MASTER

Gulf General Atomic
Incorporated

AEC RESEARCH AND
DEVELOPMENT REPORT

GA-8868
UC-32,
MATHEMATICS AND
COMPUTERS

TAC2D

A GENERAL PURPOSE TWO-DIMENSIONAL
HEAT TRANSFER COMPUTER CODE

- USER'S MANUAL -

by

J. F. Petersen

Prepared under
Contract AT(04-3)-167
Project Agreement No. 17
for the
San Francisco Operations Office
U.S. Atomic Energy Commission

6 September 1969

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Printed in the United States of America

Available from

Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U. S. Department of Commerce
Springfield, Virginia 22151

Price: Printed Copy \$3.00; Microfiche \$0.65

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P. O. Box 608, San Diego, California 92112

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Prepared under
Contract AT(04-3)-167
Project Agreement No. 17
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San Francisco Operations Office
U.S. Atomic Energy Commission

Gulf General Atomic Project 317.1801

6 September 1969

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The TAC2D computer code is described herein as it existed on September, 1969. The code has been in continuous development for 2 years and in its presented form has been applied successfully by Gulf General Atomic Incorporated to the kind of problems discussed later in this report. However, the development and improvement of the code are being continued, so that duplication of results (or even close agreement) between problems run with the code as published and the code as it existed either before or after this time is not necessarily to be expected.

Gulf General Atomic has exercised due care in preparation but does not warrant the merchantability, accuracy, and completeness of the code or of its description contained herein. The complexity of this kind of program precludes any guarantee to that effect. Therefore, any user must make his own determination of the suitability of the code for any specific use, and of the validity of the information produced by use of the code.

ABSTRACT

TAC2D is a code for calculating steady-state and transient temperatures in two-dimensional problems by the finite difference method. It is written entirely in Fortran V. The configuration of the body to be analyzed is described in the rectangular, cylindrical or circular (polar) coordinate system by orthogonal lines of constant coordinate called grid lines. The grid lines specify an array of nodal elements. Nodal points are defined as lying midway between the bounding grid lines of these elements. A finite difference equation is formulated for each nodal point in terms of its capacitance, heat generation and heat flow paths to neighboring nodal points. A system of these equations is solved by an implicit method which is the most efficient known at this time.

Some advantages of the code are:

1. The geometrical input is simple.
2. The input of thermal parameters is by Fortran V arithmetic statement functions. Many of the calculation variables (time, local temperature, local position, etc.) are available for use in these functions.
3. Internal and external flowing coolants may be used.
4. There may be internal and external thermal radiation.
5. There is a wide selection of optional output.

The principal limitations of the code are:

1. The grid line system must be orthogonal in the rectangular, cylindrical or circular coordinate system. Therefore, the sides of the nodal elements must also be orthogonal. The entire problem must be bounded by four grid lines in one of the coordinate systems. Difficulties in treating irregular

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4

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boundaries can be overcome to some extent through the use of materials having specially chosen properties.

2. All radiation is treated one-dimensionally.
3. There are no provisions for thermal expansion or change of phase. Such special heat transfer situations could be included by extensions of the existing programming.

TAC2D has been assigned operational status. The machine requirement is a 65K Univac 1108, or equivalent. In addition to input-output, a maximum of four and a minimum of no tapes are required depending upon the code options being used. The operating system under which the code has been successfully used is EXEC II as modified for Gulf General Atomic. Running time depends upon the size of the problem and is not easily defined.

A related code, TAC3D, is three-dimensional and has all the features of TAC2D described in this abstract. All symbolic elements, test cases, a users manual and a descriptive report are available through Argonne Code Center for each of the two codes.

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1. INTRODUCTION

The digital computer code TAC2D* was developed at Gulf General Atomic for obtaining temperature solutions in the wide variety of two-dimensional thermal systems which are encountered in the field of nuclear engineering. Code calculations are governed by the heat conduction equation:

$$\nabla \cdot k \nabla T + q''' = \frac{\partial}{\partial t} \rho c T$$

where

k is thermal conductivity, Btu/hr-ft-°F

T is local temperature, °F

q''' is volumetric heat generation rate, Btu/hr-ft³

ρ is density, lb/ft³

c is specific heat, Btu/lb-°F

t is time, hr

This equation is replaced by an equivalent set of linear finite difference equations, which is solved for the local temperatures at given points in time by the implicit numerical method given in Ref. 1. Steady-state results are found by extending a transient calculation to the limit where thermal equilibrium is attained. An option is available for performing this pseudo-transient calculation as efficiently as possible. If it is used, specific heats and time increments are determined as a part of the calculation rather than being given as input. In the finite difference equations, the local value of k may be an effective overall thermal conductivity which includes the effects of convection and/or radiation.

* The acronym TAC2D stands for "Thermal Analysis Code - Two Dimensional"

The problem must be modeled within the geometry envelopes of one of the three coordinate systems shown in Fig. 1. The choice depends upon whether it is best described as a rectangle, a polar rectangle or a cylinder. The code includes provision for both internal and external coolants. Use of internal coolants is optional but coolants flowing on the four outer surfaces must always be included to describe boundary conditions by assigning appropriate values to the coolant thermal parameters. There is provision for internal thermal radiation but its treatment is one-dimensional.

The purpose of this document is to provide all information required for the use of TAC2D. The mathematical formulations used and a programmer's description of the code are given in Ref. 2.

TAC2D is actually one of two generalized heat transfer codes which have been developed at Gulf General Atomic. The other code is TAC3D which is a three-dimensional version of TAC2D and is described in Refs 3 and 4. Although the following background remarks are written with reference to TAC2D, they apply as well to TAC3D.

A code was needed which could be easily used by persons not familiar with computer science. Toward this end, care was taken to keep all input and output within the scope of engineering terminology. Also, a system of input checking and easily interpreted error messages was included. As a final step, this users manual has been prepared to provide a comprehensive guide to code application and input. The result of the above provisions is that TAC2D is a "black box" type of code in which the user should be detached from programming and computer system aspects of the problem solution.

The features most desired in codes such as TAC2D are generality, simplicity of input and economy of computer time. Generality can usually be increased only by partially sacrificing the latter two features. TAC2D was formulated under the basic philosophy of obtaining a trade-off among all three features which would be an optimum for economical solution of thermal problems typically encountered in the nuclear field.

Fig. 1. Coordinate systems

CARTESIAN COORDINATES

CIRCULAR COORDINATES

CYLINDRICAL COORDINATES*

*SHOWN IN CROSS SECTION

General purpose heat transfer codes are usually developed in terms of a network of points connected by thermal resistances. In most codes, the arrangement of these points may be purely arbitrary. A high degree of generality is obtained at the expense of input simplicity since an individual set of data must usually be supplied for each point. If, on the other hand, it is chosen to confine the problem within the geometry envelope of one of the three coordinate systems shown in Fig. 1, the input complexity may be greatly reduced. The entire geometry and subdivision can be defined by giving the coordinates of constant coordinate lines, or grid lines, such as those illustrated in the figure. If the points are defined as lying midway between adjacent grid lines, then a region of points can be established by giving the four bounding grid lines of that region. Other input data such as that required to specify the resistances can be given in condensed form by referring to these regions rather than to the individual points which they contain. The above approach was used because experience had indicated that a majority of the two-dimensional thermal systems for which temperature calculations were being performed at Gulf General Atomic could be modeled within one of the geometry envelopes shown in Fig. 1. Furthermore, the computational algorithm applied in the solution for the point temperatures is the most efficient known and could not have been used had complete generality been maintained in the arrangement of the points.

Some of the definitions and instructions which follow are presented in terms of Cartesian coordinates (Fig. 1) only. These may be translated to the other two systems by means of the following correspondences:

circular coordinates

x = radial; y = theta

cylindrical coordinates

x = radial; y = axial

2. INPUT DEFINITION

2.1 GEOMETRY AND THERMAL PARAMETERS

This section describes how the system of calculation points is established and how the sets of thermal parameters governing the behavior of these points are identified and located.

2.1.1 Grid Lines and Points

In any of the three coordinate systems shown in Fig. 1 there are two sets of grid lines which are defined as lines along which the value of one of the two coordinates remains constant. Grid lines are the primary means by which the problem is subdivided and are specified as input by giving their constant coordinate values. The two extreme value grid lines of each set are the external boundaries of the problem. The lower value of each set may, but need not, be equal to zero. No grid line may have a negative value.

The relationship of the calculation points to the grid lines is illustrated in Fig. 2. The points are of two types, internal and external. An internal point is located midway between the adjacent grid lines of either coordinate direction. The temperature calculated for the point will be the temperature at the location given by the point coordinates. An external point is located outside of an external boundary midway between the two adjacent grid lines which are normal to that boundary. The temperature calculated for an external point is the temperature of the external source or sink directly adjacent to the point. The temperatures of external points reflect local boundary conditions only.

2.1.2 Thermal Parameters

Every part of a problem is defined by one of the following sets of thermal parameters. These sets are labeled materials, coolants, and

LEGEND:

- GRID LINE
- BLOCK BOUNDARY OR EXTERNAL BOUNDARY
- DENOTES A GAP ON A BOUNDARY
- DENOTES A COOLANT FLOWING IN THE INDICATED DIRECTION
- INTERNAL POINT
- ▲ EXTERNAL BOUNDARY POINT

Fig. 2. Typical problem geometry in Cartesian coordinates

gases. Their assigned thermal parameters are:

MATERIALS

thermal conductivities in the X and Y directions
volumetric specific heat
emissivities in the +X, -X, +Y or -Y directions
volumetric heat generation rate

COOLANTS

specific heat capacity (constant pressure)
Reynolds number
heat transfer coefficient
inlet temperature
mass flow rate

GASES

thermal conductivity

Coolants are flowing coolants in that the temperatures of points in coolants are influenced by an inlet temperature, a flow rate and a specific heat. Gases (in gaps) are stagnant. Their presence serves only to modify the thermal resistances between points which are adjacent in solids. As is discussed in 2.1.5, gases contain no points.

There is provision in the program for fifteen different members in each set. They are identified by number. Each of the materials, coolants and gases used is assigned a number 1 through 15. Not all of the member numbers must be used, but two members of the same set must always be assigned different numbers whenever any of their thermal parameters are not identical.

The actual values of the thermal parameters are given by Fortran V arithmetic statement functions as described in Section 2.5.

2.1.3 Boundaries and Blocks

The highest and lowest index value grid lines in either coordinate direction (a total of four) are always the external boundaries of the problem as previously discussed in 2.1.1. Either all or a part of any other grid line may be designated to be a boundary. The primary purpose of these boundaries is to subdivide the problem into regions which have the same thermal parameters. These regions are called blocks. Blocks and boundaries are illustrated in Fig. 2. A block is described by giving the values of its high and low index boundaries in both coordinate directions and defining its thermal parameters.

Blocks are either internal or external. A block is internal if none of its boundaries are coincident and it contains only internal points. It is external if either of its two boundaries in the same coordinate direction (i.e. high X, low X, or high Y, low Y) are coincident and it contains only external points. Internal blocks may contain either materials or coolants. External blocks may contain only coolants. They are used to specify the boundary conditions of the problem in terms of the thermal parameters given for the coolants which they contain.

2.1.4 Coolant Blocks

Coolant block temperatures are determined by finite difference solution of the heat balance equation

$$dq = WC_p dT_c$$

where

q is heat transferred to the coolant from adjacent material points, Btu/hr

W is coolant mass flow rate, lb/hr

C_p is coolant specific heat capacity (constant pressure), Btu/lb-°F

T_c is coolant temperature, °F

Coolants may flow parallel to either of the two coordinate axes as illustrated in Fig. 2. The flow direction may be either positive (in the direction of increasing coordinate value) or negative. Coolants may also flow normal to the plane of the problem as illustrated in Fig. 3. In this case the sign of the flow direction is immaterial.

Perfect mixing is assumed for all coolants. Therefore, all points lying on the same plane perpendicular to the flow direction in an internal coolant block will be at the same temperature.

Heat transfer in coolant blocks occurs only at the block boundaries which are parallel to the flow direction and only in a direction perpendicular to the boundary at which heat is being transferred. For external blocks the heat transfer is by convection at the external boundaries of the problem. For internal coolant blocks it is by convection at the block boundaries and by radiation between opposite block boundaries. The radiation is calculated one-dimensionally on the basis of the equations

$$\frac{q_r}{A} = \mathfrak{F}_{1-2} \sigma (T_1^4 - T_2^4) ; \quad \mathfrak{F}_{1-2} = \frac{1}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1}$$

where

q_r is heat transferred by radiation from surface 1 to surface 2, Btu/hr

A is area of the heat transfer surface located at the lowest value of the coordinate perpendicular to the direction of radiant heat flow, ft^2

T_1 is temperature of surface 1, $^{\circ}\text{R}$

T_2 is temperature of surface 2, $^{\circ}\text{R}$

σ is Stefan-Boltzmann constant, $.1713 \times 10^{-8} \text{ Btu/hr-ft}^2\text{-}^{\circ}\text{R}^4$

$\mathfrak{F}_{1-2}$ is overall radiant interchange factor between surfaces 1 and 2, dimensionless

ϵ_1 is emissivity of surface 1, dimensionless

ϵ_2 is emissivity of surface 2, dimensionless

TYPICAL PROBLEM WHERE
1 INTERNAL AND 2 EXTERNAL
COOLANT BLOCKS FLOW IN
THE NORMAL DIRECTION

LEGEND:

- /// DENOTES AN INTERNAL OR EXTERNAL COOLANT BLOCK HAVING NORMAL FLOW
- ↑ DENOTES A COOLANT FLOWING IN THE INDICATED DIRECTION
- GRID LINE
- BLOCK BOUNDARY OR EXTERNAL BOUNDARY
- INTERNAL POINT
- ▲ EXTERNAL POINT

NOTES:

1. ONLY THE POINTS IN THE NORMAL FLOW COOLANT BLOCKS ARE SHOWN.
2. THE DIMENSION H IS THE DEPTH OF THE PROBLEM IN THE NORMAL PLANE. H MUST BE SPECIFIED FOR ALL PROBLEMS CONTAINING NORMAL FLOW COOLANTS.
3. COOLANTS WITH NORMAL FLOWS ARE ALLOWED ONLY WHEN RECTANGULAR OR CIRCULAR GEOMETRY IS SPECIFIED.

Fig. 3. Coolant flows in the normal direction

2.1.5 Gaps

On boundaries between adjacent material blocks, narrow open spaces or gaps may be defined as illustrated in Fig. 2. These gaps contain the gases previously discussed. A gap is specified on the high boundary of a material block in either coordinate direction by giving its thickness and the number of the gas which it contains. It is implied that a gap is narrow because its thickness should be less than the distance between the boundary and the points adjacent to that boundary.

Heat transfer across a gap is by radiation between its surfaces and by conduction through the gas. This heat transfer is purely one-dimensional. Radiation is calculated on the basis of the same equations as given in 2.1.4 for coolant blocks. A gap contains no points and its lower surface is neither a grid line nor a boundary. A gap is used only to define the thermal resistance which is added in series to that associated with conduction between adjacent points. In performing the calculation for points adjacent to a gap it is assumed that over its thickness the gap has actually replaced the block material. Heat generation, thermal resistance and capacitance in the block material are adjusted accordingly.

2.1.6 Gap Lines

A gap line is defined as a boundary any portion of which bounds a coolant block, or along any portion of which there is a gap. From this definition, it follows that the external boundaries are always gap lines.

2.2 INITIAL TEMPERATURES

Since a transient calculation is always performed, the temperatures of the points must be given at the initial time of the calculation.

2.2.1 Specified Initial Temperatures

Regions enclosing points having the same initial temperatures may easily be defined. This is done by giving the values of the bounding grid lines and the initial temperature. The regions are of two types depending upon whether they contain internal or external points.

An internal point region is always located by four different grid line values. There may be as many such regions as there are internal points or there may be as few as one. Every internal point must be part of some region.

An external point region is located by four grid lines, two of which are coincident and are an external boundary. There may be as many external point regions as there are external points in the problem. All external points need not be included in a region, but those which are not are automatically assigned an initial temperature of 460°R.

2.2.2 Previously Punched Temperatures

If the calculation for a problem is run up to a certain point in time, results at this time may be punched on cards as part of the output. These results include all point temperatures, coolant terminal temperatures and the time. This deck may be used as initial temperature input for a succeeding problem. When so used, it will supersede the specified values described in 2.2.1. The basic purpose of the punched output is to enable a long calculation to be performed in several computer runs. However, the punched output of one problem may be used in another problem so long as both have the same number of points in both coordinate directions.

2.3 THE TIME VARIABLE

2.3.1 Initial Time Value

The time scale begins at zero if the initial temperatures are specified by regions as described in 2.2.1. If a deck of previously punched temperatures is being used, the time scale begins at the time indicated in hours on the first card of the deck. This time may be changed to zero or any other desired value by re-punching the card.

2.3.2 Time Incrementation

The time scale of the problem is broken down into finite increments called time steps. The array of point temperatures is calculated at times corresponding to the ends of each of these time steps. The calculation for each time step is called an iteration. Groups of equal and adjacent time steps are called time periods. The time incrementation of the problem is specified by giving the end of each time period and the value of the time step which is to be used within it. The beginning of the first time period is the initial time value discussed in 2.3.1.

In performing the calculation, the current time (i.e. the time corresponding to the end of the current iteration) is determined as

$$\begin{array}{l} \text{current} \\ \text{time} \end{array} = \begin{array}{l} \text{initial time} \\ \text{value} \end{array} + \sum \begin{array}{l} \text{all preceeding} \\ \text{time steps} \end{array} + \begin{array}{l} \text{current time} \\ \text{step} \end{array}$$

Within any time period, the time step given for that period is used until the current time equals or exceeds the specified end of the period. Therefore, if the length of a time period is not exactly divisible by its time step, the remainder is replaced by one whole time step and the end of the current period is accordingly moved forward from its specified value.

2.3.3 Initial Iteration

Some values within the program are initialized on the first iteration of a problem. This first iteration is always performed before the input time steps are recognized and is over an extremely small time

step of 10^{-10} seconds. It is not included in the iteration count. It is included in determining the current location on the time scale but its effect should be negligible.

2.4 THE STEADY-STATE OPTION

Steady-state results are found by performing a transient calculation for a sufficient number of iterations to attain thermal equilibrium. This may be accomplished entirely under the user's control by solving a pseudo-transient problem wherein arbitrary values of the time steps and the volumetric specific heats of the materials are given as input. Generally, however, the user does not have sufficient information to select values which will produce the steady-state solution efficiently. If, for any given set of specific heats, the time steps are chosen too large, then the unstable condition described in Section 5.1 develops. The problem is terminated and another attempt at its solution must be made using smaller time steps. If the time steps are chosen too small, then an excessively large number of iterations may be required to reach equilibrium.

The inefficiencies described above can generally be avoided by using the steady-state option. Time steps and material specific heat functions need not be given as input. Instead, values designed to affect rapid convergence are calculated within the code. The following steps are carried out for each steady-state iteration:

1. Determine a specific heat value for each material point.
These values are chosen such that all material points will tend to have approximately the same stability characteristics in the solution for material point temperatures.
2. Assign the time step according to an increasing function of time step versus number of iterations performed. Assign a value of one hour for the initial time step.
3. Solve for all temperatures.

4. Inspect the temperature results for instability as evidenced by negative or extremely large values. If instability is found, reduce the time step by a factor of two. Allow no further increase in step 2 above.

Residuals are checked at regularly spaced intervals of completed iterations. The value of the residual, R , for a material point is

$$R = \frac{qc}{qk_1 + qk_2 + qk_3 + qk_4 + qg}$$

where all terms on the right hand side are absolute values at the point and

qc is rate of heat storage, Btu/hr

qg is rate of heat generation, Btu/hr

qk_1 through qk_4 are rates of heat conduction from the point to each of its four neighboring points, Btu/hr

The steady-state iterations are terminated when the residual at every material point is less than 10^{-4} , a value based on experience. Points contained in certain classes of dummy materials are not considered either in setting specific heats or in checking residuals for convergence. Such materials require special identification as described in 4.1.1.

Upon completion of the steady-state iterations, a series of twenty smoothing iterations is performed. Specific heats remain fixed at their last computed values while the time step is reduced by a factor of ten and held constant. The purpose of the smoothing iterations is to eliminate any small oscillations which may be present at the time convergence is attained.

Temperature results are printed for the last steady-state iteration and for every fifth smoothing iteration. It is important to inspect these results for any evidence of instability. Residuals are printed for the last smoothing iteration. These should always be inspected to insure that no values have increased to greater than 10^{-4} during the smoothing iterations.

2.5 THERMAL PARAMETER FUNCTIONS

The actual values of the thermal parameters discussed in 2.1.2 are given by Fortran V arithmetic statement functions. These functions are inserted into the program by recompiling two subroutines, MADATA and FLODAT each time a problem is run. The functions for materials and gases are inserted into MADATA, and those for coolants are inserted into FLODAT. On the Univac 1108 computer system, it has been found that the cost of recompiling these subroutines is generally not a controlling factor in establishing the total cost of a TAC2D computer run.

2.5.1 Function Names

The function names contain the basic name of the thermal parameter being defined, the member number within the material, coolant or gas set and a dummy argument X. The names and definitions of the functions which may be specified for each of the three sets are given below. The dash indicates any of the integers 1 through 15 representing the member numbers. Members of the same set must be assigned different numbers whenever any of their corresponding thermal parameters cannot be defined identically. For coolants, the signed flow direction number is a thermal parameter within the scope of this restriction.

MATERIALS

<u>Function Name</u>	<u>Definition</u>	<u>Units</u>
RCØN - (X)	thermal conductivity in the X (or radial) direction	Btu/hr-ft-°R
ACØN - (X)	thermal conductivity in the Y (or theta, or axial) direction	Btu/hr-ft-°R
SPEC - (X)	volumetric specific heat	Btu/ft ³ -°R
EMRH - (X)	emissivity in the + X (or + radial) direction	dimensionless
EMRL - (X)	emissivity in the - X (or - radial) direction	dimensionless
EMAH - (X)	emissivity in the + Y (or + theta, or + axial) direction	dimensionless
EMAL - (X)	emissivity in the - Y (or - theta, or - axial) direction	dimensionless
HEAT - (X)	volumetric heat generation rate	Btu/hr-ft ³

COOLANTS

SPH - (X)	specific heat capacity	Btu/lb-°R
REYN - (X)	Reynolds number	dimensionless
H - A(X), H - B(X), H - C(X)	heat transfer coefficient in a specified low (A), middle (B), or high (C) range of Reynolds number	Btu/hr-ft ² -°R
TIN - A(X), TIN - B(X), TIN - C(X)	inlet temperature in a specified low (A), middle (B), or high (C) range of one of the variables time, mass flow rate or outlet temperature	°R
FLØ - A(X) FLØ - B(X) FLØ - C(X)	mass flow rate in a specified low (A), middle (B), or high (C) range of one of the variables time, outlet temperature or inlet temperature	lb/hr

GASES

<u>Function Name</u>	<u>Definition</u>	<u>Units</u>
GCØN - (X)	thermal conductivity	Btu/hr-ft-°R

2.5.2 Function Variables

The thermal parameter functions may be constants or they may be dependent upon current local values of some of the calculation variables. Definitions of these variables and their allowed uses are given below for each of the three sets.

MATERIALS

<u>Variable Name</u> [*]	<u>Definition</u>	<u>Units</u>
DR	1) temperature of a point, or 2) local temperature of a gap surface, or 3) local temperature of an internal coolant block boundary	°R
HR	Time	hr
FTR	X (or radial) coordinate of a point	ft
FTZ	Y (or theta, or axial) coordinate of a point	ft (radians for circular coordinates)

<u>Function Name</u>	<u>Allowed Variables</u> ^{**}
RCØN - (X), ACØN - (X)	DR ¹⁾ , FTR, FTZ
SPEC - (X)	DR ¹⁾
EMRH - (X) EMRL - (X)	DR ^{2),3)} , FTZ
EMAH - (X) EMAL - (X)	DR ^{2),3)} , FTR
HEAT - (X)	DR ¹⁾ , FTR, FTZ, HR

* For materials, DR has three different definitions depending upon the function in which it is to be used.

** DR is labeled to indicate which of its 3 above definitions apply for each function.

COOLANTS

Variable Name	Definition	Units
DR	temperature of a point in a coolant	°R
HR	time	hr
FTR	X (or radial) coordinate of a point. Only defined for coolants flowing parallel to the X (radial) axis	ft
FTZ	Y (or theta, or axial) coordinate of a point. Only defined for coolants flowing parallel to the Y (or theta, or axial) axis	ft
ST	local temperature of a coolant block boundary	°R
RE	Reynolds number at a point in a coolant	dimensionless
TIN	inlet temperature of a coolant	°R
TØUT	outlet temperature of a coolant	°R
FR	flow rate of a coolant	°R
Function Name	Allowed Variables *	
SPH - (X)	DR,FTR,FTZ,TIN,TØUT,FR	
REYN - (X)	DR,HR,FTR,FTZ,ST,TIN,TØUT,FR	
H - A(X), H - B(X), H - C(X)	DR,HR,FTR,FTZ,ST,RE,TIN,TØUT,FR	
TIN - A(X), TIN - B(X), TIN - C(X)	HR,TØUT,FR	

* FTR and FTZ are not allowed variables in functions which are used to define normal flow coolants

COOLANTS (cont)

<u>Function Name</u>	<u>Allowed Variables</u>
FLØ - A(X), FLØ - B(X), FLØ - C(X)	HR,TIN,TOUT

GASES

<u>Variable Name</u>	<u>Definition</u>	<u>Units</u>
DR	local linear average of the two surface temperatures of a gap	°R
FTR	X (or radial) coordinate of a point	ft
FTZ	Y (or theta, or axial) coordinate of a point	ft (radians for a theta coordinate)

<u>Function Name</u>	<u>Allowed Variables</u>
GCØN - (X)	DR,FTR,FTZ

2.5.3 Standard Function Values

Not all of the thermal parameters are used in every problem. Functions need not be specified for those which are not used. If no function is specified for a parameter which is used, then that parameter will automatically be set equal to a standard value as indicated below.

RCØN - (X), ACON - (X) = 10^{-6} Btu/hr-ft-°R
SPEC - (X) = 1. Btu/ft³-°R
EMRH - (X), EMRL - (X), EMAH - (X), EMAL - (X) = 10^{-6}
dimensionless
HEAT - (X) = 0.
SPH - (X) = 1. Btu/lb-°R
REYN - (X) = 0.
H - A(X), H - B(X), H - C(X) = 10^{-6} Btu/hr-ft²-°R
TIN - A(X) = 460. °R
TIN - B(X), TIN - C(X) = 0.

$$\begin{aligned} \text{FLØ} - \text{A}(X) &= 10^6 \text{ lb/hr} \\ \text{FLØ} - \text{B}(X), \text{FLØ} - \text{C}(X) &= 10^{-6} \\ \text{GCØN} - (X) &= 0. \end{aligned}$$

2.5.4 Interconnection of Coolants

Special functions may be used to define inlet temperatures such that the inlet temperature of one coolant is equal to the outlet temperature of another. As an example, the inlet temperatures of coolants 3, 5 and 2 can be defined as follows:

$$\begin{aligned} \text{TIN3A}(X) &= 560. \\ \text{TIN5A}(X) &= \text{TØ}(3) \\ \text{TIN2A}(X) &= \text{TØ}(5) \end{aligned}$$

The result is that in the A, or low range of inlet temperature, the inlet of coolant 3 is 560.°R, the inlet of 5 is the outlet of 3 and the inlet of 2 is the outlet of 5. As few as two and as many as all fifteen coolants may be interconnected in the manner illustrated. Although the example is for the A range of inlet temperature such interconnections may also be made for the B and C range functions. The blocks containing the interconnected coolants need not necessarily be adjacent. Extreme caution should be used when coolants are interconnected for a transient calculation. A large truncation error can be developed if the time steps are not taken sufficiently small. The error is discussed in 5.2.2.2.

2.5.5 Function Control Constants

The need to recompile Subroutines MADATA and FLODAT for each different set of thermal parameters imposes a limitation on using the computer to do several different problems, or consecutive cases, in one run. This limitation is partially overcome by the availability of the function control constants A1 through A18 which may be used in the parameter functions. A typical use of these constants is illustrated by the example given below.

Subroutine MADATA:

$$RCON3(X) = A5*(function\ 1) + A9*(function\ 2)$$

Problem inputs:

<u>Problem No.</u>	<u>A5</u>	<u>A9</u>
1	1.	0.
2	0.	1.

Effectively, $RCON3(X)$ = function 1 for problem 1 and $RCON3(X)$ = function 2 for problem 2.

