GENERAL ATOMIC

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TAC2D
A GENERAL PURPOSE TWO-DIMENSIONAL HEAT TRANSFER COMPUTER CODE
- USER'S MANUAL -

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The TAC2D computer code is described herein as it existed on June, 1976. The code has been in continuous development for 8 years and in its presented form has been applied successfully by General Atomic Company 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.

ACKNOWLEDGEMENT

The original TAC2D user's manual was written by J. F. Petersen under a contract with the U.S. Atomic Energy Commission and contains a description of the original TAC2D code together with certain improvements also made under USAEC contract. The document is entitled "TAC2D, A General Purpose Two-Dimensional Heat Transfer Computer Code - User's Manual", USAEC Report GA-8868, Gulf General Atomic, 6 September 1969. Since the writing of the original user's manual, various additional changes and improvements have been made to the code and it has been verified according to General Atomic Guide Standard GA-3-23. The work was performed as part of the HTGR Design, Verification and Support activities. This report updates the original user's manual and provides a single reference for the use of the verified 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 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 is no provision for change of phase. This special heat transfer situation could be included by extension of the existing programming.

TAC2D has been assigned production status and has been verified according to Guide Standard GA-3-23 (see Reference 9). The machine requirement is a 65K Univac 1110, 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 8 as modified for General Atomic. Running time depends upon the size of the problem and is not easily defined.

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1. INTRODUCTION

The digital computer code TAC2D* was developed at 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:

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

where

k is thermal conductivity, Btu/hr-ft-°F
T is local temperature, °F
$\dot{q}'''$ is volumetric heat generation rate, Btu/hr-ft^3
ρ is density, lb/ft^3
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 performing an iterative calculation until thermal equilibrium is attained. An option is available for performing this steady state calculation as efficiently as possible. 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 problem must be modeled within the geometry envelopes of one of the three coordinate systems shown in Fig. 1. The choice depends

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

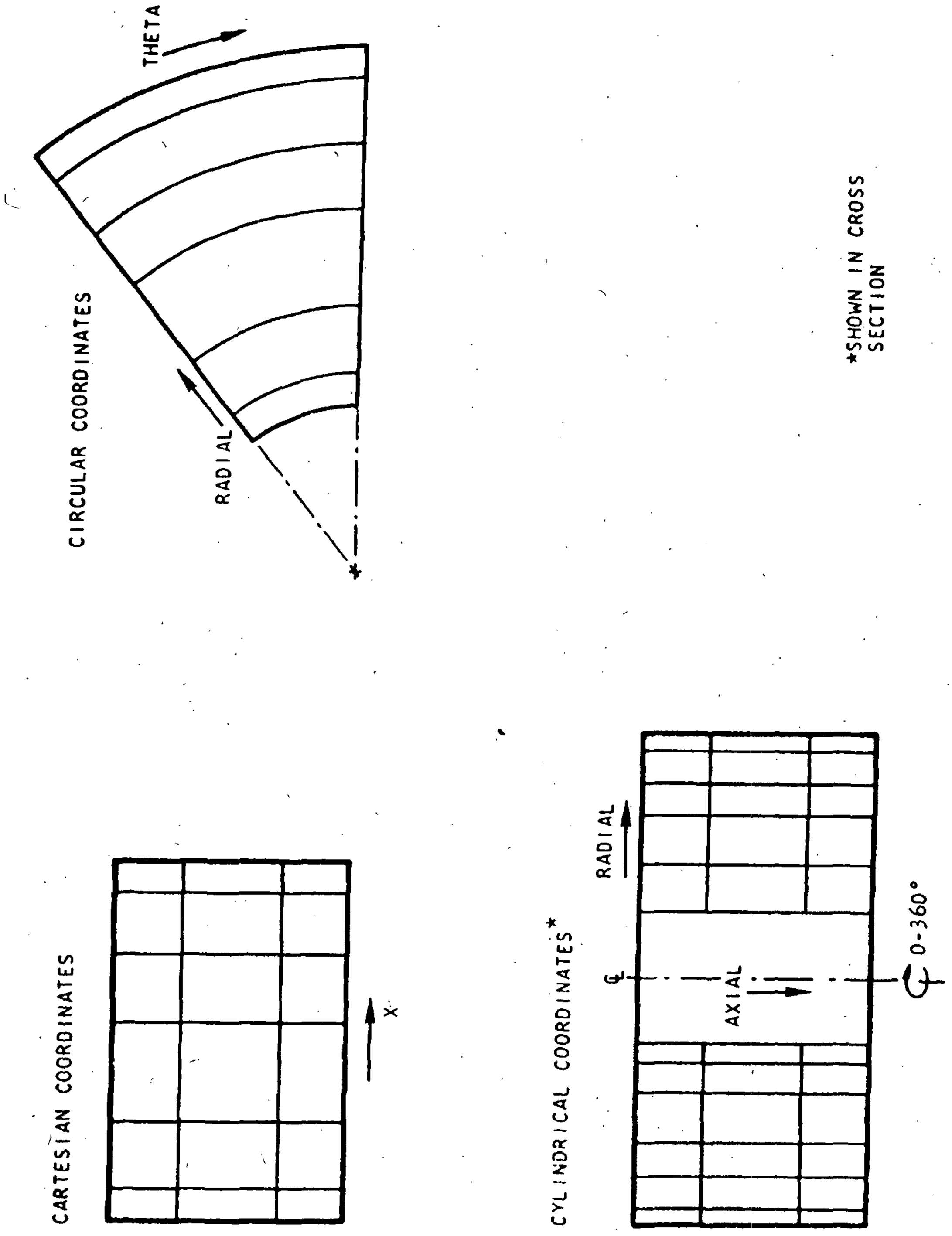


Fig. 1. Coordinate systems

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 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 user's manual has been prepared to provide a comprehensive guide to code application and input. The result of the above provisions is that the user may be detached from programming and computer system aspects of the problem solution. However, an understanding of FORTRAN statement functions would be helpful when specifying thermal properties.

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.

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 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

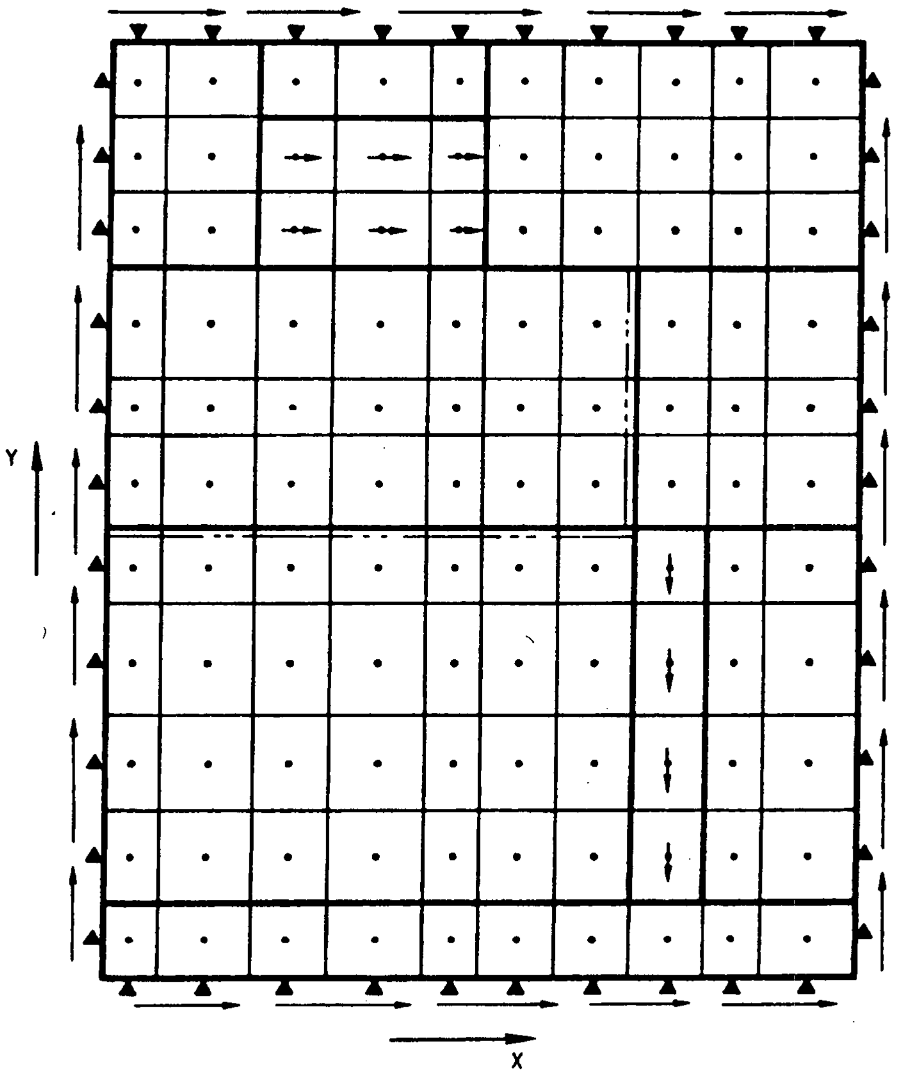
2.1 GEOMETRY AND THERMAL PARAMETERS

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.



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

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 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
- thermal expansion in the +X, -X, +Y or -Y directions
- temperature (if known - see Section 6.2)

COOLANTS

- specific heat capacity (constant pressure)
- Reynolds number
- heat transfer coefficient
- inlet temperature or temperature profile
- 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

$$d\dot{q} = WC_p \, dT_c$$

where

$\dot{q}$ 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

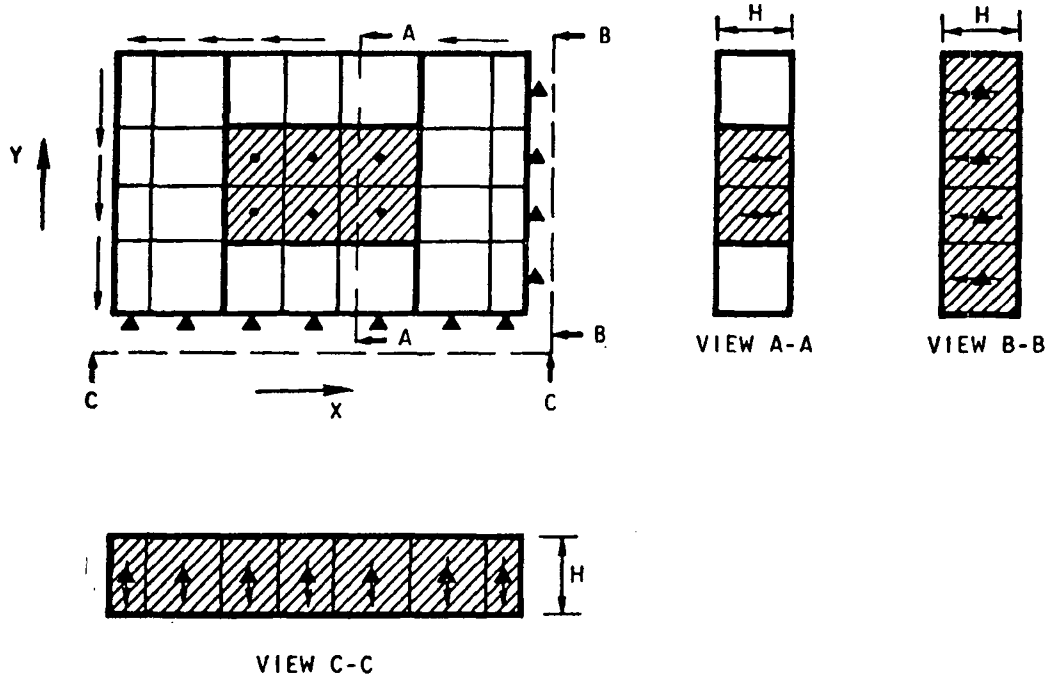
Coolants may flow parallel to either of the two coordinate axes as illustrated in Fig. 2. The flow direction may be either positive (in the direction of increasing coordinate value) or negative. Coolants may also flow normal to the plane of the problem as illustrated in Fig. 3. In this case the sign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

Perfect transverse 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

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

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.
3. COOLANTS WITH NORMAL FLOWS ARE ALLOWED ONLY WHEN THE "B" VERSION OF THE CODE IS USED. SEE SECTION 5.3.

Fig. 3. Coolant flows in the normal direction

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, °R

T_2 is temperature of surface 2, °R

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

$\mathfrak{F}_{1-2}$ 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

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.

The TAC2D code is able to account for dimensional changes in gap sizes due to thermal expansion. Section 2.6 describes this feature of the code.

2.1.6 Gap Lines

A gap line is defined as a grid line any portion of which is coincident with a coolant block boundary or an interface between two different materials, 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 or iterative calculation is always performed, the initial temperatures of the points must be specified unless a uniform default value of 0°F is desired.

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

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

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

2.4.1 Method

Steady state results are determined with this option by solving a psuedo-transient problem. Time steps and material specific heat functions need not be given as input. Instead, values designed to effect rapid convergence are calculated within the code. The following steps are carried out for each steady state iteration:

1. Determine a psuedo capacitance 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 an iteration parameter (pseudo-transient time step) as an increasing function of iterations performed. Assign a value of DTFAC for the initial iteration parameter. DTFAC is a user-specified parameter having a default value of unity. Allow the iteration parameter to increase to DTMAX, also user-specified and having a default value of 500.

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 iteration parameter to a value of 1/10 the initial value. Allow the iteration parameter to increase to a maximum value of 1/5 the value of which the instability was encountered.

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 ($= \rho V c \frac{\partial T}{\partial t}$) is rate of heat storage, Btu/hr

qg ($= \dot{q}''' V$) 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 TOL, a user-specified parameter having a default value of 0.01. The residuals are computed every nine iterations. This "odd-even" check helps to insure that oscillations in temperatures are detected and that a false convergence is avoided. 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.

If some residual is still greater than TOL after 150 iterations without an instability, the specific heat of that point is calculated according to the method presented in Ref. 6. This method effects accelerated convergence of slowly responding material points by weighting the characteristic conductances towards the conductance value in the direction of maximum heat transfer. This technique is applied only to those material points which have not yet satisfied the residual tolerance.

When the convergence criteria are satisfied, the program proceeds with the perturbation technique. This procedure was developed to provide upper and lower bounds on the steady-state temperatures and is an effective tool for determining proximity to steady-state. An arbitrarily chosen temperature increment, DELT (default value is presently 1°F) is added to the current temperature of each calculation node (excluding coolants and dummy materials). Refer to Fig. 4. Ten iterations are performed with the iteration parameter reduced by a factor of 50 to insure that no numerical oscillations will occur. The temperature of each nodal point is then compared with the initially perturbed result, which has been stored on a computer drum. If the temperature of a node has decreased, an indicator is flagged for that node meaning that it has passed the first perturbation test. The nodes which failed the test are again perturbed upward by the amount DELT. The whole nodal array is then stored, iterated upon 10 times and then checked against the stored value. This positive perturbation continues until all nodes when upwardly perturbed return to a lower level after 10 iterations. These temperature results are printed as the upper most bound of the solution.

The temperatures are then perturbed negatively by DELT degrees Fahrenheit, stored on drum and iterated upon 10 times. A test is now made to see if a node has increased or decreased in temperature. If it increases, the node is flagged as having passed the perturbation test, if not, the negative perturbation procedure is repeated. When all points have passed the negative perturbation test, the results are printed as the lower temperature bound on the solution.

Even if the convergence criteria are not satisfied, the perturbation may be initiated under one of the following circumstances: 1) the number of iterations has exceeded 2*ITMAX/3, where ITMAX is a user-specified parameter (default value-10,000) indicating the

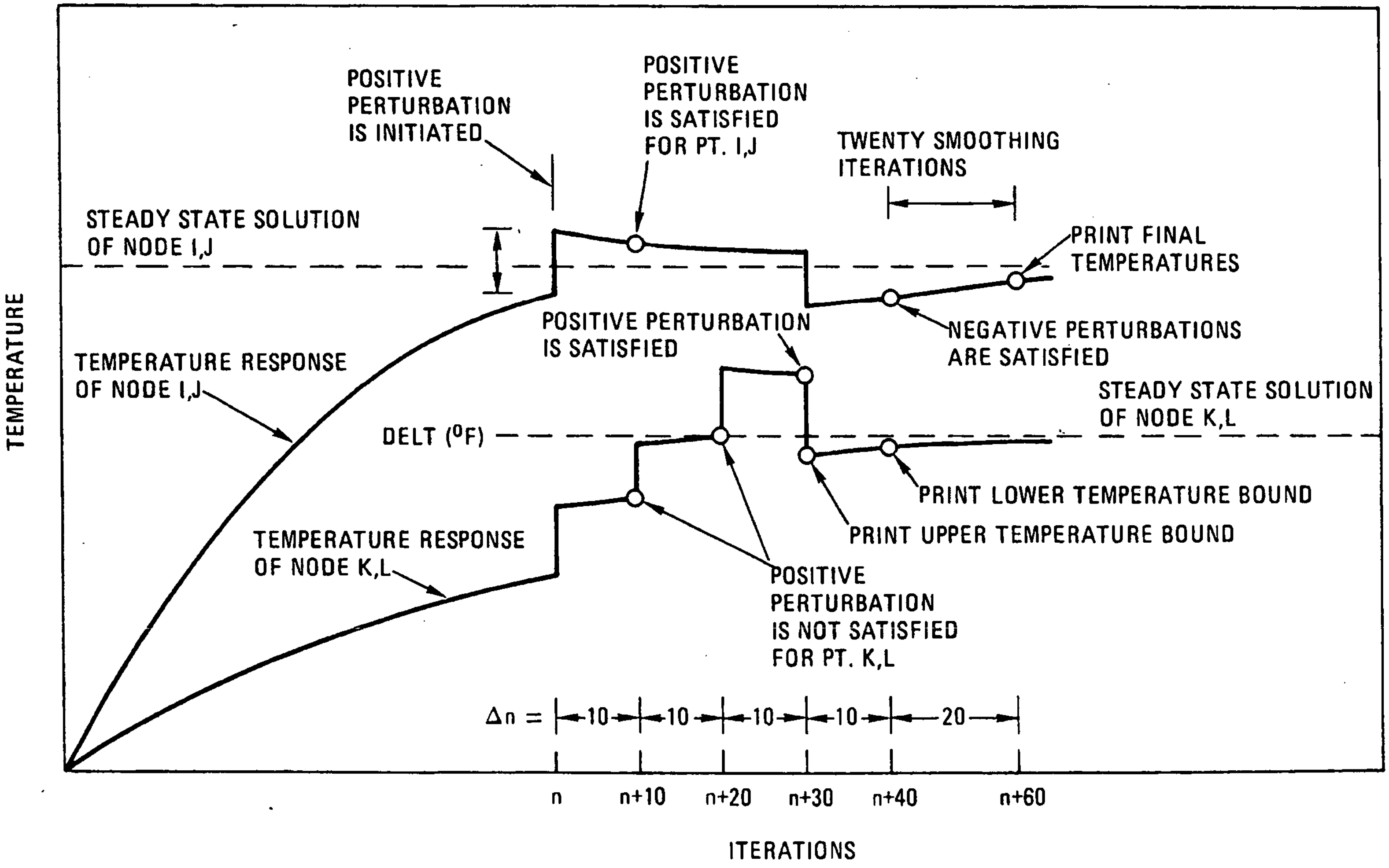


Fig. 4. The response of two n[illegible]s of a hypothetical thermal model

maximum number of allowed iterations before a series of twenty final smoothing iterations is performed; 2) the problem has limited computer time left; 3) small oscillations in some temperatures persist even after many (e.g. 300) iterations without an instability. These may be damped out by the perturbation procedure or the final smoothing iterations.

After the perturbation, the iteration parameter is reset to its prior value and twenty final smoothing iterations are performed. The psuedo capacitances remain fixed at their last computed values while the iteration parameter is again reduced, this time 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, the upper and lower temperature bounds, 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 TOL during the smoothing iterations. In addition, a message is printed at the beginning of each steady-state run which provides guidelines to help the user determine if the solution is valid.

The steady-state parameters which may be supplied by the user are summarized below, along with their default values. Input format is given in Section 4.2.

Parameter	Definition	Default Value
DELT	The magnitude of the temperature perturbation	1°F
TØL	The residual tolerance	0.01
DTFAC	The initial iteration parameter	1.0
DTMAX	The maximum iteration parameter	500.0
ITMAX	The maximum allowable iterations before final smoothing	10,000

2.4.2 Instabilities

The Peaceman-Rachford alternating direction implicit solution used in TAC2D has been shown to be unconditionally stable for problems involving constant properties, no heat sources, uniform grid spacing, constant temperature boundaries, etc. However, most "real" problems usually violate at least one of these conditions. Temperature dependent thermal properties and other non-linearities such as radiation influence the stability characteristics of the solution and may require the user to override the default values of the iteration parameters DTFAC and DTMAX. In general, the stronger the dependence of thermal properties on temperature, the smaller should be the quantities DTFAC and DTMAX. Thermal conductivities with weak temperature dependence usually do not require the parameters to be changed from the default values; however, several test problems involving strongly temperature-dependent heat generation rates required that DTFAC and DTMAX each be reduced two orders of magnitude to obtain satisfactory solutions.

As described before the code attempts to check for instabilities and automatically reduces the iteration parameter if they are encountered. However, oscillations which slowly increase in magnitude may be encountered which TAC2D is unable to detect. The program will continue iterating without satisfying the residual tolerance. Eventually, the problem will encounter the warning time or exceed the maximum allowable iterations. The perturbation may or may not be initiated. If it is initiated and completed, a satisfactory solution may be obtained. Otherwise a warning message is printed; however, the final temperature results may not necessarily be invalid.

When there is sufficient doubt as to the validity of the final printed temperature results, it is recommended that the parameters DTFAC and DTMAX be reduced at least one order of magnitude and the problem rerun. The computer run time could be increased, if possible, to insure that the problem has enough time to converge to a solution. Similarly, the parameter ITMAX could be increased to allow more iterations, unless the default value of 10,000 is being used in which case ITMAX is obviously not a controlling factor. If a punched deck has been obtained it may be used to provide initial temperatures for the next run.

There is also a possibility that the perturbation scheme will cause numerical instabilities. If this happens, it is probably caused by (1) the perturbation being applied too early in the solution and/or (2) the perturbation temperature being too large. One or both of the above could cause the solution scheme to become unstable; therefore, the optional control of these variables by the user has been provided.

The initiation of the perturbation is governed by either the residual tolerance, TOL, being satisfied or the maximum number of iterations, ITMAX, being reached. Recall that the default values of TOL and ITMAX are 0.01 and 10,000, respectively. It is obviously unlikely that ITMAX is being reached unless the user has set a lower value. By appropriately reducing TOL, the perturbation can be forced to be applied later in the solution. See Section 4.2 on instructions for the input of TOL.

A perturbation which is too large can also initiate instabilities. The present default value of DELT (1°F) was not varied in the current investigation; therefore, the effect of changes in DELT is unknown. It is doubtful that any improvement in the results can be obtained by increasing DELT. However, it may be necessary to decrease DELT in cases where the typical temperature differences of the grid are less than 100°F.

2.4.3 Unacceptable Temperature Tolerances

In certain cases the printed upper and lower temperature bounds of the steady-state solution may be outside the acceptable limits set by the user. This can be a result of not iterating close enough to the proper solution and/or a result of having perturbed the solution more than was necessary. Both problems can be overcome by re-specifying one or both of the parameters TOL and DELT.

First, the perturbation quantity DELT should be re-specified equal to or less than 25% to 30% of the acceptable temperature tolerance, e.g., 0.25°F if ± 1°F is desired (two to four perturbations are required regardless of the proximity to steady state). Second, the tolerance TOL should be reduced so that when it is multiplied by the maximum temperature difference of the grid, the product is equal to or less than the desired tolerance. For example, if a solution to a thermal model with approximately

1000°F temperature differences is desired to within ± 1°F, a tolerance of 0.001 should be specified. If none of the above changes correct the problem, it may be possible to decrease the range of the temperature bound by merely performing more iterations; i.e., by continuing a run with a pre-punched temperature deck.

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 1110 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

Function Name	Definition	Units
TMAT - (X)*	temperature (if known)	°R
RC0N - (X)	thermal conductivity in the X (or radial) direction	Btu/hr-ft-°R
AC0N - (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
EXRH - (X)**	thermal expansion of the + X (or + radial) boundary	ft
EXRL - (X)**	thermal expansion of the - X (or - radial) boundary	ft
EXAH - (X)**	thermal expansion of the + Y (or + theta, or + axial) boundary	ft (radians for circular coordinates)
EXAL - (X)**	thermal expansion of the -Y (or - theta, or - axial) boundary	ft (radians for circular coordinates)

---

* If TMAT - (X) is given, thermal conductivity, specific heat and heat generation need not be specified for that material.

** These functions require use of the gap expansion option. See Section 2.6.

COOLANTS

Function Name	Definition	Units
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
FL0 - A(X) FL0 - B(X) FL0 - 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

Function Name	Definition	Units
GC0N - (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.

---

* TIN - A(X) may also be used to define a known coolant temperature profile. See 2.5.2, "COOLANTS - Function Name".

MATERIALS

Variable Name*	Definition	Units
DR	1) temperature of a point, or 2) local temperature of a gap surface, or 3) local temperature of an internal coolant block boundary, or 4) local temperature, volume averaged in the radial - X direction, or 5) local temperature, volume averaged in the axial-Y-theta direction	°R
HR	time	hr
FTR	1) X (or radial) coordinate of a point, or 2) location of an X (or radial gap	ft
FTZ	1) Y (or theta, or axial) coordinate or a point, or 2) location of a Y (or theta, or axial) gap	ft (radians for circular coordinates)

Function Name	Allowed Variables**
TMAT - (X)	HR
RC0N - (X) AC0N - (X)	DR$^{1)}$, FTR$^{1)}$, FTZ$^{1)}$, HR
SPEC - (X)	DR$^{1)}$, FTR$^{1)}$, FTZ$^{1)}$, HR
EMRH - (X) EMRL - (X)	DR$^{2),3)}$, FTZ$^{1)}$, HR
EMAH - (X) EMAL - (X)	DR$^{2),3)}$, FTR$^{1)}$, HR
HEAT - (X)	DR$^{1)}$, FTR$^{1)}$, FTZ$^{1)}$, HR

---

* For materials, DR has five different definitions depending upon the function in which it is to be used. Similarly, FTR and FTZ each have two different definitions.

