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BODYFIT-1FE: A Computer Code for Three-dimensional Steady-state/Transient Single-phase Rod-bundle Thermal-Hydraulic Analysis

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ABSTRACT

Computer code BODYFIT-1FE (Boundary-Fitted coordinate, one Phase, Fully Elliptic) has been developed for three-dimensional steady-state/transient thermal-hydraulic analyses of reactor rod bundles. The governing equations, i.e., conservation equations for mass, momentum, and energy, are solved as a boundary-value problem in space and an initial-value problem in time. BODYFIT-1FE code uses the technique of boundary-fitted coordinate systems where all the physical boundaries are transformed to be coincident with constant coordinate lines in the transformed space. By using this technique, one can prescribe boundary conditions accurately without interpolation. The transformed governing equations in terms of the boundary-fitted coordinates are then solved by using implicit cell-by-cell procedure with a choice of either central or upwind convective derivatives.

It is a true benchmark rod-bundle code without invoking any assumptions in the case of laminar flow. However, for turbulent flow, some empiricism must be employed due to the closure problem of turbulence modeling. The detailed velocity and temperature distributions calculated from the code can be used to benchmark and calibrate empirical coefficients employed in subchannel codes and porous-medium analyses.

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EXECUTIVE SUMMARY

Computer code BODYFIT-1FE (Boundary-Fitted Coordinate - One Phase, Fully Elliptic Version) has been developed. The governing equations, i.e., conservation equations for mass, momentum, and energy, are solved as a boundary-value problem in space and an initial-value problem in time. BODYFIT-1FE is a three-dimensional steady-state/transient single-phase computer program for thermal-hydraulic analyses of rod bundles using the technique of boundary-fitted coordinates. With this technique, all the physical boundaries are transformed to be coincident with constant coordinate lines in the transformed space. Therefore, boundary conditions can be represented accurately without interpolation. The transformed governing equations in terms of the boundary-fitted coordinates are then solved by using implicit cell-by-cell procedure with a choice of central or upwind convective terms. The governing equations before and after the coordinate transformation and their finite-difference forms are derived with an appropriate set of initial and boundary conditions.

A modified staggered mesh arrangement is employed. In this arrangement, densities, pressures, and temperatures (enthalpies) are stored at centers of cells formed by grid lines, whereas velocities are stored at intersections of grid lines. This arrangement avoids specifications of pressures at physical boundaries and nonuniform treatment of pressure gradients. A one-dimensional heat-conduction model is used for fuel-pin temperature calculations. Pressure drops and flow redistributions caused by grid spacers are accounted for by a grid-resistance model. Transformed one- and two-equation turbulence models are used to calculate the turbulence effect. Two techniques are used to perform pressure calculations. The first technique is to calculate cell-by-cell pressure corrections based on the cell mass residues. The second technique is to calculate the axial planar pressure corrections based on the planar mass flux residues. The detailed calculation procedure, along with the flow chart, is described. Input descriptions and two sample problems are presented.

BODYFIT-1FE code is used to analyze hexagonal rod bundles of the Liquid Metal Fast Breeder Reactor (LMFBR). However, it can be extended to analyze square or rectangular rod bundles of the Light Water Reactor (LWR) as well. Detailed velocity and temperature distributions are computed within a rod-bundle without involving any assumption for the laminar flow. In the case of turbulent flow, a turbulence model is required where some empiricism is not avoidable due to the closure problem. These detailed velocity and temperature distributions can be used to benchmark and calibrate empirical coefficients employed in subchannel codes and porous medium analyses.

I. INTRODUCTION

Because of geometric complexity, most rod-bundle thermal-hydraulic analyses[1-5] do not account for the detailed velocity and temperature distributions in the vicinities of fuel rods. However, in the numerical solution of the Navier-Stokes and the energy equations, the regions in the immediate vicinities of solid surfaces are generally dominant in determining the character of the flow. In order to account for the detailed velocity and temperature distributions in the vicinities of fuel rods, the boundary conditions must be represented accurately in the finite-difference formulations. Also, the pressure and heat transfer near or on solid surfaces are directly dependent on the large velocity gradients that prevail in the regions near the surfaces. Accurate determinations of pressure and heat-transfer coefficients require that these large gradients be represented correctly.

Accurate representations of boundary conditions are best accomplished when the boundaries are coincident with coordinate lines. The boundaries can then be made to pass through the points of a finite-difference grid constructed on the coordinate lines. Finite-difference expressions at or adjacent to the boundaries may then be applied using only grid points on the intersections of coordinate lines, without the need for any interpolation between points of the grid.

The avoidance of interpolation is particularly important for boundaries with strong curvature or slope discontinuities, both of which are common in physical applications. The generation of a curvilinear coordinate system with coordinate lines coincident with all boundaries (called a "boundary-fitted coordinate system" here for purposes of identification) is thus an essential part of a general numerical solution of the Navier-Stokes and the energy equations.

The technique of boundary-fitted coordinate systems[6-8] is based on an automated numerical generation of a general curvilinear coordinate system having a coordinate line coincident with each boundary of a general multiconnected region containing any number of bodies with arbitrary shapes. This procedure does not use conformal transformation and consequently is not limited to two dimensions. It can also be generalized to cases with time-dependent boundaries. The detailed equations and procedures are given in Section II.

Once the curvilinear coordinates are generated, the Navier-Stokes and the energy equations are solved in the transformed plane using the finite-difference technique. This procedure provides detailed velocity and temperature distributions without invoking any assumptions for the laminar-flow case. However, for turbulent flow, some empirical methods must be employed due to the closure problem of turbulence modeling.

Computer code BODYFIT-1FE (Boundary-Fitted coordinate-1 phase Fully Elliptic Version) has been developed based on this procedure. Section III shows the governing equations both before and after the coordinate transformation. Section IV gives the finite-difference equations used in the code. Section V gives the boundary conditions and the method used for computing the boundary temperatures. Section VI gives the initial conditions for solving the difference equations of Section IV. The pressure calculation is described in Section VII. The solution procedure is given in Section VIII. Section IX gives the physical models used in BODYFIT-1FE, which includes a fuel-pin model, a duct-wall model, a grid-resistance model, and one- and two-equation turbulence models. Conclusions are given in Section X. The code description, input description, and sample problems are given in the appendixes.

II. THE COORDINATE SYSTEM

A. Boundary-fitted Coordinate System

The basic idea of the boundary-fitted coordinate systems is to numerically generate a curvilinear coordinate system having coordinate lines coincident with each boundary of the physical region of interest, regardless of the shape of these boundaries. This is done by taking the curvilinear coordinates to be solutions of elliptic partial differential equations. Constant values of one of the curvilinear coordinates are specified as Dirichlet boundary conditions on each boundary. Values of the other coordinates are either specified by a monotonic variation over a boundary as Dirichlet boundary conditions, or determined by Neumann boundary conditions. In the latter case, the curvilinear coordinate lines can be made to intersect the boundary according to some specified conditions such as being normal or parallel to some given directions. It is also possible to exercise control over the spacings of the curvilinear coordinate lines in the field in order to concentrate lines in regions of expected high gradients. In any case, the numerical generation of the coordinate system is done automatically for any shape boundaries, requiring only the input of points on the boundary.

As mentioned above, the curvilinear coordinates (ξ,η) are generated by solving an elliptic system of suitable form. One such system is, in two dimensions,

$$\xi_{xx} + \xi_{yy} = P(\xi,\eta) \tag{1a}$$

$$\eta_{xx} + \eta_{yy} = Q(\xi,\eta), \tag{1b}$$

where the subscripts xx and yy are second-order partial derivatives with respect to x and y accordingly. P and Q are functions for controlling the spacings between coordinate lines. The above partial differential equations are subject to a set of Dirichlet boundary conditions, such as

$$\begin{bmatrix} \xi \\ \eta \end{bmatrix} = \begin{bmatrix} \xi_1(x,y) \\ \eta_1 \end{bmatrix}, \quad (x,y)\varepsilon\Gamma,$$

where η_1 is a specified constant, and $\xi_1(x,y)$ is a specified monotonic function on a boundary segment Γ.

Since it is desired to perform all numerical computation in the transformed plane with uniform meshes, the dependent and independent variables must be

interchanged in Eq. (1). This results in the coupled system

$$\alpha x_{\xi\xi} - 2\beta x_{\xi\eta} + \gamma x_{\eta\eta} = -J^2[x_\xi P(\xi,\eta) + x_\eta Q(\xi,\eta)] \tag{2a}$$

$$\alpha y_{\xi\xi} - 2\beta y_{\xi\eta} + \gamma y_{\eta\eta} = -J^2[y_\xi P(\xi,\eta) + y_\eta Q(\xi,\eta)], \tag{2b}$$

where

$$\alpha = x_\eta^2 + y_\eta^2, \qquad \gamma = x_\xi^2 + y_\xi^2,$$

$$\beta = x_\xi x_\eta + y_\xi y_\eta, \qquad J = x_\xi y_\eta - x_\eta y_\xi,$$

with the transformed boundary conditions, such as

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} f_1(\xi,\eta_1) \\ f_2(\xi,\eta_1) \end{bmatrix}, \quad (\xi,\eta_1)\varepsilon\Gamma^*$$

where $f_1(\xi,\eta_1)$ and $f_2(\xi,\eta)$ are determined by the known shape of the boundary segment Γ and the specified distribution of ξ thereon. Γ^* is the boundary segment Γ in the transformed plane. The subscripts ξ and η in Eq. (2) are partial derivatives with respect to ξ and η accordingly.

The system described by Eq. (2) is a quasi-linear elliptic system for the coordinate functions $x(\xi,\eta)$ and $y(\xi,\eta)$ in the transformed plane. This set is considerably more complex than the linear system specified by Eq. (1), but the boundary conditions are specified on straight boundaries, and the coordinate spacings in the transformed plane are uniform.

The coordinate lines may be spaced as desired around the boundaries, since the assignment of the coordinate values to the (x,y) boundary points is arbitrary. Control of the spacings of the coordinate lines in the field can be accomplished by varying the functions $P(\xi,\eta)$ and $Q(\xi,\eta)$ in Eq. (2).

The effect of changing the functions $P(\xi,\eta)$ and $Q(\xi,\eta)$ on the coordinate system is discussed in Refs. 6 and 7. One particularly effective procedure is to choose P and Q as sums of exponential terms, so that the coordinates are generated as the solutions of

$$\xi_{xx} + \xi_{yy} = -\sum_{i=1}^{n} a_i \operatorname{sgn}(\xi - \xi_i)\exp(-c_i|\xi - \xi_i|)$$

$$-\sum_{j=1}^{m} b_j \operatorname{sgn}(\xi - \xi_j)\exp\left[-d_j\sqrt{(\xi - \xi_j)^2 + (\eta - \eta_j)^2}\right] \equiv P(\xi,\eta) \tag{3a}$$

$$\eta_{xx} + \eta_{yy} = - \sum_{i=1}^{n} a_i \, \mathrm{sgn}(\eta - \eta_i) \exp(- c_i |\eta - \eta_i|)$$

$$- \sum_{j=1}^{m} b_j \, \mathrm{sgn}(\eta - \eta_j) \exp\left[-d_j \sqrt{(\xi - \xi_j)^2 + (\eta - \eta_j)^2}\right] \equiv Q(\xi, \eta), \qquad (3b)$$

where the positive amplitudes and decay factors are not necessarily the same in the two equations. Here the first terms have the effect of attracting the ξ = constant lines to the $\xi = \xi_i$ lines in Eq. (3a), and attracting the η = constant lines to the $\eta = \eta_i$ lines in Eq. (3b). The second terms cause the ξ = constant lines to be attracted to the points (ξ_j, η_j) in Eq. (3a), with similar effect on the η = constant lines in Eq. (3b). Several examples of the use of coordinate system control are given in Refs. 6 and 7.

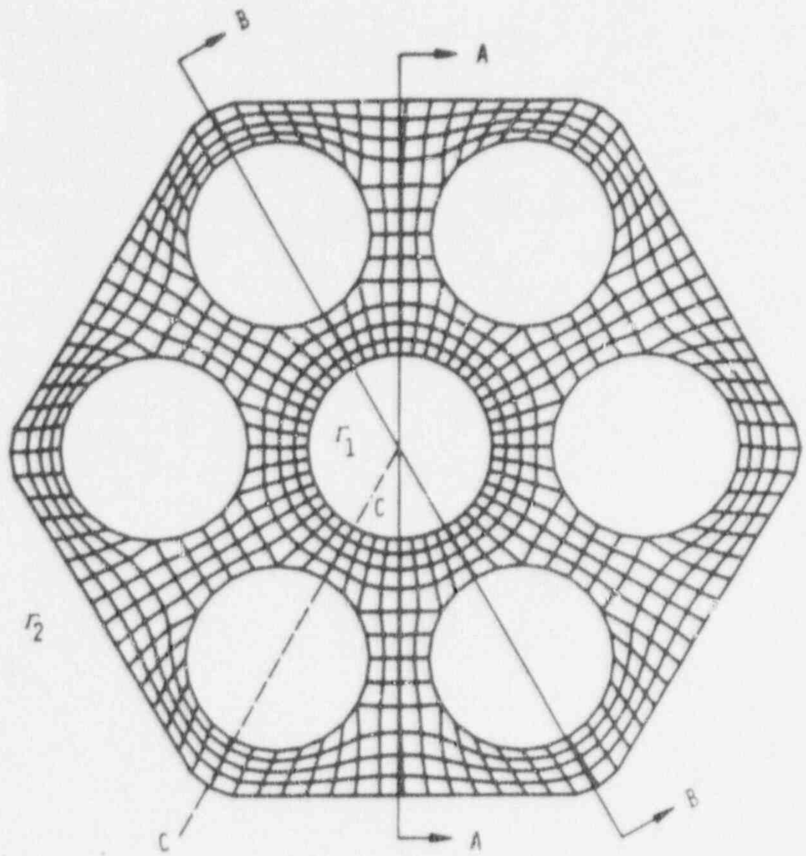
Equations (2a) and (2b) can be expressed in a finite-difference form and solved by using SOR (Successive Over-Relaxation) techniques. The solution of the equation is the specification of (x,y) coordinates at discrete (ξ,η) points in the transformed plane. These coordinates are inputs to the main part of the BODYFIT code for solving the transformed governing equations.

B. System Configuration

The present work uses a three-dimensional coordinate system for which the curvilinear coordinates in the plane normal to the assembly axis are generated from Eq. (2), and the third coordinate is simply a linear transformation of the axial distance.

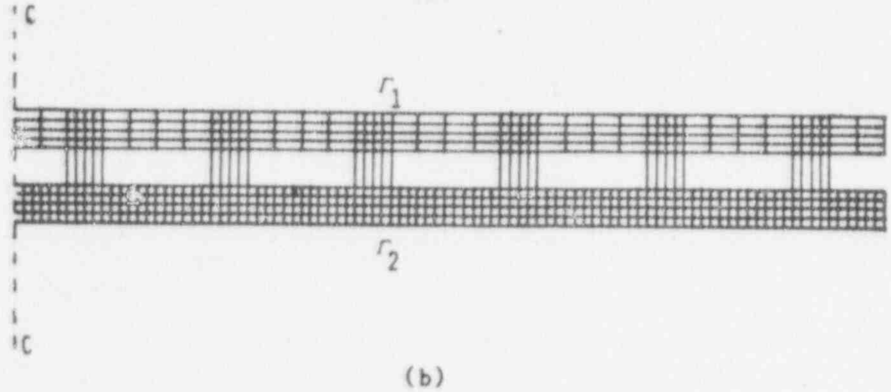
Let us first look at the coordinate transformation in the plane normal to the assembly axis. Figure 1 shows a 7-pin hexagonal assembly before and after the coordinate transformation. In the physical plane, there is a branch cut along the line CC, where the assembly is unwrapped in the transformed plane. The transformation involving a branch cut along the section CC is superior to some of the previous attempts. One example of the previous attempts is to divide the hexagonal assembly into three separate pieces (120° sectors). Each piece is individually transformed into a rectangular geometry with uniform meshes. Three pieces are then matched together using appropriate matching conditions. This method has an inherent asymmetry between cross sections AA and BB of Fig. 1a.

However, the present method of transformation will crowd the mesh grids in the inner region of the assembly, especially for assemblies with a large number of pins. One remedy is to skip some of the grid lines periodically in the inner region of the assembly. This is shown in Fig. 1b, where two grid lines were skipped for every three grid lines above the fuel-pin region. A numbering scheme was devised and implemented in the code for identifying the skipped lines.



RADIUS = 3.0 MM
GAP BETWEEN PINS = 1.9 MM
FLAT TO FLAT = 22 MM
V_M = 2.15 M/S
RE = 3.373 x 10^4
HEAT FLUX = .993 x 10^6 WATTS/M^2

(a)



(b)

Fig. 1. (a) Physical plane and dimensions, (b) transformed plane. ANL Neg. No. 110-79-192R1.

In order to define the coordinate transformation in the third direction, the ζ coordinate and the z coordinate are related by

$$d\zeta = a\,dz \tag{4}$$

where a is any given positive constant prescribing the linear transformation in the third direction. Then, we obtain

$$\frac{dz}{d\zeta} = \frac{1}{a} \tag{5}$$

The derivatives of the xyz coordinates can be easily derived by using Eq. (5) as follows

$$\left.\begin{aligned}
&x_\xi = x_{1\xi},\\
&x_\eta = x_{1\eta},\\
&x_\zeta = 0,\\
&y_\xi = x_{2\xi},\\
&y_\eta = x_{2\eta},\\
&y_\zeta = 0,\\
&z_\xi = 0,\\
&z_\eta = 0,\\
\text{and}\quad &\\
&z_\zeta = \frac{1}{a},
\end{aligned}\right\} \tag{6}$$

where x and y are also written as x_1 and x_2, and all the subscripts ξ, η, and ζ represent partial derivatives with respect to ξ, η, and ζ accordingly.

The Jacobian of the transformation can be expressed as

$$J = \frac{\partial(x,y,z)}{\partial(\xi,\eta,\zeta)} = \frac{1}{a}J_{12}, \tag{7}$$

where

$$J_{12} = x_{1\xi}\, x_{2\eta} - x_{1\eta}\, x_{2\xi}. \tag{8}$$

The volumes and surfaces before and after the transformation are related by

$$dx\,dy\,dz = J d\xi\,d\eta\,d\zeta \tag{9}$$

and

$$dx\,dy = J_{12}\,d\xi\,d\eta. \tag{10}$$

The unit vectors normal to the surfaces ξ, η, ζ = constants are given by

$$\left.\begin{aligned}
\vec{n}_\xi &= \frac{1}{\sqrt{x_{1\eta}^2 + x_{2\eta}^2}}\left(x_{2\eta}\vec{i} - x_{1\eta}\vec{j}\right),\\
\vec{n}_\eta &= \frac{-1}{\sqrt{x_{1\xi}^2 + x_{2\xi}^2}}\left(x_{2\xi}\vec{i} - x_{1\xi}\vec{j}\right),\\
&\text{and}\\
\vec{n}_\zeta &= \vec{k}.
\end{aligned}\right\} \tag{11}$$

Any vector component in the unit normal direction can be formed by the dot product of the vector and the unit normal. For example, the velocity components in the ξ, η, and ζ directions are proportional to the following quantities:

$$\left.\begin{aligned}
\tilde{u} &= x_{2\eta}u - x_{1\eta}v,\\
\tilde{v} &= -x_{2\xi}u + x_{1\xi}v,\\
&\text{and}\\
\tilde{w} &= w.
\end{aligned}\right\} \tag{12}$$

where u, v, w are the velocity components in the original x, y, z coordinates as $\vec{v} = u\vec{i} + v\vec{j} + w\vec{k}$.

Furthermore, the derivative of a function can be derived from

$$\left.\begin{aligned}
f_\xi &= f_x x_\xi + f_y y_\xi + f_z z_\xi,\\
f_\eta &= f_x x_\eta + f_y y_\eta + f_z z_\eta,\\
&\text{and}\\
f_\zeta &= f_x x_\zeta + f_y y_\zeta + f_z z_\zeta,
\end{aligned}\right\} \tag{13}$$

and Cramer's rule,

$$\left.\begin{aligned} f_x &= \frac{1}{J_{12}}\left(x_{2\eta} f_\xi - x_{2\xi} f_\eta\right), \\ f_y &= \frac{1}{J_{12}}\left(-x_{1\eta} f_\xi + x_{1\xi} f_\eta\right), \\ &\text{and} \\ f_z &= a f_\zeta, \end{aligned}\right\} \tag{14}$$

where subscripts of ξ, η, ζ, x, y, and z represent partial derivatives of f with respect to the corresponding subscripts.

Then the divergence of a vector can be written as

$$J \operatorname{div}(f\vec{v}) = \frac{\partial}{\partial \xi} f\tilde{u}\frac{1}{a} + \frac{\partial}{\partial \eta} f\tilde{v}\frac{1}{a} + \frac{\partial}{\partial \zeta}(f\tilde{w}J_{12}). \tag{15}$$

By using the Divergence theorem, we can write the surface integral of any vector $\vec{v}$ on the volume bounded by two surfaces ξ = constants, two surfaces η = constants, and two surfaces ζ = constants as

$$\iint \vec{fv} \cdot \vec{n}\, dS = \iint f\tilde{u}\ \frac{1}{a} d\eta\, d\zeta + \iint f\tilde{v}\ \frac{1}{a} d\xi d\zeta + \iint f\tilde{w}J_{12}\ d\xi\ d\eta, \tag{16}$$

where $\tilde{u}$, $\tilde{v}$, and $\tilde{w}$ are given in Eq. (12). Equation (16) is extensively used in the following sections for deriving the transformed governing equations.

III. THE GOVERNING EQUATIONS

A. Integral Form of the Governing Equations

1. Dimensional Form

Continuity:

$$\iiint \frac{\partial \rho}{\partial t} dV + \oiint \rho u_j n_j \, dS = 0 \tag{17}$$

Momentum:

$$\iiint \frac{\partial (\rho u_i)}{\partial t} dV + \oiint \rho u_i u_j n_j \, dS = \oiint \tau_{ij} n_j \, dS + \iiint \rho g_i \, dV \tag{18}$$

Energy:

$$\iiint \frac{\partial E}{\partial t} dV + \oiint E u_j n_j \, dS = \oiint u_i \tau_{ij} n_j \, dS - \oiint q_j n_j \, dS$$

$$+ \iiint \rho g_i u_i \, dV + \iiint \dot{Q} \, dV \tag{19}$$

with

$$E = \rho \left(e + \frac{u_i u_i}{2} \right), \tag{20a}$$

$$\tau_{ij} = -p\delta_{ij} + \mu \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) - \frac{2}{3} \mu \frac{\partial u_j}{\partial x_j} \delta_{ij}, \tag{20b}$$

$$q_i = -\kappa \frac{\partial T}{\partial x_i}, \tag{20c}$$

and

$$H = \rho \left(h + \frac{u_i u_i}{2} \right) = \rho \left(e + \frac{p}{\rho} + \frac{u_i u_i}{2} \right) = E + p, \tag{20d}$$

where

- S = surface of the integration,
- V = volume of the integration,
- t = time,
- u_i = velocity component in i direction,

n_i = unit vector normal to the surface S,

ρ = density,

τ_{ij} = stress tensor due to the fluid viscosity,

g_i = body force in i direction,

e = energy per unit mass,

E = energy per unit volume,

q_i = heat flux in i direction,

$\dot{Q}$ = volumetric heat-generation rate,

p = pressure,

μ = molecular viscosity,

δ_{ij} = Kronecker delta function,

κ = molecular conductivity,

T = temperature,

h = enthalpy per unit mass,

H = enthalpy per unit volume,

and the repeated indices stand for summation over the index.

Using Eq. (20d), we can rewrite the energy equation as

$$\iiint \frac{\partial H}{\partial t} dV - \iiint \frac{\partial p}{\partial t} dV + \oiint H u_j n_j \, dS = \oiint u_i \Sigma_{ij} n_j \, dS$$

$$- \oiint q_j n_j \, dS + \iiint \rho g_i u_i \, dV + \iiint \dot{Q} \, dV, \tag{21}$$

where

$$\Sigma_{ij} = \mu \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) - \frac{2}{3} \mu \frac{\partial u_j}{\partial x_j} \delta_{ij}. \tag{22}$$

Using Eq. (20b), the momentum equation becomes

$$\iiint \frac{\partial (\rho u_i)}{\partial t} dV + \oiint \rho u_i u_j n_j \, dS = - \oiint p n_i \, dS + \oiint \Sigma_{ij} n_j \, dS$$

$$+ \iiint \rho g_i \, dV. \tag{23}$$

Equations (17), (21), and (23), together with Eqs. (20a), (20c), (20d), and (22), with the equations of state and properties, form a closed computational set. However, an alternative set may be obtained as follows. By using the divergence theorem and taking the limit of an infinitesimal volume,

$$\iiint \frac{\partial A_{ij}}{\partial x_j}\, dV = \oint A_{ij} n_j \, dS, \tag{24}$$

we may convert Eqs. (17), (21), and (23) to differential forms:

$$\text{Continuity:} \quad \frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_j)}{\partial x_j} = 0. \tag{25}$$

$$\text{Momentum:} \quad \frac{\partial(\rho u_i)}{\partial t} + \frac{\partial(\rho u_i u_j)}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{\partial \Sigma_{ij}}{\partial x_j} + \rho g_i. \tag{26}$$

$$\text{Energy:} \quad \frac{\partial H}{\partial t} - \frac{\partial p}{\partial t} + \frac{\partial(H u_j)}{\partial x_j} = \frac{\partial(u_i \Sigma_{ij})}{\partial x_j} - \frac{\partial q_j}{\partial x_j} + \rho g_i u_i + \dot{Q}. \tag{27}$$

A combination may then be made by multiplying the momentum equation (Eq. 26) by u_i, subtracting the result from the energy equation (Eq. 27), and making use of the continuity equation (Eq. 25) to establish that certain terms vanish. The resultant combination then forms an alternative energy equation:

$$\rho \frac{\partial h}{\partial t} - \frac{\partial p}{\partial t} + \rho u_j \frac{\partial h}{\partial x_j} - u_j \frac{\partial p}{\partial x_j} = \Sigma_{ij} \frac{\partial u_i}{\partial x_j} - \frac{\partial p_i}{\partial x_j} + \dot{Q}. \tag{28}$$

This then may be converted back into an integral form by the use of the divergence theorem, Eq. (24), and by the following integration over the volume to obtain the alternative energy equation in an integral form:

$$\iiint \frac{\partial(\rho h)}{\partial t} dV + \oint \rho h u_j n_j \, dS = -\oint q_j n_j \, dS$$

$$+ \iiint \left(\Sigma_{ij} \frac{\partial u_i}{\partial x_j} + \frac{\partial p}{\partial t} + u_j \frac{\partial p}{\partial x_j} \right) dV + \iiint \dot{Q} \, dV. \tag{29}$$

Equations (17), (23), and (29), together with Eqs. (20c), (22), and the equations of state, then form the computational set used in the present work.

Another modification, however, is made by subtracting out the hydrostatic pressure, p_s, which satisfies

$$0 = -\oint p_s n_i \, dS + \iiint \rho_s g_i \, dV.$$

The momentum equation (Eq. 23) then can be written as

$$\iiint \frac{\partial(\rho u_i)}{\partial t}\, dV + \oiint \rho u_i u_j n_j \, dS = - \oiint (p - p_s) n_i \, dS$$
$$+ \oiint \Sigma_{ij} n_j \, dS + \iiint (\rho - \rho_s) g_i \, dV \tag{30}$$

with the hydrostatic pressure calculated from

$$p_s = p_0 + \int_{\vec{r}_0}^{\vec{r}} \rho_s \, \vec{g} \cdot d\vec{r}. \tag{31}$$

Here p_0 is the pressure at some reference point $\vec{r}_0$.

Similarly, the energy equation (29) can be written as

$$\iiint \frac{\partial(\rho h)}{\partial t}\, dV + \oiint \rho h u_j n_j \, dS = - \oiint q_j n_j \, dS$$
$$+ \iiint \left[\Sigma_{ij} \frac{\partial u_i}{\partial x_j} + \frac{\partial(p - p_s)}{\partial t} + u_j \frac{\partial(p - p_s)}{\partial x_j} \right] dV$$
$$+ \iiint \rho_s u_j g_j \, dV + \iiint \dot{Q} \, dV. \tag{32}$$

Finally, as a stabilizing measure, the products of the continuity equation and the velocity and enthalpy, respectively, are added to the momentum and energy equations as source terms. These equations then finally become

$$\iiint \frac{\partial(\rho u_i)}{\partial t}\, dV + \oiint \rho u_i u_j n_j \, dS = - \oiint (p - p_s) n_i \, dS + \oiint \Sigma_{ij} n_j \, dS$$
$$+ \iiint (\rho - \rho_s) g_i \, dV + \iiint u_i \left[\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_j)}{\partial x_j} \right] dV \tag{33}$$

and

$$\iiint \frac{\partial(\rho h)}{\partial t}\, dV + \oiint \rho h u_j n_j \, dS = - \oiint q_j n_j \, dS$$
$$+ \iiint \left[\frac{\partial u_i}{\partial x_j} \Sigma_{ij} + \frac{\partial(p - p_s)}{\partial t} + u_j \frac{\partial(p - p_s)}{\partial x_j} \right] dV + \iiint \rho_s u_j g_j \, dV$$
$$+ \iiint \dot{Q} \, dV + \iiint h \left[\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_j)}{\partial x_j} \right] dV. \tag{34}$$

Note that the analytical effect of this last use of the continuity equation would be to reduce the equations to the nonconservative forms if the equations were converted back into differential forms and terms were cancelled wherever possible. However, the effect is not the same in the difference expressions, since the use of different points in the various expressions prevents such cancellations on the discrete grid. As will be shown later, the numerical effect of these corrective terms is to resist the tendency of a large outflow of the momentum and enthalpy from a cell to catastrophically deplete the cell contents and similarly to lessen the effect of a large inflow.

2. Dimensionless Form

The following dimensionless variables are defined (an overbar denotes a dimensional quantity):

$$t = \frac{\bar{t}V_0}{L_0} ,$$

$$x = \frac{\bar{x}}{L_0} , \qquad y = \frac{\bar{y}}{L_0} , \qquad z = \frac{\bar{z}}{L_0} ,$$

$$u = \frac{\bar{u}}{V_0} , \qquad v = \frac{\bar{v}}{V_0} , \qquad w = \frac{\bar{w}}{V_0} ,$$

$$p = \frac{\bar{p} - \bar{p}_s}{\rho_0 V_0^2} ,$$

$$\rho = \frac{\bar{\rho}}{\rho_0} , \qquad \rho_s = \frac{\bar{\rho}_s}{\rho_0} ,$$

$$\mu = \frac{\bar{\mu}}{\mu_0} ,$$

$$h = \frac{\bar{h}}{h_0} ,$$

$$g_i = \frac{\bar{g}_i}{g_0} ,$$

$$T = \frac{\bar{T}C_{p0}}{h_0} ,$$

$$\kappa = \frac{\bar{\kappa}}{\kappa_0},$$

$$\dot{Q} = \frac{\bar{\dot{Q}}L_0}{\rho_0 h_0 V_0},$$

$$q_j = \frac{RePr}{\rho_0 V_0 h_0}\bar{q}_j, \qquad j = 1, 2, 3,$$

$$\Sigma_{ij} = \frac{Re}{\rho_0 V_0^2}\bar{\Sigma}_{ij}, \qquad i, j = 1, 2, 3,$$

and

$$S_m = \frac{\bar{S}_m L_0}{\rho_0 V_0}.$$

In these equations L_0, V_0, ρ_0, h_0, μ_0, g_0, κ_0, and c_{p0} are arbitrary reference length, velocity, density, enthalpy, viscosity, gravity, conductivity, and heat capacity, respectively. In the present work, the values of these variables evaluated at the entrance of the fuel assembly are taken as the reference values. The relevant dimensionless parameters are

$$Re = \frac{\rho_0 V_0 L_0}{\mu_0}, \quad \text{Reynolds number;}$$

$$Pr = \frac{\mu_0 C_{p0}}{k_0}, \quad \text{Prandtl number;}$$

$$D = \frac{V_0^2}{h_0}, \quad \text{Energy ratio;}$$

$$F = \frac{V_0}{\sqrt{g_0 L_0}}, \quad \text{Froude number.}$$

The governing equations in dimensionless form are then expressed in the general form as

$$\iiint \frac{\partial}{\partial t}(\rho\phi)\, dV + \oint\!\!\oint \rho\phi u_j n_j\, dS = \oint\!\!\oint \psi_j n_j\, dS + \iiint r\, dV + \iiint \phi S_m\, dV \quad (35)$$

with the following definitions for the respective equations:

x Momentum

$$\phi = u,$$

$$\psi_j = -P\delta_{1j} + \frac{1}{Re}\Sigma_{1j},$$

and

$$r = \frac{1}{F^2}(\rho - \rho_s)g_1.$$

y Momentum

$$\phi = v,$$

$$\psi_j = -P\delta_{2j} + \frac{1}{Re}\Sigma_{2j},$$

and

$$r = \frac{1}{F^2}(\rho - \rho_s)g_2.$$

z Momentum

$$\phi = w,$$

$$\psi_j = -P\delta_{3j} + \frac{1}{Re}\Sigma_{3j},$$

and

$$r = \frac{1}{F^2}(\rho - \rho_s)g_3.$$

Energy

$$\phi = h,$$

$$\psi_j = -\frac{1}{RePr}q_j,$$

and

$$r = \frac{D}{Re}\frac{\partial u_i}{\partial x_j}\Sigma_{ij} + \dot{Q} + D\frac{DP}{Dt} + \frac{D}{F^2}\rho_s(ug_1 + vg_2 + wg_3),$$

where DP/Dt is the substantial time derivative of P.