2.5.6 Additional Arithmetic Statement Functions

Additional functions may be defined and used in one or more of the thermal parameter functions. They are arithmetic statement functions containing the dummy argument X. Their use is illustrated in Appendix B. If an additional function is used in material and gas functions and also in coolant functions, it must be inserted into both Subroutines MADATA and FLODAT.

2.5.7 Function Subprograms

Some desired thermal parameter formulations cannot easily be expressed by the exclusive use of arithmetic statement functions. Step functions are an example. In such cases, function subprograms which contain any legitimate Fortran operations may be used as illustrated in Appendix C.

3. OUTPUT AND OUTPUT CONTROL

3.1 GENERAL

The initial pages of a problem output contain a description of the problem, mostly in tabular form. Also, the input cards are printed, one card per line, to insure the exact reproducibility of the input at a later date. Examples of printed output are available in the example problem of Appendix H. Most of the calculation results are presented as matrices of point conditions. Values for individual points are located by index numbers printed along the edges of the matrices. The coordinate value corresponding to each index is given in the problem description. The extreme high and low index values in either coordinate direction represent the external points.

3.2 BASIC OUTPUT

The basic output is matrices of the temperatures at all calculation points with each matrix corresponding to a given point in time. Printed with each matrix are the terminal temperatures and flow rates of the coolants. If the time steps of a problem are given as input, then the frequency of iterations for which basic output will be printed is also given as input. If the problem is being run under the steady-state options, basic output will be printed only for the smoothing iterations described in Section 2.4 and then only for every fifth of these. Basic output will always be printed for the final iteration of a problem regardless of the method under which the calculation is being performed.

All basic output values are converted to integers before they are printed. Temperatures are converted from their calculated real values, RTR, in °R to integers, ITF, in °F by means of the following expression

$$ITF = RTR - 459.5$$

The result is that remainders greater than or equal to $.5^{\circ}\text{R}$ are rounded upward while those less than $.5^{\circ}\text{R}$ are rounded downward.

In materials, a point temperature is the calculated temperature of the material at the location given by the coordinates of the point. In coolants, a point temperature is a mean effective coolant temperature evaluated over the interval between the two grid lines which bound the point and are normal to the flow direction. The mean effective value is that calculated for the condition of constant wall (or adjacent material block boundary) temperatures over the interval. Therefore, the location of a coolant point temperature along the flow direction is not exactly that given by the point coordinate. However, unless the grid lines are very widely spaced along the flow direction, locating the coolant temperatures by the point coordinates is sufficiently accurate for most engineering purposes.

In the case of a point in a normal flow coolant, the temperature printed is also a mean effective value based on the constant wall temperature condition. Here, however, the interval of evaluation is the specified depth normal to the plane of the problem.

3.3 AUXILIARY OUTPUT

3.3.1 Overlay

To facilitate interpretation of basic output, an overlay form is always printed. The boundaries are outlined by series of the following symbols:

- boundary with gap adjacent
- * boundary with coolant adjacent
- boundary with no gap or coolant adjacent

A scale is used which will cause the lines generated to fall between the appropriate point temperatures in a basic output matrix. This diagram can be traced onto a sheet of transparent paper which can then be laid over any basic output matrix. The resulting display contains no dimensional

information but is useful for a quick qualitative evaluation of results.

3.3.2 Overall Heat Balance

An overall problem heat balance is always printed for the last iteration of a problem. The volumetric heat generation rate for each material block and the heat gained or lost by each coolant block is itemized. The two quantities are totaled separately. The totals should approach equality as thermal equilibrium is attained. There are exceptions, particularly in problems where dummy materials having extremely high specific heats are used. However, if the two totals differ appreciably, a steady-state solution should not be assumed unless some acceptable explanation can be found.

3.3.3 Residuals

When the steady-state option is being used, a matrix of residuals for all points in the problem will always be printed. If convergence is obtained, the residuals will be those corresponding to the last smoothing iteration. If convergence is not obtained, the last available values are printed.

Residuals for coolant points and certain dummy material points are not considered in determining convergence. Zeros are printed for the residuals at these points.

3.4 OPTIONAL OUTPUT

There are six types of optional output which are described below. Some of the optional output quantities reflect a depth normal to the plane of the calculation. If the problem contains a normal flow coolant, this depth is the value H described in 2.1.4 and Fig. 3. Otherwise, it is 1 foot.

3.4.1 Decimal Temperatures

All basic output is printed in floating point numbers rather than integers. The calculated temperatures, RTR, in °R are converted to the printed values, RTF, in °F by means of the following expression

$$RTF = RTR - 460.0$$

Even when the decimal temperature option is not used, basic output in floating point numbers as well as in integers will be printed for the last iteration of the problem.

3.4.2 Geometry Factors, Effective Conductivities and Effective Conductances

The heat rate between points 1 and 2 in either coordinate direction is given by

$$q = K (T_1 - T_2)$$

where q is heat rate, Btu/hr

T is point temperature, °F

K is thermal conductance, Btu/hr-°F

K may be factored

$$K = (G)(C)$$

where G is component of K which depends purely on geometry, ft

C is component of K which depends on temperatures and
thermal parameters, Btu/hr-ft-°F

G is called the geometry factor. C is called the effective conductivity.

G , C , and K in each of the two coordinate directions are printed as matrices of point values. The value given for a point is the value between that point and its next higher indexed neighbor. C and K may be printed either for the last iteration only or for all iterations where basic output is printed.

If the option of printing G is used, node volumes will also be printed as a matrix of the volumes associated with each of the points.

3.4.3 Heat Rates and Heat Fluxes

The heat rates defined in 3.4.2 and the associated heat fluxes are printed in the same form as the effective conductivities. The heat fluxes, q'' , are determined from the heat rates by

$$q'' = \frac{q}{A}$$

where A = heat flow area at the grid line between the points, ft^2 . Heat rates and heat fluxes may be printed either for the last iteration only or for all iterations where basic output is printed.

3.4.4 Surface Temperatures

Surface temperatures are printed as integers using the conversion previously given for the point temperatures. The values printed are the temperatures of the gap* lines which are external boundaries and the temperatures of the portions of gap lines which are adjacent to gaps or coolant blocks. This output is given as two separate matrices, one for the gap lines of each coordinate direction. The point indices of the other direction and the grid line indices of the gap lines are printed along the edges of the matrices. Both the grid line and point indices are related to their coordinate system values in a separate output tabulation.

In the case of a gap line adjacent to a gap, there are two surface temperature at any location along the gap line. They will be printed as a pair of numbers in a single matrix location. No surface temperatures are calculated over portions of gap lines which are not actually adjacent to a gap or a coolant. These locations are therefore blank in the printed matrices. Surface temperatures may be printed either for the last iteration only or for all iterations where basic output is printed.

* Gap lines are special cases of grid lines as defined in 2.1.6.

3.4.5 Punched Output

The point temperature and coolant terminal temperature results of the last iteration may be obtained as a deck of punched cards. This card deck may then be used as initial temperature input for another computer run as described in 2.2.2.

If convergence is not attained for a problem being run under the steady-state option, the last available set of temperatures will be punched automatically. For all other cases, punched temperatures are produced only if the punch option is used.

Card images of the punched temperature deck are printed in the output.

3.4.6 Tape Output

A tape containing problem geometry and temperature data may be created as a part of the output. The data and its arrangement on the tape are described in Appendix G. The tape option has been designed primarily to automate the input of code results to plotting routines.

3.5 PRINT FORMAT CONTROL

The normal format for printing output matrices is with the X (or radial) coordinate increasing from left to right across the page and Y (or theta, or axial) coordinate increasing from top to bottom down the page. An option is available through which the latter directions can be reversed so that all matrices are oriented in the first quadrant of the coordinate system being used.

3.6 SPECIAL OUTPUT

The program contains a subroutine named CUSTOM which is always called immediately after the printing of basic output. This subroutine contains all the common elements of the program but has no executable statements other than RETURN. By compiling the required Fortran

instructions into CUSTOM, calculations using the variables in common may be performed and the results printed. A list of names which must not be defined in CUSTOM is given in Appendix D.

4. INPUT FORMULATION

The input is subdivided into data groups. Instructions for formulating each of these groups are given in Section 4.1. Instructions for arranging the groups into a "ready to run" card input are given in Section 4.2. A further aid to input formulation is the input card listing given for the example problem of Appendix H.

4.1 DATA GROUPS

Card descriptions, pertinent dimensional limits and special notes applicable to setting up each of the input groups are given below. The maximum values of some of the dimensional limits are given in terms of the symbols IQ, JQ, IGQ, JGQ, and LQ. The definitions of these symbols and their assigned values are discussed in Appendix E.

4.1.1 Thermal Parameter Functions (See all of Section 2.5)

Card Description

The arithmetic statement functions are given on individual cards (and continuations if required) according to the rules of Fortran V. This data group may contain only the arithmetic statement functions described in Section 2.5, and comment cards. The group of functions for materials and gases may be arranged in any order. The group of functions for coolants may also be arranged in any order. An exception is that a statement function used on the right hand side of an equal sign must have been defined previously within that group.

Limits on the Number of Functions

No arithmetic statement functions need be given. In this case, all thermal parameters relevant to the problem will have the constant standard values defined in 2.5.3.

There may be more arithmetic statement functions than those for the 300 function names defined in 2.5.1. This can occur when additional arithmetic statement functions are used as described in 2.5.6. Therefore, the allowable maximum number of arithmetic statement functions cannot be generally specified.

NOTES:

1. Only those thermal parameters which are relevant to the problem need be defined.
2. Radiation between a set of internal coolant block boundaries will be totally excluded from the calculation whenever the emissivity of the material adjacent to either boundary is 10^{-6} (the standard function value) or less. By "totally excluded" it is meant that the calculation will be performed using an algorithm which takes no account of radiation.
3. If the steady state option is being used, the material volumetric specific heat functions, SPEC -(X), may be omitted. If included, they will have no effect on the problem results. There are exceptions to the above rule for two classes of dummy materials:
 - a) materials which are intended to retain their initial temperatures by virtue of a very high heat capacity.
 - b) materials which are intended to act as nearly perfect insulators by virtue of thermal conductivities in both coordinate directions which approach zero.

For both of the above, the function SPEC-(X) must be assigned a value of $10^6 \text{ BTU/ft}^3 \cdot ^\circ\text{R}$ or greater.

4. If the steady state option is being used, no thermal parameter function may be time dependent.

4.1.2 Titles

Each title card represents one line of title information. The title cards will be printed at the beginning of the problem output in the order of their input sequence. The first title card will be printed at the top of every output page.

Card Description

Title cards may contain any alphanumeric information in columns 1-72.

Limits

	<u>Minimum</u>	<u>Maximum</u>
Number of title cards	1	no limit

NOTES:

1. Each title card must contain at least one character in columns 1-72.

4.1.3 Indicators

Certain items of information required to define the problem and specify the desired output are given by means of the indicator words and word groups described below.

Coordinate System Indicator

One of the three coordinate systems shown in Fig. 1 must be specified by means of the following indicator word groups.

<u>Indicator</u>	<u>Coordinate System</u>
RECTANGULAR GEOMETRY	cartesian
CIRCULAR GEOMETRY	circular
CYLINDRICAL GEOMETRY	cylindrical

Option Indicators

The steady state option described in Section 2.4 and any of the output options described in Sections 3.4 and 3.5 may be specified by means of the following indicators.

<u>Indicator</u>	<u>Option</u>
STEADY STATE	Use the steady-state option; calculate the steady-state solution only.
ALL DECIMAL TEMPERATURES	Print decimal rather than integer temperatures for all iterations where basic output is printed.
RESISTANCES	Print geometry factors and node volumes.
CONDUCTIVITIES	Print effective conductivities and effective conductances for the last iteration.
ALL CONDUCTIVITIES	Print effective conductivities and effective conductances for all iterations where basic output is printed.
HEAT FLUXES	Print heat rates and heat fluxes for the last iteration.
ALL HEAT FLUXES	Print heat rates and heat fluxes for all iterations where basic output is printed.
SURFACE TEMPERATURES	Print surface temperatures for the last iteration.
ALL SURFACE TEMPERATURES	Print surface temperatures for all iterations where basic output is printed.
PUNCH	Punch temperatures for the last iteration.
TAPE	Prepare a tape containing problem geometry data and results.
INVERSE PRINT	Print all output matrices with the coordinate directions reversed as described in Section 3.5.

Card Description

There is one indicator per card, starting in column 7 and spelled exactly as given above. The cards may be arranged in any order.

Limits

The coordinate system indicator must always be given. All or none of the other indicators may be given.

4.1.4 X Grid Lines (See 2.1.1)

Each X (radial) grid line is defined by giving its coordinate value in inches.

Card Description

Give the X grid lines in ascending sequence. Use format 6E12.4. Use as many cards as required.

Limits

	<u>Minimum</u>	<u>Maximum</u>
Number of X grid lines	3	(IQ-1)

4.1.5 Y Grid Lines (See 2.1.1)

Each Y (theta, axial) grid line is defined by giving its coordinate value in inches or in degrees if circular geometry is used.

Card Description

Give the Y grid lines in ascending sequence. Use format 6E12.4. Use as many cards as required.

Limits

	<u>Minimum</u>	<u>Maximum</u>
Number of Y grid lines	3	(JQ-1)

NOTES:

1. Theta grid lines may extend over a complete circle but there will be no thermal connection between points adjacent to $\theta = 0^\circ$ and $\theta = 360^\circ$.

4.1.6 Block Information (See 2.1.3 through 2.1.6 and 2.5.1)

A block is described by the following data:

1. Material number, any of 1.0 through 15.0, for material blocks.
2. Negative coolant number, any of -1.0 through -15.0 for coolant blocks.
3. Flow direction number for coolant blocks.
4. Depth of problem, H, in inches for coolant blocks having normal flow coolants (see 2.1.4 and Fig. 3).
5. The grid line values of its boundaries given in inches or in degrees for the theta coordinate.
6. Gaps located on the high block boundaries in either coordinate direction.
 - a) gap thickness in inches, or in degrees for the theta coordinate
 - b) gas number, any of 1.0 through 15.0 for the gas contained in the gap.

The flow direction number, item 3 above, is one of the following indicators:

<u>Indicator</u>	<u>Flow direction</u>
1.0	parallel to the X (radial axis)
2.0	parallel to the Y (theta, axial) axis
3.0	normal to the plane of the problem

The indicators 1.0 and 2.0 are positive when the coolant is flowing in the positive coordinate direction. They are negative for flows of opposite direction. The indicator 3.0 is always positive since it is immaterial whether a normal coolant is flowing into or out of the plane of the problem.

Blocks must be specified such that every internal point is contained in some internal block and every external point is contained in some external block.

Card Description

The data of each block are given on a set of three cards. Format 6E12.4 is used. The sets may be arranged in any order.

First Card

columns

- 1-12 material number or negative coolant number
- 13-24 flow direction number for a coolant block; not used for a material block
- 25-36 depth of problem for coolant blocks having normal flow; not used for other coolant or material blocks
- 37-72 not used

Second Card

columns

- 1-12 low X (radial) boundary
- 13-24 high X (radial) boundary
- 25-36 low Y (theta, axial) boundary
- 37-48 high Y (theta, axial) boundary
- 49-72 not used

For external blocks, the high and low boundaries of one coordinate direction are the same and are an external boundary.

Third Card

columns

- 1-12 X (radial) gap thickness on the high X boundary
- 13-24 X (radial) gap gas number, any of 1 through 15
- 25-36 Y (theta, axial) gap thickness on the high Y boundary
- 37-48 Y (theta, axial) gap gas number, any of 1 through 15
- 49-72 not used

For any high block boundary where there is no gap, the words for the gap thickness and gas number are left blank.

<u>Limits</u>	<u>Minimum</u>	<u>Maximum</u>
Number of blocks:		
total	5	LQ
internal	1	LQ less number of external blocks
external	4	LQ less number of internal blocks
number of block boundaries in the X direction	2	(IQ-1)
number of block boundaries in the Y direction	2	(JQ-1)
number of gap lines in the X direction	2	IGQ
number of gap lines in the Y direction	2	JGQ
number of materials	1	15
number of coolants	2	15
number of gases	0	15

NOTES^{*}

1. External blocks must be specified so as to completely cover all four external boundaries. The external blocks must contain only coolants. This includes the cases of the low radial boundary at 0 inches and of the high and low theta boundaries on the coincidence of 0° and 360°.
2. Materials, gases, and coolants must be assigned different numbers whenever any of their corresponding thermal parameters cannot be defined identically. For coolants, the signed flow direction number is a thermal parameter within the scope of this limitation.

*The information in some notes was previously given in Chapter 2 and is restated here to help prevent errors in input formulation.

3. The thickness of a gap must be less than the distance between the high block boundary at which it is defined and the grid line adjacent to the low side of that boundary. This limitation is illustrated in Item a of Fig. 4. Preferably, t should be much less than $d/2$.
4. There may be no gaps on an external boundary or on a boundary adjacent to an internal coolant.
5. Two internal coolant blocks having the same flow direction may not have a common boundary which is parallel to that flow direction as illustrated in Item b of Fig. 4. Within the scope of this limitation, two flow directions are considered the same if they differ only in sign.
6. A coolant block must contain at least one grid line perpendicular to the flow direction of its coolant as illustrated in Item c of Fig. 4. An exception is a coolant block having normal flow.
7. For internal coolant blocks having a flow direction within the plane of the problem (i.e. not in the normal direction), heat transfer occurs only at the block boundaries which are parallel to the flow direction. This is illustrated in item d of Fig. 4.
8. The coolant material in an internal coolant block may have a heat transfer coefficient, $H_{--}(X)$, which is defined as a function of surface temperature ST . If two opposite boundaries of the block are separated by at least two sets of points, the temperatures of these two boundaries will be used to calculate separate heat transfer coefficients for each. If two opposite boundaries of the block are separated by only one set of points, the average of the two boundary temperatures will be used to calculate one heat transfer coefficient which is applied to both boundaries. This limitation is illustrated in Item e of Fig. 4.

(a) LIMITATION ON GAP THICKNESS

(b) LIMITATION ON ADJACENT INTERNAL COOLANTS

(c) MINIMUM GRID LINE REQUIREMENT FOR COOLANT BLOCKS

(d) ADIABATIC BOUNDARIES OF AN INTERNAL COOLANT BLOCK

(e) LIMITATION ON USING HEAT TRANSFER COEFFICIENT AS A FUNCTION OF SURFACE TEMPERATURE FOR INTERNAL COOLANT BLOCKS
H--(X) IS A FUNCTION OF ST

Fig. 4. Gap and coolant limitations

9. The same numbered coolant may not be used in two different blocks unless its specific heat is a constant value.
10. If the same numbered coolant is used in different blocks, each block will have its own inlet temperature as determined by the inlet temperature functions given for the coolant. This holds true even when the blocks are adjacent.
11. Coolant flow rates and terminal temperatures printed in the output are identified by coolant number only. If the same numbered coolant is used in two different blocks, then the results printed are those for that coolant in the block which was given last in the block description input card sequence.
12. To specify different values of problem depth, H , for different normal flow coolant blocks is meaningless. The H given for the last normal flow coolant block in the block description input card sequence will be used for the entire problem.
13. Normal flow coolants are not allowed in problems for which cylindrical geometry is specified.

4.1.7 Specified Initial Temperatures (See 2.2.1)

Each initial temperature region is specified by giving the values of its bounding grid lines in inches (or in degrees for the theta coordinate) and its initial temperature in °F. All internal points must be contained within an internal point region. Only external points for which an initial temperature other than 460°R is desired need be contained within an external point region.

Card Description

The data of each initial temperature region are given on a set of two cards. Format 6E12.4 is used. The sets may be arranged in any order.

First Card

columns

- 1-12 low X (radial) bounding grid line
- 13-24 high X (radial) bounding grid line
- 25-36 low Y (theta, axial) bounding grid line
- 37-48 high Y (theta, axial) bounding grid line
- 49-72 not used

For external point regions, one set of high and low bounding grid lines are the same and are an external boundary.

Second Card

columns

- 1-12 initial temperature of the region, °F
- 13-72 not used

Limits

	<u>Minimum</u>	<u>Maximum</u>
number of internal point regions	1	number of internal points
number of external point regions	0	number of external points

NOTES

1. If the previously punched output of another computer run is used as input, specified initial temperatures must still be given. However, the values actually used in performing the calculation will be the previously punched temperatures.
2. If the steady-state option is being used either previously punched output or specified initial temperatures must be given.

4.1.8 Coolant Limits (See 2.5.1 and 2.5.2 under coolants)

Under the coolant thermal parameter function names given in 2.5.1 it is seen that heat transfer coefficient, mass flow rate and inlet temperature each have three separate names as, for example, the names H-A(X), H-B(X) and H-C(X) assigned to the heat transfer coefficient. The purpose of these names is to permit the functions to be defined differently in three ranges of an allowed variable. The variables and the limits of their ranges are specified in this data group. An indicator, called a dependence number, is used to identify the variable for which the ranges are being given.

Card Description

The dependence numbers and limits for each coolant are given on a set of three cards. There must be one set for each coolant. Format 6E12.4 is used.

First Card

This card identifies the coolant and gives the limits for functions H-A(X), H-B(X), and H-C(X). Reynolds number is the only allowed variable. Therefore, no dependence number is required.

Columns

1-12	absolute value of coolant number
13-24	Reynolds number limit 1
25-36	Reynolds number limit 2
37-48	Reynolds number limit 3
49-60	Reynolds number limit 4
61-72	not used

The Reynolds number limits must be given in ascending sequence. All four limits must always be given even though all three function names for the heat transfer coefficient are not used. See Note 1.

Second Card

This card gives the limits for the functions FLO-A(X), FLO-B(X) and FLO-C(X) and identifies the variable for which these limits are being given. The variable is identified by assigning one of the following values to the flow dependence number:

<u>Flow dependence number</u>	<u>Meaning</u>
0.0	no limits given; only the function FLO-A(X) is to be used
1.0	the limits are values of current time in hours
2.0	the limits are values of coolant outlet temperature in °F
3.0	the limits are values of coolant inlet temperature in °F

The arrangement of values on the second card is:

columns

1-12	flow dependence number
13-24	limit 1
25-36	limit 2
37-48	limit 3
49-60	limit 4
61-72	not used

If the flow dependence number is 0.0, columns 13-72 are left blank.

Third Card

This card gives the limits for the functions TIN-A(X), TIN-B(X) and TIN-C(X) and identifies the variable for which these limits are being given. The variable is identified by assigning one of the following values to the inlet temperature dependence number:

<u>Inlet temperature dependence number</u>	<u>Meaning</u>
0.0	no limits given; only the function TIN-A(X) is to be used
1.0	the limits are values of current time in hours
2.0	the limits are values of coolant flow rate in lb/hr
3.0	the limits are values of coolant outlet temperature in °F.

The arrangement of values on the third card is:

columns

1-12	inlet temperature dependence number
13-24	limit 1
25-36	limit 2
37-48	limit 3
49-60	limit 4
61-72	not used

If the inlet temperature dependence number is 0.0, columns 13-72 are left blank.

A set of three coolant limit cards must be given for each coolant which is used in the problem. The sets may be arranged in any order.

Limits

	<u>Minimum</u>	<u>Maximum</u>
number of sets of coolant limit cards	2	15

NOTES

1. Frequently it is desired to use only one range of heat transfer coefficient for a given coolant. In this case input can be minimized by utilizing the standard value of the Reynolds number function. On the first card specify 0.0, 1.0, 2.0,

and 3.0 for Reynolds number limits 1, 2, 3, and 4, respectively. In the coolant thermal parameter function input define H-A(X) as desired. Give no definition for Reynolds number so that the standard value, REYN-(X) = 0.0 applies. The Reynolds number will always lie in the low range and the heat transfer coefficient will therefore always be defined by H-A(X).

2. The coolant inlet and exit temperature limits are given in °F. When formulating the functions FLØ-A,B,C(X) and TIN-A,B,C(X) it should be remembered that the variables TIN and TØUT, whose ranges are defined by these limits are in °R.

4.1.9 Time History (See Sections 2.3 and 3.1)

The purposes of this data group are to specify the time incrementation of the problem and to designate the iterations where basic output is to be printed. If the steady-state option is being used, this data group may be omitted. If included, it will be ignored in performing the calculation. The time incrementation is given by defining the time periods as discussed in 2.3.2. The time units used are identified by means of the following indicators:

<u>Indicator</u>	<u>Units</u>
1.0	seconds
2.0	minutes
3.0	hours

The iterations where basic output is to be printed are designated by giving a print frequency number for each time period. If the print frequency number for a time period is X.0 then basic output will be printed every Xth iteration within that period. In addition, basic output will be printed for the last iteration-performed within each time period unless the print frequency for that period is 0.0. If the print frequency for all time periods is 0.0, then no basic output will be printed except that for the very last iteration of the problem. It is recommended that the length of each time period be made exactly divisible by its time step. If this is not done, the ends of the

time periods will be adjusted as described in 2.3.2, making it difficult to obtain basic output at desired times.

Card Description

Each time period is described on a single card. Format 6E12.4 is used.

columns

1-12	end of period
13-24	time step
25-36	print frequency number
37-48	time unit indicator
49-72	not used

The cards must be arranged in ascending time sequence.

Limits

	<u>Minimum</u>	<u>Maximum</u>
number of time periods	1	20

NOTES

1. All of Chapter 5 should be read before formulating the time history input for a problem.
2. If a problem is to be continued in another computer run using previously punched temperatures, the time period cards of the preceding run may, but need not, be removed.
3. If the steady-state option is being used, the time history data group may be omitted. If time period cards are inadvertently included in the input, they will be ignored.

4.1.10 Function Control Constants (See 2.5.5)

Card Description

Give the function control constants in the sequence A1 through A18. Use format 6E12.4. Leave blank columns for any constant which is not used. There must always be three cards. They will be blank cards if no constants are used.

4.1.11 Previously Punched Temperatures (See 2.2.2, 2.3.1 and 3.4.5)

This data group is included only when it is desired to supersede the specified initial temperature input described in 4.1.7 with the point and coolant terminal temperature results of a preceding calculation. Although the required input cards are punched by the computer system, it may be desired to change individual values on these cards. Therefore, a card description is given.

Card Description

The deck punched by the computer system consists of three card sets arranged in the same order in which they are described below.

Card Set 1

There is only one card in the first card set. The format is E12.6, 3F12.1

columns

1-12	time, hours (Notes 1 and 2)
13-24	number of radial points in the problem
25-36	number of axial points in the problem
37-48	iteration number (Notes 1 and 2)

Card Set 2

The values contained in the second card set are the temperatures in °R of all the points, both internal and external, in the problem. There are as many cards as required to list all of the temperatures using format 6E12.6. The point temperature array is called T(I,J) where I is the X (radial) point index and J is the Y (theta, axial) point index. The values in the T(I,J) array are listed continuously with the index I varying most frequently.

Card Set 3

The values contained in the third card set are the coolant terminal temperatures in °R. Inlet and outlet temperatures are given for all

fifteen coolants with values of 0.0°R being given for those which are not included in the problem. Format 6E12.6 is used and it follows that there are always six cards in this set. The inlet temperatures of coolants 1 through 15 are listed in order on the first three cards and their outlet temperatures are listed similarly on the last three.

NOTES

1. The time and the iteration number given in the first card set are the values at the final iteration of the problem from which the previously punched temperatures were obtained. The time given here will be the initial time for the problem in which the previously punched temperatures are to be used. The time history data group described in 4.1.9 must contain time periods which end at times greater than this value. Both the time and the iteration number may be set to any desired value by repunching the card on which they appear.
2. If a punched temperature deck is part of the input for a problem to be run under the steady-state option, the time and iteration number must both be zero. Zeros will always be punched for these values when the punching is done under the steady-state option.
3. The previously punched temperature deck ends with five (5) blank cards. They are included to separate it from other jobs which may precede it through the punching equipment. Remove these blank cards before using the deck.

4.2 CARD INPUT FOR A COMPUTER RUN

The actual input for a computer run is set up by arranging control cards, blank cards and the previously described data groups in the sequence given below. The control cards shown are those for running on the Univac 1108 computer from a Program Complex File tape number XXXX which contains on its first file the processed map, the symbolic elements for Subroutines MADATA and FLODAT and the relocatable elements for all other code routines. The left hand margin represents column one of these control cards.