** DR, FTR and FTZ are labeled to indicate which of the definitions apply to each function.

MATERIALS (cont.)

Function Name	
EXRH - (X) EXRL - (X)	DR4), FTR2), HR
EXAH - (X) EXAL - (X)	DR5), FTZ2), HR

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	lb/hr

Function Name	Allowed Variables*
SPH - (X)	DR,FTR,FTZ,TIN,TØUT,FR
REYN - (X)	DR,HR,FTR,FTZ,ST,TIN,TØUT,FR

---

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

COOLANTS (cont.)

Function Name	Allowed Variables
H - A(X), H - B(X), H - C(X)	DR,HR,FTR,FTZ,ST,RE,TIN,TOUT,FR
TIN - A(X)	HR,TOUT,FR,FTR,FTZ**
TIN - B(X), TIN - C(X)	HR,TOUT,FR
FLO - A(X), FLO - B(X) FLO - C(X)	HR,TIN,TOUT

GASES

Variable Name	Definition	Units
DR	local linear average of the two surface temperatures of a gap	°R
STGL	surface temperature on the low side of a gap	°R
STGH	surface temperature on the high side of a gap	°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 a theta coordinate)

Function Name	Allowed Variables
GCON - (X)	DR,STGL,STGH,HR,FTR,FTZ

---

* If FTR or FTZ is used to allow TIN - A(X) to define a known coolant temperature profile (see 6.1.4), SPH - (X) must be assigned a value of 10^{10}.

2.5.3 Default 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 default value as indicated below.

TMAT - (X) = 0.*
RC0N - (X), AC0N - (X) = 10^{-6} Btu/hr-ft-°R
SPEC - (X) = 1. Btu/ft^3-°R
EMRH - (X), EMRL - (X), EMAH - (X), EMAL - (X) = 10^{-6} dimensionless
HEAT - (X) = 0.
EXRH - (X), EXRL - (X), EXAH - (X), EXAL - (X) = 0.
SPH - (X) = 1. Btu/lb-°R
REYN - (X) = 0.
H - A(X), H - B(X), H - (X) = 10^{-6} Btu/hr-ft^2-°R
TIN - A(X) = 460. °R
TIN - B(X), TIN - C(X) = 0.
FL0 - A(X) = 10^6 lb/hr
FL0 - B(X), FL0 - C(X) = 10^{-6}
GC0N - (X) = 0.

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:

---

* TMAT - (X) is not used in the program unless a non-zero value is supplied by the user.

```
TIN3A(X) = 560.
TIN5A(X) = TØ(3)
TIN2A(X) = TØ(5)
```

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:

Problem No.	A5	A9
1	1.	0.
2	0.	1.

Effectively, RC0N3(X) = function 1 for problem 1 and RC0N3(X) = function 2 for problem 2.

In addition to the 18 control constants which the user may input, there are also the control constants A19 and A20(I), I = 1,100. These constants are included in common and are available to be used as desired. They may be assigned values in the subroutines MADATA, FLODAT and CUSTOM (see Section 3.6). If they are assigned values in MADATA or FLODAT, this must be done after all thermal parameter functions have been assigned, according to the rules of FORTRAN.

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 dummy arguments. 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.

2.6 THE GAP EXPANSION OPTION

In most engineering applications the dimensional changes occurring when materials are heated or cooled are generally less than 1% of the initial length. The change in thermal resistance of the material itself due to the different conduction length is negligible. When two bodies are separated by a small fluid filled gap, the change in dimension of the gap can be a significant fraction of the original gap width. This change in gap width causes a change in the conduction resistance across the gap, and can have a substantial effect on the overall system thermal resistance.

The GAP EXPANSION option allows for thermally induced changes in the gap width and the gap thermal resistance in the TAC2D thermal analysis code.

The basic equation used to calculate the change in length due to thermal expansion is:

$$\Delta L = \alpha L\ (\overline{T} - T_o) \tag{2.6.1}$$

where: α = coefficient of thermal expansion
L = reference length
$\overline{T}$ = volumetric average temperature
T_o = temperature at which reference length is specified

This expression is applicable to linear growth of unrestrained bodies and should be used with care for other configurations.

In the current application, $\overline{T}$ for a radial gap is defined as the volumetric average temperature of all radial nodes between axial grids J and J+1 in the material block adjacent to the gap. For an axial gap, $\overline{T}$ is the volumetric average temperature of all axial nodes between radial grids I and I+1 in the material block adjacent to the gap.

Use of the gap expansion option is initiated by using a TAC2D option card GAP EXPANSION. As some gaps may close because of the thermal expansion characteristics of the adjacent materials, a single minimum allowable gap may be specified for all X or radial gaps on this option card along with another minimum allowable gap for all Y, axial, or theta gaps. The expression GAP EXPANSION appears on the option card in A format beginning in Column 7, while the minimum allowable radial (or X) gap (in inches) and the minimum allowable axial (or Y or θ) gap (in inches or radians) are specified beginning in Columns 25 and 31, respectively, in F6.0 format. See Section 4.2, "CARD INPUT FOR A COMPUTER RUN", for clarification.

The expansion characteristics of the gap are defined via the functions EXRH - (X), EXRL - (X), EXAH - (X), and EXAL - (X) in the MADATA subroutine. The functions EXRH - (X) and EXRL - (X) define the radial (or X) boundary movement (in feet) on the high and low radial sides of the blocks; whereas, the functions EXAH - (X) and EXAL - (X) define the axial (or Y or θ) boundary movement (in feet or radians) on the high and low axial sides of the blocks.

It should be noted that the above four expansion functions are more than just the coefficient of thermal expansion α; they are the entire right side of Eq. (2.6.1), and they include α, the reference length, and the reference temperatures.

The volumetric average temperature $\overline{T}$ is calculated within the MADATA subroutine and is available as DR in degrees Rankine. The radial and axial distances from the origin to each gap are available as FTR and FTZ in feet.

Thermal models are often constructed such that the axes of the model coincide with the fixed axes of the real body. It is then convenient to specify the reference length as FTR or FTZ. As an example, consider a two-dimensional R-Z model of a cylindrical body. If the expansion coefficient were 6×10^{-6} inches/inch °R and all gaps specified in the input were defined at room temperature (530°R), the radial boundary movement for Material 3 would appear in the subroutine MADATA as:

```
EXRH3(X) = 6.E-6*FTR*(DR-530.)  .
```

It is exmphasized that the length term in the expansion functions EXRH - (X), EXRL - (X), EXAH - (X), and EXAL - (X) is always the distance from the moveable boundary to the fixed (or assumed fixed) line of the body. It may not necessarily be FTR or FTZ.

The final gap widths of a TAC2D run are printed when GAP EXPANSION is specified. An option ALL GAPS is available which prints the gaps at each temperature printout. This option is specified on an option card in A format beginning in Column 7. (See 4.1.3, "Option Indicators")

2.7 THE ITERATE OPTION

The ITERATE option causes the program to repeat a complete steady-state calculation until a specified nodal point temperature is attained. Results of a secant iteration method are fed into the main calculation through a parameter PAR which is applied by the code user to one or more of the input thermal parameter functions. Examples are

```
HEAT3(X) = 3.5 E6 * PAR
GC0N5(X) = (1.29 E-4 * DR ** 0.674)/PAR
TIN2A(X) = 700.0 * PAR
```

The input variables (given on the option card) and their uses are:

PAR1 - The initial values of PAR. For the first iteration cycle PAR = PAR1. A value of 1.0 is usually applicable but any value consistent with the other input may be used.

DELPAR - The change to be made to PAR1 for the second iteration cycle according to PAR = (1 + DELPAR) * PAR1. The sign of DELPAR should be positive if the user expects the temperature of the particular point to increase with increasing PAR and should be negative if the temperature will decrease with increasing PAR.

TCONV - The temperatures, in degrees Rankine to which the program is to iterate.

RLOC - The radial point index at which TCONV is defined.

ZLOC - The axial point index at which TCONV is defined.

PMT - The convergence tolerance for TCONV in degrees Rankine. The input value is always positive. The problem will terminate when the temperature at RLOC and ZLOC falls within the range of TCONV ± PMT.

The ITERATE option is engaged by including a single option card anywhere among the other option cards for the problem. The card contains the alpha-numeric characters ITERATE in Columns 7-13 followed by the values of PMT, DELPAR, TCONV, RLOC, ZLOC and PAR1 in that order. These are given as floating point numbers in 6 column words with the first word starting in Column 25 (see Section 4.2).

The thermal parameter functions may contain PAR only when the ITERATE option is engaged. In the normal calculation mode, PAR is not set and will probably be equal to zero.

The ITERATE option is intended to be used as a sizing tool. Therefore, the convergence tolerance PMT should probably be on the order of several degrees. The option may be unable to adjust the calculation fine enough to satisfy smaller convergence tolerances.

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 upper and lower temperature bounds and for the smoothing iterations described in Section 2.4 and then only for every fifth of the latter. 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°R are rounded upward while those less than .5°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 if 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 identifying symbols. The precise symbols are dependent on the printer; however, the usual set is as follows:

□ 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 heat balance is always printed for the last iteration of a problem. Three quantities are itemized and totaled: 1) the heat generation rate for each block; 2) the heat gained (or lost) by each coolant block; 3) the heat gained (or lost) by dummy material blocks (see Section 6.2). A quantity which may be called the "residual heat" (RESIDH) is calculated as follows:

$$\text{RESIDH} = (\text{Heat generated}) - (\text{Heat gained by coolants} + \text{Heat gained by dummy materials}).$$

In other words, RESIDH is the difference between the overall heat gained and the overall heat lost by the system. It should approach zero as thermal equilibrium is attained. On a more practical basis it should be no more than some small percentage of the overall heat gained (or lost) by the system. The "small percentage" is defined by the user. Generally 1% is considered adequate; however, certain problems may require a smaller value for acceptable results. If the overall heat balance does not satisfy this condition, a steady-state solution should not be assumed unless some acceptable explanation can be found (see Section 5.4).

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 coolants and extremely high values (9.999E11) for dummy materials.

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 °R by means of the following expression

$$RTF = RTR - 460.0$$

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 the 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 or are coincident with material interfaces. 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 or coincident with a material interface, there are two surface temperatures 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 are not coincident with a material interface 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.

3.4.7 Gap Thicknesses

If the gap expansion option is being used (see Section 2.6), the gap thicknesses will be printed for both coordinate directions. The printing may be done either for the last iteration only or for all iterations where basic output is printed.

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 bottom to top up the page. An option is available through which the latter directions can be reversed so that all matrices are oriented in the fourth 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 must contain only arithmetic statement functions as 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 375 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 is an exception to the above rule for dummy materials which are intended to retain their initial temperatures. In this case the function SPEC - (X) must be assigned a value of 10^6 Btu/ft^3-°R or greater.

4. If the steady state option is being used, all time dependent functions will be evaluated at -1.0 hours.

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. A blank card follows the title cards.

Limits

	Minimum	Maximum
Number of title cards	1	no limit

NOTES:

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

2. A special title card, with the characters `$WARN$` in columns 1-6, allows the user to override the default value of the warn time, which is 20 sec. The desired warn time (in seconds) is then entered in columns 11-12 with integer format. See 4.3.1 for a discussion of the warn time.

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.

Indicator	Coordinate System
RECTANGULAR GEOMETRY	cartesian
CIRCULAR GEOMETRY	circular
CYLINDRICAL GEOMETRY	cylindrical

Option Indicators

The steady state option (Section 2.4), the gap expansion option (Section 2.6), the iterate option (Section 2.7) and any of the output options described in Sections 3.4 and 3.5 may be specified by means of the following indicators.

Indicator	Option
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.

Indicator	Option
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.
GAP EXPANSION	Account for dimensional changes in gaps due to thermal expansion of materials; print gap thicknesses for the last iteration.

Indicator	Option
ALL GAPS	Used with GAP EXPANSION option; print gap thicknesses for all iterations where basic output is printed.
CENTIGRADE	Print all output temperatures in degrees Centigrade.
ITERATE	Perform a series of steady-state calculations until a specified nodal point temperature is attained.
LONG INPUT	Accept input cards in the original, longer format (See Appendix I).

Card Description

There is one indicator per card, starting in column 7. The indicators may be abbreviated to the first 6 characters, e.g. ALL HEAT FLUXES to ALL HE. The cards may be arranged in any order. A blank card follows the option indicators.

Limits

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

NOTES:

1. The steady state, gap expansion and iterate options may require additional user specified parameters on the indicator cards. See Section 4.2, "CARD INPUT FOR A COMPUTER RUN".

2. If the long input option is used refer to Appendix I.

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. A blank card follows the X grid lines.

Limits

	Minimum	Maximum
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. A blank card follows the Y grid lines.

Limits

	Minimum	Maximum
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° and theta = 360°.

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 or degrees for coolant blocks (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) gas 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:

Indicator	Flow direction
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 one or two cards. Format 5E12.4, 2F6.0 is used. The sets may be arranged in any order.* A blank card follows the last set.

First 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
49-60	material number or negative coolant number
61-66	flow direction number for a coolant block; not used for a material block
67-72	depth of problem for coolant blocks; not used for material blocks.

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

---

* For certain cases, the code may draw the overlay (See 3.3.1) incorrectly if the coolant blocks are not placed after the material blocks. This does not affect the problem execution.

Second Card

Columns	
1-12	X (radial) gap thickness on the high X boundary
13-24	X (radial) gas gas number, any of 1 though 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

If only one of the high block boundaries has a gap, the words for the other gap thickness and gas number are left blank. If there is neither a radial nor an axial gap, this card is omitted entirely.

Blank Card (after the last set)

Limits

	Minimum	Maximum
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.

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. 5. 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. 5. Within the scope of this limitation, two flow directions are considered the same if they differ only in sign.

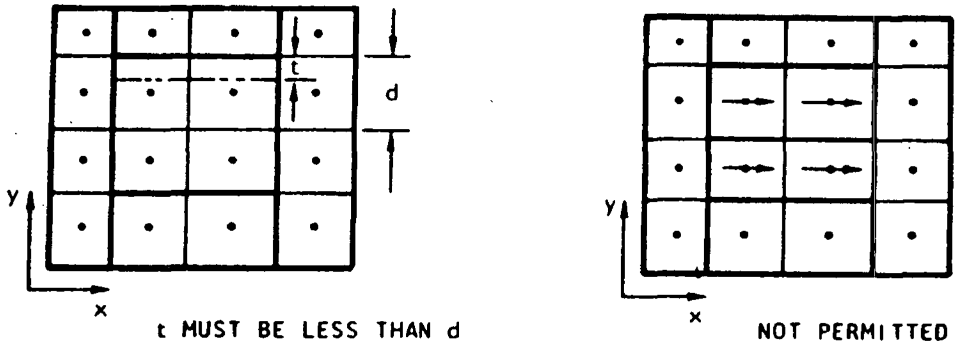
6. A coolant block must contain at least one grid line perpendicular to the flow direction of its coolant as illustrated in Item c of Fig. 5. An exception is a coolant block having normal flow.

---

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

(a) LIMITATION ON GAP THICKNESS

(b) LIMITATION ON ADJACENT INTERNAL COOLANTS

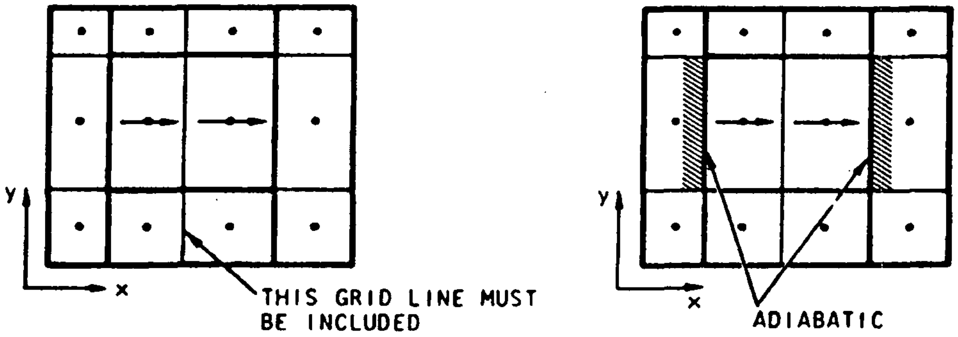


t MUST BE LESS THAN d

NOT PERMITTED

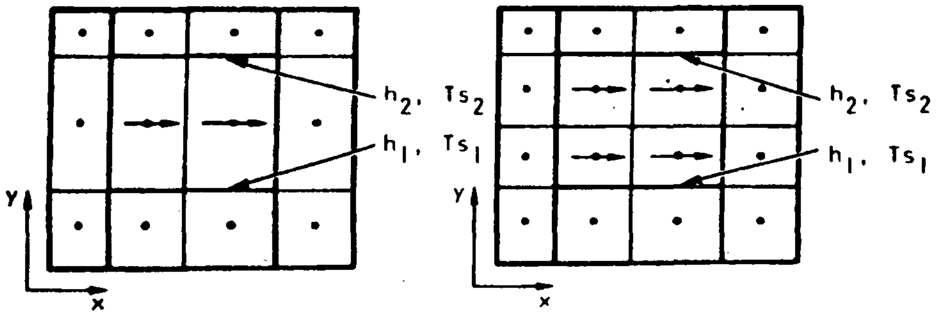
(c) MINIMUM GRID LINE REQUIREMENT FOR COOLANT BLOCKS

(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



$h_1 = h_2 = h\left(\frac{Ts_1 + Ts_2}{2}\right)$

$h_1 = h(Ts_1);\ h_2 = h(Ts_2)$

Fig. 5. Gap and coolant limitations

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. 5.

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. 5.

9. For coolants, the inlet temperature, flow rate and specific heat are identified by coolant number only. Thus it is not possible to specify different values of these thermal parameters for different blocks having the same coolant number. The values will be the same for all blocks and will be equal to those calculated for the coolant block which was given last in the input card sequence.

10. Coolant outlet temperatures printed in the output are identified by coolant number only. If the same numbered coolant is used in two different blocks, then the outlet temperature printed is that for the block which was given last in the block description input card sequence. However, the actual outlet temperatures used in the code will be the correct values for each block.

11. To specify different values of problem depth, H, for different coolant blocks is meaningless. The H given for the last coolant block in the block description input card sequence will be used for the entire problem. If H is not specified a value of 12 inches is assumed for rectangular or circular geometry, and 360° for cylindrical geometry.

12. Normal flow coolants are allowed only if the "B" version of the code is used. See Section 5.3.

The following sections of input (4.1.7 - 4.1.11) are optional in that all, some or none of them may be required for a particular problem. In each case the result of omitting one is described. Note that each section contains a heading card at the beginning and a blank card at the end. These sections may be input in any order.

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 one card. Format 6E12.4 is used. There may be as many cards as necessary. A header card precedes the data and a blank card follows it.

Header Card

Columns	
7-18	INITIAL TEMP

Data Cards

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
49-60	initial temperature of the region, °F
61-72	not used

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

Blank Card

Limits

	Minimum	Maximum
number of internal point regions	1	number of internal points
number of external point regions	0	number of external points

NOTES:

1. If this section of input is omitted, all temperatures except those specified otherwise in MADATA and FLØDAT will be 0°F initially, unless a punched deck (4.1.11) is included.

2. Omit the header card and the blank card if this section of input is omitted.

3. If a punched deck (4.1.11) follows this section of input, the punched deck will be used as initial temperature data. If the order is reversed, the INITIAL TEMP cards will be used.

4. If this section of input is included, all internal points must be assigned a temperature.

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. The sets may be in any order. Format 6E12.4 is used. A header card precedes the data and a blank card follows it.

Header Card

Columns	
7-15	FL0W DATA

Data Cards (3 per coolant)

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.

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:

Flow dependence number	Meaning
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:

Inlet temperature dependence number	Meaning
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

Columns	
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.

Blank Card (after the last set)

Limits

	Minimum	Maximum
number of sets of coolant limit cards	0	15

NOTES:

1. If this section of input is omitted, all the flows will have Reynolds number limits of 0, 10^{20}, 10^{20}, and 10^{20}; a flow dependence number of 0; and an inlet temperature dependence number of 0. In other words, only the functions H-A(X), FLO-A(X) and TIN-A(X) will be used. If any flow has limits different from the above default values, the three data cards must be supplied for that flow and each card must have all four limits specified.

2. Omit the header card and the blank card if this section of input is omitted.

3. The coolant inlet and exit temperature limits are given in °F. When formulating the functions FL0-A,B,C(X) and TIN-A,B,C(X) it should be remembered that the variables TIN and T0UT, 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:

Indicator	Units
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. A header card precedes the data and a blank card follows it.

Header Card

Columns	
7-16	TIME STEPS

Data Cards

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.

Blank Card

Limits

	Minimum	Maximum
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. In this case the header card and blank card must also 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

If no constants are used, this section of input may be omitted; otherwise, three cards must be supplied. In addition, a header card precedes the data and a blank card follows it.

Header Card

Columns	
7-16	PARAMETERS

Data Cards

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.

Blank Card

NOTES:

1. Omit the header card and blank card if this section of input is omitted.

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 (see Notes 1 and 3 of 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. A header card precedes the deck and a blank card follows it.

Header Card

Columns	
7-18	PUNCHED TEMP

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.

Blank Card

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 a number of blank cards. They are included to separate it from

other jobs which may precede it through the punching equipment. Remove unnecessary blank cards before using the deck.

4. Omit the header and the blank card if this section of input is omitted.

4.1.12 END DATA Card

This card, consisting of the characters END DATA in columns 7-14, must be included. It is the last card of the input.

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 1110 computer from the catalog file TAC2D*TFMAB-76-1 which contains the absolute element, the symbolic elements for Subroutines MADATA, FLØDAT, and CUSTØM, and the relocatable elements for all other code routines. The left hand margin represents column one of these control cards.

In addition, a convenient card-by-card description of all input sections (4.1.2 - 4.1.12) is included. Formats, units, default values and short explanatory notes are provided. For a full explanation of the input the user should refer to the appropriate section.

```
Col. 1
   ↓
   ∇ASG,AX     TAC2D*TFMAB-76-1.
   ∇ASG,T      13,U,XXXX                              (Note 1)
   ∇CØPY       TAC2D*TFMAB-76-1.,TPF$.
   ∇FREE       TAC2D*TFMAB-76-1.
   ∇ADD,P      .DRUM                                  (Note 2)
   ∇HDG,P      THERMAL PARAMETER FUNCTIONS           (optional)
   ∇FØR,WS     MADATA/S,MADATA/S,MADATA/S             (Note 3)
   -20
   Material and gas thermal parameter functions (4.1.1 and
     Note 4)

   ∇FØR,WS     FLØDAT/S,FLØDAT/S,FLØDAT/S             (Note 3)
   -20
   Coolant thermal parameter functions (4.1.1)

   ∇FØR,WS     CUSTØM/S,CUSTØM/S,CUSTØM/S         (3.6 and Note 5)
   -20
   User supplied programming

   Function Subprograms if used (see Appendix C)

   ∇PREP
   ∇MAP,S      TAC2D/i,TAC2D/ABS,TAC2D/i
   where i = A or B (Note 6)

   ∇PRT,T
   ∇HDG,P      any alphanumeric heading in cols. 13-72   (Note 7)
   ∇XQT        TAC2D/ABS                                 (Note 8)

   Input sections 4.1.2 - 4.1.12
```

NOTES:

1. Include this card only when the option TAPE (3.4.6, 4.1.3 and Appendix G) is being used. XXXX = reel number.

2. The drum card is required only when the steady-state or gap expansion option is being used. If it is included when none of these options is being used, there will be no computer charge for drum usage.

3. The S option may be omitted (∇F0R,W) to suppress the listing of MADATA and/or FL0DAT; however, FORTRAN diagnostic messages will also be suppressed. It is recommended that the S option be used during the initial check-out of a run. The FOR cards for Subroutines MADATA and FL0DAT need not be included 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. Omit this section if no additional programming is required.

6. MAP card
   a. Either the "A" or the "B" version of the TAC2D code may be used. Refer to Section 5.3 for a discussion of the differences between the two versions.
   b. The S option lists address limits for the subroutines and is useful in debugging a run. The N option will suppress this listing.
   c. The MAP card is not required if no FOR cards have been included.

7. This heading card, which is optional, 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.

8. The name TAC2D/ABS appearing on the execute card is the name of the absolute element in the standard versions 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 absolute element on the version being used.

Word	1-12
Column	1-72
Format	12A6
Title Cards Section 4.1.2	Any Descriptive Title
Symbol	ZZ(I)

At least one title card other than '$WARN$' (see below) is required. Title cards may be in any order.

Word	1		2	
Column	1-6	7-10	11-12	
Format	A6		I2	
Warn Time Card Section 4.1.2	$WARN$	B L A N K	Warn Time (Sec)	
Symbol	ZZ(1)		IWRN	

Optional. If omitted, IWRN = 20. This card may be located anywhere within the title card set.

	BLANK CARD

Required.

Word	1	2-12
Column	1-6	7-72
Format		11A6
Option Cards Section 4.1.3	BLANK	Options. See following cards for specific format of certain options. The indicators, beginning in col. 7, may be abbreviated to the first six characters.
Symbol		OPTION(I)

Use as many option cards as desired. They may be in any order. One option card indicating the geometry type is required.

Word	1	2-3	4	5	6	7	8	9
Column	1-6	7-18	19-24	25-30	31-36	37-42	43-48	49-54
Format		2A6		F6.1	F6.1	F6.1	F6.1	F6.1
Steady State Option Section 2.4	BLANK	STEADY STATE	BLANK	Temperature perturbation (°F). Defaults to 1°.	Residual tolerance. Defaults to 0.01.	Maximum iterations. Defaults to 10,000.	Beginning iteration parameter. Defaults to 1.	Maximum iteration parameter. Defaults to 500.
Symbol		OPTION (I)		DELT	TOL	ITMAX	DTFAC	DTMAX

If any of the steady state parameters is not specified, the default value will be used.

