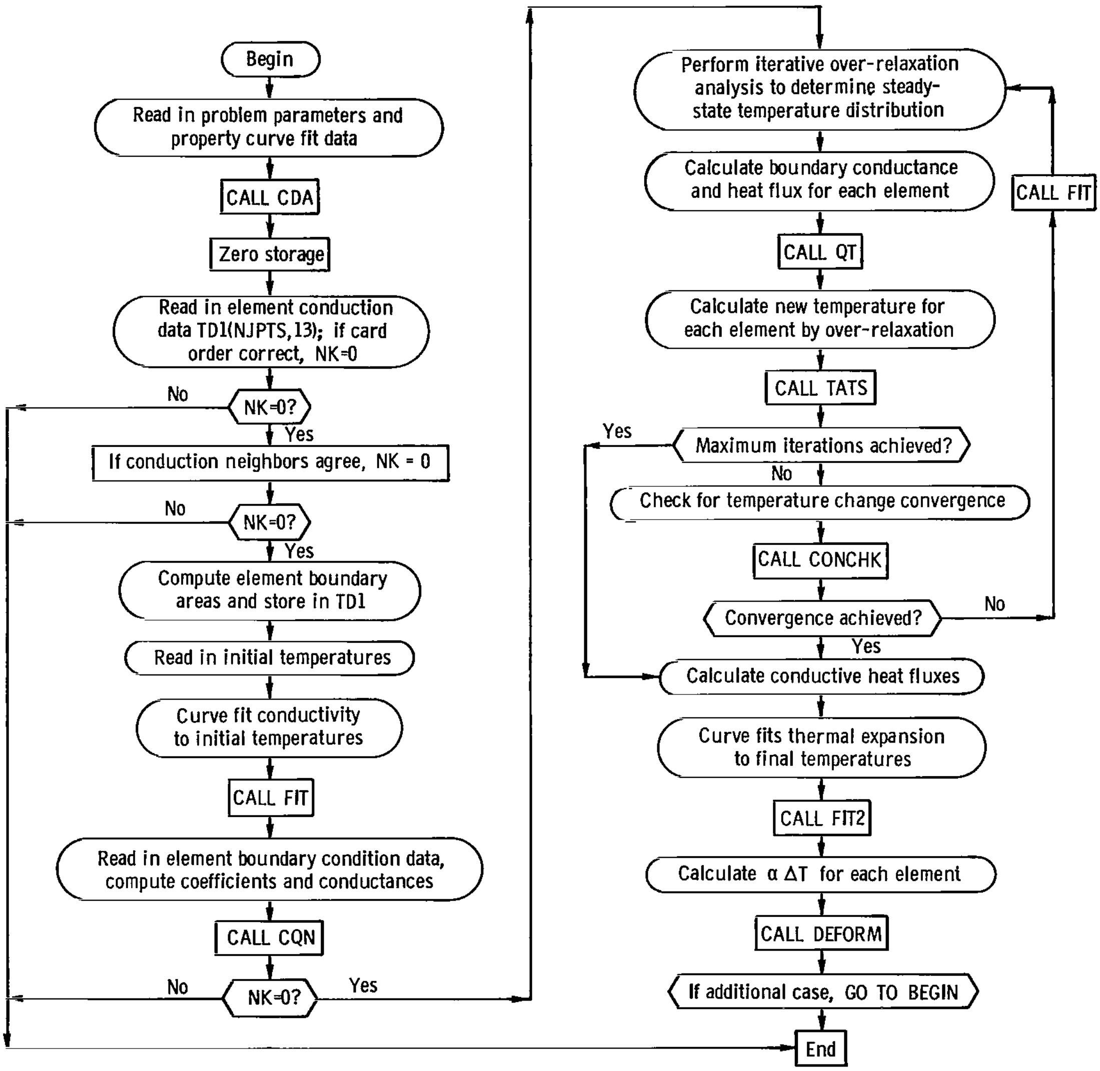


Figure 8. - Flow chart for main route SEAL2.

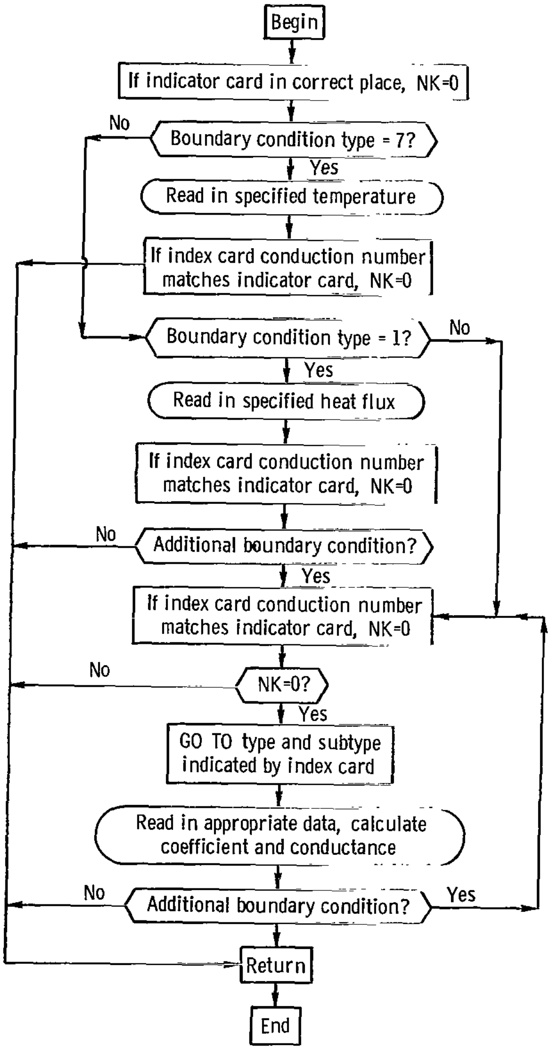


Figure 9. - Flow chart for subroutine CQN.

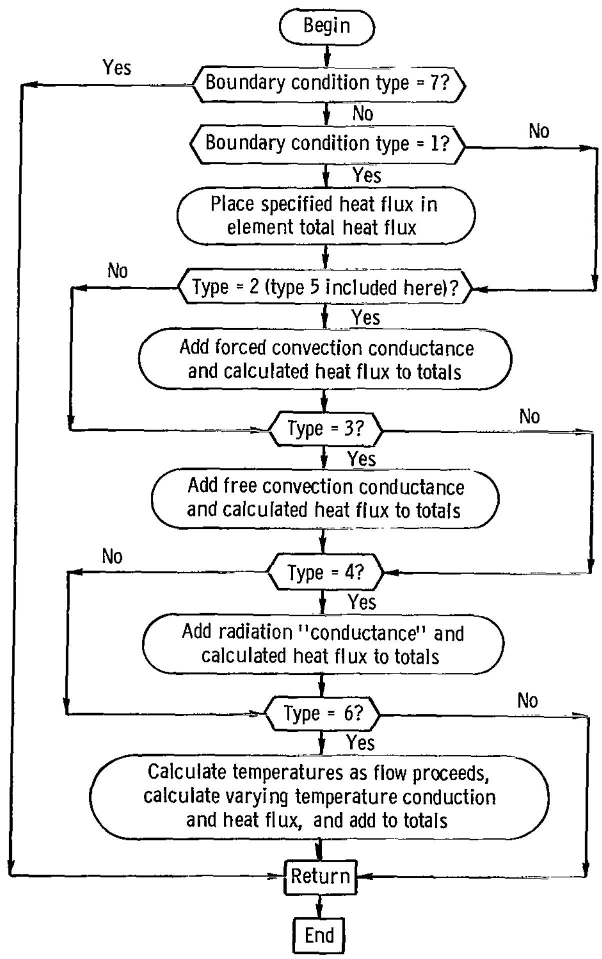


Figure 10. - Flow chart for subroutine QT.

APPENDIX B

CHANGING OF BOUNDARY CONDITION COEFFICIENTS

The program is designed to make the addition or substitution of equations for heat transfer coefficients relatively easy. The coefficients, the products of coefficient times boundary area and the products of coefficient times boundary area times bulk fluid (or environmental) temperature are calculated in subroutines SN1, SN2, SN3, SN4, SN5, FC1, FC2, FC3, and RA1.

The varying temperature coefficients, at present, use subroutines SN1 and SN3. Other calculations for the varying temperature boundary conditions are performed in subroutines CQN and QT.

Substitution of a Different Coefficient

To substitute a new expression for one of those presently used, the appropriate subroutine is rewritten using the present words in the TD2 list for the output (coefficient, etc.). This assumes that the same properties or at least the same number of properties are required. If not, the number of items to be read in must be changed in subroutine CQN. Also the TD2 words used for output must be changed in the coefficient subroutine as well as in subroutine CQN. The appropriate formats of subroutine CQN must also be changed to reflect the TD2 changes.

The TD2 list of a varying temperature condition must be compatible with the TD2 list of the coefficient subprogram used. Thus, if subroutine SN1 is changed to require more input data, subroutine VT1 (see table II) must also be changed. The output, which is common to both, must use the same new TD2 words.

TD2 word changes for a varying temperature subroutine must be made in subroutine QT as well as in subroutine CQN. Wherever a TD2 word (e.g., TD2(15)) appears in the varying temperature sections of subroutines CQN and QT, the new word must be substituted.

Also the two indicator flag words (TD2(10) and TD2(11)) must be the same for all VT (varying temperature) conditions. The calculations involving the flags require this. The sections in subroutines CQN and QT handling the temperature change along the flow and the effect of flow combination use the flags to control the flow in the subroutines. If one or both of the flag words are changed for one VT condition, it (they) must be changed for all conditions and the new word(s) must be used in subroutines CQN and QT.

A word of warning should be added. As implied previously, the TD2 list is used for both input to and output from the coefficient subroutines. This table is dimensioned for 20 items. If more are needed, the dimensions in SEAL2, CQN, and the coefficient subroutines must be increased.

Addition of New Coefficients

If an additional boundary condition is desired, a new subroutine must be written. A varying temperature condition involves the precautions mentioned under substitution. Also the TD2 list capacity must be remembered.

Also, for an added condition, a section must be added to subroutine CQN. This section will be analogous to the subtype sections already present. The products of coefficient times area and of coefficient times area times bulk fluid temperature must be stored in the correct places in the conductance matrix. An output format for the TD2 list must be composed. Unused statement and format numbers are provided for this purpose.

APPENDIX C

COMPUTER PROGRAM APPLICATION TO MAINSHAFT SEAL

Seal Description

This appendix is presented as an application of the computer program to a specific seal design. Figure 11 shows a schematic of a mainshaft seal being developed for gas-

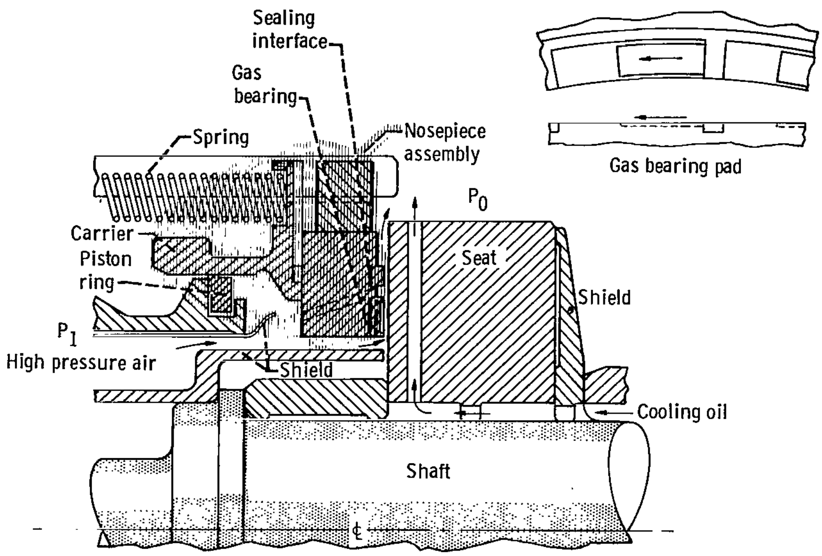


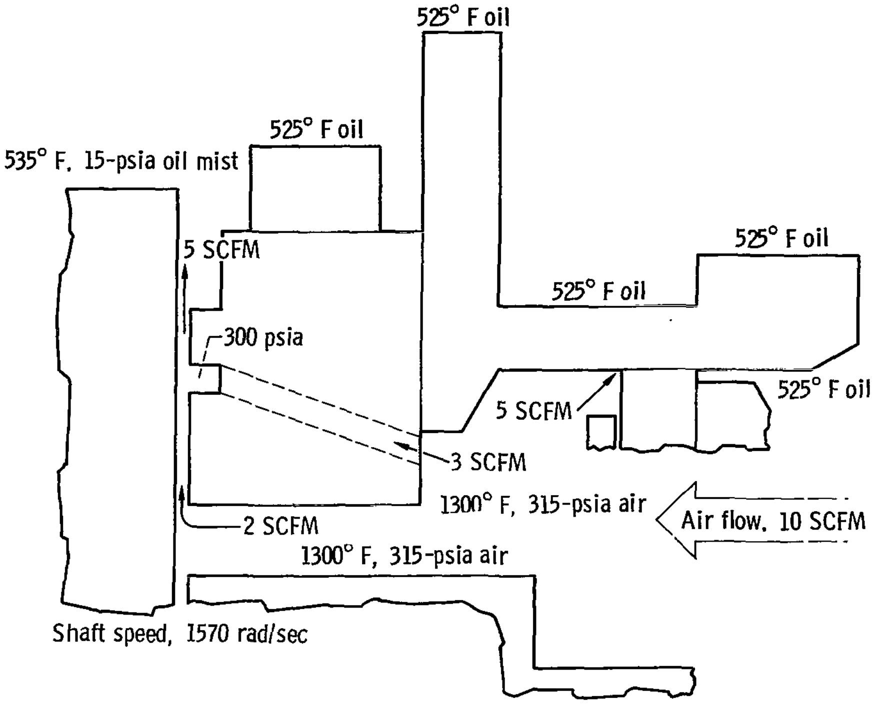
Figure 11. - Face seal with self-acting gas bearing for lift augmentation.

turbine engines. This is a face-type seal with a self-acting gas bearing which acts to prevent rubbing contact when deformation of the sealing faces occurs.

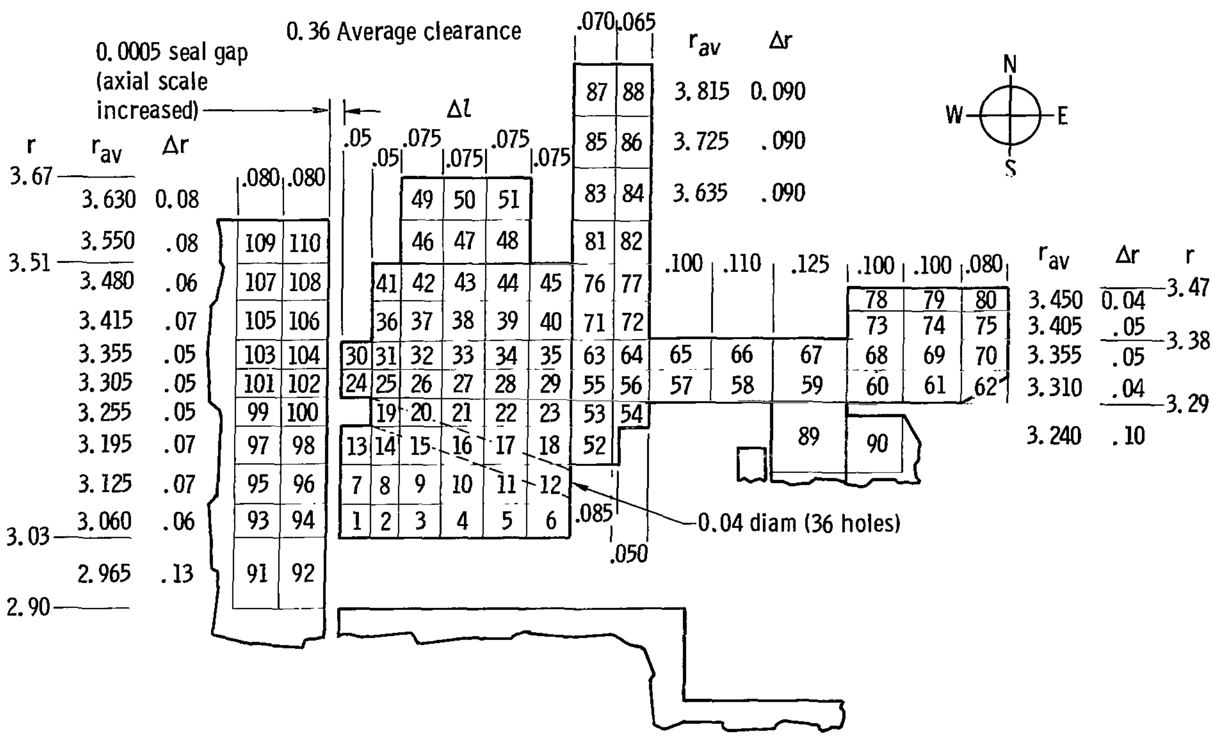
In figure 12(a) a modified version of the nosepiece assembly is presented and the boundary conditions are shown. This modification is for the purpose of concentrating on the mechanics of the program application.

Figure 12(b) shows the element schematic including conduction numbers and dimensions. A portion of the seal plate is included since it influences the temperature of the airflow through the seal gap and therefore has an effect on the nosepiece temperature. Also a portion of the piston ring and its holder, which form a conduction path to the nosepiece carrier, are included.

The numbering sequence starts with the nosepiece assembly since this is the region of interest for this problem. The desired printout is therefore available at the beginning of

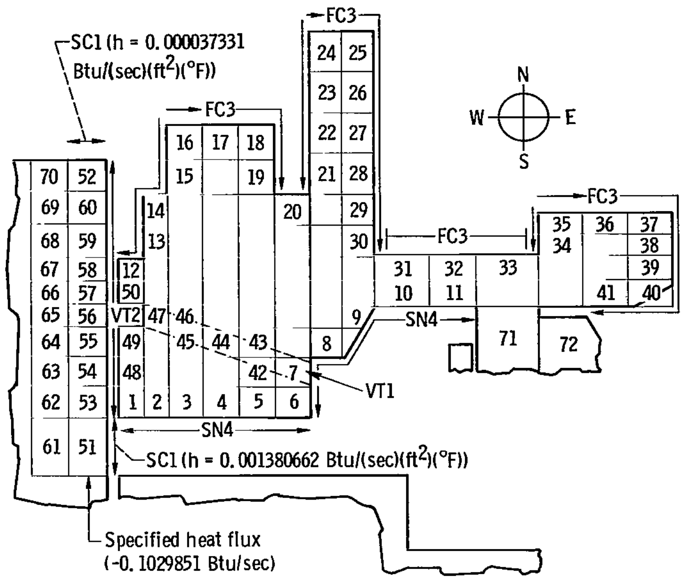


(a) Modification of and boundary conditions for nosepiece assembly of seal depicted in figure 11.



(b) Dimensions and conductance element numbering for nosepiece assembly depicted in figure 12(a). (All dimensions in inches.)

Figure 12. - Example problem.



(c) Boundary element numbering and boundary heat transfer conditions for nosepiece assembly depicted in figure 12(a).

Figure 12. - Concluded.

each section of output, and the remaining elements can be ignored. The piece by piece numbering is not necessary; any convenient order could be used.

Figure 12(c) shows the boundary numbers and the subroutines used to calculate the heat transfer coefficients. Here again, the sequence is a matter of convenience and the nosepiece assembly is numbered first. Numbers 1 to 11 are assigned to the region where concentric cylinder flow (SN4) is assumed. Conduction element 56 was ignored since only a relatively tiny part is a boundary of the piece. Numbers 12 to 41 were assigned to the liquid film cooled (FC3) boundaries. The varying temperature duct flow (VT1) is numbered next. Since conduction element 12 already has a boundary number (7), the sequence continues with 42 assigned to conduction element 11. The method used is an approximation to avoid the complexities involved if conduction elements 18 and 14 are included as should be done. For the varying temperature seal gap (VT2) flow, numbers 48 to 50 were assigned to the nosepiece elements not already given boundary numbers.

For the seal plate, the east face of conduction element 92 and the north face of 110 were assigned coefficients. The south face of 92 was assigned a heat flux. These values were obtained from a thermal analysis of the seal shown in figure 11. Boundary numbers 53 to 60 were assigned to the seal plate elements exposed to seal gap flow. The remaining boundary numbers, 61 to 72, were assigned to elements given specified temperatures obtained from the previous analysis mentioned.

The title and parameter cards (Items 1 to 5 under Computer Input in appendix A) were filled out as indicated in the first section of the printout. Also in this section, Items 6 and 7, the thermal conductivity and expansion data, are indicated.

Next are the conduction element cards (input Item 8). These are shown in the second section of printout (conduction element table). Words 1 to 8 of each card are obtained from the information in figure 12(b). In word 9, three materials were used. The nosepiece was material number 1. The piston ring and its holder were material number 3. The remaining parts were material number 2. The last four words are contact resistances.

It should be noted that each contact resistance must appear twice since the program ignores neighbor contact resistance in computing heat fluxes. Thus for elements 42 and 46, the contact resistance appears in word 11 (north contact resistance) of element 42 and in word 13 (south contact resistance) of element 46. Contact resistances between parts were calculated using a "conductance coefficient" ($h_c = 0.2$) for conductance across the interface. The resistance between elements 90 and 60 was the difference between the resistance of the air gap and the resistance of an equal volume of material number three (element 90 uses the same mean radius and radial width as element 89). The resistance between mismatched elements (elements 52 and 54 were changed in axial length to approximate the actual dimensions in the region) was calculated as illustrated in figure 13. It was assumed that the larger i^{th} element (e.g., 52) has a conduction path length of d' rather than $\Delta r/2$ as in figure 5. The area was based on Δl_m rather than Δl_i. The contact resistance was the difference between $d'/2\pi r_m \Delta l_m$ and $\Delta r_i/4\pi r_m \Delta l_i$.