▽ ASG A=XXXX TAC2D PROGRAM TAPE
 ▽D ASG DRUM2=10000 (Note 1)
 ▽D ASG DRUM3=10000
 ▽D ASG DRUM4=10000
 ▽ XQT CUR
 IN A (Note 2)
 TRI A
 ▽P HDG THERMAL PARAMETER FUNCTIONS
 ▽INW FOR,* MADATA/S, MADATA/S, MADATA/R (Note 3)
 -20
 Material and gas thermal parameter functions (4.1.1 and Note 4)

 ▽INW FOR,* FLODAT/S,FLODAT/S,FLODAT/R (Note 4)
 -20

 Coolant thermal parameter functions (4.1.1)
 Function Subprograms if used (See Appendix C)

 ▽P HDG any alphanumeric heading in Cols. 13-72 (Note 5)
 ▽ XQT TAC2D/AR (Note 6)

 Titles (4.1.2)
 Blank Card
 Indicators (4.1.3)
 Blank Card
 X (radial) Grid Lines (4.1.4)
 Blank Card
 Y (theta, axial) Grid Lines (4.1.5)
 Blank Card
 Block Information (4.1.6)
 Blank Card
 Specified Initial Temperatures (4.1.7)
 Blank Card
 Cooland Limits (4.1.8)
 Blank Card

Time History	(4.1.9 and Note 4)
Blank Card	
Function Control Constants	(4.1.10)
Blank Card	
Previously Punched Temperatures (if used)	(4.1.11 and Note 7)
Blank Card	(Note 8)

NOTE

1. The three drum assign cards are required only when the steady-state option is being used. If they are included when the steady-state option is not being used, there will be an unnecessary computer charge for requested drum usage.
2. If subroutine CUSTOM is being used (see Section 3.6) then one additional "IN A" card (a total of two) must be included at this point. The second "IN A" card is required to bring the second file of the program tape, which contains the symbolic element for CUSTOM, into the Program Complex File.
3. The FOR cards for both Subroutines MADATA and FLODAT must always be included even in a case where no thermal parameter functions are given.
4. If the steady-state option is being used, both the material volumetric specific heat functions SPEC-(X) (except as discussed in 4.1.1, Note 3) and the time history data group may be omitted. If included, they will be ignored.
5. This heading card causes the specified heading to be printed along a single line at the top of every output page produced after program execution. Printed on the next line will be the first problem title card.
6. The name TAC2D/AR appearing on the execute card is the name of the processed map in the standard version of the code. For special versions this name may be different. The name of the execute card must be the same as the name of the processed map on the version being used.

7. The location for the previously punched temperature cards contains no cards if previously punched temperatures are not used.
8. If consecutive problems are to be run, the first title card for the second problem follows the last blank card shown above. A complete set of data (i.e. first title card through last blank card) must be given for the second and subsequent problems. The only similarity requirement among consecutive problems is that the thermal parameter functions be applicable to all. The number of consecutive problems is limited only by the specified computer running time.

4.3 PERFORMANCE OF A COMPUTER RUN

4.3.1 Execution Time and Printed Page Limits for Use with The Univac 1108 Computer

The maximum allowed execution time and the maximum number of pages of printed output must be included in the run request for a problem. A non-zero warning time may, but need not, be given. These values are specified on the computer run request.

The program calls the computer library subroutine WARN before beginning each iteration. In WARN, the elapsed running time is compared with the allowed execution time. When the difference between the two becomes less than the user specified warning time, no further iterations are performed. Instead, the program is directed to preparation of basic and specified optional output (including punched temperatures) for the current iteration. A warning time of 10 seconds should be adequate to allow for preparation of all possible output. Note that the warning time is effectively subtracted from the allowed execution time. If, for instance, warning and allowed execution times of 10 and 300 seconds, respectively are given, the time available to complete the calculation is only 290 seconds. It is good practice to give a warning time so that none of the available results will be lost if the required execution time exceeds the maximum specified.

Through use of the library subroutine PAGLIM, some provision is made for recovering results, the printing of which would fall beyond the specified maximum number of output pages. Whenever the calculation approaches a point where the page limit will be exceeded, PAGLIM is called by the program thus causing the punched output for the current iteration to be prepared.

4.3.2 Error Messages

If the calculations of a problem cannot be performed according to the logic of the code, error messages will be printed. These are of two types; system error messages and program error messages. System error messages on the Univac 1108 give a description of some abnormal condition within the computer system. An example is the words "floating point overflow at" followed by an octal number which is the instruction address where the overflow occurred. Program error messages originate from write statements within the program itself. They are printed when some rule of input formulation has been violated and when difficulty is encountered in performing the calculations. Only identifiers consisting of the subroutine name from which the message was written and the message number are printed. These identifiers are related to error descriptions in Appendix A.

5. TRUNCATION AND ROUND OFF ERRORS

5.1 STABILITY OF SOLUTION

5.1.1 Basic Considerations

The solution of the matrix of point temperatures will become unstable when the temperature change at some point is greater than that required for thermal equilibrium with its four neighboring points. The stability criterion for explicit methods of solution is

$$\Delta t_i = \frac{C_i}{\sum_{j=1}^4 K_{ji}}$$

where Δt_i is the maximum stable time step for point i, hr

C_i is the thermal capacitance of point i, Btu/°R

K_{ji} is the thermal conductance between point i and its neighboring point j, Btu/hr-°R

In TAC, an implicit method of solution is used for which the stability criterion cannot be clearly defined. It can only be stated that the stable time step is proportional to the same parameter as for an explicit formulation. That is,

$$\Delta t_i \propto \frac{C_i}{\sum_{j=1}^4 K_{ji}}$$

As will be discussed in 5.2.2.3, the temperature calculation for the points in coolants is decoupled from that for the points in materials. The implicit solution is performed only for the material point temperatures.

The coolant point temperatures are calculated after the material point temperatures and this calculation has no influence on stability. Therefore, the concept of maximum stable time step is directly applicable only to the material points.

If the time step, Δt , is sufficiently greater than Δt_i , the error due to instability at point i will appear as a diverging oscillation. Although the value of Δt at which this occurs cannot be predicted for the method of solution used in TAC2D, it will be referred to as Δt^* .

A most desirable approach to the stability problem would be to keep time steps less than the minimum value of Δt_i among all material points in the problem. This approach is not possible because Δt_i values cannot be computed beforehand for the implicit method of solution used. However, the previously stated proportionality provides some qualitative basis upon which it may be endeavored to make all Δt_i values as large as possible in designing the calculation model for any given problem.

5.1.2 Practical Approaches

In steady-state calculations, the transient solution is not of interest. Stability related errors which may occur because Δt exceeds some Δt_i are not important so long as a solution which satisfies thermal equilibrium is finally obtained. The only concern is that Δt always remain less than Δt^* so that diverging oscillations will not develop and cause the calculation to be terminated before reaching steady-state. The code includes a steady-state option which may be used to obtain steady-state solutions efficiently. Under this option, described in Section 2.4, values of Δt approaching Δt^* , are used to perform the transient calculation up to a point where the approximate steady-state solution has been reached. These values are obtained by a trial and error process wherein Δt is increased for each iteration unless current results indicate that diverging oscillations are beginning to occur. In this case, Δt is reduced.

The stability related error which is incurred when Δt exceeds Δt_i at points i is a part of the transient solution. Therefore, if the transient solution is of interest, Δt must be chosen sufficiently small

that this error becomes negligible. As previously stated, the Δt_i values cannot be calculated for the implicit method of solution used in TAC2D. However, the initial minimum value of Δt_i over the points i must be less than the initial value of Δt^* , which can be bracketed for any problem by running a time test case. The problem is run, starting at time zero, through successive time periods each of which is subdivided by a larger time step than that of the period which precedes it. A time history suggested by experience is:

<u>End of Time Period</u>	<u>Time Step</u>
.01 sec	.001 sec
0.1 sec	.01 sec
1.0 sec	0.1 sec
10.0 sec	1.0 sec
100.0 sec	10.0 sec
10.0 min	1.0 min
30.0 min	2.0 min
80.0 min	5.0 min

Within one of these time periods, diverging oscillations should develop and terminate the problem. A dump of the common element MISCXX is specified as described in Appendix F and from this dump, the time period within which the problem terminated can be identified. The time step values of this and the preceding time periods are the limits of a range within which the initial value of Δt^* should lie. It is recommended that the problem be run with time steps no greater than one-half the mean value of these two limits. If thermal parameters which determine the C_i and K_{ji} in the proportionality of 5.1.1 are strongly temperature and/or time dependent it is possible that both Δt^* and the Δt_i can decrease as the calculation progresses. In such cases, the time step value indicated above should be gradually reduced throughout the calculation. The procedure outlined above is intended only to provide an approximate estimate of the maximum time step which may be used. Assurance that errors related to stability are negligible within a transient solution can be obtained only by re-running the problem with smaller time steps until the results obtained at corresponding times do not differ appreciably.

5.2 FINITE DIFFERENCE FORMULATION

All results will contain errors because distance dependent quantities are treated as constant over finite intervals rather than as continuously distributed. Transient results contain further errors because time dependent quantities are treated in the same manner. Those sources of error which could effect calculation results most significantly are discussed below. For a more detailed discussion, see any standard reference such as Ref. 5. Errors due to all of these sources will become negligible if time steps and/or grid spacing are made sufficiently small.

5.2.1 All Results

5.2.1.1 Grid Spacing

There is always an error which is due to the fact that thermal conductances, thermal capacitances and heat sources are considered as being concentrated at the calculation points. The error cannot be described in general terms. The data of Fig. 5 provides a rough guideline for setting up the grid spacing of a problem but it should be regarded as quantitative only for the one-dimensional steady-state solution on which it is based.

5.2.2 Transient Results

5.2.2.1 Nonlinearity of Time

The heat balance equations which are solved for the material point temperatures are formulated under the assumption that these temperatures vary linearly with time over each time step. The error in the transient solution due to this assumption remains negligible only if the time steps are taken sufficiently small.

Fig. 5. TAC2D code - error in steady state centerline temperature for an infinitely long cylinder with heat generation as a function of uniform grid spacing

5.2.2.2 Evaluation of Time and Temperature Dependent Quantities

Time and temperature dependent components of the conductances, capacitances and heat sources are evaluated only once for each iteration. Time dependent quantities are evaluated at the time midpoint of the iteration. Temperature dependent quantities to be used in a given iteration are evaluated from the temperatures at the beginning of the iteration (i.e. the temperature results of the preceding iteration).

Particular caution should be used when a coolant inlet temperature is a function of a coolant exit temperature since the two will be out of phase by the amount which exit temperature changes over the current iteration. If N coolants are interconnected as discussed in 2.5.4, the inlet temperature of the Nth coolant will be N iterations out of phase with the current iteration. Large errors can be developed unless the time steps are taken appropriately small. As explained in 2.3.3, some variables have arbitrary initial values on the first iteration of a problem, and therefore, this first iteration is automatically taken over an extremely small time step. Among these variables are coolant inlet temperatures and coolant block boundary temperatures. From this and the preceding discussion, it follows that if there are N interconnected coolants, then N iterations must be performed before all have a real inlet temperature. Therefore, time step input should include N-1 extremely small (i.e. 1×10^{-10} sec time step) iterations. As explained in 2.2.2, a previously punched temperature distribution includes real initial values for coolant inlet and exit temperatures. Therefore, when previously punched temperature input is included for a problem with interconnected coolants, these additional small initial iterations are not required.

5.2.2.3 Solution for Coolant Temperatures

In solving for the temperatures of material points, the temperature variation of coolant points over the time step is neglected. The coolant point temperatures remain constant while the solution for the material points is performed. The coolant point temperatures are then calculated to satisfy a heat balance with the material points adjacent

to the coolant block boundaries. Particular attention must be given to choosing appropriately small time steps when coolant temperatures are expected to change rapidly.

The error in the solution for coolant temperatures may be intensified when there is radiation across an internal coolant block. The heat transported by radiation at an internal coolant block boundary is accounted for in the value used for the overall conductances adjacent to that boundary. Whenever radiation is present, the unit value of the overall conductance between a material point and an internal coolant point contains a component

$$h_r = \frac{\mathfrak{F}_{1-2} (T_{s1}^4 - T_{s2}^4)}{T_1 - T_{c1}}$$

where h_r is the component of overall unit conductance representing radiation,

Btu/hr ft²°R

T_1 is the temperature of the material point, °R

T_{c1} is the temperature of the internal coolant point adjacent to the material point, °R

T_{s1} is the local temperature of the internal coolant block boundary separating the material point at T_1 and the coolant point at T_{c1} , °R

T_{s2} is the local temperature of the internal coolant block boundary directly opposite the location of T_{s1} , °R

$\mathfrak{F}_{1-2}$ is the overall interchange factor for one-dimensional radiation between the temperatures T_{s1} and T_{s2} , dimensionless

Within a given iteration, the T_1 used to calculate h_r is the value from the preceeding iteration, whereas the T_1 used to calculate coolant temperatures is the value obtained from the current iteration. The result is that when coolant temperatures are calculated there is an inconsistency between h_r and the value of $T_1 - T_{c1}$ on which h_r is based. In calculations where

an internal coolant temperature closely approaches the adjacent material temperature, h_r becomes large and also sensitive to very small changes in $T_1 - T_c$. Under this condition, an unusually large error may be incurred in the calculation of coolant temperatures. Therefore, in problems where internal coolant temperatures, approach adjacent material temperatures, particular attention should be given to eliminating any dependence of transient results upon the size of the time step.

The error described may become so large that the calculation is terminated due to some condition such as a floating point overflow. So that all such problems may be run to completion, the code includes the following checks and arbitrary corrective measures which are applied in calculating overall conductances and coolant temperatures for the case of radiation across an internal coolant block:

1. All values of $T_1 - T_{c1}$ are checked before overall conductances between materials and internal coolants are calculated. At locations where $|T_1 - T_{c1}| < 0.10^\circ R$ on either boundary of the coolant block, all heat transfer by radiation is excluded for the iteration being performed.
2. The exit temperature calculated for each coolant node is checked to determine if it lies within limits dictated by the inlet temperature and the adjacent material point temperatures. If it is outside these limits the point (i.e. the mean) and the exit temperatures for the node are set equal to the inlet temperature. In other words, if an error is detected, the coolant node is treated as being adiabatic for the current iteration. This is done so that coolant temperature errors will not be propagated to adjacent coolant nodes.

Unless the steady-state option is being used, one of the error messages given in Appendix A under Subroutines CONDOC and COOL is printed whenever either of the above corrective measures is applied. If the steady-state option is being used, the messages are printed only when the corrective

measures are applied during the smoothing iterations described in Section 2.4. The messages give the times and locations where corrective measures were applied so that if they are printed some judgement as to the validity of results can be made. If results are not considered satisfactory, the corrective measures can usually be eliminated from the solution by rerunning the problem with smaller time steps.

5.3 ONE-DIMENSIONAL TREATMENT OF RADIATION

The radiation across gaps and internal coolant blocks is calculated under assumptions consistent with one-dimensional radiation across a narrow region. These assumptions are:

1. Radiation occurs only along lines parallel to grid lines in one of the two coordinate directions.
2. The geometrical view factor is 1.0.
3. The mean effective area for heat transfer (both radiation and conduction) across gaps in the radial direction may be defined as that at the high radial boundary of the gap.

Errors due to the above assumptions can become significant for radiation across internal coolant blocks and gaps which are not narrow.

5.4 ROUND OFF ERRORS

Single precision is used throughout the code. Therefore, only eight significant figures are available. Situations can develop where temperature differences in the heat balance equations are so small that they appear only beyond the eighth significant figure. Changes in point temperatures between successive iterations are then lost in the roundoff. In running a problem under these conditions an apparent convergence will be obtained but if further iterations are performed using a smaller time step, the solution will change.

Probably the most common situation involving roundoff error arises in problems where the thermal conductivities of some materials are very high. The heat balance contains terms involving products of conductances and point temperature differences. If the conductances are large, due to large thermal conductivities, the true temperature difference components of these terms can become so small as to appear only beyond the eighth figure.

6. TECHNIQUES

Many of the apparent limitations of the program can be overcome through techniques such as those described in the following sections and in Ref. 2. These techniques involve the use of materials having thermal parameters which are chosen to impose some desired condition on a problem. Such materials are called dummies because they are not physically present in the system being modeled.

Dummy materials are often specified with extreme (i.e. very high or very low) values of one or more thermal parameters. For dummy solid materials it is important to consider the effect of extreme values on the maximum stable time step. As indicated by the proportionality in 5.1.1, high thermal conductivity and/or low volume specific heat tend to reduce the maximum stable time step at any point where they are applied. Therefore, in using dummy materials with such extreme parameters, it should be insured that they are no more extreme than required to impose the desired conditions.

6.1 BOUNDARY CONDITIONS

All boundary conditions must be described in terms of thermal parameters of coolants contained in the external blocks. Some special cases are illustrated below.

6.1.1 Adiabatic Boundary

A coolant having very low heat transfer coefficient is required. The other coolant parameters are not important. The standard coolant function values

$H-A(X) = 10^{-6}$	Btu/hr-ft ² -°R
$TIN-A(X) = 460.$	°R
$FLO-A(X) = 10^6$	lb/hr
$SPH-(X) = 1.$	Btu/lb-°R

are usually adequate for defining an adiabatic boundary. As discussed in 2.5.3, these values will automatically be used if definitions of these functions are simply omitted in the thermal parameter function input.

6.1.2 Constant Temperature Boundary

The coolant must be isothermal at the desired boundary temperature and must also have a very high heat transfer coefficient.

H-A(X) = very high

TIN-A(X) = desired boundary temperature

[FLO-A(X)] x [SPH-(X)] = very high

6.1.3 Boundary With Radiation

Radiation at an external boundary can be modeled by using a dummy coolant whose heat transfer coefficient is a function of surface temperature, ST. As an example, consider a case where it is desired to transfer heat at an external boundary by combined convection and radiation. Convection between the local boundary and bulk coolant temperatures, T_w and T_c , respectively is described by a film coefficient, h_c . There is radiant heat exchange with some surface which is in thermal equilibrium with the coolant. This radiation is one-dimensional and is described by an interchange factor, F, and the Stefan-Boltzmann constant, σ . The combined heat transfer is described by an effective overall heat transfer coefficient, h_e which is

$$h_e = \frac{F \sigma (T_w^4 - T_c^4)}{(T_w - T_c)} + h_c$$

If $h_c = 10. \text{Btu/hr-ft}^2\text{-}^\circ\text{R}$

$F = .50$

$\sigma = .1713 \times 10^{-8} \text{ Btu/hr-ft}^2\text{-}^\circ\text{R}^4$

then the combined heat transfer can be described by inputting the following function for the heat transfer coefficient of the coolant:

$$H-A(X) = .50*.1713E-8*(ST**4-DR**4)/(ST-DR) + 10.$$

where ST is the local surface temperature and DR is the local coolant temperature both in °R. If there is no convection, the term representing h_c is simply not included. The external source-sink temperature need not be the local coolant temperature. It may be a constant or it may be defined by an additional arithmetic statement function using any of the variables which are allowed in H-A(X). Either of these would be substituted for DR in the above function.

6.2 IRREGULAR EXTERNAL BOUNDARIES

As discussed in 2.1.3, each of the four external boundaries must coincide continuously with one of the four extreme grid lines. This limitation can be overcome to some extent by using dummy materials in regions between the external boundaries dictated by extreme grid lines and the true external boundaries of the problem. The thermal parameters of these dummy materials can be selected to impose the desired boundary conditions.

Examples 1 and 2 of this technique are given in Figs. 6 and 7, respectively. In example 1 a dummy material is used to simulate the constant temperature coolant, and gaps are used to simulate the heat transfer coefficients. The dummy material is given high specific heat and thermal conductivity so that all points which it contains will remain at their initial temperatures. These initial temperatures are specified as the constant coolant temperature, T_c .

Example 2 illustrates the use of internal coolants to impose desired conditions on an external boundary which has, of necessity, been compromised from its true configuration. A partial compensation for the boundary distortion is made by applying the heat transfer area correction to h as indicated in Fig. 7.

Dummy materials could be used in example 2 but use of dummy internal coolants in example 1 would require unnecessary compromise of the true boundary conditions. To fill the dummy region of example 1 with coolant blocks would require that some part of either the h_1 or the h_2 surface be adiabatic. This is because coolant block heat transfer occurs only normal

DUMMY THERMAL PARAMETERS

MATERIALS

RCONI(X) = HIGH, ACONI(X) = HIGH, SPECI(X) = VERY HIGH
 INITIAL TEMPERATURE OF 1 = T_c

GASES

$GCON1(X) = h_1 t_1$
 $GCON2(X) = h_2 t_2$

NO RADIATION: ALL EMISSIVITIES = 0

COOLANTS

COOLANT NUMBER	H _ A(X)	TIN _ A(X)	FLO _ A(X)	SPH _ (X)
1	10^{-6}	460	10^6	1.0
2	h_3	T_c	VERY HIGH	1.0

COOLANT 1 IS AN ADIABATIC BOUNDARY COOLANT AS DESCRIBED IN 7.1.1.

EXCEPT FOR FLOW DIRECTION COOLANT 2 IS NOT ACTUALLY A DUMMY.

Fig. 6. Irregular external boundaries, Example 1

TRUE CONFIGURATION

MODEL FOR TAC2D INPUT

C-n = COOLANT n

DUMMY MATERIAL THERMAL PARAMETERS

COOLANT NUMBER	H _ A(X)	TIN _ A(X)	FLO _ A(X)	SPH _ (X)
1	$\left(h\right)\left(\frac{l_1}{l_1'}\right)$	T_c	VERY HIGH	1.0
2	$\left(h\right)\left(\frac{l_2}{l_2'}\right)$	T_c	VERY HIGH	1.0
3	$\left(h\right)\left(\frac{l_3}{l_3'}\right)$	T_c	VERY HIGH	1.0
4	10^{-6}	460.0	10^6	1.0

COOLANT 4 IS AN ADIABATIC BOUNDARY COOLANT
AS DESCRIBED IN 7.1.1

Fig. 7. Irregular external boundaries, Example 2

to the flow direction as illustrated in Item d of Fig. 4. If there is a choice of techniques, that of using internal coolants is preferable. The principal reason is that the high thermal conductivity required for the dummy materials can cause stability problems and round-off errors as discussed in Chapter 5.

6.3 INTERNAL DUMMY MATERIALS

Dummy material and coolant techniques can be applied in describing special internal conditions for a problem. Examples are internal sources and sinks or internal voids. These can be modeled by dummy materials or coolants having extreme values of the appropriate thermal parameters.

APPENDIX A

PROGRAM ERROR MESSAGES

```

=====
SUBROUTINE BOUNDA
=====
    BOUNDA1  THE LOW BOUNDARY FOR A BLOCK IS TOO LARGE OR
              LARGER THAN THE LARGEST BOUNDARY DEFINED IN THAT
              DIMENSION.
    BOUNDA2  THE HIGH BOUNDARY OF A BLOCK IS LARGER THAN THE
              LARGEST BOUNDARY DEFINED IN THAT DIMENSION.
    BOUNDA3  AN INTERNAL COOLANT BLOCK HAS BEEN SPECIFIED IN
              VIOLATION OF CODE LIMITATIONS. MOST LIKELY ERRORS ARE
              1. A NORMAL COOLANT HAS BEEN SPECIFIED FOR A
              PROBLEM IN CYLINDRICAL COORDINATES.
              2. AN INTERNAL COOLANT HAS TWO BOUNDARIES WHICH
              ARE COINCIDENT.
=====
SUBROUTINE CHECK
=====
    CHECK1   THERE ARE TOO MANY RADIAL-X POINTS AND GRID LINES
    CHECK2   THERE ARE TOO MANY AXIAL-Y-THETA POINTS AND GRID LINES
    CHECK4   THE RADIAL-X GRID DATA IS OUT OF ORDER
    CHECK5   THE AXIAL-Y-THETA GRID DATA IS OUT OF ORDER
    CHECK7   THERE ARE TOO MANY BLOCKS.
    CHECK8   THE LOW RADIAL-X BOUNDARY IS LARGER THAN THE HIGH
              RADIAL-X BOUNDARY FOR SOME BLOCK
    CHECK9   THE LOW AXIAL-Y-THETA BOUNDARY IS GREATER THAN THE
              HIGH AXIAL-Y-THETA BOUNDARY FOR SOME BLOCK
    CHECK11  THE MATERIAL NUMBER FOR A BLOCK IS LARGER THAN THE
              MAXIMUM NUMBER OF MATERIALS AND COOLANTS ALLOWED.
    CHECK12  A RADIAL-X GAP MATERIAL NUMBER IS TOO HIGH
    CHECK13  AN AXIAL-Y-THETA GAP MATERIAL NUMBER IS TOO HIGH
=====
SUBROUTINE FLODAT
=====
    FLODAT1  THE INDEPENDENT VALUE LIES OUTSIDE THE FLOW RATE
              FUNCTION RANGES.
    FLODAT2  THE INDEPENDENT VALUE LIES OUTSIDE THE INLET
              TEMPERATURE FUNCTION RANGES.
    FLODAT3  THE REYNOLDS NUMBER LIES OUTSIDE THE SPECIFIED RANGES
=====

```

```

=====
SUBROUTINE FLOWCA
=====
FLOWCA1 THE REYNOLDS NUMBER LIMITS ARE NOT IN SEQUENCE
FLOWCA2 THE FLOWRATE LIMITS ARE NOT IN SEQUENCE
FLOWCA3 THE INLET TEMPERATURE LIMITS ARE NOT IN SEQUENCE
=====
SUBROUTINE GEOMET
=====
GLOMET1 SOME POINT HAS A NEGATIVE CALCULATED VOLUME.
=====
SUBROUTINE GRID
=====
GRID1 THERE ARE MORE GRIDLINES THEN ALLOWED IN ONE OF
      THE DIMENSIONS. A BLANK CARD HAS BEEN LEFT OUT.
=====
SUBROUTINE INITEM
=====
INITEM1 THE TEMPERATURE BLOCK'S LOWER RADIAL-X BOUNDARY DOES
        NOT COINCIDE WITH ANY OF THE RADIAL-X GRID BOUNDARIES
INITEM2 THE TEMPERATURE BLOCK'S UPPER RADIAL-X BOUNDARY DOES
        NOT COINCIDE WITH ANY OF THE RADIAL-X GRID BOUNDARIES
ITITEM3 THE TEMPERATURE BLOCK'S LOWER AXIAL-Y-THETA BOUNDARY
        DOES NOT COINCIDE WITH ANY OF THE AXIAL-Y-THETA
        GRID BOUNDARIES
ITITEM4 THE TEMPERATURE BLOCK'S UPPER AXIAL-Y-THETA BOUNDARY
        DOES NOT COINCIDE WITH ANY OF THE AXIAL-Y-THETA
        GRID BOUNDARIES
INITEM7 AN INITIAL TEMPERATURE HAS NOT BEEN ASSIGNED TO SOME
        INTERNAL POINT.
=====
SUBROUTINE INPUT
=====
INPUT1 THE GEOMETRY TYPE DESIRED HAS BEEN MISSPELLED.
INPUT2 NORMAL FLOW NOT ALLOWED IN CYLINDRICAL GEOMETRY
INPUT3 THE LOW RADIAL-X BLOCK BOUNDARY OF SOME BLOCK DOES
        NOT COINCIDE WITH A RADIAL-X GRID LINE
INPUT4 THE HIGH RADIAL-X BLOCK BOUNDARY OF SOME BLOCK DOES
        NOT COINCIDE WITH A RADIAL-X GRID LINE
INPUT5 THE LOW AXIAL-Y-THETA BLOCK BOUNDARY OF SOME BLOCK
        DOES NOT COINCIDE WITH A AXIAL-Y-THETA GRID LINE
INPUT6 THE HIGH AXIAL-Y-THETA BLOCK BOUNDARY OF SOME BLOCK
        DOES NOT COINCIDE WITH A AXIAL-Y-THETA GRID LINE
=====
SUBROUTINE MP2
=====
MP2 1 THE CURRENT TIME OF THE PREVIOUSLY PUNCHED
      TEMPERATURE DISTRIBUTION IS GREATER THAN THE ENDING
      TIME OF ANY GIVEN TIMESTEP.
=====