Word	1	2-4		5	6
Column	1-6	7-19	20-24	25-30	31-36
Format		2A6,A1		F6.1	F6.1
Gap Expansion Option Section 2.6	BLANK	GAP EXPANSION	BLANK	Minimum radial gap (in.)	Minimum axial gap (in. or radians)
Symbol		OPTION(I)		MNGAPR	MNGAPZ

If MNGAPR or MNGAPZ is not specified, 0 is assumed.

Word	1	2-3	4	5	6	7	8	9	10
Column	1-6	7-13	14-24	25-30	31-36	37-42	43-48	49-54	55-60
Format		A6.A1		F6.1	F6.1	F6.1	F6.1	F6.1	F6.1
Iterate Option Section 2.7	BLANK	ITERATE	BLANK	Convergence tolerance (°R)	Initial change to PAR1 (fraction)	Desired temperature (°R)	X(radial) index no. of TCONV	Y(axial, theta) index no. of TCONV	Initial value of PAR
Symbol		OPTION(I)		PMT	DELPAR	TCONV	RLOC	ZLOC	PAR1

No default values are assumed.

	BLANK CARD

Required.

Word	1	2	...etc.
Column	1-12	13-24	...etc.
Format	E12.4	E12.4	...etc.
X Grid Line Cards Section 4.1.4	Radial-X grid line 1 (in.)	Radial-X grid line 2 (in.)	...etc.
Symbol	RL(1)	RL(2)	...etc.

Six grid lines per card.
Minimum = 3
Maximum = IQ-1
(See Appendix E)

	BLANK CARD

Required.

Word	1	2	...etc.
Column	1-12	13-24	...etc.
Format	E12.4	E12.4	...etc.
Y Grid Line Cards Section 4.1.5	Axial-Y-theta grid line 1 (in. or °)	Axial-Y-theta grid line 2 (in. or °)	...etc.
Symbol	ZL(1)	ZL(2)	...etc.

Six grid lines per card.
Minimum = 3
Maximum = JQ-1
(See Appendix E)

	BLANK CARD

Required.

Word	1	2	3	4	5	6	7	
Column	1-12	13-24	25-36	37-48	49-60	61-66	67-72	
Format	E12.4	E12.4	E12.4	E12.4	E12.4	E12.4	E12.4	
Block Description Card 1 Section 4.1.6	Low radial-X boundary of block (in.)	High radial-X boundary of block (in.)	Low axial-Y-theta boundary of block (in. or °)	High axial-Y-theta boundary of block (in. or °)	Material no. or negative coolant no.	Coolant flow direction no.	Problem depth (in. or°)	
Symbol	RBL(K)	RBH(K)	ZBL(K)	ZBH(K)	MB(K)	IPATH(N)	HEIGHT	

Cols. 61-72 may be specified only for coolant blocks. If left blank, HEIGHT defaults to 360° (cylindrical geometry) or 12 in. (rectangular, circular geometry).

Word	1	2	3	4	
Column	1-12	13-24	25-36	37-48	
Format	E12.4	E12.4	E12.4	E12.4	
Block Description Card 2 Section 4.1.6	Radial-X gap thickness (in.)	Radial-X gap material no.	Axial-Y-theta gap thickness (in. or °)	Axial-Y-theta gap material no.	
Symbol	RDG(K)	MGR(K)	ZDG(K)	MGZ(K)	

This card (if required) and the preceding card must be input as pairs. Use as many pairs as necessary.

	BLANK CARD

Required.

The following sections (4.1.7-4.1.11) may be input in any order

Word	1	2-3	
Column	1-6	7-18	
Format		2A6	
Initial Temperature Heading Card Section 4.1.7	B L A N K	INITIAL TEMP	If this card and the next set of cards are omitted, all temperatures (except those specified in MADATA and FLØDAT) will be 0°F initially, unless a punched deck (4.1.11) is used.
Symbol		OP(I)	

Optional (see explanation)

Word	1	2	3	4	5	
Column	1-12	13-24	25-36	37-48	49-60	
Format	E12.4	E12.4	E12.4	E12.4	E12.4	
Initial Temperature Data Cards Section 4.1.7	Low radial-X boundary of region (in.)	High radial-X boundary of region (in.)	Low axial-Y-theta boundary of region (in. or °)	High axial-Y-theta boundary of region (in. or °)	Temperature of region (°F)	
Symbol	RMIN	RMAX	ZMIN	ZMAX	TEM	

Optional (see previous explanation). Use as many cards as necessary.

	BLANK CARD

Required only if preceding set of cards is included.

Word	1	2-3	
Column	1-6	7-15	
Format		A6,A3	
Coolant Limits Heading Card Section 4.1.8	B L A N K	FL0W DATA	If this card and the next set of cards are omitted, all the flows will use the low range functions H-A(X), FLO-A(X) and TIN-A(X). Otherwise, input the cards in groups of three for each flow using additional functions.
Symbol		OP(I)	

Optional (see explanation)

Word	1	2	3	4	5	
Column	1-12	13-24	25-36	37-48	49-60	
Format	E12.4	E12.4	E12.4	E12.4	E12.4	
Coolant Limits Card 1 Section 4.1.8	Coolant no.	Reynolds No. limit 1	Reynolds No. limit 2	Reynolds No. limit 3	Reynolds No. limit 4	
Symbol	N	RLIM1(N)	RLIM2(N)	RLIM3(N)	RLIM4(N)	

Optional limits for heat transfer coefficient functions. See heading card.

Word	1	2	3	4	5	
Column	1-12	13-24	25-36	37-48	49-60	
Format	E12.4	E12.4	E12.4	E12.4	E12.4	
Coolant Limits Card 2 Section 4.1.8	Flow dependence no.	Limit 1 (hr. or °F)	Limit 2 (hr. or °F)	Limit 3 (hr. or °F)	Limit 4 (hr. or °F)	
Symbol	FLODEP(N)	FLIM1(N)	FLIM2(N)	FLIM3(N)	FLIM4(N)	

Optional limits for flow rate functions. See heading card.

Word	1	22	3	4	5	
Column	1-12	13-24	25-36	37-48	49-60	
Format	E12.4	E12.4	E12.4	E12.4	E12.4	
Coolant Limits Card 3 Section 4.1.8	Inlet temperature dependence no.	Limit 1 (hr, lb/hr or °F)	Limit 2 (hr, lb/hr or °F)	Limit 3 (hr, lb/hr or °F)	Limit 4 (hr, lb/hr or °F)	
Symbol	TINDEP(N)	TLIM1(N)	TLIM2(N)	TLIM3(N)	TLIM4(N)	

Optional limits for inlet temperature functions. See heading card.

	BLANK CARD

Required only if preceding set of cards has been included. It is placed after the final group of three

Word	1	2-3	
Column	1-6	7-16	
Format		A6,A4	
Time History Heading Card Section 4.1.9	B L A N K	TIME STEPS	This card and the following set of cards are required only for a transient run. If included with a steady state run they will be ignored.
Symbol		OP(I)	

Optional (see explanation)

Word	1	2	3	4	
Column	1-12	13-24	25-36	37-48	
Format	E12.4	E12.4	E12.4	E12.4	
Time History Data Cards Section 4.1.9	End of time period M (sec, min or hr)	Time step (sec, min or hr)	Print frequency number	Unit indicator 1.0 = sec 2.0 = min 3.0 = hr	
Symbol	FTIME(M)	DTIME(M)	ITAPE(M)	IUNIT	

See previous remarks. Use as many cards as necessary.

	BLANK CARD

Required only if preceding set of cards has been included.

Word	1	2-3	
Column	1-6	7-16	
Format		A6,A4	
Function Control Constants (Parameters) Heading Card Section 4.1.10	B L A N K	PARAMETERS	Omit this and the following cards if the parameters are not used. A total of 18 parameters is allowed, 6 per card. If any parameter is specified, all three cards must be included.
Symbol		OP(I)	

Optional (see explanation

Word	1	2	...etc.
Column	1-12	13-24	...etc.
Format	E12.4	E12.4	...etc.
Function Control Constants Data Cards Section 4.1.10	Value of parameter A1	Value of parameter A2	...etc.
Symbol	A1	A2	...etc.

Optional. If included, this set must have three cards. See previous remarks.

	BLANK CARD

Required only if preceding set of cards has been included.

Word	1	2-3	
Column	1-6	7-18	
Format		2A6	
Previously Punched Temperatures Heading Card Section 4.1.11	BLANK	PUNCHED TEMP	This card and the following cards are required if a punched deck specifies the initial temperatures. If a punched deck follows the INITIAL TEMP cards (4.1.7), the punched deck is used. If the INITIAL TEMP cards follow the punched deck, the INITIAL TEMP cards are used.
Symbol		OP(I)	

Optional. See explanation.

Word	1	2	3	4	
Column	1-12	13-24	25-36	37-48	
Format	E12.6	F12.1	F12.1	F12.1	
Previously Punched Temperatures Card 1 Section 4.1.11	Current time (hr)	Number of radial points in the problem	Number of axial points in the problem	Iteration number	
Symbol	CURTI	IAMAX	JAMAX	NITER	

Optional. See explanation on heading card. This card is the first card of a punched deck.

Previously Punched Temperatures Card Sets 2 and 3 Section 4.1.11	Punched temperatures.

Optional. See explanation on heading card.

	BLANK CARD

Required only if the preceding set of cards has been included.

Word	1	2-3	
Column	1-6	7-14	
Format		A6,A2	
End Data Card Section 4.1.12	BLANK	END DATA	
Symbol		OP(I)	

Required.

4.3 PERFORMANCE OF A COMPUTER RUN

4.3.1 Execution Time and Printed Page Limits for Use With the Univac 1110 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. 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 20 seconds is automatically assigned at the beginning of the run and should be adequate to allow for preparation of all possible output. To change this value, see 4.1.2. 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.

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 1110 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. Diagnostic information is provided with certain error messages to aid debugging; for other error messages 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 ROUNDOFF 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 TAC2D, 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; however, this calculation may have an influence on stability.

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 remains 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, the variable Δt takes on values approaching Δt^*. Because it no longer has any significance as a unit of time, it is renamed an "iteration parameter". It is used to perform the computations up to a point where the approximate steady state solution has been reached. This iteration parameter is obtained by an automated process wherein it is increased for each iteration unless current results indicate that diverging oscillations are beginning to occur. In this case, it 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 much be chosen sufficiently small that this error becomes neglibigle. 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:

End of Time Period	Time Step
.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 rerunning 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 affect 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 connect discrete points while thermal capacitances and heat sources are considered as being concentrated at these points. The error cannot be described in general terms. The data of Fig. 6 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 in 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.

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

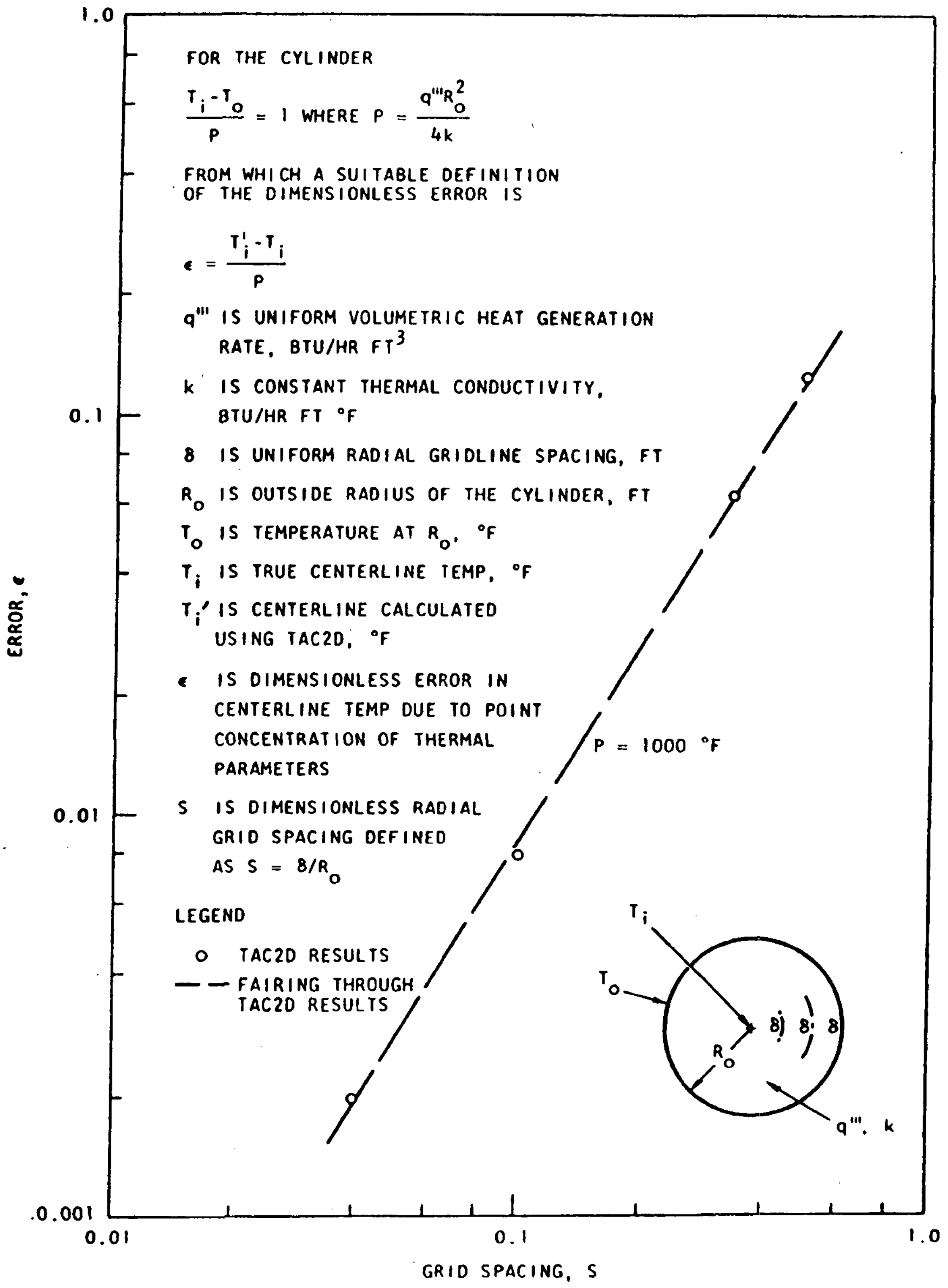


Fig. 6. TAC2D code - error in steady state centerline temperature for an infinitely long cylinder with heat generation as a function of uniform grid spacing

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.

5.3 RADIATION-TAC2D VERSIONS A AND B

The current TAC2D program contains two versions, A and B. The principal difference between them is in the method of computing the radiation across an internal coolant block. The B version uses an effective heat transfer coefficient method which may lead to instabilities. The A version was developed to eliminate these instabilities and handles the radiation by treating it as a heat source. However, normal coolants cannot be used with this version.

Since the B version is the earlier of the two, it is discussed first.

5.3.1 The B Version

Referring to the remarks of Section 5.2.2.3, the error in the solution for coolant temperatures may be intensified when there is radiation across an internal coolant block. In the B version of TAC2D 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

$$h_r = \frac{\mathcal{F}_{1-2}\left(T_{s_1}{}^4 - T_{s_2}{}^4\right)}{T_1 - T_{c_1}}$$

where

h_r is the component of overall unit conductance representing radiation, Btu/hr ft^2°R

T_1 is the temperature of the material point, °R

T_{c_1} is the temperature of the internal coolant point adjacent to the material point, °R

T_{s_1} is the local temperature of the internal coolant block boundary separating the material point at T_1 and the coolant point at T_{c_1}, °R

T_{s_2} is the local temperature of the internal coolant block boundary directly opposite the location of T_{s_1}, °R

$\mathcal{F}_{1-2}$ is the overall interchange factor for one-dimensional radiation between the temperatures T_{s_1} and T_{s_2}, dimensionless

Within a given iteration, the T_1 used to calculate h_r is the value from the preceding 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 $T_1 - T_{c_1}$ 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 dependent 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 $T_1 - T_{c_1}$ are checked before overall conductances between materials and internal coolants are calculated. At locations where $|T_1 - T_{c_1}| < 0.10°R$ 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 CONDUC 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.

Instabilities may result from these corrective measures since radiation may be included on one iteration and neglected on the next iteration. If results are not considered satisfactory, the corrective measures can usually be eliminated from the solution by rerunning the problem with smaller time steps.

5.3.2 The A Version

In the A version of TAC2D the effective heat transfer conductance method is replaced by a method whereby radiation is treated as energy source and sink terms at the nodes immediately adjacent to the coolant block. The calculation procedure at each iteration or time step is performed by first calling subroutine RAD which performs the following calculations:

1. The current net radiative heat flux between the adjacent materials at each section of surface along the flow direction is evaluated and stored for later use in evaluating surface temperatures.

2. At the same time, the material nodes adjacent to this section of the flow channel are identified and the internal heat generation rates for these nodes are increased or decreased by an amount equal to the radiative heat transfer q_r (see Section 2.1.4).

The RAD subroutine calls another subroutine AREA to evaluate the area used to calculate the net heat transfer rate. The TAC2D code then proceeds to calculate the new diffusion node temperatures as in the B version except that the calculation of an effective thermal conductance at a radiative fluid flow boundary is not performed. Also, the calculation procedure deviates slightly from the B version in the calculation of the new fluid temperature and material surface temperatures at the new time step. With the A version the material surface temperatures are recalculated simultaneously with the fluid temperatures while treating the previously stored radiative heat transfer rates as known quantities. By using the previously calculated radiation term, the necessity of iterating for surface temperatures in terms containing the temperature to the fourth power is eliminated. This procedure is only in error if the surface temperatures change by large magnitudes during a time step. However, the error is not accumulative. The result is only in error in that the radiative transport calculation lags the thermal diffusion calculation by a single time step. The error can be made as small as desired by appropriately reducing the time steps. There is no error when steady state is reached.

The calculation begins the next time step by evaluating the new radiative heat transfer rate and continues through the steps as described above.

The results of test cases utilizing this radiation algorithm show that (1) the predicted temperature distributions are the same as those predicted by the B version utilizing the effective conductance method when there were not fluid temperatures equal to adjacent material temperatures, and (2) the method is capable of handling cases where the temperature of the fluid and adjacent materials are identical, when the other method failed to produce acceptable results.

This radiation algorithm can introduce some errors in the results if a large percentage of the energy radiated to a block is convected away by the coolant, i.e., it is not conducted through the block. This error can be made totally negligible if grid lines are placed near the radiating boundaries, i.e., the heat sources are placed near the surface of the block.

A restriction on the use of the A version is that it cannot be used with problems involving normal coolants. If this is attempted, an error message is printed and program execution terminates. For normal coolant problems the B version must be used.

5.3.3 One-Dimensional Treatment of Radiation

In both versions A and B 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 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 ROUNDOFF 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. The same problem has been observed at coolant boundaries with large conductances. The roundoff errors in temperatures may cause the final heat balance to be grossly in error even when the printed temperature distribution is valid.

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 temperature, 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. Btu/hr-ft^2-°R

F = .50

σ = .1713 x 10^{-8} Btu/hr-ft^2°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 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.

6.1.4 Boundary or Coolant with Arbitrarily Specified Temperatures

This situation may arise when boundary or coolant temperatures are known independently from another thermal analysis.

A coolant with a known temperature profile is handled by using the inlet temperature and specific heat functions in the following way:

TIN-A(X) = desired coolant temperature as a function of:
radial position (FTR) for radial coolants
axial position (FTZ) for axial coolants

SPH-(X) = 10^{10}

Note that TIN-A(X) has been modified so that it is no longer an "inlet" temperature but the temperature at all points in the coolant.

To specify a boundary with a known temperature distribution, simply follow the above instructions for the coolant at the boundary and assign the heat transfer coefficient H-A(X) a very high value (e.g. 10^6).

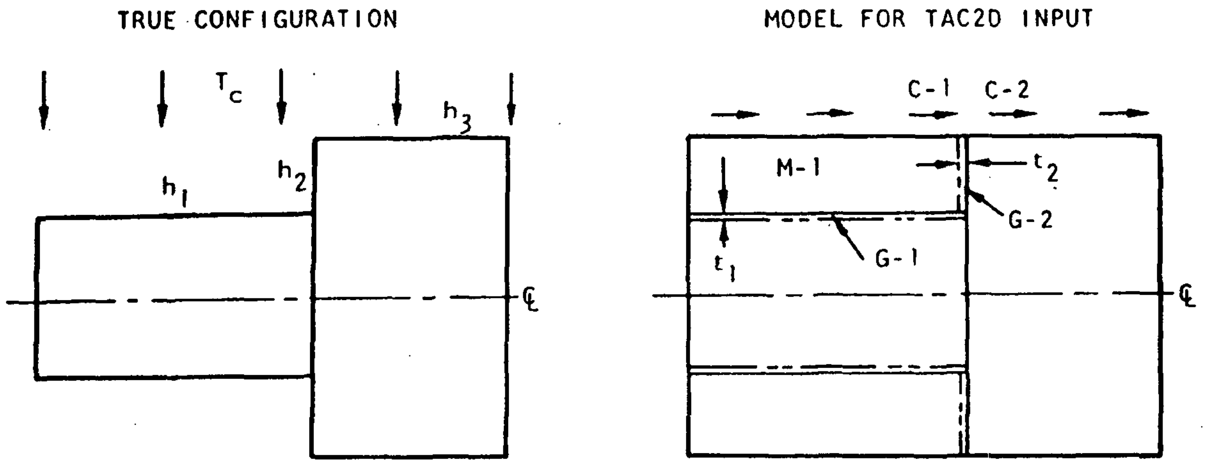
6.2 IRREGULAR EXTERNAL BOUNDARIES

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. 7 and 8, 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 simply assigned the constant coolant temperature T_c. This temperature will override the initial temperature specified for that region (4.1.7).

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. 8.

Dummy materials could be used in example 2 but use of dummy internal coolants in example 1 would require unnecessary compromise



TRUE CONFIGURATION

MODEL FOR TAC2D INPUT

M-n = MATERIAL n
G-n = GAS n
C-n = COOLANT n

DUMMY THERMAL PARAMETERS

MATERIALS

TMATI(X) = Tc
INITIAL TEMPERATURE OF I = ANYTHING

GASES

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

NO RADIATION: ALL EMISSIVITIES = 0

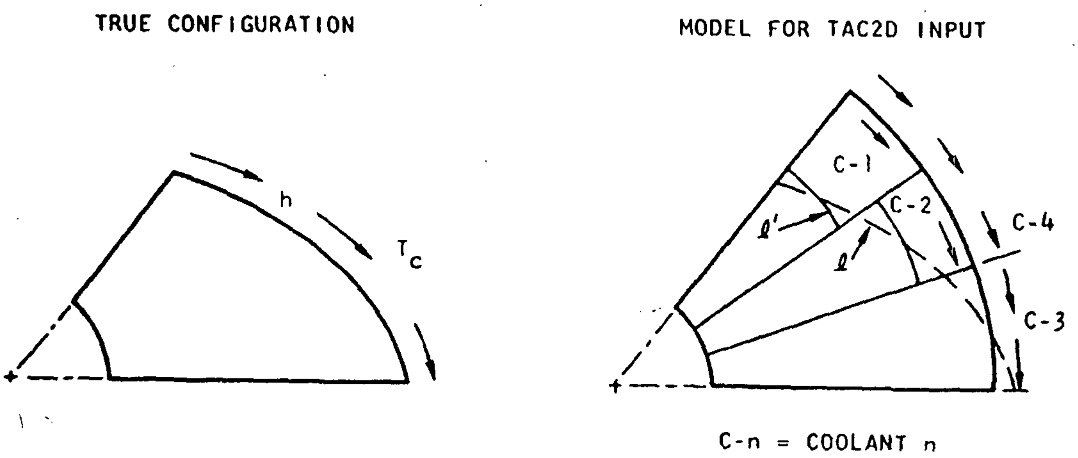
COOLANTS

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 I IS AN ADIABATIC BOUNDARY COOLANT AS DESCRIBED IN 6.1.1.

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

Fig. 7. Irregular external boundaries, Example 1



DUMMY MATERIAL THERMAL PARAMETERS

COOLANT NUMBER	H _ A(X)	TIN _ A(X)	FLO _ A(X)	SPH _ (X)
1	$(h)\left(\frac{\ell_1}{\ell_1'}\right)$	T_c	VERY HIGH	1.0
2	$(h)\left(\frac{\ell_2}{\ell_2'}\right)$	T_c	VERY HIGH	1.0
3	$(h)\left(\frac{\ell_3}{\ell_3'}\right)$	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 6.1.1

Fig. 8. Irregular external boundaries, Example 2

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 to the flow direction as illustrated in Item d of Fig. 5. 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.

6.4 FUNCTIONAL DEPENDENCE OF THERMAL PARAMETERS

As discussed in Section 2.5, thermal parameters may be functions of certain variables, e.g. temperature, position, time, etc. Sometimes the functional dependence can be expressed with a single equation. Often, however, an analytical relationship is not known; the information is available only as tabular data. To handle this situation the function subprogram TERP is used. Interpolation is performed between the data points and may be a linear, parabolic or higher order fit.

The subprogram is called by the following FORTRAN statement:

```
function = TERP(X,Y,N,Z,I)
```

where

function = one of the thermal parameter functions
X = the array of independent variable values
Y = the array of dependent variable values
N = the size of arrays X and Y
Z = independent variable for which a value of the dependent variable is to be computed
I = number of points to be used (2 = linear) (3 = parabolic) (etc.)

As an example, suppose the thermal conductivity RCØN-(X) of material 4 is a function of temperature DR. Tabular data are available as:

Temp. (°F)	Conductivity (Btu/hr-ft-°F)
100	0.0275
200	0.0308
300	0.0342
400	0.0384

The following FORTRAN statements would be included in subroutine MADATA for material 4:

```
DIMENSIØN  TEMP(4),CØND(4)*
DATA TEMP/100.0,200.0,300.0,400.0/
DATA CØND/0.0275,0.0308,0.0342,0.0384/
RCØN4(X) = TERP(TEMP,CØND,4,DR-460.,2)
```

Note that DR-460. is used since the tabular data temperatures are in °F.

---

* See Appendix D, "Restrictions on the Assignment of Names"

Function subprograms supplied by the user may also be used to define variable thermal properties. Their usage is described in Appendix C.