The initial temperature estimates (input Item 9) follow the conduction cards. These values were obtained from a previous analysis in order to reduce the computer time required. However, any reasonable estimates can be used including the use of one temperature for all elements.

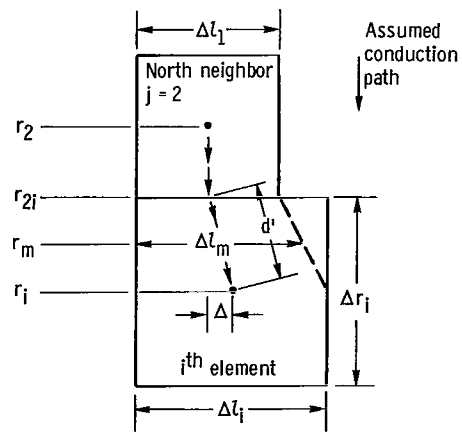


Figure 13. - Outline of calculation of contact resistance between elements of different axial dimensions. $d' = \sqrt{\Delta^2 + (\Delta l_i/2)^2}$; $\Delta l_m = (\Delta l_i + \Delta l_2)/2$.

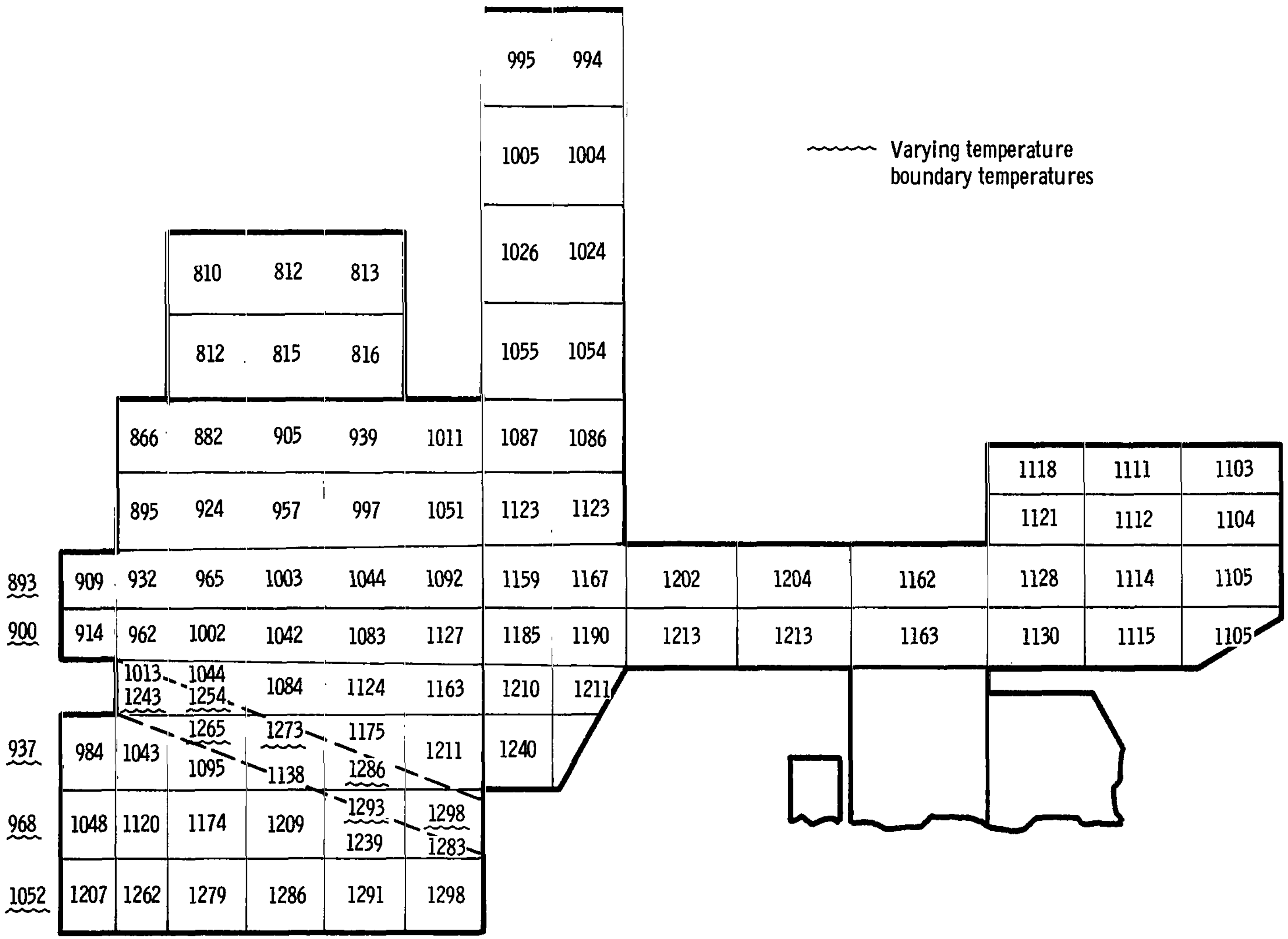


Figure 14. - Example problem of temperature distribution in °F for nosepiece assembly of seal depicted in figure 11.

The boundary heat transfer cards (input Item 9) are assembled element by element. The boundary numbers determine the order of the sets. A set consists of the indicator card for the element followed by the index card, plus any others required, for each "side" of the element that is a boundary. The indicator cards do not appear in the printout but the order of the other cards for each element is indicated in the section of printout following the initial temperatures. This section, as well as the conduction element table, are not standard output items but are included to indicate the cards required. Some calculated values (Reynolds or Prandtl numbers and the following items for each element side) are included in this printout.

In preparing the varying temperature boundary cards, the region at which the flows joined required the use of approximations because the program permits only one varying temperature condition per element. Boundary element 47 (fig. 12(c)) was assumed to be affected only by the duct flow. For boundary elements 49 and 50, special areas (code number 5) were used with the sums of the appropriate faces as the area values. Element 56 was made the combined flow element with 47 and 55 (conduction numbers 19 and 98) as the upstream elements.

The film cooled (FC3) boundary was another area where approximations were involved. It was assumed that flows originated at the northwest corners of boundary elements 16 (two 0.018 lbm/sec), 24 (two 0.018 lbm/sec), and 35 (two 0.012 lbm/sec) (see fig. 12(c)). The flows were assumed to be either toward or parallel to the axis except for elements 20 and 31 to 33. The arrows outlining the region indicate this. Elements 20 and 31 to 33 had flow around the circumference and were the only elements where the equation properly applied. For the other elements, the flow length was taken as the sum of the element sides over which the flow occurred and the length perpendicular to flow was the average circumference for the side.

After all cards were prepared and assembled, a preliminary run was made to check for errors. The LD card (input Item 2) options (or words) 1, 2, and 5 were used. Limits of 1 minute and 100 iterations were set. The results of the final run are presented in the sections of printout starting with the element center temperatures. These temperatures and the varying temperature boundary temperatures are also plotted in figure 14. Improved results could be obtained by using fluid properties based on the new film temperatures calculated from the results. This applies especially to the varying temperature flows where the properties were based on the initial flow temperatures (1300° F).