```

```

=====
SUBROUTINE POINTS
=====
POINTS1  A PART OF THE SYSTEM WAS NOT DESCRIBED BY ANY BLOCK.
POINTS2  THERE ARE TOO MANY RADIAL-X GAPS.
POINTS3  THERE ARE TOO MANY AXIAL-Y-THETA GAPS.
POINTS5  A PART OF THE SYSTEM HAS BEEN DESCRIBED BY MORE THAN
          ONE BLOCK.
POINTS6  NO FLOW DIRECTION HAS BEEN ASSIGNED FOR SOME COOLANT.
POINTS7  1. AN EXTERNAL COOLANT IS FLOWING INTO A RADIAL-X
          BOUNDARY,OR
          2. AN INTERNAL RADIAL-X FLOW COOLANT BLOCK IS NOT
          TRAVERSED BY AT LEAST ONE RADIAL-X GRID LINE.
POINTS8  1. AN EXTERNAL COOLANT IS FLOWING INTO AN AXIAL-Y-
          THETA BOUNNDARY OR
          2. AN INTERNAL AXIAL-Y-THETA FLOW COOLANT BLOCK IS
          NOT TRAVERSED BY AT LEAST ONE AXIAL-Y-THETA
          GRID LINE.
POINTS9  A GAP HAS BEEN SPECIFIED ON THE HIGH RADIAL-X
          BOUNDARY OF A COOLANT.
POINTS10 A GAP HAS BEEN SPECIFIED ON THE LOW RADIAL-X
          BOUNDARY OF A COOLANT.
POINTS11 A GAP HAS BEEN SPECIFIED ON THE HIGH AXIAL-Y-THETA
          BOUNDARY OF A COOLANT.
POINTS12 A GAP HAS BEEN SPECIFIED ON THE LOW AXIAL-Y-THETA
          BOUNDARY OF A COOLANT.
=====
SUBROUTINE PRETEM
=====
PRETEM1  THE PROBLEM SIZE DOES NOT MATCH THE INITIAL
          TEMPERATURE DISTRIBUTION DATA
=====
SUBROUTINE SURT
=====
SURT 1  INSTABILITY ENCOUNTERED WHILE CALCULATING THE
          RADIAL-X BOUNDARY TEMPERATURES OF A GAP. USE A
          SMALLER TIME STEP.
SURT 2  INSTABILITY ENCOUNTERED WHILE CALCULATING THE
          AXIAL-Y-THETA BOUNDARY TEMPERATURES OF A GAP.
          USE A SMALLER TIME STEP.
=====
SUBROUTINE TIME
=====
TIME1    THE FIRST TIME CARD DOES NOT SPECIFY TIME UNITS.
          THE PROBLEM IS NOT AFFECTED IF THE STEADY STATE
          OPTION IS BEING USED.
TIME2    TOO MANY TIME HISTORY CARDS HAVE BEEN READ.
TIME3    THE INPUT CONTAINS NO TIME HISTORY CARDS AND THE
          STEADY STATE OPTION IS NOT BEING USED.
=====

```

```

=====
SUBROUTINE CONDOC
=====
      CONDOC1 , CONDOC2
      THESE MESSAGES INDICATE THAT RADIATION BETWEEN THE
      BOUNDARIES OF AN INTERNAL COOLANT BLOCK WAS NEGLECTED
      IN ORDER COMPLETE AN ITERATION. A SMALLER TIME STEP
      SHOULD BE USED IF THE NEGLECT OF RADIATION IS
      SIGNIFICANT.

      CONDOC1  RADIATION WAS NEGLECTED BETWEEN RADIAL-X GAPLINES IGL
      AND IGH AT AXIAL-Y-THETA POINT LEVEL J.
      CONDOC2  RADIATION WAS NEGLECTED BETWEEN AXIAL-Y-THETA
      GAPLINES JGL AND JGH AT RADIAL-X POINT LEVEL I.
=====
SUBROUTINE COOL
=====
      COOL1 , COOL2 , COOL3
      THERE IS A PROGRAM LIMITATION WHICH MAY BE ENCOUNTERED
      WHEN CALCULATING COOLANT TEMPERATURES IN THE PRESENCE
      OF RADIATION BETWEEN COOLANT BLOCK BOUNDARIES. IT
      ARISES WHEN A COOLANT POINT AND AN ADJACENT MATERIAL
      POINT APPROACH THE SAME TEMPERATURE. THESE MESSAGES
      INDICATE THAT THIS LIMITATION HAS BEEN ENCOUNTERED
      AND CIRCUMVENTED BY ASSIGNING ZERO COOLANT HEAT
      TRANSFER AT THE LEVEL INDICATED. BY USING A SMALLER
      TIME STEP, THIS DIFFICULTY CAN USUALLY BE ELIMINATED.
      COOL1  HEAT TRANSFER WITHIN AN AXIAL-Y-THETA COOLANT
      IS ZERO IN BLOCK L AT AXIAL-Y-THETA POINT
      LEVEL J.
      COOL2  HEAT TRANSFER WITHIN A RADIAL-X COOLANT IS
      ZERO IN BLOCK L AT RADIAL-X POINT LEVEL J.
      COOL3  HEAT TRANSFER WITHIN A NORMAL COOLANT IS ZERO
      IN BLOCK L.
=====

```

APPENDIX B

Example Use of Additional Arithmetic Statement Functions

A typical use of additional functions would be to calculate the Reynolds numbers and heat transfer coefficients of coolants with properties evaluated at the mean film temperature. An example of this is given below where the additional functions $TFILM(X)$, $C\phi N(X)$, $VIS(X)$, $CP(X)$ and $PR(X)$ are used to define the coolant parameter functions $REYN2(X)$, $REYN7(X)$, $H2A(X)$ and $H7A(X)$.

$$\begin{aligned}TFILM(X) &= (ST + DR)/2. \\C\phi N(X) &= 1.29E-3*TFILM(X)**.674 \\VIS(X) &= 6.9E4*TFILM(X)**.674 \\CP(X) &= 1.242 \\PR(X) &= CP(X)*VIS(X)/C\phi N(X) \\REYN2(X) &= 4.*FR/(.524*VIS(X)) \\REYN7(X) &= 4.*FR/(1.048*VIS(X)) \\H2A(X) &= .021*(RE**.8)*(PR(X)**.4)*(C\phi N(X)/.167) \\H7A(X) &= .021*(RE**.8)*(PR(X)**.4)*(C\phi N(X)/.333)\end{aligned}$$

NOTES

1. The variables used in the additional functions must be only those which are allowed for the thermal parameter functions in which they are used as defined in 2.5.2.
2. One additional function may be used in several different thermal parameter functions provided that in the sequences of statements inserted into MADATA and/or FLODAT its definition always precedes its use.
3. See Appendix D for names which may not be used as additional function names.

APPENDIX C

Example Use of Function Subprograms

It is desired that the specific heat of material 3 be defined in two different temperature ranges:

$\text{SPEC3}(X) = 490. * (6.364\text{E-}5 * (\text{DR} - 460.) + .107)$ for $\text{DR} < 960^\circ\text{R}$

$\text{SPEC3}(X) = 490. * (3.333\text{E-}5 * (\text{DR} - 460.) + .119)$ for $\text{DR} \geq 960^\circ\text{R}$

This will be done using a function subprogram named VSH.

In the material parameter function statements assign:

$\text{SPEC3}(X) = \text{VSH}(\text{DR})$

At the location shown in Section 4.2 for function subprograms, place the following cards:

VP HDG any alphanumeric heading in Cols. 13-72 (Note 1)

VI FOR VSH/S,VSH/S,VSH/R (Note 1)

FUNCTION VSH(TEM)

IF(TEM.GE.960.)GO TO 10

VSH = $490. * (6.364\text{E-}5 * (\text{TEM} - 460.) + .107)$

RETURN

10 VSH = $490. * (3.333\text{E-}5 * (\text{TEM} - 460.) + .119)$

RETURN

END

NOTES

1. The first two lines in the above example are control cards for the Univac 1108 computer.

2. There may be more than one variable in the function calling sequence. An example is a thermal parameter function

$$\text{HEAT9}(X) = \text{HGF}(\text{DR}, \text{FTZ})$$

which could be evaluated from the function subprogram labeled

$$\text{FUNCTION HGF}(\text{TEM}, \text{Z})$$

In the Fortran programming of HGF, TEM corresponds to DR and Z corresponds to FTZ.

3. A function subprogram name may be used like an additional arithmetic statement function in that it may be used in several different parameter functions. For example

$$\text{SPEC3}(X) = \text{VSH}(\text{DR})$$
$$\text{SPEC6}(X) = 1.10 * \text{VSH}(\text{DR})$$

4. The variables in the function subprogram's calling sequence must be only those which are allowed for the thermal parameter functions in which they are used.
5. See Appendix D for names which may not be used as the names of function subprograms. There is no restriction on the names which may be used within the subprogram.

APPENDIX D

Restrictions on the Assignment of Names

Fortran names may have to be created in the following cases:

1. When using Subroutine CUSTOM as described in Section 3.6.
2. When using additional arithmetic statement functions to define the thermal parameter functions as described in 2.5.6 and Appendix B.
3. When using function subprograms to define the thermal parameter functions as described in 2.5.7 and Appendix C.

It is necessary to avoid redefining names which are a part of the code. Those names which can be inadvertently redefined within the above usages are tabulated below. The names included in common should never be used. The names defined in Subroutines MADATA and FLODAT should not be used for the names of additional arithmetic statement functions or function subprograms.

<u>NAME</u>	<u>INCLUDED IN COMMON</u>	<u>DEFINED IN MADATA AND FLODAT</u>
A1-A18	*	
B		*
C		*
CARD	*	
CONR	*	
CONZ	*	
CS1-CS3	*	
CURTI	*	
DATI	*	
DELR	*	
DELZ	*	
DP	*	
DR	*	
DT	*	
DTIME	*	
FIRST	*	
FLIM1-FLIM4	*	
FLODEP	*	
FLOW	*	
FR	*	
FTIME	*	
FTR	*	
FTZ	*	
GAPR	*	
GAPZ	*	
GAS	*	
GK	*	
HC		*
HEIGHT	*	
HR	*	
I		*
IA		*

<u>NAME</u>	<u>INCLUDED IN COMMON</u>	<u>DEFINED IN MADATA AND FLODAT</u>
ICOUNT	*	
IERROR	*	
IF	*	
IFLO	*	
IFLODA		*
IG		*
IGHS	*	
IGLS	*	
IGMAX		*
IGR	*	
IH	*	
IHS	*	
IL	*	
ILS	*	
IM	*	
IMAX	*	
IM1	*	
IP		*
IPATH	*	
ISHAPE	*	
IT		*
ITAPE	*	
ITER	*	
ITI	*	
ITIN	*	
ITO	*	
I1,I2		*
J		*
JG		*
JGHS	*	

<u>NAME</u>	<u>INCLUDED IN COMMON</u>	<u>DEFINED IN MADATA AND FLODAT</u>
JGLS	*	
JGMAX		*
JGZ	*	
JH	*	
JHS	*	
JL	*	
JLS	*	
JM	*	
JMAX	*	
JM1	*	
J1,J2		*
KR	*	
KZ	*	
LMAX	*	
M		*
MATRG	*	
MATZG	*	
MAXFLO	*	
MAXMAT	*	
MAXNB	*	
MAXRG	*	
MAXRP	*	
MAXZG	*	
MAXZP	*	
MB	*	
MGR	*	
MGZ	*	
MMAX	*	
MT	*	
N		*

<u>NAME</u>	<u>INCLUDED IN COMMON</u>	<u>DEFINED IN MADATA AND FLODAT</u>
NC	*	
NFLO	*	
NI	*	
NITER	*	
NPRINT	*	
NRG	*	
NTA	*	
NZG	*	
OUTTAP	*	
PNAME	*	
RATIOB	*	
RATIOC	*	
RATIOH	*	
RATIOK	*	
RBBTH	*	
RBBTL	*	
RBH	*	
RBL	*	
RCP	*	
RCPC	*	
RDG	*	
RE	*	
REMH	*	
REML	*	
RL	*	
RLIM1-RLIM4	*	
RLN	*	
RP	*	
RR	*	
RZ	*	
SCALE	*	

<u>NAME</u>	<u>INCLUDED IN COMMON</u>	<u>DEFINED IN MADATA AND FLODAT</u>
SELECT		*
ST	*	
STA		*
SW	*	
T	*	
TB	*	
TH	*	
TI	*	
TIN	*	
TINDEP	*	
TLIM1-TLIM4	*	
TO	*	
TOUT	*	
TT	*	
V	*	
W	*	
X		*
Y		*
ZA	*	
ZATIOB	*	
ZATIOH	*	
ZATIOK	*	
ZBBTH	*	
ZBBTL	*	
ZBH	*	
ZBL	*	
ZDG	*	
ZEMH	*	
ZEML	*	
ZL	*	
ZLN	*	
ZP	*	

APPENDIX E

Dimensional Limits

Computer core capacity available for array storage is distributed according to the values assigned to the following parameters:

IQ - number of X (radial) points

JQ - number of Y (theta,axial) points

IGQ - number of X (radial) gap lines

JGQ - number of Y (theta,axial) gap lines

LQ - number of blocks

In the standard version of TAC2D the values are:

IQ = 45, JQ = 45

IGQ = 25, JGQ = 25

LQ = 110

The values of the above parameters are defined in each subroutine by a single Fortran statement. It is relatively simple to change these values and compile a special version of the code which has different dimensional limits than the standard version.

The constraint on changing the parameter values is

$$P1 + P2 + P3 + P4 \leq CLIM$$

where $P1 = 7 \times IGQ \times JQ$

$P2 = 7 \times JGQ \times IQ$

$P3 = 9 \times IQ \times JQ$

$P4 = 5 \times LQ$

and

$CLIM = 34730$

The above value of CLIM is applicable only to the Univac 1108 computer installation at Gulf General Atomic. It includes an allowance of 1000 octal core locations for storage of the arithmetic statement functions (Section 2.5) to be compiled into Subroutines MADATA and FLODAT by the code user.

APPENDIX F

Dumping

Values of program variables at the termination of a computer run can be printed by means of a core dump. The most useful types of dumps are described below. Descriptions of dumps and dump cards are directly applicable only to the Univac 1108 computer installation at Gulf General Atomic.

1. Full Core Dump

Sometimes a problem fails to run successfully on the computer and the cause is not apparent from error messages alone. Assistance will have to be sought from a person familiar with the program and the computer system on which it is being used. The following card* will give a dump on error with decimal conversion of the core configuration at the time of the error.

VBREL PMD

The output pages required for dumps are not included in the page count which is subject to the specified maximum number of output pages.

2. Dump of a Given Common Element

If it is known which variables are of interest, it is possible to dump only the named common elements which contain those variables. One of the most frequent applications for such a limited dump is in the running of a time test case. Here it is expected that the problem will terminate on a system error with no output results for the current iteration. However, the only results needed are the time and number of current iteration. These variables, named CURTI and NITER, respectively, are contained in the common

*The dump cards discussed in this appendix are always placed on the back of the input data deck. The dump card is the last card.

element named MISCXX. The following card will give a dump of this element on error:

VRE PMD MISCXX

The dump is contained in less than one printed page.

APPENDIX G

Output Data Tape

The data contained in the names defined below is written on a tape whenever the tape option is specified in the input of a problem.

CURTI	current time, hr.
FLOW(M)	flow rate of coolant M, lb/hr
IGR(I)	index of the gapline at radial gridline I
IH(K)	highest radial point index in block K
IL(K)	lowest radial point index in block K
ILEN	an integer which is always 1
IMAX	total number of radial points
ISHPAE	coordinate system indicator: 0 = cylindrical, 1 = rectangular, 2 = circular
JGZ(J)	index of the gapline at axial gridline J
JH(K)	highest axial point index in block K
JL(K)	lowest axial point index in block K
JMAX	total number of axial points
LMAX	total number of blocks (material and coolant)
MAXFLO	maximum number of coolants (15)
MB(K)	number of the material or coolant in block K
NITER	current iteration number
NRG	total number of radial gaplines
NZG	total number of axial gaplines
RBBTH(IG,J)	temperature at axialpoint level J of the radial boundary of a block bounded on its high radial side by radial gapline IG, °R
RBBTL(IG,J)	temperature at axial point level J of the radial boundary of a block bounded on its low radial side by radial gapline IG, °R

RL(I)	radial grid line coordinate, ft
T(I,J)	temperature at radial point level I, axial point level J, °R
TI(M)	inlet temperature of coolant M, °R
TO(M)	outlet temperature of coolant M, °R
ZA(I)	an array of 12 Hollerith words which contains the information on the first problem title card.
ZBBTH(JG,I)	temperature at radial point level I of the axial boundary of a block bounded on its high axial side by axial gapline JG, °R
ZBBTL(JG,I)	temperature at radial point level I of the axial boundary of a block bounded on its low axial side by axial gapline JG, °R
ZL(J)	axial grid line coordinate, ft

All the above names which begin with the letters I through N contain integers. All other names contain floating point numbers except ZA which contains Hollerith words.

The data is written on tape unit 15 by executing the following write statements:

```

WRITE(15) ISHAPE, ILEN, IMAX, JMAX, LMAX, MAXFLO, NRG, NZG,
1      (ZA(I), I=1, 12), (RL(I), I=1, IMAX), (ZL(J), J=1, JMAX),
2      (IGR(I), I=1, IMAX), (JGZ(J), J=1, JMAX),
3      (IL(K), IH(K), JL(K), JH(K), MB(K), K=1, LMAX)

WRITE(15) NITER, CURTI,
1      ((RBBTL(IG, J), RBBTH(IG, J), IG=1, NRG), J=1, JMAX),
2      ((ZBBTL(JG, I), ZBBTH(JG, I), JG=1, NZG), I=1, IMAX),
3      (FLOW(M), TI(M), TO(M), M=1, MAXFLO),
4      ((T(I, J), I=1, IMAX), J=1, JMAX)

```

The first statement is executed one time as soon as all the input data has been processed and the geometrical constants calculated. The second statement is then executed each time basic output is printed.

Whenever the tape option is specified a data tape number XXXX must be assigned by means of the following card:

```
∇   ASG      15 = XXXX
```

This card may be placed immediately after the program tape assign card in the card sequence given in Section 4.2.

APPENDIX H

Example Problem

The TAC2D program input and output is illustrated by means of a sample problem in which the steady-state temperature distribution is calculated for a helium circular blower disk.

The blower disk, which is part of the helium circulator shown in Fig. H-1, is heated on one side by helium maintained at 680°F and cooled on the other side by a helium bleed flow. There is also heat conducted into the outer radial edge of the disk from the blades of the circulator blower, and the blower shaft, maintained at 175°F, acts as an additional heat sink.

Fig. H-2 shows the model for the TAC2D analysis of the blower disk. The cylindrical coordinate system is used. Because of requirements by the code, the outside boundaries of the model form a right circular cylinder. The following statements describe the major assumptions made in formulating the model:

1. A two-dimensional axisymmetric temperature distribution was assumed.
2. The model does not include the circulator blades. Instead, the outer radial edge of the disk was maintained at 680°F.
3. The effect of the mounting bolts was neglected, since they occur periodically and are insulated from the disk.
4. Although the heat transfer coefficient between the helium and the disk on each radial face of the disk varies continuously with the radial distance, discrete discontinuous values were used, as shown in Fig. H-2.

Fig. H-1. Helium circulator blower

Fig. H-2. TAC2D thermal model of helium circulator blower disc

As illustrated in Fig. H-2, the entire model is subdivided into blocks, identified by the heavy solid and dotted lines, which may have different sets of thermal parameters. The model is further subdivided by the radial and axial grid lines, as indicated by the light lines extending across the entire model. Nodal points, for which the temperatures are calculated, are located midway between these grid lines. The material and coolant blocks must have regular boundaries which coincide with the grid lines. The location of gaps within the model are indicated by the broken lines consisting of the long and short dashes. These gaps are always located on the high radial or high axial boundary of a block.

A listing of the input cards for the problem appears following this text. As the analytical model is described further, reference can be made to this input listing.

Blocks 1 through 5, labeled with the number in each block, are included in the model to fill the regions between the disk and the external boundaries, and are composed of material number 2. They are also used to describe the boundary conditions on the left hand face of the disk. The constant temperature condition of 680°F is attained by assigning this temperature as the initial temperature of these blocks, and by further assigning a very high heat capacity ($\text{SPEC2}(X)=10^6$) and a moderately high thermal conductivity ($\text{RCON2}(X)=1000, \text{ACON2}(X)=1000$) to the materials in these blocks. To maintain the high heat capacity with the steady-state option, $\text{SPEC2}(X)$ must be greater than or equal to 10^6 as discussed in 4.1.1. The heat transfer coefficients between this helium and the blower disk are simulated by gaps. The thicknesses and thermal conductivities of these gaps ($\text{GCON1}(X)$, $\text{GCON2}(X)$, and $\text{GCON3}(X)$) are chosen such that their unit conductances are equal to the appropriate heat transfer coefficients.

The blower disk is comprised of blocks 6 through 11, and it is specified by material number 1. As shown by $\text{RCON1}(X)$, the thermal conductivity of this material is a function of the local temperature DR.

Block number 12 represents the helium enclosed in a cavity with natural circulation affected by the centrifugal force field. The natural convection coefficient for this circulation was calculated as $85 \text{ Btu/hr-ft}^2\text{°F}$. The heat transfer coefficient between this helium and the blower disk was simulated by gaps along the left hand edge and outer radial edge of block number 12, although the gap on the left hand edge actually belongs to block number 8. The heat transfer coefficient between the helium and the blower shaft is modeled with a coolant as will be shown later. The thermal conductivity of block 12, which contains material number 3, is made relatively high ($\text{RCON3(X)} = \text{ACON3(X)} = 500.$) so that no thermal gradients occur across the void. This simulates the mixing due to the natural circulation.

The helium bleed flow is represented by the coolant blocks 13 through 16. The coolant numbers for these blocks are 6 through 9, respectively. As indicated in the coolant thermal parameters, the flow rate for these coolants is 50 lbm/hr and the specific heat is 1.24 Btu/lbm°F . The heat transfer coefficients vary from one coolant to the next as indicated in Fig. H-2, and the inlet temperature of each coolant is set equal to the outlet temperature of the preceeding coolant, except for the inlet coolant, i.e., coolant number 6.

Blocks 17 through 19 represent the steel separator plate. These blocks all contain material number 5, which has the properties of carbon steel. Block 20 simulates the insulation and contains material number 4.

The external boundary conditions are specified with blocks 21 through 24, and according to the requirements of TAC2D, they must be coolant blocks. Furthermore, as external blocks, they are in fact lines, i.e. one dimension of each block has a zero length. Coolant numbers 1 through 5 are used for these external blocks. Since the boundary conditions are already partially described by internal coolants and constant temperature material blocks, some of these external coolants are dummies which have zero heat transfer coefficient and therefore produce an adiabatic boundary condition. Exceptions are coolants 1 and 2 which apply,

respectively, along the high radial boundary and along the portion of the high axial boundary between the limits $r=0$ and $r=3.25$ in. The high radial boundary is maintained constant at 680°F by specifying a high flow rate, a high specific heat, and a high heat transfer coefficient for coolant number 1. The constant blower shaft temperature of 175°F is maintained by also giving coolant number 2 a high flow rate and a high specific heat. Here, however, the true heat transfer coefficient between the helium enclosed in the cavity and the blower shaft is used.

Additional remarks are now given concerning the data input cards.* This listing may be examined with reference to the instructions given in Chapter 4.

1. Six options are specified. The first CYLINDRICAL GEOMETRY, is required, and the second STEADY STATE, calls for the steady state option which produces only the steady state solution. The remaining options deal with the desired output.
2. The cards with the labels RG and AG give the radial and axial grid lines respectively.
3. The cards with the label B give block information. Three cards are used per block. For the material blocks, the first card specifies the material, the second card the block boundaries, and the third card gives gap information. For coolant blocks the first card indicates the coolant number (with a minus sign) and the flow direction. For example, in block 13 the coolant is number 6 and it flows in the negative axial direction (-2.0). The third card for every coolant block is blank.

* It is important to realize that the thermal parameter functions are FORTRAN statements belonging to the subroutines MADATA and FLODAT, whereas the cards following the XQT TAC2D/AR card are FORTRAN data cards.

4. The coolant specification cards (3 per coolant) are those cards labeled with the C. Since the heat transfer coefficients for this problem are not functions of the Reynolds number, the Reynolds number limits are arbitrary values except for the first value of 0. Leaving REYN-(X) unspecified gives it the standard value of 0. To insure that H-A(X) (the A range) is used, the lowest Reynolds number limit must be 0. Likewise, the flow rates and inlet temperatures of the coolants are constants, so their limit cards are left blank, and the A range of FLO and TIN are used.
5. No time history cards are included because the steady-state option was used. The three cards with the function control constants (labeled with a P) have all zeroes since no such constants were specified.

Directly following the input listing is the output of the TAC2D run for this problem. It is complete with the exception that pages relating primarily to the computer system have been removed. Specific items which should be noted are:

1. A page indicating the code array size and the options selected.
2. The block description giving the block dimensions, the material or coolant number, and the gap information. Note that the block number is assigned according to the order of the blocks in the data list.
3. The boundary overlay page, which aids in locating the block boundaries on the output temperature array.
4. The nodal volumes, and the radial and axial geometric conduction factors between two neighboring points; that is, the effective " $A/\Delta X$ " values.
5. The radial and axial nodal point, grid line, and gapline locations. Each of these is numbered for later identification.

6. The coolant specification page.
7. The 18 function control constants. Here they are all 0.
8. The initial temperature distribution.
9. A listing of the complete data input deck.
10. Temperature array printouts for the last steady-state iteration and for the fifth, tenth, fifteenth and twentieth smoothing iterations. On the final temperature array printout (i.e. that for the twentieth smoothing iteration) the blower disk and other essential features were drawn with aid of the boundary overlay. Note that the standard temperature array printout is done with an interger format. Also included on these pages are coolant data, number of iterations, and elapsed time during the smoothing iterations.
11. The temperature array printed in decimal format.
12. A printing of the residuals at each point except the coolant points and those points with SPEC-(X) greater than or equal to 10^6 .
13. The surface temperatures at the radial and axial gaps or coolant boundaries. For an external coolant boundary, only the one surface temperature is given. For internal coolant channels and gaps, a pair of surface temperature are given corresponding to the temperature on each side of the coolant channel or gap. When a printed surface temperature coincides with the inlet or outlet temperature of a flowing coolant, its value is meaningless and should be ignored. Such temperatures have a line drawn through them on the printout for this problem.
14. The heat rate (Btu/hr) and heat flux (Btu/hr-ft²) between neighboring points in both the radial and axial directions. A positive number indicates that the heat flow is in the positive coordinate direction and a negative number in the

negative coordinate direction. Note that at adiabatic boundaries, the heat flow is not identically 0, but instead a very small number. This results because an adiabatic boundary actually contains an $h = 10^{-6}$ Btu/hr-ft²°F. A similar situation occurs for the conduction between two coolant points in the direction of the coolant flow.

15. The effective radial and axial conductivities. The effective conductivity is that a value which yields the heat flow between the two nodal points when multiplied by the corresponding geometric factor and the nodal point temperature difference.
16. The radial and axial thermal conductances. The thermal conductance between two points equals the effective conductivity between these points multiplied by the corresponding geometric factor.

TAC2D EXAMPLE PROBLEM INPUT CARD LISTING

```

Q   ASG   A=2366      TAC2D PROGRAM TAPE
QD  ASG   DRUM2=10000
QD  ASG   DRUM3=10000
QD  ASG   DRUM4=10000
Q   XQT   CUR
      IN   A
      TRI  A
QP  HDG                      THERMAL PARAMETER FUNCTIONS
QINW FOR,* MADATA/S,MADATA/S,MADATA/R
-20
C   THE FOLLOWING STATEMENTS DEFINE THE MATERIAL THERMAL PARAMETERS
C   MATERIAL 1 IS INCONEL
      RCON1(X)=4.27E-3*(DR-460.)+8.3
      ACON1(X)=RCON1(X)
C   MATERIAL 2 IS HELIUM AT 680 DEG.
      RCON2(X)=1000.
      ACON2(X)=1000.
      SPEC2(X)=1.E6
C   MATERIAL 3 IS HELIUM WITH NATURAL CIRCULATION
      RCON3(X)=500.
      ACON3(X)=500.
C   MATERIAL 4 IS INSULATION
      RCON4(X)=.05
      ACON4(X)=.05
C   MATERIAL 5 IS CARBON STEEL
      RCON5(X)=31.88-2.739E-3*(DR-460.)-6.264E-6*(DR-460.)**2
      ACON5(X)=RCON5(X)
C   GAP GAS 1 GIVES AN EFFECTIVE H=437
      GCON1(X)=437,*.0001/12.
C   GAP GAS 2 GIVES AN EFFECTIVE H=723
      GCON2(X)=723,*.0001/12.
C   GAP GAS 3 GIVES AN EFFECTIVE H=905
      GCON3(X)=905,*.0001/12.
C   GAP GAS 4 GIVES AN EFFECTIVE H=85
      GCON4(X)=85,*.0001/12.
QINW FOR,* FLODAT/S,FLODAT/S,FLODAT/R
-20
C   THE FOLLOWING STATEMENTS DEFINE THE COOLANT THERMAL PARAMETERS
C   COOLANT 1 IS ALONG THE HIGH RADIAL BOUNDARY AND
C   SIMULATES THE HELIUM CIRCULATOR FLOW AND BLOWER BLADES AT 680 DEG.
      FLO1A(X)=1.E8
      SPH1(X)=1.E4
      H1A(X)=1.E5
      TIN1A(X)=1140.
C   COOLANT 2 SIMULATES THE BLOWER SHAFT AT 175 DEG. AND THE
C   NATURAL CONVECTION H=85
      FLO2A(X)=1.E8
      SPH2(X)=1.E4
      H2A(X)=85.
      TIN2A(X)=635.