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 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

GEOMET1	SOME POINT HAS A NEGATIVE CALCULATED VOLUME.

SUBROUTINE GRID

GRID1	THERE ARE MORE GRIDLINES THAN 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
INITEM3	THE TEMPERATURE BLOCK'S LOWER AXIAL-Y-THETA BOUNDARY DOES NOT COINCIDE WITH ANY OF THE AXIAL-Y-THETA GRID BOUNDARIES
INITEM4	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 THIS VERSION OF THE CODE
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 MP1

MP1 1	A HEADING CARD FOR SOME BLOCK OF INPUT IS OUT OF ORDER OR MISSPELLED OR END DATA CARD IS MISSING

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 BOUNDARY 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 PROBEM 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 CONDUC

CONDUC1, CONDUC2	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.
CONDUC1	RADIATION WAS NEGLECTED BETWEEN RADIAL-X GAPLINES IGL AND IGH AT AXIAL-Y-THETA POINT LEVEL J.
CONDUC2	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), CØN(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).

```
TFILM(X) = (ST + DR)/2.
CØN(X) = 1.29E-3*TFILM(X)**.674
VIS(X) = 6.9E-4*TFILM(X)**.674
CP(X) = 1.242
PR(X) = CP(X)*VIS(X)/CØN(X)
REYN2(X) = 4.*FR/(.524*VIS(X))
REYN7(X) = 4.*FR/(1.048*VIS(X))
H2A(X) = .021*(RE**.8)*(PR(X)**.4)*(CØN(X)/.167)
H7A(X) = .021*(RE**.8)*(PR(X)**.4)*(CØN(X)/.333)
```

NOTES

1. If an additional function is used in the definition of a thermal parameter function (e.g. PR(X) in H2A(X) above), the variables allowed when defining the additional function are only those which are allowed for the corresponding thermal parameter function. Thus, since PR(X) is defined in terms of ST and DR, it may be used to define H2A(X), but not FLØ2A(X).

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:

```
SPEC3(X) = 490.*(6.364E-5*(DR-460.)+.107) for DR < 960°R
SPEC3(X) = 490.*(3.333E-5*(DR-460.)+.119) for DR ≥ 960°R
```

This will be done using a function subprogram named VSH.

In the material parameter function statements assign:

```
SPEC3(X) = VSH(DR)
```

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

```
VHDG,P     any alphanumeric heading in Cols. 13-72 (Note 1)
VFØR,IS         VSH/S,VSH/S                        (Note 1)
      FUNCTION VSH(TEM)
      IF(TEM.GE.960.)GØ TØ 10
      VSH = 490.*(6.364E-5*(TEM-460.)+.107)
      RETURN
   10 VSH = 490.*(3.333E-5*(TEM-460.)+.119)
      RETURN
      END
```

NOTES

1. The first two lines in the above example are control cards for the Univac 1110 computer.

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

```
HEAT9(X) = HGF(DR,FTZ)
```

which could be evaluated from the function subprogram labeled

```
FUNCTION HGF(TEM,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

```
SPEC3(X) = VSH(DR)
SPEC6(X) = 1.10*VSH(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.
4. When using arrays with Subroutine TERP as described in Section 6.4.

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 redefined. The names defined in Subroutines MADATA and FLODAT should not be used for the names of additional arrays in those subroutines or for arithmetic statement functions or function subprograms.

NAME	INCLUDED IN COMMON	DEFINED IN MADATA AND FLODAT
ATG		*
A1-A18	*	
B		*
C		*
CARD	*	
CONR	*	
CONZ	*	
CS1-CS7	*	
CURTI	*	
DATI	*	
DELPAR	*	
DELR	*	
DELZ	*	
DP	*	
DR	*	
DT	*	
DTIME	*	
FIRST	*	
FLIM1-FLIM4	*	
FLODEP	*	
FLOW	*	
FR	*	
FTIME	*	
FTR	*	
FTZ	*	
GAPR	*	
GAPZ	*	
GAS	*	
GK	*	
HC		*
HEIGHT	*	
HR	*	

NAME	INCLUDED IN COMMON	DEFINED IN MADATA AND FLODAT
I		*
IA		*
ICOUNT	*	
IDEN		*
IDENT		*
IERROR	*	
IF	*	
IFIRST		*
IFLO	*	
IFLODA		*
IGHS	*	
IGLS	*	
IGQ	*	
IGR	*	
IH	*	
IHS	*	
IL	*	
ILS	*	
IM	*	
IMAX	*	
IM1	*	
IP		*
IPATH	*	
IQ	*	
IR		*
ISHAPE	*	
IT		*
ITAPE	*	
ITER	*	
ITI	*	
ITIN	*	
ITO	*	

NAME	INCLUDED IN COMMON	DEFINED IN MADATA AND FLODAT
J		*
JGHS	*	
JGLS	*	
JGQ	*	
JGZ	*	
JH	*	
JHS	*	
JL	*	
JLS	*	
JM	*	
JMAX	*	
JM1	*	
JQ	*	
KNOWN		*
KR	*	
KVT	*	
KZ	*	
L		*
LASTIP	*	
LMAX	*	
LQ	*	
M		*
MATRG	*	
MATZG	*	
MAXFLO	*	
MAXMAT	*	
MAXNB	*	
MAXRG	*	
MAXRP	*	
MAXZG	*	
MAXZP	*	
MB	*	
MGR	*	
MGZ	*	

NAME	INCLUDED IN COMMON	DEFINED IN MADATA AND FLODAT
MMAX	*	
MNGAPR	*	
MNGAPZ	*	
MQ	*	
MT	*	
N		*
NC	*	
NCLIM	*	
NCONDS		*
NCPS		*
NFLO	*	
NI	*	
NITER	*	
NOLIST	*	
NPRINT	*	
NQ	*	
NRG	*	
NT	*	
NTA	*	
NUMMAT		*
NZG	*	
OPTSW	*	
OUTTAP	*	
PAR	*	
PMT	*	
PNAME	*	
PRODTV	*	
RATIOB	*	
RATIOC	*	
RATIOH	*	
RATIOK	*	
RBBTH	*	

NAME	INCLUDED IN COMMON	DEFINED IN MADATA AND FLODAT
RBBTL	*	
RBH	*	
RBL	*	
RCP	*	
RCPC	*	
RDG	*	
RE	*	
REMH	*	
REML	*	
RL	*	
RLIM1-RLIM4	*	
RLN	*	
RLOC	*	
RP	*	
RR	*	
RZ	*	
SCALE	*	
SELECT		*
SPEC		*
ST	*	
STA		*
STGH		*
STGL		*
SUMTV		*
SUMV		*
SW	*	
T	*	
TB	*	
TCONV	*	
TCP		*
TFCOM	*	
TH	*	

NAME	INCLUDED IN COMMON	DEFINED IN MADATA AND FLODAT
THIGH		*
THIGHS		*
TI	*	
TIN	*	
TINDEP	*	
TK		*
TLIM1-TLIM4	*	
TLOW		*
TLOWCP		*
TO	*	
TOUT	*	
TT	*	
V	*	
VOL		*
W	*	
X		*
Y		*
ZA	*	
ZATIOB	*	
ZATIOH	*	
ZATIOK	*	
ZBBTH	*	
ZBBTL	*	
ZBH	*	
ZBL	*	
ZDG	*	
ZEMH	*	
ZEML	*	
ZL	*	
ZLN	*	
ZLOC	*	
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 = 40, JQ = 45
IGQ = 34, JGQ = 34
LQ = 150

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 x IGQ x JQ

P2 = 7 x JGQ x IQ

P3 = 9 x IQ x JQ

P4 = 5 x LQ

and

CLIM = 37000

The above value of CLIM is approximate and applicable to the Univac 1110 computer installation at General Atomic. It includes an allowance 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 1110 computer installation at 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.

   ```
   VPMD,BREL
   ```

   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

---

* 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.

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

```
     ∇PMD,RE     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 axial point 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 of 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,T     15,U,XXXX
```

This card may be placed immediately after the program catalog file 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 circulator 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.

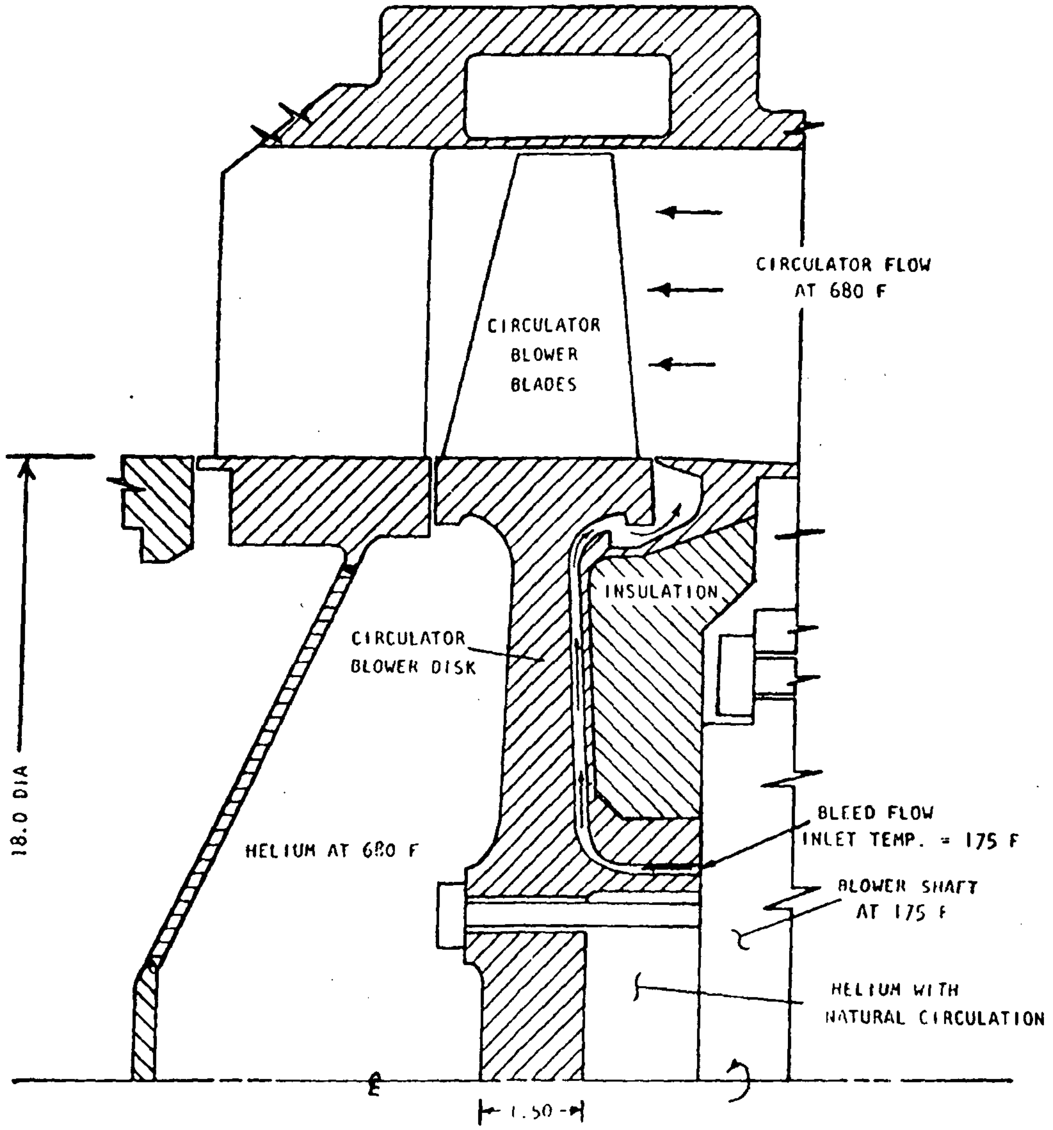


Fig. H-1. Helium circulator blower

NOTE:
Z DIRECTION REVERSED
IN EXAMPLE PROBLEM
OUTPUT.

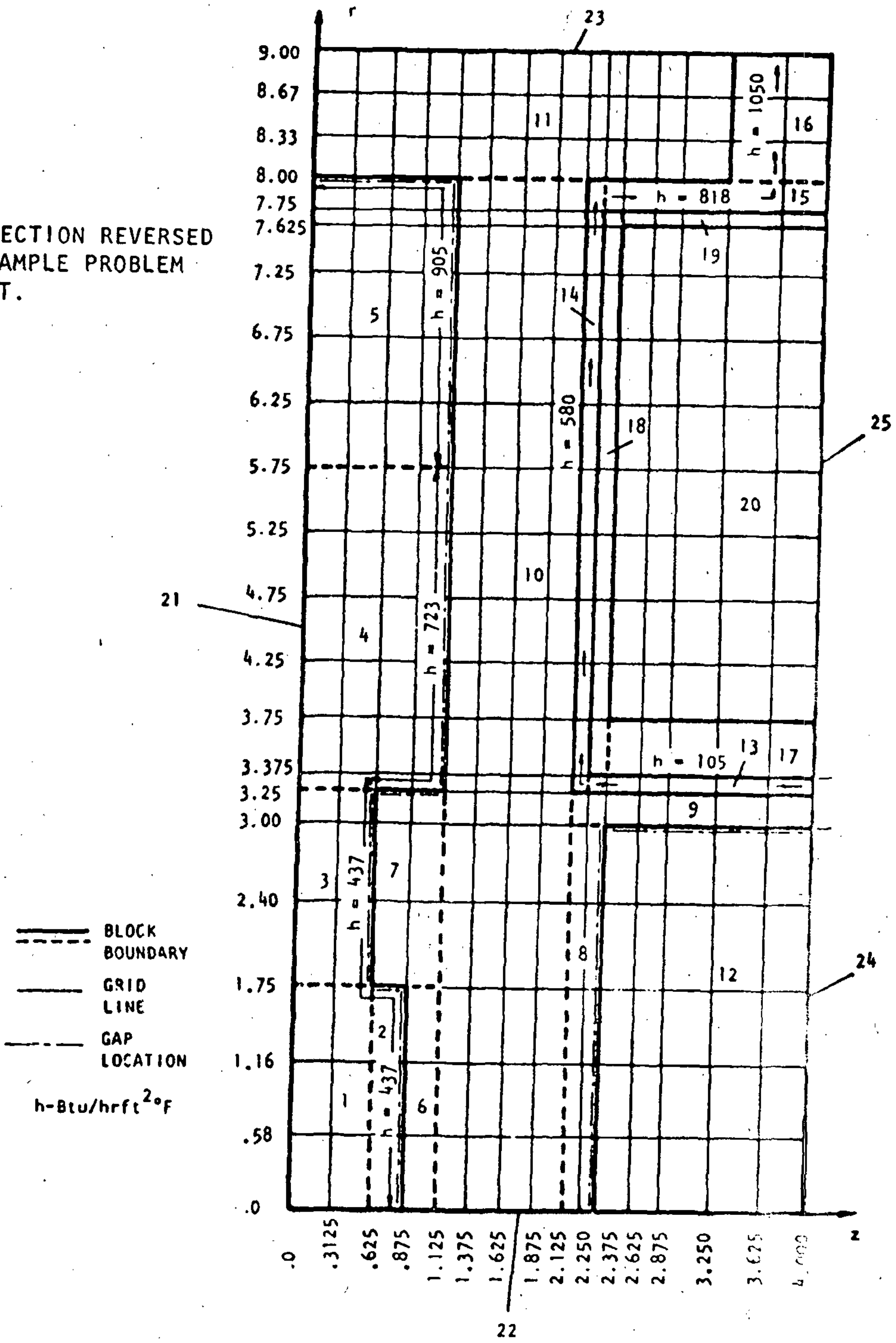


Fig. H-2. TAC2D thermal model of helium circulator blower disc

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.

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 is 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 (TMAT2(X) = 1140.) to the material in these blocks. The heat transfer coefficients between this helium and the blower disk are simulated by gaps. The thicknesses and thermal conductivities of these gaps (GCON1(X), GCON2(X), and 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 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 Btu/hr-ft^2°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 (RCON3(X) = 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 preceding coolant, except for the inlet coolant, i.e. coolant number 6.

Blocks 17 through 19 represent the steel separator plates. 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. Note that default values of the steady state parameters are used. The remaining options deal with the desired output.

---

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

3. The cards with the label B give block information. One or two cards are used per block. The first card specifies the block boundaries, material number or negative coolant number, and flow direction if the block contains a coolant. For example, block 13 contains coolant number 6 and it flows in the negative axial direction (-2.0). The second card, if required, gives gap information.

4. The coolant specification cards have been omitted since the heat transfer coefficients, flow rates and inlet temperatures of the coolants are constants. This insures that the A ranges of the H, FLO and TIN functions are used.

5. No time history cards are included because the steady state option was used. The three function control constants cards have also been omitted since the constants were not used.

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 message indicating that this TAC2D code has been verified according to General Atomic Guide Standard G[illegible]-3-[illegible]3 (see Reference 9).

2. A page indicating the code array size and the options selected.

3. 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.

4. The boundary overlay page, which aids in locating the block boundaries on the output temperature array.

5. The nodal volumes, and the radial and axial geometric conduction factors between two neighboring points; that is, the effective "A/ΔX" values.

6. The radial and axial nodal point, grid line, and gapline locations. Each of these is numbered for later identification.

7. The coolant specification page.

8. The initial temperature distribution.

9. A listing of the complete data input deck.

10. A message indicating that the steady state option is being used. The values of the steady state parameters are given along with guidelines to determine the validity of the solution.

11. Upper and lower temperature bounds for the steady state solution.

12. 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 integer format. Also included on these pages are coolant data, number of iterations, and the current value of the iteration parameter.

13. A printing of the residuals at each point except the coolant points. Extremely high residuals (e.g. 9.9999 [illegible]) correspond to the constant temperature dummy material 2 and should be ignored.

14. The surface temperatures at the radial and axial gaps, coolant boundaries, or interfaces between different materials. For an external coolant boundary, only the one surface temperature is given. For internal coolant channels and gaps, a pair of surface temperatures 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.

15. The heat rate (Btu/hr) and heat flux (Btu/hr-ft^2) 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-[illegible]F. A similar situation occurs for the conduction between two coolant points in the direction of the coolant flow.

16. The effective radial and axial conductivities. [illegible] 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.

17. 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

```
@ASG,AX     TAC2D*TFMAB-76-1.
@COPY       TAC2D*TFMAB-76-1.,TPFS.
@FREE       TAC2D*TFMAB-76-1.
@ADD,P      .DRUM
@HDG,P                THERMAL PARAMETER FUNCTIONS
@FOR,WS     MADATA/S,MADATA/S,MADATA/S
-20
C     THE FOLLOWING STATEMENTS DEFINE THE MATERIAL THERMAL PROPERTIES
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.
      TMAT2(X)=1140.
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.
@FOR,WS     FLODAT/S,FLODAT/S,FLODAT/S
-20
C     THE FOLLOWING STATEMENTS DEFINE THE COOLANT THERMAL PROPERTIES
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.
      COOLANT 2 IS ALONG 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)=TO(6)
      FLO8A(X)=50.
      SPH8(X)=1.24
      H8A(X)=818.
      TIN8A(X)=TO(7)
      FLO9A(X)=50.
      SPH9(X)=1.24
      H9A(X)=1050.
      TIN9A(X)=TO(8)
@PREP
@MAP,S      TAC2D/A,TAC2D/ABS,TAC2D/A
@PRT,T
@HDG,P      TAC2D EXAMPLE PROBLEM OUTPUT
@XQT        TAC2D/ABS
      STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC        TITLE  1
                                                                         BLANK
      CYLINDRICAL GEOMETRY                                               OPTION 1
      STEADY STATE                                                       OPTION 2
      CONDUCTIVITIES                                                     OPTION 3
      RESISTANCES                                                        OPTION 4
      HEAT FLUXES                                                        OPTION 5
      SURFACE TEMPERATURES                                               OPTION 6
                                                                         BLANK
.0          .58         1.16        1.75        2.40        3.0          RG-1
3.25        3.375       3.75        4.25        4.75        5.25         RG-2
5.75        6.25        6.75        7.25        7.625       7.75         RG-3
8.0         8.33        8.67        9.0                                  RG-4
                                                                         BLANK
0.          .3125       .625        .875        1.125       1.375        AG-1
1.625       1.875       2.125       2.250       2.375       2.625        AG-2
2.375       3.25        3.625       4.0                                  AG-3
                                                                         BLANK
0.          1.75        0.          .625        2.                       B1-1
0.          1.75        .625        .875        2.                       B2-1
[illegible] 1.          .0001                                            B2-2
            [illegible]
[illegible] 5.75        0.          1.125       2.                       B4-1
5.75        8.0         0.          1.125       2.                       B5-1
.0001       3.          .0001       3.                                   B5-2
0.          1.75        .875        1.125       1.                       B6-1
1.75        3.25        .625        1.125       1.                       B7-1
.0001       2.                                                           B7-2
0.          3.0         2.125       2.375       1.                       B8-1
                        .0001       4.                                   B8-2
3.0         3.25        2.125       4.0         1.                       B9-1
0.          8.0         1.125       2.125       1.                       B10-1
8.0         9.0         0.          3.25        1.                       B11-1
0.          3.0         2.375       4.0         3.                       B12-1
.0001       4.                                                           B12-2
```

```
 3.25        3.375       2.25        4.0         -6.         -2.         B13-1
 3.25        8.0         2.125       2.25        -7.          1.         B14-1
 7.75        8.0         2.25        4.0         -8.          2.         B15-1
 8.0         9.0         3.25        4.0         -9.          1.         B16-1
 3.375       3.75        2.375       4.0          5.                     B17-1
 3.375       7.75        2.25        2.375        5.                     B18-1
 7.625       7.75        2.375       4.0          5.                     B19-1
 3.75        7.625       2.375       4.0          4.                     B20-1
 0.          9.0         0.          0.          -3.          1.         B21-1
 0.          0.          0.          4.0         -4.          2.         B22-1
 9.0         9.0         0.          4.0         -1.          2.         B23-1
 0.          3.0         4.0         4.0         -2.          1.         B24-1
 3.0         9.0         4.0         4.0         -5.          1.         B25-1
                                                                         BLANK
      INITIAL TEMP
 0.          9.0         0.          4.0         680.                    IT-1
                                                                         BLANK
      END DATA
```

TAC2D EXAMPLE PROBLEM OUTPUT

```
   TAC2D EXAMPLE PROBLEM OUTPUT                                                                    DATE 071576        PAGE    1
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*
*TAC2D*TAC2D*       ******* *****   *****  *****  ******        ***** ***** *    *  ****  *****             *TAC2D*TAC2D*
*TAC2D*TAC2D*          *   *     * *     * *    * *     *         *   *     **  ** *    * *    *            *TAC2D*TAC2D*
*TAC2D*TAC2D*          *   *     * *            * *     *  ***    *   *     * ** * *    * *    *            *TAC2D*TAC2D*
*TAC2D*TAC2D*          *   ******* *       *****  *     *  ***    *   ****  * *  * ****** *****             *TAC2D*TAC2D*
*TAC2D*TAC2D*          *   *     * *       *      *     *  ***    *   *     *    * *    * *    *            *TAC2D*TAC2D*
*TAC2D*TAC2D*          *   *     * *     * *      *     *         *   *     *    * *    * *    *            *TAC2D*TAC2D*
*TAC2D*TAC2D*          *   *     *  ***** ******* ******          *   *     *    * *    * *****             *TAC2D*TAC2D*
*TAC2D*TAC2D*                                                                                               *TAC2D*TAC2D*
*TAC2D*TAC2D*               THIS CODE IS A VERIFIED PRODUCTION VERSION OF A TWO DIMENSIONAL                 *TAC2D*TAC2D*
*TAC2D*TAC2D*               THERMAL ANALYSIS CODE, TAC2D. THE APPLICABLE DOCUMENTATION IS:                  *TAC2D*TAC2D*
*TAC2D*TAC2D*                1. BOONSTRA,R.H.          TAC2D, A GENERAL PURPOSE TWO-DIMEN-                  *TAC2D*TAC2D*
*TAC2D*TAC2D*                                          SIONAL HEAT TRANSFER CODE USERS MAN-                 *TAC2D*TAC2D*
*TAC2D*TAC2D*                                          UAL, GA-A14032, JULY 15, 1976.                       *TAC2D*TAC2D*
*TAC2D*TAC2D*                2. PETERSON,J.F.          TAC2D, A GENERAL PURPOSE ... CODE,                   *TAC2D*TAC2D*
*TAC2D*TAC2D*                                          MATHEMATICAL FORMULATIONS AND PRO-                   *TAC2D*TAC2D*
*TAC2D*TAC2D*                                          GRAMMERS GUIDE, GA-9262, SEPT. 1969.                 *TAC2D*TAC2D*
*TAC2D*TAC2D*                3. MORCUS,S.,WILLIAMS,K.  THE TAC2D CODE, VERSION TEMAHC 75-1                  *TAC2D*TAC2D*
*TAC2D*TAC2D*                                          PART C: CODE VERIFICATION AND BENCH                  *TAC2D*TAC2D*
*TAC2D*TAC2D*                                          MARK PROBLEMS, GA-A13415, JUNE, 1975.                *TAC2D*TAC2D*
*TAC2D*TAC2D*                                                                                               *TAC2D*TAC2D*
*TAC2D*TAC2D*               THIS CODE VERSION HAS BEEN AVAILABLE SINCE 6-7-76. IT IS THE                    *TAC2D*TAC2D*
*TAC2D*TAC2D*               RECOMMENDED VERIFIED VERSION AND CONTAINS TWO SUBVERSIONS. BOTH                 *TAC2D*TAC2D*
*TAC2D*TAC2D*               ARE STORED UNDER THE SINGLE ALFA NAME OF TAC2D*TEMAB/76-1, ALFA                 *TAC2D*TAC2D*
*TAC2D*TAC2D*               REFERENCE NO. THSD 1966. THE TKFM BRANCH IS THE CODE CUSTODIAN.                 *TAC2D*TAC2D*
*TAC2D*TAC2D*                                                                                               *TAC2D*TAC2D*
*TAC2D*TAC2D*               THE USER SHALL NOTE THAT ACCESS HAS BEEN ALLOWED TO ONLY THE                    *TAC2D*TAC2D*
*TAC2D*TAC2D*               SUBROUTINE MADATA/S,FLODAT/S, AND CUSTOM/S. ACCESS TO MADATA                    *TAC2D*TAC2D*
*TAC2D*TAC2D*               AND FLODAT IS ONLY FOR PURPOSES OF INPUTTING MATERIAL AND COOLANT               *TAC2D*TAC2D*
*TAC2D*TAC2D*               DATA. ACCESS TO CUSTOM IS FOR THE PURPOSE OF PROCESSING OR                      *TAC2D*TAC2D*
*TAC2D*TAC2D*               PRINTING OF DATA BEYOND THE STANDARD CAPABILITIES OF THE CODE .                 *TAC2D*TAC2D*
*TAC2D*TAC2D*               IT SHALL BE THE SOLE RESPONSIBILITY OF THE TAC2D USER TO INSURE                 *TAC2D*TAC2D*
*TAC2D*TAC2D*               THAT ANY USER ADDITIONS TO THESE SUBROUTINES ARE FREE OF ERRORS,                *TAC2D*TAC2D*
*TAC2D*TAC2D*               [illegible], AND THAT THEY DO NOT INTERFERE WITH THE PROPER EXECUTION           *TAC2D*TAC2D*
*TAC2D*TAC2D*               OF THE TAC2D CODE. REFERENCE 1 DESCRIBES PROPER USAGE.                          *TAC2D*TAC2D*
*TAC2D*TAC2D*                                                                                               *TAC2D*TAC2D*
*TAC2D*TAC2D*                    FOR EXECUTION OF THIS VERIFIED VERSION OF TAC2D, THIS                      *TAC2D*TAC2D*
*TAC2D*TAC2D*               PAGE MUST BE PART OF A COMPLETE AND EXACT OUTPUT OF A RUN.                      *TAC2D*TAC2D*
*TAC2D*TAC2D*                                                                                               *TAC2D*TAC2D*
*TAC2D*TAC2D*               BE CERTAIN YOU ARE USING THE SUB-VERSION WHICH YOU DESIRE.                      *TAC2D*TAC2D*
*TAC2D*TAC2D*                                                                                               *TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*TAC2D*
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TAC2D EXAMPLE PROBLEM OUTPUT                                                                   DATE 071576        PAGE   2
                         T A C 2 D   C O D E    P R O D U C T I O N   V E R S I O N

        IQ              JQ              NQ              MQ              IGQ             JGQ             LQ
     RADIAL-X     AXIAL-Y-THETA    MAX NO. OF        MAX OF        MAX NO. OF      MAX NO. OF       MAX NO. OF
      POINTS          POINTS         COOLANTS         IQ,JQ         RADIAL-X     AXIAL-Y-THETA    MATL & COOL
                                                                    GAP LINES       GAPLINES         BLOCKS
        40              45              15              45              34              34              150


     STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC
  (WARN TIME IS SET AT  20 SECONDS)


     OPTIONS
               CYLINDRICAL GEOMETRY
               STEADY STATE
               CONDUCTIVITIES
               RESISTANCES
               HEAT FLUXES
               SURFACE TEMPERATURES


         THIS IS A SHORT INPUT RUN SETUP.
          USE A LONG INPUT OPTION CARD FOR A REGULAR RUN SETUP.
```