The residual mass S_m is given by

$$\iiint S_m \, dV = \iiint \frac{\partial \rho}{\partial t} dV + \oiint \rho u_j n_j \, dS. \tag{36}$$

The transport quantities in dimensionless form are

$$q_j = -\kappa \frac{\partial T}{\partial x_j} \tag{37}$$

and

$$\Sigma_{ij} = \left(-\frac{2}{3}\mu \frac{\partial u_k}{\partial x_k}\right)\delta_{ij} + \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right). \tag{38}$$

All quantities are understood to be nondimensional hereafter, unless specifically indicated to be otherwise.

B. The Governing Equation in Transformed Variables

Continuity

By using Eq. (16), we can write Eq. (36) as

$$\iiint_{V'} J \frac{\partial \rho}{\partial t} dV' + \iint_{S_\xi} \rho \tilde{u} \frac{1}{a} d\eta \, d\zeta + \iint_{S_\eta} \rho \tilde{v} \frac{1}{a} d\xi \, d\zeta$$

$$+ \iint_{S_\zeta} \rho \tilde{w} J_{12} \, d\xi \, d\eta = \iiint_{V'} J S_m \, dV', \tag{39}$$

where

$$\tilde{u} = x_{2\eta} u - x_{1\eta} v,$$

$$\tilde{v} = -x_{2\xi} u + x_{1\xi} v,$$

$$\tilde{w} = w,$$

$$J = \frac{J_{12}}{a},$$

$$J_{12} = x_{1\xi} x_{2\eta} - x_{1\eta} x_{2\xi},$$

and a is given by Eq. (4). S_ξ represents the two surfaces of constant ξ. Similar definitions hold for S_η and S_ζ. V' is the volume element bounded by these surfaces.

x Momentum

By using Eq. (22), we can write the x-momentum part of Eq. (35) as

$$\iiint\limits_{V'} J \frac{\partial}{\partial t}(\rho u)\, dV' + \iint\limits_{S_\xi} \frac{1}{a} \rho u\tilde{u}\, d\eta\, d\zeta + \iint\limits_{S_\eta} \frac{1}{a} \rho u\tilde{v}\, d\xi\, d\zeta + \iint\limits_{S_\zeta} J_{12} \rho u\tilde{w}\, d\xi\, d\eta$$

$$= -\iint\limits_{S_\xi} \frac{1}{a} x_{2\eta} P\, d\eta\, d\zeta + \iint\limits_{S_\eta} \frac{1}{a} x_{2\xi} P d\xi\, d\zeta + \frac{1}{Re} \iint\limits_{S_\xi} \frac{1}{a} \tilde{\Sigma}_{11}\, d\eta\, d\zeta$$

$$+ \frac{1}{Re} \iint\limits_{S_\eta} \frac{1}{a} \tilde{\Sigma}_{12}\, d\xi\, d\zeta + \frac{1}{Re} \iint\limits_{S_\zeta} J_{12} \tilde{\Sigma}_{13}\, d\xi\, d\eta + \frac{1}{F^2} \iiint\limits_{V'} J(\rho - \rho_s) g_x\, dV'$$

$$+ \iiint\limits_{V'} J u S_m\, dV', \tag{40}$$

where

$$\tilde{\Sigma}_{11} = x_{2\eta} \Sigma_{11} - x_{1\eta} \Sigma_{12},$$

$$\tilde{\Sigma}_{12} = -x_{2\xi} \Sigma_{11} + x_{1\xi} \Sigma_{12},$$

and

$$\tilde{\Sigma}_{13} = \Sigma_{13}. \tag{41}$$

y Momentum

By using Eq. (16), we can write the y-momentum part of Eq. (35) as

$$\iiint\limits_{V'} J \frac{\partial}{\partial t}(\rho v)\, dV' + \iint\limits_{S_\xi} \frac{1}{a} \rho v\tilde{u}\, d\eta\, d\zeta + \iint\limits_{S_\eta} \frac{1}{a} \rho v\tilde{v}\, d\xi\, d\zeta + \iint\limits_{S_\zeta} J_{12} \rho v\tilde{w}\, d\xi\, d\eta$$

$$= \iint\limits_{S_\xi} \frac{1}{a} x_{1\eta} P\, d\eta\, d\zeta - \iint\limits_{S_\eta} \frac{1}{a} x_{1\xi} P\, d\xi\, d\zeta + \frac{1}{Re} \iint\limits_{S_\xi} \frac{1}{a} \tilde{\Sigma}_{21}\, d\eta\, d\zeta$$

$$+ \frac{1}{Re} \iint\limits_{S_\eta} \frac{1}{a} \tilde{\Sigma}_{22}\, d\xi\, d\zeta + \frac{1}{Re} \iint\limits_{S_\zeta} J_{12}\, \tilde{\Sigma}_{23}\, d\xi\, d\eta + \frac{1}{F^2} \iiint\limits_{V'} J(\rho - \rho_s) g_y\, dV'$$

$$+ \iiint\limits_{V'} J v S_m\, dV', \tag{42}$$

where

$$\tilde{\Sigma}_{21} = x_{2\eta}\Sigma_{21} - x_{1\eta}\Sigma_{22},$$

$$\tilde{\Sigma}_{22} = -x_{2\xi}\Sigma_{21} + x_{1\xi}\Sigma_{22},$$

and

$$\tilde{\Sigma}_{23} = \Sigma_{23}. \tag{43}$$

z Momentum

By using Eq. (16), we can write the z-momentum part of Eq. (35) as

$$\begin{aligned} &\iiint\limits_{V'} J\frac{\partial}{\partial t}(\rho w)\, dV' + \iint\limits_{S_\xi} \frac{1}{a}\rho w\tilde{u}\, d\eta\, d\zeta + \iint\limits_{S_\eta} \frac{1}{a}\rho w\tilde{v}\, d\xi\, d\zeta + \iint\limits_{S_\zeta} J_{12}\rho w\tilde{w}\, d\xi\, d\eta \\ &\quad = -\iint\limits_{S_\zeta} J_{12}P d\xi\, d\eta + \frac{1}{Re}\iint\limits_{S_\xi}\frac{1}{a}\tilde{\Sigma}_{31}\, d\eta\, d\zeta + \frac{1}{Re}\iint\limits_{S_\eta}\frac{1}{a}\tilde{\Sigma}_{32}\, d\xi\, d\zeta \\ &\quad + \frac{1}{Re}\iint\limits_{S_\zeta} J_{12}\,\tilde{\Sigma}_{33}\, d\xi\, d\eta + \frac{1}{F^2}\iiint\limits_{V'} J(\rho - \rho_s)g_z\, dV' \\ &\quad + \iiint\limits_{V'} JwS_m\, dV', \end{aligned} \tag{44}$$

where

$$\left.\begin{aligned} &\tilde{\Sigma}_{31} = x_{2\eta}\Sigma_{31} - x_{1\eta}\Sigma_{32}, \\ &\tilde{\Sigma}_{32} = -x_{2\xi}\Sigma_{31} + x_{1\xi}\Sigma_{32}, \\ &\text{and} \\ &\tilde{\Sigma}_{33} = \Sigma_{33}. \end{aligned}\right\} \tag{45}$$

Energy Equations

$$\left.\begin{aligned} &\iiint\limits_{V'} J\frac{\partial}{\partial t}(\rho h)\, dV' + \iint\limits_{S_\xi}\frac{1}{a}\rho h\tilde{u}\, d\eta\, d\zeta + \iint\limits_{S_\eta}\frac{1}{a}\rho h\tilde{v}\, d\xi\, d\zeta \\ &\quad + \iint\limits_{S_\zeta} J_{12}\,\rho h\tilde{w}\, d\xi\, d\eta = -\frac{1}{RePr}\iint\limits_{S_\xi}\frac{1}{a}\tilde{q}_1\, d\eta\, d\zeta \end{aligned}\right\} \tag{46}$$

(Contd.)

$$\left.\begin{aligned} &- \frac{1}{RePr}\iint\limits_{S_\eta} \frac{1}{a}\tilde{q}_2\, d\xi\, d\zeta - \frac{1}{RePr}\iint\limits_{S_\zeta} J_{12}\, \tilde{q}_3\, d\xi\, d\eta \\ &+ \iiint\limits_{V'} J\left[\frac{D}{Re}\phi_D + \dot{Q} + D\frac{DP}{Dt} + \frac{D}{F^2}\rho_s\left(ug_x + vg_y + wg_z\right)\right]dV' \\ &+ \iiint\limits_{V'} JhS_m\, dV', \end{aligned}\right\} \text{(Contd.)} \quad (46)$$

where

$$\left.\begin{aligned} \tilde{q}_1 &= x_{2\eta}q_1 - x_{1\eta}q_2, \\ \tilde{q}_2 &= -x_{2\xi}q_1 + x_{1\xi}q_2, \\ \tilde{q}_3 &= q_3, \end{aligned}\right\} \quad (47)$$

$$\frac{DP}{Dt} = \frac{\partial P}{\partial t} + \frac{1}{J_{12}}\tilde{u}P_\xi + \frac{1}{J_{12}}\tilde{v}P_\eta + a\tilde{w}P_\zeta, \quad (48)$$

$$\begin{aligned} \phi_D = &\frac{1}{J_{12}}\left(u_\xi\tilde{\Sigma}_{11} + u_\eta\tilde{\Sigma}_{12} + v\tilde{\Sigma}_{21} + v_\eta\tilde{\Sigma}_{22} + w_\xi\tilde{\Sigma}_{31} + w_\eta\tilde{\Sigma}_{32}\right) \\ &+ a\left(u_\zeta\tilde{\Sigma}_{13} + v_\zeta\tilde{\Sigma}_{23} + w_\zeta\tilde{\Sigma}_{33}\right), \end{aligned} \quad (49)$$

and the subscripts ξ, η, and ζ for u, v, w, and P represent partial derivatives with respect to ξ, η, and ζ accordingly.

Transport Equations

The heat fluxes and the viscous stresses given by Eqs. (47) and (38) can be expressed in terms of the transformed variables as

$$\left.\begin{aligned} \tilde{q}_1 &= -\frac{\kappa}{J_{12}}\left[\left(x_{1\eta}^2 + x_{2\eta}^2\right)T_\xi - \left(x_{1\xi}x_{1\eta} + x_{2\xi}x_{2\eta}\right)T_\eta\right], \\ \tilde{q}_2 &= -\frac{\kappa}{J_{12}}\left[\left(x_{1\xi}^2 + x_{2\xi}^2\right)T_\eta - \left(x_{1\xi}x_{1\eta} + x_{2\xi}x_{2\eta}\right)T_\xi\right], \\ &\text{and} \\ \tilde{q}_3 &= -\kappa a T_\zeta, \end{aligned}\right\} \quad (50)$$

and

$$\left.\begin{aligned}
\Sigma_{11} &= 2\mu \; \frac{1}{J_{12}}\left(x_{2\eta}u_{\xi} - x_{2\xi}u_{\eta}\right) - \frac{2}{3}\,\mu\nabla \cdot \vec{v}, \\
\Sigma_{22} &= \frac{2\mu}{J_{12}}\left(-x_{1\eta}v_{\xi} + x_{1\xi}v_{\eta}\right) - \frac{2}{3}\,\mu\nabla \cdot \vec{v}, \\
\Sigma_{33} &= 2\mu a w_{\zeta} - \frac{2}{3}\,\mu\nabla \cdot \vec{v}, \\
\Sigma_{12} &= \mu\left[\frac{1}{J_{12}}\left(x_{2\eta}v_{\xi} - x_{1\eta}u_{\xi} + x_{1\xi}u_{\eta} - x_{2\xi}v_{\eta}\right)\right], \\
\Sigma_{13} &= \mu\left[\frac{1}{J_{12}}\left(x_{2\eta}w_{\xi} - x_{2\xi}w_{\eta}\right) + a u_{\zeta}\right], \\
&\text{and} \\
\Sigma_{23} &= \mu\left[\frac{1}{J_{12}}\left(-x_{1\eta}w_{\xi} + x_{1\xi}w_{\eta}\right) + a v_{\zeta}\right],
\end{aligned}\right\} \qquad (51)$$

where

$$\nabla \cdot \vec{v} = \frac{1}{J_{12}}\left(x_{2\eta}u_{\xi} - x_{2\xi}u_{\eta}\right) + \frac{1}{J_{12}}\left(-x_{1\eta}v_{\xi} + x_{1\xi}v_{\eta}\right) + a w_{\zeta}. \qquad (52)$$

All these equations are written in the finite-difference forms in the following section.

IV. FINITE-DIFFERENCE EQUATIONS

A. Storage of Variables

In the conventional staggered-mesh arrangement, pressure, density, and temperature (enthalpy) are stored at the center of the cell formed by the grid lines; velocities are stored on the grid lines between the intersections. However, in the transformed momentum equations (e.g., Eq. (40)), the x momentum depends not only on the pressure gradient in the ξ direction, but also on the pressure gradients in the η and ζ directions. Because of this dependence of the velocity on all three pressure gradients, it is necessary to perform a great deal of averaging of the pressures for some directions and not for the other. This nonuniform treatment of the pressure gradients is undesirable. Furthermore, it requires pressures to be specified at the physical boundaries. In order to circumvent the above-mentioned difficulties, the modified staggered-mesh arrangement was developed. In this arrangement, the pressure, density, and temperature (enthalpy) are stored at the center of the cell; velocities are stored at the intersection of the grid lines. We define the control volume formed by the grid lines as basic cells. The control volume formed by the planes midway between the grid lines is referred to as the staggered cell. This arrangement is shown in Fig. 2(a) in three dimensions and in Fig. 2(b) in two dimensions. The continuity equation, Eq. (39), and the energy equation, Eq. (46), are applied to the basic cell; the momentum equations are applied to the staggered cell. The indexes for both types of cells are the same, except that the reference point for the staggered cell is halfway diagonally off the reference point for the basic cell as shown in Fig. 2.

B. Convective Terms

All convective terms are partial donor-cell differenced. That is, for example, the flux of enthalpy through the surface at i + 1/2 is formulated as follows:

$$\langle\rho h\tilde{u}\rangle_{i+1/2,j,k} = (\rho\tilde{u})_{i+1/2,j,k}\left[\left(\frac{1}{2} + \Gamma_\xi^+\right)h_{i,j,k} + \left(\frac{1}{2} - \Gamma_\xi^+\right)h_{i+1,j,k}\right],$$

where

$$\Gamma_\xi^+ = A_0 \operatorname{sign}\left(\tilde{u}_{i+1/2,j,k}\right) + \frac{B_0\Delta t}{\Delta\xi}\tilde{u}_{i+1/2,j,k},$$

$$\tilde{u}_{i+1/2,j,k} = \frac{1}{4}\left(\tilde{u}_{i+1,j,k} + \tilde{u}_{i+1,j+1,k} + \tilde{u}_{i+1,j,k+1} + \tilde{u}_{i+1,j+1,k+1}\right),$$

and

$$\rho_{i+1/2,j,k} = \frac{1}{2}\left(\rho_{i,j,k} + \rho_{i+1,j,k}\right).$$

A_0 and B_0 are prescribed dimensionless constants. For $A_0 = 0$ and $B_0 = 0$, we get central differencing. For $A_0 = 1/2$ and $B_0 = 0$, we get pure upwind differencing. The same procedure is used at the i - 1/2 face. Thus, the ξ derivative of $\rho h\tilde{u}$ can be written as

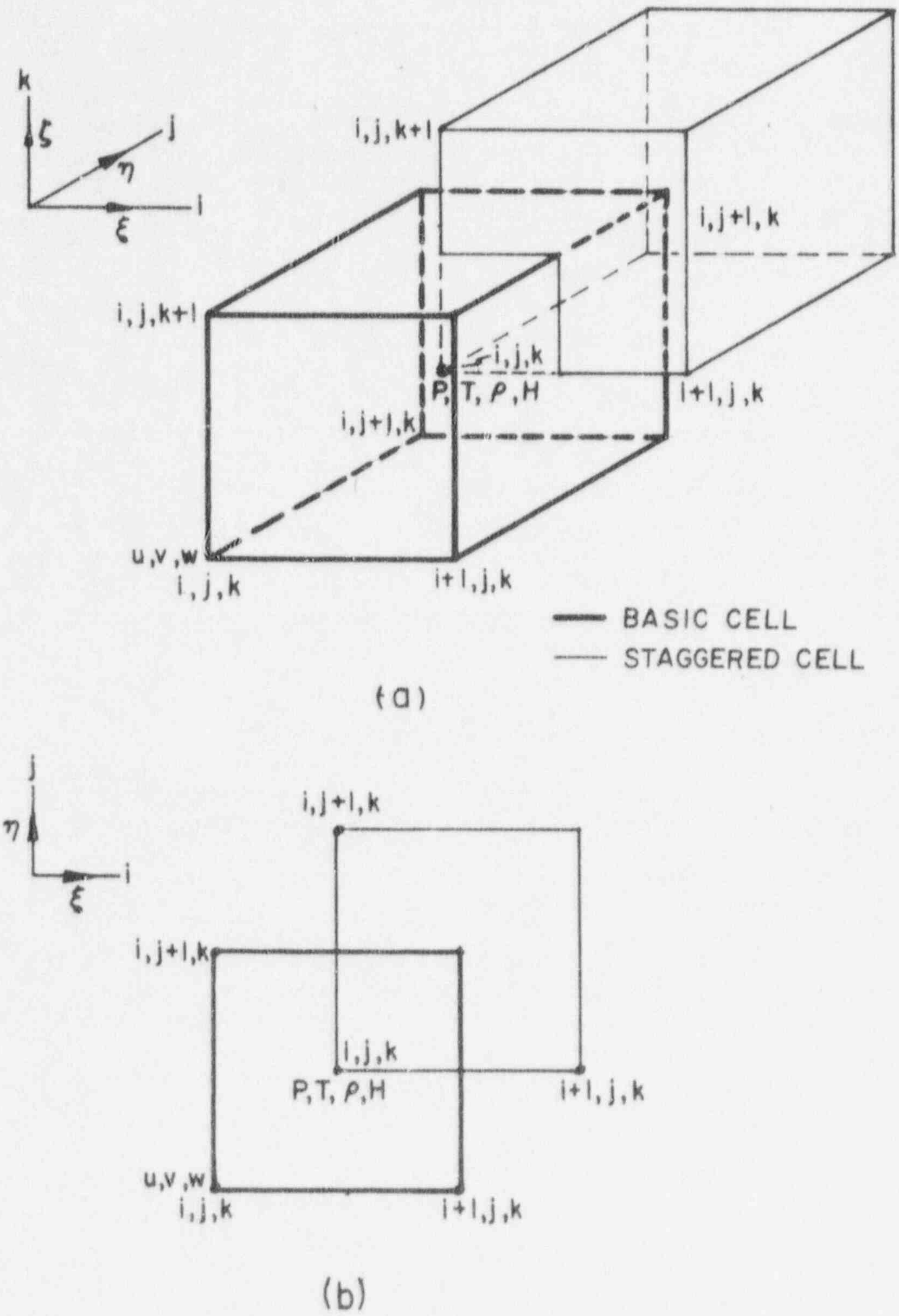


Fig. 2. Storage arrangements for basic cell and staggered cell in (a) three dimensions and (b) two dimensions

$$(\rho h\tilde{u})_\xi = (\rho\tilde{u})_{i+1/2,j,k}\left[\left(\frac{1}{2} + \Gamma_\xi^+\right)h_{i,j,k} + \left(\frac{1}{2} - \Gamma_\xi^+\right)h_{i+1,j,k}\right]$$

$$- (\rho\tilde{u})_{i-1/2,j,k}\left[\left(\frac{1}{2} + \Gamma_\xi^-\right)h_{i-1,j,k} + \left(\frac{1}{2} - \Gamma_\xi^-\right)h_{i,j,k}\right],$$

where

$$\Gamma_\xi^- = A_0 \text{ sign}(\tilde{u}_{i-1/2,j,k}) + \frac{B_0 \Delta t}{\Delta\xi}\tilde{u}_{i-1/2,j,k}.$$

C. Finite-difference Forms

Besides the convective terms having the option of upwind differencing, the time derivatives are written as first-order differences, and all diffusion space derivatives and the pressure derivatives are written as second-order central differences.

In the following difference equations, advantage has been taken of cancellation of terms that occurs among the time derivatives, the convective terms, and the mass-residue term as follows. Considering these terms in the x-momentum equation, we have, with values at the previous time step denoted by the superscript "old" and $\Delta\xi = \Delta\eta = \Delta\zeta = 1$,

$$(\rho u)_t J + (\rho u\tilde{u})_\xi \frac{1}{a} - uS_m J = \frac{1}{\Delta t}\left[\underline{(\rho u)_i} - (\rho u)_i^{old}\right](J)_i$$

$$+ \left(\frac{1}{a}\right)_i \left\{(\rho\tilde{u})_{i+1/2}\left[\left(\frac{1}{2} + \Gamma_\xi^+\right) u_i + \left(\frac{1}{2} - \Gamma_\xi^+\right)u_{i+1}\right]\right.$$

$$\left. - (\rho\tilde{u})_{i-1/2}\left[\left(\frac{1}{2} + \Gamma_\xi^-\right)u_{i-1} + \left(\frac{1}{2} - \Gamma_\xi^-\right)u_i\right]\right\} - u_i\left\{\frac{1}{\Delta t}(J)_i(\underline{\rho_i} - \rho_i^{old})\right.$$

$$\left. + \left(\frac{1}{a}\right)_i \left[(\rho\tilde{u})_{i+1/2} - (\rho\tilde{u})_{i-1/2}\right] + \ldots\right\},$$

where the subscripts t and ξ for the ρu and $\rho u\tilde{u}$ terms represent partial derivatives with respect to time and the coordinate ξ, respectively. Note that the underlined terms cancel. Also, the remaining terms from the mass residue combine with the $(1/2)u_i$ term from the convective part. The following difference equations then result (the intrinsic coordinates, x and y, are written as x_1 and x_2):

x Momentum (Staggered Cell)

$$\frac{1}{\Delta t}(J)_{i,j,k}(\rho^{old})^{st}_{i,j,k}u_{i,j,k} = \frac{1}{\Delta t}(J)_{i,j,k}(\rho^{old})^{st}_{i,j,k}u^{old}_{i,j,k}$$

$$- \left(\frac{1}{a}\right)_{i+1/2,j,k}\left[\rho^{st}_{i+1/2,j,k}\tilde{u}_{i+1/2,j,k}\left(\frac{1}{2} - \Gamma_\xi^+\right)(u_{i+1,j,k} - u_{i,j,k})\right.$$

$$
\begin{aligned}
&+ \left(x_{2\eta}P\right)_{i+1/2,j,k} - \frac{1}{Re}\left(\tilde{\Sigma}_{11}\right)_{i+1/2,j,k}\Big] \\
&+ \left(\frac{1}{a}\right)_{i-1/2,j,k}\Big[\rho^{st}_{i-1/2,j,k}\tilde{u}_{i-1/2,j,k}\left(\frac{1}{2} + \Gamma^{-}_{\xi}\right)\left(u_{i-1,j,k} - u_{i,j,k}\right) \\
&+ \left(x_{2\eta}P\right)_{i-1/2,j,k} - \frac{1}{Re}\left(\tilde{\Sigma}_{11}\right)_{i-1/2,j,k}\Big] \\
&- \left(\frac{1}{a}\right)_{i,j+1/2,k}\Big[\rho^{st}_{i,j+1/2,k}\tilde{v}_{i,j+1/2,k}\left(\frac{1}{2} - \Gamma^{+}_{\eta}\right)\left(u_{i,j+1,k} - u_{i,j,k}\right) \\
&- \left(x_{2\xi}P\right)_{i,j+1/2,k} - \frac{1}{Re}\left(\tilde{\Sigma}_{12}\right)_{i,j+1/2,k}\Big] \\
&+ \left(\frac{1}{a}\right)_{i,j-1/2,k}\Big[\rho^{st}_{i,j-1/2,k}\tilde{v}_{i,j-1/2,k}\left(\frac{1}{2} + \Gamma^{-}_{\eta}\right)\left(u_{i,j-1,k} - u_{i,j,k}\right) \\
&- \left(x_{2\xi}P\right)_{i,j-1/2,k} - \frac{1}{Re}\left(\tilde{\Sigma}_{12}\right)_{i,j-1/2,k}\Big] \\
&- \left(J_{12}\right)_{ij}\Big[\rho^{st}_{i,j,k+1/2}\tilde{w}_{i,j,k+1/2}\left(\frac{1}{2} - \Gamma^{+}_{\zeta}\right)\left(u_{i,j,k+1} - u_{i,j,k}\right) \\
&- \frac{1}{Re}\left(\tilde{\Sigma}_{13}\right)_{i,j,k+1/2}\Big] \\
&+ \left(J_{12}\right)_{ij}\Big[\rho^{st}_{i,j,k-1/2}\tilde{w}_{i,j,k-1/2}\left(\frac{1}{2} + \Gamma^{-}_{\zeta}\right)\left(u_{i,j,k-1} - u_{i,j,k}\right) \\
&- \frac{1}{Re}\left(\tilde{\Sigma}_{13}\right)_{i,j,k-1/2}\Big] \\
&+ \frac{1}{F^2}(J)_{i,j,k}\left(\rho^{st}_{i,j,k} - \rho_s\right)g_x, \qquad (53)
\end{aligned}
$$

where st stands for staggered cell and all the subscript indexes, such as i, j, and k, are with reference to the staggered cell. The same convention holds for the y- and z-momentum equations. Furthermore,

$$
\begin{aligned}
\rho^{st}_{i,j,k} = \frac{1}{8}\big(&\rho_{i,j,k} + \rho_{i-1,j,k} + \rho_{i,j-1,k} + \rho_{i-1,j-1,k} \\
&+ \rho_{i,j,k-1} + \rho_{i-1,j,k-1} + \rho_{i,j-1,k-1} + \rho_{i-1,j-1,k-1}\big),
\end{aligned}
$$

$$\rho^{st}_{i+1/2,j,k} = \frac{1}{4}\left(\rho_{i,j,k} + \rho_{i,j-1,k} + \rho_{i,j,k-1} + \rho_{i,j-1,k-1}\right),$$

$$\tilde{u}_{i+1/2,j,k} = \frac{1}{2}\left(\tilde{u}_{i,j,k} + \tilde{u}_{i+1,j,k}\right),$$

$$P_{i+1/2,j,k} = \frac{1}{4}\left(P_{i,j,k} + P_{i,j-1,k} + P_{i,j,k-1} + P_{i,j-1,k-1}\right),$$

etc.

The other quantities are averaged in the same way. Thus, for example,

$$P_{i,j-1/2,k} = \frac{1}{4}\left(P_{i,j-1,k} + P_{i-1,j-1,k} + P_{i,j-1,k-1} + P_{i-1,j-1,k-1}\right).$$

<u>y Momentum (Staggered Cell)</u>

$$\frac{1}{\Delta t}(J)_{i,j,k}\left(\rho^{old}_{i,j,k}\right)^{st} v_{i,j,k} = \frac{1}{\Delta t}(J)_{i,j,k}\left(\rho^{old}_{i,j,k}\right)^{st} v^{old}_{i,j,k}$$

$$- \left(\frac{1}{a}\right)_{i+1/2,j,k}\left[\rho^{st}_{i+1/2,j,k}\tilde{u}_{i+1/2,j,k}\left(\frac{1}{2} - \Gamma^{+}_{\xi}\right)\left(v_{i+1,j,k} - v_{i,j,k}\right)\right.$$

$$\left. - \left(x_{1\eta}P\right)_{i+1/2,j,k} - \frac{1}{Re}\left(\tilde{\Sigma}_{21}\right)_{i+1/2,j,k}\right]$$

$$+ \left(\frac{1}{a}\right)_{i-1/2,j,k}\left[\rho^{st}_{i-1/2,j,k}\tilde{u}_{i-1/2,j,k}\left(\frac{1}{2} + \Gamma^{-}_{\xi}\right)\left(v_{i-1,j,k} - v_{i,j,k}\right)\right.$$

$$\left. - \left(x_{1\eta}P\right)_{i-1/2,j,k} - \frac{1}{Re}\left(\tilde{\Sigma}_{21}\right)_{i-1/2,j,k}\right]$$

$$- \left(\frac{1}{a}\right)_{i,j+1/2,k}\left[\rho^{st}_{i,j+1/2,k}\,\tilde{v}_{i,j+1/2,k}\left(\frac{1}{2} - \Gamma^{+}_{\eta}\right)\left(v_{i,j+1,k} - v_{i,j,k}\right)\right.$$

$$\left. + \left(x_{1\xi}P\right)_{i,j+1/2,k} - Re\,\left(\Sigma_{22}\right)_{i,j+1/2,k}\right]$$

$$+ \left(\frac{1}{a}\right)_{i.j-1/2,k}\left[\rho^{st}_{i,j-1/2,k}\tilde{v}_{i,j-1/2,k}\left(\frac{1}{2} + \Gamma^{-}_{\eta}\right)\left(v_{i,j-1,k} - v_{i,j,k}\right)\right.$$

$$+ \left(x_{1\xi}P\right)_{i,j-1/2,k} - \frac{1}{Re}\left(\tilde{\Sigma}_{22}\right)_{i,j-1/2,k}\Bigg]$$

$$- \left(J_{12}\right)_{ij}\Bigg[\rho^{st}_{i,j,k+1/2}\tilde{w}_{i,j,k+1/2}\left(\frac{1}{2} - \Gamma^{+}_{\zeta}\right)\left(v_{i,j,k+1} - v_{i,j,k}\right)$$

$$- \frac{1}{Re}\left(\tilde{\Sigma}_{23}\right)_{i,j,k+1/2}\Bigg]$$

$$+ \left(J_{12}\right)_{ij}\Bigg[\rho^{st}_{i,j,k-1/2}\tilde{w}_{i,j,k-1/2}\left(\frac{1}{2} + \Gamma^{-}_{\xi}\right)\left(v_{i,j,k-1} - v_{i,j,k}\right)$$

$$- \frac{1}{Re}\left(\tilde{\Sigma}_{23}\right)_{i,j,k-1/2}\Bigg]$$

$$+ \frac{1}{F^2}(J)_{i,j,k}\left(\rho^{st}_{i,j,k} - \rho_s\right)g_y \qquad (54)$$

<u>z Momentum (Staggered Cell)</u>

$$\frac{1}{\Delta t}(J)_{i,j,k}\left(\rho^{old}_{i,j,k}\right)^{st} w_{i,j,k} = \frac{1}{\Delta t}(J)_{i,j,k}\left(\rho^{old}_{i,j,k}\right)^{st} w^{old}_{i,j,k}$$

$$- \left(\frac{1}{a}\right)_{i+1/2,j,k}\Bigg[\rho^{st}_{i+1/2,j,k}\tilde{u}_{i+1/2,j,k}\left(\frac{1}{2} - \Gamma^{+}_{\xi}\right)\left(w_{i+1,j,k} - w_{i,j,k}\right)$$

$$- \frac{1}{Re}\left(\tilde{\Sigma}_{31}\right)_{i+1/2,j,k}\Bigg]$$

$$+ \left(\frac{1}{a}\right)_{i-1/2,j,k}\Bigg[\rho^{st}_{i-1/2,j,k}\tilde{u}_{i-1/2,j,k}\left(\frac{1}{2} + \Gamma^{-}_{\xi}\right)\left(w_{i-1,j,k} - w_{i,j,k}\right)$$

$$- \frac{1}{Re}\left(\tilde{\Sigma}_{32}\right)_{i-1/2,j,k}\Bigg]$$

$$- \left(\frac{1}{a}\right)_{i,j+1/2,k}\Bigg[\rho^{st}_{i,j+1/2,k}\tilde{v}_{i,j+1/2,k}\left(\frac{1}{2} - \Gamma^{+}_{\eta}\right)\left(w_{i,j+1,k} - w_{i,j,k}\right)$$

$$- \frac{1}{Re}\left(\tilde{\Sigma}_{32}\right)_{i,j+1/2,k}\Bigg]$$

$$+ \left(\frac{1}{a}\right)_{i,j-1/2,k}\Bigg[\rho^{st}_{i,j-1/2,k}\tilde{v}_{i,j-1/2,k}\left(\frac{1}{2} + \Gamma^{-}_{\eta}\right)\left(w_{i,j-1,k} - w_{i,j,k}\right)$$

$$- \frac{1}{Re}\left(\tilde{\Sigma}_{32}\right)_{i,j-1/2,k}\Bigg]$$

$$- \left(J_{12}\right)_{ij}\Bigg[\rho^{st}_{i,j,k+1/2}\tilde{w}_{i,j,k+1/2}\left(\frac{1}{2} - \Gamma^{+}_{\zeta}\right)\left(w_{i,j,k+1} - w_{i,j,k}\right)$$

$$+ (P)_{i,j,k+1/2} - \frac{1}{Re}\left(\tilde{\Sigma}_{33}\right)_{i,j,k+1/2}\Bigg]$$

$$+ \left(J_{12}\right)_{ij}\Bigg[\rho^{st}_{i,j,k-1/2}\tilde{w}_{i,j,k-1/2}\left(\frac{1}{2} + \Gamma^{-}_{\zeta}\right)\left(w_{i,j,k-1} - w_{i,j,k}\right)$$

$$+ (P)_{i,j,k-1/2} - \frac{1}{Re}\left(\tilde{\Sigma}_{33}\right)_{i,j,k-1/2}\Bigg]$$

$$+ \frac{1}{F^2}(J)_{i,j,k}\left(\rho^{st}_{i,j,k} - \rho_s\right)g_z. \tag{55}$$