```

C COOLANTS 3, 4, AND 5 REPRESENT THE ADIABATIC BOUNDARIES
 C COOLANTS 6, 7, 8, AND 9 REPRESENT THE BLEED FLOW AND
 C ARE INTERNAL COOLANT BLOCKS 13, 14, 15, AND 16, RESPECTIVELY
 FLO6A(X)=50.
 SPH6(X)=1.24
 H6A(X)=105.
 TIN6A(X)=635.
 FLO7A(X)=50.
 SPH7(X)=1.24
 H7A(X)=580.
 TIN7A(X)=T0(6)
 FLO8A(X)=50.
 SPH8(X)=1.24
 H8A(X)=818.
 TIN8A(X)=T0(7)
 FLO9A(X)=50.
 SPH9(X)=1.24
 H9A(X)=1050.
 TIN9A(X)=T0(8)

WP HDG TAC2D EXAMPLE PROBLEM OUTPUT

Q XQT TAC2D/AR
 STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

CYLINDRICAL GEOMETRY
 STEADY STATE
 CONDUCTIVITIES
 RESISTANCES
 HEAT FLUXES
 SURFACE TEMPERATURES

.0	.58	1.16	1.75	2.40	3.0
3.25	3.375	3.75	4.25	4.75	5.25
5.75	6.25	6.75	7.25	7.625	7.75
8.0	8.33	8.67	9.0		
0.	.3125	.625	.875	1.125	1.375
1.625	1.875	2.125	2.250	2.375	2.625
2.875	3.25	3.625	4.0		
2.					
0.	1.75	0.	.625		
2.					
0.	1.75	.625	.875		
.0001	1.	.0001	1.		
2.					
1.75	3.25	0.	.625		
		.0001	1.		
2.					
3.25	5.75	0.	1.125		
		.0001	2.		
2.					
5.75	8.0	0.	1.125		
.0001	3.	.0001	3.		
1.					

TITLE 1
 BLANK
 OPTION 1
 OPTION 2
 OPTION 3
 OPTION 4
 OPTION 5
 OPTION 6
 BLANK
 RG-1
 RG-2
 RG-3
 RG-4
 BLANK
 AG-1
 AG-2
 AG-3
 BLANK
 B1-1
 B1-2
 B1-3
 B2-1
 B2-2
 B2-3
 B3-1
 B3-2
 B3-3
 B4-1
 B4-2
 B4-3
 B5-1
 B5-2
 B5-3
 B6-1

0.	1.75	.875	1.125	B6-2
1.				B6-3
1.75	3.25	.625	1.125	B7-1
.0001	2.			B7-2
1.				B7-3
0.	3.0	2.125	2.375	B8-1
		.0001	4.	B8-2
1.				B8-3
3.0	3.25	2.125	4.0	B9-1
				B9-2
1.				B9-3
0.	8.0	1.125	2.125	B10-1
				B10-2
1.				B10-3
8.0	9.0	0.	3.25	B11-1
				B11-2
				B11-3
3.				B12-1
0.	3.0	2.375	4.0	B12-2
.0001	4.			B12-3
-6.	-2.			B13-1
3.25	3.375	2.25	4.0	B13-2
				B13-3
-7.	1.			B14-1
3.25	8.0	2.125	2.250	B14-2
				B14-3
-8.	2.			B15-1
7.75	8.0	2.25	4.0	B15-2
				B15-3
-9.	1.			B16-1
8.0	9.0	3.25	4.0	B16-2
				B16-3
5.				B17-1
3.375	3.75	2.375	4.0	B17-2
				B17-3
5.				B18-1
3.375	7.75	2.25	2.375	B18-2
				B18-3
5.				B19-1
7.625	7.75	2.375	4.0	B19-2
				B19-3
4.				B20-1
3.75	7.625	2.375	4.0	B20-2
				B20-3
-3.	1.			B21-1
0.	9.0	0.	0.	B21-2
				B21-3
-4.	2.			B22-1
0.	0.	0.	4.0	B22-2
				B22-3
-1.	2.			B23-1
9.0	9.0	0.	4.0	B23-2
				B23-3
-2.	1.			B24-1
0.	3.0	4.0	4.0	B24-2

-5.	1.			
3.0	9.0	4.0	4.0	
0.	9.0	0.	4.0	
680.				
1.	0.	10.	20.	30.
		1		
2.	0.	10.	20.	30.
3.	0.	10.	20.	30.
4.	0.	10.	20.	30.
5.	0.	10.	20.	30.
6.	0.	10.	20.	30.
7.	0.	10.	20.	30.
8.	0.	10.	20.	30.
9.	0.	10.	20.	30.

B24-3
 B25-1
 B25-2
 B25-3
 BLANK
 IT-1
 IT-1
 BLANK
 C1-1
 C1-2
 C1-3
 C2-1
 C2-2
 C2-3
 C3-1
 C3-2
 C3-3
 C4-1
 C4-2
 C4-3
 C5-1
 C5-2
 C5-3
 C6-1
 C6-2
 C6-3
 C7-1
 C7-2
 C7-3
 C8-1
 C8-2
 C8-3
 C9-1
 C9-2
 C9-3
 BLANK
 BLANK
 P-1
 P-2
 P-3
 BLANK
 BLANK

TAC2D EXAMPLE PROBLEM OUTPUT

TAC2D EXAMPLE PROBLEM OUTPUT

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T A C 2 D C O D E STANDARD VERSION

IQ = 45 JQ = 45 I6Q = 25 J6Q = 25 LQ = 11n

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

OPTIONS

CYLINDRICAL GEOMETRY

STEADY STATE

CONDUCTIVITIES

RESISTANCES

HEAT FLUXES

SURFACE TEMPERATURES

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

BLOCK NUMBER	BLOCK DESCRIPTION					GAPS			
	BOUNDARIES								
	LOW RADIAL (INCHES)	HIGH RADIAL (INCHES)	LOW AXIAL (INCHES)	HIGH AXIAL (INCHES)	MATERIAL	RADIAL (INCHES)	MATERIAL	AXIAL (INCHES)	MATERIAL
1	.0000	1.7500	.0000	.6250	2				
2	.0000	1.7500	.6250	.8750	2	.0001	1	.0001	1
3	1.7500	3.2500	.0000	.6250	2			.0001	1
4	3.2500	5.7500	.0000	1.1250	2			.0001	2
5	5.7500	8.0000	.0000	1.1250	2	.0001	3	.0001	3
6	.0000	1.7500	.8750	1.1250	1				
7	1.7500	3.2500	.6250	1.1250	1	.0001	2		
8	.0000	3.0000	2.1250	2.3750	1			.0001	4
9	3.0000	3.2500	2.1250	4.0000	1				
10	.0000	8.0000	1.1250	2.1250	1				
11	8.0000	9.0000	.0000	3.2500	1				
12	.0000	3.0000	2.3750	4.0000	3	.0001	4		
13	3.2500	3.3750	2.2500	4.0000	-6				
14	3.2500	8.0000	2.1250	2.2500	-7				
15	7.7500	8.0000	2.2500	4.0000	-8				
16	8.0000	9.0000	3.2500	4.0000	-9				
17	3.3750	3.7500	2.3750	4.0000	5				
18	3.3750	7.7500	2.2500	2.3750	5				
19	7.6250	7.7500	2.3750	4.0000	5				
20	3.7500	7.6250	2.3750	4.0000	4				
21	.0000	9.0000	.0000	.0000	-3				
22	.0000	.0000	.0000	4.0000	-4				
23	9.0000	9.0000	.0000	4.0000	-1				
24	.0000	3.0000	4.0000	4.0000	-2				
25	3.0000	9.0000	4.0000	4.0000	-5				

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

BOUNDARY OVERLAY

- * WHERE COOLANTS ARE PRESENT
- ⌘ WHERE GAPS ARE PRESENT
- WHERE GAPS OR COOLANTS NOT PRESENT

THE RADIAL(I) GRID LINES ARE HORIZONTAL
THE AXIAL (J) GRID LINES ARE VERTICAL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3	*	•	•	⌘	⌘	⌘	⌘	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
4	*	⌘	⌘	⌘	•	•	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘
5	*	•	•	•	•	•	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘
6	*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
7	*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
8	*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9	*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
10	*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
11	*	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘
12	*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
13	*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
14	*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
15	*	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
16	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

NODE VOLUMES (FT**3)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	1.9112-04	5.7337-04	9.7544-04	1.5326-03	1.8408-03	8.8772-04	4.7049-04	1.5180-03	2.2726-03
3	0.0000	1.9112-04	5.7337-04	9.7544-04	1.5321-03	1.8402-03	8.8744-04	4.7049-04	1.5180-03	2.2726-03
4	0.0000	1.5284-04	4.5851-04	7.7988-04	1.2260-03	1.4726-03	7.0988-04	3.7639-04	1.2144-03	1.8181-03
5	0.0000	1.5290-04	4.5869-04	7.8035-04	1.2260-03	1.4726-03	7.0988-04	3.7624-04	1.2139-03	1.8173-03
6	0.0000	1.5290-04	4.5869-04	7.8035-04	1.2260-03	1.4726-03	7.1018-04	3.7639-04	1.2144-03	1.8181-03
7	0.0000	1.5290-04	4.5869-04	7.8035-04	1.2260-03	1.4726-03	7.1018-04	3.7639-04	1.2144-03	1.8181-03
8	0.0000	1.5290-04	4.5869-04	7.8035-04	1.2260-03	1.4726-03	7.1018-04	3.7639-04	1.2144-03	1.8181-03
9	0.0000	1.5290-04	4.5869-04	7.8035-04	1.2260-03	1.4726-03	7.1018-04	3.7639-04	1.2144-03	1.8181-03
10	0.0000	7.6449-05	2.2935-04	3.9018-04	6.1302-04	7.3631-04	3.5509-04	1.8820-04	6.0720-04	9.0903-04
11	0.0000	7.6388-05	2.2916-04	3.8986-04	6.1253-04	7.3572-04	3.5509-04	1.8820-04	6.0720-04	9.0903-04
12	0.0000	1.5290-04	4.5869-04	7.8035-04	1.2260-03	1.4723-03	7.1018-04	3.7639-04	1.2144-03	1.8181-03
13	0.0000	1.5290-04	4.5869-04	7.8035-04	1.2260-03	1.4723-03	7.1018-04	3.7639-04	1.2144-03	1.8181-03
14	0.0000	2.2935-04	6.8804-04	1.1705-03	1.8391-03	2.2085-03	1.0653-03	5.6459-04	1.8216-03	2.7271-03
15	0.0000	2.2935-04	6.8804-04	1.1705-03	1.8391-03	2.2085-03	1.0653-03	5.6459-04	1.8216-03	2.7271-03
16	0.0000	2.2935-04	6.8804-04	1.1705-03	1.8391-03	2.2085-03	1.0653-03	5.6459-04	1.8216-03	2.7271-03
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	11	12	13	14	15	16	17	18	19	20
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	2.5566-03	2.8407-03	3.1248-03	3.4088-03	3.6929-03	3.9770-03	3.1692-03	1.0919-03	2.2361-03	3.0617-03
3	2.5566-03	2.8407-03	3.1248-03	3.4088-03	3.6929-03	3.9770-03	3.1692-03	1.0919-03	2.2361-03	3.0617-03
4	2.0453-03	2.2726-03	2.4998-03	2.7271-03	2.9543-03	3.1816-03	2.5353-03	8.7352-04	1.7889-03	2.4493-03
5	2.0445-03	2.2717-03	2.4988-03	2.7260-03	2.9532-03	3.1803-03	2.5343-03	8.7317-04	1.7882-03	2.4493-03
6	2.0453-03	2.2726-03	2.4998-03	2.7271-03	2.9543-03	3.1816-03	2.5353-03	8.7352-04	1.7896-03	2.4493-03
7	2.0453-03	2.2726-03	2.4998-03	2.7271-03	2.9543-03	3.1816-03	2.5353-03	8.7352-04	1.7896-03	2.4493-03
8	2.0453-03	2.2726-03	2.4998-03	2.7271-03	2.9543-03	3.1816-03	2.5353-03	8.7352-04	1.7896-03	2.4493-03
9	2.0453-03	2.2726-03	2.4998-03	2.7271-03	2.9543-03	3.1816-03	2.5353-03	8.7352-04	1.7896-03	2.4493-03
10	1.0227-03	1.1363-03	1.2499-03	1.3635-03	1.4772-03	1.5908-03	1.2677-03	4.3676-04	8.9482-04	1.2247-03
11	1.0227-03	1.1363-03	1.2499-03	1.3635-03	1.4772-03	1.5908-03	1.2677-03	4.3676-04	8.9482-04	1.2247-03
12	2.0453-03	2.2726-03	2.4998-03	2.7271-03	2.9543-03	3.1816-03	2.5353-03	8.7352-04	1.7896-03	2.4493-03
13	2.0453-03	2.2726-03	2.4998-03	2.7271-03	2.9543-03	3.1816-03	2.5353-03	8.7352-04	1.7896-03	2.4493-03
14	3.0680-03	3.4088-03	3.7497-03	4.0906-03	4.4315-03	4.7724-03	3.8030-03	1.3103-03	2.6845-03	3.6740-03
15	3.0680-03	3.4088-03	3.7497-03	4.0906-03	4.4315-03	4.7724-03	3.8030-03	1.3103-03	2.6845-03	3.6740-03
16	3.0680-03	3.4088-03	3.7497-03	4.0906-03	4.4315-03	4.7724-03	3.8030-03	1.3103-03	2.6845-03	3.6740-03
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	21	22	23							

TAC2D EXAMPLE PROBLEM OUTPUT

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1	0.0000	0.0000	0.0000
2	3.2839-03	3.3129-03	0.0000
3	3.2839-03	3.3129-03	0.0000
4	2.6271-03	2.6503-03	0.0000
5	2.6271-03	2.6503-03	0.0000
6	2.6271-03	2.6503-03	0.0000
7	2.6271-03	2.6503-03	0.0000
8	2.6271-03	2.6503-03	0.0000
9	2.6271-03	2.6503-03	0.0000
10	1.3135-03	1.3252-03	0.0000
11	1.3135-03	1.3252-03	0.0000
12	2.6271-03	2.6503-03	0.0000
13	2.6271-03	2.6503-03	0.0000
14	3.9406-03	3.9755-03	0.0000
15	3.9406-03	3.9755-03	0.0000
16	3.9406-03	3.9755-03	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

RADIAL GEOMETRY FACTOR (HEAT FLOW AREA/RADIAL DISTANCE) BETWEEN POINTS (I,J) AND (I+1,J) (FT)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1.5924-02	1.4894-01	3.1817-01	4.6097-01	6.2146-01	1.1193+00	2.8081+00	2.2488+00	1.4126+00	1.3892+00
3	1.5924-02	1.4894-01	3.1817-01	4.6090-01	6.2126-01	1.1190+00	2.8076+00	2.2488+00	1.4126+00	1.3892+00
4	1.2737-02	1.1910-01	2.5443-01	3.6870-01	4.9717-01	8.9545-01	2.2465+00	1.7991+00	1.1301+00	1.1114+00
5	1.2740-02	1.1915-01	2.5454-01	3.6878-01	4.9717-01	8.9545-01	2.2460+00	1.7984+00	1.1296+00	1.1109+00
6	1.2740-02	1.1915-01	2.5454-01	3.6878-01	4.9717-01	8.9545-01	2.2465+00	1.7991+00	1.1301+00	1.1114+00
7	1.2740-02	1.1915-01	2.5454-01	3.6878-01	4.9717-01	8.9545-01	2.2465+00	1.7991+00	1.1301+00	1.1114+00
8	1.2740-02	1.1915-01	2.5454-01	3.6878-01	4.9717-01	8.9545-01	2.2465+00	1.7991+00	1.1301+00	1.1114+00
9	1.2740-02	1.1915-01	2.5454-01	3.6878-01	4.9717-01	8.9545-01	2.2465+00	1.7991+00	1.1301+00	1.1114+00
10	6.3698-03	5.9576-02	1.2727-01	1.8439-01	2.4858-01	4.4773-01	1.1232+00	8.9954-01	5.6504-01	5.5568-01
11	6.3672-03	5.9528-02	1.2717-01	1.8424-01	2.4839-01	4.4755-01	1.1232+00	8.9954-01	5.6504-01	5.5568-01
12	1.2740-02	1.1915-01	2.5454-01	3.6878-01	4.9717-01	8.9545-01	2.2465+00	1.7991+00	1.1301+00	1.1114+00
13	1.2740-02	1.1915-01	2.5454-01	3.6878-01	4.9717-01	8.9545-01	2.2465+00	1.7991+00	1.1301+00	1.1114+00
14	1.9109-02	1.7873-01	3.8180-01	5.5317-01	7.4575-01	1.3432+00	3.3697+00	2.6986+00	1.6951+00	1.6670+00
15	1.9109-02	1.7873-01	3.8180-01	5.5317-01	7.4575-01	1.3432+00	3.3697+00	2.6986+00	1.6951+00	1.6670+00
16	1.9109-02	1.7873-01	3.8180-01	5.5317-01	7.4575-01	1.3432+00	3.3697+00	2.6986+00	1.6951+00	1.6670+00
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	11	12	13	14	15	16	17	18	19	20
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1.5530+00	1.7168+00	1.8805+00	2.0442+00	2.2079+00	2.6990+00	4.9492+00	6.7901+00	4.5246+00	4.0693+00
3	1.5530+00	1.7168+00	1.8805+00	2.0442+00	2.2079+00	2.6990+00	4.9492+00	6.7901+00	4.5246+00	4.0693+00
4	1.2424+00	1.3734+00	1.5044+00	1.6354+00	1.7663+00	2.1592+00	3.9594+00	5.4321+00	3.6197+00	3.2554+00
5	1.2419+00	1.3729+00	1.5038+00	1.6347+00	1.7656+00	2.1583+00	3.9578+00	5.4299+00	3.6189+00	3.2554+00
6	1.2424+00	1.3734+00	1.5044+00	1.6354+00	1.7663+00	2.1592+00	3.9594+00	5.4321+00	3.6197+00	3.2554+00
7	1.2424+00	1.3734+00	1.5044+00	1.6354+00	1.7663+00	2.1592+00	3.9594+00	5.4321+00	3.6197+00	3.2554+00
8	1.2424+00	1.3734+00	1.5044+00	1.6354+00	1.7663+00	2.1592+00	3.9594+00	5.4321+00	3.6197+00	3.2554+00
9	1.2424+00	1.3734+00	1.5044+00	1.6354+00	1.7663+00	2.1592+00	3.9594+00	5.4321+00	3.6197+00	3.2554+00
10	6.2120-01	6.8670-01	7.5220-01	8.1769-01	8.8317-01	1.0796+00	1.9797+00	2.7160+00	1.8098+00	1.6277+00
11	6.2120-01	6.8670-01	7.5220-01	8.1769-01	8.8317-01	1.0796+00	1.9797+00	2.7160+00	1.8098+00	1.6277+00
12	1.2424+00	1.3734+00	1.5044+00	1.6354+00	1.7663+00	2.1592+00	3.9594+00	5.4321+00	3.6197+00	3.2554+00
13	1.2424+00	1.3734+00	1.5044+00	1.6354+00	1.7663+00	2.1592+00	3.9594+00	5.4321+00	3.6197+00	3.2554+00
14	1.8636+00	2.0601+00	2.2566+00	2.4531+00	2.6495+00	3.2388+00	5.9390+00	8.1481+00	5.4295+00	4.8832+00
15	1.8636+00	2.0601+00	2.2566+00	2.4531+00	2.6495+00	3.2388+00	5.9390+00	8.1481+00	5.4295+00	4.8832+00
16	1.8636+00	2.0601+00	2.2566+00	2.4531+00	2.6495+00	3.2388+00	5.9390+00	8.1481+00	5.4295+00	4.8832+00
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	21	22	23							

TAC2D EXAMPLE PROBLEM OUTPUT

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1	0.0000	0.0000	0.0000
2	4.2330+00	8.8429+00	0.0000
3	4.2330+00	8.8429+00	0.0000
4	3.3864+00	7.0743+00	0.0000
5	3.3864+00	7.0743+00	0.0000
6	3.3864+00	7.0743+00	0.0000
7	3.3864+00	7.0743+00	0.0000
8	3.3864+00	7.0743+00	0.0000
9	3.3864+00	7.0743+00	0.0000
10	1.6932+00	3.5372+00	0.0000
11	1.6932+00	3.5372+00	0.0000
12	3.3864+00	7.0743+00	0.0000
13	3.3864+00	7.0743+00	0.0000
14	5.0795+00	1.0612+01	0.0000
15	5.0795+00	1.0612+01	0.0000
16	5.0795+00	1.0612+01	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

AXIAL GEOMETRY FACTOR (HEAT FLOW AREA/AXIAL DISTANCE) BETWEEN POINTS (I,J) AND (I,J+1) (FT)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	5.6364-01	1.6909+00	2.8767+00	4.5197+00	5.4287+00	2.6180+00	1.3875+00	4.4768+00	6.7021+00
2	0.0000	2.8182-01	8.4547-01	1.4383+00	2.2599+00	2.7143+00	1.3090+00	6.9377-01	2.2384+00	3.3510+00
3	0.0000	3.1314-01	9.3941-01	1.5980+00	2.5109+00	3.0159+00	1.4541+00	7.7085-01	2.4871+00	3.7234+00
4	0.0000	3.5228-01	1.0568+00	1.7978+00	2.8248+00	3.3929+00	1.6356+00	8.6721-01	2.7980+00	4.1888+00
5	0.0000	3.5228-01	1.0568+00	1.7979+00	2.8248+00	3.3929+00	1.6359+00	8.6721-01	2.7980+00	4.1888+00
6	0.0000	3.5228-01	1.0568+00	1.7979+00	2.8248+00	3.3929+00	1.6362+00	8.6721-01	2.7980+00	4.1888+00
7	0.0000	3.5228-01	1.0568+00	1.7979+00	2.8248+00	3.3929+00	1.6362+00	8.6721-01	2.7980+00	4.1888+00
8	0.0000	3.5228-01	1.0568+00	1.7979+00	2.8248+00	3.3929+00	1.6362+00	8.6721-01	2.7980+00	4.1888+00
9	0.0000	4.6970-01	1.4091+00	2.3972+00	3.7664+00	4.5239+00	2.1817+00	1.1563+00	3.7306+00	5.5851+00
10	0.0000	7.0455-01	2.1137+00	3.5959+00	5.6496+00	6.7858+00	3.2725+00	1.7344+00	5.5960+00	8.3776+00
11	0.0000	4.6970-01	1.4091+00	2.3972+00	3.7664+00	4.5235+00	2.1817+00	1.1563+00	3.7306+00	5.5851+00
12	0.0000	3.5228-01	1.0568+00	1.7979+00	2.8248+00	3.3923+00	1.6362+00	8.6721-01	2.7980+00	4.1888+00
13	0.0000	2.8182-01	8.4547-01	1.4383+00	2.2599+00	2.7138+00	1.3090+00	6.9377-01	2.2384+00	3.3510+00
14	0.0000	2.3485-01	7.0455-01	1.1986+00	1.8832+00	2.2615+00	1.0908+00	5.7814-01	1.8653+00	2.7925+00
15	0.0000	2.3485-01	7.0455-01	1.1986+00	1.8832+00	2.2615+00	1.0908+00	5.7814-01	1.8653+00	2.7925+00
16	0.0000	4.6970-01	1.4091+00	2.3972+00	3.7664+00	4.5235+00	2.1817+00	1.1563+00	3.7306+00	5.5851+00
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	11	12	13	14	15	16	17	18	19	20
1	7.5398+00	8.3776+00	9.2153+00	1.0053+01	1.0891+01	1.1729+01	9.3462+00	3.2201+00	6.5960+00	9.0292+00
2	3.7699+00	4.1888+00	4.6077+00	5.0265+00	5.4454+00	5.8643+00	4.6731+00	1.6101+00	3.2973+00	4.5146+00
3	4.1688+00	4.6542+00	5.1196+00	5.5851+00	6.0505+00	6.5159+00	5.1924+00	1.7890+00	3.6637+00	5.0162+00
4	4.7124+00	5.2360+00	5.7596+00	6.2832+00	6.8068+00	7.3304+00	5.8414+00	2.0126+00	4.1217+00	5.6432+00
5	4.7124+00	5.2360+00	5.7596+00	6.2832+00	6.8068+00	7.3304+00	5.8414+00	2.0126+00	4.1225+00	5.6432+00
6	4.7124+00	5.2360+00	5.7596+00	6.2832+00	6.8068+00	7.3304+00	5.8414+00	2.0126+00	4.1233+00	5.6432+00
7	4.7124+00	5.2360+00	5.7596+00	6.2832+00	6.8068+00	7.3304+00	5.8414+00	2.0126+00	4.1233+00	5.6432+00
8	4.7124+00	5.2360+00	5.7596+00	6.2832+00	6.8068+00	7.3304+00	5.8414+00	2.0126+00	4.1233+00	5.6432+00
9	6.2632+00	6.9813+00	7.6794+00	8.3776+00	9.0757+00	9.7738+00	7.7885+00	2.6834+00	5.4978+00	7.5243+00
10	9.4248+00	1.0472+01	1.1519+01	1.2566+01	1.3614+01	1.4661+01	1.1663+01	4.0252+00	8.2467+00	1.1286+01
11	6.2632+00	6.9813+00	7.6794+00	8.3776+00	9.0757+00	9.7738+00	7.7885+00	2.6834+00	5.4978+00	7.5243+00
12	4.7124+00	5.2360+00	5.7596+00	6.2832+00	6.8068+00	7.3304+00	5.8414+00	2.0126+00	4.1233+00	5.6432+00
13	3.7699+00	4.1888+00	4.6077+00	5.0265+00	5.4454+00	5.8643+00	4.6731+00	1.6101+00	3.2987+00	4.5146+00
14	3.1416+00	3.4907+00	3.8397+00	4.1888+00	4.5379+00	4.8869+00	3.8943+00	1.3417+00	2.7489+00	3.7622+00
15	3.1416+00	3.4907+00	3.8397+00	4.1888+00	4.5379+00	4.8869+00	3.8943+00	1.3417+00	2.7489+00	3.7622+00
16	6.2632+00	6.9813+00	7.6794+00	8.3776+00	9.0757+00	9.7738+00	7.7885+00	2.6834+00	5.4978+00	7.5243+00
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	21	22	23							

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TAC2D EXAMPLE PROBLEM OUTPUT

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1	9.6645+00	9.7701+00	0.0000
2	4.8422+00	4.8851+00	0.0000
3	5.3803+00	5.4278+00	0.0000
4	6.0528+00	6.1063+00	0.0000
5	6.0528+00	6.1063+00	0.0000
6	6.0528+00	6.1063+00	0.0000
7	6.0528+00	6.1063+00	0.0000
8	6.0528+00	6.1063+00	0.0000
9	8.0704+00	8.1418+00	0.0000
10	1.2106+01	1.2213+01	0.0000
11	8.0704+00	8.1418+00	0.0000
12	6.0528+00	6.1063+00	0.0000
13	4.8422+00	4.8851+00	0.0000
14	4.0352+00	4.0709+00	0.0000
15	4.0352+00	4.0709+00	0.0000
16	8.0704+00	8.1418+00	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

RADIAL BOUNDARY ASSIGNMENTS

SEQUENCE NUMBER	POINT LOCATION (INCHES)	GRID LINE LOCATION (INCHES)	COOLANT OR GAP BOUNDARY NUMBER
1	.0000		
1		.0000	1
2	.2900		
2		.5800	
3	.8700		
3		1.1600	
4	1.4550		
4		1.7500	2
5	2.0750		
5		2.4000	
6	2.7000		
6		3.0000	3
7	3.1250		
7		3.2500	4
8	3.3125		
8		3.3750	5
9	3.5625		
9		3.7500	
10	4.0000		
10		4.2500	
11	4.5000		
11		4.7500	
12	5.0000		
12		5.2500	
13	5.5000		
13		5.7500	
14	6.0000		
14		6.2500	
15	6.5000		
15		6.7500	
16	7.0000		
16		7.2500	
17	7.4375		
17		7.6250	
18	7.6875		
18		7.7500	6
19	7.8750		
19		8.0000	7
20	8.1650		
20		8.3300	
21	8.5000		
21		8.6700	
22	8.8350		
22		9.0000	8
23	9.0000		