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                       STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

                                          BLOCK  DESCRIPTION

 BLOCK     . . . . . .        BOUNDARIES  . . . . . .                       . . .   GAPS  . . .
 NUMBER
           LOW RADIAL   HIGH RADIAL   LOW AXIAL    HIGH AXIAL   MATERIAL    RADIAL  MATERIAL     AXIAL  MATERIAL
            (INCHES)     (INCHES)     (INCHES)      (INCHES)               (INCHES)             (INCHES)

      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
      4      3.2500       5.7500        .0000        1.1250        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
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 TAC2D EXAMPLE PROBLEM OUTPUT                                                                 DATE 071576        PAGE     4
                                  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

16       **********************************************************************************************************
15       * 12M                    "  9M* 13C* 17M. 20M                                   . 19M* 15C* 16C          *
14       *                        "    *    *    .                                       .    *    ****************
13       *                        "    *    *    .                                       .    *    * 11M          *
12       *                        "    *    *    .                                       .    *    *              *
11       *"""""""""""""""""""""""""    *    *.................................................*    *              *
10       *  8M                    .    *************************************************************              *
 9       *.............................*************************************************************              *
 8       * 10M                                                                                     .              *
 7       *                                                                                         .              *
 6       *                                                                                         .              *
 5       *............................."..............................""""""""""""""""""""""""""""""              *
 4       *"""""""""""""""  7M          "  4M                         .  5M                         "              *
 3       *..............".............."                             .                             "              *
 2       *  1M          .  3M          .                             .                             "              *
 1       **********************************************************************************************************

         1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22
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                    STEADY-STATE TEMPERATURE IN [illegible]LIUM CIRCULATOR BLOWER DISC

                                    NODE  VOLUMES      (FT**3)

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

17  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
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
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
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
13  0.0000     1.5290-04  4.5870-04  7.8035-04  1.2261-03  1.4724-03  7.1018-04  3.7639-04  1.2144-03  1.8181-03
12  0.0000     1.5290-04  4.5870-04  7.8035-04  1.2261-03  1.4724-03  7.1018-04  3.7639-04  1.2144-03  1.8181-03
11  0.0000     7.6388-05  2.2916-04  3.8987-04  6.1254-04  7.3572-04  3.5509-04  1.8820-04  6.0720-04  9.0903-04
10  0.0000     7.6449-05  2.2935-04  3.9018-04  6.1303-04  7.3631-04  3.5509-04  1.8820-04  6.0720-04  9.0903-04
 9  0.0000     1.5290-04  4.5870-04  7.8035-04  1.2261-03  1.4726-03  7.1018-04  3.7639-04  1.2144-03  1.8181-03
 8  0.0000     1.5290-04  4.5870-04  7.8035-04  1.2261-03  1.4726-03  7.1018-04  3.7639-04  1.2144-03  1.8181-03
 7  0.0000     1.5290-04  4.5870-04  7.8035-04  1.2261-03  1.4726-03  7.1018-04  3.7639-04  1.2144-03  1.8181-03
 6  0.0000     1.5290-04  4.5870-04  7.8035-04  1.2261-03  1.4726-03  7.1018-04  3.7639-04  1.2144-03  1.8181-03
 5  0.0000     1.5290-04  4.5870-04  7.8035-04  1.2261-03  1.4726-03  7.1018-04  3.7639-04  1.2144-03  1.8181-03
 4  0.0000     1.5284-04  4.5851-04  7.7988-04  1.2261-03  1.4726-03  7.0988-04  3.7639-04  1.2144-03  1.8181-03
 3  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
 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
 1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

       1          2          3          4          5          6          7          8          9         10

17  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
16  3.0680-03  3.4089-03  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  3.4089-03  3.7497-03  4.0906-03  4.4315-03  4.7724-03  3.8030-03  1.3103-03  2.6845-03  3.6740-03
14  3.0680-03  3.4089-03  3.7497-03  4.0906-03  4.4315-03  4.7724-03  3.8030-03  1.3103-03  2.6845-03  3.6740-03
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
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
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
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
 9  [illegible] 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
 7  [illegible]
 6  [illegible]                                          2.5353-03  8.7352-04  1.7896-03  2.4493-03
 5  2.0453-03  2.2726-03  2.4998-03  2.7260-03  2.9532-03  3.1803-03  2.5343-03  8.7317-04  1.7862-03  2.4493-03
 4  [illegible]
 3  [illegible]                                                          [illegible]-03        3.0617-
 2  [illegible]                                                     3.1692-     [illegible]-03        3.0617-03
 1  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

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

        21          22          23
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                        STEADY-STATE TEMPERATURE IN [illegible]ELIUM 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

 17  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 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
 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
 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
 13  1.2740-02   1.1915-01   2.5454-01   3.6878-01   4.9717-01   8.9546-01   2.2465+00   1.7991+00   1.1301+00   1.1114+00
 12  1.2740-02   1.1915-01   2.5454-01   3.6878-01   4.9717-01   8.9546-01   2.2465+00   1.7991+00   1.1301+00   1.1114+00
 11  6.3647-03   5.9526-02   1.2717-01   1.8424-01   2.4839-01   4.4748-01   1.1232+00   8.9954-01   5.6504-01   5.5568-01
 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
  9  1.2740-02   1.1915-01   2.5454-01   3.6878-01   4.9717-01   8.9546-01   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   8.9546-01   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   8.9546-01   2.2465+00   1.7991+00   1.1301+00   1.1114+00
  6  1.2740-02   1.1915-01   2.5454-01   3.6878-01   4.9717-01   8.9546-01   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   8.9546-01   2.2465+00   1.7991+00   1.1301+00   1.1114+00
  4  1.2734-02   1.1910-01   2.5443-01   3.6871-01   4.9717-01   8.9546-01   2.2465+00   1.7991+00   1.1301+00   1.1114+00
  3  1.5924-02   1.4894-01   3.1817-01   4.6097-01   6.2146-01   1.1193+00   2.8081+00   2.2489+00   1.4126+00   1.3892+00
  2  1.5924-02   1.4894-01   3.1817-01   4.6097-01   6.2146-01   1.1193+00   2.8081+00   2.2489+00   1.4126+00   1.3892+00
  1  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

         1           2           3           4           5           6           7           8           9          10

 17  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 16  1.8635+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  1.8635+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
 14  1.8635+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
 13  [illegible] [illegible] [illegible] [illegible] 1.7663+00   2.1592+00   3.9594+00   5.4321+00   3.6197+00   3.2555+00
 12  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 5.4321+00   3.6197+00   3.2555+00
 11  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
 10  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 1.6277+00
  9  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 5.4321+00   3.6197+00   3.2555+00
  8  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 3.6197+00   3.2555+00
  7  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 5.4321+00   3.6197+00   3.2555+00
  6  [illegible] [illegible] [illegible] [illegible] 1.7663+00   2.1592+00   [illegible] 5.4321+00   3.6197+00   3.2555+00
  5  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
  4  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
  3  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 6.7901+00   [illegible] [illegible]
  2  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 6.7901+00   [illegible] [illegible]
  1  [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] 0.0000      0.0000      0.0000

        11          12          13          14          15          16          17          18          19          20

 17  0.0000      0.0000      0.0000
 16  5.0796+00   1.0612+01   0.0000
 15  5.0796+00   1.0612+01   0.0000
 14  5.0796+00   1.0612+01   0.0000
 13  3.3864+00   7.0744+00   0.0000
 12  3.3864+00   7.0744+00   0.0000
 11  1.6932+00   3.5372+00   0.0000
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TAC2D EXAMPLE PROBLEM OUTPUT                                                              DATE 071576          PAGE      8

 10    1.6932+00    3.5372+00    0.0000
  9    3.3864+00    7.0744+00    0.0000
  8    3.3864+00    7.0744+00    0.0000
  7    3.3864+00    7.0744+00    0.0000
  6    3.3864+00    7.0744+00    0.0000
  5    3.3864+00    7.0744+00    0.0000
  4    3.3864+00    7.0744+00    0.0000
  3    4.2330+00    8.8429+00    0.0000
  2    4.2330+00    8.8429+00    0.0000
  1    0.0000       0.0000       0.0000

          21           22           23
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TAC2D EXAMPLE PROBLEM OUTPUT                                                                                DATE 071576        PAGE    9

                                      STEADY-STATE TEMPERATURE IN [illegible]LIUM 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

 17  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 16  0.0000      4.6970-01   1.4091+00   2.3973+00   3.7664+00   4.5231+00   2.1817+00   1.1563+00   3.7307+00   5.5851+00
 15  0.0000      2.3485-01   7.0456-01   1.1986+00   1.8832+00   2.2615+00   1.0908+00   5.7814-01   1.8653+00   2.7925+00
 14  0.0000      2.3485-01   7.0456-01   1.1986+00   1.8832+00   2.2615+00   1.0908+00   5.7814-01   1.8653+00   2.7925+00
 13  0.0000      2.8182-01   8.4547-01   1.4384+00   2.2599+00   2.7138+00   1.3090+00   6.9377-01   2.2384+00   3.3510+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
 11  0.0000      4.6970-01   1.4091+00   2.3973+00   3.7664+00   4.5233+00   2.1817+00   1.1563+00   3.7307+00   5.5851+00
 10  0.0000      7.0456-01   2.1137+00   3.5959+00   5.6496+00   6.7859+00   3.2725+00   1.7344+00   5.5960+00   8.3776+00
  9  0.0000      4.6970-01   1.4091+00   2.3973+00   3.7664+00   4.5239+00   2.1817+00   1.1563+00   3.7307+00   5.5851+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
  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
  6  0.0000      3.5228-01   1.0568+00   1.7979+00   2.6248+00   3.3929+00   1.6362+00   8.6721-01   2.7980+00   4.1668+00
  5  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   4.1688+00
  4  0.0000      3.5228-01   1.0568+00   1.7978+00   2.5248+00   3.3929+00   1.6359+00   8.6721-01   2.7980+00   4.1888+00
  3  0.0000      3.1314-01   9.3941-01   1.5980+00   2.5110+00   3.0159+00   1.4542+00   7.7086-01   2.4871+00   3.7234+00
  2  0.0000      2.8182-01   8.4547-01   1.4384+00   2.2599+00   2.7143+00   1.3090+00   6.9377-01   2.2384+00   3.3510+00
  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

       1           2           3           4           5           6           7           8           9          10

 17  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 16  6.2832+00   6.9813+00   7.6795+00   8.3776+00   9.0757+00   9.7739+00   7.7886+00   2.6835+00   5.4978+00   7.5243+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
 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
 13  3.7699+00   4.1888+00   4.6077+00   5.0266+00   5.4454+00   5.8643+00   4.6731+00   1.6101+00   3.2987+00   4.5146+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   4.1234+00   5.6433+00
 11  6.2832+00   6.9813+00   7.6795+00   8.3776+00   9.0757+00   9.7739+00   7.7886+00   2.6835+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   1.1683+01   4.0252+00   8.2467+00   1.1287+01
  9  6.2832+00   6.9813+00   7.6795+00   8.3776+00   9.0757+00   9.7739+00   7.7886+00   2.6835+00   5.4978+00   7.5243+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   4.1234+00   5.6433+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   4.1234+00   5.6433+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   4.1234+00   5.6433+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   5.6433+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   5.6433+00
  3  4.1888+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
  2  3.7699+00   4.1888+00   4.6077+00   5.0266+00   5.4454+00   5.8643+00   4.6731+00   1.6101+00   3.2973+00   4.5146+00
  1  7.5398+00   8.3776+00   9.2154+00   1.0053+01   1.0891+01   1.1729+01   9.3463+00   3.2201+00   6.5947+00   9.0292+00

      11          12          13          14          15          16          17          18          19          20

 17  0.0000      0.0000      0.0000
 16  8.0704+00   8.1418+00   0.0000
 15  4.0352+00   4.0709+00   0.0000
 14  4.0352+00   4.0709+00   0.0000
 13  4.8423+00   4.8851+00   0.0000
 12  6.0528+00   6.1063+00   0.0000
 11  8.0704+00   8.1418+00   0.0000
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10    1.2106+01    1.2213+01    0.0000
 9    8.0704+00    8.1418+00    0.0000
 8    6.0528+00    6.1063+00    0.0000
 7    6.0528+00    6.1063+00    0.0000
 6    6.0528+00    6.1063+00    0.0000
 5    6.0528+00    6.1063+00    0.0000
 4    6.0528+00    6.1063+00    0.0000
 3    5.3803+00    5.4278+00    0.0000
 2    4.8423+00    4.8851+00    0.0000
 1    9.6845+00    9.7701+00    0.0000

         21           22           23
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 TAC2D EXAMPLE.PROBLEM OUTPUT                                                          DATE 071576       PAGE  11
                                 STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

             RADIAL BOUNDARY ASSIGNMENTS                                           AXIAL BOUNDARY ASSIGNMENTS

SEQUENCE   POINT      GRID LINE   BOUNDARY NUMBER AT                  SEQUENCE   POINT      GRID LINE   BOUNDARY NUMBER AT
 NUMBER   LOCATION    LOCATION    A MATERIAL INTERFACE                 NUMBER   LOCATION    LOCATION    A MATERIAL INTERFACE
          (INCHES)    (INCHES)    A COOLANT OR A GAP                            (INCHES)    (INCHES)    A COOLANT OR A GAP
   1          .00001                                                     1          .00000
      1                     .00001         1                                1                     .00000         1
   2          .29000                                                     2          .15625
      2                     .58000                                          2                     .31250
   3          .87000                                                     3          .46875
      3                    1.16000                                          3                     .62500         2
   4         1.45500                                                     4          .75000
      4                    1.75000         2                                4                     .87500         3
   5         2.07500                                                     5         1.00000
      5                    2.40000                                          5                    1.12500         4
   6         2.70000                                                     6         1.25000
      6                    3.00000         3                                6                    1.37500
   7         3.12500                                                     7         1.50000
      7                    3.25000         4                                7                    1.62500
   8         3.31250                                                     8         1.75000
      8                    3.37500         5                                8                    1.87500
   9         3.56250                                                     9         2.00000
      9                    3.75000         6                                9                    2.12500         5
  10         4.00000                                                    10         2.18750
     10                    4.25000                                         10                    2.25000         6
  11         4.50000                                                    11         2.31250
     11                    4.75000                                         11                    2.37500         7
  12         5.00000                                                    12         2.50000
     12                    5.25000                                         12                    2.62500
  13         5.50000                                                    13         2.75000
     13                    5.75000                                         13                    2.87500
  14         6.00000                                                    14         3.06250
     14                    6.25000                                         14                    3.25000         8
  15         6.50000                                                    15         3.43750
     15                    6.75000                                         15                    3.62500
  16         7.00000                                                    16         3.81250
     16                    7.25000                                         16                    4.00000         9
  17         7.43750                                                    17         4.00000
     17                    7.62500         7
  18         7.68750
     18                    7.75000         8
  19         7.87500
     19                    8.00000         9
  20         8.16500
     20                    8.33000
  21         8.50000
     21                    8.67000
  22         8.83500
     22                    9.00000        10
  23         9.00000
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                                 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+20      1.0000+20      1.0000+20
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+20      1.0000+20      1.0000+20
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+20      1.0000+20      1.0000+20
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+20      1.0000+20      1.0000+20
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+20      1.0000+20      1.0000+20
NO STEP CHANGES IN FLOW
NO STEP CHANGES IN INLET TEMPERATURE


SPECIFICATIONS FOR COOLANT  6

THE COOLANT IS FLOWING IN THE NEGATIVE AXIAL  DIRECTION
THE REY[illegible]S NUMBER LIMITS ARE      0.0000         1.0000+20      [illegible]000+20      1.0000+20
NO STEP[illegible]NGES IN FLOW
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NO STEP [illegible]GES 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+20      1.0000+20      1.0000+20
 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+20      1.0000+20      1.0000+20
 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+20      1.0000+20      1.0000+20
 NO STEP CHANGES IN FLOW
 NO STEP CHANGES IN INLET TEMPERATURE
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        TAC2D EXAMPLE PROBLEM OUTPUT                                                                   DATE 071576        PAGE   14
                                              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

     17      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      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
     15      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
     13      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
     11      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
      9      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
      7      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
      5      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
      3      0    680    680    680    680    680    680    680    680    680    680    680    680    680    680    680    680    680    680    680    680    680      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
      1      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0      0

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

    STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC         TITLE  1
                                                                        BLANK
    CYLINDRICAL GEOMETRY                                                OPTION 1
    STEADY STATE                                                        OPTION 2
    CONDUCTIVITIES                                                      OPTION 3
    RESISTANCES                                                         OPTION 4
    HEAT FLUXES                                                         OPTION 5
    SURFACE TEMPERATURES                                                OPTION 6
                                                                        BLANK
      .00000      .58000     1.16000     1.75000     2.40000     3.00000RG-1
     3.25000     3.37500     3.75000     4.25000     4.75000     5.25000RG-2
     5.75000     6.25000     6.75000     7.25000     7.62500     7.75000RG-3
     8.00000     8.33000     8.67000     9.00000      .00000      .00000RG-4
                                                                        BLANK
      .00000      .31250      .62500      .87500     1.12500     1.37500AG-1
     1.62500     1.87500     2.12500     2.25000     2.37500     2.62500AG-2
     2.87500     3.25000     3.62500     4.00000      .00000      .00000AG-3
                                                                        BLANK
    .00000      1.7500      .00000      .62500      2.0000      .00   .00B1-1
    .00000      1.7500      .62500      .87500      2.0000      .00   .00B2-1
    .10000-03   1.0000      .10000-03   1.0000      .00000      .00   .00B2-2
    1.7500      3.2500      .00000      .62500      2.0000      .00   .00B3-1
    3.2500      5.7500      .00000      1.1250      2.0000      .00   .00B4-1
    5.7500      8.0000      .00000      1.1250      2.0000      .00   .00B5-1
    .10000-03   3.0000      .10000-03   3.0000      .00000      .00   .00B5-2
    .00000      1.7500      .87500      1.1250      1.0000      .00   .00B6-1
    1.7500      3.2500      .62500      1.1250      1.0000      .00   .00B7-1
    .10000-03   2.0000      .00000      .00000      .00000      .00   .00B7-2
    .00000      3.0000      2.1250      2.3750      1.0000      .00   .00B8-1
    .00000      .00000      .10000-03   4.0000      .00000      .00   .00B8-2
    3.0000      3.2500      2.1250      4.0000      1.0000      .00   .00B9-1
    .00000      8.0000      1.1250      2.1250      1.0000      .00   .00B10-1
    8.0000      9.0000      .00000      3.2500      1.0000      .00   .00B11-1
    .00000      3.0000      2.3750      4.0000      3.0000      .00   .00B12-1
    .10000-03   4.0000      .00000      .00000      .00000      .00   .00B12-2
    3.2500      3.3750      2.2500      4.0000     -6.0000    -2.00   .00B13-1
    3.2500      8.0000      2.1250      2.2500     -7.0000     1.00   .00B14-1
    7.7500      8.0000      2.2500      4.0000     -8.0000     2.00   .00B15-1
    8.0000      9.0000      3.2500      4.0000     -9.0000     1.00   .00B16-1
    3.3750      3.7500      2.3750      4.0000      5.0000      .00   .00B17-1
    3.3750      7.7500      2.2500      2.3750      5.0000      .00   .00B18-1
    7.6250      7.7500      2.3750      4.0000      5.0000      .00   .00B19-1
    3.7500      7.6250      2.3750      4.0000      4.0000      .00   .00B20-1
    .00000      9.0000      .00000      .00000     -3.0000     1.00   .00B21-1
    .00000      .00000      .00000      4.0000     -4.0000     2.00   .00B22-1
    9.0000      9.0000      .00000      4.0000     -1.0000     2.00   .00B23-1
    .00000      3.0000      4.0000      4.0000     -2.0000     1.00   .00B24-1
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       3.0000      9.0000      4.0000      4.0000     -5.0000      1.00   .00825-1
                                                                          BLANK
          INITIAL TEMP
          .00000     9.00000      .00000     4.00000   680.00000          IT-1
                                                                          BLANK
          END DATA
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*****ATTENTION*****ATTENTION*****ATTENTION*****ATTENTION*****ATTENTION*****ATTENTION*****ATTENTION*****ATTENTION*****
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THIS VERSION OF TAC2D USES A NEW STEADY STATE SOLUTION PROCEDURE.
IT SHOULD PROVIDE YOU WITH THE UPPER AND LOWER TEMPERATURE ERROR
BOUNDS, AS WELL AS THE FINAL SOLUTION. IN ORDER TO INSURE THAT YOU
HAVE A PROPER STEADY STATE SOLUTION, YOU SHOULD CHECK YOUR RESULTS
 IN THE FOLLOWING WAYS:


    1.) IS THE LAST ITERATION NUMBER LESS THAN  10000 ?

    2.) IS THE RESIDUAL LESS THAN      .1000-01 ?

    3.) DOES THE FINAL ENERGY BALANCE AGREE WITHIN    1.000   %?

    4.) IS EACH TEMPERATURE OF THE FINAL RESULT BETWEEN THE UPPER AND LOWER BOUNDS ?

    5.) WAS THE RUN NORMALLY TERMINATED,E.G.THE WARNING TIME LIMIT WAS NOT ENCOUNTERED ?


IF THE ANSWER TO ALL OF THE ABOVE IS TRUE, THEN YOUR SOLUTION SHOULD
BE A VALID STEADY STATE RESULT AT LEAST WITHIN THE PRINTED
UPPER AND LOWER TEMPERATURE BOUNDS. IF THE ANSWER TO ANY ONE IS FALSE,
THE RESULTS ARE NOT NECESSARILY INVALID. HOWEVER, INSPECT YOUR RESULTS FOR
INCONSISTENCIES: OBSERVE THE UPPER AND LOWER TEMPERATURE BOUNDS.