Energy Equation (Basic Cell)

$$\frac{1}{\Delta t}(J)^c_{i,j,k}\rho^{old}_{i,j,k}h_{i,j,k} = \frac{1}{\Delta t}(J)^c_{i,j,k}\rho^{old}_{i,j,k}h^{old}_{i,j,k}$$

$$- \left(\frac{1}{a}\right)^c_{i+1/2,j,k}\Bigg[\rho_{i+1/2,j,k}\tilde{u}^c_{i+1/2,j,k}\left(\frac{1}{2} - \Gamma^{c+}_{\xi}\right)\left(h_{i+1,j,k} - h_{i,j,k}\right)$$

$$+ \frac{1}{RePr}\left(\tilde{q}_1\right)^c_{i+1/2,j,k}\Bigg]$$

$$+ \left(\frac{1}{a}\right)^c_{i-1/2,j,k}\Bigg[\rho_{i-1/2,j,k}\tilde{u}^c_{i-1/2,j,k}\left(\frac{1}{2} + \Gamma^{c-}_{\xi}\right)\left(h_{i-1,j,k} - h_{i,j,k}\right)$$

$$+ \frac{1}{RePr}\left(\tilde{q}_1\right)^c_{i-1/2,j,k}\Bigg]$$

$$- \left(\frac{1}{a}\right)^c_{i,j+1/2,k}\Bigg[\rho_{i,j+1/2,k}\tilde{v}^c_{i,j+1/2,k}\left(\frac{1}{2} - \Gamma^{c+}_{\eta}\right)\left(h_{i,j+1,k} - h_{i,j,k}\right)$$

$$+ \frac{1}{RePr}\left(\tilde{q}_2\right)^c_{i,j+1/2,k}\Bigg]$$

$$+ \left(\frac{1}{a}\right)^c_{i,j-1/2,k}\Bigg[\rho_{i,j-1/2,k}\tilde{v}^c_{i,j-1/2,k}\left(\frac{1}{2} + \Gamma^{c-}_\eta\right)\left(h_{i,j-1,k} - h_{i,j,k}\right)$$

$$+ \frac{1}{RePr}\left(\tilde{q}_2\right)^c_{i,j-1/2,k}\Bigg]$$

$$- \left(J_{11}\right)^c_{ij}\Bigg[\rho_{i,j,k+1/2}\tilde{w}^c_{i,j,k+1/2}\left(\frac{1}{2} - \Gamma^{c+}_\zeta\right)\left(h_{i,j,k+1} - h_{i,j,k}\right)$$

$$+ \frac{1}{RePr}\left(\tilde{q}_3\right)^c_{i,j,k+1/2}\Bigg]$$

$$+ \left(J_{12}\right)^c_{ij}\Bigg[\rho_{i,j,k-1/2}\tilde{w}^c_{i,j,k-1/2}\left(\frac{1}{2} + \Gamma^{c-}_\zeta\right)\left(h_{i,j,k-1} - h_{i,j,k}\right)$$

$$+ \frac{1}{RePr}\left(\tilde{q}_3\right)^c_{i,j,k-1/2}\Bigg]$$

$$+ (J)^c_{i,j,k}\Bigg[\frac{D}{Re}\left(\phi_D\right)_{i,j,k} + Q_{i,j,k}$$

$$+ D\left(\frac{DP}{Dt}\right)_{i,j,k} + \frac{D}{F^2}\rho_s\left(ug_x + vg_y + wg_z\right)_{i,j,k}\Bigg], \tag{56}$$

where the superscript c denotes the basic cell and all the subscript indexes are with reference to the basic cell. Thus,

$$\left.\begin{aligned}
\rho_{i+1/2,j,k} &= \frac{1}{2}\left(\rho_{i,j,k} + \rho_{i+1,j,k}\right),\\
\rho_{i-1/2,j,k} &= \frac{1}{2}\left(\rho_{i,j,k} + \rho_{i-1,j,k}\right),\\
\tilde{u}^c_{i+1/2,j,k} &= \frac{1}{4}\left(\tilde{u}_{i+1,j,k} + \tilde{u}_{i+1,j+1,k} + \tilde{u}_{i+1,j,k+1} + \tilde{u}_{i+1,j+1,k+1}\right),\\
\tilde{u}^c_{i-1/2,j,k} &= \frac{1}{4}\left(\tilde{u}_{i,j,k} + \tilde{u}_{i,j+1,k} + \tilde{u}_{i,j,k+1} + \tilde{u}_{i,j+1,k+1}\right),\\
&\text{etc.}
\end{aligned}\right\} \tag{57}$$

The pressure-work term is found in Eq. (48). In finite-difference form

$$\left(\frac{DP}{Dt}\right)_{i,j,k} = \frac{1}{\Delta t}\left(P_{i,j,k} - P^{old}_{i,j,k}\right) + \frac{1}{(J_{12})^c_{ij}}\left[\tilde{u}^c_{i,j,k}(P_\xi)_{i,j,k}\right.$$

$$\left. + \tilde{v}^c_{i,j,k}(P_\eta)_{i,j,k}\right] + a\tilde{w}_{i,j,k}(P_\zeta)_{i,j,k} \tag{58}$$

where

$$\left.\begin{aligned} \tilde{u}^c_{i,j,k} &= \frac{1}{8}(\tilde{u}_{i,j,k} + \tilde{u}_{i+1,j,k} + \tilde{u}_{i,j+1,k} + \tilde{u}_{i+1,j+1,k} + \tilde{u}_{i,j,k+1} \\ &\quad + \tilde{u}_{i+1,j,k+1} + \tilde{u}_{i,j+1,k+1} + \tilde{u}_{i+1,j+1,k+1}), \\ (P_\xi)_{i,j,k} &= \frac{1}{2}(P_{i+1,j,k} - P_{i-1,j,k}), \\ (P_\eta)_{i,j,k} &= \frac{1}{2}(P_{i,j+1,k} - P_{i,j-1,k}), \end{aligned}\right\} \tag{59}$$

etc.

The contribution to the pressure work from the hydrostatic pressure is found in Eq. (52).

$$\frac{D}{F^2}\rho_s(u^c_{i,j,k}g_x + v^c_{i,j,k}g_y + w^c_{i,j,k}g_z), \tag{60}$$

where

$$u^c_{i,j,k} = \frac{1}{8}(u_{i,j,k} + u_{i+1,j,k} + u_{i,j+1,k} + u_{i+1,j+1,k} + u_{i,j,k+1}$$

$$+ u_{i+1,j,k+1} + u_{i,j+1,k+1} + u_{i+1,j+1,k+1}). \tag{61}$$

Residual Mass Source (Basic Cell)

The mass residues, S_m, are computed at the basic cells from Eq. (23),

$$\int_V S_m \, dV = \int_V \frac{\partial \rho}{\partial t} dV + \oint \rho u_j n_j \, dS.$$

In transformed variables, this becomes

$$\int_{V'} JS_m \, dV' = \int_{V'} J \frac{\partial \rho}{\partial t} dV' + \int_{S_\xi} \left(\frac{1}{a}\right) \rho \tilde{u} \, d\eta \, d\zeta$$

$$+ \int_{S_\eta} \left(\frac{1}{a}\right) \rho \tilde{u} \, d\xi \, d\zeta + \int_{S_\zeta} J_{12} \, \rho \tilde{w} \, d\xi \, d\eta .$$

The finite-difference form is

$$\begin{aligned}
(J)^c_{i,j,k}\left(S_m\right)_{i,j,k} = {} & \frac{1}{\Delta t}(J)^c_{i,j,k}\left(\rho_{i,j,k} - \rho^{old}_{i,j,k}\right) \\
& + \left(\frac{1}{a}\right)^c_{i+1/2,j,k} \rho_{i+1/2,j,k} \tilde{u}^c_{i+1/2,j,k} \\
& - \left(\frac{1}{a}\right)^c_{i-1/2,j,k} \rho_{i-1/2,j,k} \tilde{u}^c_{i-1/2,j,k} \\
& + \left(\frac{1}{a}\right)^c_{i,j+1/2,k} \rho_{i,j+1/2,k} \tilde{v}^c_{i,j+1/2,k} \\
& - \left(\frac{1}{a}\right)^c_{i,j-1/2,k} \rho_{i,j-1/2,k} \tilde{v}^c_{i,j-1/2,k} \\
& + \left(J_{12}\right)^c_{i,j} \rho_{i,j,k+1/2} \tilde{w}^c_{i,j,k+1/2} \\
& - \left(J_{12}\right)^c_{i,j} \rho_{i,j,k-1/2} \tilde{w}^c_{i,j,k-1/2} .
\end{aligned} \tag{62}$$

Transport Terms

In computing the finite-difference equations for momentum, we need

$(\tilde{\Sigma}_{11})_{i+1/2,j,k}$	$(\tilde{\Sigma}_{21})_{i+1/2,j,k}$	$(\tilde{\Sigma}_{31})_{i+1/2,j,k}$
$(\tilde{\Sigma}_{11})_{i-1/2,j,k}$	$(\tilde{\Sigma}_{21})_{i-1/2,j,k}$	$(\tilde{\Sigma}_{31})_{i-1/2,j,k}$

$(\tilde{\Sigma}_{12})_{i,j+1/2,k}$ $\qquad$ $(\tilde{\Sigma}_{22})_{i,j+1/2,k}$ $\qquad$ $(\tilde{\Sigma}_{32})_{i,j+1/2,k}$

$(\tilde{\Sigma}_{12})_{i,j-1/2,k}$ $\qquad$ $(\tilde{\Sigma}_{22})_{i,j-1/2,k}$ $\qquad$ $(\tilde{\Sigma}_{32})_{i,j-1/2,k}$

$(\tilde{\Sigma}_{13})_{i,j,k+1/2}$ $\qquad$ $(\tilde{\Sigma}_{23})_{i,j,k+1/2}$ $\qquad$ $(\tilde{\Sigma}_{33})_{i,j,k+1/2}$

$(\tilde{\Sigma}_{13})_{i,j,k-1/2}$ $\qquad$ $(\tilde{\Sigma}_{23})_{i,j,k-1/2}$ $\qquad$ $(\tilde{\Sigma}_{33})_{i,j,k-1/2}$

In the evaluation of the energy equation, we need

$(\tilde{q}_1)^c_{i+1/2,j,k}$ $\qquad$ $(\tilde{q}_2)^c_{i,j+1/2,k}$ $\qquad$ $(\tilde{q}_3)^c_{i,j,k+1/2}$

$(\tilde{q}_1)^c_{i-1/2,j,k}$ $\qquad$ $(\tilde{q}_2)^c_{i,j-1/2,k}$ $\qquad$ $(\tilde{q}_3)^c_{i,j,k-1/2}$

<u>Stress Terms</u>

The stress terms are evaluated from the Eqs. (41), (43), and (45). Thus,

$$(\tilde{\Sigma}_{11})_{i\pm1/2,j,k} = (x_{2\eta})_{i\pm1/2,j}(\Sigma_{11})_{i\pm1/2,j,k} - (x_{1\eta})_{i\pm1/2,j}(\Sigma_{12})_{i\pm1/2,j,k}$$

$$(\tilde{\Sigma}_{12})_{i,j\pm1/2,k} = -(x_{2\xi})_{i,j\pm1/2}(\Sigma_{11})_{i,j\pm1/2,k} + (x_{1\xi})_{i,j\pm1/2}(\Sigma_{12})_{i,j\pm1/2,k}$$

$$(\tilde{\Sigma}_{13})_{i,j,k\pm1/2} = (\Sigma_{13})_{i,j,k\pm1/2}$$

$$(\tilde{\Sigma}_{21})_{i\pm1/2,j,k} = (x_{2\eta})_{i\pm1/2,j}(\Sigma_{21})_{i\pm1/2,j,k} - (x_{1\eta})_{i\pm1/2,j}(\Sigma_{22})_{i\pm1/2,j,k}$$

$$(\tilde{\Sigma}_{22})_{i,j\pm1/2,k} = -(x_{2\xi})_{i,j\pm1/2}(\Sigma_{21})_{i,j\pm1/2,k} + (x_{1\xi})_{i,j\pm1/2}(\Sigma_{22})_{i,j\pm1/2,k}$$

$$(\tilde{\Sigma}_{23})_{i,j,k\pm1/2} = (\Sigma_{23})_{i,j,k\pm1/2}$$

$$(\tilde{\Sigma}_{31})_{i\pm1/2,j,k} = (x_{2\eta})_{i\pm1/2,j}(\Sigma_{31})_{i\pm1/2,j,k} - (x_{1\eta})_{i\pm1/2,j}(\Sigma_{32})_{i\pm1/2,j,k}$$

$$(\tilde{\Sigma}_{32})_{i,j\pm1/2,k} = -(x_{2\xi})_{i,j\pm1/2}(\Sigma_{31})_{i,j\pm1/2,k} + (x_{1\xi})_{i,j\pm1/2}(\Sigma_{32})_{i,j\pm1/2,k}$$

$$(\tilde{\Sigma}_{33})_{i,j,k\pm1/2} = (\Sigma_{33})_{i,j,k\pm1/2} \tag{63}$$

The terms $(\Sigma_{11})_{i\pm1/2,j,k}$, $(\Sigma_{13})_{i\pm1/2,j,k}$, etc. are found from Eq. (51). Therefore, for example,

$$(\Sigma_{11})_{i+1/2,j,k} = 2\mu_{i+1/2,j,k}\left(\frac{1}{(J_{12})_{i+1/2,j}}\left\{\left[\left(x_{2\eta}u\right)_{\xi}\right]_{i+1/2,j,k} - \left[\left(x_{2\xi}u\right)_{\eta}\right]_{i+1/2,j,k}\right\}\right) - \frac{2}{3}\mu\ \ldots, \tag{64}$$

etc.

The ξ, η, and ξ derivatives are evaluated as follows (f stands for any quantity):

$$\left.\begin{aligned}
(f_{\xi})_{i+1/2,j,k} &= f_{i+1,j,k} - f_{i,j,k}, \\
(f_{\xi})_{i-1/2,j,k} &= f_{i,j,k} - f_{i-1,j,k}, \\
(f_{\eta})_{i+1/2,j,k} &= \frac{1}{4}\left(f_{i,j+1,k} + f_{i+1,j+1,k} - f_{i,j-1,k} - f_{i+1,j-1,k}\right), \\
(f_{\eta})_{i-1/2,j,k} &= \frac{1}{4}\left(f_{i,j+1,k} + f_{i-1,j+1,k} - f_{i,j-1,k} - f_{i-1,j-1,k}\right), \\
(f_{\zeta})_{i+1/2,j,k} &= \frac{1}{4}\left(f_{i,j,k+1} + f_{i+1,j,k+1} - f_{i,j,k-1} - f_{i+1,j,k-1}\right), \\
(f_{\zeta})_{i-1/2,j,k} &= \frac{1}{4}\left(f_{i,j,k+1} + f_{i-1,j,k+1} - f_{i,j,k-1} - f_{i-1,j,k-1}\right), \\
(f_{\xi})_{i,j+1/2,k} &= \frac{1}{4}\left(f_{i+1,j,k} + f_{i+1,j+1,k} - f_{i-1,j,k} - f_{i-1,j+1,k}\right),
\end{aligned}\right\} \begin{matrix}(65)\\ \text{(Contd.)}\end{matrix}$$

$$\left.\begin{aligned}
(f_\xi)_{i,j-1/2,k} &= \frac{1}{4}\left(f_{i+1,j,k} + f_{i+1,j-1,k} - f_{i-1,j,k} - f_{i-1,j-1,k}\right),\\
(f_\eta)_{i,j+1/2,k} &= f_{i,j+1,k} - f_{i,j,k},\\
(f_\eta)_{i,j-1/2,k} &= f_{i,j,k} - f_{i,j-1,k},\\
(f_\zeta)_{i,j+1/2,k} &= \frac{1}{4}\left(f_{i,j,k+1} + f_{i,j+1,k+1} - f_{i,j,k-1} - f_{i,j+1,k-1}\right),\\
(f_\zeta)_{i,j-1/2,k} &= \frac{1}{4}\left(f_{i,j,k+1} + f_{i,j-1,k+1} - f_{i,j,k-1} - f_{i,j-1,k-1}\right),\\
(f_\xi)_{i,j,k+1/2} &= \frac{1}{4}\left(f_{i+1,j,k} + f_{i+1,j,k+1} - f_{i-1,j,k} - f_{i-1,j,k+1}\right),\\
(f_\xi)_{i,j,k-1/2} &= \frac{1}{4}\left(f_{i+1,j,k} + f_{i+1,j,k-1} - f_{i-1,j,k} - f_{i-1,j,k-1}\right),\\
(f_\eta)_{i,j,k+1/2} &= \frac{1}{4}\left(f_{i,j+1,k} + f_{i,j+1,k+1} - f_{i,j-1,k} - f_{i,j-1,k+1}\right),\\
(f_\eta)_{i,j,k-1/2} &= \frac{1}{4}\left(f_{i,j+1,k} + f_{i,j+1,k-1} - f_{i,j-1,k} - f_{i,j-1,k-1}\right),\\
(f_\zeta)_{i,j,k+1/2} &= \left(f_{i,j,k+1} - f_{i,j,k}\right),\\
&\text{and}\\
(f_\zeta)_{i,j,k-1/2} &= \left(f_{i,j,k} - f_{i,j,k-1}\right).
\end{aligned}\right\} \begin{array}{c}\text{(Contd.)}\\(65)\end{array}$$

Heat-flux Terms

The heat-flux terms are evaluated from Eq. (50). In finite-difference forms, these become

$$\left.(\tilde{q}_1)^c_{i\pm1/2,j,k} = -\left(\frac{\kappa}{J_{12}}\right)^c_{i\pm1/2,j,k}\left[\left(x^2_{1\eta} + x^2_{2\eta}\right)^c_{i\pm1/2,j,k}\left(T_\xi\right)^c_{i\pm1/2,j,k}\right.\right\} \begin{array}{c}(66)\\\text{(Contd.)}\end{array}$$

$$\left.\begin{aligned}
&\qquad - \left(x_{1\xi}x_{1\eta} + x_{2\xi}x_{2\eta}\right)^c_{i\pm1/2,j,k} \left(T_\eta\right)^c_{i\pm1/2,j,k}\Big],\\
(\tilde{q}_2)^c_{i,j\pm1/2,k} &= -\left(\frac{k}{J_{12}}\right)^c_{i,j\pm1/2,k} \Big[\left(x_{1\xi}^2 + x_{2\xi}^2\right)^c_{i,j\pm1/2,k} \left(T_\eta\right)^c_{i,j\pm1/2,k}\\
&\qquad - \left(x_{1\xi}x_{1\eta} + x_{2\xi}x_{2\eta}\right)^c_{i,j\pm1/2,k} \left(T_\xi\right)^c_{i,j\pm1/2,k}\Big],\\
&\text{and}\\
(\tilde{q}_3)^c_{i,j,k\pm1/2} &= -k^c_{i,j,k\pm1/2}\, a\left(T_\zeta\right)_{i,j,k\pm1/2},
\end{aligned}\right\}\text{(Contd.)}\ (66)$$

where c stands for centered or basic cell, and

$$\left.\begin{aligned}
(T_\xi)^c_{i+1/2,j,k} &= T_{i+1,j,k} - T_{i,j,k},\\
(T_\xi)^c_{i-1/2,j,k} &= T_{i,j,k} - T_{i-1,j,k},\\
(T_\eta)^c_{i+1/2,j,k} &= \frac{1}{4}\left[T_{i,j+1,k} + T_{i+1,j+1,k} - T_{i,j-1,k} - T_{i+1,j-1,k}\right],\\
(T_\eta)^c_{i-1/2,j,k} &= \frac{1}{4}\left[T_{i,j+1,k} + T_{i-1,j+1,k} - T_{i,j-1,k} - T_{i-1,j-1,k}\right],\\
(T_\eta)^c_{i,j+1/2,k} &= T_{i,j+1,k} - T_{i,j,k},\\
(T_\eta)^c_{i,j-1/2,k} &= T_{i,j,k} - T_{i,j-1,k},\\
(T_\xi)^c_{i,j+1/2,k} &= \frac{1}{4}\left[T_{i+1,j,k} + T_{i+1,j+1,k} - T_{i-1,j,k} - T_{i-1,j+1,k}\right],\\
(T_\xi)^c_{i,j-1/2,k} &= \frac{1}{4}\left[T_{i+1,j,k} + T_{i+1,j-1,k} - T_{i-1,j,k} - T_{i-1,j-1,k}\right],\\
(T_\zeta)^c_{i,j,k+1/2} &= T_{i,j,k+1} - T_{i,j,k},\\
&\text{and}\\
(T_\zeta)^c_{i,j,k-1/2} &= T_{i,j,k} - T_{i,j,k-1}.
\end{aligned}\right\}(67)$$

Also,

$$k^{c}_{i+1/2,j,k} = \text{sodium conductivity at } T^{c}_{i+1/2,j,k},$$

where

$$T^{c}_{i+1/2,j,k} = \frac{1}{2}\left(T_{i,j,k} + T_{i+1,j,k}\right)$$

and so forth.

$$\left(J_{12}\right)^{c}_{1+1/2,j} = \frac{1}{2}\left[\left(J_{12}\right)_{i+1,j} + \left(J_{12}\right)_{i+1,j+1}\right], \text{ etc.},$$

and similarly for the other terms.

All the above finite-difference equations are solved subject to the boundary conditions to be described in the following section.

V. BOUNDARY CONDITIONS

A. Velocity

Suppose there is a solid boundary at $j = 1$ as shown in Fig. 3. The velocity must vanish on the boundary, so

$$u(i,1,k) = 0, \quad v(i,1,k) = 0, \quad w(i,1,k) = 0.$$

The momentum equations are not solved, therefore, at $j = 1$. They are written for staggered cells at $j = 2$. But these are interior cells, so no special treatment is needed for the momentum equations.

B. Heat Flux and Boundary Temperatures

The energy equation and residual mass are evaluated at $j = 1$. When the energy Eq. (56) is written with $j = 1$, it involves $\tilde{v}^c_{i,j-1/2,k}$.

But

$$\tilde{v} = -x_{2\xi}u + x_{1\xi}v.$$

Thus, $\tilde{v}^c_{i,j-1/2,k}$ is zero for $j = 1$, so the convective terms vanish at solid boundaries.

The energy equation involves $(\tilde{q}_2)^c_{i,j-1/2,k}$. From Eq. (11) we know that the component of a vector normal to a surface η = const. is

$$V_\eta = \frac{-1}{\sqrt{x_{1\xi}^2 + x_{2\xi}^2}} \left(x_{2\xi}V_x - x_{1\xi}V_y\right).$$

Therefore, the heat flux normal to the wall is

$$Q_{wall} = \frac{-1}{\sqrt{x_{1\xi}^2 + x_{2\xi}^2}} \left(x_{2\xi}q_x - x_{1\xi}q_y\right).$$

So

$$Q_{wall} = \frac{1}{\sqrt{x_{1\xi}^2 + x_{2\xi}^2}} \tilde{q}_2.$$

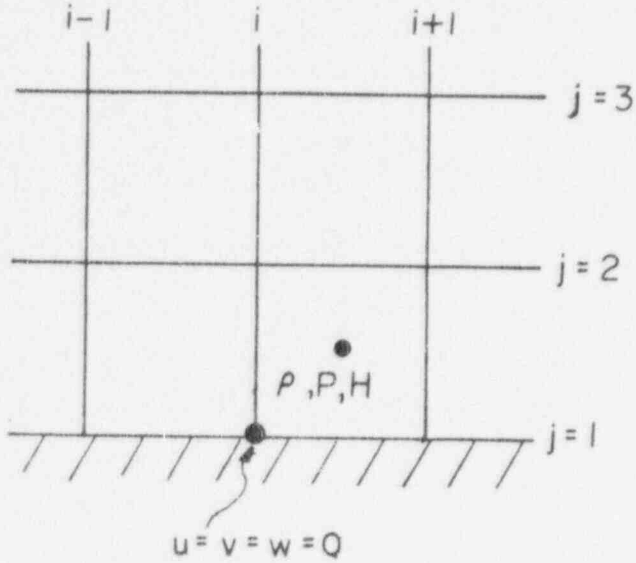


Fig. 3. Variable storage location for computational cells near a solid boundary.

Therefore, at $j = 1$

$$(\tilde{q}_2)_{i,j-1/2,k} = \sqrt{\left(x_{1\xi}^2 + x_{2\xi}^2\right)_{i,j-1/2}^c}\, Q_{wall}(k),$$

where Q_{wall} is a prescribed function of k.

We can generalize the above example to the fuel-pin case. Let us define A, B, and C as

$$\left.\begin{aligned} A &= x_{1\eta}^2 + x_{2\eta}^2, \\ B &= x_{1\xi}x_{1\eta} + x_{2\xi}x_{2\eta}, \\ &\text{and} \\ C &= x_{1\xi}^2 + x_{2\xi}^2. \end{aligned}\right\} \tag{68}$$

Then the heat fluxes normal to the surfaces of ξ = constant, η = constant, and ζ = constant are given as

$$\left.\begin{aligned} q_\xi &= \frac{1}{A}\left[x_{2\eta}q_x - x_{1\eta}q_y\right] = \frac{1}{A}\tilde{q}_1, \\ q_\eta &= \frac{1}{C}\left[-x_{2\xi}q_x + x_{1\xi}q_y\right] = \frac{1}{C}\tilde{q}_2, \\ &\text{and} \\ q_\zeta &= q_z = \tilde{q}_3 \end{aligned}\right\} \tag{69}$$

by using Eqs. (11) and (47). By using Eq. (69), Fourier's Law, $q = -\kappa\nabla T$, and Eq. (14), one can relate the heat fluxes at the boundary to the boundary temperatures as

$$\left.\begin{aligned} \tilde{q}_1 &= -\frac{\kappa}{J_{12}}\left(AT_\xi - BT_\eta\right), \\ \tilde{q}_2 &= -\frac{\kappa}{J_{12}}\left(CT_\eta - BT_\xi\right), \\ &\text{and} \\ \tilde{q}_3 &= -\kappa a T_\zeta. \end{aligned}\right\} \tag{70}$$

The boundary temperatures are defined at the face center of the cell adjacent to the boundary. The pin boundary temperatures will be assigned clockwise according to the indices of the coordinates; the wall boundary temperatures are assigned counterclockwise as shown in Fig. 4. To discretize Eq. (70) in terms of finite difference equation, four cases are considered.

Pin Top or Wall Bottom (Fig. 5a)

In this case, Q_{pin} or Q_{wall} is related to the boundary temperatures by

$$\tilde{q}_2 = \sqrt{C}\ \mathrm{Qpin} \text{ or } \sqrt{C}\ \mathrm{Qwall}$$

$$= -\frac{\kappa}{J_{12}}\left(CT_\eta - BT_\xi\right),$$

where T_η and T_ξ can be discretized as

$$T_\eta = \left(T_{ijk} - TB_{ijk}\right)/0.5$$

and

$$T_\xi = \left(TB_{i+1,j,k} - TB_{i-1,i,k}\right)/2.$$

Therefore one obtains

$$TB_{ijk} = T_{ijk} + \frac{J_{12}}{2\kappa\sqrt{C}} Q_{pin} - \frac{B}{4C}\left(TB_{i+1,j,k} - TB_{i-1,j,k}\right), \tag{71}$$

where B, C, and J_{12} are evaluated at the face center, i.e.,

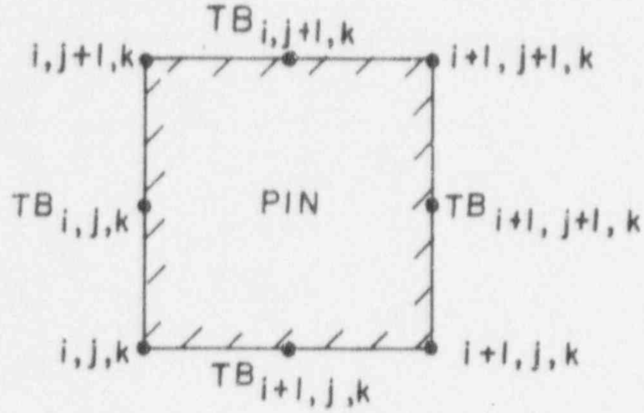
$$B = \frac{1}{2}\left(B_{i,j} + B_{i+1,j}\right), \text{ etc.}$$

Pin Bottom or Wall Top (Fig. 5b)

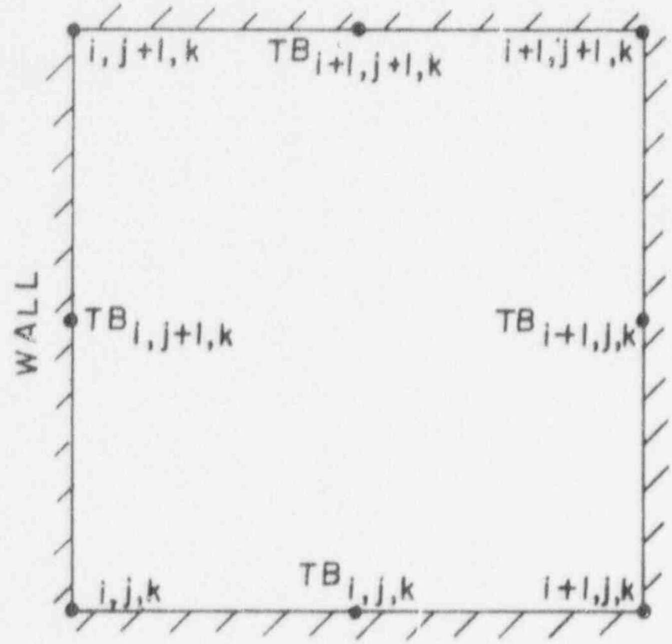
In this case, Q_{pin} or Q_{wall} is related to the boundary temperature by

$$\tilde{q}_2 = -\sqrt{C}\ Q_{pin} \text{ or } -\sqrt{C}\ Q_{wall}$$

$$= -\frac{\kappa}{J_{12}}\left(CT_\eta - BT_\xi\right),$$



(a)



(b)

Fig. 4. Locations of boundary temperatures for the case of (a) fuel pin and (b) duct wall.

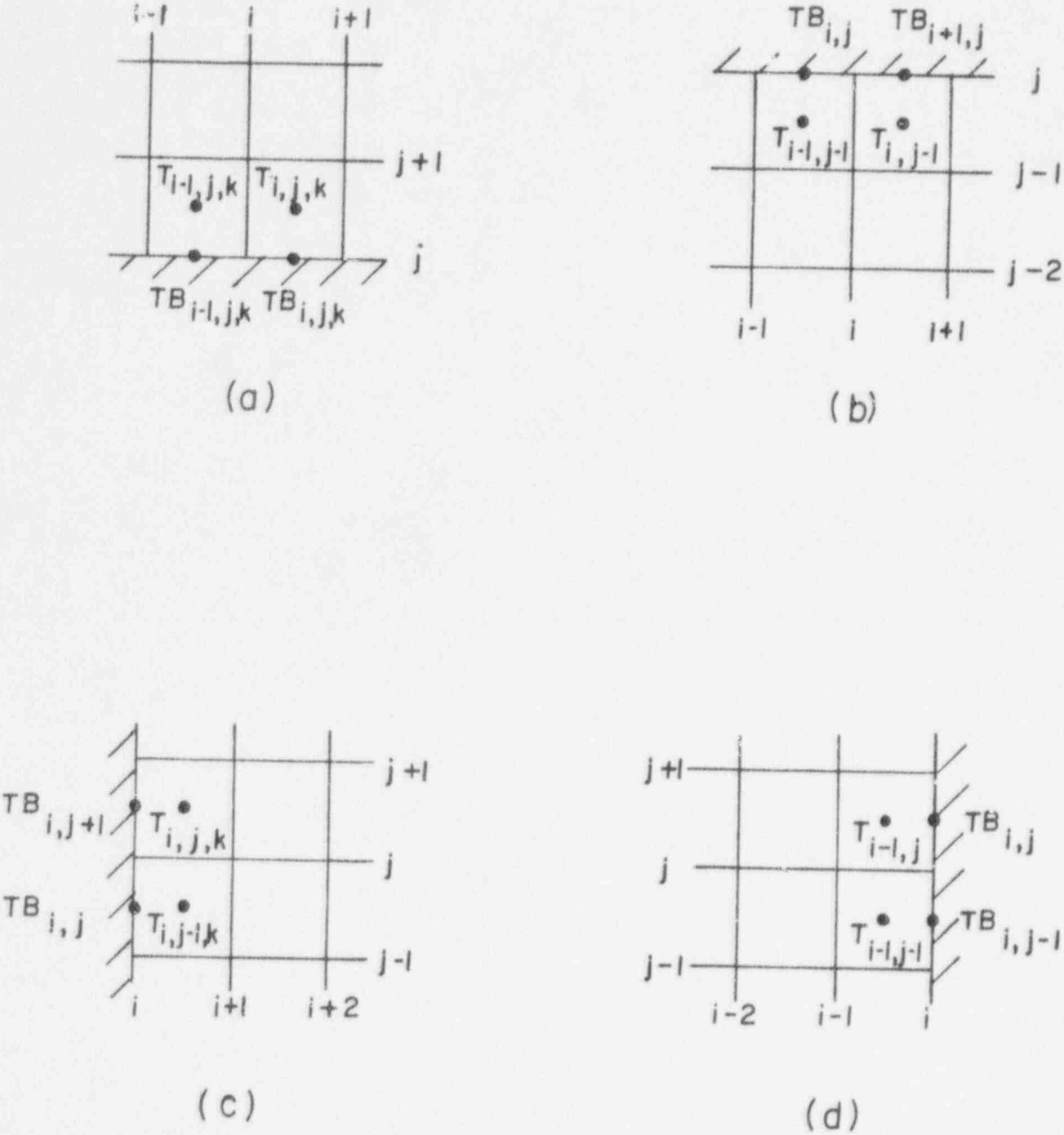


Fig. 5. Locations of boundary temperatures for the case of (a) pin top, (b) pin bottom, (c) pin right, and (d) pin left.

where T_η and T_ξ can be discretized as

$$T_\eta = (TB_{i,j} - T_{i-1,j-1})/0.5$$

and

$$T_\xi = (TB_{i+1,j} - TB_{i-1,j})/2.$$

Therefore, one obtains

$$TB_{i,j} = T_{i-1,j-1} + \frac{J_{12}}{2\kappa\sqrt{C}} Q_{pin} + \frac{B}{4C}(TB_{i+1,j} - TB_{i-1,j}), \tag{72}$$

where B, C, and J_{12} are evaluated at the face center, i.e.,

$$B = \frac{1}{2}(B_{i-1,j} + B_{i,j}) \text{ etc.}$$

Pin Right or Wall Left (Fig. 5c)

In this case, Q_{pin} or Q_{wall} is related to the boundary temperature by

$$\tilde{q}_1 = \sqrt{A}\, Q_{pin} \text{ or } \sqrt{A}\, Q_{wall}$$

$$= -\frac{\kappa}{J_{12}}(AT_\xi - BT_\eta),$$

where T_ξ and T_η can be discretized as

$$T_\xi = (T_{i,j-1,k} - TB_{i,j})/0.5$$

and

$$T_\eta = (TB_{i,j+1} - TB_{i,j-1})/2.$$

Therefore, one obtains

$$TB_{i,j} = T_{i,j-1,k} + \frac{J_{12}}{2\kappa\sqrt{A}} Q_{pin} - \frac{B}{4A}(TB_{i,j+1} - TB_{i,j-1}), \tag{73}$$

where

$$A = \frac{1}{2}(A_{i,j-1} + A_{i,j}) \text{ etc.}$$

Pin Left or Wall Right (Fig. 5d)

In this case, Q_{pin} or Q_{wall} is related to the boundary temperatures by

$$\tilde{q}_1 = -\sqrt{A}\, Q_{pin} \text{ or } -\sqrt{A}\, Q_{wall}$$

$$= -\frac{\kappa}{J_{12}}\left(AT_\xi - BT_\eta\right)$$

where

$$T_\xi = \left(TB_{i,j} - T_{i-1,j}\right)/0.5$$

and

$$T_\eta = \left(TB_{i,j+1} - TB_{i,j-1}\right)/2.$$

Therefore, one obtains

$$TB_{i,j} = T_{i-1,j} + \frac{J_{12}}{2\kappa\sqrt{A}} Q_{pin} + \frac{B}{4A}\left(TB_{i,j+1} - TB_{i,j-1}\right), \tag{74}$$

where A, B, and J_{12} are evaluated at the face center as

$$A = \frac{1}{2}\left(A_{i,j+1} + A_{i,j}\right), \text{ etc.}$$

Equations (71)-(74) can be solved once the interior fluid temperature and the dimensionless heat fluxes are known.