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

AXIAL BOUNDARY ASSIGNMENTS

SEQUENCE NUMBER	POINT LOCATION (INCHES)	GRID LINE LOCATION (INCHES)	COOLANT OR GAP BOUNDARY NUMBER
1	.0000		
1		.0000	1
2	.1562	.3125	
2			
3	.4687	.6250	2
3			
4	.7500	.8750	3
4			
5	1.0000	1.1250	4
5			
6	1.2500	1.3750	
6			
7	1.5000	1.6250	
7			
8	1.7500	1.8750	
8			
9	2.0000	2.1250	5
9			
10	2.1875	2.2500	6
10			
11	2.3125	2.3750	7
11			
12	2.5000	2.6250	
12			
13	2.7500	2.8750	
13			
14	3.0625	3.2500	8
14			
15	3.4375	3.6250	
15			
16	3.8125	4.0000	9
16			
17	4.0000		

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

COOLANT SPECIFICATIONS

SPECIFICATIONS FOR COOLANT 1

THE COOLANT IS FLOWING IN THE POSITIVE AXIAL DIRECTION
THE REYNOLDS NUMBER LIMITS ARE 0.0000 1.0000+01 2.0000+01 3.0000+01
NO STEP CHANGES IN FLOW
NO STEP CHANGES IN INLET TEMPERATURE

SPECIFICATIONS FOR COOLANT 2

THE COOLANT IS FLOWING IN THE POSITIVE RADIAL DIRECTION
THE REYNOLDS NUMBER LIMITS ARE 0.0000 1.0000+01 2.0000+01 3.0000+01
NO STEP CHANGES IN FLOW
NO STEP CHANGES IN INLET TEMPERATURE

SPECIFICATIONS FOR COOLANT 3

THE COOLANT IS FLOWING IN THE POSITIVE RADIAL DIRECTION
THE REYNOLDS NUMBER LIMITS ARE 0.0000 1.0000+01 2.0000+01 3.0000+01
NO STEP CHANGES IN FLOW
NO STEP CHANGES IN INLET TEMPERATURE

SPECIFICATIONS FOR COOLANT 4

THE COOLANT IS FLOWING IN THE POSITIVE AXIAL DIRECTION
THE REYNOLDS NUMBER LIMITS ARE 0.0000 1.0000+01 2.0000+01 3.0000+01
NO STEP CHANGES IN FLOW
NO STEP CHANGES IN INLET TEMPERATURE

SPECIFICATIONS FOR COOLANT 5

THE COOLANT IS FLOWING IN THE POSITIVE RADIAL DIRECTION
THE REYNOLDS NUMBER LIMITS ARE 0.0000 1.0000+01 2.0000+01 3.0000+01
NO STEP CHANGES IN FLOW
NO STEP CHANGES IN INLET TEMPERATURE

SPECIFICATIONS FOR COOLANT 6

TAC2D EXAMPLE PROBLEM OUTPUT

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THE COOLANT IS FLOWING IN THE NEGATIVE AXIAL DIRECTION
 THE REYNOLDS NUMBER LIMITS ARE 0.0000 1.0000+01 2.0000+01 3.000n+01
 NO STEP CHANGES IN FLOW
 NO STEP CHANGES IN INLET TEMPERATURE

SPECIFICATIONS FOR COOLANT 7

THE COOLANT IS FLOWING IN THE POSITIVE RADIAL DIRECTION
 THE REYNOLDS NUMBER LIMITS ARE 0.0000 1.0000+01 2.0000+01 3.000n+01
 NO STEP CHANGES IN FLOW
 NO STEP CHANGES IN INLET TEMPERATURE

SPECIFICATIONS FOR COOLANT 8

THE COOLANT IS FLOWING IN THE POSITIVE AXIAL DIRECTION
 THE REYNOLDS NUMBER LIMITS ARE 0.0000 1.0000+01 2.0000+01 3.000n+01
 NO STEP CHANGES IN FLOW
 NO STEP CHANGES IN INLET TEMPERATURE

SPECIFICATIONS FOR COOLANT 9

THE COOLANT IS FLOWING IN THE POSITIVE RADIAL DIRECTION
 THE REYNOLDS NUMBER LIMITS ARE 0.0000 1.0000+01 2.0000+01 3.000n+01
 NO STEP CHANGES IN FLOW
 NO STEP CHANGES IN INLET TEMPERATURE

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

FUNCTION CONTROL CONSTANTS

CONSTANT NUMBER	VALUE
1	0.000000
2	0.000000
3	0.000000
4	0.000000
5	0.000000
6	0.000000
7	0.000000
8	0.000000
9	0.000000
10	0.000000
11	0.000000
12	0.000000
13	0.000000
14	0.000000
15	0.000000
16	0.000000
17	0.000000
18	0.000000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

INPUT TEMPERATURE DISTRIBUTION

TEMPERATURES (F)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
3	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
4	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
5	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
6	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
7	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
8	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
9	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
10	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
11	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
12	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
13	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
14	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
15	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
16	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

PROBLEM INPUT CARDS

0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0

XX

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

CYLINDRICAL GEOMETRY
 STEADY STATE
 CONDUCTIVITIES
 RESISTANCES
 HEAT FLUXES
 SURFACE TEMPERATURES

TITLE 1
 BLANK
 OPTION 1
 OPTION 2
 OPTION 3
 OPTION 4
 OPTION 5
 OPTION 6
 BLANK

.00000	.58000	1.16000	1.75000	2.40000	3.00000	RG-1
3.25000	3.37500	3.75000	4.25000	4.75000	5.25000	RG-2
5.75000	6.25000	6.75000	7.25000	7.62500	7.75000	RG-3
8.00000	8.33000	8.67000	9.00000	.00000	.00000	RG-4
						BLANK
.00000	.31250	.62500	.87500	1.12500	1.37500	AG-1
1.62500	1.87500	2.12500	2.25000	2.37500	2.62500	AG-2
2.87500	3.25000	3.62500	4.00000	.00000	.00000	AG-3
						BLANK
2.00000	.00000	.00000				B1-1
.00000	1.75000	.00000	.62500			B1-2
.00000	.00000	.00000	.00000			B1-3
2.00000	.00000	.00000				B2-1
.00000	1.75000	.62500	.87500			B2-2
.00010	1.00000	.00010	1.00000			B2-3
2.00000	.00000	.00000				B3-1
1.75000	3.25000	.00000	.62500			B3-2
.00000	.00000	.00010	1.00000			B3-3
2.00000	.00000	.00000				B4-1
3.25000	5.75000	.00000	1.12500			B4-2
.00000	.00000	.00010	2.00000			B4-3
2.00000	.00000	.00000				B5-1
5.75000	8.00000	.00000	1.12500			B5-2
.00010	3.00000	.00010	3.00000			B5-3
1.00000	.00000	.00000				B6-1
.00000	1.75000	.87500	1.12500			B6-2
.00000	.00000	.00000	.00000			B6-3
1.00000	.00000	.00000				B7-1
1.75000	3.25000	.62500	1.12500			B7-2
.00010	2.00000	.00000	.00000			B7-3
1.00000	.00000	.00000				B8-1
.00000	3.00000	2.12500	2.37500			B8-2
.00000	.00000	.00010	4.00000			B8-3
1.00000	.00000	.00000				B9-1
3.00000	3.25000	2.12500	4.00000			B9-2

TAC2D EXAMPLE PROBLEM OUTPUT

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.00000	.00000	.00000	.00000
1.00000	.00000	.00000	
.00000	8.00000	1.12500	2.12500
.00000	.00000	.00000	.00000
1.00000	.00000	.00000	
8.00000	9.00000	.00000	3.25000
.00000	.00000	.00000	.00000
3.00000	.00000	.00000	
.00000	3.00000	2.37500	4.00000
.00010	4.00000	.00000	.00000
-.60000+01	-.20000+01	.00000	
3.25000	3.37500	2.25000	4.00000
.00000	.00000	.00000	.00000
-.70000+01	1.00000	.00000	
3.25000	8.00000	2.12500	2.25000
.00000	.00000	.00000	.00000
-.80000+01	2.00000	.00000	
7.75000	8.00000	2.25000	4.00000
.00000	.00000	.00000	.00000
-.90000+01	1.00000	.00000	
8.00000	9.00000	3.25000	4.00000
.00000	.00000	.00000	.00000
5.00000	.00000	.00000	
3.37500	3.75000	2.37500	4.00000
.00000	.00000	.00000	.00000
5.00000	.00000	.00000	
3.37500	7.75000	2.25000	2.37500
.00000	.00000	.00000	.00000
5.00000	.00000	.00000	
7.62500	7.75000	2.37500	4.00000
.00000	.00000	.00000	.00000
4.00000	.00000	.00000	
3.75000	7.62500	2.37500	4.00000
.00000	.00000	.00000	.00000
-.30000+01	1.00000	.00000	
.00000	9.00000	.00000	.00000
.00000	.00000	.00000	.00000
-.40000+01	2.00000	.00000	
.00000	.00000	.00000	4.00000
.00000	.00000	.00000	.00000
-.10000+01	2.00000	.00000	
9.00000	9.00000	.00000	4.00000
.00000	.00000	.00000	.00000
-.20000+01	1.00000	.00000	
.00000	3.00000	4.00000	4.00000
.00000	.00000	.00000	.00000
-.50000+01	1.00000	.00000	
3.00000	9.00000	4.00000	4.00000
.00000	.00000	.00000	.00000
.00000	9.00000	.00000	4.00000
680.00000			
1.00000	.00000	10.00000	20.00000
			30.00000

B0-3
 B10-1
 B10-2
 B10-3
 B11-1
 B11-2
 B11-3
 B12-1
 B12-2
 B12-3
 B13-1
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 B23-1
 B23-2
 B23-3
 B24-1
 B24-2
 B24-3
 B25-1
 B25-2
 B25-3
 BLANK
 IT-1
 IT-1
 BLANK
 C1-1

TAC2D EXAMPLE PROBLEM OUTPUT

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.00000	.00000	.00000	.00000	.00000	C1-2
.00000	.00000	.00000	.00000	.00000	C1-3
2.00000	.00000	10.00000	20.00000	30.00000	C2-1
.00000	.00000	.00000	.00000	.00000	C2-2
.00000	.00000	.00000	.00000	.00000	C2-3
3.00000	.00000	10.00000	20.00000	30.00000	C3-1
.00000	.00000	.00000	.00000	.00000	C3-2
.00000	.00000	.00000	.00000	.00000	C3-3
4.00000	.00000	10.00000	20.00000	30.00000	C4-1
.00000	.00000	.00000	.00000	.00000	C4-2
.00000	.00000	.00000	.00000	.00000	C4-3
5.00000	.00000	10.00000	20.00000	30.00000	C5-1
.00000	.00000	.00000	.00000	.00000	C5-2
.00000	.00000	.00000	.00000	.00000	C5-3
6.00000	.00000	10.00000	20.00000	30.00000	C6-1
.00000	.00000	.00000	.00000	.00000	C6-2
.00000	.00000	.00000	.00000	.00000	C6-3
7.00000	.00000	10.00000	20.00000	30.00000	C7-1
.00000	.00000	.00000	.00000	.00000	C7-2
.00000	.00000	.00000	.00000	.00000	C7-3
8.00000	.00000	10.00000	20.00000	30.00000	C8-1
.00000	.00000	.00000	.00000	.00000	C8-2
.00000	.00000	.00000	.00000	.00000	C8-3
9.00000	.00000	10.00000	20.00000	30.00000	C9-1
.00000	.00000	.00000	.00000	.00000	C9-2
.00000	.00000	.00000	.00000	.00000	C9-3
					BLANK
					BLANK
.00000	.00000	.00000	.00000	.00000	.00000P-1
.00000	.00000	.00000	.00000	.00000	.00000P-2
.00000	.00000	.00000	.00000	.00000	.00000P-3
					BLANK
					BLANK

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)	COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)
1	680	680	100000000	2	175	175	100000000
3	0	0	1000000	4	0	0	1000000
5	0	0	1000000	6	175	218	50
7	218	609	50	8	609	627	50
9	627	656	50				

THE CURRENT TIME IS .0000 HOURS = .0000 MINUTES = .00000 SECONDS 140 ITERATIONS HAVE BEEN PERFORMED

TEMPERATURES (F)

THE RADIAL (I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	1A	19	20	21	22	23
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	680	680
3	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	679	680
4	0	680	680	680	640	640	657	680	680	680	680	680	680	680	680	680	680	680	680	677	677	679	680
5	0	626	625	621	610	611	635	680	680	680	680	680	680	680	680	680	680	680	680	675	675	678	680
6	0	595	593	589	579	577	588	595	600	605	613	622	631	642	649	655	661	664	666	668	672	677	680
7	0	564	562	557	547	538	535	535	535	543	558	574	591	607	621	633	643	649	654	661	669	676	680
8	0	534	531	526	515	498	479	471	466	478	501	525	549	572	592	610	625	635	642	653	665	675	680
9	0	504	501	496	484	460	422	395	386	407	441	474	507	536	563	587	607	619	628	647	661	674	680
10	0	482	480	474	462	436	389	227	260	308	357	404	448	487	523	554	579	592	603	645	659	673	680
11	0	468	465	460	449	422	361	216	257	307	358	404	448	487	523	555	582	600	611	641	658	673	680
12	0	293	293	293	292	292	315	209	249	297	354	403	447	487	524	558	590	611	617	638	656	672	680
13	0	292	292	292	292	292	281	202	240	284	348	400	446	488	527	564	600	619	622	638	653	670	680
14	0	292	292	292	291	291	255	195	231	273	341	397	445	489	530	570	607	625	627	636	648	666	680
15	0	291	291	291	291	290	241	187	224	266	336	394	445	490	532	574	611	627	628	630	638	650	680
16	0	290	290	290	290	290	234	179	220	263	334	393	444	490	533	575	612	627	627	630	638	650	680
17	0	175	175	175	175	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)	COOLANT TEMPERATURES (F)	COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)
1	680	680	10000000		2	175	175	10000000
3	0	0	1000000		4	0	0	1000000
5	0	0	1000000		6	175	218	50
7	218	609	50		8	609	627	50
9	627	656	50					

THE CURRENT TIME IS 250.0000 HOURS = 15000.0000 MINUTES = 900000.01000 SECONDS 145 ITERATIONS HAVE BEEN PERFORMED

TEMPERATURES (F)

THE RADIAL (I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	680	680
3	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	679	680
4	0	680	680	680	640	640	657	680	680	680	680	680	680	680	680	680	680	680	680	677	677	679	680
5	0	626	625	621	610	611	635	680	680	680	680	680	680	680	680	680	680	680	680	675	675	678	680
6	0	595	593	589	579	577	588	595	600	605	613	622	631	642	649	655	661	664	666	668	672	677	680
7	0	564	562	557	547	538	535	535	535	543	558	574	591	607	621	633	643	649	654	661	669	676	680
8	0	534	531	526	515	498	479	471	466	478	501	525	549	572	592	610	625	634	642	653	665	675	680
9	0	504	501	496	484	460	422	395	386	407	441	474	507	536	563	587	607	618	628	647	661	674	680
10	0	482	480	474	462	436	389	227	260	308	357	404	448	487	523	554	579	592	603	645	659	673	680
11	0	468	465	460	449	422	361	216	257	307	358	404	448	487	522	555	582	600	611	641	658	673	680
12	0	293	293	293	292	292	315	209	249	297	354	403	447	487	524	558	590	611	617	638	656	672	680
13	0	292	292	292	292	292	281	202	240	284	348	400	446	488	527	564	600	619	622	638	653	670	680
14	0	292	292	292	291	291	255	195	231	273	341	397	445	489	530	570	607	625	627	636	648	666	680
15	0	291	291	291	291	290	241	187	224	266	336	394	445	490	532	574	611	627	628	630	637	650	680
16	0	290	290	290	290	290	234	179	220	263	334	393	444	490	533	575	612	627	627	630	637	650	680
17	0	175	175	175	175	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

COOLANT TEMPERATURES (F)				COOLANT TEMPERATURES (F)			
COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)	COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)
1	680	680	100000000	2	175	175	100000000
3	0	0	1000000	4	0	0	1000000
5	0	0	1000000	6	175	218	50
7	218	609	50	8	609	627	50
9	627	656	50				

THE CURRENT TIME IS 500.0000 HOURS = 30000.0000 MINUTES = 1800000.0000 SECONDS 150 ITERATIONS HAVE BEEN PERFORMED

TEMPERATURES (F)

THE RADIAL (I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	680	680
3	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	679	680
4	0	680	680	680	640	640	657	680	680	680	680	680	680	680	680	680	680	680	680	677	677	679	680
5	0	626	625	621	610	611	635	680	680	680	680	680	680	680	680	680	680	680	680	675	675	678	680
6	0	595	593	589	579	577	588	595	600	605	613	622	631	642	649	655	661	664	666	668	672	677	680
7	0	564	562	557	547	538	535	535	535	543	558	574	591	607	621	633	643	649	654	661	669	676	680
8	0	534	531	526	515	498	479	471	466	478	501	525	549	572	592	610	625	634	642	653	665	675	680
9	0	504	501	496	484	460	422	395	386	407	441	474	507	536	563	587	607	618	628	647	661	674	680
10	0	462	460	474	462	436	389	227	260	308	357	404	448	487	523	554	579	592	603	645	659	673	680
11	0	468	465	460	449	422	361	216	257	307	358	404	448	487	522	555	582	600	611	641	658	673	680
12	0	293	293	293	292	292	315	209	249	297	354	403	447	487	524	558	590	611	617	638	656	672	680
13	0	292	292	292	292	292	281	202	240	284	348	400	446	488	527	564	600	619	622	638	653	670	680
14	0	292	292	292	291	291	255	195	231	273	341	397	445	489	530	570	607	625	627	636	648	666	680
15	0	291	291	291	291	290	241	187	224	266	336	394	445	490	532	574	611	627	628	630	637	650	680
16	0	290	290	290	290	290	234	179	220	263	334	393	444	490	533	575	612	627	627	630	637	650	680
17	0	175	175	175	175	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)	COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)
1	680	680	100000000	2	175	175	100000000
3	0	0	1000000	4	0	0	1000000
5	0	0	1000000	6	175	218	50
7	218	609	50	8	609	627	50
9	627	656	50				

THE CURRENT TIME IS 750.0000 HOURS = 45000.0000 MINUTES = 2700000.00000 SECONDS 155 ITERATIONS HAVE BEEN PERFORMED

TEMPERATURES (F)

THE RADIAL (I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	680	680
3	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	679	680
4	0	680	680	680	640	640	657	680	680	680	680	680	680	680	680	680	680	680	680	677	677	679	680
5	0	626	625	621	610	611	635	680	680	680	680	680	680	680	680	680	680	680	680	675	675	678	680
6	0	595	593	589	579	577	588	595	600	605	613	622	631	642	649	655	661	664	666	668	672	677	680
7	0	564	562	557	547	538	535	535	543	558	574	591	607	621	633	643	649	654	661	669	676	680	680
8	0	534	531	526	515	498	479	471	466	478	501	525	549	572	592	610	625	634	642	653	665	675	680
9	0	504	501	496	484	460	422	395	386	407	441	474	507	536	563	587	607	618	628	647	661	674	680
10	0	482	480	474	462	436	389	227	260	308	357	404	448	487	523	554	579	592	603	645	659	673	680
11	0	468	465	460	449	422	361	216	257	307	358	404	448	487	522	555	582	600	611	641	658	673	680
12	0	293	293	293	292	292	315	209	249	297	354	403	447	487	524	558	590	611	617	638	656	672	680
13	0	292	292	292	292	292	281	202	240	284	348	400	446	488	527	564	600	619	622	638	653	670	680
14	0	292	292	292	291	291	255	195	231	273	341	397	445	489	530	570	607	625	627	636	648	666	680
15	0	291	291	291	291	290	241	187	224	266	336	394	445	490	532	574	611	627	628	630	637	650	680
16	0	290	290	290	290	290	234	179	220	263	334	393	444	490	533	575	612	627	627	630	637	650	680
17	0	175	175	175	175	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)	COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)
1	680	680	100000000	2	175	175	100000000
3	0	0	1000000	4	0	0	1000000
5	0	0	1000000	6	175	218	50
7	218	609	50	8	609	627	50
9	627	656	50				

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

TEMPERATURES (F)

THE RADIAL (I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	680	680
3	0	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	679	680
4	0	680	680	680	640	640	657	680	680	680	680	680	680	680	680	680	680	680	680	677	677	679	680
5	0	626	625	621	610	611	635	680	680	680	680	680	680	680	680	680	680	680	680	675	675	678	680
6	0	595	593	589	579	577	588	595	600	605	613	622	631	642	649	655	661	664	666	668	672	677	680
7	0	564	562	557	547	538	535	535	535	543	558	574	591	607	621	633	643	649	654	661	669	676	680
8	0	534	531	526	515	498	479	471	466	478	501	525	549	572	592	610	625	634	642	653	665	675	680
9	0	504	501	496	484	460	422	395	386	407	441	474	507	536	563	587	607	618	628	647	661	674	680
10	0	482	480	474	462	436	389	227	260	308	357	404	448	487	523	554	579	592	603	645	659	673	680
11	0	468	465	460	449	422	361	216	257	307	358	404	448	487	522	555	582	600	611	641	658	673	680
12	0	293	293	293	292	292	315	209	249	297	354	403	447	487	524	558	590	611	617	638	656	672	680
13	0	292	292	292	292	292	281	202	240	284	348	400	446	488	527	564	600	619	622	637	653	670	680
14	0	292	292	292	291	291	255	195	231	273	341	397	445	489	530	570	607	625	627	636	648	666	680
15	0	291	291	291	291	290	241	187	224	266	336	394	445	490	532	574	611	627	628	630	637	650	680
16	0	290	290	290	290	290	234	179	220	263	334	393	444	490	533	575	612	627	627	630	637	650	680
17	0	175	175	175	175	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

COOLANT NUMBER	INLET	OUTLET	COOLANT TEMPERATURES (F) FLOW (LB/HR)	COOLANT NUMBER	INLET	OUTLET	FLOW (LB/HR)
1	6.8000000+02	6.8000000+02	1.0000000+08	2	1.7500000+02	1.7500000+02	1.0000000+08
3	0.0000000	0.0000000	1.0000000+06	4	0.0000000	0.0000000	1.0000000+06
5	0.0000000	0.0000000	1.0000000+06	6	1.7500000+02	2.1848753+02	5.0000000+01
7	2.1848752+02	6.0926289+02	5.0000000+01	8	6.0926285+02	6.2719009+02	5.0000000+01
9	6.2719183+02	6.5565591+02	5.0000000+01				

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

DECIMAL TEMPERATURES (F)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.00000	6.79995+02	6.79993+02	6.79993+02	6.79995+02	6.79993+02	6.79994+02	6.79994+02	6.79994+02	6.79994+02
3	0.00000	6.79994+02	6.79993+02	6.79994+02	6.79995+02	6.79993+02	6.79994+02	6.79994+02	6.79994+02	6.79993+02
4	0.00000	6.79995+02	6.79995+02	6.79994+02	6.39559+02	6.39655+02	6.57402+02	6.79994+02	6.79995+02	6.79993+02
5	0.00000	6.26282+02	6.24904+02	6.21390+02	6.10424+02	6.11349+02	6.35079+02	6.79994+02	6.79995+02	6.79992+02
6	0.00000	5.95164+02	5.93185+02	5.88630+02	5.79337+02	5.76504+02	5.87554+02	5.95176+02	6.00154+02	6.05406+02
7	0.00000	5.64337+02	5.61948+02	5.56714+02	5.47135+02	5.37784+02	5.34500+02	5.34578+02	5.35300+02	5.43235+02
8	0.00000	5.33944+02	5.31320+02	5.25621+02	5.14906+02	4.97912+02	4.78693+02	4.65877+02	4.65877+02	4.77644+02
9	0.00000	5.04073+02	5.01397+02	4.95533+02	4.83850+02	4.59981+02	4.21604+02	3.95298+02	3.86137+02	4.07211+02
10	0.00000	4.82146+02	4.79584+02	4.73936+02	4.62337+02	4.36156+02	3.89100+02	2.27479+02	2.59714+02	3.07791+02
11	0.00000	4.67612+02	4.65179+02	4.59803+02	4.48636+02	4.22242+02	3.60670+02	2.15957+02	2.56717+02	3.07203+02
12	0.00000	2.93017+02	2.92921+02	2.92747+02	2.92499+02	2.92257+02	3.15443+02	2.09429+02	2.48971+02	2.96836+02
13	0.00000	2.92456+02	2.92367+02	2.92207+02	2.91979+02	2.91745+02	2.80615+02	2.02151+02	2.40284+02	2.84058+02
14	0.00000	2.91795+02	2.91712+02	2.91562+02	2.91345+02	2.91085+02	2.55321+02	1.94912+02	2.31409+02	2.73443+02
15	0.00000	2.91065+02	2.90985+02	2.90841+02	2.90623+02	2.90328+02	2.40933+02	1.87033+02	2.24149+02	2.66058+02
16	0.00000	2.90394+02	2.90317+02	2.90174+02	2.89954+02	2.89639+02	2.34451+02	1.79168+02	2.20330+02	2.62522+02
17	0.00000	1.75000+02	1.75000+02	1.75000+02	1.75000+02	1.75000+02	0.00000	0.00000	0.00000	0.00000
	11	12	13	14	15	16	17	18	19	20
1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2	6.79997+02	6.79996+02	6.79994+02	6.79994+02	6.79994+02	6.79994+02	6.79993+02	6.79995+02	6.79994+02	6.79302+02
3	6.79997+02	6.79993+02	6.79995+02	6.79994+02	6.79994+02	6.79995+02	6.79992+02	6.79995+02	6.79994+02	6.79778+02
4	6.79994+02	6.79992+02	6.79995+02	6.79994+02	6.79994+02	6.79993+02	6.79993+02	6.79994+02	6.79992+02	6.77404+02
5	6.79993+02	6.79993+02	6.79994+02	6.79994+02	6.79993+02	6.79993+02	6.79994+02	6.79995+02	6.79993+02	6.74634+02
6	6.13257+02	6.22019+02	6.31086+02	6.41603+02	6.48990+02	6.55466+02	6.60857+02	6.63853+02	6.65937+02	6.68198+02
7	5.57944+02	5.74238+02	5.90582+02	6.06767+02	6.20550+02	6.32921+02	6.43287+02	6.49347+02	6.53852+02	6.60801+02
8	5.00509+02	5.25076+02	5.49058+02	5.71717+02	5.91877+02	6.10092+02	6.25307+02	6.34484+02	6.41531+02	6.53328+02
9	4.40520+02	4.74383+02	5.06571+02	5.36307+02	5.62957+02	5.86936+02	6.06575+02	6.18481+02	6.28040+02	6.46779+02
10	3.57381+02	4.04300+02	4.47781+02	4.87363+02	5.22810+02	5.54429+02	5.79036+02	5.92373+02	6.03433+02	6.44568+02

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11	3.57712+02	4.04431+02	4.47602+02	4.86976+02	5.22472+02	5.54662+02	5.81769+02	5.99700+02	6.11018+02	6.40989+02
12	3.54154+02	4.02983+02	4.47154+02	4.87329+02	5.23946+02	5.58218+02	5.90057+02	6.10643+02	6.16590+02	6.38419+02
13	3.47688+02	4.00090+02	4.46298+02	4.88123+02	5.26794+02	5.64203+02	5.99875+02	6.19008+02	6.22441+02	6.37497+02
14	3.41094+02	3.96866+02	4.45345+02	4.89052+02	5.29835+02	5.69818+02	6.07106+02	6.25009+02	6.27245+02	6.35842+02
15	3.35994+02	3.94162+02	4.44524+02	4.89831+02	5.32183+02	5.73520+02	6.10573+02	6.26994+02	6.27833+02	6.29887+02
16	3.33500+02	3.92789+02	4.44098+02	4.90214+02	5.33293+02	5.75077+02	6.11609+02	6.27136+02	6.27258+02	6.29887+02
17	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

21

22

23

1	0.00000	0.00000	0.00000
2	6.79172+02	6.79654+02	6.80000+02
3	6.78642+02	6.79450+02	6.80000+02
4	6.77425+02	6.79008+02	6.80000+02
5	6.75467+02	6.78352+02	6.80000+02
6	6.72341+02	6.77401+02	6.80000+02
7	6.68603+02	6.76266+02	6.80000+02
8	6.64756+02	6.75081+02	6.80000+02
9	6.61250+02	6.73958+02	6.80000+02
10	6.59095+02	6.73181+02	6.80000+02
11	6.57629+02	6.72650+02	6.80000+02
12	6.55614+02	6.71801+02	6.80000+02
13	6.53660+02	6.70194+02	6.80000+02
14	6.48267+02	6.65934+02	6.80000+02
15	6.37327+02	6.49536+02	6.80000+02
16	6.37327+02	6.49536+02	6.80000+02
17	0.00000	0.00000	0.00000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