Computer Output for Sample Problem

```
                    SAMPLE PROBLEM* MAINSHAFT SEAL NOSEPIECE

ID=      1, 1     2, 1     3, 1     4, -0     5, 1     6, -0     7, -0     8, -0     9, -0    10, -0

NI=      1, 1     2, -0    3, -0    4, -0     5, -0

RD=      1, 1.500000E 00    2, 7.000000E 01    3, 1.000000E 02    4,-0.              5,-0.

CD=      1, 1.100000E 02    2, 7.200000E 01    3, 1.000000E 03    4, 5.000000E-02    5,-0.
       6, 1.300000E 03    7, 1.300000E 03    8,-0.               9, 2.000000E 01   10,-0.

                                          DATA FOR ALPHA.
       1 1.5000000E 03    2 1.0000000E 00    3 1.0000000E 00    4 1.0000000E 00    5 1.0000000E 00    6 1.3500000E-06
       7 1.5000000E-09

                                          DATA FOR ALPHA.
       1 1.8000000E 03    2 2.0000000E 00    3 1.0000000E 00    4 1.0000000E 00    5 1.0000000E 00    6 2.9447000E-06
       7 2.5400000E-09

                                          DATA FOR ALPHA.
       1 1.6000000E 03    2 3.0000000E 00    3 2.0000000E 00    4 1.0000000E 00    5 1.0000000E 00    6 7.0200000E-06
       7 8.6071429E-10    8 3.5714290E-13



                              CONDUCTION ELEMENT TABLE (TD1)

 1      1, 1.0000E 00    2, 3.0600E 00    3, 6.0000E-02    4, 5.0000E-02    5, 2.0000E 00    6, 7.0000E 00    7, 0.
      8, 0.            9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

 2      1, 2.0000E 00    2, 3.0600E 00    3, 6.0000E-02    4, 5.0000E-02    5, 3.0000E 00    6, 8.0000E 00    7, 1.0000E 00
      8,-0.            9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

 3      1, 3.0000E 00    2, 3.0600E 00    3, 6.0000E-02    4, 7.5000E-02    5, 4.0000E 00    6, 9.0000E 00    7, 2.0000E 00
      8,-0.            9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

 4      1, 4.0000E 00    2, 3.0600E 00    3, 6.0000E-02    4, 7.5000E-02    5, 5.0000E 00    6, 1.0000E 01    7, 3.0000E 00
      8,-0.            9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

 5      1, 5.0000E 00    2, 3.0600E 00    3, 6.0000E-02    4, 7.5000E-02    5, 6.0000E 00    6, 1.1000E 01    7, 4.0000E 00
      8,-0.            9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

 6      1, 6.0000E 00    2, 3.0600E 00    3, 6.0000E-02    4, 7.5000E-02    5, 0.             6, 1.2000E 01    7, 5.0000E 00
      8,-0.            9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

 7      1, 7.0000E 00    2, 3.1250E 00    3, 7.0000E-02    4, 5.0000E-02    5, 8.0000E 00    6, 1.3000E 01    7, 0.
      8, 1.0000E 00    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

 8      1, 8.0000E 00    2, 3.1250E 00    3, 7.0000E-02    4, 5.0000E-02    5, 9.0000E 00    6, 1.4000E 01    7, 7.0000E 00
      8, 2.0000E 00    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

 9      1, 9.0000E 00    2, 3.1250E 00    3, 7.0000E-02    4, 7.5000E-02    5, 1.0000E 01    6, 1.5000E 01    7, 8.0000E 00
      8, 3.0000E 00    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

10      1, 1.0000E 01    2, 3.1250E 00    3, 7.0000E-02    4, 7.5000E-02    5, 1.1000E 01    6, 1.6000E 01    7, 9.0000E 00
      8, 4.0000E 00    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

11      1, 1.1000E 01    2, 3.1250E 00    3, 7.0000E-02    4, 7.5000E-02    5, 1.2000E 01    6, 1.7000E 01    7, 1.0000E 01
      8, 5.0000E 00    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

12      1, 1.2000E 01    2, 3.1250E 00    3, 7.0000E-02    4, 7.5000E-02    5, 0.             6, 1.8000E 01    7, 1.1000E 01
      8, 6.0000E 00    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

13      1, 1.3000E 01    2, 3.1950E 00    3, 7.0000E-02    4, 5.0000E-02    5, 1.4000E 01    6, 0.             7, 0.
      8, 7.0000E 00    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

14      1, 1.4000E 01    2, 3.1950E 00    3, 7.0000E-02    4, 5.0000E-02    5, 1.5000E 01    6, 1.9000E 01    7, 1.3000E 01
      8, 8.0000E 00    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

15      1, 1.5000E 01    2, 3.1950E 00    3, 7.0000E-02    4, 7.5000E-02    5, 1.6000E 01    6, 2.0000E 01    7, 1.4000E 01
      8, 9.0000E 00    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.

16      1, 1.6000E 01    2, 3.1950E 00    3, 7.0000E-02    4, 7.5000E-02    5, 1.7000E 01    6, 2.1000E 01    7, 1.5000E 01
      8, 1.0000E 01    9, 1.0000E 00   10,-0.            11,-0.            12,-0.            13,-0.
```

```
17   1, 1.7000E 01   2, 3.1950E 00   3, 7.0000E-02   4, 7.5000E-02   5, 1.8000E 01   6, 2.2000E 01   7, 1.6000E 01
     8, 1.1000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

18   1, 1.8000E 01   2, 3.1950E 00   3, 7.0000E-02   4, 7.5000E-02   5, 5.2000E 01   6, 2.3000E 01   7, 1.7000E 01
     8, 1.2000E 01   9, 1.0000E 00  10, 5.1200E 02  11,-0.          12,-0.          13,-0.

19   1, 1.9000E 01   2, 3.2550E 00   3, 5.0000E-02   4, 5.0000E-02   5, 2.0000E 01   6, 2.5000E 01   7, 0.
     8, 1.4000E 01   9, 1.0000E 00  10, 0.          11,-0.          12,-0.          13,-0.

20   1, 2.0000E 01   2, 3.2550E 00   3, 5.0000E-02   4, 7.5000E-02   5, 2.1000E 01   6, 2.6000E 01   7, 1.9000E 01
     8, 1.5000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

21   1, 2.1000E 01   2, 3.2550E 00   3, 5.0000E-02   4, 7.5000E-02   5, 2.2000E 01   6, 2.7000E 01   7, 2.0000E 01
     8, 1.6000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

22   1, 2.2000E 01   2, 3.2550E 00   3, 5.0000E-02   4, 7.5000E-02   5, 2.3000E 01   6, 2.8000E 01   7, 2.1000E 01
     8, 1.7000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

23   1, 2.3000E 01   2, 3.2550E 00   3, 5.0000E-02   4, 7.5000E-02   5, 5.3000E 01   6, 2.9000E 01   7, 2.2000E 01
     8, 1.8000E 01   9, 1.0000E 00  10, 7.0400E 02  11,-0.          12,-0.          13,-0.

24   1, 2.4000E 01   2, 3.3050E 00   3, 5.0000E-02   4, 5.0000E-02   5, 2.5000E 01   6, 3.0000E 01   7, 0.
     8, 0.           9, 1.0000E 00  10, 0.          11,-0.          12,-0.          13,-0.

25   1, 2.5000E 01   2, 3.3050E 00   3, 5.0000E-02   4, 5.0000E-02   5, 2.6000E 01   6, 3.1000E 01   7, 2.4000E 01
     8, 1.9000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

26   1, 2.6000E 01   2, 3.3050E 00   3, 5.0000E-02   4, 7.5000E-02   5, 2.7000E 01   6, 3.2000E 01   7, 2.5000E 01
     8, 2.0000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

27   1, 2.7000E 01   2, 3.3050E 00   3, 5.0000E-02   4, 7.5000E-02   5, 2.8000E 01   6, 3.3000E 01   7, 2.6000E 01
     8, 2.1000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

28   1, 2.8000E 01   2, 3.3050E 00   3, 5.0000E-02   4, 7.5000E-02   5, 2.9000E 01   6, 3.4000E 01   7, 2.7000E 01
     8, 2.2000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

29   1, 2.9000E 01   2, 3.3050E 00   3, 5.0000E-02   4, 7.5000E-02   5, 5.5000E 01   6, 3.5000E 01   7, 2.8000E 01
     8, 2.3000E 01   9, 1.0000E 00  10, 6.9300E 02  11,-0.          12,-0.          13,-0.

30   1, 3.0000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 5.0000E-02   5, 3.1000E 01   6, 0.           7, 0.
     8, 2.4000E 01   9, 1.0000E 00  10, 0.          11,-0.          12,-0.          13,-0.

31   1, 3.1000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 5.0000E-02   5, 3.2000E 01   6, 3.6000E 01   7, 3.0000E 01
     8, 2.5000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

32   1, 3.2000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 7.5000E-02   5, 3.3000E 01   6, 3.7000E 01   7, 3.1000E 01
     8, 2.6000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

33   1, 3.3000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 7.5000E-02   5, 3.4000E 01   6, 3.8000E 01   7, 3.2000E 01
     8, 2.7000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

34   1, 3.4000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 7.5000E-02   5, 3.5000E 01   6, 3.9000E 01   7, 3.3000E 01
     8, 2.8000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

35   1, 3.5000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 7.5000E-02   5, 6.3000E 01   6, 4.0000E 01   7, 3.4000E 01
     8, 2.9000E 01   9, 1.0000E 00  10, 6.8300E 02  11,-0.          12,-0.          13,-0.

36   1, 3.6000E 01   2, 3.4150E 00   3, 7.0000E-02   4, 5.0000E-02   5, 3.7000E 01   6, 4.1000E 01   7, 0.
     8, 3.1000E 01   9, 1.0000E 00  10, 0.          11,-0.          12,-0.          13,-0.

37   1, 3.7000E 01   2, 3.4150E 00   3, 7.0000E-02   4, 7.5000E-02   5, 3.8000E 01   6, 4.2000E 01   7, 3.6000E 01
     8, 3.2000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

38   1, 3.8000E 01   2, 3.4150E 00   3, 7.0000E-02   4, 7.5000E-02   5, 3.9000E 01   6, 4.3000E 01   7, 3.7000E 01
     8, 3.3000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

39   1, 3.9000E 01   2, 3.4150E 00   3, 7.0000E-02   4, 7.5000E-02   5, 4.0000E 01   6, 4.4000E 01   7, 3.8000E 01
     8, 3.4000E 01   9, 1.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

40   1, 4.0000E 01   2, 3.4150E 00   3, 7.0000E-02   4, 7.5000E-02   5, 7.1000E 01   6, 4.5000E 01   7, 3.9000E 01
     8, 3.5000E 01   9, 1.0000E 00  10, 4.7900E 02  11,-0.          12,-0.          13,-0.

41   1, 4.1000E 01   2, 3.4800E 00   3, 6.0000E-02   4, 5.0000E-02   5, 4.2000E 01   6, 0.           7, 0.
     8, 3.6000E 01   9, 1.0000E 00  10, 0.          11,-0.          12,-0.          13,-0.
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42   1, 4.2000E 01   2, 3.4800E 00   3, 6.0000E-02   4, 7.5000E-02   5, 4.3000E 01   6, 4.6000E 01   7, 4.1000E 01
     8, 3.7000E 01   9, 1.0000E 00  10,-0.          11, 4.3500E 02  12,-0.          13,-0.

43   1, 4.3000E 01   2, 3.4800E 00   3, 6.0000E-02   4, 7.5000E-02   5, 4.4000E 01   6, 4.7000E 01   7, 4.2000E 01
     8, 3.8000E 01   9, 1.0000E 00  10,-0.          11, 4.3500E 02  12,-0.          13,-0.

44   1, 4.4000E 01   2, 3.4800E 00   3, 6.0000E-02   4, 7.5000E-02   5, 4.5000E 01   6, 4.8000E 01   7, 4.3000E 01
     8, 3.9000E 01   9, 1.0000E 00  10,-0.          11, 4.3500E 02  12,-0.          13,-0.

45   1, 4.5000E 01   2, 3.4800E 00   3, 6.0000E-02   4, 7.5000E-02   5, 7.6000E 01   6, 0.           7, 4.4000E 01
     8, 4.0000E 01   9, 1.0000E 00  10, 5.4900E 02  11, 0.          12,-0.          13,-0.

46   1, 4.6000E 01   2, 3.5500E 00   3, 8.0000E-02   4, 7.5000E-02   5, 4.7000E 01   6, 4.9000E 01   7, 0.
     8, 4.2000E 01   9, 2.0000E 00  10, 0.          11,-0.          12,-0.          13, 4.3500E 02

47   1, 4.7000E 01   2, 3.5500E 00   3, 8.0000E-02   4, 7.5000E-02   5, 4.8000E 01   6, 5.0000E 01   7, 4.6000E 01
     8, 4.3000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13, 4.3500E 02

48   1, 4.8000E 01   2, 3.5500E 00   3, 8.0000E-02   4, 7.5000E-02   5, 0.           6, 5.1000E 01   7, 4.7000E 01
     8, 4.4000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13, 4.3500E 02

49   1, 4.9000E 01   2, 3.6300E 00   3, 8.0000E-02   4, 7.5000E-02   5, 5.0000E 01   6, 0.           7, 0.
     8, 4.6000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13, 0.

50   1, 5.0000E 01   2, 3.6300E 00   3, 8.0000E-02   4, 7.5000E-02   5, 5.1000E 01   6, 0.           7, 4.9000E 01
     8, 4.7000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

51   1, 5.1000E 01   2, 3.6300E 00   3, 8.0000E-02   4, 7.5000E-02   5, 0.           6, 0.           7, 5.0000E 01
     8, 4.8000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

52   1, 5.2000E 01   2, 3.1950E 00   3, 7.0000E-02   4, 8.5000E-02   5, 0.           6, 5.3000E 01   7, 1.8000E 01
     8, 0.           9, 2.0000E 00  10, 0.          11, 1.6000E 00  12, 5.1200E 02  13,-0.

53   1, 5.3000E 01   2, 3.2550E 00   3, 5.0000E-02   4, 7.0000E-02   5, 5.4000E 01   6, 5.5000E 01   7, 2.3000E 01
     8, 5.2000E 01   9, 2.0000E 00  10,-0.          11, 0.          12, 7.0400E 02  13, 1.6000E 00

54   1, 5.4000E 01   2, 3.2550E 00   3, 5.0000E-02   4, 5.0000E-02   5, 0.           6, 5.6000E 01   7, 5.3000E 01
     8, 0.           9, 2.0000E 00  10,-0.          11, 2.2000E 00  12, 0.          13, 0.

55   1, 5.5000E 01   2, 3.3050E 00   3, 5.0000E-02   4, 7.0000E-02   5, 5.6000E 01   6, 6.3000E 01   7, 2.9000E 01
     8, 5.3000E 01   9, 2.0000E 00  10,-0.          11, 0.          12, 6.9300E 02  13, 0.

56   1, 5.6000E 01   2, 3.3050E 00   3, 5.0000E-02   4, 6.5000E-02   5, 5.7000E 01   6, 6.4000E 01   7, 5.5000E 01
     8, 5.4000E 01   9, 2.0000E 00  10,-0.          11,-0.          12, 0.          13, 2.2000E 00

57   1, 5.7000E 01   2, 3.3100E 00   3, 4.0000E-02   4, 1.0000E-01   5, 5.8000E 01   6, 6.5000E 01   7, 5.6000E 01
     8, 0.           9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13, 0.

58   1, 5.8000E 01   2, 3.3100E 00   3, 4.0000E-02   4, 1.1000E-01   5, 5.9000E 01   6, 6.6000E 01   7, 5.7000E 01
     8, 0.           9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13, 0.

59   1, 5.9000E 01   2, 3.3100E 00   3, 4.0000E-02   4, 1.2500E-01   5, 6.0000E 01   6, 6.7000E 01   7, 5.8000E 01
     8, 8.9000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13, 2.7900E 02

60   1, 6.0000E 01   2, 3.3100E 00   3, 4.0000E-02   4, 1.0000E-01   5, 6.1000E 01   6, 6.8000E 01   7, 5.9000E 01
     8, 5.0000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13, 5.4438E 05

61   1, 6.1000E 01   2, 3.3100E 00   3, 4.0000E-02   4, 1.0000E-01   5, 6.2000E 01   6, 6.9000E 01   7, 6.0000E 01
     8, 0.           9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13, 0.

62   1, 6.2000E 01   2, 3.3100E 00   3, 4.0000E-02   4, 8.0000E-02   5, 0.           6, 7.0000E 01   7, 6.1000E 01
     8, 0.           9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

63   1, 6.3000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 7.0000E-02   5, 6.4000E 01   6, 7.1000E 01   7, 3.5000E 01
     8, 5.5000E 01   9, 2.0000E 00  10,-0.          11,-0.          12, 6.8300E 02  13,-0.

64   1, 6.4000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 6.5000E-02   5, 6.5000E 01   6, 7.2000E 01   7, 6.3000E 01
     8, 5.6000E 01   9, 2.0000E 00  10,-0.          11,-0.          12, 0.          13,-0.

65   1, 6.5000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 1.0000E-01   5, 6.6000E 01   6, 0.           7, 6.4000E 01
     8, 5.7000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

66   1, 6.6000E 01   2, 3.3550E 00   3, 5.0000E-02   4, 1.1000E-01   5, 6.7000E 01   6, 0.           7, 6.5000E 01
     8, 5.8000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.
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67	1, 6.7000E 01	2, 3.3550E 00	3, 5.0000E-02	4, 1.2500E-01	5, 6.8000E 01	6, 0.	7, 6.6000E 01
	8, 5.9000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
68	1, 6.8000E 01	2, 3.3550E 00	3, 5.0000E-02	4, 1.0000E-01	5, 6.9000E 01	6, 7.3000E 01	7, 6.7000E 01
	8, 6.0000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
69	1, 6.9000E 01	2, 3.3550E 00	3, 5.0000E-02	4, 1.0000E-01	5, 7.0000E 01	6, 7.4000E 01	7, 6.8000E 01
	8, 6.1000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
70	1, 7.0000E 01	2, 3.3550E 00	3, 5.0000E-02	4, 8.0000E-02	5, 0.	6, 7.5000E 01	7, 6.9000E 01
	8, 6.2000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
71	1, 7.1000E 01	2, 3.1450E 00	3, 7.0000E-02	4, 7.0000E-02	5, 7.2000E 01	6, 7.6000E 01	7, 4.0000E 01
	8, 6.3000E 01	9, 2.0000E 00	10,-0.	11,-0.	12, 4.7900E 02	13,-0.	
72	1, 7.2000E 01	2, 3.1450E 00	3, 7.0000E-02	4, 6.5000E-02	5, 0.	6, 7.7000E 01	7, 7.1000E 01
	8, 6.4000E 01	9, 2.0000E 00	10,-0.	11,-0.	12, 0.	13,-0.	
73	1, 7.3000E 01	2, 3.0450E 00	3, 5.0000E-02	4, 1.0000E-01	5, 7.4000E 01	6, 7.8000E 01	7, 0.
	8, 6.8000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
74	1, 7.4000E 01	2, 3.0450E 00	3, 5.0000E-02	4, 1.0000E-01	5, 7.5000E 01	6, 7.9000E 01	7, 7.3000E 01
	8, 6.9000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
75	1, 7.5000E 01	2, 3.0450E 00	3, 5.0000E-02	4, 8.0000E-02	5, 0.	6, 8.0000E 01	7, 7.4000E 01
	8, 7.0000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
76	1, 7.6000E 01	2, 3.4800E 00	3, 6.0000E-02	4, 7.0000E-02	5, 7.7000E 01	6, 8.1000E 01	7, 4.5000E 01
	8, 7.1000E 01	9, 2.0000E 00	10,-0.	11,-0.	12, 5.4900E 02	13,-0.	
77	1, 7.7000E 01	2, 3.4800E 00	3, 6.0000E-02	4, 6.5000E-02	5, 0.	6, 8.2000E 01	7, 7.6000E 01
	8, 7.2000E 01	9, 2.0000E 00	10,-0.	11,-0.	12, 0.	13,-0.	
78	1, 7.8000E 01	2, 3.4500E 00	3, 4.0000E-02	4, 1.0000E-01	5, 7.9000E 01	6, 0.	7, 0.
	8, 7.3000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
79	1, 7.9000E 01	2, 3.4500E 00	3, 4.0000E-02	4, 1.0000E-01	5, 8.0000E 01	6, 0.	7, 7.8000E 01
	8, 7.4000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
80	1, 8.0000E 01	2, 3.4500E 00	3, 4.0000E-02	4, 8.0000E-02	5, 0.	6, 0.	7, 7.9000E 01
	8, 7.5000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
81	1, 8.1000E 01	2, 3.5500E 00	3, 8.0000E-02	4, 7.0000E-02	5, 8.2000E 01	6, 8.3000E 01	7, 0.
	8, 7.6000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
82	1, 8.2000E 01	2, 3.5500E 00	3, 8.0000E-02	4, 6.5000E-02	5, 0.	6, 8.4000E 01	7, 8.1000E 01
	8, 7.7000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
83	1, 8.3000E 01	2, 3.6350E 00	3, 9.0000E-02	4, 7.0000E-02	5, 8.4000E 01	6, 8.5000E 01	7, 0.
	8, 8.1000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
84	1, 8.4000E 01	2, 3.6350E 00	3, 9.0000E-02	4, 6.5000E-02	5, 0.	6, 8.6000E 01	7, 8.3000E 01
	8, 8.2000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
85	1, 8.5000E 01	2, 3.7250E 00	3, 9.0000E-02	4, 7.0000E-02	5, 8.6000E 01	6, 8.7000E 01	7, 0.
	8, 8.3000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
86	1, 8.6000E 01	2, 3.7250E 00	3, 9.0000E-02	4, 6.5000E-02	5, 0.	6, 8.8000E 01	7, 8.5000E 01