C. Inflow Boundary

Supposed there is an inflow boundary at k = 1. The three velocity components are prescribed at k = 1 as u(i,j,1) = 0, v(i,j,1) = 0, w(i,j,1) = 1.

The temperature of the entering fluid is prescribed as T(i,j,1). Therefore, ρ(i,j,1) can be computed. The inlet pressure P(i,j,1) is also prescribed arbitrarily. Then from P and T, enthalpy at the inlet can be calculated from the equations of state. Note that these inlet properties can be varied with time for transient applications.

The energy and residual-mass computations start with k = 1; the momentum computation starts with k = 2. Therefore the pressures at k = 1 level are adjusted right away through the use of the pressure-correction equations to be described in Sec. VI. Indexes for an inflow boundary are shown in Fig. 6a.

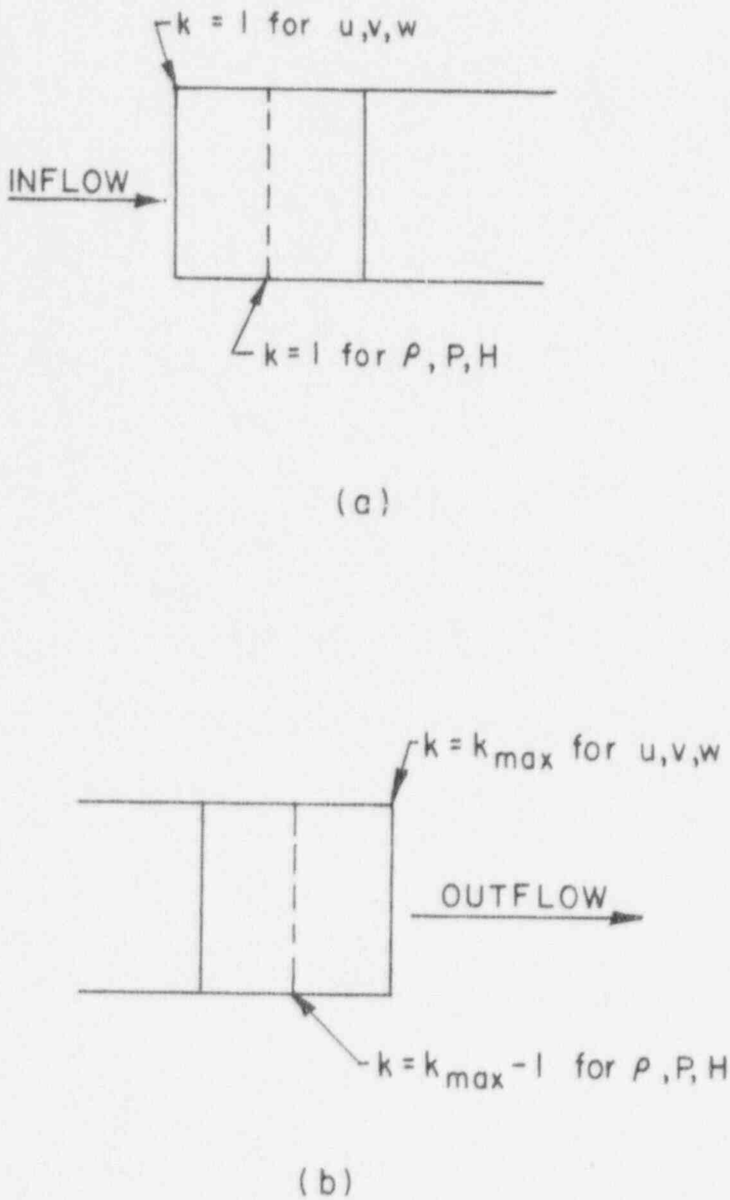


Fig. 6. Indices for (a) an inflow boundary and (b) an outflow boundary

D. Outflow Boundary

Suppose there is an outflow boundary at $k = k_{max}$. At the outflow boundary, the velocities, pressures, and temperatures are allowed to float. A zero or a constant gradient condition can be prescribed for velocities, pressure, and temperature. When a zero gradient condition is chosen, the values of the variables at the exit plane are assumed to be the same as those at the previous plane, i.e.,

$$f(i,j,k_{max}) = f(i,j,k_{max}-1).$$

When the constant gradient condition is chosen, the values of the variables at the exit plane are extrapolated from two previous planes, i.e.,

$$f(i,j,k_{max}) = 2f(i,j,k_{max}-1) - f(i,j,k_{max}-2).$$

Both the momentum and the energy equations are computed for the $k_{max}-1$ level. The residual-mass computation is also performed for the $k_{max}-1$ level. Therefore, the pressure is corrected for the $k_{max}-1$ level. These are interior cells, so no modifications are needed for the equations. The exit enthalpy and density are found from the equations of state. Indexes for an outflow boundary are shown in Fig. 6b.

VI. INITIAL CONDITIONS

Initially, the three velocity components, temperatures, and pressures must be prescribed. They can be prescribed arbitrarily, except that the velocities must be zero on solid surfaces. However, in order to expedite the convergence, 1-D calculations were performed to give better estimates of the axial pressure and temperature distributions. Velocities in the interior of the flow region are initialized to be the same as the inlet velocities.

A simple friction-factor correlation for laminar flow in the dimensionless form,

$$\Delta P = \frac{32}{Re} \Delta L,$$

can be used to estimate the pressure drop of the rod bundle. This estimated overall pressure drop is divided uniformly along the rod bundle.

The hydrostatic pressure P_s must also be found. It is obtained by solving the following three equations in dimensionless forms:

$$\frac{\partial P_s}{\partial x} = \frac{1}{F^2} \rho_s g_x,$$

$$\frac{\partial P_s}{\partial y} = \frac{1}{F^2} \rho_s g_y,$$

and

$$\frac{\partial P_s}{\partial z} = \frac{1}{F^2} \rho_s g_z,$$

where ρ_s is the initial density. These equations can be solved to give

$$(P_s)_{i,j,k} = P_{1,1,1} + \frac{\rho_s}{F^2} [g_x(x_{i,j,k} - x_{1,1,1}) + g_y(y_{i,j,k} - y_{1,1,1}) + g_z(z_{i,j,k} - z_{1,1,1})],$$

where $P_{1,1,1}$ is the pressure at reference point (1,1,1), and

$$x_{i,j,k} = (x_1)_{i,j},$$

$$y_{i,j,k} = (x_2)_{i,j},$$

and

$$z_{i,j,k} = z(k)_{i,j}.$$

The initial temperature distribution is estimated by solving the one-dimensional heat-balance equation,

$$\rho w A_f C_p \left(T_{k+1} - T_k\right) = \Delta z P_h \bar{q}''(k),$$

where A_f is the flow area, Δz is the axial length between level k+1 and k, P_h is the heated perimeter and $\bar{q}''(k)$ is the axial heat flux of the rod bundle. The above equation can be cast into a more direct form as

$$T_{k+1} = T_k + \frac{\Delta z P_h \bar{q}''(k)}{\rho w A_f C_p} .$$

VII. PRESSURE-CORRECTION SCHEME

In the case of a highly incompressible fluid, the density is a very weak function of pressure. Therefore, even if the density and temperature are known, the pressure cannot be accurately determined by using the equations of state. This deficiency necessitates an independent calculation scheme for the pressure computation. The present pressure-correction scheme consists of two parts. The first part deals with the pressure corrections in the ξ-η plane and the second with those in the ζ direction.

In the ξ-η plane, a procedure analogous to the Chorin procedure[9] for incompressible flow is used for the continuity equation. The pressure at each point is updated in proportion to the residue of the continuity equation. Thus,

$$p^{(n+1)} = p^{(n)} - \phi[\rho_t + \nabla \cdot (\rho\vec{v})], \tag{75}$$

where the form of the factor ϕ is obtained from the combination of the three momentum equations and the continuity equation as follows. The divergence of the momentum equation, Eq. (26), yields

$$\frac{\partial}{\partial t}[\nabla \cdot (\rho\vec{v})] = -\nabla^2 p + \text{other terms}.$$

Then, in difference form,

$$-\frac{\nabla \cdot (\rho\vec{v})}{\Delta t} = -\left(-\frac{2p}{\Delta x^2} - \frac{2p}{\Delta y^2} - \frac{2p}{\Delta z^2}\right) + \text{other terms}.$$

Thus,

$$p \approx -\frac{1}{2\Delta t}\,\frac{\Delta x^2 \Delta y^2 \Delta z^2}{\Delta y^2 \Delta z^2 + \Delta x^2 \Delta z^2 + \Delta x^2 \Delta y^2}\,\nabla \cdot (\rho\vec{v}).$$

In the transformed plane,

$$\Delta x \Delta y \approx J_{12},$$

$$\Delta x^2 + \Delta y^2 \approx \left(x_{1\eta}^2 + x_{2\eta}^2\right) + \left(x_{1\xi}^2 + x_{2\xi}^2\right)$$

and

$$\Delta z^2 \approx 1/a^2.$$

Thus,

$$p \approx -\frac{1}{2\Delta t}\frac{\Delta x^2 \Delta y^2}{\Delta y^2 + \Delta x^2 + \dfrac{\Delta x^2 \Delta y^2}{\Delta z^2}} \nabla \cdot (\rho \vec{v})$$

or

$$p \approx -\frac{1}{2\Delta t}\frac{J_{12}^2}{\left(x_{1\eta}^2 + x_{2\eta}^2\right) + \left(x_{1\xi}^2 + x_{2\xi}^2\right) + \left(aJ_{12}\right)^2} \nabla \cdot (\rho \vec{v}).$$

The proper functional form of the factor ϕ is thus

$$\phi = \frac{1}{2\Delta t}\frac{\omega_1 J_{12}^2}{\left(x_{1\eta}^2 + x_{2\eta}^2\right) + \left(x_{1\xi}^2 + x_{2\xi}^2\right) + \left(aJ_{12}\right)^2}, \tag{76}$$

where ω_1 is an acceleration parameter. This numerical factor has been inserted simply for correspondence with the SOR form of the Laplacian. Equations (75) and (76) can be used to determine the pressure change after the mass residue is computed for the cell. If the residual mass is positive, a case of more mass outflow than inflow, the pressure of the cell is lowered to pull more mass into the cell. The pressure is raised when the residual mass is negative. However, ϕ as given by Eq. (76) is negligibly small when Δt is large. This implies that the pressure correction becomes ineffective when a large Δt is chosen ror a steady-state calculation. Due to this reason, a constant term, Ω, is added to the $1/\Delta t$ term so that when Δt is small, this Ω term is negligible and when Δt is large, this constant term becomes dominating. The final formula for the pressure correction is given as

$$\Delta p = S_m \frac{-\omega_1 J_{12}^2}{\left(x_{1\eta}^2 + x_{2\eta}^2\right) + \left(x_{1\xi}^2 + x_{2\xi}^2\right) + \left(aJ_{12}\right)^2}\left(\Omega + \frac{1}{z\Delta t}\right), \tag{77}$$

where S_m is the residue from the continuity equation and Ω can be specified by users.

This pressure-correction scheme becomes very ineffective for calculating the axial pressure drop when the shape of the computational cell is very elongated in the axial direction. The third term in the denominator of Eq. (77) is negligibly small in this case. In order to remedy this deficiency, the following scheme has been devised.

Once the pressure corrections for all the cells in a given plane are completed, the overall planar mass flow rate is computed for the given plane. The

difference between this computed planar mass flow rate and the inlet planar mass flow rate is used to correct axially all the downstream pressures according to the following formula:

$$\Delta P_{axial} = -\frac{\omega_2 \omega_1}{a(\sum_i J_{12})}\left(\Omega + \frac{1}{2\Delta t}\right)\left[\frac{1}{\Delta t}\sum_i \frac{J_{12}}{a}(\rho - \rho^{old}) + \Delta(\sum_i \rho w J_{12})\right], \quad (78)$$

where a is defined in Eq. (4), ω_2 is the axial acceleration factor, ρ^{old} is the density at the previous time step, and all the summations, $\sum_i$'s are summing over all the cells in a given plane. The above formula can be derived from the residue mass equation, Eq. (62), and the cell pressure-correction equation, Eq. (77). Summation of Eq. (62) over all the cells in a given axial plane yields

$$\frac{1}{a}\bar{J}_{12}\sum_i S_m = \frac{1}{\Delta t}\sum_i J(\rho - \rho^{old}) + \Delta(\sum_i \rho w J_{12}),$$

where $\bar{J}_{12}$ is the averaged surface area in the axial plane as defined by

$$\bar{J}_{12} = \frac{\sum_i J_{12} S_m}{\sum_i S_m}.$$

Summation of Eq. (77) over all the cells in the same axial plane yields

$$\sum_i \Delta P = -\frac{\omega_1}{a^2}\left(\Omega + \frac{1}{2\Delta t}\right)\sum_i S_m,$$

where all the derivatives of x_1 and x_2 have been omitted since only the axial direction is considered here. Cancellation of $\sum_i S_m$ from the above equations gives the following result:

$$\sum_i \Delta P = -\frac{\omega_1}{a\bar{J}_{12}}\left(\Omega + \frac{1}{2\Delta t}\right)\left[\frac{1}{\Delta t}\sum_i \frac{J_{12}}{a}(\rho - \rho^{old}) + \Delta(\sum_i \rho w J_{12})\right].$$

Dividing by the total number of cells in the axial plane in the above equation, one obtains the average axial pressure-correction equation as given by Eq. (78).

This axial pressure correction for a given plane is added on to all the planes downstream of the given plane. This procedure provides a very effective means of obtaining rapidly converging solutions for both steady-state and transient calculations.

VIII. CALCULATION PROCEDURE

The solution is done by a cell-by-cell successive overrelaxation (SOR) iterative method. The momentum equation is solved first. All the terms containing the velocity of the cell to be solved by the momentum equation are called central terms. An analogous definition is also used for the energy equation. The central terms from convective and stress terms are factored to the left of the momentum equation to be combined with the rate-change term in order to enhance convergence. The energy equation is solved next for the given cell. The central terms from the convective terms are also factored to the left of the energy equation to enhance convergence. However, such a factoring procedure cannot be performed for the heat-conduction terms due to the absence of a simple relation between enthalpies and temperatures. A false-position type of Newton iteration is performed at each cell to produce the same effect. This technique enhances the rate of convergence tremendously for the enthalpy calculation. It deserves a brief description as follows.

The heat-conduction terms are first separated into two groups: the central terms and the noncentral terms. An interim enthalpy is first calculated with convective terms, noncentral heat-conduction terms, and source terms included, except the central heat-conduction terms. Let us call this interim enthalpy h*. The enthalpy of the cell is then calculated as

$$h^{n+1} = h^{*} + \Lambda T^{n}, \tag{79}$$

where n is the index of iteration, T^n is the temperature corresponding to the previously iterated enthalpy h^n, and ΛT^n is the central term of the heat-conduction terms. Based on the iterated enthalpy, the temperature is updated and the next iterated enthalpy is calculated using Eq. (79). This process is repeated until the iterated enthalpy satisfies a given tolerance criterion.

The above calculations for the momentum and the energy equations are continued from cell to cell for a given plane. After the sweeping for the plane is completed, the residual masses for all the cells in the plane are computed and the pressures are corrected in proportion to the residual masses. This procedure is then repeated for the next plane. The entire computational field is swept down the assembly from the inlet to the outlet until the convergence criteria are satisfied. The sweeping within a given plane can be performed with a fixed orientation or alternating orientations.

Once the coolant temperatures are computed, the fuel-pin and duct-wall temperatures are computed by using the fuel-pin model and the duct-wall model described in the following section. These latest fuel-pin and duct-wall tempertures are to be used to update the new heat flux coming out of the fuel pin and the duct wall. These updated heat fluxes are then used to calculate the coolant temperatures throughout the entire flow field. This iterative computation

procedure is repeated at a given time step until the changes in the heat fluxes are less than a prescribed convergence limit. Then the entire coolant and fuel-pin temperature computation is repeated for the next time step.

Due to the staggered-grid arrangement, the velocity computation for the k = 1 level is not performed, whereas the energy equation is. At the exit level, the velocity, enthalpy, and pressure are extrapolated based on those values on the previous levels. The detailed flow chart showing all the major computational steps and logic is given in Appendix A.

IX. PHYSICAL MODELS

A. Fuel-pin Model

A 1-D multizone fuel-pin model is included in the code. This model is similar to the one used in COMMIX-1A[10] and SAS2A.[11] It takes into account the coolant, cladding, cladding-fuel gap, and several rings of fuel regions. It allows for the thermal expansions of all these regions. It includes the radial heat conduction and neglects the circumferential and axial heat conduction. Because of the 1-D feature it uses the Tri-Diagonal Matrix Algorithm (TDMA) in solving all the radial temperatures. To allow for the use of a large time step in a steady-state calculation, the finite-difference equations are formulated fully implicit in time. The main equations of the model are derived briefly in the following paragraphs.

The radial nodes in the fuel and the cladding of a fuel rod are shown in Fig. 7. The time-dependent temperature distribution is obtained by solving the heat-balance equation in cylindrical coordinates,

$$\frac{1}{r}\frac{d}{dr}\left(\kappa r\frac{\partial T}{\partial r}\right) + Q = \rho C_p \frac{\partial T}{\partial t}, \tag{80}$$

where

T = temperature,

κ = thermal conductivity,

ρ = density,

C_p = heat capacity,

and

Q = volumetric rate of heat generation.

Equation (80) is applied to a control volume within a fuel pin. When the control volume is next to the surface of the pin, the heat conduction on the surface is replaced by the heat-transfer coefficients multiplied by the temperature gradient. Heat balances of Eq. (80) for various regions are given below. The dashed lines in Fig. 7 indicate the boundaries of various control volumes. For simplicity, all the conductivities and heat capacities are assumed to be independent of temperature.

1. Inner Fuel Surface

The heat-balance equation for this region is given as

$$\rho C_p \frac{\partial T_1}{\partial t}\left(r_2^2 - r_1^2\right)\pi\Delta z = \kappa\left.\frac{\partial T}{\partial r}\right|_{r_2} 2\pi r_2\Delta z + Q_1\left(r_2^2 - r_1^2\right)\pi\Delta z. \tag{81}$$

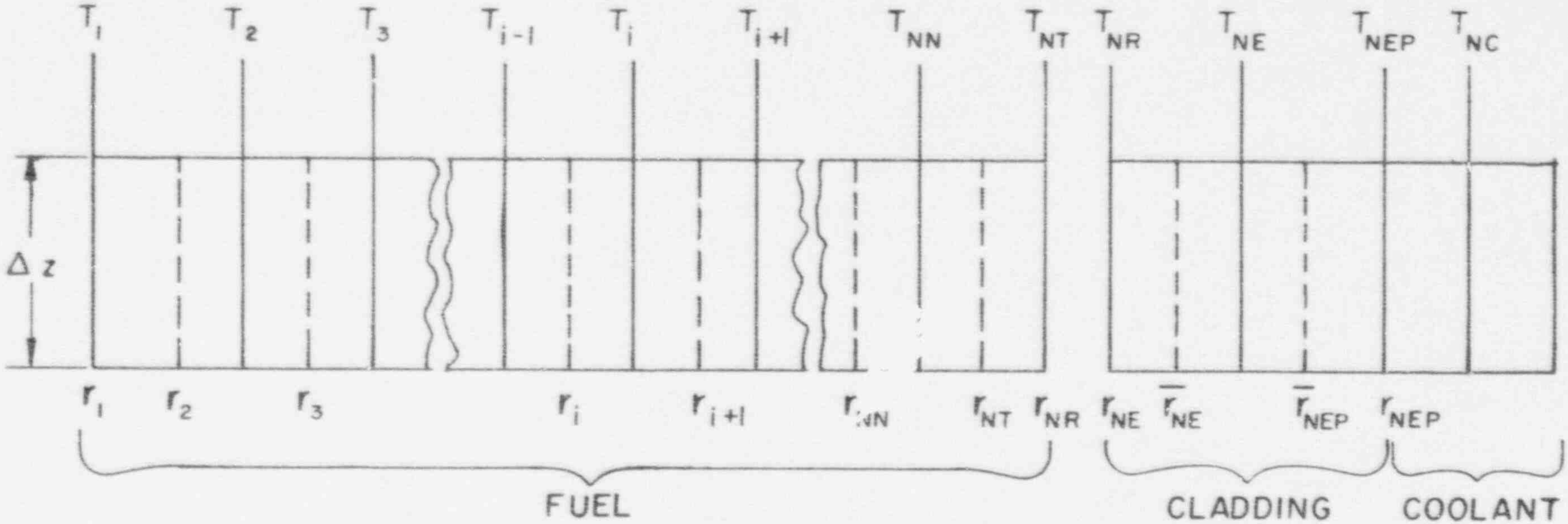


Fig. 7. Radial nodes in the fuel and the clad region of a fuel rod

The time derivative and radial derivative can be expressed as

$$\frac{\partial T_1}{\partial t} = \frac{T_1 - T_1^{old}}{\Delta t}$$

and

$$\frac{\partial T}{\partial r} = \frac{2(T_2 - T_1)}{r_2 + r_3 - 2r_1},$$

where all the temperatures are evaluated at the new time except T^{old}, which is evaluated at the old time. The subscripts are the radial indices. Substituting these two equations into Eq. (81), one obtains

$$\rho C_p \frac{T_1 - T_1^{old}}{\Delta t}(r_2^2 - r_1^2) = \frac{4\kappa(T_2 - T_1)r_2}{r_2 + r_3 - 2r_1} + Q_1(r_2^2 - r_1^2). \tag{82}$$

Rearranging Eq. (82) with the source term on the right-hand side of the equation, one obtains

$$T_1\left[\frac{\rho C_p}{\Delta t}(r_2^2 - r_1^2) + \frac{4\kappa r_2}{r_2 + r_3 - 2r_1}\right] + T_2\left(-\frac{4\kappa r_2}{r_2 + r_3 - 2r_1}\right)$$

$$= \frac{\rho C_p}{\Delta t} T_1^{old}(r_2^2 - r_1^2) + Q_1(r_2^2 - r_1^2). \tag{83}$$

2. Second Fuel Region

The heat balance for the second control volume is given as

$$\rho C_p \frac{\partial T_2}{\partial t}(r_3^2 - r_2^2)\pi\Delta z = -\kappa\frac{\partial T}{\partial r}\bigg|_{r_2} \cdot \partial\pi r_2\Delta z + \kappa\frac{\partial T}{\partial r}\bigg|_{r_3} \cdot 2\pi r_3\Delta z$$

$$+ Q_2\pi(r_3^2 - r_2^2)\Delta z. \tag{84}$$

If the finite-difference expressions for the derivatives are inserted in Eq. (84), one obtains

$$\rho C_p \frac{T_2 - T_2^{old}}{\Delta t}(r_3^2 - r_2^2) = -\frac{4\kappa(T_2 - T_1)r_2}{r_2 + r_3 - 2r_1} + \frac{4\kappa(T_3 - T_2)r_3}{r_4 - r_2} + Q_2(r_3^2 - r_2^2).$$

This equation can be rearranged to give

$$T_1\left(-\frac{4\kappa r_2}{r_2 + r_3 + 2r_1}\right) + T_2\left[\frac{\rho C_p}{\Delta t}\left(r_3^2 - r_2^2\right) + \frac{4\kappa r_2}{r_2 + r_3 + 2r_1} + \frac{4\kappa r_3}{r_4 - r_2}\right]$$

$$+ T_3\left(-\frac{4\kappa r_2}{r_4 - r_2}\right) = \frac{\rho C_p}{\Delta t} T_2^{old}\left(r_3^2 - r_2^2\right) + Q_2\left(r_3^2 - r_2^2\right). \tag{85}$$

3. Third to NNth Region

The heat balance for these regions is given as

$$\rho C_p \frac{\partial T_i}{\partial t}\left(r_{i+1}^2 - r_i^2\right)\pi\Delta z = -\kappa \frac{\partial T}{\partial r}\bigg|_{r_i} \cdot 2\pi r_i \Delta z + \kappa \frac{\partial T}{\partial r}\bigg|_{r_{i+1}} 2\pi r_{i+1}\Delta z$$

$$+ Q_i\left(r_{i+1}^2 - r_i^2\right)\pi\Delta z.$$

The finite-difference form after rearrangement is

$$T_{i-1}\left(-\frac{4\kappa r_i}{r_{i+1} - r_{i-1}}\right) + T_i\left[\frac{\rho C_p}{\Delta t}\left(r_{i+1}^2 - r_i^2\right) + \frac{4\kappa r_i}{r_{i+1} - r_{i-1}} + \frac{4\kappa r_i}{r_{i+2} - r_i}\right]$$

$$+ T_{i+1}\left(-\frac{4\kappa r_{i+1}}{r_{i+2} - r_i}\right) = T_i^{old}\frac{\rho C_p}{\Delta t}\left(r_{i+1}^2 - r_i^2\right) + Q_i\left(r_{i+1}^2 - r_i^2\right). \tag{86}$$

4. Outer Fuel Surface

The heat balance in this region is given by

$$\rho C_p \frac{\partial T_{NT}}{\partial t}\left(r_{NR}^2 - r_{NT}^2\right)\pi\Delta z = -\kappa \frac{\partial T}{\partial r}\bigg|_{r_{NT}} 2\pi r_{NT}\Delta z - \left(T_{NT} - T_{NR}\right)h_b 2\pi r_{NR}\Delta z$$

$$+ Q_{NT}\left(r_{NR}^2 - r_{NT}^2\right)\pi\Delta z,$$

where h_b is the bond conductance.

The finite-difference form after rearrangement is

$$T_{NN}\left(-\frac{4\kappa r_{NT}}{2r_{NR} - r_{NT} - r_{NN}}\right) + T_{NT}\left[\frac{\rho C_p}{\Delta t}\left(r_{NR}^2 - r_{NT}^2\right) + \frac{4k r_{NT}}{2r_{NR} - r_{NT} - r_{NN}} + 2h_b r_{NR}\right]$$

$$+ T_{NR}\left(-2h_b r_{NR}\right) = T_{NT}^{old}\frac{\rho C_p}{\Delta t}\left(r_{NR}^2 - r_{NT}^2\right) + Q_{NT}\left(r_{NR}^2 - r_{NT}^2\right), \tag{87}$$

where the Stefan-Boltzmann radiation from the fuel surface is neglected.

5. Inner Surface of Cladding

The heat balance for this region is similar to the one for the outer surface of the fuel. One obtains

$$\rho C_p \frac{\partial T_{NR}}{\partial t}(\bar{r}^2_{NE} - r^2_{NE})\pi\Delta z = (T_{NT} - T_{NR})h_b 2\pi r_{NR}\Delta z + \kappa \frac{\partial T}{\partial r}\bigg|_{\bar{r}_{NE}} \cdot 2\pi\bar{r}_{NE}\Delta z.$$

We have assumed that there is no heat generation in the cladding. The finite-difference form after rearrangement becomes

$$T_{NT}(-2h_b r_{NR}) + T_{NR}\left[\frac{\rho C_p}{\Delta t}(\bar{r}^2_{NE} - r^2_{NE}) + 2h_b r_{NR} + \frac{4\kappa\bar{r}_{NE}}{r_{NEP} - r_{NE}}\right]$$

$$+ T_{NE}\left(-\frac{4\kappa\bar{r}_{NE}}{r_{NEP} - r_{NE}}\right) = T^{old}_{NR}\frac{\rho C_p}{\Delta t}(\bar{r}^2_{NE} - r^2_{NE}). \tag{88}$$

6. Central Cladding Region

The heat balance for this region is given as

$$\rho C_p \frac{\partial T_{NE}}{\partial t}(\bar{r}^2_{NEP} - \bar{r}^2_{NE})\pi\Delta z = -\kappa\frac{\partial T}{\partial r}\bigg|_{\bar{r}_{NE}} 2\pi\bar{r}_{NE}\Delta z + \kappa\frac{\partial T}{\partial r}\bigg|_{\bar{r}_{NEP}} \cdot 2\pi\bar{r}_{NEp}\Delta z,$$

which gives the following expression after rearranging:

$$T_{NR}\left(-\frac{4\kappa\bar{r}_{NE}}{r_{NEP} - r_{NE}}\right) + T_{NE}\left[\frac{\rho C_p}{\Delta t}(\bar{r}^2_{NEP} - \bar{r}^2_{NE}) + \frac{4\kappa\bar{r}_{NE}}{r_{NEP} - r_{NE}} + \frac{4\kappa\bar{r}_{NEp}}{r_{NEP} - r_{NE}}\right]$$

$$+ T_{NEP}\left(-\frac{4k\bar{r}_{NEP}}{r_{NEP} - r_{NE}}\right) = T^{old}_{NE}\frac{\rho C_p}{\Delta t}(\bar{r}^2_{NEP} - \bar{r}^2_{NE}). \tag{89}$$

7. Outer Surface of Cladding

The heat balance for this region is

$$\rho C_p \frac{\partial T_{NEP}}{\partial t}(r^2_{NEP} - \bar{r}^2_{NEP})\pi\Delta z = -\kappa\frac{\partial T}{\partial r}\bigg|_{\bar{r}_{NEP}} 2\pi\bar{r}_{NEP}\Delta z$$

$$- (T_{NEP} - T_{NC})h_C 2\pi r_{NEP}\Delta z,$$

where h_c is the heat-transfer coefficient on the surface of the cladding. On inserting the finite-difference expressions for the derivatives and rearranging, one obtains

$$T_{NE}\left(-\frac{4\kappa\bar{r}_{NEP}}{r_{NEP}-r_{NE}}\right)+T_{NEP}\left[\frac{\rho C_p}{\Delta t}\left(r_{NEP}^2-\bar{r}_{NEP}^2\right)+\frac{4\kappa\bar{r}_{NEP}}{r_{NEP}-r_{NE}}+2h_c r_{NEP}\right]$$

$$=T_{NEP}^{old}\frac{\rho C_p}{\Delta t}\left(r_{NEP}^2-\bar{r}_{NEP}^2\right)+2T_{NC}h_c r_{NEP}. \tag{90}$$

In order to combine all the above finite-difference equations, let us define the following quantities:

$$\left.\begin{aligned}
\alpha_i &= \frac{\Delta t}{\rho C_p\left(r_{i+1}^2-r_i^2\right)} \quad \text{for } i = 1 \text{ to NT},\\
\alpha_{NR} &= \frac{\Delta t}{\rho C_p\left(\bar{r}_{NE}^2-r_{NE}^2\right)},\\
\alpha_{NE} &= \frac{\Delta t}{\rho C_p\left(\bar{r}_{NEP}^2-\bar{r}_{NE}^2\right)},\\
\alpha_{NEP} &= \frac{\Delta t}{\rho C_p\left(r_{NEP}^2-\bar{r}_{NEP}^2\right)},\\
\beta_1 &= 0,\\
\beta_2 &= \frac{4\kappa r_2}{r_2+r_3-2r_1},\\
\beta_i &= \frac{4kr_i}{r_{i+1}-r_{i-1}} \quad \text{for } i = 3 \text{ to NN},\\
\beta_{NT} &= \frac{4\kappa r_{NT}}{2r_{NR}-r_{NT}-r_{NN}},\\
\beta_{NR} &= 2h_b r_{NR},\\
\beta_{NE} &= \frac{4\kappa\bar{r}_{NEP}}{r_{NEP}-r_{NE}},
\end{aligned}\right\} \tag{91}$$

(Contd.)

$$\left.\begin{aligned}
\beta_{NEP} &= \frac{4\kappa\bar{r}_{NEP}}{r_{NEP} - r_{NE}}, \\
\beta_{NC} &= 2h_c r_{NEP}, \\
\psi_i &= Q_i\left(r_{i+1}^2 - r_i^2\right) \quad \text{for } i = 1 \text{ to NN}, \\
\psi_{NT} &= Q_{NT}\left(r_{NR}^2 - r_{NT}^2\right), \\
\psi_{NR} &= 0, \\
\psi_{NE} &= 0, \\
\psi_{NEp} &= 0, \\
d_i &= T_i^{old}\left(\frac{1}{\alpha_1}\right) + \psi_i \quad \text{for } i = 1 \text{ to NEP}.
\end{aligned}\right\} \qquad \text{(Contd.)} \tag{91}$$

With these definitions, Eqs. (83)-(90) can be combined as

$$T_{i-1}\left(-\beta_i\right) + T_i\left(\frac{1}{\alpha_i} + \beta_i + \beta_{i+1}\right) + T_{i+1}\left(-\beta_{i+1}\right) = d_i \quad \text{for } i = 1 \text{ to NEP}. \tag{92}$$

Equation (92) can be solved by the Gaussian elimination process and back substitution.