        NOTE: THE CURRENT VALUES OF THE STEADY STATE PARAMETERS ARE:

   DELT =     1.000    DEG F PER PERTURBATION
   TOL  =     .1000-01 ALLOWABLE FRACTIONAL ENERGY UNBALANCE
   ITMAX=     10000    MAX ITERATIONS BEFORE FINAL SMOOTHING
   DTFAC=     1.000    MINIMUM ITERATION PARAMETER
   DTMAX=     500.0    MAXIMUM ITERATION PARAMETER

IF YOU ENCOUNTER ANY DIFFICULTIES IN ATTAINING A SATISFACTORY
STEADY STATE SOLUTION WITH THIS TAC2D VERSION, PLEASE CONTACT:

              T+FM SECTION, SYSTEMS ANALYSIS BRANCH

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TAC2D EXAMPLE PROBLEM OUTPUT                                                          DATE 071576        PAGE    18

  POSITIVE PERTURBATION HAS BEEN INITIATED...AND COMPLETED IN   3135.20   MS.
  THESE RESULTS REPRESENT AN UPPER TEMPERATURE BOUND-THERE WERE    1   1.DEG F PERTURBATIONS

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

 17      0   175   175   175   175   175     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
 16      0   297   297   297   297   297   238   179   224   269   343   404   456   502   544   583   618   634   632   635   642   653   680
 15      0   298   298   298   298   297   245   188   228   273   346   406   457   502   543   582   615   629   631   635   642   653   680
 14      0   299   299   299   298   298   261   196   236   281   353   410   460   503   542   579   613   629   632   640   652   668   680
 13      0   300   300   299   299   299   288   204   246   293   361   415   462   503   540   574   607   624   628   642   656   671   680
 12      0   300   300   300   300   299   325   212   256   308   369   420   465   504   538   570   598   617   623   642   658   673   680
 11      0   477   475   472   463   438   374   219   264   319   374   423   466   504   538   567   591   607   617   645   660   673   680
 10      0   491   490   486   477   453   404   232   208   320   374   423   467   505   538   567   589   600   611   648   661   674   680
  9      0   513   512   508   500   478   440   413   405   428   463   497   527   552   575   596   614   624   633   650   663   675   680
  8      0   542   541   538   532   518   501   495   492   505   528   550   570   586   602   617   631   639   645   656   666   676   680
  7      0   572   571   569   565   559   561   564   568   577   590   603   613   618   628   638   647   652   656   663   670   677   680
  6      0   601   600   599   599   599   614   633   642   646   650   654   657   649   653   658   663   665   667   669   673   678   680
  5      0   630   630   630   632   635   651   680   680   680   680   680   680   680   680   680   680   680   680   675   676   678   680
  4      0   680   680   680   665   665   672   680   680   680   680   680   680   680   680   680   680   680   680   677   677   679   680
  3      0   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   678   678   679   680
  2      0   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   681   680
  1      0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0

         1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20    21    22    23
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TAC2D-EXAMPLE PROBLEM OUTPUT                                                      DATE 071576        PAGE [illegible]19.

   NEGA[illegible] PERTURBATION HAS BEEN INITIATED...AND COMPLETED IN [illegible]719.80   MS.
   THESE RESULTS REPRESENT A LOWER TEMPERATURE BOUND-THERE WERE   2 - 1. DEG F PERTURBATIONS

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

 17      0  175  175  175  175  175    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 16      0  296  295  295  295  295  237  179  224  269  343  404  456  502  544  583  617  632  632  635  642  653  680
 15      0  296  296  296  296  296  244  188  228  273  346  406  457  502  543  582  617  632  633  635  642  653  680
 14      0  297  297  297  297  296  260  196  236  281  352  410  459  503  542  579  614  630  632  640  651  667  680
 13      0  298  298  297  297  297  287  204  246  293  361  415  462  503  540  575  607  625  628  642  656  671  680
 12      0  298  298  296  298  298  324  212  255  307  369  420  465  504  538  570  599  617  623  642  658  673  680
 11      0  476  474  471  462  437  373  219  264  319  373  423  466  504  537  567  591  607  617  645  660  673  680
 10      0  490  489  485  476  452  404  231  267  320  374  423  467  505  538  567  589  600  611  648  661  674  680
  9      0  512  511  507  499  477  439  413  405  428  463  497  527  552  575  596  614  624  633  650  663  675  680
  8      0  542  540  538  531  517  501  494  491  505  528  550  570  586  602  617  631  639  645  656  666  676  680
  7      0  571  570  568  565  559  560  564  568  577  590  603  613  618  628  638  647  652  656  663  670  677  680
  6      0  601  600  599  599  599  614  632  642  646  650  654  657  649  653  658  663  665  667  669  673  678  680
  5      0  630  630  629  632  634  651  680  680  680  680  680  680  680  660  680  680  680  680  675  676  679  680
  4      0  680  680  680  665  665  672  680  680  680  680  680  680  680  680  680  680  680  680  678  678  679  680
  3      0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  2      0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  1      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

         1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23
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TAC2D EXAMPLE PROBLEM OUTPUT                                                                        DATE 071576        PAGE    20
                                  STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC


                                             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         222               50
        7             222         616              50                   8             616         634               50
        9             634         658              50

THE CURRENT ITERATION PARAMETER IS    19.93    .                        100 ITERATIONS HAVE BEEN PERFORMED.


                                              TEMPERATURES     (F)

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

 17     0  175  175  175  175  175    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 16     0  297  296  296  296  296  238  179  224  269  343  405  457  502  544  584  619  634  633  636  643  654  680
 15     0  297  297  297  297  297  245  189  223  273  346  407  458  503  544  583  618  633  634  636  643  654  680
 14     0  298  298  298  296  297  250  196  236  281  353  411  460  503  542  580  615  631  633  642  653  668  680
 13     0  299  299  298  298  298  287  204  245  293  361  416  462  503  540  575  608  625  628  642  656  671  680
 12     0  299  299  299  299  299  324  212  256  308  369  420  465  504  538  570  599  618  623  643  658  673  680
 11     0  476  475  471  463  437  373  219  264  319  374  423  466  505  538  567  591  607  617  645  660  673  680
 10     0  491  489  486  477  452  404  232  267  320  374  423  467  505  538  567  589  600  611  648  661  674  680
  9     0  513  511  508  499  477  440  413  404  428  463  497  527  552  575  596  614  624  633  650  663  675  680
  8     0  542  541  536  532  518  501  495  492  505  528  550  570  586  602  617  631  639  645  656  666  676  680
  7     0  571  570  569  565  559  560  564  568  577  590  603  613  618  628  638  647  652  656  663  670  677  680
  6     0  601  600  599  599  599  614  632  642  646  650  654  657  649  653  658  603  665  667  669  673  678  680
  5     0  630  630  630  632  634  651  680  680  680  680  680  680  680  680  680  680  680  680  675  676  679  680
  4     0  680  680  680  665  665  671  680  680  680  680  680  680  680  680  680  680  680  680  678  678  679  680
  3     0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  2     0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  1     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

        1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23
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                                STEADY-STATE TEMPERATURE I[illegible]HELIUM CIRCULATOR BLOWER DISC


                                              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        222             50
       7               222        615             50                  8             616        633             50
       9               633        658             50

THE CURRENT ITERATION PARAMETER IS   19.93   .                        105 ITERATIONS HAVE BEEN PERFORMED.


                                              TEMPERATURES     (F)

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


 17      0  175  175  175  175  175    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 16      0  296  296  296  296  296  238  179  224  269  343  404  456  502  544  584  619  634  633  636  643  654  680
 15      0  297  297  297  297  296  245  188  228  273  346  406  457  502  543  582  617  632  633  636  643  654  680
 14      0  298  298  298  298  297  260  196  236  281  353  410  460  503  542  579  614  630  632  641  652  665  680
 13      0  299  299  298  298  296  287  204  246  293  361  415  462  503  540  575  607  624  628  642  656  671  680
 12      0  299  299  299  299  299  325  212  256  308  369  420  465  504  538  570  598  617  623  642  658  673  680
 11      0  476  475  471  463  437  373  219  264  319  374  423  466  504  537  567  591  607  617  645  660  673  680
 10      0  491  489  486  477  452  404  232  267  320  374  423  467  505  538  567  589  600  610  648  661  674  680
  9      0  513  511  508  499  477  439  413  405  428  463  497  527  552  575  596  614  624  633  650  663  675  680
  8      0  542  541  538  532  518  501  495  492  505  528  550  570  586  602  617  631  639  645  656  666  676  680
  7      0  571  570  569  565  559  560  564  568  577  590  603  613  618  628  638  647  652  656  663  670  677  680
  6      0  601  600  599  599  599  614  632  642  646  650  654  657  649  653  658  663  665  667  669  673  678  680
  5      0  630  630  630  632  634  651  680  680  680  680  680  680  680  680  680  680  680  680  675  676  679  680
  4      0  680  680  680  665  665  672  680  680  680  680  680  680  680  680  680  650  680  680  678  678  679  680
  3      0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  2      0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  1      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

         1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23
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                                        STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC


                                                     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        222             50
          7              222        615              50                  8             615        633             50
          9              633        657              50

  THE CURRENT ITERATION PARAMETER IS    19.93    .                   110 ITERATIONS HAVE BEEN PERFORMED.


                                                  TEMPERATURES     (F)

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


   17       0  175  175  175  175  175    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   16       0  296  296  296  296  296  238  179  224  269  343  404  456  502  544  584  619  634  633  636  642  653  680
   15       0  297  297  297  297  296  245  188  228  273  346  406  457  502  543  582  616  632  632  636  642  653  680
   14       0  298  298  298  298  297  260  196  236  281  353  410  460  503  542  579  613  630  632  640  652  668  680
   13       0  299  299  298  298  298  237  204  246  293  361  415  462  503  540  574  607  624  628  642  656  671  680
   12       0  299  299  299  299  298  325  212  255  308  369  420  465  504  538  570  598  617  622  642  658  673  680
   11       0  476  475  471  463  437  373  219  264  319  374  423  466  504  537  567  591  607  617  645  660  673  680
   10       0  491  489  486  477  452  404  232  267  320  374  423  467  505  538  567  589  600  610  648  661  674  680
    9       0  513  511  508  499  477  439  413  405  428  463  497  527  552  575  596  614  624  633  650  663  675  680
    8       0  542  541  538  532  518  501  495  492  505  528  550  570  586  602  617  631  639  645  656  666  676  680
    7       0  571  570  569  565  559  560  564  568  577  590  603  613  618  628  638  647  652  656  663  670  677  680
    6       0  601  600  599  599  599  614  632  642  646  650  654  657  649  653  658  663  665  667  669  673  678  680
    5       0  630  630  630  632  634  651  680  680  680  680  680  680  680  680  680  680  680  680  675  676  679  680
    4       0  680  680  680  665  665  672  680  680  680  680  680  680  680  680  680  680  680  680  678  678  679  680
    3       0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
    2       0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
    1       0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

            1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23
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 TAC2D EXAMPLE PROBLEM OUTPUT                                                                            DATE 071576        PAGE   23
                                          STEADY-STATE TEMPERATURE I     ELIUM CIRCULATOR BLOWER DISC


                                                   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         222               50
       7                222          616             50                   8                616         633               50
       9                633          657             50

THE CURRENT ITERATION PARAMETER IS    19.93    .                                  115 ITERATIONS HAVE BEEN PERFORMED.


                                                  TEMPERATURES     (F)

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


 17       0   175   175   175   175   175     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
 16       0   296   296   296   296   296   238   179   224   269   343   404   456   502   544   584   618   634   632   635   642   653   680
 15       0   297   297   297   297   296   245   188   228   273   346   406   457   502   543   582   616   631   632   635   642   653   680
 14       0   298   298   298   297   297   260   196   236   281   353   410   460   503   542   579   613   629   632   640   652   668   680
 13       0   299   299   298   298   298   287   204   246   293   361   415   462   503   540   574   607   624   628   641   656   671   680
 12       0   299   299   299   299   298   325   212   255   308   369   420   465   504   538   570   598   617   622   642   658   673   680
 11       0   476   475   471   463   437   373   219   264   319   374   423   466   504   537   567   591   607   617   645   660   673   680
 10       0   491   489   486   477   452   404   232   267   320   374   423   467   505   538   567   589   600   610   648   661   674   680
  9       0   513   511   508   499   477   439   413   405   428   453   497   527   552   575   596   614   624   633   650   663   675   680
  8       0   542   541   538   532   518   501   495   492   505   528   550   570   586   602   617   631   639   645   656   666   676   680
  7       0   571   570   569   565   559   560   564   568   577   590   603   613   618   628   638   647   652   656   663   670   677   680
  6       0   601   600   599   599   599   614   632   642   646   650   654   657   649   653   658   663   665   667   669   673   678   680
  5       0   630   630   630   632   634   651   680   680   680   680   680   680   680   680   680   680   680   680   675   676   679   680
  4       0   680   680   680   665   665   672   680   680   680   680   680   680   680   680   680   680   680   660   678   678   679   680
  3       0   680   680   680   660   680   680   680   680   680   680   680   680   680   680   680   680   680   680   679   679   680   680
  2       0   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   679   679   680   680
  1       0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0

          1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20    21    22    23
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                              STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC


                                                    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        222             50
      7               222        616             50                  8              616        633             50
      9               633        657             50

THE CURRENT ITERATION PARAMETER IS    19.93    .                             120 ITERATIONS HAVE BEEN PERFORMED.


                                                    TEMPERATURES     (F)

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


 17      0  175  175  175  175  175    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 16      0  296  296  296  296  296  238  179  224  269  343  404  456  502  544  584  618  633  632  635  642  653  680
 15      0  297  297  297  297  296  245  188  228  273  346  406  457  502  543  582  616  630  632  635  642  653  680
 14      0  298  298  298  297  297  260  196  236  281  353  410  459  502  541  579  613  629  632  640  652  667  680
 13      0  299  298  298  298  298  287  204  246  293  361  415  462  503  540  574  607  624  628  641  656  671  680
 12      0  299  299  299  299  298  325  212  255  308  369  420  465  504  538  570  598  617  622  642  658  673  680
 11      0  476  475  471  463  437  373  219  264  319  374  423  466  504  537  567  591  607  617  645  660  673  680
 10      0  491  489  486  477  452  404  232  267  320  374  423  467  505  538  567  569  600  610  648  661  674  680
  9      0  513  511  508  499  477  439  413  405  428  463  497  527  552  575  596  614  624  633  650  663  675  680
  8      0  542  541  538  532  518  501  495  492  505  528  550  570  586  602  617  631  637  645  656  666  676  680
  7      0  571  570  569  565  559  560  564  568  577  590  603  613  618  628  638  647  652  656  663  670  677  680
  6      0  601  600  599  599  599  614  632  642  646  650  654  657  649  653  658  663  665  667  669  673  678  680
  5      0  630  630  630  632  634  651  680  680  680  680  680  680  680  680  680  680  680  680  675  676  679  680
  4      0  680  680  680  665  665  672  680  680  680  680  680  680  680  680  680  680  680  680  678  678  679  680
  3      0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  2      0  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  1      0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

         1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23
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TAC2D EXAMPLE PROBLEM OUTPUT                                                                DATE 071576         PAGE      5

                                     STEADY-STATE TEMPERATURE IN A [illegible]LIUM CIRCULATOR BLOWER DISC


                                               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           222              50
       7               222           616              50                 8             616           633              50
       9               633           657              50

THE CURRENT ITERATION PARAMETER IS    19.93    .                              120 ITERATIONS HAVE BEEN PERFORMED.


                                               TEMPERATURES      (F)

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


 17      0   175  175  175  175  175    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 16      0   296  296  296  296  296  238  179  224  269  343  404  456  502  544  584  618  633  632  635  642  653  680
 15      0   297  297  297  297  296  245  188  228  273  346  406  457  502  543  582  616  630  632  635  642  653  680
 14      0   298  298  298  297  297  260  196  236  281  353  410  459  502  541  579  613  629  632  640  652  667  680
 13      0   299  298  298  298  298  287  204  246  293  361  415  462  503  540  574  607  624  628  641  656  671  680
 12      0   299  299  299  299  298  325  212  255  308  369  420  465  504  538  570  598  617  622  642  658  673  680
 11      0   476  475  471  463  437  373  219  264  319  374  423  466  504  537  567  591  607  617  645  660  673  680
 10      0   491  489  486  477  452  404  232  267  320  374  423  467  505  538  567  589  600  610  648  661  674  680
  9      0   513  511  508  499  477  439  413  405  428  463  497  527  552  575  596  614  624  633  650  663  675  680
  8      0   542  541  538  532  518  501  495  492  505  528  550  570  586  602  617  631  639  645  656  666  676  680
  7      0   571  570  569  565  559  560  564  568  577  590  603  613  618  628  638  647  652  656  663  670  677  680
  6      0   601  600  599  599  599  614  632  642  646  650  654  657  649  653  658  663  665  667  669  673  678  680
  5      0   630  630  630  632  634  651  680  680  680  680  680  680  680  660  680  680  680  680  675  676  679  680
  4      0   680  680  680  665  665  672  680  680  680  680  680  680  680  680  680  680  680  680  678  678  679  680
  3      0   680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  2      0   680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  680  679  679  680  680
  1      0     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

         1     2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23
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TAC2D EXAMPLE PROBLEM OUTPUT                                                                          DATE 071576         PAGE    26

                                        STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

 THE CURRENT TIME IS   797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS      120 ITERATIONS HAVE BEEN PERFORMED



                                                        RESIDUALS

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

 17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 16   0.0000      8.0425-07   2.7491-06   2.7466-06   2.7261-06   1.8430-06   6.4727-07   0.0000      9.3707-07   2.8179-07
 15   0.0000      9.7656-07   1.7400-04   1.5950-04   1.4453-04   5.3800-06   6.5579-07   0.0000      1.5030-07   1.6650-06
 14   0.0000      1.0590-06   1.9245-04   1.7957-04   1.6708-04   7.6963-06   9.7289-07   0.0000      1.5702-07   5.6291-07
 13   0.0000      9.9052-07   1.9943-04   1.8588-04   1.7778-04   2.5565-05   7.8581-07   0.0000      2.7583-07   5.0400-07
 12   0.0000      4.5491-07   1.2583-06   1.2887-06   1.3647-06   1.3415-06   3.9425-07   0.0000      5.6565-07   3.0710-07
 11   0.0000      2.1686-07   7.0682-07   6.4311-07   5.5275-07   4.3203-07   2.4214-07   0.0000      2.8669-07   5.2607-07
 10   0.0000      3.2984-07   3.8303-06   3.2398-06   2.1740-06   1.2501-06   2.9954-07   0.0000      0.0000      0.0000
  9   0.0000      1.5759-07   1.6040-06   1.2822-06   8.0364-07   3.8535-07   3.0333-07   4.6265-08   5.9841-08   3.4643-08
  8   0.0000      2.3846-07   2.1377-06   1.9174-06   1.4955-06   9.7409-07   4.8932-07   6.7640-07   3.4450-07   2.8191-07
  7   0.0000      1.3132-07   1.2034-06   9.6553-07   7.8113-07   4.6627-07   2.0075-07   1.4733-07   8.4534-08   7.5354-08
  6   0.0000      5.1147-08   6.2836-07   5.6567-07   4.3121-07   1.6869-07   1.3618-07   1.1762-07   3.6665-08   2.7457-08
  5   0.0000      6.7031-08   5.9063-07   4.5816-07   4.1070-07   3.0636-07   0.0000      9.9999+11   9.9999+11   9.9999+11
  4   0.0000      9.9999+11   9.9999+11   9.9999+11   1.9243-07   2.9305-08   3.4979-08   9.9999+11   9.9999+11   9.9999+11
  3   0.0000      9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11
  2   0.0000      9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11
  1   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

        1           2           3           4           5           6           7           8           9          10
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 17  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 16  3.5775-07   6.5892-07   1.2264-06   2.1989-06   3.4509-06   4.2983-06   3.2070-06   2.3558-07   0.0000      0.0000
 15  2.2362-06   3.8858-06   6.1704-06   8.7793-06   1.2196-05   2.4548-05   9.4232-05   2.7808-04   0.0000      0.0000
 14  1.4199-06   2.6523-06   4.3691-06   6.7730-06   9.4469-06   1.3423-05   2.7170-05   7.1203-05   0.0000      4.6215-05
 13  1.0041-06   1.7711-06   2.8061-06   4.4470-06   6.5965-06   8.1579-06   9.8078-07   5.9865-05   0.0000      1.7699-06
 12  8.4330-07   8.0957-07   1.2010-06   1.9324-06   3.0569-06   3.1901-06   5.0238-06   3.0960-05   0.0000      4.8746-06
 11  4.5340-07   5.5149-07   7.1007-07   9.9321-07   1.2632-06   5.4137-07   4.0924-06   1.4477-05   0.0000      4.1039-06
 10  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      3.4974-06
  9  4.1346-08   7.6314-08   1.7433-07   3.2694-07   3.9738-07   1.3730-07   9.6068-07   1.9308-06   2.0318-06   1.8900-06
  8  2.7168-07   2.6840-07   3.1369-07   3.5964-07   3.4533-07   8.6604-08   6.4132-07   1.1871-06   1.4770-06   1.0442-06
  7  6.1980-08   8.4046-08   5.9676-08   5.8750-08   0.0000      3.0518-07   8.5405-07   1.3179-06   1.5121-06   1.6581-06
  6  3.1086-08   0.0000      0.0000      2.1034-08   7.5184-08   2.0649-07   4.5523-07   6.1943-07   7.8041-07   1.4254-06
  5  9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   4.4087-07
  4  9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   1.0077-06
  3  9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   5.2561-07
  2  9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   9.9999+11   0.0000
  1  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
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17   0.0000       0.0000       0.0000
16   0.0000       0.0000       0.0000
15   0.0000       0.0000       0.0000
14   1.9413-05    8.8954-06    0.0000
13   8.9263-06    4.5839-06    0.0000
12   2.0536-06    2.4676-06    0.0000
11   7.6980-07    9.9896-07    0.0000
10   4.7183-07    4.5723-07    0.0000
 9   7.7201-07    8.1911-08    0.0000
 8   1.1040-06    2.8914-07    0.0000
 7   1.5423-06    7.4032-07    0.0000
 6   1.1604-06    6.9522-07    0.0000
 5   5.7860-07    2.7621-07    0.0000
 4   1.0679-06    0.0000       0.0000
 3   0.0000       8.3894-07    0.0000
 2   0.0000       0.0000       0.0000
 1   0.0000       0.0000       0.0000

        21           22           23
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 TAC2D EXAMPLE PROBLEM OUTPUT                                                                       DATE 071576       PAGE [illegible]29
                                         STEADY-STATE TEMPERATURE IN [illegible]ELIUM CIRCULATOR BLOWER DISC
THE CURRENT TIME IS   797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 ITERATIONS HAVE BEEN PERFORMED


      SURFACE  TEMPERATURES  ALONG  RADIAL  GRID  LINES  AT  COOLANT  BOUNDARIES, GAPS  OR  MATERIAL  INTERFACES     (F)
                                          THE RADIAL(I) DIRECTION GRIDLINES ARE HORIZONTAL
                                          THE AXIAL (J) DIRECTION POINTS ARE VERTICAL
 17
 16      296                   295   243     232        222       224   224   633   633    633        0         0
 15      297                   296   249     239        226       228   228   630   630    631        0         0
 14      298                   297   263     253        234       236   236   629   629    629      636       680
 13      299                   298   288     279        244       246   246   624   624    625      634       680
 12      290                   299   323     313        253       256   256   617   617    618      632       680
 11      476                                 358        262                                608      631       680
 10      491                                                                                                   680
  9      513                                                                                                   680
  8      542                                                                                                   680
  7      571                                                                                                   680
  6      601                                                                                                   680
  5      630                               663   680                                                           680
  4      680        680   672              675   680                                          680   678      680
  3      680                                                                                  680   679      680
  2      680                                                                                  680   679      680
  1                                                                                           680   680      680

          1          4          6          7          8          9         17         18         19         22
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TAC2D EXAMPLE PROBLEM OUTPUT                                                         DATE 071576        PAGE    30
                                 STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC
THE CURRENT TIME IS    797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 ITERATIONS HAVE BEEN PERFORMED


     SURFACE  TEMPERATURES  ALONG  AXIAL   GRID  LINES  AT  COOLANT  BOUNDARIES, GAPS  OR  MATERIAL  INTERFACES     (F)
                                     THE RADIAL(I) DIRECTION POINTS ARE HORIZONTAL
                                     THE AXIAL (J) DIRECTION GRIDLINES ARE VERTICAL

  16         296   296   296   296   295   238     0   224   269   343   404   456   502   544   584   618   633     0     0     0     0

  14                                                                                                                   637   646   659

  11         299   299   299   299   299                     319   374   423   466   504   537   567   591
             469   467   464   456   432                     319   374   423   466   504   537   567   591

  10                                                 0   264   319   374   423   466   504   537   567   591   606     0

   9                                               345   353   388   430   470   505   535   562   586   605   616   625

   5                                               680   680   680   680   680   680   663   665   668   671   672   673
                                                   680   680   680   680   680   680   680   680   680   680   680   680

   4         645   644   644
             680   680   680

   3                             680   680   680
                                 680   680   680

   1         680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   680   679   679   680

          1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20    21    22    23
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                                   STEADY-STATE TEMPERATURE IN A[illegible]LIUM CIRCULATOR BLOWER DISC
THE CURRENT TIME IS   797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 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

17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
16  -4.8503-11   6.6502+00   2.6618+01   6.0954+01   1.2106+02   2.1997+02   2.9091+02  -2.4682+02  -6.7528+00  -6.1964+00
15  -4.8618-11   6.7470+00   2.6627+01   5.9538+01   1.1172+02   1.9636+02   2.8372+02  -2.2320+02  -6.7343+00  -6.1215+00
14  -4.8742-11   6.8916+00   2.6948+01   5.7865+01   9.6528+01   1.4064+02   3.1903+02  -2.2029+02  -6.6025+00  -5.9548+00
13  -3.2569-11   4.7857+00   1.8708+01   3.9300+01   5.5924+01   2.6582+01   2.7770+02  -1.5394+02  -4.7717+00  -3.7611+00
12  -3.2632-11   5.0249+00   1.9630+01   4.1639+01   5.5798+01  -6.7056+01   3.7688+02  -1.6009+02  -5.2728+00  -3.4130+00
11  -2.5944-11   8.5717-01   4.5344+00   1.6413+01   6.4006+01   2.8918+02   2.5820+02  -8.2737+01  -9.5290+02  -9.1134+02
10  -2.6761-11   8.9333-01   4.6960+00   1.6803+01   6.3178+01   2.1923+02   5.9273-06  -3.2242-07  -2.9883-07  -2.9699-07
 9  -5.5907-11   1.7973+00   9.2683+00   3.2061+01   1.1273+02   3.5062+02   6.0667+02   1.4614+02  -2.6978+02  -3.9357+02
 8  -5.9112-11   1.5768+00   7.6743+00   2.4138+01   7.3787+01   1.5625+02   1.4789+02   5.7657+01  -1.5874+02  -2.6380+02
 7  -6.2325-11   1.2022+00   5.2178+00   1.3110+01   3.1510+01  -1.1263+01  -8.6946+01  -7.9277+01  -1.0686+02  -1.5398+02
 6  -6.5535-11   7.8197-01   2.6116+00   1.2986+00  -1.2443+00  -1.4820+02  -4.4508+02  -1.5260+02  -5.3422+01  -5.2220+01
 5  -6.8731-11   4.1944-01   6.3178-01  -1.0449+01  -1.2906+01  -1.6163+02  -4.4159+02   0.0000     -3.4488-01   1.6958-01
 4  -7.4147-11   0.0000     -3.8824-02   6.4149+01  -3.2053+00  -6.1344+01  -1.2869+02  -5.4904-01   1.7244-01  -1.6958-01
 3  -9.2721-11   2.2726-02   0.0000     -7.0339-02   0.0000      1.7079-01  -4.2848-01  -3.4315-01   4.3109-01  -2.1198-01
 2  -9.2721-11   2.2726-02   0.0000     -7.0339-02   0.0000      1.7079-01  -4.2848-01  -3.4315-01   4.3109-01  -4.2395-01
 1   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