	8, 8.4000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
87	1, 8.7000E 01	2, 3.8150E 00	3, 9.0000E-02	4, 7.0000E-02	5, 8.8000E 01	6, 0.	7, 0.
	8, 8.5000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
88	1, 8.8000E 01	2, 3.8150E 00	3, 9.0000E-02	4, 6.5000E-02	5, 0.	6, 0.	7, 8.7000E 01
	8, 8.6000E 01	9, 2.0000E 00	10,-0.	11,-0.	12,-0.	13,-0.	
89	1, 8.9000E 01	2, 3.2400E 00	3, 1.0000E-01	4, 1.2500E-01	5, 9.0000E 01	6, 5.9000E 01	7, 0.
	8, 0.	9, 3.0000E 00	10,-0.	11, 2.7900E 02	12,-0.	13,-0.	
90	1, 9.0000E 01	2, 3.2400E 00	3, 1.0000E-01	4, 1.0000E-01	5, 0.	6, 6.0000E 01	7, 8.9000E 01
	8, 0.	9, 3.0000E 00	10,-0.	11, 5.4438E 05	12,-0.	13,-0.	
91	1, 9.1000E 01	2, 2.9650E 00	3, 1.3000E-01	4, 8.0000E-02	5, 9.2000E 01	6, 9.3000E 01	7, 0.
	8, 0.	9, 2.0000E 00	10,-0.	11, 0.	12,-0.	13,-0.	

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 92    1, 9.2000E 01   2, 2.9650E 00   3, 1.3000E-01   4, 8.0000E-02   5, 0.           6, 9.4000E 01   7, 9.1000E 01
      8, 0.           9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

 93    1, 9.3000E 01   2, 3.0600E 00   3, 6.0000E-02   4, 8.0000E-02   5, 9.4000E 01   6, 9.5000E 01   7, 0.
      8, 9.1000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

 94    1, 9.4000E 01   2, 3.0600E 00   3, 6.0000E-02   4, 8.0000E-02   5, 0.           6, 9.6000E 01   7, 9.3000E 01
      8, 9.2000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

 95    1, 9.5000E 01   2, 3.1250E 00   3, 7.0000E-02   4, 8.0000E-02   5, 9.6000E 01   6, 9.7000E 01   7, 0.
      8, 9.3000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

 96    1, 9.6000E 01   2, 3.1250E 00   3, 7.0000E-02   4, 8.0000E-02   5, 0.           6, 9.8000E 01   7, 9.5000E 01
      8, 9.4000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

 97    1, 9.7000E 01   2, 3.1950E 00   3, 7.0000E-02   4, 8.0000E-02   5, 9.8000E 01   6, 9.9000E 01   7, 0.
      8, 9.5000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

 98    1, 9.8000E 01   2, 3.1950E 00   3, 7.0000E-02   4, 8.0000E-02   5, 0.           6, 1.0000E 02   7, 9.7000E 01
      8, 9.6000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

 99    1, 9.9000E 01   2, 3.2550E 00   3, 5.0000E-02   4, 8.0000E-02   5, 1.0000E 02   6, 1.0100E 02   7, 0.
      8, 9.7000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

100    1, 1.0000E 02   2, 3.2550E 00   3, 5.0000E-02   4, 8.0000E-02   5, 0.           6, 1.0200E 02   7, 9.9000E 01
      8, 9.8000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

101    1, 1.0100E 02   2, 3.3050E 00   3, 5.0000E-02   4, 8.0000E-02   5, 1.0200E 02   6, 1.0300E 02   7, 0.
      8, 9.9000E 01   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

102    1, 1.0200E 02   2, 3.3050E 00   3, 5.0000E-02   4, 8.0000E-02   5, 0.           6, 1.0400E 02   7, 1.0100E 02
      8, 1.0000E 02   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

103    1, 1.0300E 02   2, 3.3550E 00   3, 5.0000E-02   4, 8.0000E-02   5, 1.0400E 02   6, 1.0500E 02   7, 0.
      8, 1.0100E 02   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

104    1, 1.0400E 02   2, 3.3550E 00   3, 5.0000E-02   4, 8.0000E-02   5, 0.           6, 1.0600E 02   7, 1.0300E 02
      8, 1.0200E 02   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

105    1, 1.0500E 02   2, 3.4150E 00   3, 7.0000E-02   4, 8.0000E-02   5, 1.0600E 02   6, 1.0700E 02   7, 0.
      8, 1.0300E 02   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

106    1, 1.0600E 02   2, 3.4150E 00   3, 7.0000E-02   4, 8.0000E-02   5, 0.           6, 1.0800E 02   7, 1.0500E 02
      8, 1.0400E 02   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

107    1, 1.0700E 02   2, 3.4800E 00   3, 6.0000E-02   4, 8.0000E-02   5, 1.0800E 02   6, 1.0900E 02   7, 0.
      8, 1.0500E 02   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

108    1, 1.0800E 02   2, 3.4800E 00   3, 6.0000E-02   4, 8.0000E-02   5, 0.           6, 1.1000E 02   7, 1.0700E 02
      8, 1.0600E 02   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

109    1, 1.0900E 02   2, 3.5500E 00   3, 8.0000E-02   4, 8.0000E-02   5, 1.1000E 02   6, 0.           7, 0.
      8, 1.0700E 02   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.

110    1, 1.1000E 02   2, 3.5500E 00   3, 8.0000E-02   4, 8.0000E-02   5, 0.           6, 0.           7, 1.0900E 02
      8, 1.0800E 02   9, 2.0000E 00  10,-0.          11,-0.          12,-0.          13,-0.
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ELEMENT STARTING TEMPERATURES

1	1057.0	2	1110.0	3	1123.0	4	1163.0	5	1205.0	6	1251.0	7	1042.0	8	1157.0	9	1080.0	10	1127.0
11	1172.0	12	1223.0	13	1016.0	14	1130.0	15	1052.0	16	1100.0	17	1141.0	18	1174.0	19	1040.0	20	1053.0
21	1090.0	22	1129.0	23	1158.0	24	943.0	25	947.0	26	1054.0	27	1085.0	28	1120.0	29	1146.0	30	941.0
31	946.0	32	1053.0	33	1085.0	34	1113.0	35	1138.0	36	1058.0	37	1065.0	38	1086.0	39	1108.0	40	1132.0
41	1062.0	42	1073.0	43	1086.0	44	1101.0	45	1120.0	46	1005.0	47	1007.0	48	1009.0	49	995.0	50	987.0
51	989.0	52	1181.0	53	1179.0	54	1180.0	55	1177.0	56	1177.0	57	1179.0	58	1175.0	59	1169.0	60	1165.0
61	1163.0	62	1162.0	63	1174.0	64	1175.0	65	1176.0	66	1174.0	67	1169.0	68	1165.0	69	1163.0	70	1163.0
71	1172.0	72	1173.0	73	1164.0	74	1163.0	75	1163.0	76	1170.0	77	1171.0	78	1164.0	79	1163.0	80	1162.0
81	1169.0	82	1169.0	83	1167.0	84	1167.0	85	1166.0	86	1166.0	87	1165.0	88	1165.0	89	1107.0	90	1060.0
91	871.0	92	881.0	93	869.0	94	877.0	95	866.0	96	872.0	97	864.0	98	868.0	99	861.0	100	865.0
101	860.0	102	864.0	103	858.0	104	860.0	105	856.0	106	858.0	107	855.0	108	856.0	109	853.0	110	854.0

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 ELEMENT=  1.  TYPE=2.  SUBTYPE=4.  NEXT=1.  ITEMS READ= 9.   AREA CODE=4.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1018E-04  C-P= 0.2679E 00  MU= 0.2683E-04  NU= 0.5593E-04  R-O= 0.2525E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.3134E 00                RE= 0.1502E 06  PR**1/3= 0.8903E 00  H COEFF= 0.9706356E 00          COEFF*AREA= 0.6416322E-02

 ELEMENT=  1.  TYPE=6.  SUBTYPE=2.  NEXT=0.  ITEMS READ=14.   AREA CODE=3.  SPECIAL AREA=-0.          SQ.FEET

 VAR.TEMP.RADIAL SEAL GAP
T-B=1062.  K-F= 0.9654E-05  C-P= 0.2647E 00  MU= 0.2562E-04  NU= 0.4990E-04  R-AV= 0.2550E 00  GAP= 0.4333E-04  OMEGA= 1570.
R-O= 0.2992E 00  FLAG-C=0.  FLAG-I=2.  ANN.NBR.= 94.  FLO.NBR.=  0.  MASS FLOW= 0.2382E-02
RE= 0.2046E 07  PR**1/3= 0.8890E 00  RE-C= 0.6754E 07           H COEFF= 0.3961579E 00  COEFF*AREA= 0.3173645E-02
HT.GEN.FACTOR= 0.10000E 01

 ELEMENT=  2.  TYPE=2.  SUBTYPE=4.  NEXT=0.  ITEMS READ= 9.   AREA CODE=4.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1021E-04  C-P= 0.2680E 00  MU= 0.2690E-04  NU= 0.5632E-04  R-O= 0.2525E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.3134E 00                RE= 0.1492E 06  PR**1/3= 0.8904E 00  H COEFF= 0.9672406E 00          COEFF*AREA= 0.6393880E-02

 ELEMENT=  3.  TYPE=2.  SUBTYPE=4.  NEXT=0.  ITEMS READ= 9.   AREA CODE=4.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1024E-04  C-P= 0.2682E 00  MU= 0.2696E-04  NU= 0.5664E-04  R-O= 0.2525E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.3134E 00                RE= 0.1483E 06  PR**1/3= 0.8905E 00  H COEFF= 0.9643760E 00          COEFF*AREA= 0.9562416E-02

 ELEMENT=  4.  TYPE=2.  SUBTYPE=4.  NEXT=0.  ITEMS READ= 9.   AREA CODE=4.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1033E-04  C-P= 0.2687E 00  MU= 0.2716E-04  NU= 0.5774E-04  R-O= 0.2525E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.3134E 00                RE= 0.1455E 06  PR**1/3= 0.8907E 00  H COEFF= 0.9549769E 00          COEFF*AREA= 0.9469218E-02

 ELEMENT=  5.  TYPE=2.  SUBTYPE=4.  NEXT=0.  ITEMS READ= 9.   AREA CODE=4.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1042E-04  C-P= 0.2692E 00  MU= 0.2736E-04  NU= 0.5890E-04  R-O= 0.2525E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.3134E 00                RE= 0.1427E 06  PR**1/3= 0.8910E 00  H COEFF= 0.9452609E 00          COEFF*AREA= 0.9372877E-02

 ELEMENT=  6.  TYPE=2.  SUBTYPE=4.  NEXT=1.  ITEMS READ= 9.   AREA CODE=1.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1051E-04  C-P= 0.2698E 00  MU= 0.2759E-04  NU= 0.6018E-04  R-O= 0.2550E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.                        RE= 0.1727E 06  PR**1/3= 0.8912E 00  H COEFF= 0.9318566E 00          COEFF*AREA= 0.7465160E-02

 ELEMENT=  6.  TYPE=2.  SUBTYPE=4.  NEXT=0.  ITEMS READ= 9.   AREA CODE=4.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1051E-04  C-P= 0.2698E 00  MU= 0.2759E-04  NU= 0.6018E-04  R-O= 0.2525E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.3134E 00                RE= 0.1396E 06  PR**1/3= 0.8912E 00  H COEFF= 0.9348986E 00          COEFF*AREA= 0.9270129E-02

 ELEMENT= 12.  TYPE=2.  SUBTYPE=4.  NEXT=1.  ITEMS READ= 9.   AREA CODE=1.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1045E-04  C-P= 0.2694E 00  MU= 0.2745E-04  NU= 0.5940E-04  R-O= 0.2608E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.                        RE= 0.2543E 06  PR**1/3= 0.8911E 00  H COEFF= 0.9354691E 00          COEFF*AREA= 0.8928836E-02

 ELEMENT= 12.  TYPE=6.  SUBTYPE=1.  NEXT=0.  ITEMS READ=12.   AREA CODE=5.  SPECIAL AREA= 0.23562E-02 SQ.FEET

 VAR.TEMP.DUCT FLOW, LIQUID
T-B=1285.  K-F= 0.1042E-04  C-P= 0.2693E 00  MU= 0.2732E-04  MASS FLOW= 0.5685E 01  D-HYDR= 0.3333E-02  L-FLOW= 0.3125E-02
ANN.NBR.=  0.  FLOW NBR=  0.  FLAG-C=0.  FLAG-I=1.  X-SEC= 0.3142E-03
RE= 0.6920E 03  PR= 0.7074E 00       H COEFF= 0.3122549E-01  COEFF*AREA= 0.7357350E-04

 ELEMENT= 52.  TYPE=2.  SUBTYPE=4.  NEXT=1.  ITEMS READ= 9.   AREA CODE=1.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1036E-04  C-P= 0.2689E 00  MU= 0.2725E-04  NU= 0.5824E-04  R-O= 0.2662E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.4726E 00                RE= 0.3366E 06  PR**1/3= 0.8908E 00  H COEFF= 0.9456614E 00          COEFF*AREA= 0.9228304E-02

 ELEMENT= 52.  TYPE=2.  SUBTYPE=4.  NEXT=0.  ITEMS READ= 9.   AREA CODE=4.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1036E-04  C-P= 0.2689E 00  MU= 0.2725E-04  NU= 0.5824E-04  R-O= 0.2633E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.4726E 00                RE= 0.2949E 06  PR**1/3= 0.8908E 00  H COEFF= 0.9450770E 00          COEFF*AREA= 0.1107619E-01

 ELEMENT= 54.  TYPE=2.  SUBTYPE=4.  NEXT=1.  ITEMS READ= 9.   AREA CODE=1.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1036E-04  C-P= 0.2689E 00  MU= 0.2725E-04  NU= 0.5824E-04  R-O= 0.2712E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.4726E 00                RE= 0.4090E 06  PR**1/3= 0.8908E 00  H COEFF= 0.9476610E 00          COEFF*AREA= 0.6729633E-02

 ELEMENT= 54.  TYPE=2.  SUBTYPE=4.  NEXT=0.  ITEMS READ= 9.   AREA CODE=5.  SPECIAL AREA= 0.17617E-02 SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1036E-04  C-P= 0.2689E 00  MU= 0.2725E-04  NU= 0.5824E-04  R-O= 0.2692E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.4726E 00                RE= 0.3787E 06  PR**1/3= 0.8909E 00  H COEFF= 0.9467012E 00          COEFF*AREA= 0.1667804E-02

 ELEMENT= 57.  TYPE=2.  SUBTYPE=4.  NEXT=0.  ITEMS READ= 9.   AREA CODE=4.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1036E-04  C-P= 0.2689E 00  MU= 0.2724E-04  NU= 0.5818E-04  R-O= 0.2742E 00  R-I= 0.2417E 00  OMEGA= 1570.
V-AX= 0.4726E 00                RE= 0.4524E 06  PR**1/3= 0.8908E 00  H COEFF= 0.9497571E 00          COEFF*AREA= 0.1363408E-01

 ELEMENT= 58.  TYPE=2.  SUBTYPE=4.  NEXT=0.  ITEMS READ= 9.   AREA CODE=4.  SPECIAL AREA=-0.          SQ.FEET

 CONCENTRIC CYLINDERS
T-B=1300.  K-F= 0.1035E-04  C-P= 0.2688E 00  MU= 0.2722E-04  NU= 0.5807E-04  R-O= 0.2742E 00  R-I= 0.2283E 00  OMEGA= 1570.
V-AX= 0.9321E 00                RE= 0.6228E 06  PR**1/3= 0.8908E 00  H COEFF= 0.9274974E 00          COEFF*AREA= 0.1464599E-01
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 ELEMENT= 30.  TYPE=3.  SUBTYPE=3.  NEXT=1.  ITEMS READ= 4.   AREA CODE=2.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1000E-01  C-P= 0.5030E 00  L-FLOW= 0.8849E 00          H COEFF= 0.5684258E-02  COEFF*AREA= 0.4191581E-04

 ELEMENT= 30.  TYPE=6.  SUBTYPE=2.  NEXT=0.  ITEMS READ=14.   AREA CODE=3.  SPECIAL AREA=-0.         SQ.FEET

 VAR.TEMP.RADIAL SEAL GAP
T-B= 955.  K-F= 0.9048E-05  C-P= 0.2611E 00  MU= 0.2423E-04  NU= 0.1571E-03  R-AV= 0.2796E 00  GAP= 0.4333E-04  OMEGA= 1570.
R-O= 0.2992E 00  FLAG-C=0.  FLAG-I=2.  ANN.NBR.=104.  FLO.NBR.= 24.  MASS FLOW= 0.5954E-02
RE= 0.7811E 06  PR**1/3= 0.8876E 00  RE-C= 0.6754E 07          H COEFF= 0.3706926E 00  COEFF*AREA= 0.2713275E-02
HT.GEN.FACTOR= 0.10000E 01

 ELEMENT= 36.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=3.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1000E-01  C-P= 0.5030E 00  L-FLOW= 0.2339E 00          H COEFF= 0.2150492E-01  COEFF*AREA= 0.2243075E-03

 ELEMENT= 41.  TYPE=3.  SUBTYPE=3.  NEXT=1.  ITEMS READ= 4.   AREA CODE=2.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1000E-01  C-P= 0.5030E 00  L-FLOW= 0.9189E 00          H COEFF= 0.5473936E-02  COEFF*AREA= 0.4191739E-04

 ELEMENT= 41.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=3.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1000E-01  C-P= 0.5030E 00  L-FLOW= 0.2339E 00          H COEFF= 0.2150492E-01  COEFF*AREA= 0.1959231E-03

 ELEMENT= 46.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=3.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.2000E-01  C-P= 0.5030E 00  L-FLOW= 0.2450E 00          H COEFF= 0.4106122E-01  COEFF*AREA= 0.5088240E-03

 ELEMENT= 49.  TYPE=3.  SUBTYPE=3.  NEXT=1.  ITEMS READ= 4.   AREA CODE=2.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.9608E 00          H COEFF= 0.7852831E-02  COEFF*AREA= 0.9431286E-04

 ELEMENT= 49.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=3.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.2000E-01  C-P= 0.5030E 00  L-FLOW= 0.2450E 00          H COEFF= 0.4106122E-01  COEFF*AREA= 0.5202905E-03

 ELEMENT= 50.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=2.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.9608E 00          H COEFF= 0.7852831E-02  COEFF*AREA= 0.9431286E-04

 ELEMENT= 51.  TYPE=3.  SUBTYPE=3.  NEXT=1.  ITEMS READ= 4.   AREA CODE=1.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.5000E-02  C-P= 0.5030E 00  L-FLOW= 0.2450E 00          H COEFF= 0.1026531E-01  COEFF*AREA= 0.1300726E-03

 ELEMENT= 51.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=2.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.9608E 00          H COEFF= 0.7852831E-02  COEFF*AREA= 0.9431286E-04

 ELEMENT= 48.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=1.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.5000E-02  C-P= 0.5030E 00  L-FLOW= 0.2450E 00          H COEFF= 0.1026531E-01  COEFF*AREA= 0.1272060E-03

 ELEMENT= 45.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=2.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.2000E-01  C-P= 0.5030E 00  L-FLOW= 0.9189E 00          H COEFF= 0.1094787E-01  COEFF*AREA= 0.1257522E-03

 ELEMENT= 81.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=3.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.2361E 00          H COEFF= 0.3195680E-01  COEFF*AREA= 0.3960034E-03

 ELEMENT= 83.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=3.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.2361E 00          H COEFF= 0.3195680E-01  COEFF*AREA= 0.4561709E-03

 ELEMENT= 85.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=3.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.2361E 00          H COEFF= 0.3195680E-01  COEFF*AREA= 0.4674653E-03

 ELEMENT= 87.  TYPE=3.  SUBTYPE=3.  NEXT=1.  ITEMS READ= 4.   AREA CODE=2.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.1010E 01          H COEFF= 0.7466601E-02  COEFF*AREA= 0.8802897E-04

 ELEMENT= 87.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=3.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.2631E 00          H COEFF= 0.2867731E-01  COEFF*AREA= 0.4296282E-03

 ELEMENT= 88.  TYPE=3.  SUBTYPE=3.  NEXT=1.  ITEMS READ= 4.   AREA CODE=1.  SPECIAL AREA=-0.         SQ.FEET

 LIQUID FILM COOLING
T-B= 525.  W/L= 0.2500E-01  C-P= 0.5030E 00  L-FLOW= 0.2669E 00          H COEFF= 0.4711502E-01  COEFF*AREA= 0.7058523E-03

 ELEMENT= 88.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.   AREA CODE=2.  SPECIAL AREA=-0.         SQ.FEET
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LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.1010E 01        H COEFF= 0.7466601E-02  COEFF*AREA= 0.8174119E-04

ELEMENT= 96.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=1.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.2500E-01  C-P= 0.5030E 00  L-FLOW= 0.2669E 00        H COEFF= 0.4711502E-01  COEFF*AREA= 0.6892005E-03

ELEMENT= 84.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=1.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.2500E-01  C-P= 0.5030E 00  L-FLOW= 0.2669E 00        H COEFF= 0.4711502E-01  COEFF*AREA= 0.6725486E-03

ELEMENT= 82.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=1.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.2500E-01  C-P= 0.5030E 00  L-FLOW= 0.2669E 00        H COEFF= 0.4711502E-01  COEFF*AREA= 0.5838417E-03

ELEMENT= 77.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=1.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.2500E-01  C-P= 0.5030E 00  L-FLOW= 0.2669E 00        H COEFF= 0.4711502E-01  COEFF*AREA= 0.4292470E-03

ELEMENT= 72.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=1.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.2500E-01  C-P= 0.5030E 00  L-FLOW= 0.2669E 00        H COEFF= 0.4711502E-01  COEFF*AREA= 0.4525801E-03