RESIDUALS

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	1.9872-09	5.3834-09	0.0000	0.0000	0.0000	0.0000
5	0.0000	5.8891-09	2.7323-09	1.6885-09	0.0000	0.0000	6.8681-09	0.0000	0.0000	0.0000
6	0.0000	3.4186-09	5.5868-09	4.2605-09	0.0000	0.0000	2.0444-09	0.0000	6.4685-10	5.6770-10
7	0.0000	0.0000	1.1329-09	5.9930-09	7.8412-09	6.3737-09	1.0821-08	1.6178-09	1.3492-09	2.8924-10
8	0.0000	5.8338-10	1.1542-09	0.0000	4.6800-09	2.1539-09	1.1145-08	8.3971-09	8.8917-10	3.7306-09
9	0.0000	5.4297-09	7.4212-09	7.8944-09	6.1483-10	4.5181-09	6.1708-09	2.7058-09	1.3522-09	1.5297-09
10	0.0000	6.3632-09	0.0000	9.1145-10	5.3923-09	1.2748-08	1.2639-08	0.0000	0.0000	0.0000
11	0.0000	6.1225-09	1.8506-09	6.2250-10	1.2573-09	3.0389-09	1.8991-09	0.0000	6.5156-09	7.0103-09
12	0.0000	3.1112-07	2.7837-07	2.0909-07	1.6007-07	8.5974-08	2.0413-09	0.0000	0.0000	3.1833-09
13	0.0000	1.4574-07	2.3339-07	3.2014-07	3.5142-07	4.6356-07	3.1537-09	0.0000	9.6669-09	5.9009-09
14	0.0000	5.4077-07	5.0944-07	4.7062-07	4.8113-07	4.4030-07	3.7343-09	0.0000	2.2825-08	7.0115-09
15	0.0000	1.7298-07	1.9992-07	1.9350-07	1.3050-07	6.2446-08	3.3236-09	0.0000	4.3461-09	9.7271-09
16	0.0000	4.4224-07	4.1924-07	4.0172-07	4.0526-07	2.9616-07	2.6223-09	0.0000	8.5249-09	2.6773-09
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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	11	12	13	14	15	16	17	18	19	20
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.6923-07
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0928-07
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	6.7431-08
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.0089-08
6	3.1046-09	2.8430-09	8.2933-10	1.9812-09	2.4464-09	3.1084-09	2.3135-09	0.0000	4.2315-09	5.5575-09
7	3.1656-10	2.1778-09	4.2313-09	2.9588-09	1.0790-08	1.3547-08	8.5544-09	3.8066-09	7.0267-09	1.2365-08
8	5.9014-09	6.4729-09	6.3811-09	4.7016-09	2.2718-09	5.6427-09	1.9156-09	5.9901-09	8.4501-09	3.8336-08
9	3.9512-09	4.5957-09	3.0362-09	2.7974-09	1.1059-08	1.7774-08	1.2552-08	1.1614-08	1.9857-09	1.4523-08
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.8640-08
11	1.1547-08	1.6856-08	1.1063-08	1.4190-08	5.2997-08	7.1463-08	3.6650-08	4.0845-08	0.0000	9.4619-08
12	2.0031-08	4.2391-08	4.4522-08	0.0000	1.3637-08	1.0529-08	6.6648-08	1.1311-07	0.0000	2.1846-07
13	1.3840-08	2.2203-08	3.2764-08	4.2204-08	4.7696-08	5.9398-08	1.7511-07	1.8137-07	0.0000	3.1296-07
14	1.9175-08	2.8671-08	4.3482-08	6.2734-08	9.7725-08	1.4261-07	1.7878-07	1.8722-06	0.0000	1.1933-06
15	8.4248-09	2.7931-08	5.4711-08	8.7071-08	1.2465-07	2.1348-07	4.4095-07	4.4940-06	0.0000	0.0000
16	1.2906-08	1.8454-08	3.5323-08	6.3602-08	1.1028-07	1.7926-07	3.5198-07	4.8713-05	0.0000	0.0000
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

25 JUL 69 PAGE 36

	21	22	23
1	0.0000	0.0000	0.0000
2	1.5619-07	0.0000	0.0000
3	8.6362-08	1.2224-07	0.0000
4	6.9465-08	3.6750-08	0.0000
5	1.3228-08	0.0000	0.0000
6	2.3782-08	1.4348-08	0.0000
7	3.5297-08	3.1234-08	0.0000
8	3.4328-08	3.3054-08	0.0000
9	5.9069-08	3.8171-08	0.0000
10	1.1281-07	9.0189-08	0.0000
11	2.5695-07	1.6915-07	0.0000
12	1.8678-07	1.2834-07	0.0000
13	4.2490-07	1.0374-07	0.0000
14	4.4707-07	2.3337-07	0.0000
15	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

SURFACE TEMPERATURES AT THE RADIAL GAP OR COOLANT BOUNDARIES (F)

THE RADIAL (I) DIRECTION GAP OR COOLANT BOUNDARY GRIDLINES ARE HORIZONTAL
THE AXIAL (J) DIRECTION POINTS ARE VERTICAL

	1	4	6	7	8	18	19	22
1								
2	680						680	680
3	680						680	679
4	680	680	659	667	680		680	679
5	626			653	680		680	677
6	595							680
7	564							680
8	534							680
9	504							680
10	482							680
11	468			346	255	601	626	680
12	293		292	314	305	247	611	627
13	292		292	282	272	238	619	630
14	292		291	258	249	230	625	632
15	291		290	245	235	222	627	628
16	290		289	239	229	218	627	627
17								680

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

SURFACE TEMPERATURES AT THE AXIAL GAP OR COOLANT BOUNDARIES (F)

THE RADIAL(I) DIRECTION POINTS ARE HORIZONTAL
THE AXIAL (J) DIRECTION GAP OR COOLANT BOUNDARY GRIDLINES ARE VERTICAL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	680	679	679	680	
3					680	680	680																
					651	651	664																
4	680	680	680																				
	642	641	639																				
5								680	680	680	680	680	680	680	680	680	680	680	680				
								630	633	636	640	646	651	659	663	667	670	671	672				
9								332	338	370	410	449	485	519	548	575	597	609	619				
10								227	257	307	358	404	448	487	523	555	582	599	603				
11	460	458	453	442	417																		
	293	293	293	293	292																		
14																				632	642	656	
16	290	290	290	290	289	234	70	220	263	334	393	444	490	533	575	612	627	245	0	0	0		

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

HEAT RATE IN RADIAL DIRECTION BETWEEN POINTS (I,J) AND (I+1,J) (BTU/HR)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	-9.2720-11	2.6817-01	1.0195-01	-1.0973+00	1.3371+00	-1.5030+00	3.4279-01	2.4020-01	4.3109-01	-4.9178+00
3	-9.2720-11	1.1363-01	-2.3789-01	-5.1339-01	8.3421-01	-6.1466-01	-5.9978-01	7.5492-01	5.3887-01	-4.8754+00
4	-7.4161-11	1.0904-02	2.7176-01	1.6897+02	-5.2972-01	-1.7564+02	-3.4171+02	-2.3059+00	2.9142+00	-1.4923+00
5	-6.8317-11	1.8017+00	9.8051+00	4.4204+01	-5.0136+00	-2.3244+02	-6.7683+02	-4.1161-01	3.1543+00	-1.1357+00
6	-6.4922-11	2.5556+00	1.2550+01	3.6994+01	1.5168+01	-1.0661+02	-1.8527+02	-9.7229+01	-6.4549+01	-9.5113+00
7	-6.1560-11	3.0472+00	1.4242+01	3.7649+01	4.9364+01	3.0299+01	2.8132-01	-1.3760+01	-9.5091+01	-1.7410+00
8	-5.8244-11	3.3070+00	1.5317+01	4.1576+01	8.8428+01	1.7903+02	1.8112+02	9.2850+01	-1.3720+02	-2.6394+00
9	-5.4986-11	3.3314+00	1.5566+01	4.4773+01	1.2247+02	3.5113+02	5.9471+02	1.6413+02	-2.3813+02	-3.7415+00
10	-2.6297-11	1.5802+00	7.4313+00	2.2028+01	6.6539+01	2.1254+02	5.5541-06	-2.8996-07	-2.7166-07	-2.7557-00
11	-2.5494-11	1.4906+00	7.0263+00	2.1068+01	6.6640+01	2.7634+02	2.4192+02	-7.4894+01	-8.7254+02	-8.4979+00
12	-3.1963-11	5.7084+00	2.2072+01	4.5826+01	6.0221+01	-5.8932+01	3.5373+02	-1.4532+02	-4.8478+00	-3.1851+00
13	-3.1902-11	5.3212+00	2.0404+01	4.1963+01	5.8125+01	2.8253+01	2.6139+02	-1.4016+02	-4.4335+00	-3.5358+00
14	-4.7745-11	7.4315+00	2.8573+01	6.0032+01	9.6897+01	1.3605+02	3.0149+02	-2.0123+02	-6.3860+00	-5.6388+00
15	-4.7625-11	7.0777+00	2.7552+01	6.0290+01	1.1013+02	1.8779+02	2.6882+02	-2.0466+02	-6.3669+00	-5.8293+00
16	-4.7516-11	6.9188+00	2.7182+01	6.0973+01	1.1755+02	2.0977+02	2.7543+02	-2.2698+02	-6.4099+00	-5.9162+00
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

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	11	12	13	14	15	16	17	18	19	20
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	2.2512+00	2.7767+00	8.0344-01	1.8715-01	-3.7059-01	3.4182+00	-1.0195+01	2.6938+00	3.2406+01	5.9149+00
3	5.8057+00	-3.4316+00	1.9799+00	1.1229+00	-2.1562+00	7.6189+00	-1.8049+01	9.1176+00	5.6911+01	6.2155+00
4	2.6730+00	-4.9457+00	2.0201+00	6.7375-01	9.4333-01	-2.3063-01	-4.1082+00	1.1107+01	9.6890+01	-7.6670-01
5	-4.5480-01	-1.0055+00	-5.7365-01	2.3447+00	1.6165-01	-1.5479+00	-4.7105+00	1.0191+01	2.0043+02	-3.0334+01
6	-1.1906+02	-1.3666+02	-1.7431+02	-1.3354+02	-1.2679+02	-1.2930+02	-1.3197+02	-1.2612+02	-9.1253+01	-1.5055+02
7	-2.1693+02	-2.4211+02	-2.6431+02	-2.4614+02	-2.3984+02	-2.4667+02	-2.6520+02	-2.7129+02	-2.7943+02	-2.9290+02
8	-3.2011+02	-3.4886+02	-3.6446+02	-3.5551+02	-3.4959+02	-3.5915+02	-3.9897+02	-4.2220+02	-4.7257+02	-4.1351+02
9	-4.3127+02	-4.5941+02	-4.7082+02	-4.6396+02	-4.5549+02	-4.5971+02	-5.1396+02	-5.6953+02	-7.4792+02	-5.2259+02
10	-2.9146-07	-2.9858-07	-2.9774-07	-2.8985-07	-2.7924-07	-2.6566-07	-2.6402-07	-3.0041-07	-1.7095-06	-2.6208+02
11	-8.6854+02	-8.7681+02	-8.6578+02	-8.3889+02	-8.1273+02	-8.2880+02	-9.9819+02	-3.3946+02	-5.3255+02	-2.9989+02
12	-3.0333+00	-3.0332+00	-3.0219+00	-2.9941+00	-3.0268+00	-3.4373+00	-5.4085+00	-3.5649+02	-7.7536+02	-6.1926+02
13	-3.2552+00	-3.1731+00	-3.1461+00	-3.1621+00	-3.3038+00	-3.8511+00	-5.0268+00	-2.0573+02	-5.3469+02	-5.6011+02
14	-5.1969+00	-4.9936+00	-4.9315+00	-5.0021+00	-5.2968+00	-6.0384+00	-7.0554+00	-2.0091+02	-4.5782+02	-6.6991+02
15	-5.4201+00	-5.1876+00	-5.1119+00	-5.1947+00	-5.4760+00	-6.0004+00	-6.4713+00	-7.5366+01	-1.9759-07	-3.6329-07
16	-5.5245+00	-5.2851+00	-5.2033+00	-5.2837+00	-5.5354+00	-5.9159+00	-6.1189+00	-1.0973+01	-2.5289-07	-3.6329-07
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

25 JUL 69 PAGE 41

	21	22	23
1	0.0000	0.0000	0.0000
2	-2.2846+01	-3.4008+01	0.0000
3	-3.8324+01	-5.4046+01	0.0000
4	-6.0020+01	-7.7981+01	0.0000
5	-1.0931+02	-1.2948+02	0.0000
6	-1.9159+02	-2.0415+02	0.0000
7	-2.8987+02	-2.9319+02	0.0000
8	-3.9020+02	-3.8599+02	0.0000
9	-4.7982+02	-4.7393+02	0.0000
10	-2.6577+02	-2.6739+02	0.0000
11	-2.8331+02	-2.8813+02	0.0000
12	-6.1029+02	-6.4261+02	0.0000
13	-6.4543+02	-7.6812+02	0.0000
14	-9.9652+02	-1.6501+03	0.0000
15	-6.2016-07	-3.2327-06	0.0000
16	-6.2016-07	-3.2327-06	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.0000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

HEAT FLUX IN RADIAL DIRECTION BASED ON THE AREA OF GRIDLIN (I)
BETWEEN POINTS (I,J) AND (I+1,J) (BTU/HR-FT**2)

THE RADIAL (I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	-6.7999-04	3.3909+01	6.4457+00	-4.5985+01	4.0858+01	-3.6742+01	7.7352+00	5.2196+00	8.4309+00	-8.4863+01
3	-6.7999-04	1.4368+01	-1.5040+01	-2.1519+01	2.5500+01	-1.5031+01	-1.3537+01	1.6404+01	1.0539+01	-8.4131+01
4	-6.8000-04	1.7242+00	2.1486+01	8.8533+03	-2.0234+01	-5.3670+03	-9.6387+03	-6.2635+01	7.1241+01	-3.2189+01
5	-6.2628-04	2.8478+02	7.7489+02	2.3156+03	-1.9151+02	-7.1028+03	-1.9095+04	-1.1185+01	7.7142+01	-2.4508+01
6	-5.9516-04	4.0394+02	9.9185+02	1.9379+03	5.7936+02	-3.2579+03	-5.2259+03	-2.6410+03	-1.5780+03	-2.0516+03
7	-5.6434-04	4.8163+02	1.1255+03	1.9722+03	1.8856+03	9.2587+02	7.9352+00	-3.7375+02	-2.3246+03	-3.7553+03
8	-5.3394-04	5.2269+02	1.2104+03	2.1780+03	3.3777+03	5.4708+03	5.1090+03	2.5220+03	-3.3539+03	-5.6932+03
9	-5.0407-04	5.2654+02	1.2301+03	2.3454+03	4.6780+03	1.0730+04	1.6775+04	4.4582+03	-5.8213+03	-8.0705+03
10	-4.8215-04	4.9952+02	1.1746+03	2.3079+03	5.0832+03	1.2990+04	3.1344+04	-1.5752+05	-1.3282+05	-1.1888+05
11	-4.6761-04	4.7158+02	1.1114+03	2.2090+03	5.0950+03	1.6896+04	1.3648+04	-4.0686+03	-4.2661+04	-3.6660+04
12	-2.9302-04	9.0226+02	1.7443+03	2.4006+03	2.3003+03	-1.8008+03	9.9779+03	-3.9473+03	-1.1851+02	-6.8702+01
13	-2.9246-04	8.8105+02	1.6125+03	2.1982+03	2.2202+03	8.6336+02	7.3730+03	-3.8070+03	-1.0838+02	-7.6268+01
14	-2.9180-04	7.8307+02	1.5054+03	2.0965+03	2.4675+03	2.7716+03	5.6605+03	-3.6439+03	-1.0408+02	-8.1087+01
15	-2.9106-04	7.8579+02	1.4516+03	2.1055+03	2.8045+03	3.8257+03	5.0551+03	-3.7060+03	-1.0376+02	-8.3827+01
16	-2.9039-04	7.2905+02	1.4321+03	2.1294+03	2.9933+03	4.2733+03	5.1852+03	-4.1101+03	-1.0447+02	-8.5076+01
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

25 JUL 69 PAGE 43

	11	12	13	14	15	16	17	18	19	20
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	3.4758+01	3.8789+01	1.0247+01	2.1961+00	-4.0265+00	3.4577+01	-9.8058+01	2.5492+01	2.9707+02	5.2076+01
3	8.9639+01	-4.7937+01	2.5253+01	1.3177+01	-2.3427+01	7.7070+01	-1.7360+02	8.6280+01	5.2172+02	5.4722+01
4	5.1588+01	-8.6360+01	3.2206+01	9.8824+00	1.2812+01	-2.9162+00	-4.9302+01	1.3138+02	1.1103+03	-8.4377+00
5	-8.7809+00	-1.7565+01	-9.1495+00	3.4405+01	2.1963+00	-1.9580+01	-5.6656+01	1.2060+02	2.2972+03	-3.3383+02
6	-2.2978+03	-2.3863+03	-2.7790+03	-1.9588+03	-1.7220+03	-1.6350+03	-1.5866+03	-1.4918+03	-1.0457+03	-1.6569+03
7	-4.1667+03	-4.2276+03	-4.2140+03	-3.6103+03	-3.2573+03	-3.1190+03	-3.1885+03	-3.2090+03	-3.2020+03	-3.1134+03
8	-6.1780+03	-6.0916+03	-5.8107+03	-5.2145+03	-4.7478+03	-4.5413+03	-4.7967+03	-4.9941+03	-5.4153+03	-4.5507+03
9	-8.3233+03	-8.0220+03	-7.5063+03	-6.8053+03	-6.1861+03	-5.8129+03	-6.1791+03	-6.7368+03	-8.5705+03	-5.7512+03
10	-1.1250-05	-1.0427-05	-9.4938-06	-8.5028-06	-7.5850-06	-6.7183-06	-6.3486-06	-7.1070-06	-3.9180-05	-5.7684+03
11	-3.3525+04	-3.0621+04	-2.7606+04	-2.4609+04	-2.2076+04	-2.0960+04	-2.4002+04	-8.0309+03	-1.2205+04	-6.6008+03
12	-5.8541+01	-5.2965+01	-4.8179+01	-4.3917+01	-4.1108+01	-4.3463+01	-6.5024+01	-4.2169+03	-8.8850+03	-6.8151+03
13	-6.2825+01	-5.8407+01	-5.0159+01	-4.6381+01	-4.4869+01	-4.8696+01	-6.0436+01	-2.4335+03	-6.1271+03	-6.1642+03
14	-6.6865+01	-5.8130+01	-5.2416+01	-4.8913+01	-4.7958+01	-5.0902+01	-5.6550+01	-1.5844+03	-3.4975+03	-4.9150+03
15	-6.9737+01	-6.0389+01	-5.4334+01	-5.0796+01	-4.9581+01	-5.0581+01	-5.1868+01	-5.9433+02	-1.5094-06	-2.6654-06
16	-7.1081+01	-6.1524+01	-5.5305+01	-5.1666+01	-5.0118+01	-4.9870+01	-4.9044+01	-8.6528+01	-1.9320-06	-2.6654-06
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

25 JUL 69 PAGE 44

	21	22	23
1	0.0000	0.0000	0.0000
2	-1.9325+02	-2.7713+02	0.0000
3	-3.2418+02	-4.4040+02	0.0000
4	-6.3462+02	-7.9431+02	0.0000
5	-1.1558+03	-1.3189+03	0.0000
6	-2.0258+03	-2.0794+03	0.0000
7	-3.0650+03	-2.9864+03	0.0000
8	-4.1259+03	-3.9317+03	0.0000
9	-5.0735+03	-4.8274+03	0.0000
10	-5.6204+03	-5.4472+03	0.0000
11	-5.9913+03	-5.8698+03	0.0000
12	-6.4529+03	-6.8456+03	0.0000
13	-6.8246+03	-7.8240+03	0.0000
14	-7.0246+03	-1.1205+04	0.0000
15	-4.3715-06	-2.1952-05	0.0000
16	-4.3715-06	-2.1952-05	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.0000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

HEAT RATE IN AXIAL DIRECTION BETWEEN POINTS (I,J) AND (I,J+1) (BTU/HR)

THE RADIAL (I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	-4.9906-06	-1.4972-05	-2.5470-05	-4.0018-05	-4.8066-05	-2.31A0-05	-1.2285-05	-3.9638-05	-5.9341-05
2	0.0000	3.3542-01	1.2901-01	-1.3168+00	7.9310-01	-1.2425+00	4.3942-01	0.0000	5.1233-01	1.0227+00
3	0.0000	-5.7815-01	-2.3651+00	-1.1216+00	7.3319+02	8.7852+02	2.3770+02	1.1762-01	-3.6472+00	2.7271+00
4	0.0000	1.2137+02	3.7340+02	6.7541+02	9.0269+02	1.0536+03	4.0377+02	-4.6314-01	1.4516+00	3.0680+00
5	0.0000	1.1957+02	3.6539+02	6.4101+02	9.5190+02	1.2810+03	8.4817+02	6.5088+02	1.9783+03	2.7691+03
6	0.0000	1.1701+02	3.5540+02	6.1657+02	9.7374+02	1.4028+03	9.26A2+02	5.6285+02	1.9457+03	2.7997+03
7	0.0000	1.1397+02	3.4420+02	5.9316+02	9.6201+02	1.4219+03	9.56A6+02	5.7687+02	2.0270+03	2.8787+03
8	0.0000	1.1066+02	3.3219+02	5.6690+02	9.1517+02	1.3313+03	9.5473+02	6.6517+02	2.2570+03	3.0054+03
9	0.0000	1.0733+02	3.1996+02	5.3769+02	8.3746+02	1.1026+03	7.1118+02	1.0957+03	2.6593+03	3.1415+03
10	0.0000	1.0575+02	3.1412+02	5.2311+02	7.9298+02	9.5665+02	9.2372+02	3.9969-07	9.2257+01	2.70A7+01
11	0.0000	1.0426+02	3.0857+02	5.0905+02	7.4738+02	7.4692+02	9.5813+02	7.5483-08	8.8990+02	4.33A9+00
12	0.0000	9.8660+01	2.9255+02	4.8591+02	7.3384+02	8.6697+02	5.4547+02	6.3113-08	7.4942+02	2.6762+00
13	0.0000	9.3180+01	2.7694+02	4.6348+02	7.1630+02	8.9553+02	3.1233+02	5.0222-0A	6.1371+02	1.77A5+00
14	0.0000	8.8798+01	2.5600+02	4.3231+02	6.8010+02	8.5687+02	1.46A9+02	4.5553-08	4.1885+02	1.0312+00
15	0.0000	7.8722+01	2.3554+02	3.9955+02	6.3008+02	7.7913+02	6.58A5+01	4.5471-08	2.2057+02	4.9376-01
16	0.0000	7.1795+01	2.1524+02	3.6573+02	5.7351+02	6.8689+02	7.9921-06	1.2632-06	1.2843-05	2.2909-05
17	0.0000	0.8000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

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	11	12	13	14	15	16	17	18	19	20
1	-6.6759-05	-7.4176-05	-8.1593-05	-8.9011-05	-9.6429-05	-1.0385-04	-8.2752-05	-2.8511-05	-5.8402-05	-7.9864-05
2	1.2655+00	1.0994+01	-4.5700+00	-1.8408+00	4.9854-01	-4.2057+00	3.9218+00	-1.2038+00	6.5407-01	2.6489+01
3	1.2144+01	6.1075+00	-1.4843+00	0.0000	-8.3091-01	8.9482+00	-8.0814+00	1.8835+00	6.4289+00	7.7179+01
4	4.9615+00	-7.6699+00	8.0854+00	-2.0133+00	4.7777+00	1.9015+00	-2.0501+00	-1.0134+00	-2.7672+00	1.7483+02
5	2.7909+03	2.6976+03	2.5069+03	2.4408+03	2.1381+03	1.8237+03	1.1350+03	3.3001+02	5.8885+02	4.0561+02
6	2.8149+03	2.7152+03	2.5446+03	2.4000+03	2.1314+03	1.8262+03	1.1376+03	3.2417+02	5.5400+02	4.6490+02
7	2.8577+03	2.7404+03	2.5668+03	2.3818+03	2.1251+03	1.8330+03	1.1562+03	3.3024+02	5.6214+02	4.6837+02
8	2.9139+03	2.7691+03	2.5824+03	2.3729+03	2.1191+03	1.8426+03	1.1950+03	3.5348+02	6.1250+02	4.0932+02
9	2.9710+03	2.7973+03	2.5938+03	2.3660+03	2.1107+03	1.8468+03	1.2502+03	4.0904+02	7.9089+02	1.8398+02
10	-1.7082+01	-7.5204+00	1.1279+01	2.6654+01	2.5166+01	-1.8652+01	-1.7424+02	-1.6082+02	-1.2510-06	4.4606+02
11	1.6752+00	7.5747-01	2.5779-01	-2.2169-01	-1.0023+00	-2.6047+00	-4.8359+00	-8.1961+02	-3.0632-07	2.1334+02
12	1.5235+00	7.5742-01	2.4657-01	-2.4960-01	-9.6945-01	-2.1934+00	-2.8674+00	-4.6848+02	-2.4128-07	5.7331+01
13	1.2429+00	6.7527-01	2.1956-01	-2.3351-01	-8.2774-01	-1.6465+00	-1.6897+00	-2.6809+02	-1.5846-07	8.2323+01
14	8.0104-01	4.7196-01	1.5749-01	-1.6308-01	-5.3295-01	-9.0454-01	-6.7509-01	-7.3799+01	-1.6161-08	2.9529+02
15	3.9172-01	2.3986-01	8.1882-02	-8.0254-02	-2.5164-01	-3.6049-01	-2.0157-01	-5.2626+00	1.5807-08	0.0000
16	3.2741-05	4.2847-05	5.3288-05	6.4169-05	7.5625-05	8.7824-05	7.4450-05	2.6295-05	2.1028-05	4.7395-05
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

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	21	22	23
1	-8.5644-05	-8.6462-05	0.0000
2	2.8769+01	1.1160+01	0.0000
3	7.3295+01	2.6881+01	0.0000
4	1.3255+02	4.4837+01	0.0000
5	2.1152+02	6.5019+01	0.0000
6	2.5256+02	7.7570+01	0.0000
7	2.5953+02	8.0882+01	0.0000
8	2.3621+02	7.6675+01	0.0000
9	1.9345+02	7.0769+01	0.0000
10	1.9718+02	7.2396+01	0.0000
11	1.8057+02	7.7193+01	0.0000
12	1.7146+02	1.0958+02	0.0000
13	2.5709+02	2.3208+02	0.0000
14	5.8353+02	8.8595+02	0.0000
15	0.0000	0.0000	0.0000
16	5.1435-07	5.2884-07	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

HEAT FLUX IN AXIAL DIRECTION BASED ON THE AREA OF GRIDLIN (J)
BETWEEN POINTS (I,J) AND (I,J+1) (BTU/HR-FT.*2)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	-6.7999-04	-6.7999-04	-6.7999-04	-6.8000-04	-6.7999-04	-6.7999-04	-6.7999-04	-6.7999-04	-6.7999-04
2	0.0000	4.8703+01	5.8594+00	-3.5156+01	1.3477+01	-1.7578+01	1.2801+01	0.0000	8.7891+00	1.1719+01
3	0.0000	-7.8776+01	-1.0742+02	-2.9948+01	1.2458+04	1.2428+04	6.9746+03	6.5104+00	-6.2500+01	3.1250+01
4	0.0000	1.6538+04	1.6959+04	1.8033+04	1.5339+04	1.4906+04	1.1850+04	-2.5635+01	2.4902+01	3.5156+01
5	0.0000	1.6292+04	1.6596+04	1.7113+04	1.6175+04	1.8123+04	2.4887+04	3.6026+04	3.3939+04	3.1732+04
6	0.0000	1.5944+04	1.6142+04	1.6461+04	1.6546+04	1.9846+04	2.7189+04	3.1154+04	3.3379+04	3.2082+04
7	0.0000	1.5529+04	1.5633+04	1.5836+04	1.6347+04	2.0116+04	2.8070+04	3.1930+04	3.4774+04	3.2988+04
8	0.0000	1.5078+04	1.5088+04	1.5135+04	1.5551+04	1.8834+04	2.8007+04	3.6817+04	3.8720+04	3.4440+04
9	0.0000	1.4624+04	1.4532+04	1.4355+04	1.4230+04	1.5599+04	2.0863+04	6.0649+04	4.5621+04	3.5999+04
10	0.0000	1.4409+04	1.4267+04	1.3966+04	1.3475+04	1.3534+04	2.7098+04	2.2123-05	1.5827+03	3.1040+02
11	0.0000	1.4206+04	1.4015+04	1.3590+04	1.2700+04	1.0568+04	2.8107+04	4.1780-06	1.5267+04	4.9721+01
12	0.0000	1.3443+04	1.3287+04	1.2972+04	1.2470+04	1.2267+04	1.6002+04	3.4933-06	1.2857+04	3.0667+01
13	0.0000	1.2696+04	1.2578+04	1.2374+04	1.2172+04	1.2671+04	9.1625+03	2.7798-06	1.0528+04	2.0380+01
14	0.0000	1.1691+04	1.1627+04	1.1542+04	1.1557+04	1.2125+04	4.3002+03	2.5214-06	7.1855+03	1.1817+01
15	0.0000	1.0726+04	1.0698+04	1.0667+04	1.0706+04	1.1024+04	1.9322+03	2.5168-06	3.7840+03	5.6581+00
16	0.0000	9.7825+03	9.7760+03	9.7639+03	9.7452+03	9.7185+03	2.3445-04	6.9919-05	2.2033-04	2.6252-04
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