         1           2           3           4           5           6           7           8           9          10
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TAC2D EXAMPLE PROBLEM OUTPUT                                                                   DATE 071576        PAGE    32




17   0.0000     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
16  -5.7083+00 -5.3532+00  -5.1496+00  -5.1177+00  -5.2855+00  -5.6452+00  -5.9573+00   1.1929+02  -1.7478-09  -3.2837-07
15  -5.6094+00 -5.2554+00  -5.0481+00  -4.9985+00  -5.1459+00  -5.5137+00  -5.7896+00  -9.7624+01  -2.0959-09  -3.2837-07
14  -5.3945+00 -5.0572+00  -4.8508+00  -4.7819+00  -4.9411+00  -5.5166+00  -6.3532+00  -2.3905+02  -4.5338+02  -6.1712+02
13  -3.3924+00 -3.2124+00  -3.0773+00  -2.9967+00  -3.0569+00  -3.5034+00  -4.5435+00  -2.0729+02  -4.9494+02  -5.1260+02
12  -3.1746+00 -3.0702+00  -2.9361+00  -2.8082+00  -2.7735+00  -3.1033+00  -4.8810+00  -3.3496+02  -7.0467+02  -5.6394+02
11  -9.0784+02 -8.8313+02  -8.3251+02  -7.7675+02  -7.3630+02  -7.4043+02  -8.9018+02  -3.0575+02  -4.8640+02  -2.7285+02
10  -3.0681-07 -3.0262-07  -2.8633-07  -2.6784-07  -2.5326-07  -2.3714-07  -2.2951-07  -2.7977-07  -1.5536-06  -2.3615+02
 9  -4.3230+02 -4.3090+02  -4.0432+02  -4.0419+02  -4.0390+02  -4.0950+02  -4.6003+02  -5.1531+02  -6.7855+02  -4.7405+02
 8  -2.9739+02 -2.9115+02  -2.5247+02  -2.8388+02  -3.0116+02  -3.1770+02  -3.5721+02  -3.7944+02  -4.2730+02  -3.7444+02
 7  -1.7280+02 -1.5896+02  -8.2973+01  -1.6757+02  -1.9891+02  -2.1616+02  -2.3657+02  -2.4303+02  -2.5168+02  -2.5571+02
 6  -5.6459+01 -4.1250+01   1.2605+02  -6.5756+01  -1.0063+02  -1.1213+02  -1.1701+02  -1.1223+02  -8.1144+01  -1.3574+02
 5   0.0000     0.0000      2.2951-01  -4.9888-01   2.6941-01   3.2933-01   0.0000     -8.2854-01   1.8172+02  -2.7121+01
 4   1.8958-01  2.0957-01   0.0000     -2.4954-01   0.0000      6.5893-01  -6.0415-01  -8.2887-01   6.7790+01  -4.7930-01
 3  -2.3697-01  2.6196-01   2.8694-01   0.0000     -3.3690-01   4.1183-01  -1.5104+00   1.0361+00   5.1421+01   5.8327+00
 2   0.0000     5.2391-01   0.0000      0.0000     -3.3690-01   4.1183-01  -7.5519-01  -1.0361+00   2.9540+01   5.3997+00
 1   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
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17    0.0000        0.0000        0.0000
16  -5.6125-07    -2.8489-08      0.0000
15  -5.6125-07    -2.8489-08      0.0000
14  -8.9904+02    -1.4699+03      0.0000
13  -5.8367+02    -6.9041+02      0.0000
12  -5.5290+02    -5.8027+02      0.0000
11  -2.5678+02    -2.6762+02      0.0000
10  -2.4090+02    -2.4202+02      0.0000
 9  -4.3485+02    -4.2919+02      0.0000
 8  -3.5340+02    -3.4951+02      0.0000
 7  -2.6229+02    -2.6534+02      0.0000
 6  -1.7319+02    -1.8463+02      0.0000
 5  -9.8707+01    -1.1700+02      0.0000
 4  -5.4114+01    -7.0384+01      0.0000
 3  -3.4448+01    -4.8705+01      0.0000
 2  -2.0618+01    -3.0680+01      0.0000
 1    0.0000        0.0000        0.0000

        21            22            23
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TAC2D EXAMPLE PROBLEM OUTPUT                                                                          DATE 071576        PAGE   34

                                        STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

 THE CURRENT TIME IS    797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 ITERATIONS HAVE BEEN PERFORMED


                    HEAT  FLUX  IN  RADIAL  DIRECTION  BASED  ON  THE  AREA  OF  GRIDLINE (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

 17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 16  -2.9643-04   7.0074+02   1.4024+03   2.1287+03   3.0827+03   4.4812+03   5.4704+03  -4.4694+03  -1.1005+02  -8.9104+01
 15  -2.9713-04   7.1094+02   1.4029+03   2.0773+03   2.8448+03   4.0001+03   5.3353+03  -4.0418+03  -1.0975+02  -8.8028+01
 14  -2.9769-04   7.2617+02   1.4198+03   2.0208+03   2.4581+03   2.8651+03   5.9993+03  -3.9890+03  -1.1086+02  -8.5631+01
 13  -2.9857-04   7.5642+02   1.4785+03   2.0587+03   2.1361+03   8.1230+02   7.8332+03  -4.1814+03  -1.1665+02  -8.1127+01
 12  -2.9915-04   7.9485+02   1.5514+03   2.1813+03   2.1313+03  -2.0491+03   1.0631+04  -4.3484+03  -1.2890+02  -7.3619+01
 11  -4.7606-04   2.7118+02   7.1726+02   1.7210+03   4.8936+03   1.7683+04   1.4566+04  -4.4947+03  -4.6590+04  -3.9315+04
 10  -4.9065-04   2.8239+02   7.4224+02   1.7604+03   4.8265+03   1.3398+04   3.3439-04  -1.7515-05  -1.4610-05  -1.2812-05
  9  -5.1252-04   2.8408+02   7.3246+02   1.6795+03   4.3060+03   1.0720+04   1.7112+04   3.9695+03  -6.5951+03  -8.4895+03
  8  -5.4199-04   2.4923+02   6.0649+02   1.2645+03   2.8184+03   4.7748+03   4.1716+03   1.5661+03  -3.8805+03  -5.6903+03
  7  -5.7135-04   1.9001+02   4.1235+02   6.8677+02   1.2036+03  -3.4416+02  -2.4525+03  -2.1534+03  -2.6122+03  -3.3214+03
  6  -6.0078-04   1.2360+02   2.0639+02   6.8027+01  -4.7528+01  -4.5287+03  -1.2554+04  -4.9600+03  -1.3060+03  -1.1264+03
  5  -6.3008-04   6.6295+01   4.9928+01  -5.4738+02  -4.9298+02  -4.9390+03  -1.2456+04   0.0000     -8.4309+00   3.6579+00
  4  -6.8000-04   0.0000     -3.0694+00   3.3610+03  -1.2743+02  -1.8745+03  -3.6299+03  -1.4913+01   4.2154+00  -3.6579+00
  3  -6.8000-04   2.8737+00   0.0000     -2.9477+00   0.0000      4.1753+00  -9.6690+00  -7.4566+00   8.4309+00  -3.6579+00
  2  -6.8000-04   2.8737+00   0.0000     -2.9477+00   0.0000      4.1753+00  -9.6690+00  -7.4566+00   8.4309+00  -7.3158+00
  1   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

          1           2           3           4           5           6           7           8           9          10
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17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
16  -7.3445+01  -6.2317+01  -5.4734+01  -5.0043+01  -4.7855+01  -4.7587+01  -4.7749+01   9.4068+02  -1.3352-08  -2.4092-06
15  -7.2172+01  -6.1178+01  -5.3455+01  -4.8478+01  -4.6592+01  -4.6479+01  -4.6405+01  -7.0985+02  -1.6011-08  -2.4092-06
14  -6.9408+01  -5.8871+01  -5.1556+01  -4.6760+01  -4.4737+01  -4.6504+01  -5.0922+01  -1.8851+03  -3.4636+03  -4.5276+03
13  -6.5472+01  -5.6093+01  -4.9062+01  -4.3955+01  -4.1516+01  -4.4299+01  -5.4623+01  -2.4520+03  -5.6715+03  -5.6419+03
12  -6.1268+01  -5.3610+01  -4.6811+01  -4.1190+01  -3.7667+01  -3.9240+01  -5.6683+01  -3.9622+03  -6.0749+03  -6.2062+03
11  -3.5042+04  -3.0842+04  -2.6546+04  -2.2786+04  -2.9000+04  -1.8725+04  -2.1405+04  -7.2353+03  -1.1147+04  -6.0056+03
10  -1.1843-05  -1.0568-05  -9.1290-06  -7.8571-06  -6.8791-06  -5.9971-06  -5.5187-06  -6.6186-06  -3.5606-05  -5.2418+03
 9  -8.3431+03  -7.5243+03  -6.4461+03  -5.9286+03  -5.4854+03  -5.1780+03  -5.5308+03  -6.0955+03  -7.7756+03  -5.2170+03
 8  -5.7395+03  -5.0839+03  -4.0251+03  -4.1638+03  -4.0901+03  -4.0172+03  -4.2947+03  -4.4931+03  -4.8964+03  -4.1208+03
 7  -3.3351+03  -2.7757+03  -1.3228+03  -2.4579+03  -2.7014+03  -2.7333+03  -2.8442+03  -2.6747+03  -2.8840+03  -2.8141+03
 6  -1.0896+03  -7.2029+02   2.0192+03  -9.6449+02  -1.3667+03  -1.4178+03  -1.4067+03  -1.3275+03  -9.2984+02  -1.4938+03
 5   0.0000      0.0000      3.6598+00  -7.3203+00   3.6604+00   4.1660+00   0.0000     -9.8045+00   2.0827+03  -2.9848+02
 4   3.6587+00   3.6593+00   0.0000     -3.6602+00   0.0000      8.3319+00  -7.2635+00  -9.8045+00   1.0060+03  -5.2748+00
 3  -3.6587+00   3.6593+00   3.6598+00   0.0000     -3.6604+00   4.1660+00  -1.4527+01   9.8045+00   4.7139+02   5.1351+01
 2   0.0000      7.3187+00   0.0000      0.0000     -3.6604+00   4.1660+00  -7.2635+00  -9.8045+00   2.7061+02   4.7540+01
 1   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
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 17   0.0000       0.0000       0.0000
 16  -3.9563-06   -1.9346-07    0.0000
 15  -3.9563-06   -1.9346-07    0.0000
 14  -6.3374+03   -9.9813+03    0.0000
 13  -6.1730+03   -7.0325+03    0.0000
 12  -5.8461+03   -5.9105+03    0.0000
 11  -5.4302+03   -5.3094+03    0.0000
 10  -5.0943+03   -4.9304+03    0.0000
  9  -4.5980+03   -4.3717+03    0.0000
  8  -3.7367+03   -3.5601+03    0.0000
  7  -2.7734+03   -2.7028+03    0.0000
  6  -1.8312+03   -1.8806+03    0.0000
  5  -1.0437+03   -1.1918+03    0.0000
  4  -5.7218+02   -7.1692+02    0.0000
  3  -2.9139+02   -3.9688+02    0.0000
  2  -1.7441+02   -2.5000+02    0.0000
  1   0.0000       0.0000       0.0000

         21           22           23
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 TAC2D EXAMPLE PROBLEM OUTPUT                                                                     DATE 071576        PAGE [illegible]37.

                                   STEADY-STATE TEMPERATURE I[illegible]LIUM CIRCULATOR BLOWER DISC

  THE CURRENT TIME IS   797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 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

  17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
  16   0.0000      7.5551+01   2.2651+02   3.8491+02   6.0366+02   7.2298+02   8.1065-06   2.0752-08   1.3071-05   2.3447-05
  15   0.0000      8.2397+01   2.4681+02   4.1986+02   6.6447+02   8.2629+02   7.0804+01   4.0662-08   2.3867+02   5.6042-01
  14   0.0000      8.8931+01   2.6622+02   4.5191+02   7.1571+02   9.0555+02   1.5832+02   4.8826-08   4.5655+02   1.1685+00
  13   0.0000      9.5867+01   2.8624+02   4.8277+02   7.5408+02   9.5157+02   3.3668+02   5.3894-08   6.7001+02   2.0167+00
  12   0.0000      1.0151+02   3.0237+02   5.0789+02   7.8035+02   9.3761+02   5.8781+02   6.7892-08   8.1918+02   3.0272+00
  11   0.0000      1.0556+02   3.1462+02   5.2515+02   7.8462+02   7.9835+02   1.0317+03   8.1167-08   9.7392+02   4.8882+00
  10   0.0000      1.0652+02   3.1830+02   5.3704+02   8.3223+02   1.0236+03   1.0007+03   2.1788-09   1.0384+02   4.6385+01
   9   0.0000      1.0741+02   3.2211+02   5.4916+02   8.7863+02   1.1796+03   7.8159+02   1.1868+03   2.8971+03   3.4273+03
   8   0.0000      1.0920+02   3.2957+02   5.7193+02   9.5927+02   1.4177+03   1.0373+03   7.2633+02   2.4811+03   3.3035+03
   7   0.0000      1.1078+02   3.3567+02   5.6841+02   1.0089+03   1.5002+03   1.0291+03   6.3599+02   2.2046+03   3.1965+03
   6   0.0000      1.1199+02   3.3968+02   5.9629+02   1.0273+03   1.4574+03   9.5335+02   6.4367+02   2.2372+03   3.1513+03
   5   0.0000      1.1277+02   3.4151+02   5.9498+02   1.0248+03   1.3105+03   6.5642+02   9.0620+02   2.3063+03   3.1525+03
   4   0.0000      1.1319+02   3.4173+02   5.8390+02   1.0223+03   1.1617+03   3.7650+02   0.0000      8.5368-01  -6.3916-01
   3   0.0000      4.7781-02   0.0000     -2.4364-01   9.5496+02   1.1036+03   3.0914+02   1.1762-01   0.0000     -5.6814-01
   2   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
   1   0.0000     -4.9906-06  -1.4972-05  -2.5471-05  -4.0018-05  -4.8066-05  -2.3180-05  -1.2286-05  -3.9638-05  -5.9341-05

          1           2           3           4           5           6           7           8           9          10
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17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
16   3.3676-05   4.4100-05   5.4746-05   6.5697-05   7.7069-05   8.9112-05   7.5253-05   2.6561-05   3.4755-07   4.7808-07
15   4.8945-01   3.5862-01   2.1218-01   4.3175-02  -1.7361-01  -4.4438-01  -5.1215-01  -1.1335+02  -1.7623-08   0.0000
14   1.0005+00   7.0911-01   4.1069-01   8.1707-02  -3.1217-01  -7.1399-01  -5.6551-01  -5.4730+01   2.7453-09   2.3560+02
13   1.5606+00   1.0464+00   6.1729-01   1.5036-01  -4.7380-01  -1.2977+00  -1.4115+00  -2.1715+02  -1.3425-07   6.7229+01
12   1.9276+00   1.2262+00   7.5244-01   2.3109-01  -5.3432-01  -1.7516+00  -2.4761+00  -4.0235+02  -2.0906-07   5.1575+01
11   2.1657+00   1.3308+00   8.8616-01   3.5892-01  -4.9999-01  -2.0830+00  -4.2490+00  -7.3351+02  -2.8639-07   1.9297+02
10   5.6856+00   2.6037+01   5.1512+01   5.6105+01   3.9828+01  -6.6596+00  -1.5463+02  -1.5084+02  -5.5840-09   4.0650+02
 9   3.2051+03   2.9483+03   2.6319+03   2.2658+03   1.9537+03   1.6835+03   1.1389+03   3.7786+02   7.2140+02   1.6848+02
 8   3.1663+03   2.9496+03   2.6545+03   2.2059+03   1.9539+03   1.6778+03   1.0884+03   3.2264+02   5.5828+02   3.7261+02
 7   3.1328+03   2.9559+03   2.6972+03   2.2345+03   1.9367+03   1.6613+03   1.0489+03   2.9999+02   5.1083+02   4.2544+02
 6   3.1139+03   2.9697+03   2.7732+03   2.1499+03   1.9053+03   1.6440+03   1.0285+03   2.9354+02   5.0215+02   4.2144+02
 5   3.1097+03   2.9849+03   2.9410+03   1.9575+03   1.8704+03   1.6325+03   1.0236+03   2.9831+02   5.3323+02   3.6683+02
 4   7.1906-01   0.0000     -8.7865-01   0.0000     -1.0356+00   0.0000     -8.9133-01   0.0000      0.0000      1.5800+02
 3  -6.3916-01   7.1018-01   7.8120-01   0.0000     -9.2323-01   0.0000      7.9229-01   5.4595-01   0.0000      6.9733+01
 2   5.7524-01   0.0000     -7.0308-01   0.0000      0.0000      0.0000      0.0000     -2.4568-01   5.0313-01   2.3547+01
 1  -6.6759-05  -7.4177-05  -8.1594-05  -8.9012-05  -9.6430-05  -1.0385-04  -8.2753-05  -2.8512-05  -5.8390-05  -7.9872-05

        11          12          13          14          15          16          17          18          19          20
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 17   0.0000       0.0000      0.0000
 16   5.1820-07    5.3178-07   0.0000
 15   0.0000       0.0000      0.0000
 14   5.0447+02    7.7423+02   0.0000
 13   2.2268+02    2.0230+02   0.0000
 12   1.5066+02    9.6135+01   0.0000
 11   1.6178+02    6.8653+01   0.0000
 10   1.7793+02    6.4907+01   0.0000
  9   1.7512+02    6.3775+01   0.0000
  8   2.1445+02    6.9462+01   0.0000
  7   2.3556+02    7.3344+01   0.0000
  6   2.2897+02    7.0310+01   0.0000
  5   1.9150+02    5.8883+01   0.0000
  4   1.1994+02    4.0584+01   0.0000
  3   6.6289+01    2.4309+01   0.0000
  2   2.5771+01    1.0039+01   0.0000
  1  -8.5654-05   -8.6467-05   0.0000

        21           22          23
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   TAC2D EXAMPLE PROBLEM OUTPUT                                                                         DATE 071576          PAGE    40

                                     STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC

 THE CURRENT TIME IS   797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 ITERATIONS HAVE BEEN PERFORMED


                  HEAT  FLUX  IN  AXIAL  DIRECTION  BASED  ON  THE  AREA  OF  GRIDLINE (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

   17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
   16   0.0000      1.0294+04   1.0288+04   1.0276+04   1.0257+04   1.0230+04   2.3781-04   1.1486-06   2.2423-04   2.6868-04
   15   0.0000      1.1227+04   1.1210+04   1.1209+04   1.1291+04   1.1692+04   2.0771+03   2.6934-06   4.0943+03   6.4219+00
   14   0.0000      1.2117+04   1.2092+04   1.2065+04   1.2161+04   1.2813+04   4.6442+03   2.7025-06   7.8322+03   1.3390+01
   13   0.0000      1.3062+04   1.3001+04   1.2849+04   1.2813+04   1.3464+04   9.8768+03   2.9830-06   1.1494+04   2.3110+01
   12   0.0000      1.3831+04   1.3733+04   1.3559+04   1.3255+04   1.3267+04   1.7244+04   3.7578-06   1.4053+04   3.4689+01
   11   0.0000      1.4396+04   1.4290+04   1.4020+04   1.3332+04   1.1296+04   3.0267+04   4.4926-06   1.6708+04   5.6014+01
   10   0.0000      1.4514+04   1.4457+04   1.4338+04   1.4141+04   1.4481+04   2.9357+04   1.2060-07   1.7814+03   5.3154+02
    9   0.0000      1.4635+04   1.4630+04   1.4601+04   1.4930+04   1.6688+04   2.2928+04   6.5667+04   4.9700+04   3.9274+04
    8   0.0000      1.4880+04   1.4969+04   1.5269+04   1.6300+04   2.0056+04   3.0430+04   4.0202+04   4.2564+04   3.7856+04
    7   0.0000      1.5095+04   1.5246+04   1.5709+04   1.7144+04   2.1223+04   3.0188+04   3.5202+04   3.8852+04   3.6652+04
    6   0.0000      1.5259+04   1.5428+04   1.5919+04   1.7457+04   2.0618+04   2.7967+04   3.5627+04   3.8379+04   3.6112+04
    5   0.0000      1.5365+04   1.5511+04   1.5884+04   1.7413+04   1.8539+04   1.9260+04   5.0158+04   4.0595+04   3.6125+04
    4   0.0000      1.5422+04   1.5521+04   1.5590+04   1.7372+04   1.6435+04   1.1049+04   0.0000      1.4648+01  -7.3242+00
    3   0.0000      6.5104+00   0.0000     -6.5104+00   1.6227+04   1.5612+04   9.0705+03   6.5104+00   0.0000     -6.5104+00
    2   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
    1   0.0000     -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04

          1           2           3           4           5           6           7           8           9          10
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17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
16   3.4302-04   4.0428-04   4.5625-04   5.0169-04   5.4361-04   5.8351-04   6.1837-04   6.3349-04   4.0458-06   4.0664-06
15   4.9654+00   3.2876+00   1.7683+00   3.2983-01  -1.2243+00  -2.9099+00  -4.2084+00  -2.7034+03  -2.0515-07   0.0000
14   1.0191+01   6.5006+00   3.4227+00   6.2419-01  -2.2014+00  -4.6753+00  -4.6469+00  -1.3053+03   3.1958-08   2.0039+03
13   1.5896+01   9.5924+00   5.1444+00   1.1487+00  -3.3411+00  -8.4974+00  -1.1598+01  -5.1771+03  -1.5528-06   5.7183+02
12   1.9655+01   1.1241+01   6.2708+00   1.7654+00  -3.7679+00  -1.1470+01  -2.0363+01  -9.5959+03  -2.4337-06   4.3868+02
11   2.2070+01   1.2200+01   7.3852+00   2.7419+00  -3.5258+00  -1.3640+01  -3.4915+01  -1.7494+04  -3.3339-06   1.6414+03
10   5.7912+01   2.3869+02   4.2929+02   4.2861+02   2.8086+02  -4.3607+01  -1.2706+03  -3.5974+03  -6.5004-08   3.4575+03
 9   3.2647+04   2.7028+04   2.1934+04   1.7310+04   1.3777+04   1.1023+04   9.3589+03   9.0120+03   8.3979+03   1.4330+03
 8   3.2252+04   2.7040+04   2.2156+04   1.7310+04   1.3779+04   1.0986+04   8.9436+03   7.6948+03   6.4990+03   3.1693+03
 7   3.1910+04   2.7097+04   2.2478+04   1.7070+04   1.3657+04   1.0878+04   8.6192+03   7.1547+03   5.9466+03   3.6187+03
 6   3.1718+04   2.7224+04   2.3111+04   1.6424+04   1.3436+04   1.0705+04   8.4515+03   7.0009+03   5.8456+03   3.5846+03
 5   3.1675+04   2.7364+04   2.4510+04   1.4954+04   1.3190+04   1.0690+04   8.4114+03   7.1147+03   6.2066+03   3.1202+03
 4   7.3242+00   0.0000     -7.3242+00   0.0000     -7.3242+00   0.0000     -7.3242+00   0.0000      0.0000      1.3439+03
 3  -6.5104+00   6.5104+00   6.5104+00   0.0000     -6.5104+00   0.0000      6.5104+00   1.3021+01   0.0000      5.9313+02
 2   5.8594+00   0.0000     -5.8594+00   0.0000      0.0000      0.0000      0.0000     -5.8594+00   5.8594+00   2.0029+02
 1  -6.6000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.8000-04  -6.7937-04

      11          12          13          14          15          16          17          18          19          20
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 17   0.0000       0.0000       0.0000
 16   4.1095-06    4.1802-06    0.0000
 15   0.0000       0.0000       0.0000
 14   4.0005+03    6.0860+03    0.0000
 13   1.7659+03    1.5903+03    0.0000
 12   1.1947+03    7.5569+02    0.0000
 11   1.2830+03    5.3966+02    0.0000
 10   1.4110+03    5.1022+02    0.0000
  9   1.3887+03    5.0132+02    0.0000
  8   1.7007+03    5.4602+02    0.0000
  7   1.8681+03    5.7654+02    0.0000
  6   1.8157+03    5.5269+02    0.0000
  5   1.5187+03    4.6286+02    0.0000
  4   9.5111+02    3.1902+02    0.0000
  3   5.2569+02    1.9108+02    0.0000
  2   2.0437+02    7.8914+01    0.0000
  1  -6.7925-04   -6.7969-04    0.0000

        21           22           23
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  TAC2D [illegible]PLE PROBLEM OUTPUT                                                                          DATE 071576         PAGE     3
                                       STEADY-STATE TEMPERATURF IN A HELIUM CIRCULATOR BLOWER DISC

 THE CURRENT TIME IS   797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 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