ELEMENT= 65.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=2.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1200E-01  C-P= 0.5030E 00  L-FLOW= 0.8849E 00        H COEFF= 0.6821110E-02  COEFF*AREA= 0.1005979E-03

ELEMENT= 66.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=2.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1100E-01  C-P= 0.5030E 00  L-FLOW= 0.8849E 00        H COEFF= 0.6252684E-02  COEFF*AREA= 0.1014363E-03

ELEMENT= 67.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=2.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1200E-01  C-P= 0.5030E 00  L-FLOW= 0.8849E 00        H COEFF= 0.6821110E-02  COEFF*AREA= 0.1257474E-03

ELEMENT= 73.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=3.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1000E-01  C-P= 0.5030E 00  L-FLOW= 0.2298E 00        H COEFF= 0.2188860E-01  COEFF*AREA= 0.1454094E-03

ELEMENT= 78.  TYPE=3.  SUBTYPE=3.  NEXT=1.  ITEMS READ= 4.  AREA CODE=2.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.9084E 00        H COEFF= 0.8305812E-02  COEFF*AREA= 0.1257561E-03

ELEMENT= 78.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=3.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1000E-01  C-P= 0.5030E 00  L-FLOW= 0.2298E 00        H COEFF= 0.2188860E-01  COEFF*AREA= 0.1317997E-03

ELEMENT= 79.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=2.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.9084E 00        H COEFF= 0.8305812E-02  COEFF*AREA= 0.1257561E-03

ELEMENT= 80.  TYPE=3.  SUBTYPE=3.  NEXT=1.  ITEMS READ= 4.  AREA CODE=1.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.2325E 00        H COEFF= 0.3245161E-01  COEFF*AREA= 0.1954037E-03

ELEMENT= 80.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=2.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.9084E 00        H COEFF= 0.8305812E-02  COEFF*AREA= 0.1006049E-03

ELEMENT= 75.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=1.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.2325E 00        H COEFF= 0.3245161E-01  COEFF*AREA= 0.2155812E-03

ELEMENT= 70.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=1.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.2325E 00        H COEFF= 0.3245161E-01  COEFF*AREA= 0.2375287E-03

ELEMENT= 62.  TYPE=3.  SUBTYPE=3.  NEXT=1.  ITEMS READ= 4.  AREA CODE=1.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1500E-01  C-P= 0.5030E 00  L-FLOW= 0.2325E 00        H COEFF= 0.3245161E-01  COEFF*AREA= 0.1874742E-03

ELEMENT= 62.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=4.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.1000E-01  C-P= 0.5030E 00  L-FLOW= 0.8613E 00        H COEFF= 0.5840009E-02  COEFF*AREA= 0.6706822E-04

ELEMENT= 61.  TYPE=3.  SUBTYPE=3.  NEXT=0.  ITEMS READ= 4.  AREA CODE=4.  SPECIAL AREA=-0.        SQ.FEET

LIQUID FILM COOLING
T-B= 525.  W/L= 0.5000E-02  C-P= 0.5030E 00  L-FLOW= 0.8613E 00        H COEFF= 0.2920005E-02  COEFF*AREA= 0.4191764E-04

ELEMENT= 11.  TYPE=6.  SUBTYPE=1.  NEXT=0.  ITEMS READ=12.  AREA CODE=5.  SPECIAL AREA= 0.16115E-02 SQ.FEET
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VAR.TEMP.DUCT FLOW, LIQUID
T-B=1255.  K-F= 0.1035E-04  C-P= 0.2688E 00  MU= 0.2721E-04  MASS FLOW= 0.5685E 01  D-HYDR= 0.3333E-02  L-FLOW= 0.7835E-02
ANN.NBR.=  0.  FLOW NBR= 12.  FLAG-C=0.  FLAG-I=1.  X-SEC= 0.3142E-03
RE= 0.6965E 03  PR= 0.7069E 00       H COEFF= 0.2280963E-01  COEFF*AREA= 0.3675772E-04

 ELEMENT= 17.  TYPE=6.  SUBTYPE=1.  NEXT=0.  ITEMS READ=12.   AREA CODE=5.  SPECIAL AREA= 0.16115E-02 SQ.FEET

VAR.TEMP.DUCT FLOW, LIQUID
T-B=1240.  K-F= 0.1028E-04  C-P= 0.2684E 00  MU= 0.2705E-04  MASS FLOW= 0.5685E 01  D-HYDR= 0.3333E-02  L-FLOW= 0.1133E-01
ANN.NBR.=  0.  FLOW NBR= 11.  FLAG-C=0.  FLAG-I=1.  X-SEC= 0.3142E-03
RE= 0.7006E 03  PR= 0.7064E 00       H COEFF= 0.1982752E-01  COEFF*AREA= 0.3195205E-04
 ELEMENT= 16.  TYPE=6.  SUBTYPE=1.  NEXT=0.  ITEMS READ=12.   AREA CODE=5.  SPECIAL AREA= 0.23562E-02 SQ.FEET

VAR.TEMP.DUCT FLOW, LIQUID
T-B=1210.  K-F= 0.1019E-04  C-P= 0.2679E 00  MU= 0.2685E-04  MASS FLOW= 0.5685E 01  D-HYDR= 0.3333E-02  L-FLOW= 0.1643E-01
ANN.NBR.=  0.  FLOW NBR= 17.  FLAG-C=0.  FLAG-I=1.  X-SEC= 0.3142E-03
RE= 0.7057E 03  PR= 0.7059E 00       H COEFF= 0.1755946E-01  COEFF*AREA= 0.4160923E-04

 ELEMENT= 15.  TYPE=6.  SUBTYPE=1.  NEXT=0.  ITEMS READ=12.   AREA CODE=5.  SPECIAL AREA= 0.15087E-02 SQ.FEET

VAR.TEMP.DUCT FLOW, LIQUID
T-B=1180.  K-F= 0.1009E-04  C-P= 0.2673E 00  MU= 0.2661E-04  MASS FLOW= 0.5685E 01  D-HYDR= 0.3333E-02  L-FLOW= 0.2103E-01
ANN.NBR.=  0.  FLOW NBR= 16.  FLAG-C=0.  FLAG-I=1.  X-SEC= 0.3142E-03
RE= 0.7121E 03  PR= 0.7053E 00       H COEFF= 0.1514010E-01  COEFF*AREA= 0.2435057E-04

 ELEMENT= 20.  TYPE=6.  SUBTYPE=1.  NEXT=0.  ITEMS READ=12.   AREA CODE=5.  SPECIAL AREA= 0.15087E-02 SQ.FEET

VAR.TEMP.DUCT FLOW, LIQUID
T-B=1165.  K-F= 0.1009E-04  C-P= 0.2673E 00  MU= 0.2661E-04  MASS FLOW= 0.5685E 01  D-HYDR= 0.3333E-02  L-FLOW= 0.2497E-01
ANN.NBR.=  0.  FLOW NBR= 15.  FLAG-C=0.  FLAG-I=1.  X-SEC= 0.3142E-03
RE= 0.7121E 03  PR= 0.7053E 00       H COEFF= 0.1524155E-01  COEFF*AREA= 0.2299492E-04

 ELEMENT= 19.  TYPE=6.  SUBTYPE=1.  NEXT=0.  ITEMS READ=12.   AREA CODE=5.  SPECIAL AREA= 0.15708E-02 SQ.FEET

VAR.TEMP.DUCT FLOW, LIQUID
T-B=1150.  K-F= 0.1006E-04  C-P= 0.2671E 00  MU= 0.2655E-04  MASS FLOW= 0.5685E 01  D-HYDR= 0.3333E-02  L-FLOW= 0.2848E-01
ANN.NBR.=  0.  FLOW NBR= 20.  FLAG-C=0.  FLAG-I=1.  X-SEC= 0.3142E-03
RE= 0.7137E 03  PR= 0.7051E 00       H COEFF= 0.1455088E-01  COEFF*AREA= 0.2287223E-04

 ELEMENT=  7.  TYPE=6.  SUBTYPE=2.  NEXT=0.  ITEMS READ=14.   AREA CODE=3.  SPECIAL AREA=-0.          SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B= 975.  K-F= 0.9229E-05  C-P= 0.2628E 00  MU= 0.2488E-04  NU= 0.4696E-04  R-AV= 0.2604E 0C  GAP= 0.4333E-04  OMEGA= 1570.
R-O= 0.2992E 00  FLAG-C=0.  FLAG-I=2.  ANN.NBR.= 96.  FLO.NBR.=  1.  MASS FLOW= 0.2382E-02
RE= 0.2267E 07  PR**1/3= 0.8883E 00  RE-C= 0.6754E 07          H COEFF= 0.3824877E 00  COEFF*AREA= 0.3650757E-02
HT.GEN.FACTOR= 0.10000E 01

 ELEMENT= 13.  TYPE=6.  SUBTYPE=2.  NEXT=0.  ITEMS READ=14.   AREA CODE=5.  SPECIAL AREA= 0.16805E-01 SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B= 945.  K-F= 0.9431E-05  C-P= 0.2634E 00  MU= 0.2511E-04  NU= 0.4919E-04  R-AV= 0.2675E 0C  GAP= 0.9152E-03  OMEGA= 1570.
R-O= 0.2992E 00  FLAG-C=0.  FLAG-I=2.  ANN.NBR.= 98.  FLO.NBR.=  7.  MASS FLOW= 0.2382E-02
RE= 0.2284E 07  PR**1/3= 0.8885E 00  RE-C= 0.2278E 06          H COEFF= 0.2927813E 00  COEFF*AREA= 0.4920307E-02
HT.GEN.FACTOR= 0.19315E 01

 ELEMENT= 24.  TYPE=6.  SUBTYPE=2.  NEXT=0.  ITEMS READ=14.   AREA CODE=5.  SPECIAL AREA= 0.14366E-01 SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B=1005.  K-F= 0.9170E-05  C-P= 0.2618E 00  MU= 0.2451E-04  NU= 0.2928E-04  R-AV= 0.2744E 00  GAP= 0.1078E-02  OMEGA= 1570.
R-O= 0.2992E 00  FLAG-C=0.  FLAG-I=2.  ANN.NBR.=102.  FLO.NBR.=100.  MASS FLOW= 0.5954E-02
RE= 0.4037E 07  PR**1/3= 0.8879E 00  RE-C= 0.1900E 06          H COEFF= 0.4274941E 00  COEFF*AREA= 0.6141509E-02
HT.GEN.FACTOR= 0.18512E 01

 ELEMENT= 92.  TYPE=5.  SUBTYPE=0.  NEXT=0.  ITEMS READ= 2.   AREA CODE=1.  SPECIAL AREA=-0.          SQ.FEET

SPECIFIED COEFFICIENT
T-B=1300.  H COEFF= 0.1380662E-02      COEFF*AREA= 0.2322056E-04

 ELEMENT=110.  TYPE=5.  SUBTYPE=0.  NEXT=1.  ITEMS READ= 2.   AREA CODE=2.  SPECIAL AREA=-0.          SQ.FEET

SPECIFIED COEFFICIENT
T-B= 535.  H COEFF= 0.3733100E-04      COEFF*AREA= 0.4678121E-06

 ELEMENT=110.  TYPE=6.  SUBTYPE=2.  NEXT=0.  ITEMS READ=14.   AREA CODE=1.  SPECIAL AREA=-0.          SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B= 900.  K-F= 0.8707E-05  C-P= 0.2590E 00  MU= 0.2345E-04  NU= 0.8278E-03  R-AV= 0.2958E 00  GAP= 0.8375E-02  OMEGA= 1570.
R-O= 0.2992E 00  FLAG-C=0.  FLAG-I=2.  ANN.NBR.=  0.  FLO.NBR.=108.  MASS FLOW= 0.5954E-02
RE= 0.1659E 06  PR**1/3= 0.8869E 00  RE-C= 0.1947E 05          H COEFF= 0.2106143E-01  COEFF*AREA= 0.2609898E-03
HT.GEN.FACTOR= 0.16334E 01

 ELEMENT= 94.  TYPE=6.  SUBTYPE=2.  NEXT=0.  ITEMS READ=14.   AREA CODE=1.  SPECIAL AREA=-0.          SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B=1062.  K-F= 0.9147E-05  C-P= 0.2617E 00  MU= 0.2446E-04  NU= 0.4423E-04  R-AV= 0.2550E 00  GAP= 0.4333E-04  OMEGA= 1570.
R-O= 0.2992E 00  FLAG-C=0.  FLAG-I=2.  ANN.NBR.=  1.  FLO.NBR.=  0.  MASS FLOW= 0.2382E-02
RE= 0.2306E 07  PR**1/3= 0.8878E 00  RE-C= 0.6754E 07          H COEFF= 0.3748462E 00  COEFF*AREA= 0.3002915E-02
HT.GEN.FACTOR= 0.10000E 01

 ELEMENT= 96.  TYPE=6.  SUBTYPE=2.  NEXT=0.  ITEMS READ=14.   AREA CODE=1.  SPECIAL AREA=-0.          SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B= 975.  K-F= 0.8929E-05  C-P= 0.2604E 00  MU= 0.2396E-04  NU= 0.4261E-04  R-AV= 0.2604E 00  GAP= 0.4333E-04  OMEGA= 1570.
R-O= 0.2992E 00  FLAG-C=0.  FLAG-I=2.  ANN.NBR.=  7.  FLO.NBR.= 94.  MASS FLOW= 0.2382E-02
RE= 0.2498E 07  PR**1/3= 0.8874E 00  RE-C= 0.6754E 07          H COEFF= 0.3657236E 00  COEFF*AREA= 0.3490747E-02
HT.GEN.FACTOR= 0.10000E 01

 ELEMENT= 98.  TYPE=6.  SUBTYPE=2.  NEXT=0.  ITEMS READ=14.   AREA CODE=1.  SPECIAL AREA=-0.          SQ.FEET
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VAR.TEMP.RADIAL SEAL GAP
T-B= 945. K-F= 0.8847E-05 C-P= 0.2599E 00 MU= 0.2377E-04 NU= 0.4245E-04 R-AV= 0.2663E 00 GAP= 0.4333E-04 OMEGA= 1570.
R-O= 0.2992E 00 FLAG-C=0. FLAG-I=2. ANN.NBR.= 13. FLO.NBR.= 96. MASS FLOW= 0.2382E-02
RE= 0.2623E 07 PR**1/3= 0.8872E 00 RE-C= 0.6754E 07 H COEFF= 0.3623054E 00 COEFF*AREA= 0.3535583E-02
HT.GEN.FACTOR= 0.1000CE 01

ELEMENT=100. TYPE=6. SUBTYPE=2. NEXT=0. ITEMS READ=14. AREA CODE=1. SPECIAL AREA=-0. SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B=1050. K-F= 0.9090E-05 C-P= 0.2614E 00 MU= 0.2433E-04 NU= 0.4552E-04 R-AV= 0.2713E 00 GAP= 0.4208E-02 OMEGA= 1570.
R-O= 0.2992E 00 FLAG-C=1. FLAG-I=0. ANN.NBR.= 0. FLO.NBR.= 98. MASS FLOW= 0.5954E-02
RE= 0.2539E 07 PR**1/3= 0.8877E 00 RE-C= 0.4183E 05 H COEFF= 0.2351904E 00 COEFF*AREA= 0.1670160E-02
HT.GEN.FACTOR= 0.18866E 01

COMBINED FLOW ELEMENT, CONDUCTION NO.= 100 FLOW FROM COND.ELEMENTS 98AND 19

ELEMENT=102. TYPE=6. SUBTYPE=2. NEXT=0. ITEMS READ=14. AREA CODE=1. SPECIAL AREA=-0. SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B=1005. K-F= 0.8981E-05 C-P= 0.2607E 00 MU= 0.2408E-04 NU= 0.5563E-04 R-AV= 0.2754E 00 GAP= 0.4333E-04 OMEGA= 1570.
R-O= 0.2992E 00 FLAG-C=0. FLAG-I=2. ANN.NBR.= 24. FLO.NBR.=100. MASS FLOW= 0.5954E-02
RE= 0.2141E 07 PR**1/3= 0.8875E 00 RE-C= 0.6754E 07 H COEFF= 0.3679046E 00 COEFF*AREA= 0.2652736E-02
HT.GEN.FACTOR= 0.10000E 01

ELEMENT=104. TYPE=6. SUBTYPE=2. NEXT=0. ITEMS READ=14. AREA CODE=1. SPECIAL AREA=-0. SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B= 955. K-F= [illegible]52E-05 C-P= 0.2599E 00 MU= 0.2378E-04 NU= 0.1497E-03 R-AV= 0.2796E 00 GAP= 0.4333E-04 OMEGA= 1570.
R-O= [illegible]92E 00 FLAG-C=0. FLAG-I=2. ANN.NBR.= 30. FLO.NBR.=102. MASS FLOW= 0.5954E-02
RE= 0.8197E 06 PR**1/3= 0.8872E 00 RE-C= 0.6754E 07 H COEFF= 0.3625071E 00 COEFF*AREA= 0.2653361E-02
HT.GEN.FACTOR= 0.10000E 01

ELEMENT=106. TYPE=6. SUBTYPE=2. NEXT=0. ITEMS READ=14. AREA CODE=1. SPECIAL AREA=-0. SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B= 925. K-F= 0.8799E-05 C-P= 0.2596E 00 MU= 0.2366E-04 NU= 0.8472E-03 R-AV= 0.2846E 00 GAP= 0.4208E-02 OMEGA= 1570.
R-O= 0.2992E 00 FLAG-C=0. FLAG-I=2. ANN.NBR.= 0. FLO.NBR.=104. MASS FLOW= 0.5954E-02
RE= 0.1501E 06 PR**1/3= 0.8871E 00 RE-C= 0.4183E 05 H COEFF= 0.2275467E-01 COEFF*AREA= 0.2373432E-03
HT.GEN.FACTOR= 0.17420E 01

ELEMENT=108. TYPE=6. SUBTYPE=2. NEXT=0. ITEMS READ=14. AREA CODE=1. SPECIAL AREA=-0. SQ.FEET

VAR.TEMP.RADIAL SEAL GAP
T-B= 915. K-F= 0.8746E-05 C-P= 0.2593E 00 MU= 0.2354E-04 NU= 0.8360E-03 R-AV= 0.2900E 00 GAP= 0.4208E-02 OMEGA= 1570.
R-O= 0.2992E 00 FLAG-C=0. FLAG-I=2. ANN.NBR.= 0. FLO.NBR.=106. MASS FLOW= 0.5954E-02
RE= 0.1579E 06 PR**1/3= 0.8870E 00 RE-C= 0.4183E 05 H COEFF= 0.2318910E-01 COEFF*AREA= 0.2112670E-03
HT.GEN.FACTOR= 0.16882E 01

BOUNDARY COEFFICIENT MATRIX -(H*A)BTU/F.SEC AND (H*A*T-B) OR W*C-P BTU/SEC

BNDRY	COND.	FIXED FLUX	FORCED CONVECTION		FREE CONVECTION		RADIATION		VAR.TEMP.CONVECTION	
ELEM.	ELEM.	W	H*A	H*A*T-B	H*A	H*A*T-B	H*A	H*A*T-E	H*A	W*C-P
1	1	0.	0.64163E-02	0.83412E 01	0.	0.	0.	0.	0.31736E-02	0.63061E-03
2	2	0.	0.63939E-02	0.83120E 01	0.	0.	0.	0.	0.	0.
3	3	0.	0.95624E-02	0.12431E 02	0.	0.	0.	0.	0.	0.
4	4	0.	0.94652E-02	0.12310E 02	0.	0.	0.	0.	0.	0.
5	5	0.	0.93729E-02	0.12185E 02	0.	0.	0.	0.	0.	0.
6	6	0.	0.16735E-01	0.21756E 02	0.	0.	0.	0.	0.	0.
7	12	0.	0.89288E-02	0.11607E 02	0.	0.	0.	0.	0.73574E-04	0.15308E 01
8	52	0.	0.20304E-01	0.26396E 02	0.	0.	0.	0.	0.	0.
9	54	0.	0.83974E-02	0.10917E 02	0.	0.	0.	0.	0.	0.
10	57	0.	0.13634E-01	0.17724E 02	0.	0.	0.	0.	0.	0.
11	58	0.	0.14646E-01	0.19040E 02	0.	0.	0.	0.	0.	0.
12	30	0.	0.	0.	0.41916E-04	0.22006E-01	0.	0.	0.27133E-02	0.15546E-02
13	36	0.	0.	0.	0.22431E-03	0.11776E 00	0.	0.	0.	0.
14	41	0.	0.	0.	0.23784E-03	0.12487E 00	0.	0.	0.	0.
15	46	0.	0.	0.	0.50882E-03	0.26713E 00	0.	0.	0.	0.
16	49	0.	0.	0.	0.61460E-03	0.32267E 00	0.	0.	0.	0.
17	50	0.	0.	0.	0.94313E-04	0.49514E-01	0.	0.	0.	0.
18	51	0.	0.	0.	0.22439E-03	0.11780E 00	0.	0.	0.	0.
19	48	0.	0.	0.	0.12721E-03	0.66783E-01	0.	0.	0.	0.
20	45	0.	0.	0.	0.12575E-03	0.66020E-01	0.	0.	0.	0.
21	81	0.	0.	0.	0.39600E-03	0.20790E 00	0.	0.	0.	0.
22	83	0.	0.	0.	0.45617E-03	0.23949E 00	0.	0.	0.	0.
23	85	0.	0.	0.	0.46747E-03	0.24542E 00	0.	0.	0.	0.
24	87	0.	0.	0.	0.51766E-03	0.27177E 00	0.	0.	0.	0.
25	88	0.	0.	0.	0.78759E-03	0.41349E 00	0.	0.	0.	0.
26	86	0.	0.	0.	0.68920E-03	0.36183E 00	0.	0.	0.	0.
27	84	0.	0.	0.	0.67255E-03	0.35309E 00	0.	0.	0.	0.
28	82	0.	0.	0.	0.58384E-03	0.30652E 00	0.	0.	0.	0.
29	77	0.	0.	0.	0.42925E-03	0.22535E 00	0.	0.	0.	0.
30	72	0.	0.	0.	0.45258E-03	0.23760E 00	0.	0.	0.	0.
31	65	0.	0.	0.	0.10060E-03	0.52814E-01	0.	0.	0.	0.
32	66	0.	0.	0.	0.10144E-03	0.53254E-01	0.	0.	0.	0.
33	67	0.	0.	0.	0.12575E-03	0.66017E-01	0.	0.	0.	0.
34	73	0.	0.	0.	0.14541E-03	0.76340E-01	0.	0.	0.	0.
35	78	0.	0.	0.	0.25756E-03	0.13522E 00	0.	0.	0.	0.
36	79	0.	0.	0.	0.12576E-03	0.66022E-01	0.	0.	0.	0.
37	80	0.	0.	0.	0.29601E-03	0.15540E 00	0.	0.	0.	0.
38	75	0.	0.	0.	0.21558E-03	0.11318E 00	0.	0.	0.	0.
39	70	0.	0.	0.	0.23753E-03	0.12470E 00	0.	0.	0.	0.
40	62	0.	0.	0.	0.25454E-03	0.13363E 00	0.	0.	0.	0.
41	61	0.	0.	0.	0.41918E-04	0.22007E-01	0.	0.	0.	0.

42	11	0.	0.	0.	0.	0.	0.	0.	0.35758E-04	0.43011E-03
43	17	0.	0.	0.	0.	0.	0.	0.	0.31952E-04	0.47940E-03
44	16	0.	0.	0.	0.	0.	0.	0.	0.41609E-04	0.47849E-03
45	15	0.	0.	0.	0.	0.	0.	0.	0.24351E-04	0.47740E-03
46	20	0.	0.	0.	0.	0.	0.	0.	0.22995E-04	0.47740E-03
47	19	0.	0.	0.	0.	0.	0.	0.	0.22872E-04	0.47713E-03
48	7	0.	0.	0.	0.	0.	0.	0.	0.35508E-02	0.62599E-03
49	13	0.	0.	0.	0.	0.	0.	0.	0.49203E-02	0.62744E-03
50	24	0.	0.	0.	0.	0.	0.	0.	0.61415E-02	0.15591E-02
51	92	-0.10299E 00	0.23221E-04	0.30187E-01	0.	0.	0.	0.	0.	0.
52	110	0.	0.46781E-06	0.25028E-03	0.	0.	0.	0.	0.26099E-03	0.15424E-02
53	94	0.	0.	0.	0.	0.	0.	0.	0.30029E-02	0.62337E-03
54	96	0.	0.	0.	0.	0.	0.	0.	0.34907E-02	0.62025E-03
55	98	0.	0.	0.	0.	0.	0.	0.	0.35355E-02	0.61908E-03
56	100	0.	0.	0.	0.	0.	0.	0.	0.15702E-02	0.15561E-02
57	102	0.	0.	0.	0.	0.	0.	0.	0.25527E-02	0.15523E-02
58	104	0.	0.	0.	0.	0.	0.	0.	0.25534E-02	0.15476E-02
59	106	0.	0.	0.	0.	0.	0.	0.	0.23734E-03	0.15457E-02
60	108	0.	0.	0.	0.	0.	0.	0.	0.21127E-03	0.15438E-02
61	91	0.	0.	0.	0.	0.	0.	0.	0.	0.
62	93	0.	0.	0.	0.	0.	0.	0.	0.	0.
63	95	0.	0.	0.	0.	0.	0.	0.	0.	0.
64	97	0.	0.	0.	0.	0.	0.	0.	0.	0.
65	99	0.	0.	0.	0.	0.	0.	0.	0.	0.
66	101	0.	0.	0.	0.	0.	0.	0.	0.	0.
67	103	0.	0.	0.	0.	0.	0.	0.	0.	0.
68	105	0.	0.	0.	0.	0.	0.	0.	0.	0.
69	107	0.	0.	0.	0.	0.	0.	0.	0.	0.
70	109	0.	0.	0.	0.	0.	0.	0.	0.	0.
71	89	0.	0.	0.	0.	0.	0.	0.	0.	0.
72	90	0.	0.	0.	0.	0.	0.	0.	0.	0.

VAR.TEMP.CONVECTION DIMENSIONLESS COEFFICIENTS (H*A/W*C-P)

1 1, 5.0327E 00	2 12, 1.5299E-01	3 30, 1.7453E 00	4 11, 7.6561E-02	5 17, 6.6650E-02	6 16, 8.5960E-02
7 15, 5.1007E-02	8 20, 4.8167E-02	9 19, 4.7937E-02	10 7, 5.8320E 00	11 13, 7.8418E 00	12 24, 3.9393E 00
13 110, 1.6921E-01	14 94, 4.8172E 00	15 96, 5.6280E 00	16 98, 5.7110E 00	17 100, 1.0733E 00	18 102, 1.7089E 00
19 104, 1.7145E 00	20 106, 1.5355E-01	21 108, 1.3685E-01			

FLUID SHEAR HEAT GENERATION, BTU/SEC

1 1, 3.0329E-02	2 12, 0.	3 30, 3.1501E-02	4 11, 0.	5 17, 0.	6 16, 0.
7 15, 0.	8 20, 0.	9 19, 0.	10 7, 3.6591E-02	11 13, 3.6094E-03	12 24, 2.2674E-03
13 110, 4.8837E-04	14 94, 2.8952E-02	15 96, 3.5241E-02	16 98, 3.7368E-02	17 100, 5.6112E-04	18 102, 2.9926E-02
19 104, 3.0920E-02	20 106, 8.1461E-04	21 108, 7.1239E-04			

DATA TIME= 0.1306 MINUTES

CONDUCT.ELEMENT NO. 1 VAR.TEMP.ELEMENT NO. 1 FLOW CODE= 2

CONDUCT.ELEMENT NO. 12 VAR.TEMP.ELEMENT NO. 2 FLOW CODE= 1

CONDUCT.ELEMENT NO. 30 VAR.TEMP.ELEMENT NO. 3 FLOW CODE= 2

CONDUCT.ELEMENT NO. 11 VAR.TEMP.ELEMENT NO. 4 FLOW CODE= 1

CONDUCT.ELEMENT NO. 17 VAR.TEMP.ELEMENT NO. 5 FLOW CODE= 1

CONDUCT.ELEMENT NO. 16 VAR.TEMP.ELEMENT NO. 6 FLOW CODE= 1

CONDUCT.ELEMENT NO. 15 VAR.TEMP.ELEMENT NO. 7 FLOW CODE= 1

CONDUCT.ELEMENT NO. 20 VAR.TEMP.ELEMENT NO. 8 FLOW CODE= 1

CONDUCT.ELEMENT NO. 19 VAR.TEMP.ELEMENT NO. 9 FLOW CODE= 1

CONDUCT.ELEMENT NO. 7 VAR.TEMP.ELEMENT NO. 10 FLOW CODE= 2

CONDUCT.ELEMENT NO. 13 VAR.TEMP.ELEMENT NO. 11 FLOW CODE= 2

CONDUCT.ELEMENT NO. 24 VAR.TEMP.ELEMENT NO. 12 FLOW CODE= 2

CONDUCT.ELEMENT NO. 110 VAR.TEMP.ELEMENT NO. 13 FLOW CODE= 2

CONDUCT.ELEMENT NO. 94 VAR.TEMP.ELEMENT NO. 14 FLOW CODE= 2

CONDUCT.ELEMENT NO. 96 VAR.TEMP.ELEMENT NO. 15 FLOW CODE= 2

CONDUCT.ELEMENT NO. 98 VAR.TEMP.ELEMENT NO. 16 FLOW CODE= 2