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	11	12	13	14	15	16	17	18	19	20
1	-6.8000-04	-6.8000-04	-6.7999-04	-6.7999-04	-6.7999-04	-6.7999-04	-6.7999-04	-6.7999-04	-6.7999-04	-6.7930-04
2	1.2891+01	1.0078+02	-3.8086+01	-1.4063+01	3.5156+00	-2.7539+01	3.2227+01	-2.8711+01	7.6172+00	2.2531+02
3	1.2370+02	5.5990+01	-1.2370+01	0.0000	-5.8594+00	5.8594+01	-6.6406+01	4.4922+01	7.4870+01	6.5647+02
4	5.0537+01	-7.0312+01	6.7383+01	-1.5381+01	3.3691+01	1.2451+01	-1.6846+01	-2.4170+01	-3.2227+01	1.4871+03
5	2.8428+04	2.4730+04	2.0892+04	1.8646+04	1.5077+04	1.1942+04	9.3261+03	7.8708+03	6.8562+03	3.4500+03
6	2.8672+04	2.4891+04	2.1206+04	1.8335+04	1.5030+04	1.1958+04	9.3480+03	7.7313+03	6.4491+03	3.9543+03
7	2.9108+04	2.5122+04	2.1391+04	1.8196+04	1.4986+04	1.2003+04	9.5004+03	7.8763+03	6.5439+03	3.9838+03
8	2.9680+04	2.5386+04	2.1521+04	1.8127+04	1.4944+04	1.2066+04	9.8275+03	8.4305+03	7.1301+03	3.4816+03
9	3.0262+04	2.5644+04	2.1616+04	1.8075+04	1.4884+04	1.2093+04	1.0273+04	9.7567+03	9.2068+03	1.5649+03
10	-1.7400+02	-6.8942+01	9.3998+01	2.0362+02	1.7746+02	-1.2213+02	-1.4318+03	-3.8355+03	-1.4563-05	3.7941+03
11	1.7063+01	6.9440+00	2.1484+00	-1.6936+00	-7.0678+00	-1.7056+01	-3.9746+01	-1.9548+04	-3.5659-06	1.8146+03
12	1.5519+01	6.9435+00	2.0549+00	-1.9068+00	-6.8364+00	-1.4362+01	-2.3562+01	-1.1173+04	-2.8087-06	4.8765+02
13	1.2660+01	6.1904+00	1.8298+00	-1.7839+00	-5.8371+00	-1.0782+01	-1.3884+01	-6.3939+03	-1.8447-06	7.0022+02
14	8.1593+00	4.3266+00	1.3125+00	-1.2458+00	-3.7582+00	-5.9230+00	-5.5473+00	-1.7601+03	-1.8813-07	2.5117+03
15	3.9900+00	2.1961+00	6.8240-01	-6.1310-01	-1.7745+00	-2.4915+00	-1.6572+00	-1.2551+02	1.8401-07	0.0000
16	3.3350-04	3.9279-04	4.4410-04	4.9021-04	5.3329-04	5.7508-04	6.1161-04	6.2714-04	2.4478-04	4.0313-06
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

25 JUL 69 PAGE 50

	21	22	23
1	-6.7917-04	-6.7965-04	0.0000
2	2.2814+02	8.7728+01	0.0000
3	5.8125+02	2.1131+02	0.0000
4	1.0511+03	3.5245+02	0.0000
5	1.6774+03	5.1109+02	0.0000
6	2.0029+03	6.0976+02	0.0000
7	2.0581+03	6.3579+02	0.0000
8	1.8732+03	6.0272+02	0.0000
9	1.5341+03	5.8629+02	0.0000
10	1.5637+03	5.6909+02	0.0000
11	1.4319+03	6.0679+02	0.0000
12	1.3597+03	8.6140+02	0.0000
13	2.0388+03	1.8243+03	0.0000
14	4.6275+03	6.9642+03	0.0000
15	0.0000	0.0000	0.0000
16	4.0789-06	4.1570-06	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

EFFECTIVE RADIAL CONDUCTIVITY BETWEEN POINTS (I,J) AND (I+1,J) (BTU/HR-FT-F)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	8.5626-12	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03
3	8.5626-12	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03
4	8.5626-12	1.0000+03	1.0000+03	1.1334+01	1.1031+01	1.1052+01	6.7359+00	1.0000+03	1.0000+03	1.0000+03
5	8.5626-12	1.0972+01	1.0962+01	1.0931+01	1.0908+01	1.0939+01	6.7092+00	1.0000+03	1.0000+03	1.0000+03
6	8.5626-12	1.0838+01	1.0824+01	1.0794+01	1.0768+01	1.0775+01	1.0819+01	1.0857+01	1.0875+01	1.0901+01
7	8.5626-12	1.0706+01	1.0690+01	1.0658+01	1.0618+01	1.0593+01	1.0583+01	1.0585+01	1.0605+01	1.0650+01
8	8.5626-12	1.0576+01	1.0558+01	1.0522+01	1.0466+01	1.0403+01	1.0333+01	1.0295+01	1.0317+01	1.0387+01
9	8.5626-12	1.0448+01	1.0430+01	1.0392+01	1.0320+01	1.0218+01	1.0063+01	9.9588+00	9.9987+00	1.0107+01
10	8.5626-12	1.0355+01	1.0337+01	1.0300+01	1.0224+01	1.0106+01	3.0590-08	1.0000-08	1.0000-08	1.0000-08
11	8.5626-12	1.0293+01	1.0276+01	1.0240+01	1.0165+01	1.0028+01	1.4883+00	2.0427+00	3.0587+01	3.0277+01
12	8.5626-12	5.0000+02	5.0000+02	5.0000+02	5.0000+02	2.8384+00	1.4853+00	2.0428+00	8.9623-02	5.0000-02
13	8.5626-12	5.0000+02	5.0000+02	5.0000+02	5.0000+02	2.8348+00	1.4829+00	2.0430+00	8.9623-02	5.0000-02
14	8.5626-12	5.0000+02	5.0000+02	5.0000+02	5.0000+02	2.8321+00	1.4811+00	2.0431+00	8.9623-02	5.0000-02
15	8.5626-12	5.0000+02	5.0000+02	5.0000+02	5.0000+02	2.8305+00	1.4801+00	2.0433+00	8.9623-02	5.0000-02
16	8.5626-12	5.0000+02	5.0000+02	5.0000+02	5.0000+02	2.8298+00	1.4796+00	2.0433+00	8.9624-02	5.0000-02
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

25 JUL 69 PAGE 52

	11	12	13	14	15	16	17	18	19	20
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0345+01	1.1200+01
3	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0344+01	1.1198+01
4	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0341+01	1.1193+01
5	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0335+01	1.1182+01
6	1.0937+01	1.0975+01	1.1017+01	1.1055+01	1.1085+01	1.1109+01	1.1125+01	1.1141+01	1.1149+01	1.1162+01
7	1.0716+01	1.0786+01	1.0855+01	1.0920+01	1.0976+01	1.1021+01	1.1053+01	1.1085+01	1.1109+01	1.1138+01
8	1.0488+01	1.0592+01	1.0692+01	1.0783+01	1.0865+01	1.0932+01	1.0980+01	1.1029+01	1.1068+01	1.1114+01
9	1.0251+01	1.0392+01	1.0525+01	1.0645+01	1.0754+01	1.0841+01	1.0903+01	1.0968+01	1.1027+01	1.1093+01
10	1.0000-08	1.0000-08	1.0000-08	1.0000-08	1.0000-08	1.0000-08	1.0000-08	1.0000-08	2.2963-08	1.1083+01
11	2.9927+01	2.9576+01	2.9233+01	2.8902+01	2.8588+01	2.8321+01	2.8121+01	1.1043+01	9.8179+00	1.1073+01
12	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	6.6355-02	1.1037+01	9.8130+00	1.1063+01
13	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	6.6355-02	1.1032+01	9.8112+00	1.1055+01
14	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	6.6355-02	1.1029+01	9.8080+00	1.1042+01
15	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	6.6355-02	1.1028+01	1.7714-08	1.0000-08
16	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	6.6355-02	1.1027+01	1.7714-08	1.0000-08
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

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	21	22	23
1	0.0000	0.0000	0.0000
2	1.1201+01	1.1112+01	0.0000
3	1.1199+01	1.1112+01	0.0000
4	1.1196+01	1.1110+01	0.0000
5	1.1190+01	1.1107+01	0.0000
6	1.1181+01	1.1103+01	0.0000
7	1.1171+01	1.1098+01	0.0000
8	1.1160+01	1.1093+01	0.0000
9	1.1150+01	1.1088+01	0.0000
10	1.1144+01	1.1085+01	0.0000
11	1.1139+01	1.1083+01	0.0000
12	1.1133+01	1.1079+01	0.0000
13	1.1124+01	1.1073+01	0.0000
14	1.1105+01	1.1055+01	0.0000
15	1.0000-08	1.0000-08	0.0000
16	1.0000-08	1.0000-08	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

EFFECTIVE AXIAL CONDUCTIVITY BETWEEN POINTS (I,J) AND (I,J+1) (BTU/HR-FT-F)

THE RADIAL (I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08
2	0.0000	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03
3	0.0000	1.0000+03	1.0000+03	1.0000+03	7.2212+00	7.2213+00	7.2356+00	1.0000+03	1.0000+03	1.0000+03
4	0.0000	6.4143+00	6.4133+00	6.4108+00	1.0968+01	1.0971+01	1.1059+01	1.0000+03	1.0000+03	1.0000+03
5	0.0000	1.0907+01	1.0900+01	1.0883+01	1.0840+01	1.0836+01	1.0909+01	8.8488+00	8.8559+00	8.8634+00
6	0.0000	1.0775+01	1.0766+01	1.0745+01	1.0705+01	1.0678+01	1.0605+01	1.0710+01	1.0722+01	1.0751+01
7	0.0000	1.0644+01	1.0634+01	1.0610+01	1.0567+01	1.0511+01	1.0442+01	1.0445+01	1.0435+01	1.0478+01
8	0.0000	1.0516+01	1.0504+01	1.0480+01	1.0432+01	1.0344+01	1.0251+01	1.0147+01	1.0116+01	1.0187+01
9	0.0000	1.0421+01	1.0410+01	1.0385+01	1.0335+01	1.0230+01	1.0054+01	5.6468+00	5.6384+00	5.6576+00
10	0.0000	1.0328+01	1.0317+01	1.0293+01	1.0245+01	1.0133+01	9.9006+00	2.0000-08	5.5015+00	5.4963+00
11	0.0000	1.2713+00	1.2712+00	1.2711+00	1.2709+00	1.2703+00	9.7105+00	1.0000-08	3.0795+01	7.4938-02
12	0.0000	5.0000+02	5.0000+02	5.0000+02	5.0000+02	5.0000+02	9.5750+00	1.0000-08	3.0835+01	5.0000-02
13	0.0000	5.0000+02	5.0000+02	5.0000+02	5.0000+02	5.0000+02	9.4331+00	1.0000-08	3.0891+01	5.0000-02
14	0.0000	5.0000+02	5.0000+02	5.0000+02	5.0000+02	5.0000+02	9.3504+00	1.0000-08	3.0931+01	5.0000-02
15	0.0000	5.0000+02	5.0000+02	5.0000+02	5.0000+02	5.0000+02	9.3149+00	1.0000-08	3.0962+01	5.0000-02
16	0.0000	1.3246+00	1.3246+00	1.3246+00	1.3246+00	1.3246+00	1.5625-08	6.0976-09	1.5625-08	1.5625-08
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

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	11	12	13	14	15	16	17	18	19	20
1	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08	1.3021-08
2	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.1200+01
3	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.1196+01
4	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.0000+03	1.1187+01
5	8.8745+00	8.8868+00	8.8995+00	1.0118+01	1.0132+01	1.0143+01	1.0153+01	1.0158+01	1.0162+01	1.1167+01
6	1.0799+01	1.0853+01	1.0908+01	1.0965+01	1.1010+01	1.1050+01	1.1084+01	1.1104+01	1.1118+01	1.1137+01
7	1.0558+01	1.0646+01	1.0732+01	1.0816+01	1.0888+01	1.0954+01	1.1008+01	1.1041+01	1.1066+01	1.1106+01
8	1.0308+01	1.0433+01	1.0553+01	1.0665+01	1.0765+01	1.0855+01	1.0930+01	1.0975+01	1.1010+01	1.1076+01
9	5.6874+00	5.7173+00	5.7451+00	5.7704+00	5.7928+00	5.8127+00	5.8288+00	5.8385+00	5.8462+00	1.1059+01
10	5.4906+00	5.4847+00	5.4787+00	5.4728+00	5.4670+00	5.4614+00	5.4565+00	5.4530+00	2.0000-08	1.1045+01
11	7.4938-02	7.4937-02	7.4936-02	7.4936-02	7.4935-02	7.4934-02	7.4933-02	2.7909+01	1.0000-08	1.1030+01
12	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	2.7828+01	1.0000-08	1.1024+01
13	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	2.7746+01	1.0000-08	1.1018+01
14	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	2.7711+01	1.0000-08	1.3181+01
15	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	5.0000-02	2.7699+01	1.0000-08	2.0000-08
16	1.5625-08	1.5625-08	1.5625-08	1.5625-08	1.5625-08	1.5625-08	1.5625-08	1.5625-08	6.0976-09	1.0000-10
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

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	21	22	23
1	1.3021-08	1.3021-08	0.0000
2	1.1199+01	1.1202+01	0.0000
3	1.1195+01	1.1200+01	0.0000
4	1.1188+01	1.1198+01	0.0000
5	1.1178+01	1.1195+01	0.0000
6	1.1163+01	1.1190+01	0.0000
7	1.1147+01	1.1185+01	0.0000
8	1.1131+01	1.1180+01	0.0000
9	1.1120+01	1.1177+01	0.0000
10	1.1111+01	1.1173+01	0.0000
11	1.1102+01	1.1170+01	0.0000
12	1.1094+01	1.1165+01	0.0000
13	1.1076+01	1.1151+01	0.0000
14	1.3219+01	1.3272+01	0.0000
15	2.0000-08	2.0000-08	0.0000
16	1.0000-10	1.0000-10	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

RADIAL THERMAL CONDUCTANCE BETWEEN POINTS (I,J) AND (I+1,J) (BTU/HR-F)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1.3635-13	1.4894+02	3.1817+02	4.6097+02	6.2146+02	1.1193+03	2.8021+03	2.2488+03	1.4126+03	1.3892+03
3	1.3635-13	1.4894+02	3.1817+02	4.6090+02	6.2126+02	1.1190+03	2.8076+03	2.2488+03	1.4126+03	1.3892+03
4	1.0906-13	1.1910+02	2.5443+02	4.1788+00	5.4843+00	9.8969+00	1.5125+01	1.7991+03	1.1301+03	1.1114+03
5	1.0908-13	1.3073+00	2.7902+00	4.0310+00	5.4232+00	9.7950+00	1.5069+01	1.7984+03	1.1296+03	1.1109+03
6	1.0908-13	1.2914+00	2.7552+00	3.9807+00	5.3537+00	9.6483+00	2.4306+01	1.9533+01	1.2290+01	1.2115+01
7	1.0908-13	1.2756+00	2.7209+00	3.9303+00	5.2791+00	9.4851+00	2.3774+01	1.9043+01	1.1944+01	1.1836+01
8	1.0908-13	1.2601+00	2.6874+00	3.8804+00	5.2034+00	9.3154+00	2.3213+01	1.8521+01	1.1659+01	1.1543+01
9	1.0908-13	1.2449+00	2.6548+00	3.8323+00	5.1309+00	9.1496+00	2.2607+01	1.7917+01	1.1299+01	1.1233+01
10	5.4542-14	6.1689-01	1.3156+00	1.8992+00	2.5415+00	4.5245+00	3.4340-08	8.9954-09	5.6504-09	5.5568-09
11	5.4520-14	6.1272-01	1.3068+00	1.8867+00	2.5248+00	4.4881+00	1.6717+00	1.8375+00	1.7243+01	1.6824+01
12	1.0908-13	5.9576+01	1.2727+02	1.8439+02	2.4858+02	2.5417+00	3.3347+00	3.6752+00	1.0128-01	5.5568-02
13	1.0908-13	5.9576+01	1.2727+02	1.8439+02	2.4858+02	2.5384+00	3.3313+00	3.6755+00	1.0128-01	5.5568-02
14	1.6362-13	8.9364+01	1.9090+02	2.7658+02	3.7288+02	3.8040+00	4.9909+00	5.5136+00	1.5192-01	8.3352-02
15	1.6362-13	8.9364+01	1.9090+02	2.7658+02	3.7288+02	3.8019+00	4.9874+00	5.5140+00	1.5192-01	8.3352-02
16	1.6362-13	8.9364+01	1.9090+02	2.7658+02	3.7288+02	3.8009+00	4.9858+00	5.5142+00	1.5192-01	8.3352-02
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

25 JUL 69 PAGE 5A

	11	12	13	14	15	16	17	18	19	20
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1.5530+03	1.7168+03	1.8805+03	2.0442+03	2.2079+03	2.6990+03	4.9492+03	6.7901+03	4.6805+01	4.5578+01
3	1.5530+03	1.7168+03	1.8805+03	2.0442+03	2.2079+03	2.6990+03	4.9492+03	6.7901+03	4.6800+01	4.5568+01
4	1.2424+03	1.3734+03	1.5044+03	1.6354+03	1.7663+03	2.1592+03	3.9504+03	5.4321+03	3.7430+01	3.6437+01
5	1.2419+03	1.3729+03	1.5038+03	1.6347+03	1.7656+03	2.1583+03	3.9578+03	5.4299+03	3.7402+01	3.6404+01
6	1.3588+01	1.5073+01	1.6573+01	1.8079+01	1.9579+01	2.3985+01	4.4048+01	6.0516+01	4.0356+01	3.6338+01
7	1.3514+01	1.4814+01	1.6331+01	1.7858+01	1.9387+01	2.3797+01	4.3764+01	6.0217+01	4.0210+01	3.6260+01
8	1.3030+01	1.4547+01	1.6084+01	1.7635+01	1.9192+01	2.3605+01	4.3473+01	5.9912+01	4.0061+01	3.6182+01
9	1.2736+01	1.4273+01	1.5833+01	1.7409+01	1.8995+01	2.3409+01	4.3167+01	5.9579+01	3.9913+01	3.6112+01
10	6.2120-09	6.8670-09	7.5220-09	8.1769-09	8.8317-09	1.0796-08	1.9797-08	2.7160-08	4.1560-08	1.8041+01
11	1.8590+01	2.0310+01	2.1989+01	2.3633+01	2.5248+01	3.0575+01	5.5671+01	2.9992+01	1.7769+01	1.8023+01
12	6.2120-02	6.8670-02	7.5220-02	8.1769-02	8.8317-02	1.0796-01	2.6272-01	5.9952+01	3.5520+01	3.6014+01
13	6.2120-02	6.8670-02	7.5220-02	8.1769-02	8.8317-02	1.0796-01	2.6272-01	5.9927+01	3.5513+01	3.5990+01
14	9.3180-02	1.0301-01	1.1283-01	1.2265-01	1.3248-01	1.6194-01	3.9408-01	8.9863+01	5.3253+01	5.3918+01
15	9.3180-02	1.0301-01	1.1283-01	1.2265-01	1.3248-01	1.6194-01	3.9408-01	8.9854+01	9.6178-08	4.8832-08
16	9.3180-02	1.0301-01	1.1283-01	1.2265-01	1.3248-01	1.6194-01	3.9408-01	8.9853+01	9.6178-08	4.8832-08
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

25 JUL 69 PAGE 59

	21	22	23
1	0.0000	0.0000	0.0000
2	4.7414+01	9.8266+01	0.0000
3	4.7407+01	9.8259+01	0.0000
4	3.7913+01	7.8594+01	0.0000
5	3.7894+01	7.8574+01	0.0000
6	3.7664+01	7.8546+01	0.0000
7	3.7829+01	7.8512+01	0.0000
8	3.7792+01	7.8477+01	0.0000
9	3.7758+01	7.8444+01	0.0000
10	1.8868+01	3.9210+01	0.0000
11	1.8661+01	3.9202+01	0.0000
12	3.7701+01	7.8380+01	0.0000
13	3.7670+01	7.8332+01	0.0000
14	5.6407+01	1.1731+02	0.0000
15	5.0795-08	1.0612-07	0.0000
16	5.0795-08	1.0612-07	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

AXIAL THERMAL CONDUCTANCE BETWEEN POINTS (I,J) AND (I,J+1) (BTU/HR-F)

THE RADIAL(I) DIRECTION IS HORIZONTAL
THE AXIAL (J) DIRECTION IS VERTICAL

	1	2	3	4	5	6	7	8	9	10
1	0.0000	7.3391-09	2.2017-08	3.7457-08	5.8850-08	7.0686-08	3.4088-08	1.8067-08	5.8291-08	8.7266-08
2	0.0000	2.8182+02	8.4547+02	1.4383+03	2.2599+03	2.7143+03	1.3090+03	6.9377+02	2.2384+03	3.3510+03
3	0.0000	3.1314+02	9.3941+02	1.5980+03	1.8132+01	2.1779+01	1.0522+01	7.7085+02	2.4871+03	3.7234+03
4	0.0000	2.2596+00	6.7778+00	1.1525+01	3.0984+01	3.7222+01	1.8098+01	8.6721+02	2.7980+03	4.1888+03
5	0.0000	3.8424+00	1.1520+01	1.9567+01	3.0620+01	3.6764+01	1.7847+01	7.6738+00	2.4779+01	3.7127+01
6	0.0000	3.7958+00	1.1378+01	1.9319+01	3.0238+01	3.6231+01	1.7499+01	9.2882+00	3.0001+01	4.5032+01
7	0.0000	3.7498+00	1.1238+01	1.9077+01	2.9850+01	3.5661+01	1.7118+01	9.0579+00	2.9198+01	4.3889+01
8	0.0000	3.7045+00	1.1101+01	1.8842+01	2.9468+01	3.5098+01	1.6724+01	8.7994+00	2.8305+01	4.2671+01
9	0.0000	4.8948+00	1.4668+01	2.4895+01	3.8927+01	4.6279+01	2.1934+01	6.5293+00	2.1035+01	3.1598+01
10	0.0000	7.2764+00	2.1807+01	3.7014+01	5.7880+01	6.8758+01	3.2399+01	3.4688-08	3.0786+01	4.6046+01
11	0.0000	5.9713-01	1.7913+00	3.0472+00	4.7867+00	5.7462+00	2.1185+01	1.1563-08	1.1488+02	4.1854-01
12	0.0000	1.7614+02	5.2842+02	8.9897+02	1.4124+03	1.6961+03	1.5662+01	8.6721-09	8.6276+01	2.0944-01
13	0.0000	1.4091+02	4.2273+02	7.1917+02	1.1299+03	1.3569+03	1.2348+01	6.9377-09	6.9145+01	1.6755-01
14	0.0000	1.1743+02	3.5228+02	5.9931+02	9.4161+02	1.1308+03	1.0210+01	5.7814-09	5.7696+01	1.3963-01
15	0.0000	1.1743+02	3.5228+02	5.9931+02	9.4161+02	1.1308+03	1.0161+01	5.7814-09	5.7754+01	1.3963-01
16	0.0000	6.2217-01	1.8665+00	3.1754+00	4.9890+00	5.9918+00	3.4088-08	7.0505-09	5.8291-08	8.7266-08
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

25 JUL 69 PAGE 61

	11	12	13	14	15	16	17	18	19	20
1	9.8175-08	1.0908-07	1.1999-07	1.3090-07	1.4181-07	1.5272-07	1.2170-07	4.1929-08	8.5885-08	1.1757-07
2	3.7699+03	4.1888+03	4.6077+03	5.0265+03	5.4454+03	5.8643+03	4.6731+03	1.6101+03	3.2973+03	5.0561+01
3	4.1888+03	4.6542+03	5.1196+03	5.5851+03	6.0505+03	6.5159+03	5.1924+03	1.7890+03	3.6637+03	5.6160+01
4	4.7124+03	5.2360+03	5.7596+03	6.2832+03	6.8068+03	7.3304+03	5.8414+03	2.0126+03	4.1217+03	6.3129+01
5	4.1820+01	4.6531+01	5.1257+01	6.3576+01	6.8964+01	7.4354+01	5.9307+01	2.0444+01	4.1892+01	6.3018+01
6	5.0890+01	5.6826+01	6.2823+01	6.8894+01	7.4944+01	8.1004+01	6.4747+01	2.2347+01	4.5842+01	6.2851+01
7	4.9755+01	5.5742+01	6.1814+01	6.7956+01	7.4114+01	8.0294+01	6.4304+01	2.2221+01	4.5627+01	6.2672+01
8	4.8573+01	5.4626+01	6.0781+01	6.7011+01	7.3277+01	7.9574+01	6.3846+01	2.2088+01	4.5400+01	6.2503+01
9	3.5735+01	3.9914+01	4.4119+01	4.8342+01	5.2574+01	5.6812+01	4.5308+01	1.5667+01	3.2141+01	8.3208+01
10	5.1748+01	5.7436+01	6.3110+01	6.8773+01	7.4426+01	8.0069+01	6.3747+01	2.1949+01	1.6493-07	1.2466+02
11	4.7085-01	5.2316-01	5.7547-01	6.2778-01	6.8009-01	7.3239-01	5.8362-01	7.4893+01	5.4978-08	8.2991+01
12	2.3562-01	2.6180-01	2.8798-01	3.1416-01	3.4034-01	3.6652-01	2.9207-01	5.6006+01	4.1233-08	6.2212+01
13	1.8850-01	2.0944-01	2.3038-01	2.5133-01	2.7227-01	2.9322-01	2.3366-01	4.4674+01	3.2987-08	4.9741+01
14	1.5708-01	1.7453-01	1.9199-01	2.0944-01	2.2689-01	2.4435-01	1.9471-01	3.7180+01	2.7489-08	4.9588+01
15	1.5708-01	1.7453-01	1.9199-01	2.0944-01	2.2689-01	2.4435-01	1.9471-01	3.7165+01	2.7489-08	7.5243-08
16	9.8175-08	1.0908-07	1.1999-07	1.3090-07	1.4181-07	1.5272-07	1.2170-07	4.1929-08	3.3523-08	7.5243-10
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TAC2D EXAMPLE PROBLEM OUTPUT

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	21	22	23
1	1.2610-07	1.2721-07	0.0000
2	5.4228+01	5.4721+01	0.0000
3	6.0235+01	6.0794+01	0.0000
4	6.7721+01	6.8378+01	0.0000
5	6.7656+01	6.8357+01	0.0000
6	6.7567+01	6.8330+01	0.0000
7	6.7469+01	6.8300+01	0.0000
8	6.7374+01	6.8270+01	0.0000
9	8.9747+01	9.0998+01	0.0000
10	1.3451+02	1.3646+02	0.0000
11	8.9600+01	9.0942+01	0.0000
12	6.7150+01	6.8178+01	0.0000
13	5.3634+01	5.4472+01	0.0000
14	5.3340+01	5.4030+01	0.0000
15	8.0704-08	8.1418-08	0.0000
16	8.0704-10	8.1418-10	0.0000
17	0.0000	0.0000	0.0000

STEADY STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

THE CURRENT TIME IS 1000.0000 HOURS = 60000.0000 MINUTES = 3600000.00000 SECONDS 160 ITERATIONS HAVE BEEN PERFORMED

HEAT BALANCE

HEAT GENERATED		HEAT LOST/GAINED BY COOLANTS	
BLOCK NUMBER	BTU/HR	COOLANT NUMBER	BTU/HR
		6	2.6962272+03
		7	2.4228077+04
		8	1.1114954+03
		9	1.7647737+03
		3	1.2014085+03
		4	8.2617173+10
		1	-5.2691334+03
		2	1.9131629+03
		5	5.2477133+04
<hr/>		<hr/>	
	0.0000000		2.6444604+04

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