Let us define the following new variables:

$$A_1 = \frac{1}{\alpha_1} + \beta_2,$$

$$A_i = \frac{1}{\alpha_i} + \beta_i + \beta_{i+1} - \frac{\beta_i^2}{A_{i-1}} \quad \text{for } i = 2 \text{ to NEP},$$

$$S_1 = d_1,$$

and

$$S_i = d_i + \frac{\beta_i S_{i-1}}{A_{i-1}} \quad \text{for } i = 2 \text{ to NEP}.$$

Then by solving Eq. (92) for $i = 1$, one obtains T_1 in terms of T_2,

$$T_1 = \frac{d_1 + \beta_2 T_2}{\frac{1}{\alpha_1} + \beta_1 + \beta_2} = \frac{S_1 + \beta_2 T_2}{A_1}. \tag{93}$$

By substituting Eq. (93) into Eq. (92) for $i = 2$, one obtains T_2 in terms of T_3 as

$$T_2 = \frac{d_2 + \frac{\beta_2 d_1}{A_1} + \beta_3 T_3}{\frac{1}{\alpha_2} + \beta_2 + \beta_3 - \frac{\beta_2^2}{A_1}} = \frac{S_2 + \beta_3 T_3}{A_2}. \tag{94}$$

By continuing this substitution, one obtains the following general expression:

$$T_i = \frac{S_1 + \beta_{i+1} T_{i+1}}{A_1} \quad \text{for } i = 1 \text{ to NEP}. \tag{95}$$

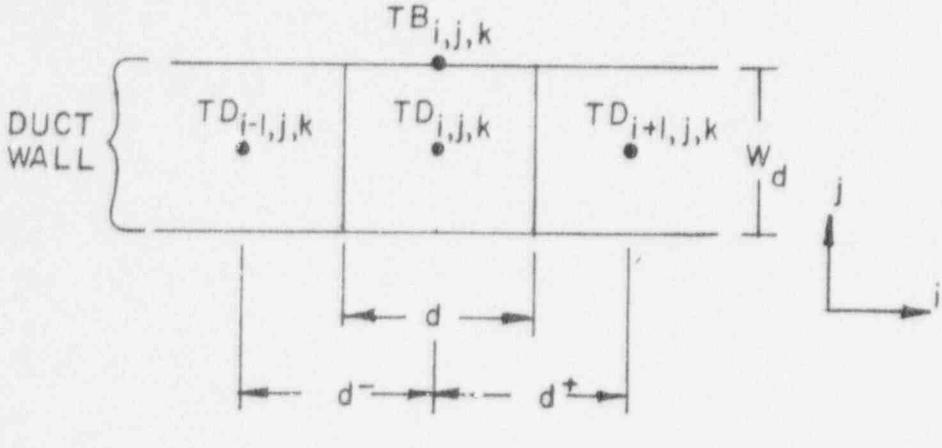
When $i = \text{NEP}$, $T_{i+1} = T_{NC}$, which is the coolant temperature.

Therefore, once the coolant temperature is known, Eq. (95) can be used in a reverse order to solve all the temperatures inside the fuel pin. This implicit numerical scheme eliminates the restriction on the time-step size. It is particularly advantageous when the steady-state solution is desired. In that case, the time-step size can be chosen as an extremely large number, such as 10^{20} s, and the steady-state solutions are yielded directly.

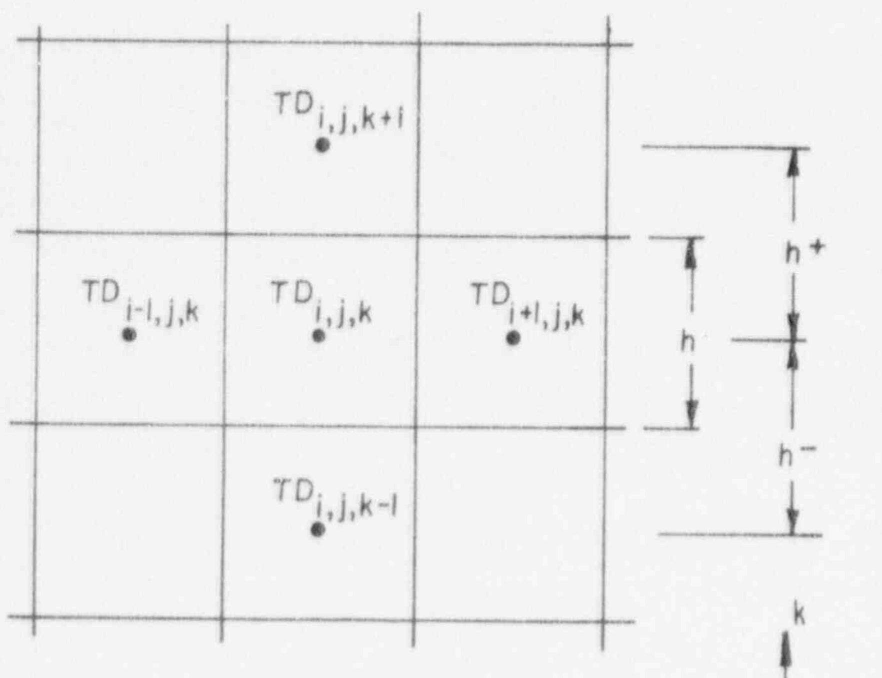
B. Duct-wall Model

The radial, axial, and circumferential heat transfers are all included in this duct-wall heat-transfer model. Figure 8 shows the cross-sectional view of the duct wall and the location indices. The heat balance of the cell gives

$$\begin{aligned}
\rho C_p \frac{TD_{i,j,k} - TD_{i,j,k}^{old}}{\Delta t} W_d hd &= \kappa \frac{TB_{i,j,k} - TD_{i,j,k}}{W_d/2} hd \\
&+ \kappa \frac{TD_{i+1,j,k} - TD_{i,j,k}}{d_+} W_d h + \kappa \frac{TD_{i-1,j,k} - TD_{i,j,k}}{d_-} W_d h \\
&+ \kappa \frac{TD_{i,j,k+1} - TD_{i,j,k}}{h_+} W_d d + \kappa \frac{TD_{i,j,k-1} - TD_{i,j,k}}{h_-} W_d d,
\end{aligned} \tag{96}$$



(a)



(b)

Fig. 8. Locations of duct-wall temperatures in (a) ij plane and (b) ik plane

where

$$d = \frac{1}{2}\left(d_+ + d_-\right),$$

$$h = \frac{1}{2}\left(h_+ + h_-\right),$$

$TB_{i,j,k}$ is the boundary temperature, and $TD_{i,j,k}$ is the duct-wall temperature at location (i,j,k). All the temperatures except TD^{old} in Eq. (96) are evaluated at the present time. This implicitness in time is consistent with those used in the fuel-pin model. Rearranging all the central terms to the left, one can write Eq. (96) as

$$TD_{i,j,k}\left(\frac{\rho C_p}{\Delta t} + \frac{2\kappa}{W_d^2} + \frac{2\kappa}{d_+ d_-} + \frac{2\kappa}{h_+ h_-}\right) = TD^{old}_{i,j,k}\frac{\rho C_p}{\Delta t} + TB_{i,j,k}\frac{2\kappa}{W_d^2}$$

$$+ TD_{i+1,j,k}\frac{\kappa}{d_+ d} + TD_{i-1,j,k}\frac{\kappa}{d_- d} + TD_{i,j,k+1}\frac{\kappa}{h_+ h}$$

$$+ TD_{i,j,k-1}\frac{\kappa}{h_- h}. \qquad (97)$$

Therefore, TD can be solved once the TD^{old}, TB, and the neighboring TD's are known. This is done by cell-by-cell iterative procedure within the momentum and energy calculational loop.

C. Grid-resistance Model

Two major effects due to the presence of the grid are the pressure drop and the flow redistribution. These two effects are modeled by empirical correlations as follows. The flow region inside the rod bundle is first divided into three types of subchannels: the central, the wall, and the corner subchannels. The averaged subchannel velocity, $\bar{w}$, is computed for each subchannel, and the pressure drop of the subchannel due to the presence of the grid in the given axial level is modeled[12] by

$$\Delta p = n_G C_v \varepsilon^2 \frac{\rho \bar{w}^2}{2}, \qquad (98)$$

where n_G is the number of grids within the given axial step, C_v is the drag coefficient in the range of 6 or 7, and ε is the fraction of the cross-sectional area blocked by the grid spacer; ε's are different for different subchannels. Most of detailed information on the grid-space design are of a proprietary nature. Therefore, ε's are to be estimated by users. They are usually in the range of 0.3-0.4.

Equation (98) is included in the z-momentum equation (Eq. 55) as

$$\frac{1}{\Delta t}(J)_{i,j,k}\left(\rho_{i,j,k}^{old}\right)^{st} w_{i,j,k} = \text{other terms}$$

$$- (J)_{i,j,k} K_f \frac{1}{2}\left(\rho_{i,j,k}\right)^{st} \bar{w}^2, \tag{99}$$

where

$$K_f = \frac{n_G C_v \varepsilon^2}{\Delta z}$$

and Δz is the dimensionless axial length of the grid spacer. The pressure drop due to the presence of the grid is therefore calculated by the additional term in Eq. (99). The flow redistribution is also accounted for by the different K_f used for the different subchannels. In those regions where there is no grid spacer, the additional term in Eq. (99) is omitted in the z-momentum calculation.

D. Turbulence Model

Presently, the code includes one- and two-equation turbulence models. It can also accept effective conductivity and viscosity as input data. Details of these models can be found elsewhere.[13,14] Only a brief description is given here.

Turbulences equations can be derived from Eqs. (25)-(27) by time-averaging them over a time interval large enough to smooth out the turbulence fluctuation of the velocities. All the thermal-hydraulic variables can be written as two parts (the time-averaged part and the fluctuating part) as

$$h = H + h',$$

$$\vec{v} = \vec{V} + \vec{v}\,',$$

and

$$p = P + p'. \tag{100}$$

The time average of the prime quantity will be zero by definition. Time averaging of Eqs. (26) and (27) will give the following equations:

Turbulence Momentum Equation

$$\rho \frac{\overline{D\vec{V}}}{Dt} = \nabla\cdot\vec{\Sigma}^t + \nabla\cdot\vec{\Sigma} - \nabla P + \rho\vec{g} \tag{101}$$

and

Turbulence Energy Equation

$$\rho \frac{DH}{Dt} = -\nabla \cdot \vec{q}^{\,t} - \nabla \cdot \vec{q} + \mu\Phi + \mu\Phi^t + \frac{DP}{Dt} , \tag{102}$$

where DP/Dt is the substantial time derivative, $\vec{\Sigma}^t$ is called the turbulence momentum flux or Reynolds stresses resulting from the time averaging of the cross products of velocities,

$$(\vec{\Sigma}^t)_{i,j} = -\overline{\rho \vec{v}_i' \vec{v}_j'} , \tag{103}$$

q^t is the turbulence energy flux resulting from the time averaging of the cross products of enthalpies and velocities as

$$\vec{q}_i^{\,t} = \overline{\rho h' \vec{v}_i'} , \tag{104}$$

and $\mu\Phi^t$ is the turbulence energy dissipation term defined as

$$\mu\Phi^t = \overline{\Sigma' : \nabla v'} = \overline{\Sigma_{ij}' \frac{\partial v_i'}{\partial x_j}} . \tag{105}$$

We have neglected the cross-product terms between velocities and derivatives of pressures. In order to complete the solution of Eqs. (101) and (102), Eqs. (103)-(105) have to be modeled.

1. Two-equation Turbulence Model

In a two-equation turbulence model, Reynolds stress is expressed analogously to the viscous stress for the Newtonian fluid with turbulence viscosity replacing the laminar viscosity as

$$\Sigma_{ij}^t = -\mu^t \left[\frac{2}{3} \delta_{ij} (\nabla \cdot \vec{V}) - \left(\frac{\partial V_i}{\partial x_j} + \frac{\partial V_j}{\partial x_i} \right) \right], \tag{106}$$

where V_i is time-averaged velocity as defined in Eq. (100). Equation (105) is also modeled similarly as

$$\mu\Phi^t = \mu^t \Phi = \Sigma_{ij}^t \frac{\partial V_j}{\partial x_i} . \tag{107}$$

Equation (104) is modeled as

$$q_i^t = -\frac{\mu^t}{\sigma_h^{\,t}} \frac{\partial H}{\partial x_i} , \tag{108}$$

where σ_h^t is an empirical constant to be supplied by the user. The turbulence viscosity is a function of k and ε,

$$\mu^t = \rho C_\mu \frac{k^2}{\varepsilon} , \tag{109}$$

where

$$k = \text{turbulence kiretic energy} = \frac{1}{2}\left(v_1'^2 + v_2'^2 + v_3'^2\right),$$

$$\varepsilon = \text{rate of dissipation},$$

and C_μ is an empirical constant about 0.09.

Both k and ε are solved by differential equations with wall functions specifying the value of k and ε near the solid boundaries. The differential equations for k and ε are given as

$$\underset{\text{(convection)}}{\frac{D(\rho k)}{Dt}} \quad \underset{\text{(diffusion)}}{- \frac{\partial}{\partial x_i}\left(\frac{\mu^t}{\sigma_k} \frac{\partial k}{\partial x_i}\right)} \quad \underset{\text{(production)}}{- \quad \mu^t G} \quad \underset{\text{(dissipation)}}{+ \quad \rho\varepsilon} = 0 \tag{110}$$

and

$$\frac{D(\rho\varepsilon)}{Dt} - \frac{\partial}{\partial x_i}\left(\frac{\mu^t}{\sigma_\varepsilon} \frac{\partial \varepsilon}{\partial x_i}\right) - \frac{C_1 \varepsilon}{k} \mu^t G + C_2 \rho \frac{\varepsilon^2}{k} = 0, \tag{111}$$

where

$$G = \left(\frac{\partial V_i}{\partial x_j} + \frac{\partial V_j}{\partial x_i}\right) \frac{\partial V_i}{\partial x_j} \tag{112}$$

and σ_k, σ_ε, C_1, and C_2 are all empirical constants to be determined by experiments. The commonly used values for them are $\sigma_k = 1.0$, $\sigma_\varepsilon = 1.3$, $C_1 = 1.44$, and $C_2 = 1.92$. The above differential equations are subject to the following boundary conditions:

$$\frac{V}{\sqrt{\frac{\Sigma_w}{\rho}}} = \frac{1}{K} \ln \frac{Ey\rho\sqrt{\Sigma_w/\rho}}{\mu^\ell} \tag{113}$$

or

$$\frac{dV}{dy} = \sqrt{\frac{\Sigma_w}{\rho}} \frac{1}{Ky} , \tag{114}$$

$$k = \frac{\Sigma_w}{\rho} \frac{1}{\sqrt{C_\mu}} , \tag{115}$$

and

$$\varepsilon = \left(\frac{\Sigma_w}{\rho}\right)^{3/2} \frac{1}{Ky} , \tag{116}$$

where y is the distance to the wall, E and K are empirical constants given usually by $E \cong 9.8$ and $K \cong 0.42$, and Σ_w is the shear stress on the wall.

In order to solve the nonlinear Eq. (113) for $\sqrt{\Sigma_w/\rho}$, the Aitken's interpolation technique[15] was used with $\sqrt{\Sigma_w/\rho} = Kw_{ijk}/2y$ derived from Eq. (114) as the initial guess. This procedure is very effective in getting $\sqrt{\Sigma_w/\rho}$ with an average number of iterations around 3.

Besides the boundary conditions, one also requires inlet boundary conditions for solving Eqs. (110)-(112). They are

$$\left.\begin{aligned} k_{in} &= f_1 V_{in}^2, \\ \varepsilon_{in} &= C_\mu k^{3/2} \quad \ell_\varepsilon, \\ \ell_\varepsilon &= C_\mu^{1/4} \ell_m, \\ \text{and} \\ \ell_m &= f_2 D_e , \end{aligned}\right\} \tag{117}$$

where V_{in} is the inlet flow velocity, ℓ_m is the mixing length, D_e is the hydraulic diameter of the assembly, and f_1 and f_2 are empirical constants to be supplied by users. The commonly used value for f_1 is in the range of 0.01-0.03 and for f_2 is about 0.07. This means that the turbulent kinetic energy is about 1-3% of the inlet kinetic energy and the mixing length is about 7% of the assembly hydraulic diameter.

The exit boundary condition is treated in the same way as the flow exit condition. Either a zero gradient or a constant gradient in k and ε can be specified by the user.

Equations (110)-(112) have to be solved in the transformed variables. The Laplacian operator in the transformed variables can be written as

$$\frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} + \frac{\partial^2 f}{\partial z^2} = \frac{1}{J^2}\left(D_{11}\frac{\partial^2 f}{\partial \xi^2} + 2D_{12}\frac{\partial^2 f}{\partial \xi \partial \eta} + D_{22}\frac{\partial^2 f}{\partial \eta^2} + D_{33}\frac{\partial^2 f}{\partial \zeta^2}\right)$$

$$+ P(\xi,\eta)\frac{\partial f}{\partial \xi} + Q(\xi,\eta)\frac{\partial f}{\partial \eta}, \qquad (118)$$

where J is the Jacobian given by Eq. (7), P and Q are given by Eq. (1),

$$D_{11} = \left(x_{2\eta}^2 + x_{1\eta}^2\right)\Big/a^2,$$

$$D_{12} = -\left(x_{1\xi}x_{1\eta} + x_{2\xi}x_{2\eta}\right)\Big/a^2,$$

$$D_{22} = \left(x_{2\xi}^2 + x_{1\xi}^2\right)\Big/a^2,$$

and

$$D_{33} = \left(x_{1\xi}x_{2\eta} - x_{2\xi}x_{1\eta}\right)^2. \qquad (119)$$

By using Eqs. (114), (118) and (119) one can express Eqs. (110)-(112) in terms of the transformed variables, ξ, η, and ζ, as

$$\frac{\partial(\rho k)}{\partial t} + \frac{\tilde{V}_1}{J_{12}}\frac{\partial(\rho k)}{\partial \xi} + \frac{\tilde{V}_2}{J_{12}}\frac{\partial(\rho k)}{\partial \eta} + a\tilde{V}_3\frac{\partial(\rho k)}{\partial \zeta}$$

$$-\left(\frac{a}{J_{12}}\right)^2\left\{D_{11}\frac{\partial}{\partial \xi}\left(\frac{\mu^t}{\sigma_k}\right)\frac{\partial k}{\partial \xi} + D_{12}\left[\frac{\partial}{\partial \xi}\left(\frac{\mu^t}{\sigma_k}\right)\frac{\partial k}{\partial \eta} + \frac{\partial}{\partial \eta}\left(\frac{\mu^t}{\sigma_k}\right)\frac{\partial k}{\partial \xi}\right]\right.$$

$$\left. + D_{22}\frac{\partial}{\partial \eta}\left(\frac{\mu^t}{\sigma_k}\right)\frac{\partial k}{\partial \eta}\right\} - a^2\frac{\partial}{\partial \zeta}\left(\frac{\mu^t}{\sigma_k}\right)\frac{\partial k}{\partial \zeta} - \frac{\mu^t}{\sigma_{kJ}{}^2}\left(D_{11}\frac{\partial^2 k}{\partial \xi^2} + 2D_{12}\frac{\partial^2 k}{\partial \xi \partial \eta}\right.$$

$$\left. + D_{22}\frac{\partial^2 k}{\partial \eta^2} + D_{33}\frac{\partial^2 k}{\partial \zeta^2}\right) - \frac{\mu^t}{\sigma_k}\left(P\frac{\partial k}{\partial \xi} + Q\frac{\partial k}{\partial \eta}\right) - \mu^t\tilde{G} + \rho\varepsilon = 0 \qquad (120)$$

and

$$\left.\begin{aligned}&\frac{\partial(\rho\varepsilon)}{\partial t} + \frac{\tilde{V}_1}{J_{12}}\frac{\partial(\rho\varepsilon)}{\partial \xi} + \frac{\tilde{V}_2}{J_{12}}\frac{\partial(\rho\varepsilon)}{\partial \eta} + a\tilde{V}_3\frac{\partial(\rho\varepsilon)}{\partial \zeta}\\ &-\left(\frac{a}{J_{12}}\right)^2\left\{D_{11}\frac{\partial}{\partial \xi}\left(\frac{\mu^t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial \xi} + D_{12}\left[\frac{\partial}{\partial \xi}\left(\frac{\mu^t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial \eta}\right.\right.\end{aligned}\right\} \qquad \begin{matrix}(121)\\ \text{(Contd.)}\end{matrix}$$

$$
\left.
\begin{aligned}
&+ \frac{\partial}{\partial \eta}\left(\frac{\mu^t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial \xi} + D_{22}\frac{\partial}{\partial \eta}\left(\frac{\mu^t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial \eta}\Bigg\} - a^2\frac{\partial}{\partial \zeta}\left(\frac{\mu^t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial \zeta} \\
&- \frac{\mu^t}{\sigma_\varepsilon J^2}\left(D_{11}\frac{\partial^2 \varepsilon}{\partial \xi^2} + 2D_{12}\frac{\partial^2 \varepsilon}{\partial \xi \partial \eta} + D_{22}\frac{\partial^2 \varepsilon}{\partial \eta^2} + D_{33}\frac{\partial^2 \varepsilon}{\partial \zeta^2}\right) \\
&- \frac{\mu^t}{\sigma_\varepsilon}\left(P\frac{\partial \varepsilon}{\partial \xi} + Q\frac{\partial \varepsilon}{\partial \eta}\right) - \frac{C_1 \varepsilon}{k}\mu^t \widetilde{G} + C_2 \rho \frac{\varepsilon^2}{k} = 0,
\end{aligned}
\right\}
\begin{matrix}\text{(Contd.)}\\ (121)\end{matrix}
$$

where

$$
\left.
\begin{aligned}
\widetilde{V}_1 &= x_{2\eta}V_1 - x_{1\eta}V_2. \\
\widetilde{V}_2 &= -x_{2\xi}V_1 + x_{1\xi}V_2, \\
\widetilde{V}_3 &= V_3.
\end{aligned}
\right\}
\qquad (122)
$$

and

$$
\begin{aligned}
\widetilde{G} = {} & \frac{a^2}{J_{12}^2}\left(D_{11}\frac{\partial V_i}{\partial \xi}\frac{\partial V_i}{\partial \xi} + 2D_{12}\frac{\partial V_i}{\partial \xi}\frac{\partial V_i}{\partial \eta} + D_{22}\frac{\partial V_i}{\partial \eta}\frac{\partial V_i}{\partial \eta}\right) + a^2\frac{\partial V_i}{\partial \zeta}\frac{\partial V_i}{\partial \zeta} \\
& + \frac{1}{J_{12}^2}\left[\left(x_{2\eta}\frac{\partial V_1}{\partial \xi} - x_{2\xi}\frac{\partial V_1}{\partial \eta}\right)^2 + \left(-x_{1\eta}\frac{\partial V_2}{\partial \xi} + x_{1\xi}\frac{\partial V_2}{\partial \eta}\right)^2\right] + \left(a\frac{\partial V_3}{\partial \zeta}\right)^2 \\
& + \frac{2}{J_{12}^2}\left(x_{2\eta}\frac{\partial V_2}{\partial \xi} - x_{2\xi}\frac{\partial V_2}{\partial \eta}\right)\left(-x_{1\eta}\frac{\partial V_1}{\partial \xi} + x_{1\xi}\frac{\partial V_1}{\partial \eta}\right) \\
& + \frac{2a}{J_{12}}\left[\frac{\partial V_1}{\partial \zeta}\left(x_{2\eta}\frac{\partial V_3}{\partial \xi} - x_{2\xi}\frac{\partial V_3}{\partial \eta}\right) + \frac{\partial V_2}{\partial \zeta}\left(-x_{1\eta}\frac{\partial V_3}{\partial \xi} + x_{1\xi}\frac{\partial V_3}{2\eta}\right)\right] . \qquad (123)
\end{aligned}
$$

Then the finite-difference equations can be written for the resulting transformed equations. Fully implicit formulations in time are again used to allow the use of a large time step for steady-state applications. The central terms involving k_{ijk} and ε_{ijk} are also factored to the left of the finite-difference equations to enhance convergence, as in the case of the momentum and energy equations.

Once the difference equations are solved, one obtains k and ε for all the interior nodes within the flow region. The turbulence viscosity is then derived from Eq. (109). This turbulence viscosity, μ^t, is to be combined with the laminar viscosity, μ^ℓ, to give an effective viscosity,

$$\mu_{eff} = \frac{\mu^\ell}{\sigma_\mu^\ell} + \frac{\mu^t}{\sigma_\mu^t}, \tag{124}$$

where σ_μ^ℓ and σ_μ^t are the Prandl-Schmidt numbers. A similar expression holds for the effective conductivity,

$$K_{eff} = \frac{K^\ell}{\sigma_T^\ell} + \frac{\mu^t C_p}{\sigma_T^t}. \tag{125}$$

Commonly used values for the constants in Eqs. (124) and (125) are $\sigma_\mu^\ell = 1.0$, $\sigma_\mu^t = 1.0$, $\sigma_T^\ell = 1.0$, and $\sigma_T^t = 1.3$. This effective viscosity and conductivity are to be used in the momentum and energy equations to account for the turbulence influence on the time-averaged velocity and enthalpy.

2. One-equation Turbulence Model

In a one-equation turbulence model, only the differential equation for k (Eq. 110) is used. Equation (109) is replaced by

$$\mu^t = \rho \ell_\varepsilon \sqrt{k}, \tag{126}$$

where ℓ_ε is determined by

$$\left.\begin{aligned} \frac{\ell_\varepsilon}{\delta} &= K\frac{y}{\delta}C_\mu^{1/4} && \text{for } \frac{y}{\delta} < \frac{\lambda}{K} \\ &= \lambda C_\mu^{1/4} && \text{for } \frac{y}{\delta} > \frac{\lambda}{K}, \end{aligned}\right\} \tag{127}$$

where δ is the distance from the point with 1% of the maximum velocity to the point of maximum velocity, and λ is again an empirical constant usually given as 0.09; δ is sometimes referred to as the turbulence width.

All the calculation procedures for the one-equation turbulence model are the same as those in the two-equation turbulence model, except that the ε equation is completely omitted. Once k is obtained, μ^t is computed from Eqs. (126) and (127). Effective viscosities and conductivities are again determined from Eqs. (124) and (125).

3. Zero-equation Turbulence Model or Mixing-length Model

In this model, both differential equations for k and ε are omitted. Instead, simple equations are used for the determination of turbulence viscosity, μ^t, as

$$\mu^t = \rho \ell_m \left| \frac{\partial V}{\partial y} \right| \tag{128}$$

and

$$\left.\begin{aligned} \frac{\ell_m}{\delta} &= \frac{Ky}{\delta} \quad \text{for } \frac{y}{\delta} < \frac{\lambda}{K} \\ &= \lambda \quad \text{for } \frac{y}{\delta} > \frac{\lambda}{K}, \end{aligned}\right\} \tag{129}$$

where δ and λ are determined in the same way as those used in the one-equation turbulence model.

X. CONCLUSION

Computer code BODYFIT-1FE (Boundary-Fitted Coordinate - One Phase, Fully Elliptic Version) has been completed. It is a three-dimensional steady-state/transient single-phase computer program for thermal-hydraulic analyses of reactor rod bundles using the technique of boundary-fitted coordinates. It can presently be used to analyze hexagonal rod bundles. It can be extended to analyze square rod bundles as well. It includes a fuel-pin model, a duct-wall model, a grid-resistance model, and one- or two-equation turbulence models. It has incorporated sodium properties. It can be used for hexagonal rod bundles with one-twelfth or no symmetry. It provides detailed velocity and temperature distributions within a rod bundle without invoking any assumption for the laminar-flow case. In turbulent flow, a turbulence model is required due to the closure problem. The detail of the velocity and the temperature distributions can be increased by increasing the number of computational meshes, easily done by the coordinate generation code. This detailed velocity and temperature distribution can be used to benchmark and to provide input constants for coarse mesh codes such as COBRA[2] and COMMIX-1.[4] Although there is no substitution for experimental data, BODYFIT-1FE can be used to fill the gap when the experimental data are not available.

Future work on BODYFIT will include the capability of analyzing two-phase flow problems and will generalize the transformation to three-dimensional coordinates. With this generalization, distorted and even wire-wrapped rod bundles can be analyzed. Presently, a wire-wrapped rod bundle can only be modeled by effective viscosities and conductivities. This is due to the fact that the wire wrap destroys the geometric uniformity in the z direction of the assembly axis. A simple linear-coordinate transformation in the z direction is not possible to represent the helical geometry of the wire wrap. A general three-dimensional coordinate transformation is required.

The code uses isotropic one- or two-equation turbulence models, which have uniform turbulent viscosity in all directions at a given point. However, the turbulent intensities are often anisotropic within the rod bundle. Therefore, in order to more accurately represent the turbulent phenomena, an anisotropic turbulence model will be tested in the future and included in the code.

In conclusion, BODYFIT-1FE presents a unique and flexible approach to the thermal-hydraulic analyses of reactor rod bundles. It separates the geometric uncertainties inherent in the subchannel approach from the physical-modeling uncertainties arising from various physical-modeling processes, such as the turbulence model and the grid-resistance model. It provides a fundamental approach to the thermal-hydraulic analysis. Although it requires more computer storage and running time, it is a valuable complement to the existing thermal-hydraulic codes.

APPENDIX A

Code Description

BODYFIT-1FE consists of two separate programs. The first program performs the coordinate transformation and generates all the geometric information needed by the second program. The second program uses this information and solves the transformed governing equations. These programs are described below.

The flow charts for the first program are given in Figs. 9 and 10. Only the major steps are shown. In the MAIN subroutine, the number of pins and the number of grid lines between pins are read in. The necessary dimensions and spaces required for all the variables are then computed and allocated. Subroutine DRIVER is then called to compute the coordinate transformation.

In Subroutine DRIVER, HEXBUN is called to compute the x and y coordinates of the boundaries for hexagonal rod bundles. In the hexagonal bundles, at least one pin has to be included inside the hexagonal duct wall. All the geometric dimensions are read in from these two subroutines. Inputs for various printing and writing options are then read in DRIVER, and Subroutine SLABO is called to determine the grid lines to be skipped for the inner region of the hexagonal bundle. Every two out of three grid lines are skipped as the grid lines emerge toward the central region of the hexagonal bundle. This skipping ratio is fixed to optimize the uniformity of the various sizes of the computational cells. Figure 11 shows how the skipping of grid lines is done in the tranformed plane for a one-sixth section of a 19-pin hexagonal rod bundle. After the skipping of grid lines is determined, Subroutine SLABO is called again to identify the fuel-pin boundaries. The interior grid lines inside a pin are skipped again. The computational cells are numbered next without including any of the skipped grid lines. This minimizes the computer storage required for the computation.

Once the numbering of the computational cells is completed, the boundary coordinates are reassigned according to the new numbering scheme. Array NB is then calculated to identify the position of a computational cell relative to the pin boundary. Subroutine NCHANL is called to identify the subchannel numbers for all the computational cells. Figure 12 shows the subchannel numbering order for a 19-pin hexagonal rod bundle. The boundaries of the subchannels are not the same as the ones usually defined for the subchannels. This is due to the fact that the computational grid lines are not necessarily coincident with the conventional subchannel boundaries. These subchannel divisions are used to compute the subchannel average temperatures, which in turn are used in the fuel-pin temperature calculations.