COMBINED FLOWS ELEMENT, COMBINATION NO. 1 CONDUCT.NO.=100 BNDRY.NO.= 17 PREVIOUS ELEMENT VAR.TEMP.NOS.= 16 AND 9

CONDUCT.ELEMENT NO. 102 VAR.TEMP.ELEMENT NO. 17 FLOW CODE= 2

CONDUCT.ELEMENT NO. 104 VAR.TEMP.ELEMENT NO. 18 FLOW CODE= 2

CONDUCT.ELEMENT NO. 106 VAR.TEMP.ELEMENT NO. 19 FLOW CODE= 2

CONDUCT.ELEMENT NO. 108 VAR.TEMP.ELEMENT NO. 20 FLOW CODE= 2

CONVERGENCE CRITERIA, ITERATION= 100

COND.NO.	NEW TEMP.	OLD TEMP.	DIFFERENCE	MAX.DIFF.
1	0.1207188E 04	0.1207189E 04	-0.9002686E-03	0.5000000E-01
2	0.1262054E 04	0.1262066E 04	-0.1525879E-02	0.5000000E-01
3	0.1279193E 04	0.1279195E 04	-0.2044678E-02	0.5000000E-01
4	0.1285989E 04	0.1285991E 04	-0.2151489E-02	0.5000000E-01
5	0.1290989E 04	0.1290990E 04	-0.1678467E-02	0.5000000E-01
6	0.1298050E 04	0.1298050E 04	-0.3662109E-03	0.5000000E-01
7	0.1047630E 04	0.1047635E 04	-0.5157471E-02	0.5000000E-01
8	0.1120079E 04	0.1120088E 04	-0.9185791E-02	0.5000000E-01
9	0.1173756E 04	0.1173768E 04	-0.1269531E-01	0.5000000E-01
10	0.1209530E 04	0.1209544E 04	-0.1362610E-01	0.5000000E-01
11	0.1239491E 04	0.1239502E 04	-0.1098633E-01	0.5000000E-01
12	0.1283117E 04	0.1283120E 04	-0.3250122E-02	0.5000000E-01
13	0.9841284E 03	0.9841373E 03	-0.8911133E-02	0.5000000E-01
14	0.1043133E 04	0.1043151E 04	-0.1814270E-01	0.5000000E-01
15	0.1095047E 04	0.1095072E 04	-0.2456665E-01	0.5000000E-01
16	0.1138706E 04	0.1138733E 04	-0.2659607E-01	0.5000000E-01
17	0.1175654E 04	0.1175677E 04	-0.2363586E-01	0.5000000E-01
18	0.1211240E 04	0.1211257E 04	-0.1673889E-01	0.5000000E-01
19	0.1013473E 04	0.1013504E 04	-0.3154755E-01	0.5000000E-01
20	0.1044790E 04	0.1044827E 04	-0.3697205E-01	0.5000000E-01
21	0.1084893E 04	0.1084932E 04	-0.3944397E-01	0.5000000E-01
22	0.1124159E 04	0.1124195E 04	-0.3547668E-01	0.5000000E-01
23	0.1163354E 04	0.1163381E 04	-0.2624512E-01	0.5000000E-01
24	0.9142733E 03	0.9142952E 03	-0.2188873E-01	0.5000000E-01
25	0.9630659E 03	0.9631024E 03	-0.3651428E-01	0.5000000E-01
26	0.1002695E 04	0.1002742E 04	-0.4723358E-01	0.5000000E-01
27	0.1043344E 04	0.1043395E 04	-0.5065918E-01	0.5000000E-01
28	0.1084042E 04	0.1084088E 04	-0.4553223E-01	0.5000000E-01
29	0.1127134E 04	0.1127168E 04	-0.3353882E-01	0.5000000E-01
30	0.9091663E 03	0.9091920E 03	-0.2575684E-01	0.5000000E-01
31	0.9330364E 03	0.9330827E 03	-0.4633331E-01	0.5000000E-01
32	0.9659154E 03	0.9659751E 03	-0.5961609E-01	0.5000000E-01
33	0.1004118E 04	0.1004181E 04	-0.6332397E-01	0.5000000E-01
34	0.1045186E 04	0.1045242E 04	-0.5645752E-01	0.5000000E-01
35	0.1092378E 04	0.1092418E 04	-0.4060364E-01	0.5000000E-01
36	0.8963174E 03	0.8963848E 03	-0.6735992E-01	0.5000000E-01
37	0.9249237E 03	0.9250017E 03	-0.7803345E-01	0.5000000E-01
38	0.9584564E 03	0.9585373E 03	-0.8094788E-01	0.5000000E-01
39	0.9984394E 03	0.9985108E 03	-0.7141113E-01	0.5000000E-01
40	0.1051777E 04	0.1051825E 04	-0.4855347E-01	0.5000000E-01
41	0.8576335E 03	0.8577148E 03	-0.8129120E-01	0.5000000E-01
42	0.8835890E 03	0.8836909E 03	-0.1019058E 00	0.5000000E-01
43	0.9070508E 03	0.9071563E 03	-0.1055069E 00	0.5000000E-01
44	0.9411399E 03	0.9412338E 03	-0.9381104E-01	0.5000000E-01
45	0.1011581E 04	0.1011636E 04	-0.5464172E-01	0.5000000E-01
46	0.8149281E 03	0.8150896E 03	-0.1614914E 00	0.5000000E-01
47	0.8176213E 03	0.8177812E 03	-0.1599426E 00	0.5000000E-01
48	0.8188905E 03	0.8190473E 03	-0.1567459E 00	0.5000000E-01
49	0.8127623E 03	0.8129218E 03	-0.1594925E 00	0.5000000E-01
50	0.8151225E 03	0.8152804E 03	-0.1579361E 00	0.5000000E-01
51	0.8159731E 03	0.8161280E 03	-0.1548691E 00	0.5000000E-01
52	0.1239837E 04	0.1239845E 04	-0.7919312E-02	0.5000000E-01
53	0.1210087E 04	0.1210098E 04	-0.1136780E-01	0.5000000E-01
54	0.1210826E 04	0.1210837E 04	-0.1107788E-01	0.5000000E-01
55	0.1185108E 04	0.1185122E 04	-0.1371765E-01	0.5000000E-01
56	0.1189948E 04	0.1189961E 04	-0.1325989E-01	0.5000000E-01
57	0.1212945E 04	0.1212958E 04	-0.1272583E-01	0.5000000E-01
58	0.1212910E 04	0.1212927E 04	-0.1690674E-01	0.5000000E-01
59	0.1163028E 04	0.1163059E 04	-0.3027344E-01	0.5000000E-01
60	0.1131062E 04	0.1131106E 04	-0.4396057E-01	0.5000000E-01
61	0.1115488E 04	0.1115537E 04	-0.4867554E-01	0.5000000E-01
62	0.1105840E 04	0.1105889E 04	-0.4917908E-01	0.5000000E-01
63	0.1159076E 04	0.1159092E 04	-0.1539612E-01	0.5000000E-01
64	0.1166984E 04	0.1166998E 04	-0.1463318E-01	0.5000000E-01
65	0.1202627E 04	0.1202641E 04	-0.1374817E-01	0.5000000E-01
66	0.1204443E 04	0.1204461E 04	-0.1806641E-01	0.5000000E-01
67	0.1163022E 04	0.1163053E 04	-0.3030396E-01	0.5000000E-01
68	0.1128746E 04	0.1128790E 04	-0.4391479E-01	0.5000000E-01
69	0.1114913E 04	0.1114961E 04	-0.4800415E-01	0.5000000E-01
70	0.1105842E 04	0.1105890E 04	-0.4837036E-01	0.5000000E-01
71	0.1123232E 04	0.1123249E 04	-0.1690674E-01	0.5000000E-01
72	0.1123567E 04	0.1123583E 04	-0.1597595E-01	0.5000000E-01
73	0.1121688E 04	0.1121733E 04	-0.4518127E-01	0.5000000E-01
74	0.1113244E 04	0.1113292E 04	-0.4743958E-01	0.5000000E-01
75	0.1105152E 04	0.1105199E 04	-0.4751587E-01	0.5000000E-01
76	0.1087554E 04	0.1087571E 04	-0.1757813E-01	0.5000000E-01
77	0.1086031E 04	0.1086048E 04	-0.1666260E-01	0.5000000E-01
78	0.1118345E 04	0.1118390E 04	-0.4495239E-01	0.5000000E-01
79	0.1111852E 04	0.1111898E 04	-0.4653931E-01	0.5000000E-01
80	0.1104256E 04	0.1104302E 04	-0.4646301E-01	0.5000000E-01
81	0.1055370E 04	0.1055387E 04	-0.1722717E-01	0.5000000E-01
82	0.1053982E 04	0.1053999E 04	-0.1670837E-01	0.5000000E-01
83	0.1026047E 04	0.1026064E 04	-0.1692200E-01	0.5000000E-01
84	0.1024746E 04	0.1024763E 04	-0.1649475E-01	0.5000000E-01
85	0.1005677E 04	0.1005693E 04	-0.1657867E-01	0.5000000E-01
86	0.1004407E 04	0.1004423E 04	-0.1618195E-01	0.5000000E-01
87	0.9953152E 03	0.9953313E 03	-0.1615906E-01	0.5000000E-01
88	0.9939358E 03	0.9939516E 03	-0.1577759E-01	0.5000000E-01
89	0.1107000E 04	0.1107000E 04	0.	0.5000000E-01
90	0.1060000E 04	0.1060000E 04	0.	0.5000000E-01
91	0.8710000E 03	0.8710000E 03	0.	0.5000000E-01
92	0.8726228E 03	0.8726228E 03	-0.7629395E-05	0.5000000E-01
93	0.8690000E 03	0.8690000E 03	0.	0.5000000E-01
94	0.8791839E 03	0.8791839E 03	0.	0.5000000E-01
95	0.8560000E 03	0.8560000E 03	0.	0.5000000E-01

96	0.8760228E 03	0.8760228E 03	-0.7629395E-05	0.5000000E-01
97	0.8540000E 03	0.8540000E 03	0.	0.5000000E-01
98	0.8712150E 03	0.8712150E 03	-0.1525879E-04	0.5000000E-01
99	0.8610000E 03	0.8510000E 03	0.	0.5000000E-01
100	0.8561229E 03	0.8561230E 03	-0.2288818E-04	0.5000000E-01
101	0.8600000E 03	0.8500000E 03	0.	0.5000000E-01
102	0.8573022E 03	0.8573022E 03	-0.1525879E-04	0.5000000E-01
103	0.8580000E 03	0.8580000E 03	0.	0.5000000E-01
104	0.8648023E 03	0.8648024E 03	-0.7629395E-05	0.5000000E-01
105	0.8560000E 03	0.8560000E 03	0.	0.5000000E-01
106	0.8599932E 03	0.8599932E 03	0.	0.5000000E-01
107	0.8550000E 03	0.8550000E 03	0.	0.5000000E-01
108	0.8572584E 03	0.8572584E 03	0.	0.5000000E-01
109	0.8530000E 03	0.8530000E 03	0.	0.5000000E-01
110	0.8554687E 03	0.8554687E 03	0.	0.5000000E-01

CONVERGENCE CRITERION ACHEIVED, ITERATIONS= 131

ELEMENT(AT CENTER) TEMPERATURES (DEGREES F), ITERATIONS= 130

1, 1.2073900E 03	2, 1.2621996E 03	3, 1.2792890E 03	4, 1.2860528E 03	5, 1.2910258E 03	6, 1.2980559E 03
7, 1.0485211E 03	8, 1.1208364E 03	9, 1.1743483E 03	10, 1.2099351E 03	11, 1.2397363E 03	12, 1.2831623E 03
13, 9.8575897E 02	14, 1.0444335E 03	15, 1.0960944E 03	16, 1.1394177E 03	17, 1.1759955E 03	18, 1.2112994E 03
19, 1.0149709E 03	20, 1.0458352E 03	21, 1.0853686E 03	22, 1.1243037E 03	23, 1.1633123E 03	24, 9.1654068E 02
25, 9.6442071E 02	26, 1.0033938E 03	27, 1.0435496E 03	28, 1.0839858E 03	29, 1.1269771E 03	30, 9.1070828E 02
31, 9.3385793E 02	32, 9.6617658E 02	33, 1.0039886E 03	34, 1.0448881E 03	35, 1.0920869E 03	36, 8.9623836E 02
37, 9.2457432E 02	38, 9.5786542E 02	39, 9.9780642E 02	40, 1.0513206E 03	41, 8.6706945E 02	42, 8.8259656E 02
43, 9.0588249E 02	44, 9.4004122E 02	45, 1.0109861E 03	46, 8.1260896E 02	47, 8.1532953E 02	48, 8.1665190E 02
49, 8.1047188E 02	50, 8.1286117E 02	51, 8.1376455E 02	52, 1.2397408E 03	53, 1.2099419E 03	54, 1.2106788E 03
55, 1.1849299E 03	56, 1.1897669E 03	57, 1.2127559E 03	58, 1.2126390E 03	59, 1.1625276E 03	60, 1.1303272E 03
61, 1.1146724E 03	62, 1.1050158E 03	63, 1.1588738E 03	64, 1.1667836E 03	65, 1.2024228E 03	66, 1.2041541E 03
67, 1.1625215E 03	68, 1.1280120E 03	69, 1.1141088E 03	70, 1.1050314E 03	71, 1.1230080E 03	72, 1.1233525E 03
73, 1.1209323E 03	74, 1.1124499E 03	75, 1.1043562E 03	76, 1.0873188E 03	77, 1.0858072E 03	78, 1.1175932E 03
79, 1.1110728E 03	80, 1.1034779E 03	81, 1.0551364E 03	82, 1.0537560E 03	83, 1.0258155E 03	84, 1.0245209E 03
85, 1.0054487E 03	86, 1.0041852E 03	87, 9.9509299E 02	88, 9.9371971E 02	89, 1.1070000E 03	90, 1.0600000E 03
91, 8.7099999E 02	92, 8.7280047E 02	93, 8.6899999E 02	94, 8.7969958E 02	95, 8.6600000E 02	96, 8.7711291E 02
97, 8.6400000E 02	98, 8.7383481E 02	99, 8.6099999E 02	100, 8.7193322E 02	101, 8.5999999E 02	102, 8.7032722E 02
103, 8.5799999E 02	104, 8.6639888E 02	105, 8.5599999E 02	106, 8.6073503E 02	107, 8.5500000E 02	108, 8.5761781E 02
109, 8.5300000E 02	110, 8.5565917E 02				

ELEMENT(AT CENTER) TEMPERATURES (DEGREES F), ITERATIONS= 131

1, 1.2071725E 03	2, 1.2620373E 03	3, 1.2791568E 03	4, 1.2859512E 03	5, 1.2909592E 03	6, 1.2980433E 03
7, 1.0475390E 03	8, 1.1199171E 03	9, 1.1735314E 03	10, 1.2092899E 03	11, 1.2392973E 03	12, 1.2830593E 03
13, 9.8397003E 02	14, 1.0428129E 03	15, 1.0946141E 03	16, 1.1382373E 03	17, 1.1752374E 03	18, 1.2109470E 03
19, 1.0129158E 03	20, 1.0441371E 03	21, 1.0841971E 03	22, 1.1235345E 03	23, 1.1628938E 03	24, 9.1388555E 02
25, 9.6242095E 02	26, 1.0018606E 03	27, 1.0424498E 03	28, 1.0832400E 03	29, 1.1265452E 03	30, 9.0971111E 02
31, 9.3221756E 02	32, 9.6486228E 02	33, 1.0030000E 03	34, 1.0441905E 03	35, 1.0916644E 03	36, 8.9512587E 02
37, 9.2354479E 02	38, 9.5702671E 02	39, 9.9717945E 02	40, 1.0509228E 03	41, 8.6619644E 02	42, 8.8178753E 02
43, 9.0518625E 02	44, 9.3948340E 02	45, 1.0106195E 03	46, 8.1207172E 02	47, 8.1479235E 02	48, 8.1611314E 02
49, 8.0994133E 02	50, 8.1232901E 02	51, 8.1323395E 02	52, 1.2397008E 03	53, 1.2098909E 03	54, 1.2105354E 03
55, 1.1848719E 03	56, 1.1897191E 03	57, 1.2127252E 03	58, 1.2126175E 03	59, 1.1625043E 03	60, 1.1303005E 03
61, 1.1146448E 03	62, 1.1049883E 03	63, 1.1588108E 03	64, 1.1667315E 03	65, 1.2023893E 03	66, 1.2041306E 03
67, 1.1624979E 03	68, 1.1279854E 03	69, 1.1140814E 03	70, 1.1050041E 03	71, 1.1229402E 03	72, 1.1232921E 03
73, 1.1209056E 03	74, 1.1124227E 03	75, 1.1043292E 03	76, 1.0872511E 03	77, 1.0857446E 03	78, 1.1175565E 03
79, 1.1110459E 03	80, 1.1034512E 03	81, 1.0550741E 03	82, 1.0536952E 03	83, 1.0257570E 03	84, 1.0244530E 03
85, 1.0053927E 03	86, 1.0041295E 03	87, 9.9503328E 02	88, 9.9366528E 02	89, 1.1070000E 03	90, 1.0500000E 03
91, 8.7099999E 02	92, 8.7262275E 02	93, 8.6899999E 02	94, 8.7918385E 02	95, 8.6600000E 02	96, 8.7602273E 02
97, 8.6400000E 02	98, 8.7121484E 02	99, 8.6099999E 02	100, 8.6512252E 02	101, 8.5999999E 02	102, 8.5730202E 02
103, 8.5799999E 02	104, 8.6480223E 02	105, 8.5599999E 02	106, 8.5999316E 02	107, 8.5500000E 02	108, 8.5725842E 02
109, 8.5300000E 02	110, 8.5546871E 02				

ELEMENT FORCED CONVECTION, FREE CONVECT., RADIATION AND VAR.TEMP.CONVECT. CONDUCTANCES(H*A) BTU/HR.F

1	1	0.2309876E 02	0.	0.	0.1142512E 02
2	2	0.2301797E 02	0.	0.	0.
3	3	0.3442470E 02	0.	0.	0.
4	4	0.3408918E 02	0.	0.	0.
5	5	0.3374236E 02	0.	0.	0.
6	6	0.6024704E 02	0.	0.	0.
7	12	0.3214381E 02	0.	0.	0.2648646E 00
8	52	0.7309619E 02	0.	0.	0.
9	54	0.3023077E 02	0.	0.	0.
10	57	0.4908268E 02	0.	0.	0.
11	58	0.5272555E 02	0.	0.	0.
12	30	0.	0.1508969E 00	0.	0.9767791E 01
13	36	0.	0.8075071E 00	0.	0.
14	41	0.	0.8562257E 00	0.	0.
15	46	0.	0.1831766E 01	0.	0.
16	49	0.	0.2712572E 01	0.	0.
17	50	0.	0.3395263E 00	0.	0.
18	51	0.	0.8077877E 00	0.	0.
19	48	0.	0.4579416E 00	0.	0.
20	45	0.	0.4527078E 00	0.	0.

21	81	0.	0.1425612E 01	0.	0.
22	83	0.	0.1642215E 01	0.	0.
23	85	0.	0.1682875E 01	0.	0.
24	87	0.	0.1863566E 01	0.	0.
25	88	0.	0.2835336E 01	0.	0.
26	86	0.	0.2481122E 01	0.	0.
27	84	0.	0.2421175E 01	0.	0.
28	82	0.	0.2101830E 01	0.	0.
29	77	0.	0.1545289E 01	0.	0.
30	72	0.	0.1629288E 01	0.	0.
31	65	0.	0.3621526E 00	0.	0.
32	66	0.	0.3651705E 00	0.	0.
33	67	0.	0.4526907E 00	0.	0.
34	73	0.	0.5234740E 00	0.	0.
35	78	0.	0.9272007E 00	0.	0.
36	79	0.	0.4527218E 00	0.	0.
37	80	0.	0.1065631E 01	0.	0.
38	75	0.	0.7760924E 00	0.	0.
39	70	0.	0.8551035E 00	0.	0.
40	62	0.	0.9163529E 00	0.	0.
41	61	0.	0.1509035E 00	0.	0.
42	11	0.	0.	0.	0.1323278E 00
43	17	0.	0.	0.	0.1150274E 00
44	15	0.	0.	0.	0.1497932E 00
45	15	0.	0.	0.	0.8766205E-01
46	20	0.	0.	0.	0.8278172E-01
47	19	0.	0.	0.	0.8234002E-01
48	7	0.	0.	0.	0.1314272E 02
49	13	0.	0.	0.	0.1771311E 02
50	24	0.	0.	0.	0.2210943E 02
51	92	0.8359403E-01	0.	0.	0.
52	110	0.1684123E-02	0.	0.	0.9395632E 00
53	94	0.	0.	0.	0.1081050E 02
54	96	0.	0.	0.	0.1256669E 02
55	98	0.	0.	0.	0.1272810E 02
56	100	0.	0.	0.	0.6012575E 01
57	102	0.	0.	0.	0.9549849E 01
58	104	0.	0.	0.	0.9552101E 01
59	106	0.	0.	0.	0.8544354E 00
60	108	0.	0.	0.	0.7605613E 00
61	91	0.	0.	0.	0.
62	93	0.	0.	0.	0.
63	95	0.	0.	0.	0.
64	97	0.	0.	0.	0.
65	99	0.	0.	0.	0.
66	101	0.	0.	0.	0.
67	103	0.	0.	0.	0.
68	105	0.	0.	0.	0.
69	107	0.	0.	0.	0.
70	109	0.	0.	0.	0.
71	89	0.	0.	0.	0.
72	90	0.	0.	0.	0.

VAR.TEMP.CONVECTION BOUNDARY TEMPS.(F)

1 1, 1.0516E 03	2 12, 1.2976E 03	3 30, 8.9297E 02	4 11, 1.2933E 03	5 17, 1.2857E 03	6 16, 1.2734E 03
7 15, 1.2645E 03	8 20, 1.2541E 03	9 19, 1.2428E 03	10 7, 9.6841E 02	11 13, 9.3688E 02	12 24, 8.9985E 02
13 110, 9.1990E 02	14 94, 1.0620E 03	15 95, 9.7500E 02	16 98, 9.4500E 02	17 100, 7.5451E 02	18 102, 1.0050E 03
19 104, 9.5500E 02	20 106, 9.4192E 02	21 108, 9.3149E 02			

ELEMENT THERMAL CONDUCTIVITIES BTU/HR.FT.F

1, 3.3891022E 00	2, 3.2509139E 00	3, 3.2088574E 00	4, 3.1923199E 00	5, 3.1801741E 00	6, 3.1630672E 00
7, 3.8219351E 00	8, 3.6198994E 00	9, 3.4764545E 00	10, 3.3836611E 00	11, 3.3075424E 00	12, 3.1993524E 00
13, 4.0075200E 00	14, 3.8354569E 00	15, 3.6894091E 00	16, 3.5702831E 00	17, 3.4719671E 00	18, 3.3794140E 00
19, 3.9220373E 00	20, 3.8316448E 00	21, 3.7183625E 00	22, 3.6100353E 00	23, 3.5044902E 00	24, 4.2211350E 00
25, 4.0721750E 00	26, 3.9544748E 00	27, 3.8364705E 00	28, 3.7210288E 00	29, 3.6018634E 00	30, 4.2373451E 00
31, 4.1643429E 00	32, 4.0647814E 00	33, 3.9511051E 00	34, 3.8314753E 00	35, 3.6975774E 00	36, 4.2799824E 00
37, 4.1911136E 00	38, 4.0884663E 00	39, 3.9682653E 00	40, 3.8122348E 00	41, 4.3720887E 00	42, 4.3222151E 00
43, 4.2483087E 00	44, 4.1419617E 00	45, 3.9287386E 00	46, 7.3044968E 01	47, 7.3021833E 01	48, 7.3010582E 01
49, 7.3063127E 01	50, 7.3042787E 01	51, 7.3035095E 01	52, 6.9873211E 01	53, 7.0071213E 01	54, 7.0065240E 01
55, 7.0239279E 01	56, 7.0206575E 01	57, 7.0052282E 01	58, 7.0052993E 01	59, 7.0391088E 01	60, 7.0512513E 01
61, 7.0721455E 01	62, 7.0789098E 01	63, 7.0416341E 01	64, 7.0362301E 01	65, 7.0121414E 01	66, 7.0109738E 01
67, 7.0391131E 01	68, 7.0628570E 01	69, 7.0725393E 01	70, 7.0788989E 01	71, 7.0663680E 01	72, 7.0561235E 01
73, 7.0677786E 01	74, 7.0736992E 01	75, 7.0793731E 01	76, 7.0914325E 01	77, 7.0925013E 01	78, 7.0701063E 01
79, 7.0746629E 01	80, 7.0799901E 01	81, 7.1144552E 01	82, 7.1154514E 01	83, 7.1358092E 01	84, 7.1357505E 01
85, 7.1508669E 01	86, 7.1518073E 01	87, 7.1585967E 01	88, 7.1596256E 01	89, 7.5937494E 01	90, 7.2999394E 01
91, 7.2554519E 01	92, 7.2541301E 01	93, 7.2570832E 01	94, 7.2488013E 01	95, 7.2595346E 01	96, 7.2513555E 01
97, 7.2611717E 01	98, 7.2552767E 01	99, 7.2536321E 01	100, 7.2594343E 01	101, 7.2644534E 01	102, 7.2584701E 01
103, 7.2660978E 01	104, 7.2605148E 01	105, 7.2577446E 01	106, 7.2644590E 01	107, 7.2685690E 01	108, 7.2567081E 01
109, 7.2702194E 01	110, 7.2681825E 01				