 17   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
 16   8.5626-12    5.0000+02    5.0000+02    5.0000+02    5.0000+02    2.8302+00    1.4798+00    2.0433+00    8.9623-02    5.0000-02
 15   8.5626-12    5.0000+02    5.0000+02    5.0000+02    5.0000+02    2.8309+00    1.4803+00    2.0432+00    8.9623-02    5.0000-02
 14   8.5626-12    5.0000+02    5.0000+02    5.0000+02    5.0000+02    2.8326+00    1.4815+00    2.0430+00    8.9623-02    5.0000-02
 13   8.5626-12    5.0000+02    5.0000+02    5.0000+02    5.0000+02    2.8355+00    1.4834+00    2.0429+00    8.9623-02    5.0000-02
 12   8.5626-12    5.0000+02    5.0000+02    5.0000+02    5.0000+02    2.8394+00    1.4859+00    2.0427+00    8.9623-02    5.0000-02
 11   8.5626-12    1.0331+01    1.0320+01    1.0294+01    1.0227+01    1.0090+01    1.4892+00    2.0425+00    3.0523+01    3.0179+01
 10   8.5626-12    1.0393+01    1.0382+01    1.0356+01    1.0289+01    1.0172+01    3.0590-08    1.0000-08    1.0000-08    1.0000-08
  9   8.5626-12    1.0486+01    1.0476+01    1.0450+01    1.0390+01    1.0293+01    1.0139+01    1.0037+01    1.0084+01    1.0200+01
  8   8.5626-12    1.0612+01    1.0603+01    1.0584+01    1.0543+01    1.0490+01    1.0430+01    1.0402+01    1.0431+01    1.0503+01
  7   8.5626-12    1.0738+01    1.0732+01    1.0721+01    1.0702+01    1.0689+01    1.0698+01    1.0722+01    1.0747+01    1.0790+01
  6   8.5626-12    1.0864+01    1.0861+01    1.0858+01    1.0858+01    1.0876+01    1.0948+01    1.1030+01    1.1050+01    1.1067+01
  5   8.5626-12    1.0990+01    1.0969+01    1.0993+01    1.1004+01    1.1029+01    6.7393+00    1.0000+04    1.0000+04    1.0000+04
  4   8.5626-12    1.0000+04    1.0000+04    1.1449+01    1.1140+01    1.1148+01    6.7612+00    1.0000+04    1.0000+04    1.0000+04
  3   8.5626-12    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04
  2   8.5626-12    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04    1.0000+04
  1   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

          1            2            3            4            5            6            7            8            9           10
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 17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 16   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   6.6354-02   1.1024+01   1.0000-10   1.0000-08
 15   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   6.6354-02   1.1026+01   1.0000-10   1.0000-08
 14   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   6.6355-02   1.1026+01   9.8162+00   1.1058+01
 13   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   6.6355-02   1.1029+01   9.8188+00   1.1070+01
 12   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   6.6355-02   1.1033+01   9.8204+00   1.1076+01
 11   2.9797+01   2.9425+01   2.9075+01   2.8754+01   2.8459+01   2.8213+01   2.8032+01   1.1039+01   9.8248+00   1.1085+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   1.1095+01
  9   1.0347+01   1.0483+01   1.0601+01   1.0705+01   1.0800+01   1.0877+01   1.0932+01   1.0990+01   1.1043+01   1.1103+01
  8   1.0600+01   1.0690+01   1.0766+01   1.0834+01   1.0902+01   1.0960+01   1.1002+01   1.1046+01   1.1081+01   1.1123+01
  7   1.0845+01   1.0895+01   1.0929+01   1.0960+01   1.1001+01   1.1040+01   1.1068+01   1.1097+01   1.1118+01   1.1145+01
  6   1.1065+01   1.1099+01   1.1089+01   1.1080+01   1.1099+01   1.1119+01   1.1133+01   1.1147+01   1.1154+01   1.1166+01
  5   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0378+01   1.1185+01
  4   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0383+01   1.1194+01
  3   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0386+01   1.1199+01
  2   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0387+01   1.1201+01
  1   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
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```
17  0.0000      0.0000      0.0000
16  1.0000-08   1.0000-10   0.0000
15  1.0000-08   1.0000-10   0.0000
14  1.1115+01   1.1061+01   0.0000
13  1.1132+01   1.1077+01   0.0000
12  1.1140+01   1.1083+01   0.0000
11  1.1145+01   1.1086+01   0.0000
10  1.1149+01   1.1088+01   0.0000
 9  1.1155+01   1.1091+01   0.0000
 8  1.1164+01   1.1095+01   0.0000
 7  1.1174+01   1.1100+01   0.0000
 6  1.1164+01   1.1104+01   0.0000
 5  1.1192+01   1.1108+01   0.0000
 4  1.1197+01   1.1110+01   0.0000
 3  1.1200+01   1.1112+01   0.0000
 2  1.1201+01   1.1113+01   0.0000
 1  0.0000      0.0000      0.0000

       21          22          23
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                                  STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC
 THE CURRENT TIME IS    797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 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

 17  0.0000       0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 16  0.0000      1.3246+00   1.3246+00   1.3246+00   1.3246+00   1.3246+00   1.5625-08   1.0000-10   1.5625-08   1.5625-08
 15  0.0000      5.0000+02   5.0000+02   5.0000+02   5.0000+02   5.0000+02   9.3303+00   1.0000-08   3.0939+01   5.0000-02
 14  0.0000      5.0000+02   5.0000+02   5.0000+02   5.0000+02   5.0000+02   9.3781+00   1.0000-08   3.0905+01   5.0000-02
 13  0.0000      5.0000+02   5.0000+02   5.0000+02   5.0000+02   5.0000+02   9.4573+00   1.0000-08   3.0861+01   5.0000-02
 12  0.0000      5.0000+02   5.0000+02   5.0000+02   5.0000+02   5.0000+02   9.6065+00   1.0000-08   3.0799+01   5.0000-02
 11  0.0000      1.2715+00   1.2715+00   1.2714+00   1.2712+00   1.2706+00   9.7551+00   1.0000-08   3.0754+01   7.4938-02
 10  0.0000      1.0364+01   1.0358+01   1.0343+01   1.0306+01   1.0199+01   9.9592+00   1.0000-10   5.5008+00   5.4950+00
  9  0.0000      1.0457+01   1.0451+01   1.0436+01   1.0400+01   1.0302+01   1.0125+01   5.6626+00   5.6553+00   5.6766+00
  8  0.0000      1.0551+01   1.0545+01   1.0532+01   1.0501+01   1.0424+01   1.0306+01   1.0234+01   1.0210+01   1.0290+01
  7  0.0000      1.0676+01   1.0672+01   1.0662+01   1.0641+01   1.0598+01   1.0564+01   1.0558+01   1.0560+01   1.0608+01
  6  0.0000      1.0802+01   1.0799+01   1.0793+01   1.0785+01   1.0773+01   1.0807+01   1.0853+01   1.0881+01   1.0909+01
  5  0.0000      1.0928+01   1.0926+01   1.0923+01   1.0928+01   1.0933+01   1.1001+01   2.1977+01   2.2055+01   2.2092+01
  4  0.0000      6.4357+00   6.4354+00   6.4353+00   1.1068+01   1.1075+01   1.1123+01   1.0000+04   1.0000+04   1.0000+04
  3  0.0000      1.0000+04   1.0000+04   1.0000+04   2.5027+01   2.5033+01   2.5092+01   1.0000+04   1.0000+04   1.0000+04
  2  0.0000      1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04
  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

        1           2           3           4           5           6           7           8           9          10
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```
 17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 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   1.0000-10   1.0000-10
 15   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   2.7647+01   1.0000-08   2.0000-08
 14   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   2.7671+01   1.0000-08   1.3194+01
 13   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   2.7700+01   1.0000-08   1.1036+01
 12   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   5.0000-02   2.7769+01   1.0000-08   1.1041+01
 11   7.4938-02   7.4937-02   7.4936-02   7.4935-02   7.4934-02   7.4934-02   7.4933-02   2.7841+01   1.0000-08   1.1046+01
 10   5.4887+00   5.4822+00   5.4759+00   5.4700+00   5.4645+00   5.4593+00   5.4547+00   5.4516+00   1.0000-10   1.1059+01
  9   5.7073+00   5.7366+00   5.7622+00   5.7836+00   5.8029+00   5.8203+00   5.8345+00   5.8432+00   5.8501+00   1.1072+01
  8   1.0413+01   1.0534+01   1.0640+01   1.0728+01   1.0812+01   1.0891+01   1.0957+01   1.0997+01   1.1029+01   1.1088+01
  7   1.0684+01   1.0760+01   1.0825+01   1.0879+01   1.0924+01   1.0980+01   1.1028+01   1.1057+01   1.1079+01   1.1115+01
  6   1.0946+01   1.0982+01   1.1011+01   1.1006+01   1.1034+01   1.1067+01   1.1096+01   1.1114+01   1.1126+01   1.1144+01
  5   2.2128+01   2.2163+01   2.2186+01   1.0179+01   1.0185+01   1.0195+01   1.0203+01   1.0208+01   1.0211+01   1.1171+01
  4   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.1188+01
  3   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.1197+01
  2   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.0000+04   1.1200+01
  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

        11          12          13          14          15          16          17          18          19          20
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17   0.0000        0.0000        0.0000
16   1.0000-10     1.0000-10     0.0000
15   2.0000-08     2.0000-08     0.0000
14   1.3229+01     1.3277+01     0.0000
13   1.1089+01     1.1156+01     0.0000
12   1.1105+01     1.1169+01     0.0000
11   1.1112+01     1.1173+01     0.0000
10   1.1120+01     1.1176+01     0.0000
 9   1.1128+01     1.1179+01     0.0000
 8   1.1138+01     1.1182+01     0.0000
 7   1.1152+01     1.1187+01     0.0000
 6   1.1167+01     1.1191+01     0.0000
 5   1.1180+01     1.1195+01     0.0000
 4   1.1190+01     1.1199+01     0.0000
 3   1.1196+01     1.1201+01     0.0000
 2   1.1199+01     1.1202+01     0.0000
 1   1.3021-08     1.3021-08     0.0000

        21            22            23
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  TAC2D EXAMPLE PROBLEM OUTPUT                                                               DATE 071576        PAGE [illegible]49

                                           STEADY-STATE TEMPERATURE IN [redacted]RCULATOR BLOWER DISC

THE CURRENT TIME IS   797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 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

 17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
 16   1.6362-13   8.9364+01   1.9090+02   2.7658+02   3.7288+02   3.8014+00   4.9867+00   5.5140+00   1.5192-01   8.3352-02
 15   1.6362-13   8.9364+01   1.9090+02   2.7658+02   3.7288+02   3.8025+00   4.9883+00   5.5138+00   1.5192-01   8.3352-02
 14   1.6362-13   8.9364+01   1.9090+02   2.7659+02   3.7288+02   3.8047+00   4.9921+00   5.5134+00   1.5192-01   8.3352-02
 13   1.0908-13   5.9576+01   1.2727+02   1.8439+02   2.4858+02   2.5391+00   3.3324+00   3.6753+00   1.0128-01   5.5568-02
 12   1.0908-13   5.9576+01   1.2727+02   1.8439+02   2.4858+02   2.5426+00   3.3381+00   3.6750+00   1.0128-01   5.5568-02
 11   5.4498-14   6.1496-01   1.3124+00   1.8966+00   2.5402+00   4.5149+00   1.6727+00   1.8373+00   1.7247+01   1.6770+01
 10   5.4542-14   6.1916-01   1.3213+00   1.9095+00   2.5576+00   4.5545+00   3.4360-03   8.9954-09   5.6504-09   5.5568-09
  9   1.0908-13   1.2495+00   2.6665+00   3.6539+00   5.1656+00   9.2168+00   2.2777+01   1.8057+01   1.1396+01   1.1336+01
  8   1.0908-13   1.2644+00   2.6989+00   3.9031+00   5.2417+00   9.3933+00   2.3431+01   1.8714+01   1.1768+01   1.1673+01
  7   1.0908-13   1.2795+00   2.7317+00   3.9536+00   5.3207+00   9.5719+00   2.4033+01   1.9289+01   1.2145+01   1.1992+01
  6   1.0908-13   1.2945+00   2.7645+00   4.0042+00   5.3982+00   9.7393+00   2.4595+01   1.9843+01   1.2467+01   1.2299+01
  5   1.0908-13   1.3095+00   2.7970+00   4.0541+00   5.4707+00   9.8756+00   1.5140+01   1.7991+04   1.1301+04   1.1114+04
  4   1.0904-13   1.1910+03   2.5443+03   4.2214+00   5.5384+00   9.9830+00   1.5169+01   1.7991+04   1.1301+04   1.1114+04
  3   1.3635-13   1.4894+03   3.1817+03   4.6097+03   6.2146+03   1.1193+04   2.8081+04   2.2489+04   1.4126+04   1.3892+04
  2   1.3635-13   1.4894+03   3.1817+03   4.6097+03   6.2146+03   1.1193+04   2.8081+04   2.2489+04   1.4126+04   1.3892+04
  1   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

        1           2           3           4           5           6           7           8           9          10
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```
17  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
16  9.3180-02   1.0301-01   1.1283-01   1.2265-01   1.3248-01   1.6194-01   3.9408-01   8.9824+01   5.4295-10   4.8832-08
15  9.3180-02   1.0301-01   1.1283-01   1.2265-01   1.3248-01   1.6194-01   3.9408-01   8.9838+01   5.4295-10   4.8832-08
14  9.3180-02   1.0301-01   1.1283-01   1.2265-01   1.3248-01   1.6194-01   3.9408-01   8.9815+01   5.3247+01   5.3997+01
13  6.2120-02   6.8671-02   7.5220-02   8.1769-02   8.8317-02   1.0796-01   2.6272-01   5.9912+01   3.5541+01   3.6036+01
12  6.2120-02   6.8671-02   7.5220-02   8.1769-02   8.8317-02   1.0796-01   2.6272-01   5.9933+01   3.5546+01   3.6058+01
11  1.8510+01   2.0207+01   2.1871+01   2.3512+01   2.5134+01   3.0459+01   5.5495+01   2.9981+01   1.7781+01   1.8043+01
10  6.2120-09   6.8671-09   7.5220-09   8.1769-09   8.8317-09   1.0796-08   1.9797-08   2.7160-08   4.1560-08   1.8059+01
 9  1.2355+01   1.4397+01   1.5949+01   1.7507+01   1.9076+01   2.3486+01   4.3282+01   5.9700+01   3.9973+01   3.6146+01
 8  1.3169+01   1.4682+01   1.6197+01   1.7717+01   1.9256+01   2.3664+01   4.3559+01   6.0002+01   4.0108+01   3.6209+01
 7  1.3474+01   1.4964+01   1.6442+01   1.7923+01   1.9432+01   2.3838+01   4.3823+01   6.0280+01   4.0243+01   3.6251+01
 6  1.3772+01   1.5244+01   1.6683+01   1.8121+01   1.9605+01   2.4007+01   4.4080+01   6.0551+01   4.0375+01   3.6351+01
 5  1.2424+04   1.3734+04   1.5041+04   1.6347+04   1.7656+04   2.1583+04   3.9578+04   5.4299+04   3.7559+01   3.6411+01
 4  1.2424+04   1.3734+04   1.5044+04   1.6354+04   1.7663+04   2.1592+04   3.9594+04   5.4321+04   3.7584+01   3.6440+01
 3  1.5530+04   1.7168+04   1.8805+04   2.0442+04   2.2079+04   2.6990+04   4.9492+04   6.7901+04   4.6992+01   4.5571+01
 2  1.5530+04   1.7168+04   1.8805+04   2.0442+04   2.2079+04   2.6990+04   4.9492+04   6.7901+04   4.6996+01   4.5579+01
 1  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
```

```
TAC2D EXAMPLE PROBLEM OUTPUT                                              DATE 071576       PAGE

 17     0.0000        0.0000        0.0000
 16     5.0796-08     1.0612-09     0.0000
 15     5.0796-08     1.0612-09     0.0000
 14     5.6460+01     1.1738+02     0.0000
 13     3.7697+01     7.8352+01     0.0000
 12     3.7724+01     7.8403+01     0.0000
 11     1.8871+01     3.9213+01     0.0000
 10     1.8878+01     3.9220+01     0.0000
  9     3.7775+01     7.8461+01     0.0000
  8     3.7806+01     7.8491+01     0.0000
  7     3.7839+01     7.8523+01     0.0000
  6     3.7872+01     7.8554+01     0.0000
  5     3.7899+01     7.8579+01     0.0000
  4     3.7916+01     7.8597+01     0.0000
  3     4.7409+01     9.8261+01     0.0000
  2     4.7415+01     9.8268+01     0.0000
  1     0.0000        0.0000        0.0000

           21            22            23
```

```
TAC2D EXAMPLE PROBLEM OUTPUT                                                                                DATE 071576        PAGE    52
                                              STEADY-STATE TEMPERATURE IN A HELIUM CIRCULATOR BLOWER DISC
THE CURRENT TIME IS    797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS       120 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

17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
16   0.0000      6.2217-01   1.8665+00   3.1754+00   4.9890+00   5.9913+00   3.4089-08   1.1563-10   5.8291-08   8.7267-08
15   0.0000      1.1743+02   3.5228+02   5.9931+02   9.4161+02   1.1308+03   1.0178+01   5.7814-09   5.7712+01   1.3963-01
14   0.0000      1.1743+02   3.5228+02   5.9931+02   9.4161+02   1.1308+03   1.0230+01   5.7814-09   5.7649+01   1.3963-01
13   0.0000      1.4091+02   4.2273+02   7.1918+02   1.1299+03   1.3569+03   1.2380+01   6.9377-09   6.9078+01   1.6755-01
12   0.0000      1.7614+02   5.2842+02   8.9897+02   1.4124+03   1.6961+03   1.5719+01   8.6721-09   8.6176+01   2.0944-01
11   0.0000      5.9722-01   1.7916+00   3.0478+00   4.7879+00   5.7475+00   2.1282+01   1.1563-08   1.1473+02   4.1854-01
10   0.0000      7.3019+00   2.1893+01   3.7191+01   5.8223+01   6.9269+01   3.2591+01   1.7344-10   3.0782+01   4.6035+01
 9   0.0000      4.9118+00   1.4727+01   2.5018+01   3.9170+01   4.6607+01   2.2090+01   6.5476+00   2.1098+01   3.1704+01
 8   0.0000      3.7168+00   1.1144+01   1.8935+01   2.9662+01   3.5367+01   1.6863+01   8.8753+00   2.8567+01   4.3103+01
 7   0.0000      3.7611+00   1.1278+01   1.9169+01   3.0060+01   3.5959+01   1.7286+01   9.1562+00   2.9546+01   4.4434+01
 6   0.0000      3.8654+00   1.1413+01   1.9405+01   3.0465+01   3.6550+01   1.7683+01   9.4115+00   3.0444+01   4.5695+01
 5   0.0000      3.8495+00   1.1546+01   1.9639+01   3.0869+01   3.7096+01   1.7996+01   1.9059+01   6.1711+01   9.2538+01
 4   0.0000      2.2671+00   6.8012+00   1.1569+01   3.1266+01   3.7576+01   1.8193+01   8.6721+03   2.7980+04   4.1888+04
 3   0.0000      3.1314+03   9.3941+03   1.5960+04   6.2842+01   7.5497+01   3.6488+01   7.7086+03   2.4871+04   3.7234+04
 2   0.0000      2.8182+03   8.4547+03   1.4384+04   2.2599+04   2.7143+04   1.3090+04   6.9377+03   2.2384+04   3.3510+04
 1   0.0000      7.3391-09   2.2017-08   3.7457-08   5.8850-08   7.0686-08   3.4089-08   1.8067-08   5.8291-08   8.7267-08

        1           2           3           4           5           6           7           8           9          10
```

```
17   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
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   5.4978-10   7.5243-10
15   1.5708-01   1.7453-01   1.9199-01   2.0944-01   2.2689-01   2.4435-01   1.9471-01   3.7094+01   2.7489-08   7.5243-08
14   1.5708-01   1.7453-01   1.9199-01   2.0944-01   2.2689-01   2.4435-01   1.9471-01   3.7127+01   2.7489-08   4.9637+01
13   1.8850-01   2.0944-01   2.3038-01   2.5133-01   2.7227-01   2.9322-01   2.3366-01   4.4599+01   3.2987-08   4.9822+01
12   2.3562-01   2.6180-01   2.8798-01   3.1416-01   3.4034-01   3.6652-01   2.9207-01   5.5867+01   4.1234-08   6.2306+01
11   4.7065-01   5.2316-01   5.7547-01   6.2778-01   6.8069-01   7.3239-01   5.8362-01   7.4709+01   5.4978-08   8.3113+01
10   5.1730+01   5.7410+01   6.3079+01   6.8738+01   7.4391+01   8.0037+01   6.3726+01   2.1944+01   8.2467-10   1.2482+02
 9   3.5860+01   4.0049+01   4.4251+01   4.6453+01   5.2665+01   5.6887+01   4.5443+01   1.5680+01   3.2163+01   8.3311+01
 8   4.9071+01   5.5155+01   6.1285+01   6.7407+01   7.3594+01   7.9432+01   6.4002+01   2.2132+01   4.5475+01   6.2571+01
 7   5.0347+01   5.6340+01   6.2350+01   6.8297+01   7.4359+01   8.0484+01   6.4417+01   2.2253+01   4.5682+01   6.2725+01
 6   5.1561+01   5.7504+01   6.3420+01   6.9154+01   7.5106+01   8.1125+01   6.4818+01   2.2367+01   4.5877+01   6.2887+01
 5   1.0428+02   1.1605+02   1.2778+02   6.3955+01   6.9329+01   7.4730+01   5.9599+01   2.0544+01   4.2095+01   6.3038+01
 4   4.7124+04   5.2360+04   5.7596+04   6.2832+04   6.8068+04   7.3304+04   5.8414+04   2.0126+04   4.1217+04   6.3138+01
 3   4.1888+04   4.6542+04   5.1196+04   5.5851+04   6.0505+04   6.5159+04   5.1924+04   1.7890+04   3.6637+04   5.6165+01
 2   3.7699+04   4.1888+04   4.6077+04   5.0266+04   5.4454+04   5.8643+04   4.0731+04   1.6101+04   3.2973+04   5.0563+01
 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   8.5868-08   1.1757-07

       11          12          13          14          15          16          17          18          19          20
```

```
 17   0.0000        0.0000        0.0000
 16   8.0704-10     8.1418-10     0.0000
 15   8.0704-08     8.1418-08     0.0000
 14   5.3360+01     5.4049+01     0.0000
 13   5.3697+01     5.4500+01     0.0000
 12   6.7214+01     6.8202+01     0.0000
 11   8.9678+01     9.0969+01     0.0000
 10   1.3461+02     1.3649+02     0.0000
  9   8.9810+01     9.1019+01     0.0000
  8   6.7015+01     6.8283+01     0.0000
  7   6.7502+01     6.8311+01     0.0000
  6   6.7591+01     6.8338+01     0.0000
  5   6.7671+01     6.8363+01     0.0000
  4   6.7730+01     6.8382+01     0.0000
  3   6.0239+01     6.0796+01     0.0000
  2   5.4230+01     5.4722+01     0.0000
  1   1.2610-07     1.2722-07     0.0000

         21            22            23
```

```
   TAC2D EXAMPLE PROBLEM OUTPUT                                                                        DATE 071576        PAGE [illegible]
                                             STEADY-STATE TEMPERATURE IN A [illegible]LIUM CIRCULATOR BLOWER DISC
  THE CURRENT TIME IS   797.0180 HOURS  =  47821.0791 MINUTES  =  2869264.75000 SECONDS     120 ITERATIONS HAVE BEEN PERFORMED


                                                              HEAT BALANCE


            HEAT GENERATED                           HEAT LOST/GAINED BY COOLANTS                 HEAT GAINED/LOST BY DUMMY BLOCKS

  MAT NUM      BLK NUM      BTU/HR                       COOL NUM       BTU/HR                    MAT NUM       BLK NUM        BTU/HR


                                                                                                    2             1           3.3669058-01
                                                                                                    2             2          -1.1031549+03
                                                                                                    2             3          -2.3669676+03
                                                                                                    2             4          -1.6032365+04
                                                                                                    2             5          -7.6655798+03
                                                           6          2.8935150+03
                                                           7          2.4420302+04
                                                           8          1.0740022+03
                                                           9          1.5142967+03
                                                           3          1.2014303-03
                                                           4          8.3496900-10
                                                           1         -4.7386322+03
                                                           2          2.0136144+03
                                                           5          5.1275508-04

                         ----------------                  ----------------                                                ----------------

                           0.0000000                          2.7177100+04                                                   -2.7167731+04



     RESIDU = (HEAT GENERATED)-(HEAT LOST/GAINED BY COOLANTS+HEAT GAINED/LOST BY DUMMY MATERIALS)= -9.3688965+00




 **EXIT LOC**002113

 @FIN                                                                       CR


 12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789**SEQ NO. 00
```

APPENDIX I

Long Input

Earlier versions of TAC2D required a different input format than that which is used with the current version, described in Section 4.1. The old format was longer and resulted in the frequent necessity of substituting blank cards in place of data which were not needed for a TAC2D problem. The current input format was developed to eliminate this necessity and to combine the required data onto a fewer number of cards. However, the old format was retained to make the current TAC2D code compatible with earlier TAC2D models. Only the differences between the long input format and the current (short) format are noted here.

1. The LONG INPUT option card must be used (see 4.1.3).

2. Block Information (4.1.6). Each material or coolant block must be described by three cards. The first card contains the material number or negative coolant number in columns 1-12. If it is a coolant give the flow direction number in columns 13-24 and the problem depth (default value applies) in columns 25-36. Use E12.4 format. The second card contains the low and high X (radial) boundaries and the low and high Y (theta, axial) boundaries in that order, beginning in column 1, with E12.4 format. The third card gives the gap information in the same format as that for the short input. This card must be blank if there is no gap information and blank for a coolant.

3. Sections 4.1.7-4.1.11 must be input in the following order. The order may not be arbitrary.

4. Specified Initial Temperatures (4.1.7). This section of input <u>must</u> be included (even if a punched deck is used); however, omit the header card. Two cards are required for specifying the initial temperature of a region. The first card gives the low and high X and Y boundaries of the region (same format as second card of block information). The second card gives the temperature (°F) in columns 1-12, format E12.4.

5. Coolant Limits (4.1.8). This section of input is also optional under the long input format. However, omit the header card and retain the final blank card (even if the coolant limits are omitted).

6. Time History (4.1.9). Also optional under the long input format. However, omit the header card and retain the final blank card (even if the time history is omitted).

7. Function Control Constants (4.1.10). This section of input <u>must</u> be included. If no function control constants are needed give three blank cards. Omit the header card but retain the final blank card at the end of the data (in addition to the three blank cards given if the data are not needed).

8. Previously Punched Temperatures (4.1.11). Also optional under the long input format. However, omit the header card and retain the final blank card (even if the punched temperatures are omitted).

9. End Data Card (4.1.12). Omit.

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