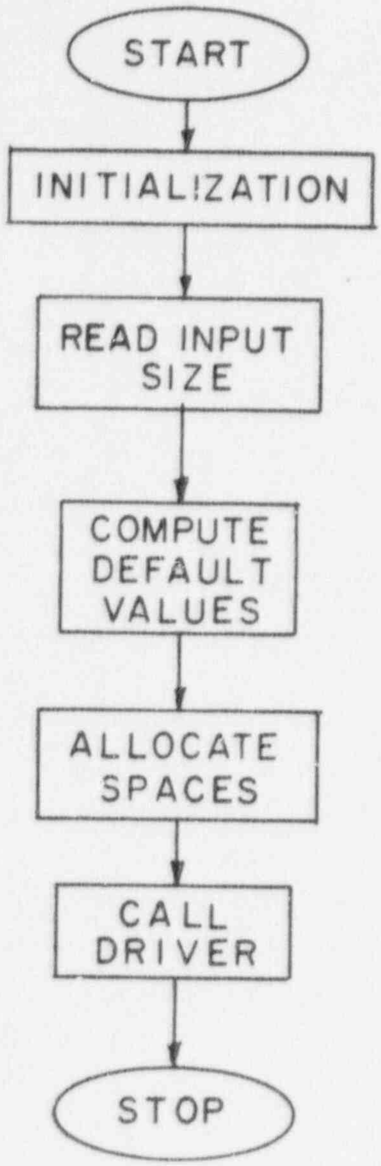


Fig. 9

Flow chart for the MAIN subroutine of the coordinate generation program

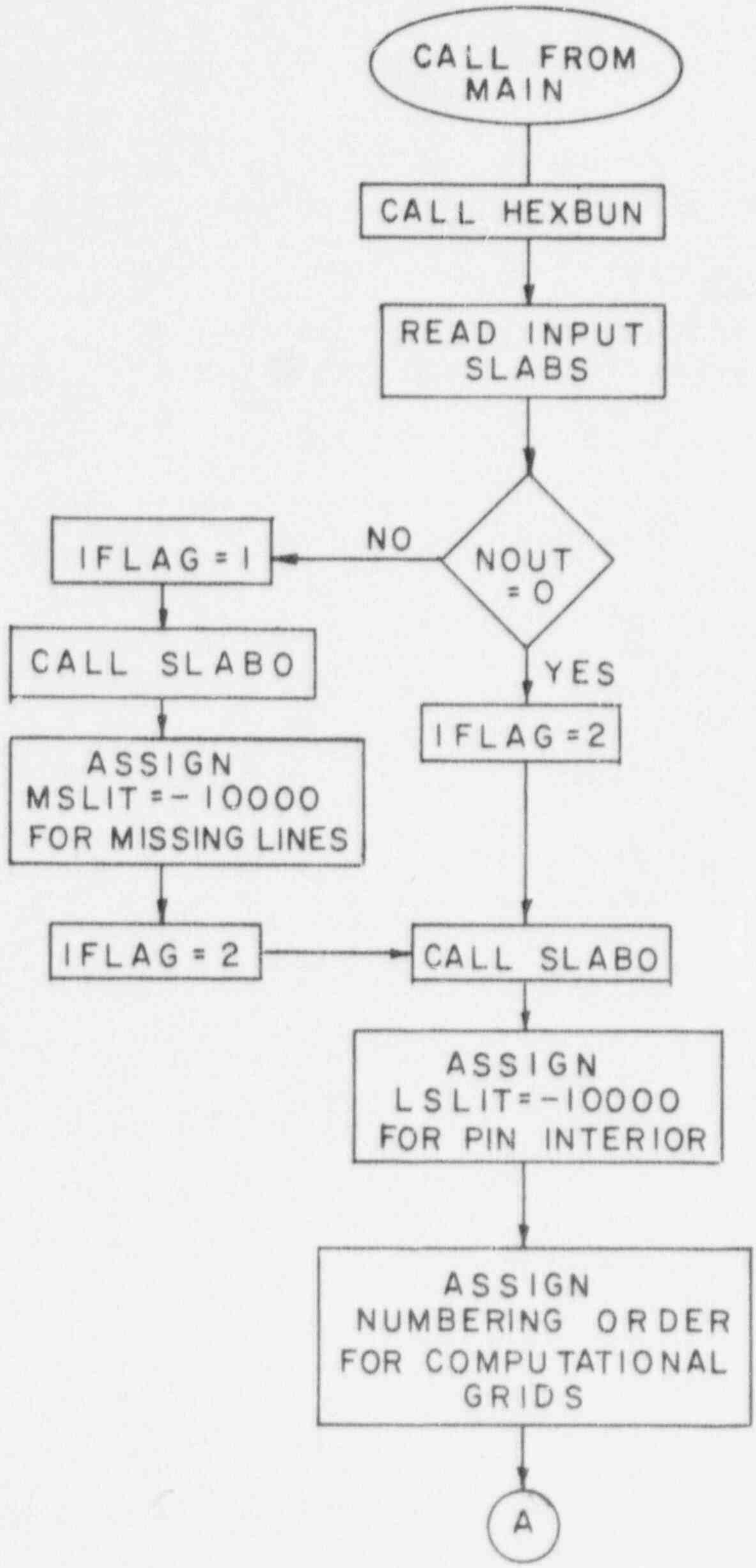


Fig. 10. Flow chart for subroutine DRIVER of the coordinate generation program

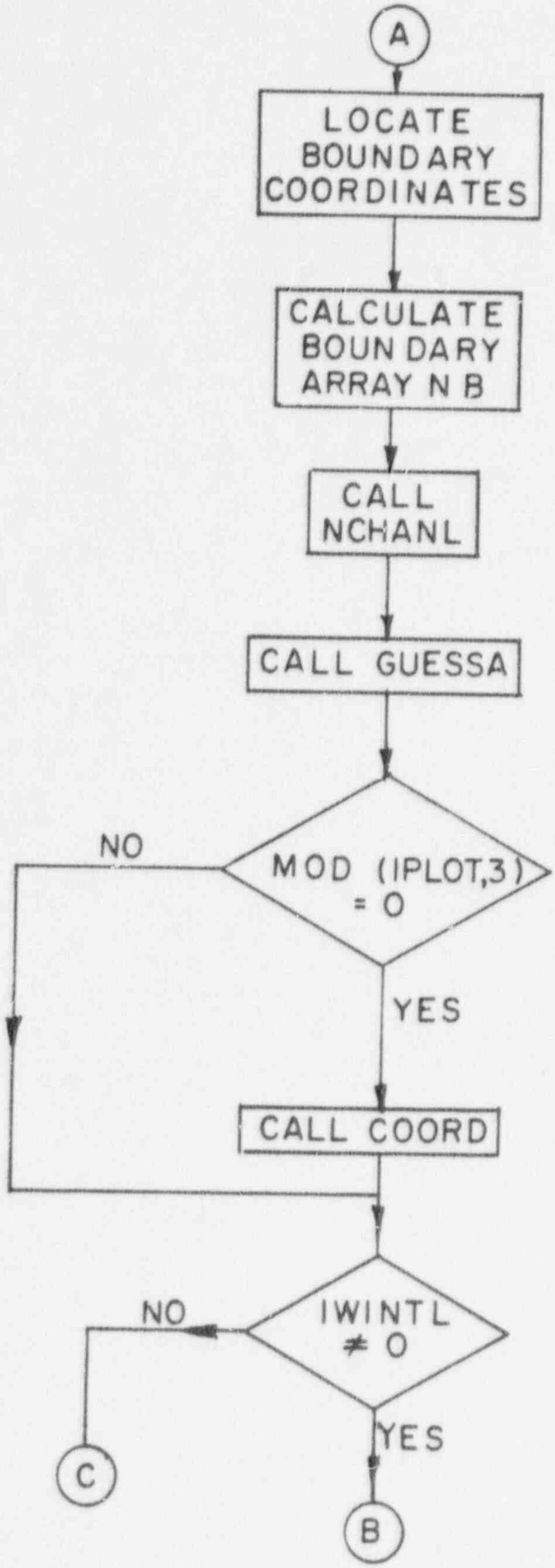

A
LOCATE
BOUNDARY
COORDINATES
CALCULATE
BOUN DARY
ARRAY N B
CALL
NCHANL
CALL GUESSA
MOD (IPLOT,3)
= 0
NO
YES
CALL COORD
IWINTL
≠ 0
NO
YES
C
B

Fig. 10 (Contd.)

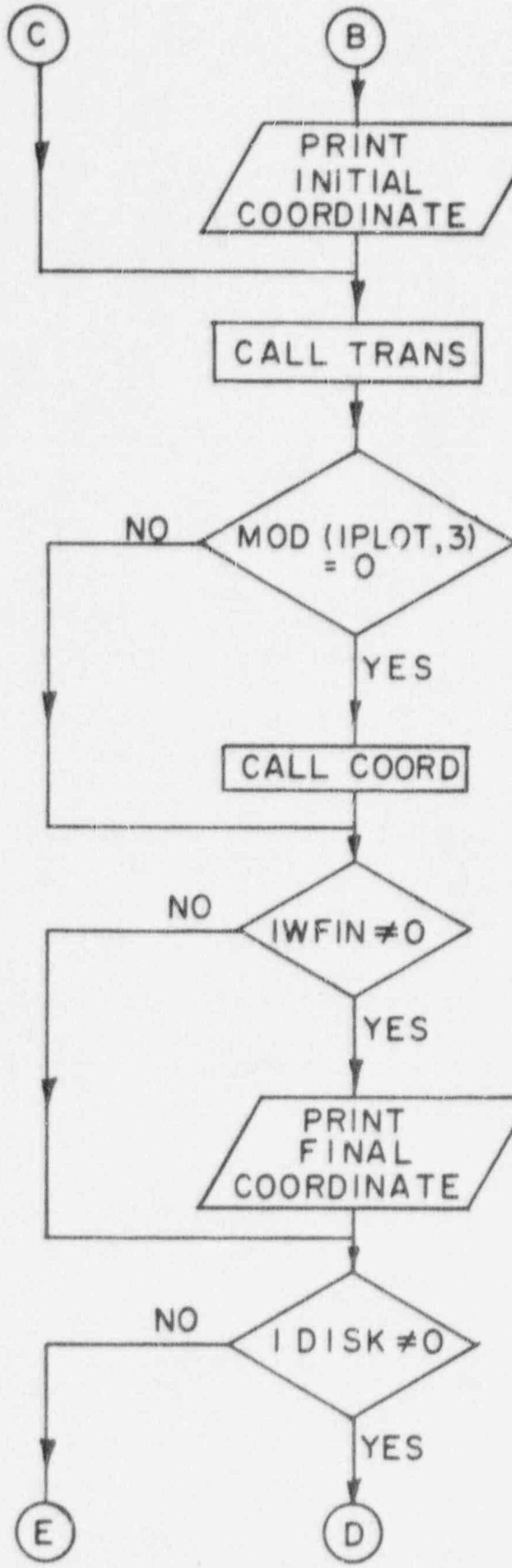

C
B
PRINT INITIAL COORDINATE
CALL TRANS
MOD (IPLOT,3) = 0
NO
YES
CALL COORD
IWFIN ≠ 0
NO
YES
PRINT FINAL COORDINATE
IDISK ≠ 0
NO
YES
E
D

Fig. 10 (Contd.)

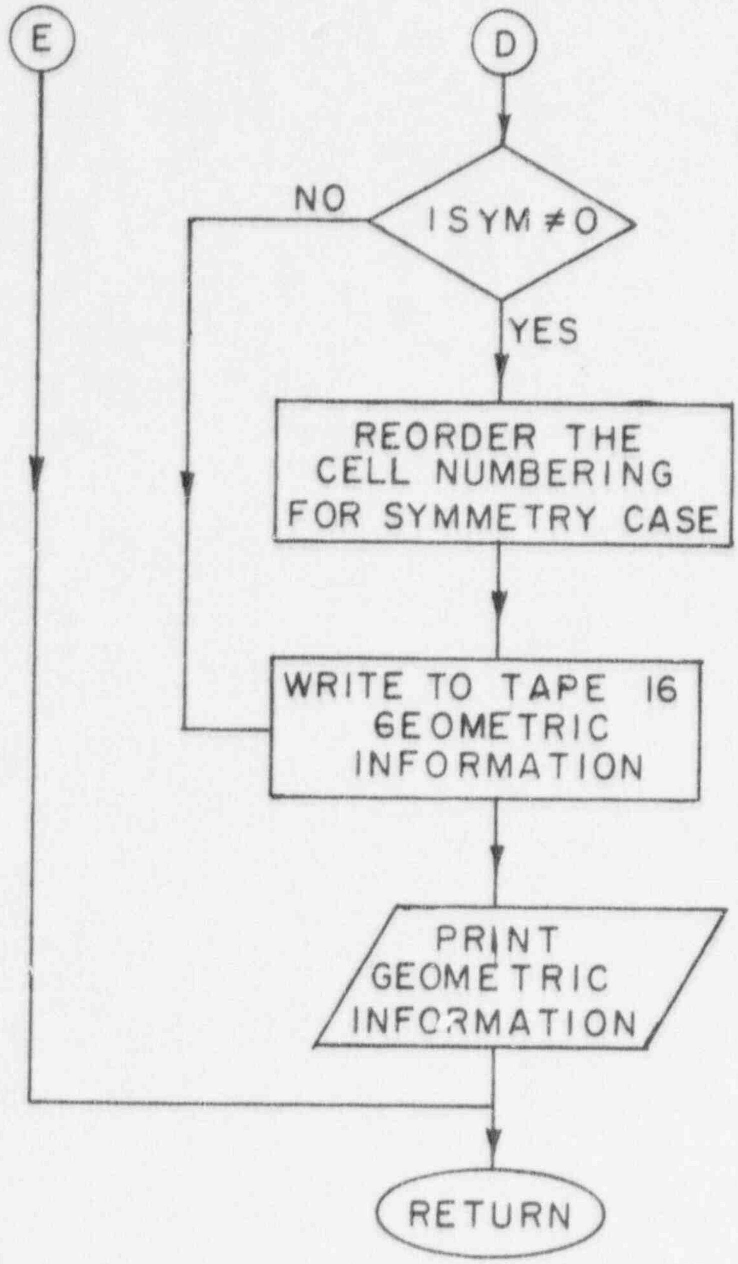

E
D
NO
ISYM ≠ 0
YES
REORDER THE CELL NUMBERING FOR SYMMETRY CASE
WRITE TO TAPE 16 GEOMETRIC INFORMATION
PRINT GEOMETRIC INFORMATION
RETURN

Fig. 10 (Contd.)

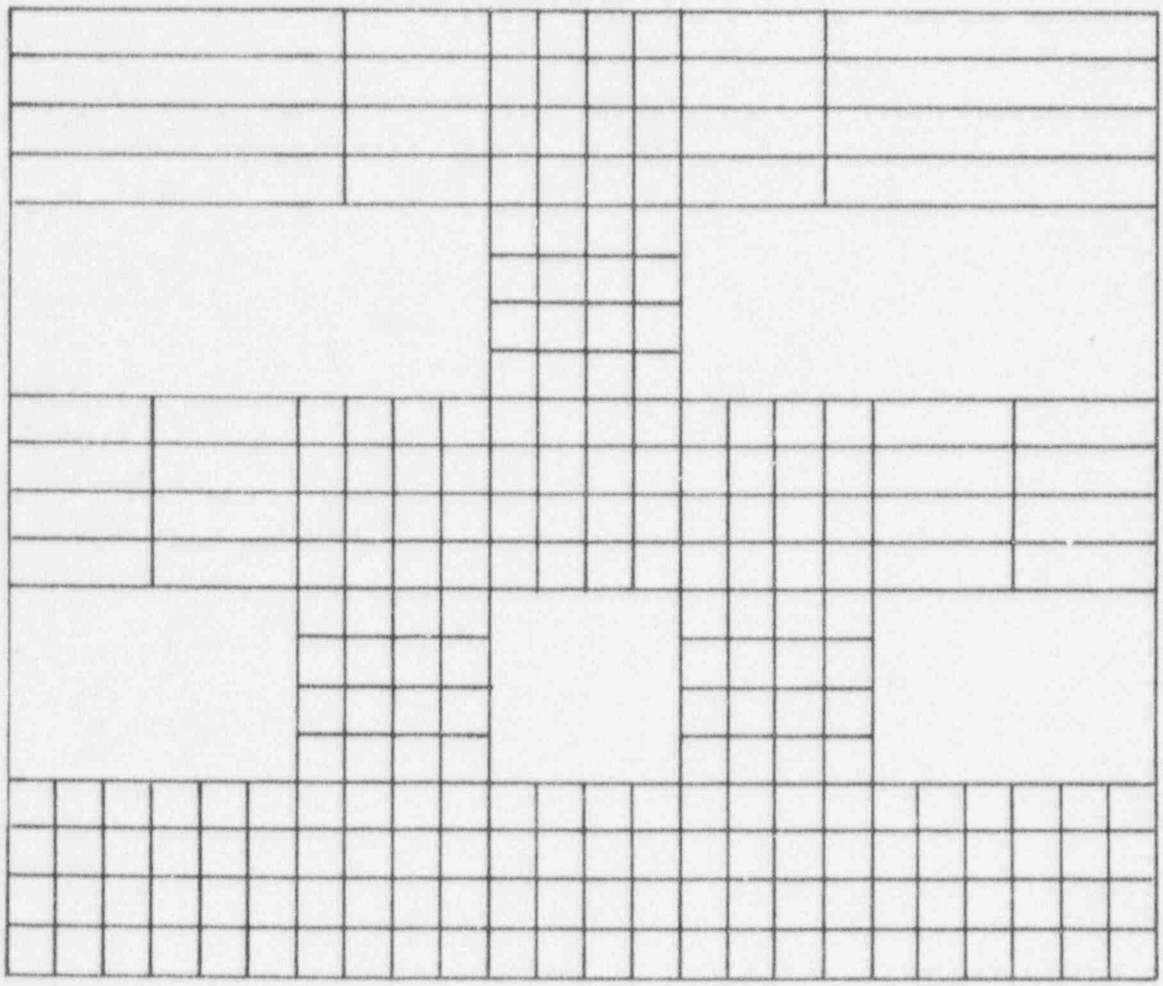


Fig. 11. Computational grid lines in the transformed plane for a one-sixth sector of a 19-pin hexagonal rod bundle

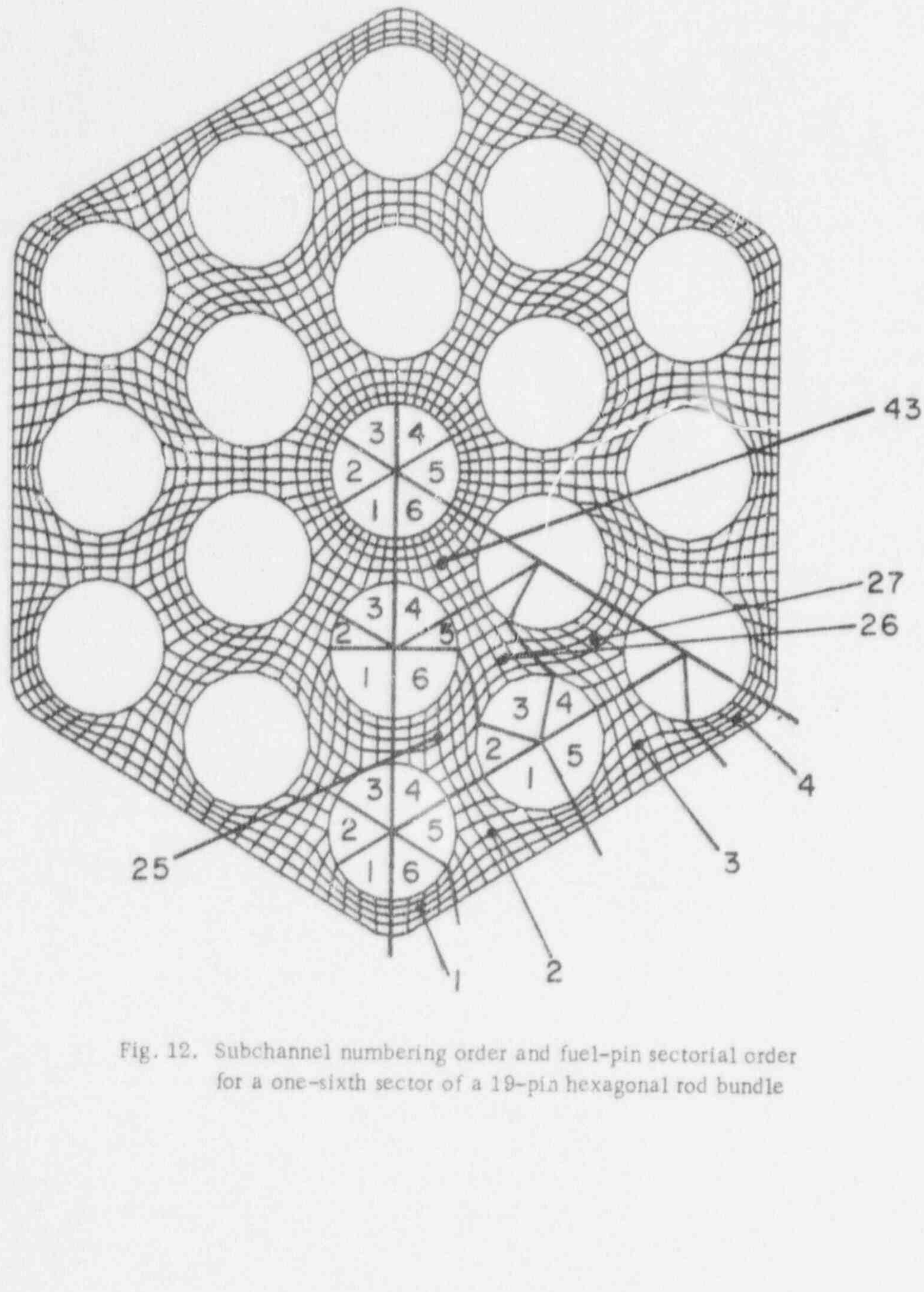


Fig. 12. Subchannel numbering order and fuel-pin sectorial order for a one-sixth sector of a 19-pin hexagonal rod bundle

Subroutine GUESSA is then called to give an initial guess of the coordinates of all the cells. These initial coordinates can be plotted by calling Subroutine COORD. With this initial guess, the difference equations of the transformed Laplacian equations are then solved by a cell-by-cell and successive overrelaxation (SOR) iterative procedure. Subroutine TRANS performs this task. Once the coordinates satisfing the transformed Laplacian equations are found within a given error limit, they can be plotted and printed out.

For physical problems having symmetry, the computational cells are further reduced by renumbering the computational cells. Finally, all the geometric information can be written to a tape. This information can be read into the second program of BODYFIT over and over again for various physical problems with the same geometry.

The second program of BODYFIT is to solve the transformed governing equations. The flow chart for the MAIN subroutine is given in Fig. 13. The flow chart for the SOLN subroutine is given in Fig. 14. These two subroutines are the main subroutines. Again, only the major steps are shown in the flow charts.

The MAIN subroutine starts with the reading of IFR, which determines the status for various restart cases. In a restart case, the READRS subroutine is called to read in all the common blocks, and then IFRET is checked to see whether the previous run was terminated due to insufficient computer time allocation or was terminated normally at the end of the specified time step. In the case of a new run for a given physical problem, all the variables have to be initialized. Inputs for name list SET are read in. All the geometric information is read in from a tape generated by the coordinate-transformation program. This information is also printed as it is read in. The beginning and ending I's and J's are calculated next. They are not necessarily equal to either one or the maximum values allowed by the dimensions inside the common blocks. For physical problems having symmetry conditions, extra computational cells are included on both sides of the symmetry lines to account for the symmetry conditions, such as the velocities on both sides of the symmetry line being the same. In the present work, I0 is the beginning I, I9 is the I for the symmetry line, and I8 is the I for the grid line before I9. Similar definitions are used for J's. Energy computations are performed from I = I0 up to I8 cells; momentum computations are performed up to I = I9 cells.

The coordinates are nondimensionalized. Subroutine COEFF is then called to compute the derivatives of all the dimensionless coordinates. Dimensionless flow area and heated perimeter are calculated. The time step and the iteration step are initialized. This is the starting point for time steps. First, the reference conditions are computed based on the inlet conditions, which can be changing with time. Then the static pressures due to the presence of gravity are computed. This static pressure and the entrance pressure are substracted out of the total pressure to make the relative pressure equal to zero at the

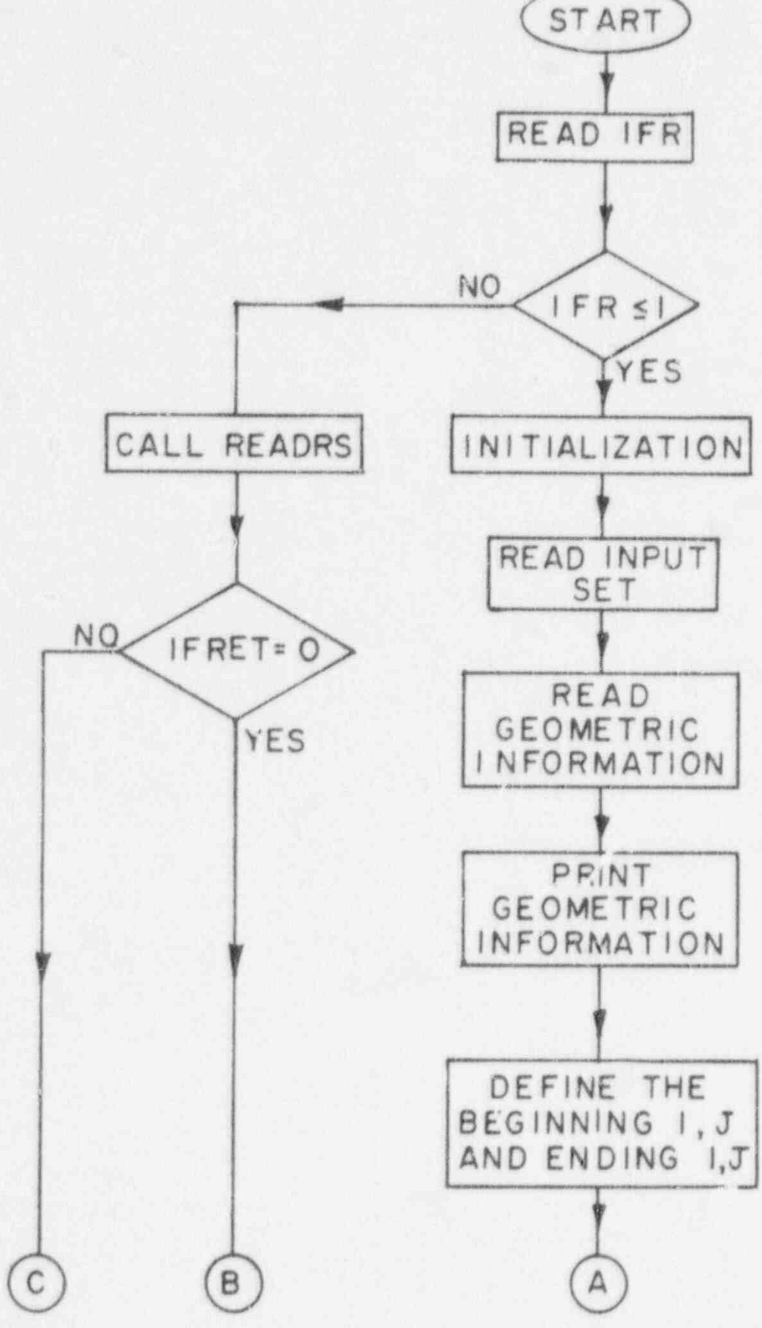


Fig. 13

Flow chart for subroutine MAIN of the program for solving the governing equations

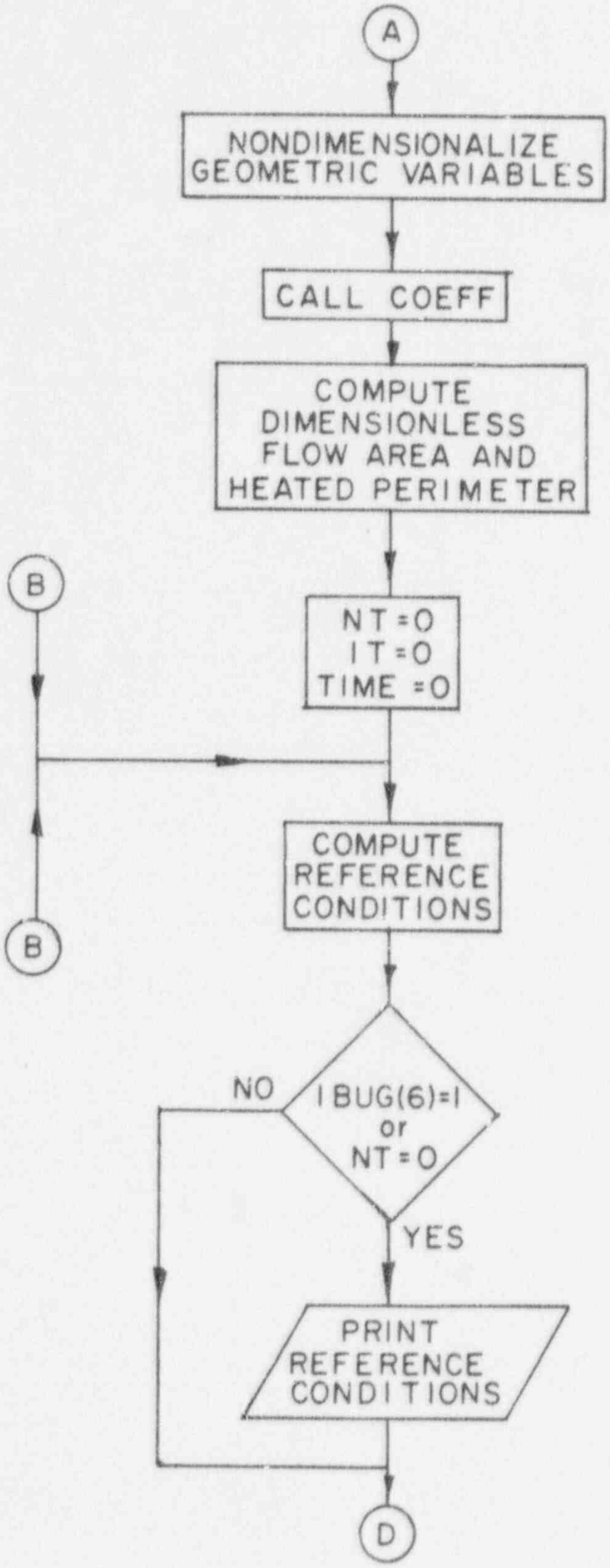

A
NONDIMENSIONALIZE GEOMETRIC VARIABLES
CALL COEFF
COMPUTE DIMENSIONLESS FLOW AREA AND HEATED PERIMETER
B
NT=0
IT=0
TIME=0
COMPUTE REFERENCE CONDITIONS
B
NO
IBUG(6)=1 or NT=0
YES
PRINT REFERENCE CONDITIONS
D

Fig. 13 (Contd.)

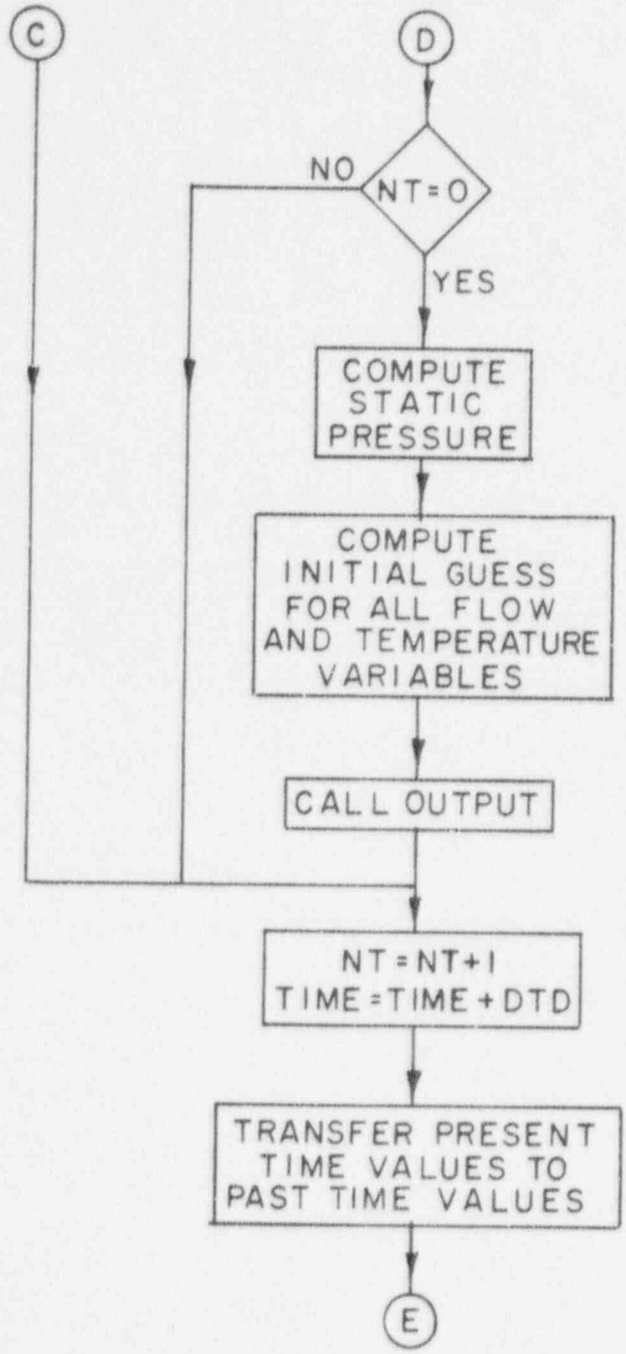

C
D
NO
NT=0
YES
COMPUTE STATIC PRESSURE
COMPUTE INITIAL GUESS FOR ALL FLOW AND TEMPERATURE VARIABLES
CALL OUTPUT
NT=NT+1
TIME=TIME+DTD
TRANSFER PRESENT TIME VALUES TO PAST TIME VALUES
E

Fig. 13 (Contd.)