ELEMENT ENWS CONDUCTION HEAT FLUXES	1	0.3500629E 03	-0.7173817E 03	0.	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	2	0.8493505E 02	-0.5087063E 03	-0.3500629E 03	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES		0.2787327E 02	-0.6604753E 03	-0.8493505E 02	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	4	0.2045288E 02	-0.4715087E 03	-0.2787327E 02	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	5	0.2879872E 02	-0.3134156E 03	-0.2045288E 02	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	6	0.	-0.8908973E 02	-0.2879872E 02	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	7	0.6164732E 03	-0.2938891E 03	0.	0.7173817E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	8	0.3470744E 03	-0.3393345E 03	-0.6164732E 03	0.6087063E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	9	0.1872781E 03	-0.5007160E 03	-0.3470744E 03	0.6604753E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	10	0.1532962E 03	-0.4375617E 03	-0.1872781E 03	0.4715087E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	11	0.2173733E 03	-0.3846594E 03	-0.1532962E 03	0.3134156E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	12	0.	-0.4201151E 03	-0.2173733E 03	0.8908973E 02	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	13	0.5401655E 03	0.	0.	0.2938891E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	14	0.3636212E 03	-0.1628458E 03	-0.5401655E 03	0.3393345E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	15	0.2471701E 03	-0.3992199E 03	-0.3636212E 03	0.5007160E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	16	0.2033787E 03	-0.4140727E 03	-0.2471701E 03	0.4375617E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	17	0.1909676E 03	-0.3849976E 03	-0.2033787E 03	0.3846594E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	18	0.1197314E 03	-0.3479073E 03	-0.1909676E 03	0.4201151E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	19	0.1646259E 03	-0.3464769E 03	0.	0.1628458E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	20	0.1717864E 03	-0.4238508E 03	-0.1646259E 03	0.3992199E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	21	0.1637377E 03	-0.4061137E 03	-0.1717864E 03	0.4140727E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	22	0.1590473E 03	-0.3803781E 03	-0.1637377E 03	0.3849976E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	23	0.1437275E 03	-0.3326274E 03	-0.1590473E 03	0.3479073E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	24	0.3481610E 03	-0.3816319E 02	0.	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	25	0.2184400E 03	-0.2168363E 03	-0.3481610E 03	0.3464769E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	26	0.1823687E 03	-0.3878909E 03	-0.2184400E 03	0.4238508E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	27	0.1777793E 03	-0.4016309E 03	-0.1823687E 03	0.4061137E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	28	0.1828759E 03	-0.3855568E 03	-0.1777793E 03	0.3803781E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	29	0.1830797E 03	-0.3328724E 03	-0.1828759E 03	0.3326274E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	30	0.1734538E 03	0.	0.	0.3816319E 02	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	31	0.1882795E 03	-0.2317683E 03	-0.1734538E 03	0.2168363E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	32	0.1789737E 03	-0.3787090E 03	-0.1882795E 03	0.3878909E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	33	0.1876667E 03	-0.4104379E 03	-0.1789737E 03	0.4016309E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	34	0.2092321E 03	-0.4072054E 03	-0.1876667E 03	0.3855568E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	35	0.2150110E 03	-0.3396829E 03	-0.2092321E 03	0.3328724E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	36	0.2405199E 03	-0.1736076E 03	0.	0.2317683E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	37	0.2312853E 03	-0.3696520E 03	-0.2405199E 03	0.3787090E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	38	0.2698817E 03	-0.4491997E 03	-0.2312853E 03	0.4104379E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	39	0.3487814E 03	-0.4862198E 03	-0.2698817E 03	0.4072054E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	40	0.3335038E 03	-0.3244261E 03	-0.3487814E 03	0.3396829E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	41	0.1184190E 03	0.	0.	0.1736076E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	42	0.1461514E 03	-0.3975692E 03	-0.1184190E 03	0.3696520E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	43	0.2097017E 03	-0.5129126E 03	-0.1461514E 03	0.4491997E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	44	0.4181535E 03	-0.5947881E 03	-0.2097017E 03	0.4862198E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	45	0.3136507E 03	0.	-0.4181535E 03	0.3244261E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	46	0.3939557E 03	-0.2742551E 03	0.	0.3975692E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	47	0.1919342E 03	-0.3170224E 03	-0.3939557E 03	0.5129126E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	48	0.	-0.3711374E 03	-0.1919342E 03	0.6947881E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	49	0.3536301E 03	0.	0.	0.2742551E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	50	0.1340007E 03	0.	-0.3536301E 03	0.3170224E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	51	0.	0.	-0.1340007E 03	0.3711374E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	52	0.	-0.4289205E 04	-0.1187314E 03	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	53	0.7408617E 02	-0.4220089E 04	-0.1437275E 03	0.4289205E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	54	0.	-0.2627680E 04	-0.7408617E 02	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	55	0.4363274E 03	-0.4473862E 04	-0.1830797E 03	0.4220089E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	56	0.1470416E 04	-0.3662107E 04	-0.4363274E 03	0.2627680E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	57	-0.4984610E 01	-0.2809042E 04	-0.1470416E 04	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	58	-0.2076528E 04	-0.2536940E 04	0.4984610E 01	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	59	-0.1398827E 04	-0.2196907E 01	0.2076528E 04	-0.6777360E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	60	-0.7669700E 03	-0.6339728E 03	0.1398827E 04	-0.4648849E 00	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	61	-0.5262595E 03	-0.1545058E 03	0.7669700E 03	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	62	0.	0.3467910E 01	0.5262595E 03	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	63	0.7254982E 03	-0.4983809E 04	-0.2160110E 03	0.4473862E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	64	0.2665624E 04	-0.5602479E 04	-0.7254982E 03	0.3662107E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	65	0.1021304E 03	0.	-0.2665624E 04	0.2809042E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	66	-0.2186558E 04	0.	-0.1021304E 03	0.2536940E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	67	-0.1899557E 04	0.	0.2186558E 04	0.2196907E 01	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	68	-0.8631382E 03	-0.1671667E 04	0.1899557E 04	0.6339728E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	69	-0.6267930E 03	-0.3920681E 03	0.8631382E 03	0.1545058E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	70	0.	-0.1277191E 03	0.6267930E 03	-0.3467910E 01	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	71	0.4246203E 02	-0.4693337E 04	-0.3335038E 03	0.4983809E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	72	0.	-0.4585237E 04	-0.4246203E 02	0.5602479E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	73	-0.4781506E 03	-0.3833292E 03	0.	0.1671667E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	74	-0.5072814E 03	-0.3645066E 03	0.4781506E 03	0.3920681E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	75	0.	-0.1860999E 03	0.5072814E 03	0.1277191E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	76	-0.1730384E 03	-0.4207191E 04	-0.3136507E 03	0.4693337E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	77	0.	-0.3891766E 04	0.1730384E 03	0.4585237E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	78	-0.3332247E 03	0.	0.	0.8833292E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	79	-0.4315122E 03	0.	0.3332247E 03	0.3645066E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	80	0.	0.	0.4315122E 03	0.1860999E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	81	-0.2161438E 03	-0.3235988E 04	0.	0.4207191E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	82	0.	-0.2996551E 04	0.2161438E 03	0.3891766E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	83	-0.2343526E 03	-0.2179990E 04	0.	0.3235988E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	84	0.	-0.2021472E 04	0.2343526E 03	0.2996551E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	85	-0.2349137E 03	-0.1137354E 04	0.	0.2179990E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	86	0.	-0.1067466E 04	0.2349137E 03	0.2021472E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	87	-0.2617961E 03	0.	0.	0.1137354E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	88	0.	0.	0.2617961E 03	0.1067466E 04	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	89	-0.5287456E 04	0.6777360E 03	0.	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	90	0.	0.4648849E 00	0.5287456E 04	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	91	0.2969990E 03	-0.1927497E 03	0.	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	92	0.	0.6320201E 03	-0.2969990E 03	0.	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	93	0.8875800E 03	-0.4339453E 03	0.	0.1927497E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	94	0.	-0.4567316E 03	-0.8875800E 03	-0.6320201E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	95	0.1041136E 04	-0.2745692E 03	0.	0.4339453E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	96	0.	-0.6594095E 03	-0.1041136E 04	0.4567316E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	97	0.7665407E 03	-0.4905089E 03	0.	0.2745692E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	98	0.	-0.8320146E 03	-0.7665407E 03	0.6594095E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	99	0.3952253E 03	-0.1996018E 03	0.	0.4905089E 03	BTU/HR

ELEMENT ENWS CONDUCTION HEAT FLUXES	100	0.	0.2352648E 03	-0.3962253E 03	0.8320146E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	101	0.5734788E 03	-0.4053579E 03	0.	0.1996018E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	102	0.	-0.5062507E 03	-0.5734788E 03	-0.2352648E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	103	0.5424470E 03	-0.3434600E 03	0.	0.4053579E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	104	0.	-0.8253795E 03	-0.5424470E 03	0.5062507E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	105	0.4539583E 03	-0.1614701E 03	0.	0.3434600E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	106	0.	-0.4414204E 03	-0.4539583E 03	0.8253795E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	107	0.2243036E 03	-0.3058020E 03	0.	0.1614701E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	108	0.	-0.2735725E 03	-0.2243036E 03	0.4414204E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	109	0.3335688E 03	0.	0.	0.3058020E 03	BTU/HR
ELEMENT ENWS CONDUCTION HEAT FLUXES	110	0.	0.	-0.3335688E 03	0.2735725E 03	BTU/HR

ELEMENT ENWS CONDUCTANCES TO NABORS(BTU/HR.F)

1	0.6380464E 01	0.4493929E 01	0.	0.
2	0.4961302E 01	0.4283041E 01	0.6380464E 01	0.
3	0.4102397E 01	0.6252999E 01	0.4961302E 01	0.
4	0.4084020E 01	0.6150550E 01	0.4102397E 01	0.
5	0.4065258E 01	0.6066671E 01	0.4084020E 01	0.
6	0.	0.5945660E 01	0.4065258E 01	0.
7	0.8517389E 01	0.4623222E 01	0.	0.4493929E 01
8	0.6473546E 01	0.4400985E 01	0.8517389E 01	0.4283041E 01
9	0.5237299E 01	0.6344815E 01	0.6473546E 01	0.6252999E 01
10	0.5108618E 01	0.6158279E 01	0.5237299E 01	0.6150550E 01
11	0.4967171E 01	0.6004692E 01	0.5108618E 01	0.6066671E 01
12	0.	0.5825843E 01	0.4967171E 01	0.5945660E 01
13	0.9179930E 01	0.	0.	0.4623222E 01
14	0.7019563E 01	0.5446862E 01	0.9179930E 01	0.4400986E 01
15	0.5666012E 01	0.7908951E 01	0.7019563E 01	0.6344815E 01
16	0.5496713E 01	0.7662297E 01	0.5666012E 01	0.6158279E 01
17	0.5347800E 01	0.7446346E 01	0.5496713E 01	0.6004682E 01
18	0.4129233E 01	0.7240057E 01	0.5347800E 01	0.5825843E 01
19	0.5272871E 01	0.6861634E 01	0.	0.5446862E 01
20	0.4288229E 01	0.1002569E 02	0.5272871E 01	0.7908951E 01
21	0.4162387E 01	0.9727925E 01	0.4288229E 01	0.7662297E 01
22	0.4040905E 01	0.9439952E 01	0.4162387E 01	0.7446346E 01
23	0.3058222E 01	0.9151030E 01	0.4040905E 01	0.7240057E 01
24	0.7173489E 01	0.7373895E 01	0.	0.
25	0.5538589E 01	0.7179228E 01	0.7173489E 01	0.6861634E 01
26	0.4493030E 01	0.1048401E 02	0.5538589E 01	0.1002569E 02
27	0.4358385E 01	0.1018080E 02	0.4493030E 01	0.9727925E 01
28	0.4222955E 01	0.9873525E 01	0.4358385E 01	0.9439952E 01
29	0.3138867E 01	0.9543145E 01	0.4222955E 01	0.9151030E 01
30	0.7378956E 01	0.	0.	0.7373895E 01
31	0.5767553E 01	0.6248674E 01	0.7378956E 01	0.7179228E 01
32	0.4692822E 01	0.9165828E 01	0.5767553E 01	0.1048401E 02
33	0.4556075E 01	0.8927738E 01	0.4692822E 01	0.1018080E 02
34	0.4407302E 01	0.8661914E 01	0.4556075E 01	0.9873525E 01
35	0.3217019E 01	0.8337477E 01	0.4407302E 01	0.9543145E 01
36	0.8463673E 01	0.6000863E 01	0.	0.6248674E 01
37	0.6907766E 01	0.8852423E 01	0.8463673E 01	0.9165828E 01
38	0.6721378E 01	0.8665041E 01	0.6907766E 01	0.8927738E 01
39	0.6489764E 01	0.8427264E 01	0.6721378E 01	0.8661914E 01
40	0.4630875E 01	0.8049619E 01	0.6489764E 01	0.8337477E 01
41	0.7595242E 01	0.	0.	0.6000853E 01
42	0.6246157E 01	0.5702704E 01	0.7595242E 01	0.8852423E 01
43	0.6114262E 01	0.5674195E 01	0.6246157E 01	0.8665041E 01
44	0.5878220E 01	0.5631959E 01	0.6114262E 01	0.8427264E 01
45	0.4092969E 01	0.	0.5878220E 01	0.8049619E 01
46	0.1448029E 03	0.1287345E 03	0.	0.5702704E 01
47	0.1447688E 03	0.1286961E 03	0.1448029E 03	0.5674195E 01
48	0.	0.1286794E 03	0.1447688E 03	0.5631959E 01
49	0.1481057E 03	0.	0.	0.1287345E 03
50	0.1480773E 03	0.	0.1481057E 03	0.1286961E 03
51	0.	0.	0.1480773E 03	0.1286794E 03
52	0.	0.1438851E 03	0.4129233E 01	0.
53	0.9951651E 02	0.1686754E 03	0.3058222E 01	0.1438851E 03
54	0.	0.1256288E 03	0.9951651E 02	0.
55	0.9001584E 02	0.1716679E 03	0.3138867E 01	0.1686754E 03
56	0.6391423E 02	0.1593078E 03	0.9001584E 02	0.1256288E 03
57	0.4625108E 02	0.2717758E 03	0.6391423E 02	0.
58	0.4143682E 02	0.2989272E 03	0.4625108E 02	0.
59	0.4343676E 02	0.3411766E 03	0.4143682E 02	0.1221050E 02
60	0.4898949E 02	0.2738342E 03	0.4343676E 02	0.6612817E-02
61	0.5449790E 02	0.2742306E 03	0.4898949E 02	0.
62	0.	0.2195874E 03	0.5449790E 02	0.
63	0.9159468E 02	0.1389386E 03	0.3217019E 01	0.1716679E 03
64	0.7475564E 02	0.1289722E 03	0.9159468E 02	0.1593078E 03
65	0.5865224E 02	0.	0.7475564E 02	0.2717758E 03
66	0.5252016E 02	0.	0.5865224E 02	0.2989272E 03
67	0.5503968E 02	0.	0.5252016E 02	0.3411766E 03
68	0.6207817E 02	0.2361166E 03	0.5503968E 02	0.2738342E 03
69	0.6905060E 02	0.2363741E 03	0.6207817E 02	0.2742306E 03
70	0.	0.1892597E 03	0.6905060E 02	0.2195874E 03
71	0.1206709E 03	0.1315060E 03	0.4630875E 01	0.1389386E 03
72	0.	0.1221184E 03	0.1206709E 03	0.1289722E 03
73	0.5636644E 02	0.2645487E 03	0.	0.2361166E 03
74	0.6267794E 02	0.2647491E 03	0.5636644E 02	0.2363741E 03
75	0.	0.2119648E 03	0.6267794E 02	0.1892597E 03
76	0.1148658E 03	0.1307518E 03	0.4092969E 01	0.1315060E 03
77	0.	0.1214300E 03	0.1148658E 03	0.1221184E 03
78	0.5110266E 02	0.	0.	0.2645487E 03
79	0.5681803E 02	0.	0.5110266E 02	0.2647491E 03
80	0.	0.	0.5681803E 02	0.2119648E 03

81	0.1567415E 03	0.1103788E 03	0.	0.1307518E 03
82	0.	0.1025085E 03	0.1567415E 03	0.1214300E 03
83	0.1810977E 03	0.1070493E 03	0.	0.1103788E 03
84	0.	0.9941604E 02	0.1810977E 03	0.1025086E 03
85	0.1859730E 03	0.1098429E 03	0.	0.1070493E 03
86	0.	0.1020110E 03	0.1859730E 03	0.9941604E 02
87	0.1906733E 03	0.	0.	0.1098429E 03
88	0.	0.	0.1906733E 03	0.1020110E 03
89	0.1124991E 03	0.1221050E 02	0.	0.
90	0.	0.6512817E-02	0.1124991E 03	0.
91	0.1830213E 03	0.9637487E 02	0.	0.
92	0.	0.9632843E 02	0.1830213E 03	0.
93	0.8715561E 02	0.1446484E 03	0.	0.9637487E 02
94	0.	0.1444846E 03	0.8715561E 02	0.9632843E 02
95	0.1038774E 03	0.1372846E 03	0.	0.1446484E 03
96	0.	0.1371515E 03	0.1038774E 03	0.1444846E 03
97	0.1062448E 03	0.1635030E 03	0.	0.1372846E 03
98	0.	0.1633861E 03	0.1062448E 03	0.1371515E 03
99	0.7734957E 02	0.1996018E 03	0.	0.1635030E 03
100	0.	0.1994620E 03	0.7734957E 02	0.1633861E 03
101	0.7853696E 02	0.2026789E 03	0.	0.1996018E 03
102	0.	0.2025176E 03	0.7853696E 02	0.1994620E 03
103	0.7974536E 02	0.1717300E 03	0.	0.2026789E 03
104	0.	0.1716296E 03	0.7974536E 02	0.2025176E 03
105	0.1136339E 03	0.1614701E 03	0.	0.1717300E 03
106	0.	0.1614117E 03	0.1136339E 03	0.1716296E 03
107	0.9931902E 02	0.1529010E 03	0.	0.1614701E 03
108	0.	0.1528598E 03	0.9931902E 02	0.1614117E 03
109	0.1351181E 03	0.	0.	0.1529010E 03
110	0.	0.	0.1351181E 03	0.1528598E 03

ELEMENT BOUNDARY NO, CONDUCTION NO, BNDRY CONDUCTANCE(H*A) SUM(BTU/HR.F) AND BNDRY HEAT FLUX SUM(BTU/HR)

1	1	0.3452368E 02	0.3673041E 03	2	2	0.2301797E 02	0.8738152E 03	3	3	0.3442470E 02	0.7174999E 03
4	4	0.3408918E 02	0.4788905E 03	5	5	0.3374236E 02	0.3050405E 03	6	6	0.6024704E 02	0.1173790E 03
7	12	0.3240867E 02	0.5483548E 03	8	52	0.7309619E 02	0.4407473E 04	9	54	0.3023077E 02	0.2701465E 04
10	57	0.4908268E 02	0.4283502E 04	11	58	0.5272555E 02	0.4607039E 04	12	30	0.9918587E 01	-0.2117325E 03
13	36	0.8075071E 00	-0.2988954E 03	14	41	0.8562257E 00	-0.2921620E 03	15	46	0.1831765E 01	-0.5259372E 03
16	49	0.2212572E 01	-0.6305592E 03	17	50	0.3395263E 00	-0.9757187E 02	18	51	0.8077877E 00	-0.2328594E 03
19	48	0.4579416E 00	-0.1333367E 03	20	45	0.4527078E 00	-0.2198511E 03	21	81	0.1425612E 01	-0.7555872E 03
22	83	0.1642215E 01	-0.8223586E 03	23	85	0.1682875E 01	-0.8084487E 03	24	87	0.1863565E 01	-0.8759558E 03
25	88	0.2335336E 01	-0.1328835E 04	26	86	0.2481122E 01	-0.1188790E 04	27	84	0.2421175E 01	-0.1209299E 04
28	82	0.2101830E 01	-0.1111237E 04	29	77	0.1545289E 01	-0.8665199E 03	30	72	0.1529288E 01	-0.9747977E 03
31	65	0.3621526E 00	-0.2453197E 03	32	66	0.3651705E 00	-0.2480004E 03	33	67	0.4526907E 00	-0.2385933E 03
34	73	0.5234740E 00	-0.3119478E 03	35	78	0.9272007E 00	-0.5494400E 03	36	79	0.4527218E 00	-0.2553218E 03
37	80	0.1065631E 01	-0.6164296E 03	38	75	0.7760924E 00	-0.4496235E 03	39	70	0.8551035E 00	-0.4959753E 03
40	62	0.9163529E 00	-0.5514868E 03	41	61	0.1509035E 00	-0.8898155E 02	42	11	0.1323278E 00	0.7143526E 01
43	17	0.1150274E 00	0.1270090E 02	44	16	0.1497932E 00	0.2023887E 02	45	15	0.8765205E-01	0.1488822E 02
46	20	0.8278172E-01	0.1737897E 02	47	19	0.8234002E-01	0.1892660E 02	48	7	0.1314272E 02	-0.1040005E 04
49	13	0.1771311E 02	-0.3341237E 03	50	24	0.2210943E 02	-0.3101982E 03	51	92	0.8359403E-01	-0.3350202E 03
52	110	0.9412473E 00	0.5999754E 02	53	94	0.1081050E 02	0.1976333E 04	54	96	0.1255669E 02	0.1243815E 04
55	98	0.1272810E 02	0.9391448E 03	56	100	0.5012575E 01	-0.6710515E 03	57	102	0.9549849E 01	0.1314995E 04
58	104	0.9552101E 01	0.8615781E 03	59	106	0.8544354E 00	0.6999946E 02	60	108	0.7605613E 00	0.5645594E 02
61	91	0.	0.	62	93	0.	0.	63	95	0.	0.
64	97	0.	0.	65	99	0.	0.	66	101	0.	0.
67	103	0.	0.	68	105	0.	0.	69	107	0.	0.
70	109	0.	0.	71	89	0.	0.	72	90	0.	0.

ELEMENT FREE THERMAL EXPANSION,ALPHA*(T-TO)

1, 3.5943291E-03	2, 3.8658456E-03	3, 3.9524164E-03	4, 3.9870181E-03	5, 4.0126103E-03	6, 4.0489390E-03
7, 2.8556995E-03	8, 3.1811310E-03	9, 3.4323287E-03	10, 3.6046590E-03	11, 3.7522281E-03	12, 3.9722755E-03
13, 2.5828532E-03	14, 2.8350141E-03	15, 3.0655976E-03	16, 3.2660188E-03	17, 3.4404786E-03	18, 3.6127419E-03
19, 2.7056181E-03	20, 2.8408324E-03	21, 3.0186032E-03	22, 3.1978439E-03	23, 3.3818226E-03	24, 2.2960979E-03
25, 2.4931405E-03	26, 2.6584636E-03	27, 2.8334689E-03	28, 3.0143082E-03	29, 3.2117509E-03	30, 2.2755098E-03
31, 2.3697116E-03	32, 2.5032663E-03	33, 2.6633292E-03	34, 2.8410915E-03	35, 3.0522736E-03	36, 2.2218905E-03
37, 2.3348097E-03	38, 2.4709482E-03	39, 2.6386291E-03	40, 2.8706202E-03	41, 2.1094527E-03	42, 2.1597587E-03
43, 2.2616254E-03	44, 2.3992145E-03	45, 2.6958183E-03	46, 3.7161562E-03	47, 3.7349236E-03	48, 3.7440777E-03
49, 3.7014799E-03	50, 3.7179224E-03	51, 3.7241565E-03	52, 7.1276395E-03	53, 6.8596904E-03	54, 6.8563255E-03
55, 6.6382678E-03	56, 6.6809345E-03	57, 6.9849771E-03	58, 6.8840256E-03	59, 6.4430768E-03	60, 6.1564581E-03
61, 6.0338784E-03	62, 5.9527183E-03	63, 6.4110420E-03	64, 6.4797431E-03	65, 6.7929769E-03	66, 6.3084495E-03
67, 6.4430209E-03	68, 6.1467721E-03	69, 6.0291285E-03	70, 5.9528487E-03	71, 6.1039015E-03	72, 6.1053804E-03
73, 6.0867442E-03	74, 6.0151572E-03	75, 5.9471924E-03	76, 5.8047992E-03	77, 5.7923142E-03	78, 5.0585200E-03
79, 6.0035700E-03	80, 5.9398372E-03	81, 5.5406761E-03	82, 5.5294732E-03	83, 5.3046070E-03	84, 5.2942355E-03
85, 5.1431972E-03	86, 5.1332539E-03	87, 5.0519350E-03	88, 5.0511997E-03	89, 8.7216585E-03	90, 8.2503062E-03
91, 4.1307889E-03	92, 4.1424658E-03	93, 4.1164160E-03	94, 4.1898140E-03	95, 4.0948945E-03	96, 4.1569745E-03
97, 4.0805723E-03	98, 4.1323342E-03	99, 4.0591272E-03	100, 4.0957727E-03	101, 4.0519889E-03	102, 4.1042293E-03
103, 4.0377277E-03	104, 4.0863148E-03	105, 4.0234867E-03	106, 4.0519401E-03	107, 4.0163739E-03	108, 4.0324449E-03
109, 4.0021635E-03	110, 4.0197072E-03				

01 EXIT IN SEAL2

APPENDIX D

HEAT TRANSFER COEFFICIENT EQUATIONS

The equations used to calculate boundary heat transfer coefficients are mostly obtained from books by McAdams (ref. 9) and by Kreith (ref. 10).

Radiation

The radiation equation is based on information from chapter 4 of Kreith and chapter 5 of McAdams. The basic expression is in terms of the heat flux but can also be expressed as

$$h = \frac{Q}{A\ \Delta T}$$

The number of properties required is reduced by substitution of others as explained in the references.

Liquid Film Cooling

The gravity-flow liquid film cooling equation can be found in chapter 9 of McAdams. Strictly, it applies only to flow over horizontal cylinders. However, in the program, it is also used for flow down vertical surfaces.

Other Free Convection Coefficients

The two other free convection subtype expressions are obtained from a study of chapter 7 of McAdams and of chapter 7 of Kreith. They are actually for nonenclosed spaces, but are considered acceptable for two reasons. First, the boundaries at which free convection occurs are far enough from the parts of interest (seal plate and nosepiece) that they have little influence. Second, the knowledge of coefficients in enclosed spaces appears to be limited and to be expressed in terms of overall coefficients.

Comparison of the two conditions (table I) shows the equations for turbulent flow are identical and those for laminar flow differ only in the constant used. Transition from laminar to turbulent flow is considered to occur at $GrPr = 10^9$ (ref. 9).

Use of Local Coefficients

The expression for free convection at vertical surfaces is for a local coefficient instead of an average as is the case for the other cases already mentioned.

The program deals with small sections of boundary surfaces. There are few, if any, places where a fully established velocity profile (e.g., in duct flow) or boundary film (e.g., in flat plate flow) exists in seal applications. In the problem of appendix C, as an example, the use of a local coefficient is generally preferable.

While free convection around a horizontal cylinder should properly be considered a circumferential flow, the assumption of an axisymmetric temperature distribution implies a uniform coefficient around the circumference as well as along the cylinder.

The conversion of average coefficients to local coefficients is based on text and equations in chapter 6 of Kreith.

Flat Plate

These coefficients and the critical Reynolds number for laminar turbulent transition are obtained directly from chapter 6 of Kreith's book.

Duct Flow, Liquid

For the most accurate result, the equation used for duct flow depends on the shape of the cross section and on the viscosity of the fluid. However, McAdams and also Jakob (ref. 11) indicate that the use of pipe flow equations with an equivalent (hydraulic) diameter is acceptable.

In the example of appendix C, the only fluid flowing in a duct is a synthetic oil with a viscosity in the range covered by McAdams recommended equation for turbulent flow. The laminar flow expression as well as that for turbulent flow are taken from chapter 9 of McAdams.

McAdams' data indicate that transition from laminar to turbulent flow can be considered as occurring over the Reynolds number range between 2500 and 7500. Kreith and also Jakob agree with the overall trend during transition. The equation presented in table I seems to be an acceptable approximation of the coefficient in this range.

Concentric Cylinders

This expression is obtained from reference 12. The experimental conditions are similar to those found in the problem of appendix C. One assumption is made in the problem; the axial flow has a negligible effect on the boundary film. This seems reasonable for the high rotational speed and the low axial flow velocities. Therefore, the entrance effect term is dropped.

Rotors

The equations for the remaining two flow types are derived from the results of reference 13. While the completely shrouded disk used does not duplicate the flow in a seal gap, no work applicable to laminar flow (the most probable regime in a seal gap) has yet been found. Also the derivation involves using the Reynolds analogy so the resulting expressions are only rough approximations.

In applying the results, the assumption is made that one or the other of the following situations exists:

(1) The clearance between the side of a rotating part and the housing or other stationary part is so small that the boundary layers are merged at all times (seal gap).

(2) The clearance is large enough that the boundary layers are separate at all times (sides of rotors). This should be a good approximation of the situation in the problem of appendix C except for the seal gap.

The laminar to turbulent transition for the sides of rotors case occurs at a Reynolds number of 158 000. For the seal gap case, the critical Reynolds number is a function of the ratio of gap clearance to rotor outer radius, that is,

$$Re_c = \frac{366.34}{\left(\frac{S}{r_o}\right)^{1019}}$$

Derivation of Equations for the Rotor Coefficients

The Reynolds analogy (ref. 14)

$$Nu = \frac{C_f Re Pr^{1/3}}{2} \tag{D1}$$

requires an expression for the wall shear stress τ_t because the skin friction coefficient

$$C_f = \frac{2\tau_t}{\rho V_\infty^2} \tag{D2}$$

The torque coefficients C_M obtained in reference 13 are, in effect, functions of τ_t; that is

$$C_M = \frac{8\pi}{\rho\omega^2 a^5} \int_0^a r^2 \tau_t \, dr \tag{D3}$$

A general form of the equation for shear stress in a pipe (ref. 14, p. 509)

$$\tau_t = A\rho^v \omega^w r^x \nu^y s^z \tag{D4}$$

is used to obtain the following expression for the torque coefficient:

$$C_M = \frac{8\pi A}{3 + X} \frac{\rho^{v-1} \nu^y s^z}{\omega^{2-w} a^{2-x}} \tag{D5}$$

This is matched with an empirical equation from reference 13 to evaluate the constant A and the coefficients of the properties. Substitution in equations (D4), (D2), and (D1) gives an expression for the Nusselt number. The heat transfer coefficient h is a factor of the Nusselt number; that is,

$$Nu = \frac{hr_{av}}{k}$$

The free stream velocity V_∞ must still be evaluated. For the seal gap with merged boundary layers, $V_\infty = r\omega/2$. For the case of separated boundary layers, the difference between the free stream velocity and the rotor velocity is required for a rotating part. For a nonrotating part, of course, the difference is the free stream velocity $V_\infty = \beta r$. Information in reference 13 indicates that β is a function of the rotor angular velocity and the ratio s/a, or that $\beta = K\omega$ where $K = F(s/a)$. Evaluating the data presented yields the following expressions for K (the coefficient equation can be expressed in terms of K, see table I):

$$\left.\begin{aligned} K_{stator} &= 0.50185 - 0.6508\left(\frac{s}{a}\right) \\ K_{rotor} &= 0.49815 + 0.6508\left(\frac{s}{a}\right) \end{aligned}\right\} \text{laminar flow}$$

$$\left.\begin{aligned} K_{stator} &= 0.48558 - 0.35778\left(\frac{s}{a}\right) \\ K_{rotor} &= 0.51442 + 0.35778\left(\frac{s}{a}\right) \end{aligned}\right\} \text{turbulent flow}$$

APPENDIX E

SAMPLE THERMAL PROBLEM FOR COMPARISON WITH EXACT SOLUTION

To demonstrate the accuracy of the program, the following sample problem (see fig. 15) was solved.

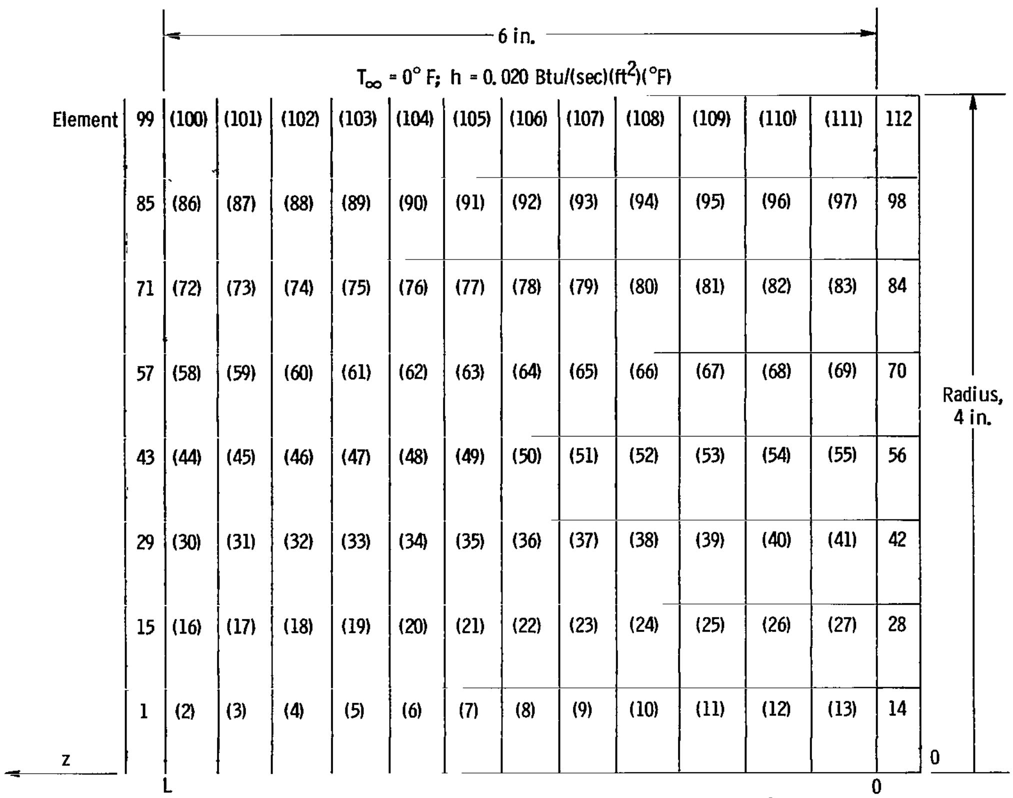

Figure 15. - Thermal sample problem. Solid cylinder with right end (z = 0) held at 200° F and left end (z = L) held at 0° F. Right side boundary elements (i.e., 14, 28, 42, 56, 70, 84, 98, and 112) held at 200° F. Left side elements held at 0° F.

For the finite cylinder with $0 \leq r \leq a$ and $0 \leq z \leq L$,

$$z = 0 \text{ held at } 200^{\circ} \text{ F (366 K)}$$

$$z = L \text{ held at } 0^{\circ} \text{ F (255 K)}$$

Forced convection into a medium at $T_{\infty} = 0^{\circ}$ F (255 K) occurs at $r = a$.

For an exact solution, the temperature has to satisfy the following equation for an isotropic homogeneous solid:

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial z^2} = 0 \qquad 0 \le r \le a,\ 0 \le z \le L$$

which is subject to the following boundary conditions:

$$T = 0^{\circ}\ \mathrm{F}\ (255\ \mathrm{K})\ \text{at}\ \ z = L\ \ \text{and}\ \ 0 \le r \le a$$

$$T = 200^{\circ}\ \mathrm{F}\ (366\ \mathrm{K})\ \text{at}\ \ z = 0\ \ \text{and}\ \ 0 \le r \le a$$

$$k\frac{\partial T}{\partial r} + hT = 0\ \ \text{at}\ \ r = a\ \ \text{and}\ \ 0 < z < L$$

If the following definitions are used:

J_o Bessel function of first kind, zero order

J_o' derivative with respect to its arguments

α root of equation $\alpha J_o'(\alpha a) + h_c J_o(\alpha a) = 0$

the exact solution is given by

$$T = T_{\infty} \sum_{n=1}^{\infty} \frac{2h_c J_o(r\alpha_n)\sinh\left[(L - z)\alpha_n\right]}{a\ h_c^2 + \alpha_n^2\ J_o(a\alpha_n)\sinh(L\alpha_n)} \tag{E1}$$

For the numerical solution, a coarse mesh of 112 elements was chosen. As indicated in figure 15, the 96 elements between $z = 0$ and $z = L$ had 0.5-inch (1.27-cm) radial and axial dimensions. The 16 elements constituting boundary conditions had 0.25-inch (0.635-cm) axial dimensions.

The temperatures were calculated by means of the program and of equation (E1). The following values were required to obtain solutions:

a = 4.0 in. (10 cm) $\qquad h_c$ = 0.020 Btu/(sec)(ft^2)(^{o}F); 0.0098 cal/(sec)(cm^2)(^{o}C)

L = 6.0 in. (15 cm) $\qquad$ k = 0.00361 Btu/(sec)(ft)(^{o}F); 0.0537 cal/(sec)(cm)(^{o}C)

The results are shown in figure 16 and table III. The maximum error using this coarse mesh is 15 percent. A finer mesh would be expected to show a lesser error.

(Element)	(99)	(100)	(101)	(102)	(103)	(104)	(105)	(106)	(107)	(108)	(109)	(110)	(111)	(112)
Exact solution	0	2.71	8.23	14.09	20.55	27.90	36.50	46.81	59.50	75.54	96.55	125.55	169.61	200
Program solution		2.57	7.26	12.94	19.22	26.41	34.90	45.17	57.91	74.15	95.52	124.98	163.09	
	(85)	(86)	(87)	(88)	(89)	(90)	(91)	(92)	(93)	(94)	(95)	(96)	(97)	(92)
	0	3.23	9.81	16.80	24.48	33.19	43.33	55.42	70.11	88.35	111.44	141.15	178.86	200
		3.11	8.65	15.39	22.84	31.34	41.34	53.36	68.12	86.59	110.16	140.81	175.96	
	(71)	(72)	(73)	(74)	(75)	(76)	(77)	(78)	(79)	(80)	(81)	(82)	(83)	(84)
	0	3.70	11.23	19.21	27.95	37.82	49.23	62.66	78.72	98.13	121.68	149.99	182.68	200
		3.55	9.87	17.54	25.99	35.60	46.82	60.18	76.33	96.06	120.32	150.00	180.94	
	(57)	(58)	(59)	(60)	(61)	(62)	(63)	(64)	(65)	(66)	(67)	(68)	(69)	(70)
	0	4.10	12.45	21.27	30.90	41.71	54.09	68.49	85.39	105.30	128.59	155.30	184.74	200
		3.92	10.88	19.32	28.59	39.09	51.25	65.58	82.62	102.98	127.19	155.50	183.40	
	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)	(56)
	0	4.43	13.44	22.94	33.28	44.80	57.90	72.95	90.34	110.38	133.22	158.65	185.99	200
		4.21	11.68	20.72	30.62	41.77	54.62	69.60	87.19	107.81	131.73	158.87	184.78	
	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)
	0	4.67	14.19	24.20	35.06	47.10	60.69	76.16	93.82	113.84	136.25	160.77	186.77	200
		4.41	12.24	21.70	32.04	43.65	56.95	72.35	90.25	110.96	134.58	160.89	185.58	
	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
	0	4.84	14.69	25.04	36.24	48.62	62.52	78.23	96.02	115.99	138.10	162.03	187.22	200
		4.53	12.57	22.28	32.88	44.75	58.30	73.93	91.99	112.71	136.13	161.97	186.00	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	0	4.93	14.94	25.47	36.83	49.37	63.42	79.25	97.08	117.02	138.97	162.62	187.41	200
		4.57	12.68	22.47	33.15	45.11	58.75	74.45	92.55	113.27	136.63	162.31	186.14	

Figure 16. - Thermal sample problem showing thermal distribution.

TABLE III. - THERMAL SAMPLE PROBLEM COMPARISON WITH EXACT SOLUTION

Element number	Exact temperature, ^{o}F	Calculated temperature, ^{o}F	Percent error	Element number	Exact temperature, ^{o}F	Calculated temperature, ^{o}F	Percent error
2	4.925	4.571	7.19	58	4.097	3.920	4.32
3	14.943	12.682	15.13	59	12.448	10.883	12.57
4	25.465	22.471	11.76	60	21.270	19.322	9.16
5	36.830	33.150	9.99	61	30.903	28.592	7.48
6	49.372	45.109	8.63	62	41.707	39.088	6.28
7	63.415	58.746	7.36	63	54.087	51.250	5.25
8	79.246	74.446	6.06	64	68.487	65.576	4.25
9	97.082	92.548	4.67	65	85.394	82.621	3.25
10	117.018	113.272	3.20	66	105.298	102.978	2.20
11	138.969	136.631	1.68	67	128.585	127.185	1.09
12	162.620	162.308	.19	68	155.300	155.304	.13
13	187.408	186.137	.68	69	184.744	183.395	.73
16	4.841	4.532	6.38	72	3.695	3.552	3.87
17	14.691	12.573	14.42	73	11.230	9.868	12.13
18	25.044	22.281	11.03	74	19.210	17.536	8.71
19	36.240	32.876	9.28	75	27.954	25.986	7.06
20	48.619	44.749	7.96	76	37.822	35.598	5.88
21	62.515	58.303	6.74	77	49.226	46.819	4.89
22	78.233	73.932	5.50	78	62.661	60.178	3.96
23	96.016	91.985	4.20	79	78.724	76.328	3.04
24	115.990	112.708	2.83	80	98.134	96.063	2.11
25	138.096	136.134	1.42	81	121.684	120.316	1.12
26	162.028	161.968	.04	82	149.987	150.003	.11
27	187.216	186.004	.65	83	182.681	180.937	.95
30	4.670	4.412	5.52	86	3.227	3.106	3.75
31	14.188	12.242	13.72	87	9.811	8.650	11.83
32	24.202	21.702	10.33	88	16.797	15.391	8.37
33	35.056	32.041	8.60	89	24.477	22.837	6.70
34	47.102	43.654	7.32	90	33.187	31.344	5.55
35	60.690	56.952	6.16	91	43.330	41.338	4.60
36	76.162	72.354	5.00	92	55.415	53.359	3.71
37	93.815	90.252	3.80	93	70.114	68.116	2.85
38	113.843	110.955	2.54	94	88.353	86.586	2.00
39	136.253	134.579	1.23	95	111.444	110.157	1.15
40	160.767	160.892	.08	96	141.150	140.806	.24
41	186.765	185.584	.63	97	178.863	175.963	1.62
44	4.425	4.207	4.93	100	2.705	2.574	4.84
45	13.437	11.678	13.09	101	8.227	7.260	11.75
46	22.941	20.716	9.70	102	14.091	12.941	8.16
47	33.276	30.616	7.99	103	20.551	19.220	6.48
48	44.802	41.774	6.76	104	27.899	26.411	5.33
49	57.897	54.618	5.66	105	36.497	34.896	4.39
50	72.951	69.603	4.59	106	46.814	45.168	3.52
51	90.343	87.192	3.49	107	59.503	37.913	2.67
52	110.384	107.809	2.33	108	75.544	74.148	1.85
53	133.215	131.727	1.12	109	96.548	95.518	1.07
54	158.647	158.871	.14	110	125.551	124.981	.45
55	185.989	184.781	.65	111	169.610	163.090	3.84

REFERENCES

1. Bisson, Edmond E.; and Anderson, William J.: Advanced Bearing Technology. NASA SP-38, 1964.
2. Schevchenko, Richard P.: Shaft, Bearing and Seal Systems for a Small Engine. Paper 670064, SAE, Jan. 1967.
3. Cheng, H. S.; Chow, C. Y.; and Wilcock, D. F.: Behavior of Hydrostatic and Hydrodynamic Noncontacting Face Seals. Paper 67-WA/Lub-19, ASME, Nov. 1967.
4. Parks, A. J.; McKibbin, R. H.; Ng, C. C. W.; and Slayton, R. M.: Development of Main Shaft Seals for Advanced Air Breathing Propulsion Systems. Rep. PWA-3161, Pratt and Whitney Aircraft (NASA CR-72338), Aug. 14, 1967.
5. Austin, R. M.; and Fisher, M. J.: A Hydrostatic Seal for Boiler Feed Pumps. Paper E-4, 2nd International Conference on Fluid Sealing, the British Hydromechanics Research Association, Apr. 1964.
6. Ludwig, Lawrence P.; Strom, Thomas N.; Allen, Gordon P.; and Johnson, Robert L.: Improving Performance of Face Contact Seal in Liquid Sodium (400° to 1000° F) by Incorporation of Spiral-Groove Geometry. NASA TN D-3942, 1967.
7. Johnson, Robert L.; and Ludwig, Lawrence P.: Shaft Face Seal with Self-Acting Lift Augmentation for Advanced Gas Turbine Engines. NASA TN D-5170, 1969.
8. Carslaw, H. S.; and Jaeger, J. C.: Conduction of Heat in Solids. Second ed., Clarendon Press, Oxford, 1959.
9. McAdams, William H.: Heat Transmission. Third ed., McGraw-Hill Book Co., Inc., 1954.
10. Kreith, Frank: Principles of Heat Transfer. International Textbook Co., 1958.
11. Jakob, Max: Heat Transfer. Vol. I. John Wiley & Sons, Inc., 1949.
12. Tachibana, Fujio; and Fukui, Sukeo: Convective Heat Transfer of the Rotational and Axial Flow Between Two Concentric Cylinders. Bull. Japan Soc. Mech. Eng., vol. 7, no. 26, 1964, pp. 385-391.
13. Daily, J. W.; and Nece, R. E.: Chamber Dimension Effects on Induced Flow and Frictional Resistance of Enclosed Rotating Disks. J. Basic Eng., vol. 82, no. 1, Mar. 1960, pp. 217-232.
14. Schlichting, Hermann (J. Kestin, trans.): Boundary Layer Theory. Fourth ed., McGraw-Hill Book Co., Inc., 1960.

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