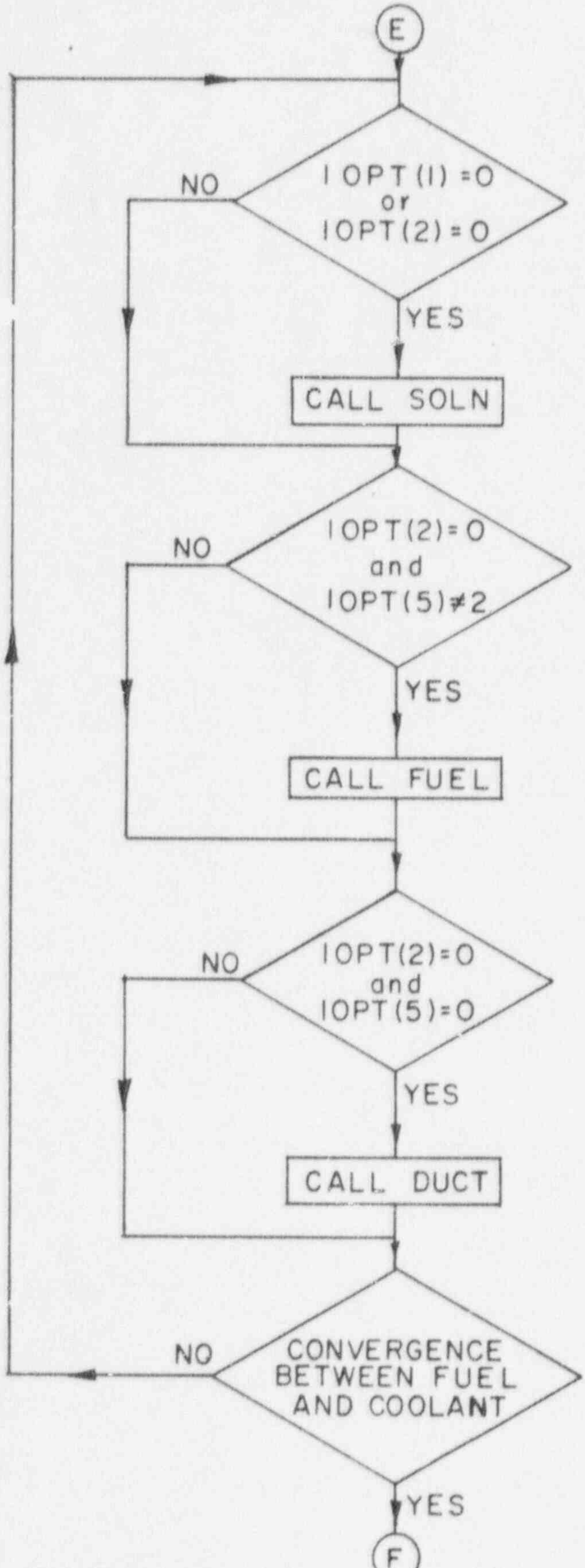

E
IOPT(1)=0
or
IOPT(2)=0
NO
YES
CALL SOLN
IOPT(2)=0
and
IOPT(5)≠2
NO
YES
CALL FUEL
IOPT(2)=0
and
IOPT(5)=0
NO
YES
CALL DUCT
CONVERGENCE
BETWEEN FUEL
AND COOLANT
NO
YES
F

Fig. 13 (Contd.)

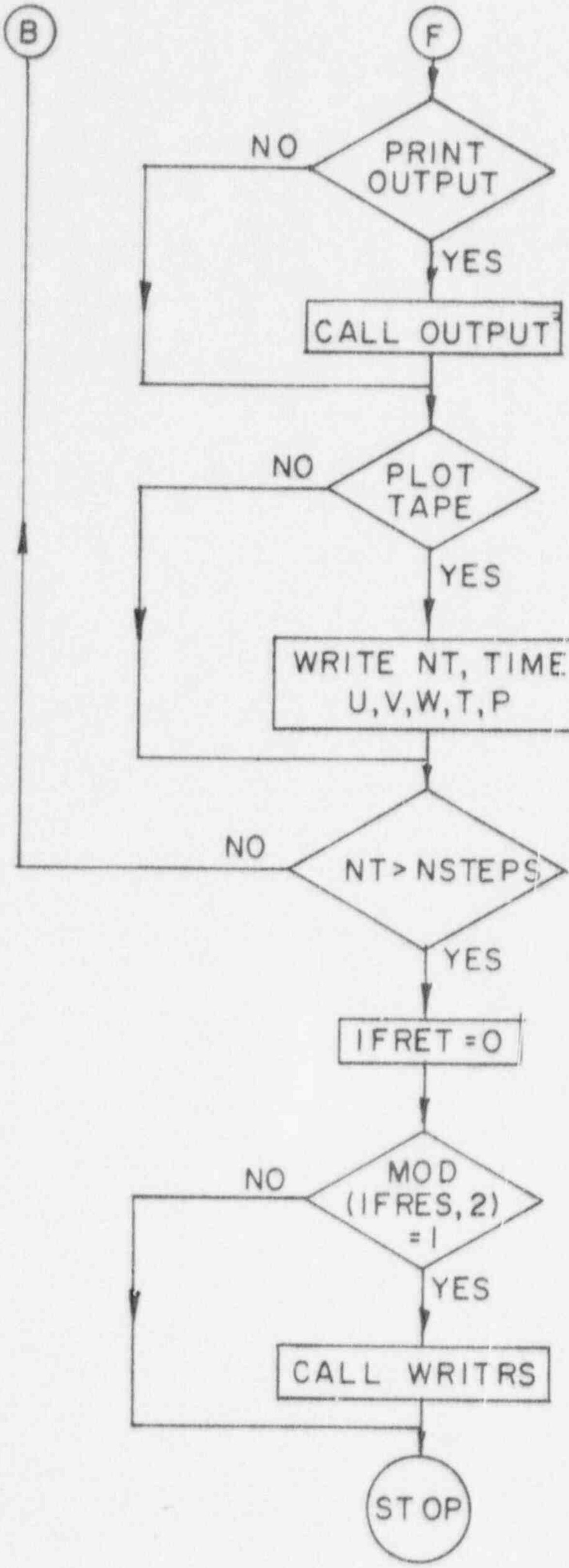

B
F
PRINT OUTPUT
NO
YES
CALL OUTPUT
PLOT TAPE
NO
YES
WRITE NT, TIME U,V,W,T,P
NT > NSTEPS
NO
YES
IFRET = 0
MOD (IFRES, 2) = 1
NO
YES
CALL WRITRS
STOP

Fig. 13 (Contd.)

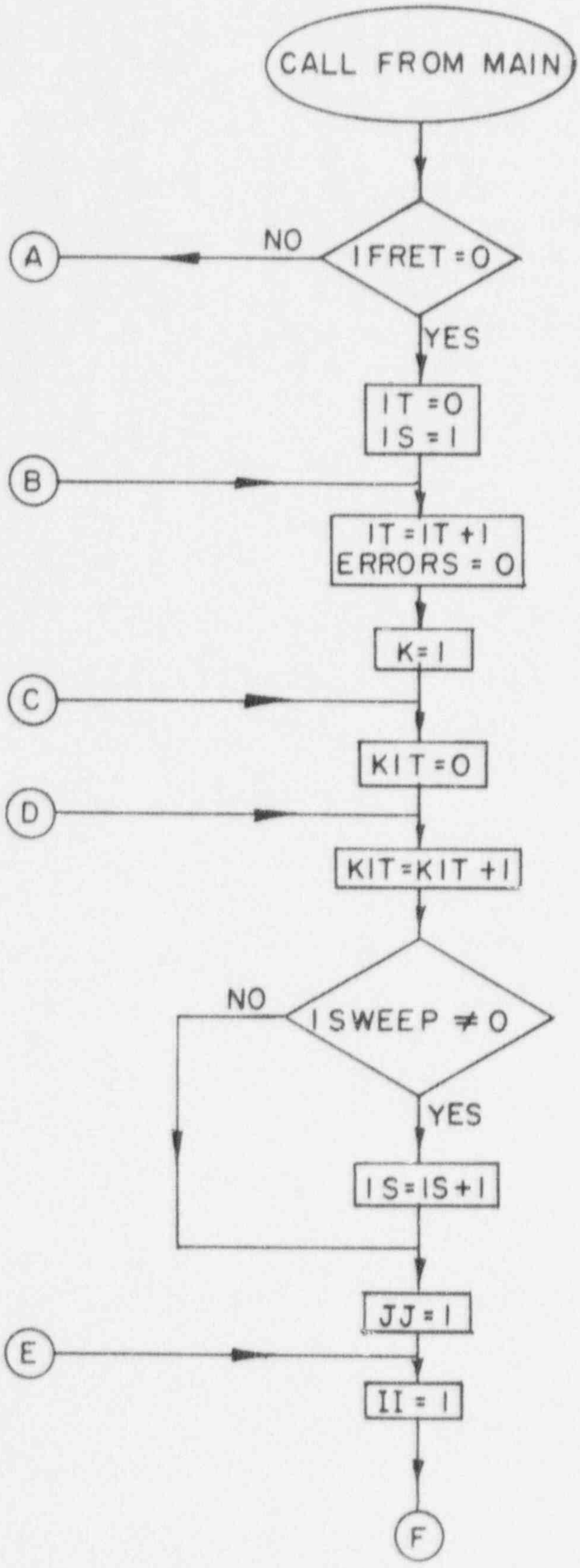


Fig. 14

Flow chart for subroutine SOLN of the program for solving the governing equations

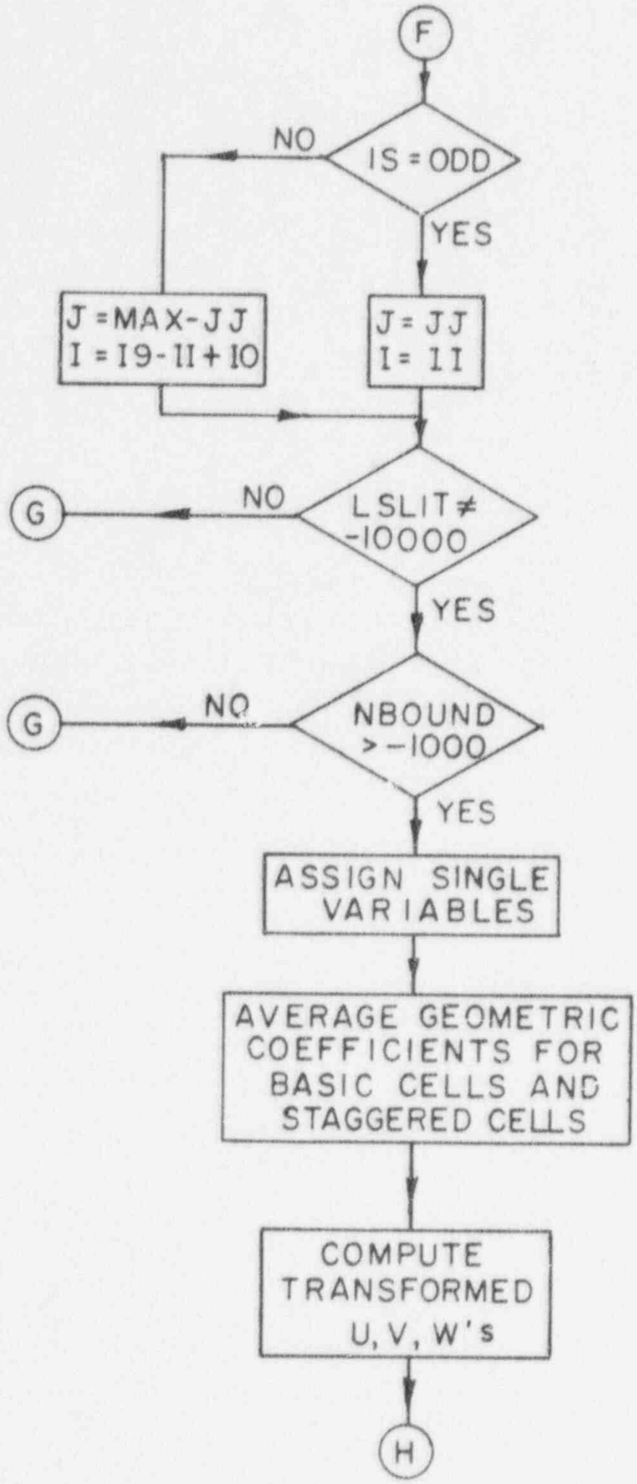

F
IS = ODD
NO
YES
J = MAX-JJ
I = I9-II+I0
J = JJ
I = II
LSLIT ≠ -10000
NO
G
YES
NBOUND > -1000
NO
G
YES
ASSIGN SINGLE VARIABLES
AVERAGE GEOMETRIC COEFFICIENTS FOR BASIC CELLS AND STAGGERED CELLS
COMPUTE TRANSFORMED U, V, W's
H

Fig. 14 (Contd.)

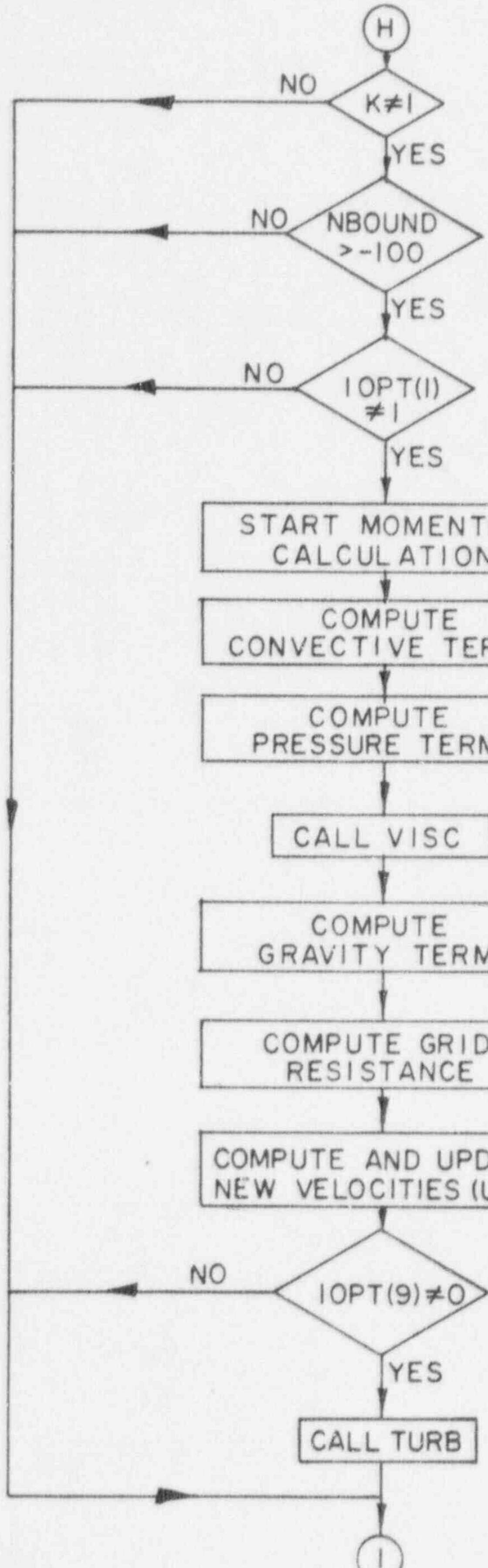

H
NO
K≠1
YES
NO
NBOUND >-100
YES
NO
IOPT(I) ≠1
YES
START MOMENTUM CALCULATION
COMPUTE CONVECTIVE TERMS
COMPUTE PRESSURE TERMS
CALL VISC
COMPUTE GRAVITY TERMS
COMPUTE GRID RESISTANCE
COMPUTE AND UPDATE NEW VELOCITIES (U,V,W)
NO
IOPT(9)≠0
YES
CALL TURB
I

Fig. 14 (Contd.)

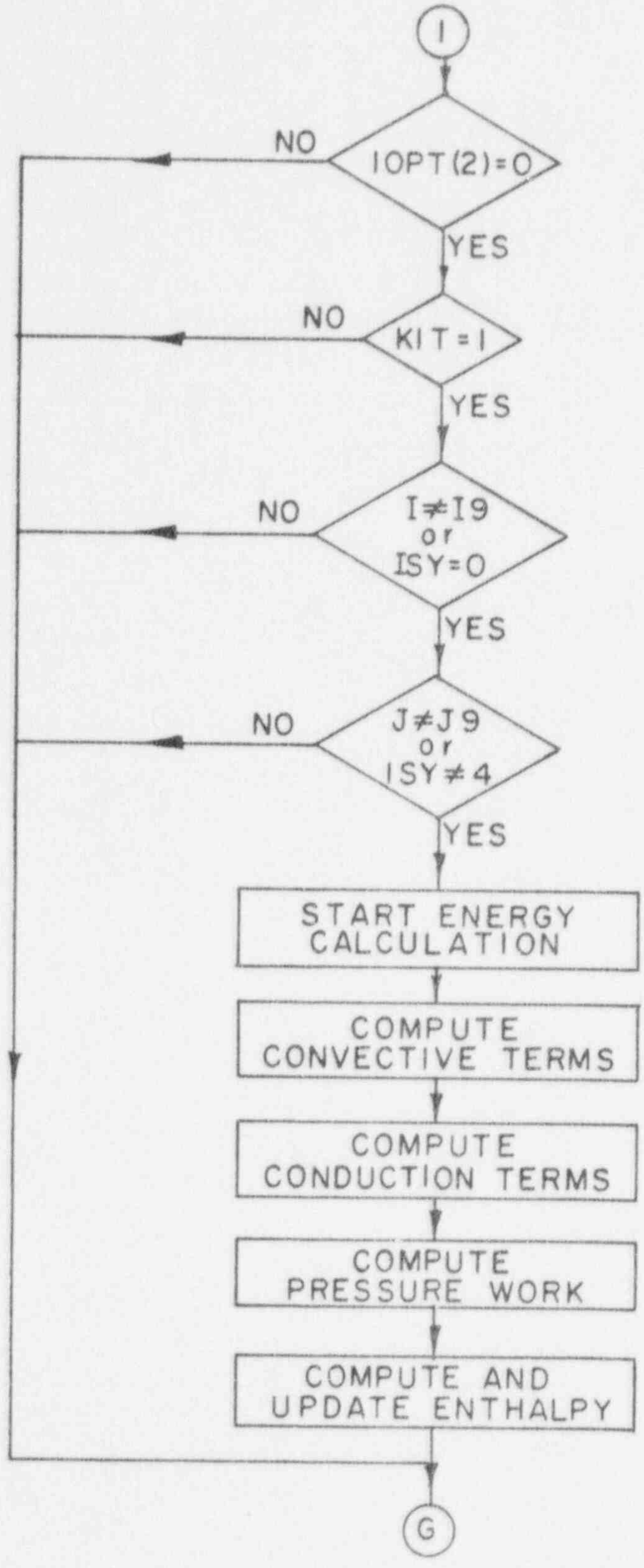

I
NO
IOPT(2)=O
YES
NO
KIT=1
YES
NO
I≠I9
or
ISY=O
YES
NO
J≠J9
or
ISY≠4
YES
START ENERGY
CALCULATION
COMPUTE
CONVECTIVE TERMS
COMPUTE
CONDUCTION TERMS
COMPUTE
PRESSURE WORK
COMPUTE AND
UPDATE ENTHALPY
G

Fig. 14 (Contd.)

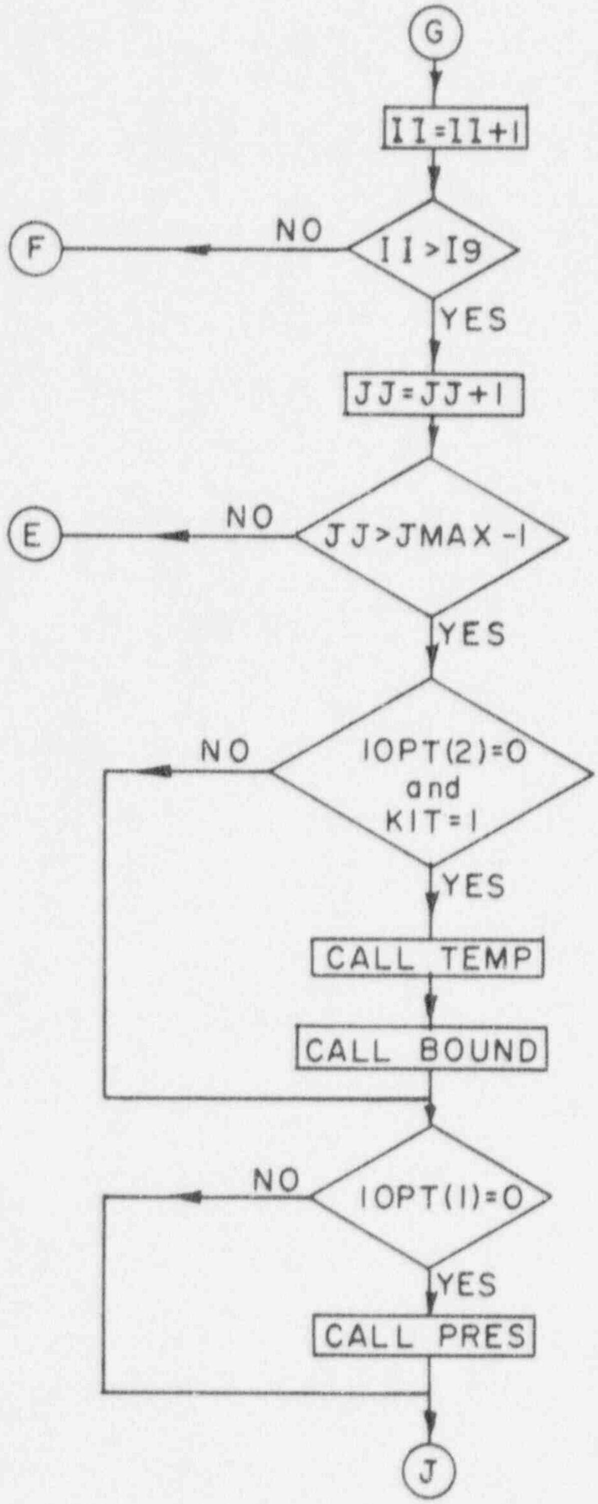

G
II=II+1
NO
F
II>I9
YES
JJ=JJ+1
NO
E
JJ>JMAX-1
YES
NO
IOPT(2)=0
and
KIT=1
YES
CALL TEMP
CALL BOUND
NO
IOPT(1)=0
YES
CALL PRES
J

Fig. 14 (Contd.)

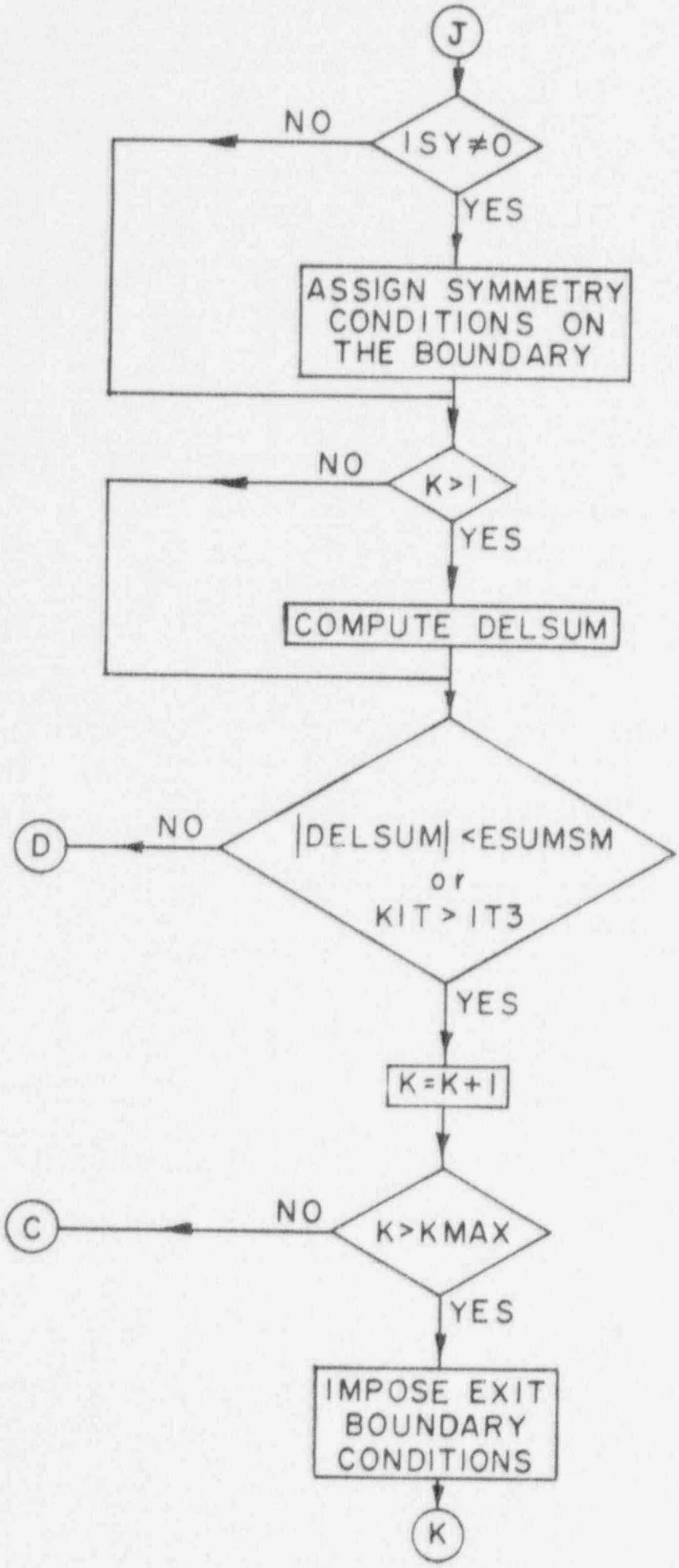

J
NO
ISY≠0
YES
ASSIGN SYMMETRY CONDITIONS ON THE BOUNDARY
NO
K>1
YES
COMPUTE DELSUM
D
NO
|DELSUM| <ESUMSM or KIT > IT3
YES
K=K+1
C
NO
K>KMAX
YES
IMPOSE EXIT BOUNDARY CONDITIONS
K

Fig. 14 (Contd.)

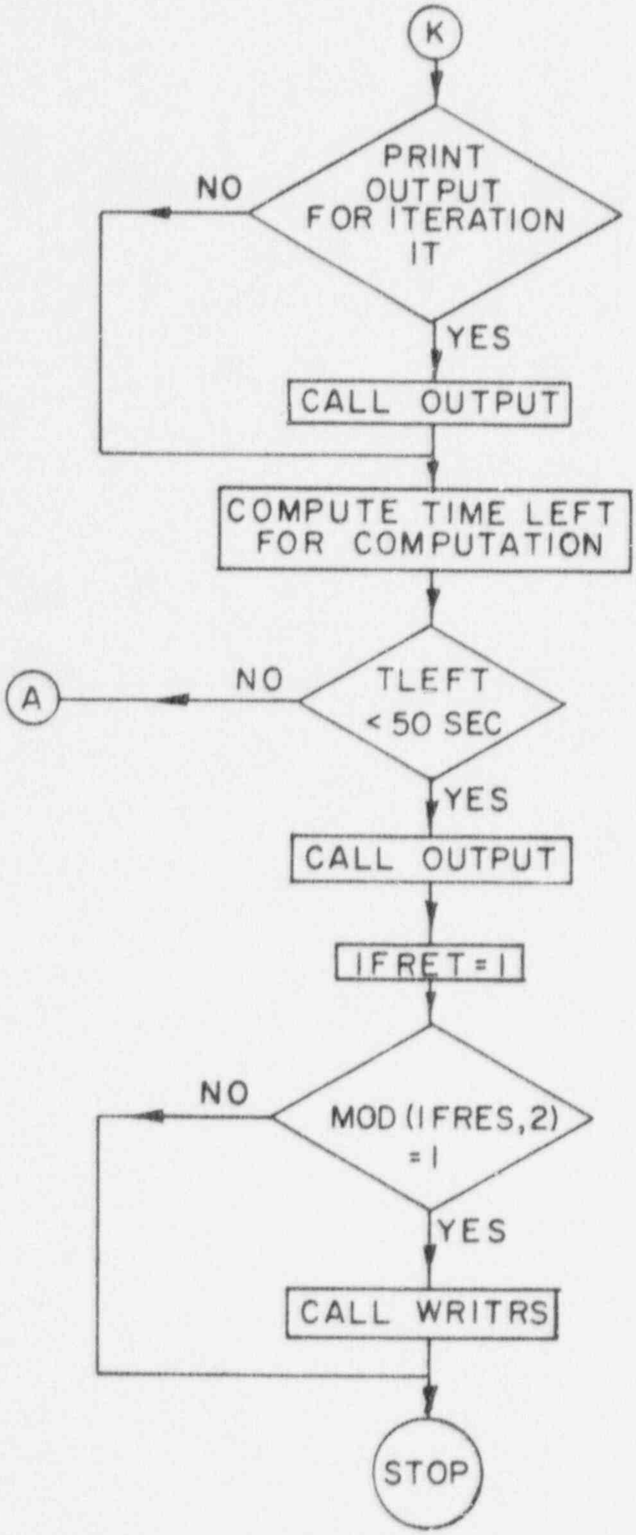

K
PRINT OUTPUT FOR ITERATION IT
NO
YES
CALL OUTPUT
COMPUTE TIME LEFT FOR COMPUTATION
TLEFT < 50 SEC
NO
A
YES
CALL OUTPUT
IFRET=1
MOD (IFRES,2) =1
NO
YES
CALL WRITRS
STOP

Fig. 14 (Contd.)

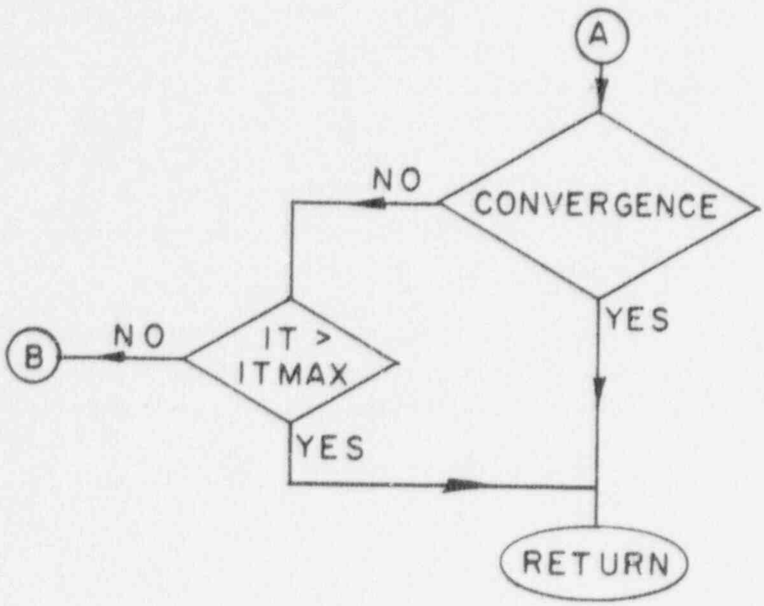


Fig. 14 (Contd.)

entrance level. All the initial guesses for flow velocities, temperature variables, density, and turbulent energy, conductivity, and viscosity are calculated. Then the subroutine OUTPUT is called to print out the initial values of all these variables. The time step is incremented. The present time values of all the variables are transferred to the old time variables. Depending on the options, subroutines SOLN, FUEL, and DUCT may then be called. Subroutine SOLN solves u, v, and w velocities based on the momentum equations and solves enthalpies based on the energy equation. Calculations of the turbulence variables are nested inside this subroutine. Subroutine FUEL computes the fuel-pin temperatures based on the subchannel coolant temperatures. It uses a modified implicit numerical scheme and a 1-D fuel-pin model. Detailed equations are given in Sec. IX.A. All the fuel pins are divided into five or six sectors, corresponding to the various subchannels adjacent to the pins. Finer division of the fuel pin is not warranted due to the tremendous increase in the computer storage requirement for the fuel-pin temperature calculation. Figure 12 also shows the fuel-pin sectorial orders for a hexagonal rod bundle. Duct-wall temperatures are calculated next. For hexagonal bundles, only the temperatures for the bottom duct walls (TDB) are calculated.

An iterative calculational loop is performed between the momentum and enthalpy calculations and the fuel-pin and duct-wall temperature calculations. The feedbacks from the subroutines FUEL and DUCT to the subroutine SOLN are the heat fluxes on the surfaces of the fuel pins and duct walls. With these heat fluxes, the coolant temperatures are recomputed in the subroutine SOLN. Then new subchannel temperatures are calculated based on the updated temperature profiles from SOLN. These new subchannel temperatures are used in the subroutines FUEL and DUCT to recompute fuel-pin and duct-wall temperatures based on the heat-generation rates inside the fuel pins. Then new fuel-pin surface heat fluxes are calculated. This process is repeated until the changes in the fuel-pin heat fluxes are within a specified tolerance limit or until the number of iterations has reached a specified maximum value.

Subroutine OUTPUT might be called, depending on the printing options specified by users. Plot tape for the given time step and u, v, w, T, P variables might be created according to user's specifications. Then a comparison is made between the current time step and the maximum allowable time step. If the maximum time step is reached, a restart tape is written for all the variables inside the common blocks if requested. If the time step has not reached the specified maximum value, then calculation starts at the next time step again, as shown by B in Fig. 13.

The flow chart for subroutine SOLN starts with the initialization of the iteration counter (IT), the sweeping counter (IS), and the variables representing errors within a given iteration loop. The sweeping counter (IS) determines the direction of the sweeping for the momentum and the energy calculations in

the I and J directions. Cells lying outside the flow region are identified, and the calculations for these cells are skipped. Two arrays are used to identify the position of a computational cell relative to the physical boundaries. They are LSLIT(I,J) and NB(N) arrays. LSLIT(I,J) identifies the physical boundaries; NB(N) identifies the position of a cell relative to these boundaries. Figure 15 shows LSLIT(I,J) for a 7-pin hexagonal rod bundle. The interior points of a fuel pin have LSLIT = -10000. NB array for a 7-pin hexagonal rod bundle is shown in Fig. 16. These two arrays are read in along with all the other geometric information from the tape created by the coordinate transformation program.

Average geometric coefficients are calculated next for basic cells and staggered cells. The transformed velocities $(\tilde{u},\tilde{v},\tilde{w})$ are computed. Then the various terms inside the momentum equations are solved. They are convective terms, pressure terms, stress terms due to the presence of the viscosity (Subroutine VISC), gravity terms, and grid-resistance terms. A special treatment in Subroutine VISC is worth mentioning here. All the coefficients associated with velocity of the calculational node are factored together to form a diagonal term. This diagonal term is moved to the left-hand side of the momentum equation to enhance the rate of convergence in the cell-to-cell velocity calculation. Once velocities are updated, the turbulence energy and the rate of dissipation are solved based on the one- or two-equation turbulence models (Subroutine TURB) specified by user's options.

The energy equation is solved next. It includes convective terms, conduction terms, and pressure-work terms. Dissipation terms and internal heat-generation terms are neglected in the present work. The central terms within the heat-conduction terms are factored out again to enhance the calculational rate of convergence. This false-position type of Newton iteration scheme was described briefly in Sec. VIII.

The momentum, turbulence, and enthalpy calculation procedure is repeated from cell to cell until all the cells within the given axial plane are exhausted. Subroutine TEMP is called then to compute the subchannel average temperatures. Subroutine BOUND is called to compute the boundary temperatures based on the heat flux from the previous iteration or from the initial guess. Subroutine PRES is called next to compute the residual mass for each cell, and then the pressure corrections are performed for all the cells. The planar mass flux is computed also, and the overall axial pressure correction is performed to reduce the residue of the axial planar mass flux. For rod bundles having symmetrical boundary conditions, symmetric conditions are imposed next. If the planar-mass-flux residue is not within the tolerance limit specified by the user, momentum calculations are repeated for the given plane. With the newly calculated velocities, pressure corrections for all the cells and for all the downstream planes are performed again. The planar-mass-flux residue is checked again. The above calculational loop is repeated until the convergence limit has been achieved or the allowable maximum number of iterations has been reached.

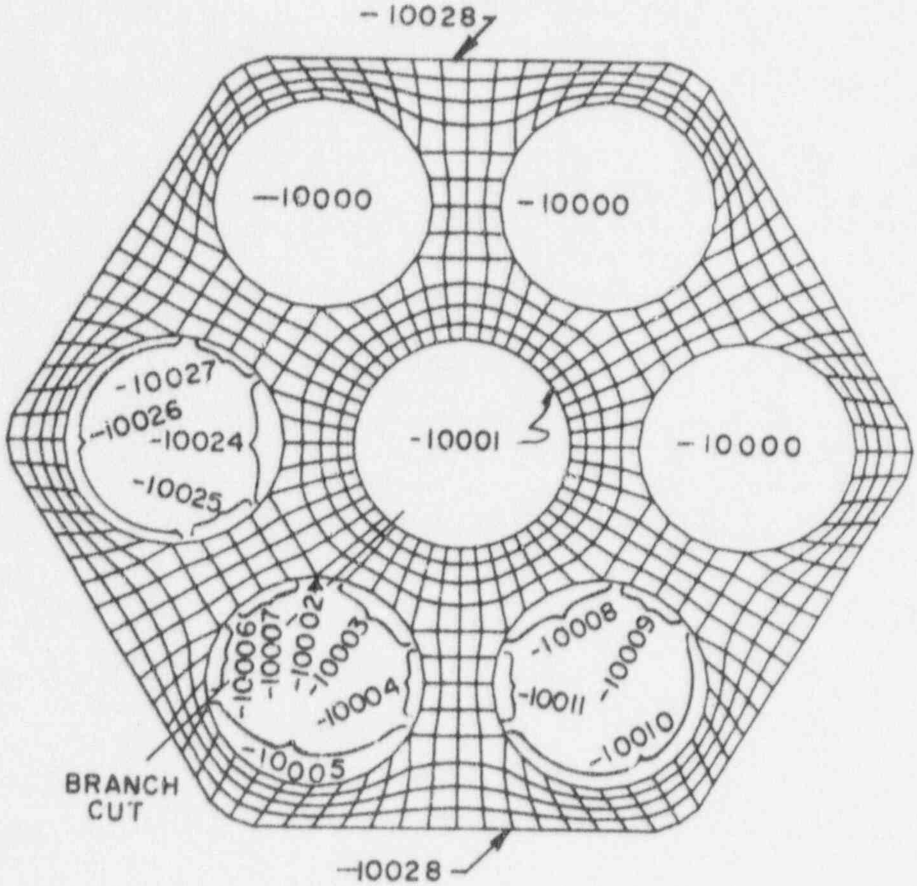


Fig. 15. LSLIT(I,J) array for a 7-pin hexagonal rod bundle

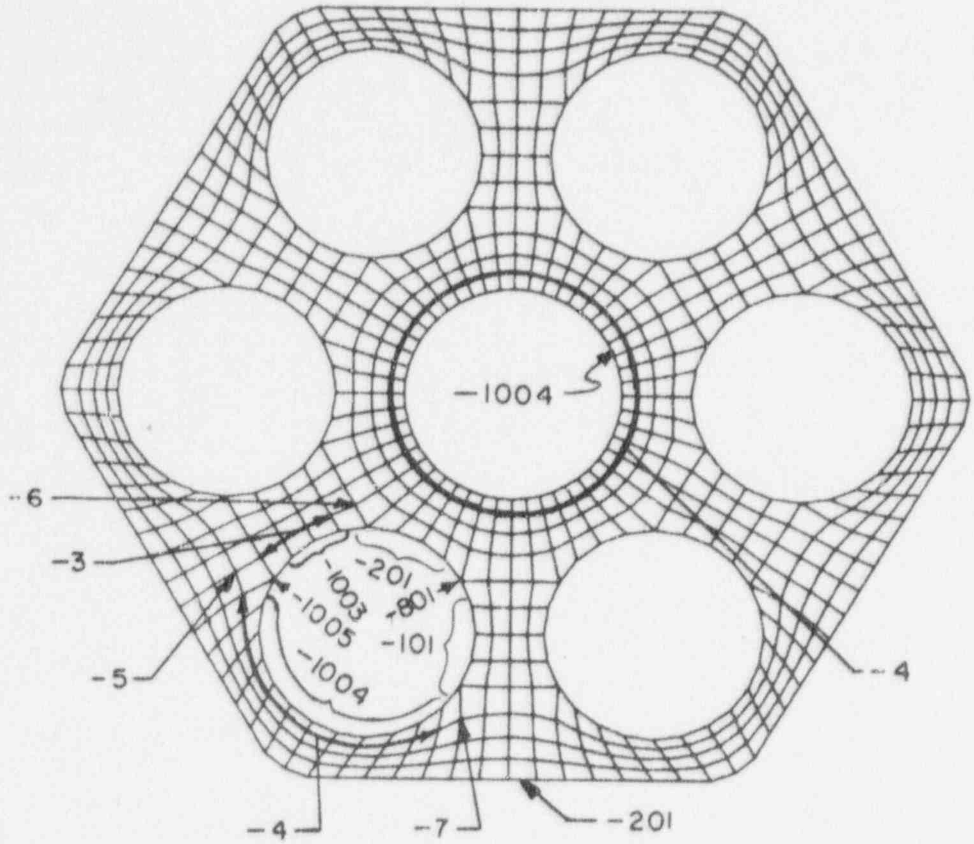


Fig. 16. NB(N) array for a 7-pin hexagonal rod bundle

The above calculational procedure for a given axial plane is repeated for the next plane from the inlet plane to the exit plane. Then the exit boundary conditions are imposed for the k = kmax plane, which is the exit plane. Printing options are checked. The remaining computer running time is checked. If there is not enough time left for another iteration loop, calculation is terminated and a restart tape may be written. If enough time is left for another calculational loop, the convergence of the current calculation is checked. If the calculation has not converged yet and the number of iterations has not reached the allowable maximum, another velocity, turbulence, and enthalpy calculation is repeated from the inlet plane to the exit plane. All these procedures are outlined in the flow charts shown in Figs. 13 and 14.

APPENDIX B

Common Block Description

A sample COMMON BLOCK is shown in Fig. 17. All the dimensions of the variables inside the common block have to be changed from geometry to geometry, depending on the size of the geometry. The dimensions are determined as follows.

U, V, W, H, T, P, RHO, UOLD, VOLD, WOLD, HOLD, POLD, RHOLD, PS, GX1A, TB, AK, AEP, AMU, AKOLD, and AEPOLD are all two-dimensional arrays. The first dimension is the total number of computational grid points. It is provided by the printout of the coordinate generation program under the variable name NTOT. The second dimension is the total number of axial levels.

NCHNL, X1, X1ETA, X1XI, X2, X2ETA, X2XI, JACB, NBOUND, HALF, HBET, and HGAM are one-dimensional arrays. The only dimension is the total number of computational grid points.

N and LSLIT are two-dimensional arrays. The first dimension is the number of grid points in the I direction. The second dimension is the number of grid points in the J direction.

NPNQ and NPQ are two-dimensional arrays. The first dimension is the total number of pins. The second dimension is the number of sectors in a pin. It is currently fixed to be 6.

NCHTP is a one-dimensional array. Its dimension is the total number of subchannels. It is provided by the printout of the coordinate generation program under the variable name NCHT.

ALFA, BETA, GAMA, TINITL, SUMSM, ATEMP, SUMH, DTSM, DZDARC, QAXIAL, ARC, XA, ZA, and KA are one-dimensional arrays. Their dimensions are given by the number of axial levels.

QPIN is a two-dimensional array. The first dimension is the number of axial levels. The second dimension is the total number of sectors of all the fuel pins to be included in the calculation. In physical problems having symmetry, the sectors outside the symmetry lines are not counted.

QRAD is a one-dimensional array. Its dimension is given by the number of pins.

C, IBUG, EPS, IOPT, and FAC are one-dimensional arrays. The dimension is fixed to be 30.

NPIN is a one-dimensional array. Its dimension is given by the coordinate generation program under the variable name NBDY.

NTPRNT, ITPRNT, NTHPR, ISTPR, and NTPLOT are one-dimensional arrays. Their dimensions are fixed to be 50.

```
 COMMON/VAR/        U( 238,10),     V( 238,10),      W( 238,10),
1                   H( 238,10),     T( 238,10),      P( 238,10),
2                 RHO( 238,10),  UOLD( 238,10),   VOLD( 238,10),
3                WOLD( 238,10),  HOLD( 238,10),   POLD( 238,10),
4               RHOLD( 238,10),    PS( 238,10),   GX1A( 238,10),
5                  TB( 238,10), NCHNL(238    ),
6                  X1( 238   ), X1ETA( 238   ),   X1XI( 238   ),
7                  X2( 238   ), X2ETA( 238   ),   X2XI( 238   ),
8                JACB( 238   ),                  NBOUND( 238   ),
9                HALF( 238   ),  HBET( 238   ),   HGAM( 238   ),
A     N(21,21),     LSLIT( 21,21 ),    NPNQ(  19, 6), NPQ( 19, 6),
B NCHTP( 48),   ALFA(       10),  BETA(       10),   GAMA(     10),
C   TINITL( 10),    SUMSM(10),     ATEMP(  10),    SUMH(     10),
D   DISM(  10),                 QPIN(  10,  10),DZDARC(      10),
E QAXIAL( 10),  QRAD(     19 ),  C(          30),    IBUG(     30),
F EPS(    30),  IOPT(       30),    FAC(   30),  NPIN(  76),VAREND
 COMMON /RPAR/  RE,D,PR,PE, DTD,DT,DREF,VEL,TOLVEL,TOLENT,TOLPRE,
1 EU, EV, EW, EH,  EP, EQP,  EQO,  ESUMSM,  PREF,HREF,RREF,
2 TREF,  CNREFI,VSREFI,CPREFI,HREFI, RREFI, RIN,AO,BO,FLAREA,
3   PIN, TIN,   GX,GY,GZ,FLRT,    F, ESMR, TURBK  ,TURBF, RPAEND
 COMMON /IPAR/  ITMAX, I,J,K,I0,I8,I9,NTOT,IMAX,JMAX,KMAX,NROW,
1 IMXM1, JMXM1, KMXM1, IMXM2, JMXM2, KMXM2, NPORD, IBHAX, IBVAX,
2 IBHSOL,IBVSOL,IBPSOL,IBITER,IBLO,  IBHI,  JBLO,  JBHI,  KBLO,
3 KBHI,  IFRES, INPLOT,IT1,IT2,IT3,  ITSET, IFRET, NSTEPS,NBDY,IS,
4 IIM,JJM,KKM,IIP,JJP,KKP,ISWEEP,IPRES,IPROB,ISY,NCHT,NPINS,IGEO,
5 IPQ,J0,J8,J9,IPAEND
 COMMON /OUT/ NTPRNT(50),ITPRNT(50),NTHPR(50),ISTPR(50),NTPLOT(50),
1              TIME,NIT,NNT,NOT,IT,NT,JUNK1,OUTEND
 COMMON /PRE/   ARC(10),XA(10),ZA(10),KA(10),JUNK3,PREEND
 REAL   JINO, JINIM, JINIP, JINJM, JINJP
 COMMON /VIS/ GINIM, GINIP, GINJM, GINJP, GINKM, GINKP,  JINO,
1       ALFAM, ALFAP, BETAM, BETAP, JINIM, JINIP, JINJM, JINJP,
2       X1CJM, X1CJP, X1NIM, X1NIP, X2CJM, X2CJP, X2NIM, X2NIP,
3      GX1AIM,GX1AIP,GX1AJM,GX1AJP,     IO,     IP,     IM,     JO,
4          JP,     JM,     KO,     KP,     KM,JOK,UO,     VO,     WO,
5      STRSX1,STRSY1,STRSZ1,STRSX2,STRSY2,STRSZ2,
6     NIOJO, NIMJO, NIPJO, NIOJM, NIMJM, NIPJM, NIOJP, NIMJP,NIPJP,
7      VISEND
 COMMON/FUE/   WCH(     48, 10),  TCH(     48, 10),  HCOE(    48, 10),
1  TCOLD( 7, 10, 10),  TLL( 7, 10, 10),
2  DECH(  3), ALFR(  7),  BETR(  7),  AAA(  7),  DDD(  7),
3  SSS( 7), FI( 7), RADIAL( 7),Q( 7), HCOND,NC, NTFU,TOLTDO,
4  TDL( 21, 10), TDR( 21, 10), TDT( 21, 10), TDB( 21, 10),
5  TDLOLD( 21, 10),TDROLD( 21, 10),TDTOLD( 21, 10),TDBOLD( 21, 10),
6  QDOL( 21, 10),QDOR( 21, 10), QDOT(  21, 10),QDOB( 21, 10),
7  WDOC,FUEEND
 COMMON/TUR/ AK(238,10),AEP(238,10),AMU(238,10),AKOLD(238,10),
1            AEPOLD(238,10),TUREND
```

Fig. 17. A sample COMMON BLOCK

WCH, TCH, and HCOE are two-dimensional arrays. The first dimension is the number of subchannels provided by the coordinate generation program under the variable name NCHT. The second dimension is the number of axial levels.

TCOLD and TCL are three-dimensional arrays. The first dimension is the number of radial nodes to be used in the fuel-pin temperature calculation. The second dimension is the total number of sectors to be included in the calculation. The third dimension is the number of axial levels.

DECH is a one-dimensional array. Its dimension is fixed to be 3.

ALFR, BETR, AAA, DDD, SSS, FI, RADIAL, and Q are one-dimensional arrays. Their dimensions are the number of radial nodes to be used in the fuel-pin temperature calculation.

TDL, TDR, TDLOLD, TDROLD, QDUL, and QDUR are two-dimensional arrays. The first dimension is the number of grid points in the J direction. The second dimension is the number of axial levels.

TDT, TDB, TDTOLD, TDBOLD, QDUT, and QDUB are two-dimensional arrays. The first dimension is the number of grid points in the I direction. The second dimension is the number of axial levels.

The above descriptions include all the dimensional variables used in the code.

APPENDIX C

Input Description

The following input description is for the coordinate generation program.

```
*************** INPUT DESCRIPTION ******************

 C1         FIRST TITLE CARD. (80 CHARACTERS)
 C2         SECOND TITLE CARD. (80 CHARACTERS)

***** NAMELIST /SIZE/ *****

  FOLLOWING INPUTS MUST BE ENTERED

 NPINS      NUMBER OF PINS.
 NROW       NUMBER OF ROWS OF PINS. (7 PIN HEX BUNDLE HAS 2 ROWS)
 IGEO       1--HEX GEOMETRY
            2--RECTANGULAR GEOMETRY (NOT OPERATIONAL)

   FOLLOWING INPUTS WILL BE CALCULATED BY CODE IF OMITTED FROM INPUTS

 N1         NUMBER OF LINES BETWEEN TWO SOLID BOUNDARIES.
            FOR RECTANGULAR ASSEMBLY, N1 CAN BE ANY NUMBER.
            FOR HEX ASSEMBLY, N1 CAN ONLY BE ANY ODD NUMBER IN ORDER
            TO PRESERVE GRID SYMMETRY.
 NPOS       NUMBER OF POINTS ON BOTTOM  WALL.
            NUMBER OF POINTS ON THE DUCT WALL FOR HEX CASE.
 NPOI       NUMBER OF POINTS FOR CENTER PIN (FOR HEX GEOMETRY ONLY)
 NPOP       NUMBER OF POINTS ON EACH PIN.
 NOUT       NUMBER OF LINES OMITTED IN THE CENTER REGION
            (0 FOR RECTANGULAR BUNDLE)
 NTOT       TOTAL NUMBER OF CALCULATIONAL POINTS
 NTOTS      TOTAL NUMBER OF CALCULATIONAL POINTS FOR SYMMETRICAL CASE
 NCHT       TOTAL NUMBER OF SUBCHANNELS
 NCHTS      TOTAL NUMBER OF SUBCHANNELS FOR SYMMETRICAL CASE

***** NAMELIST /SET/ *****

 R          PIN RADIUS. (METER)
 CLRSI      CLEARANCE BETWEEN PINS. (METER)
 CLRSW      CLEARANCE BETWEEN WALL AND PINS. (METER)
 RX         DELTA X RATIOS UP TO 100 RATIOS IN THE X DIRECTION.(1.0)
 RY         DELTA Y RATIOS UP TO 100 RATIOS IN THE Y DIRECTION.(1.0)
            THE ABOVE TWO RATIOS ARE USED TO CONTROL VARIABLE SPACINGS
            FOR RECTANGULAR BUNDLE ONLY. THEY DO NOT HAVE TO BE
            NORMALIZED.
 IPRNT      0--NO COORDINATES PRINTED.
            1--COORDINATES PRINTED.
 SCALE      SCALE FACTOR TO CONVERT X AND Y COORDINATES TO INCHES FOR
            PLOTTING PURPOSE.  ASSUME A SCREEN SIZE OF 11X11 INCHES.
 X0         X ORIGIN OF THE PLOT IN INCHES
 Y0         Y  ORIGIN OF THE PLOT IN INCHES
```

```
****** NAMELIST /SLABS/ ******

  ITER       MAXIMUM NUMBER OF ITERATIONS FOR THIS RUN. (100)
  IDISK      0--DO NOT WRITE SOLUTION OF THE COORDINATE TRANSFORMATION
                ON TAPE FILE 16.
             1--WRITE SOLUTION ON FILE 16.
  IWIR       0--DO NOT WRITE EACH ITERATION ERROR.
             1--WRITE EACH ITERATION ERROR.
  IWINTL     0--DO NOT WRITE INITIAL GUESSES.
             1--WRITE INITIAL GUESSES.
  IWFIN      0--WRITE FINAL VALUES.
             1--SUPRESS PRINT OF FINAL VALUES.
  IBUG       0--NO DEBUGGING.
             1--VARIOUS DEBUGGING PERFORMED.
  ISYM       0--NO SYMMETRY
             1--ONE TWELFTH SYMMETRY FOR A HEXAGONAL BUNDLE
             2--HALF SYMMETRY IN X-DIRECTION FOR A RECTANGULAR BUNDLE
             4--QUARTER SYMMETRY FOR A RECTANGULAR ROD BUNDLE.
  R(1)       GAUSS-SEIDEL ACCELERATION PARAMETER OMEGA.  (1.4)
             A ZERO VALUE CAUSES VARIABLE ACCELERATION PARAMETER
             TO BE CALCULATED INTERNALLY.
  R(2)       ALLOWABLE X-ERROR.  (0.0001)
  R(3)       ALLOWABLE Y-ERROR.  (0.00001)
  IPLOT      1--NO PLOTTING PERFORMED.
             DIVISIBLE BY 2--PLOT PIN AND DUCT WALLS.
             DIVISIBLE BY 3--PLOT THE INITIAL COORDINATE SYSTEM.
             DIVISIBLE BY 5--PLOT THE FINAL COORDINATE SYSTEM.
  ISLABO     0--GENERATE SLAB BOUNDARY INDICES INTERNALLY.
                THIS DEFAULT VALUE IS STRONGLY RECOMMENDED.
             1--READ SLAB BOUNDARY INDICES FROM CARDS AS DESCRIBED
                BELOW. THE SLAB INDICES FOR MISSING REGION ARE FIRST
                READ IN, AND THEN THE PHYSICAL BOUNDARIES.

    THE FOLLOWING DESCRIBES THE SLAB BOUNDARY INDICES AND IS TO
    BE INPUT ONLY IF ISLABO=1.
    EACH PIN IS TRANSFORMED INTO FOUR HORIZONTAL OR VERTICAL SLAB
    SIDES.  THE PINS MUST BE TRAVERSED IN THE SAME ORDER IN WHICH
    THE POINTS ARE GENERATED IN SUBROUTINE ***BUN.  POINTS MUST NOT
    BE REPEATED.  AFTER THE DUCT IS TRAVERSED THE PIN BOUNDARY
    IS TRAVERSED STARTING AT THE LOWER LEFT CORNER AND PROCEEDING
    CLOCKWISE FOR BOTH PIN AND DUCTS.

*** NBDY CARDS IN FORMAT (4I5) ***

  LB1        FIRST INDEX OF SLAB SIDE END.
  LB2        LAST INDEX OF SLAB SIDE END.
  LB3        INDEX OF LINE ON WHICH SLAB IS LOCATED.
  LTYPE     -1--HORIZONTAL SLAB.
            -2--VERTICAL SLAB.

  THE FOLLOWING INPUTS HAVE NO DEFAULT VALUES.
  THE LAST TWO SETS OF INPUTS ARE IN THE FORMAT OF 6I5 FOR
  NPNQ(NP,NQ) FIRST AND THEN FOR NPQ(NP,NQ). EACH HAS NPINS CARDS.
  NPNQ(NP,NQ) IS THE CHANNEL NUMBER FOR PIN NP AND SECTOR NQ.
  NPQ(NP,NQ) IS THE PIN SECTOR ORDER FOR PIN NP AND
  SECTOR NQ. REFER TO BODYFIT DOCUMENT FOR THE NUMBERING SCHEMES.

******** END OF INPUT DESCRIPTION ********
```

The following input description is for the second program of BODYFIT-1FE in solving the transformed governing equations.

```
******************************************************************************

 INPUT DESCRIPTION FOR NAMELIST &SET.
 VALUES INSIDE THE BRACKETS AFTER THE DESCRIPTIONS ARE DEFAULTS


C1,C2     FIRST TWO CARDS ARE TITLES IN 20A4 FORMAT.
IFRES     RESTART OPTIONS IN I5 FORMAT.
          0--NEW CASE WITH NO RESTART WRITTEN. (DEFAULT)
          1--NEW CASE WITH RESTART WRITTEN TO TAPE 26.
          2--RESTART OF PREVIOUS RUN READ FROM TAPE 25 WITH NO
             RESTART TAPE WRITTEN.
          3--RESTART OF PREVIOUS RUN READ FROM TAPE 25 WITH A
             RESTART TAPE WRITTEN TO TAPE 26.

 ALL THE FOLLOWING INPUTS ARE FOR THE NAMELIST SET

GX       UNIT VECTOR GRAVITY COMPONENT IN THE X-DIRECTION.(0)
GY       UNIT VECTOR GRAVITY COMPONENT IN THE Y-DIRECTION.(0)
GZ       UNIT VECTOR GRAVITY COMPONENT IN THE Z-DIRECTION.(1)
    ARRAY OUTPUT IS DONE IN SUBROUTINE OUTPUT WHICH IS CALLED
    ONCE AFTER INITIALIZATION AND ACCORDING TO THE ARRAYS NTPRNT
    AND ITPRNT.  OUTPUT IS CALLED DURING AN ITERATION ONLY IF
    OUTPUT IS CALLED DURING THE CURRENT TIME STEP.
NTPRNT      >0--UP TO 50 TIME STEPS AT WHICH THE OUTPUT ROUTINE IS
             TO BE CALLED.
NTPRNT(1)   -1--OUTPUT IS CALLED EVERY TIMESTEP.
            -N--OUTPUT IS CALLED EVERY NTH TIMESTEP.
             0--OUTPUT IS CALLED ONLY AFTER INITIALIZATION.
ITPRNT      >0--UP TO 50 ITERATIONS AT WHICH THE OUTPUT ROUTINE IS
                TO BE CALLED.
ITPRNT(1)   -1--OUTPUT IS CALLED EVERY ITERATION DURING SPECIFIED
                TIMESTEPS.
            -N--OUTPUT IS CALLED EVERY NTH ITERATION DURING SPECIFIED
                TIMESTEPS.
             0--OUTPUT IS NOT CALLED DURING ITERATION LOOP.
NTPLOT      >0--UP TO 50 TIME STEPS WHERE PLOT TAPE IS WRITTEN FOR
            U,V,W,T,P
ISTPR       UP TO 50 VALUES WHICH SPECIFY THE ARRAYS TO BE PRINTED
            IN THE FIRST CALL TO OUTPUT. (0)
NTHPR       UP TO 50 VALUES WHICH SPECIFY THE ARRAYS TO BE PRINTED
            IN ALL SUBSEQUENT CALLS TO OUTPUT. (0)
    EACH VALUE OF ISTPR AND NTHPR IS A SIGNED FOUR-DIGIT INTEGER
    OF THE FORM 'SVPLL' WHOSE VALUE IS SPECIFIED ACCORDING TO THE
    FOLLOWING RULES:

    S  +  ONLY THE PLANE SPECIFIED BY VPLL IS PRINTED.
          (PLUS IS ASSUMED AND NEED NOT BE SPECIFIED.)
```

```
   -  ALL PLANES BETWEEN VPLL AND THE NEXT VPLL ARE PRINTED.
 V      1--U IS PRINTED           2--V IS PRINTED.
        3--W IS PRINTED.          4--H IS PRINTED.
        5--T IS PRINTED.          6--P IS PRINTED.
        7--RHO   IS PRINTED.      8--TB    IS PRINTED.
        9--PS    IS PRINTED.     10--UOLD IS PRINTED.
       11--VOLD IS PRINTED.      12--WOLD IS PRINTED.

       THE FOLLOWING 1-D VARIABLES CAN BE PRINTED FOR K-PLANE ONLY
       13--X1 IS PRINTED.        14--JACB IS PRINTED.
       15--X1XI IS PRINTED.      16--X2XI IS PRINTED.
       17--X1ETA IS PRINTED.     18--X2ETA IS PRINTED.
       19--X2 IS PRINTED.
       FOLLOWING 2 OUTPUTS ARE PRINTED FOR K-PLANE ONLY
       20--TCL (FUEL PIN TEMPERATURE) IS PRINTED.
       21--TDU (DUCT WALL TEMPERATURE) IS PRINTED.
 P     PLANE INDEX OF THE DESIRED OUTPUT
       1--I PLANE
       2--J PLANE
       3--K PLANE
 LL    TWO DIGITS FOR INDEX OF THE PLANE DEFINED BY P

SLIPR   SLIP RATIO
        0--NO SLIP
KMAX    NUMBER OF AXIAL POINTS.
NSTEPS  NUMBER OF TIME STEPS.
IT1     THE NUMBER OF ITERATIONS PER TIME STEP THROUGH TIME STEP
        ITSET.
IT2     THE NUMBER OF ITERATIONS PER TIME STEP AFTER TIME STEP
        ITSET.
ITSET   THE TIME STEP AFTER WHICH THE NUMBER OF ITERATIONS PER TIME
        STEP IS CHANGED FROM IT1 TO IT2.
IT3     THE NUMBER OF VELOCITY ITERATIONS PER PRESSURE CORRECTIUN
DTD     TIME STEP IN SECONDS.
VEL     ENTRANCE VELOCITY IN M/SEC.
PENT    ENTRANCE PRESSURE IN ATM.
TENC    ENTRANCE TEMPERATURE IN C
WDUC    THICKNESS OF DUCT WALL  IN M
DREF    REFERENCE LENGTH (USUALLY THE HYDRAULIC DIAMETER) IN M
TOLVEL  TOLERANCE FOR VELOCITY CONVERGENCE .
TOLENT  TOLERANCE FOR ENTHALPY CONVERGENCE .
TOLPRE  TOLERANCE FOR PRESSURE CONVERGENCE .
TOLTDU  TOLERANCE FOR DUCT WALL TEMPERATURE CONVERGENCE
ESUMSM  TOLERANCE FOR CONVERGENCE  ON PLANAR MASS FLUX .
XA      X COORDINATES FOR THE AXIS OF THE ASSEMBLY IN M
ZA      Z COORDINATES FOR THE AXIS OF THE ASSEMBLY IN M
QDUL    LEFT DUCT WALL HEAT FLUX IN W/(M**2).  INPUT ONE VALUE FOR
        EACH ETA LINE AND THEN FOR EACH ZETA LINE. QDUL(J,K)
QDUR    RIGHT DUCT WALL HEAT FLUX. QDUR(J,K)
QDUT    TOP DUCT WALL HEAT FLUX. INPUT ONE VALUE FOR EACH XI LI E
        AND THEN FOR EACH ZETA LINE. QDUT(I,K)
QDUB    BOTTOM DUCT WALL HEAT FLUX. QDUB(I,K)
QPIN    FUEL PIN HEAT FLUX IN W/(M**2).  INPUT ONE VALUE FOR EACH
        AXIAL GRID LINE AND THEN FOR EACH SECTOR. QPIN(K,MPQ)
QRAD    NORMALIZED RADIAL HEAT FLUX DISTRIBUTION.  INPUT ONE VALUE
        FOR EACH PIN. NUMBER THE PINS IN ALL COLUMNS FROM
```

```
         BOTTOM TO TOP AND LEFT TO RIGHT STARTING FROM THE LEFT
         BOTTOM CORNER FOR THE RECTANGULAR ROD BUNDLE.
         NUMBER THE PIN FROM INSIDE OUT AND CLOCKWISE STARTING WITH
         BOTTOM PIN OF EACH ROW FOR HEXAGONAL ROD BUNDLE.
NPORD    1--ZERO FIRST DERIVATIVE ON EXIT BOUNDARY CONDITIONS.
         2--ZERO SECOND DERIVATIVE ON EXIT BOUNDARY CONDITIONS.
PGRAD    INITIAL AXIAL PRESSURE GRADIENT IN ATM (0.0).
TURBF    MULTIPLYING FACTOR FOR TURBULENT VISCOSITY. (1.0)
TURBK    MULTIPLYING FACTOR FOR TURBULENT CONDUCTIVITY. (1.0)
IPRES    1--ITERATE VELOCITY FOR EACH PRESSURE CORRECTION
         0--NO VELOCITY ITERATION FOR EACH PRESSURE CORRECTION
ISWEEP   1 --FOR ALTERNATING SWEEP IN I AND J DIRECTION
         0 --FOR FIXED DIRECTION  OF SWEEPING
IPROB    0 --FOR CONSTANT INLET VELOCITY
         1 --FOR CONSTANT INLET AND OUTLET PRESSURE(NOT OPERATIONAL)
AO,BO    AO=0.5,BO=0 FOR UPWIND DIFFERENCING
         AO=0.0,BO=0.0 FOR CENTRAL DIFFERENCING
AVHTF    AVERAGE HEAT FLUX IN J/M**2/SEC
QACC     RATE OF HEAT FLUX CHANGE FOR TRANSIENT CASE IN W/M2/S.
VACC     RATE OF INLET VELOCITY CHANGE FOR TRANSIENT CASE IN M/S.
TACC     RATE OF INLET TEMPERATURE CHANGE FOR TRANSIENT CASE IN C/S.
KA       AXIAL INDICES FOR LEVELS HAVING GRIDS
DECH     HYDRAULIC DIAMETERS FOR THREE SUBCHANNEL TYPES
         IN THE ORDER OF CENTRAL, WALL AND CORNER CHANNELS.
NC       TOTAL NUMBER OF RADIAL GRID LINES USED IN FUEL PIN
         TEMPERATURE CALCULATION.
NTFU     NUMBER OF GRID LINES INSIDE THE PIN FOR FUEL PIN
         TEMPERATURE CALCULATION.
RADIAL   RADIAL DISTANCE FOR EACH ZONE INSIDE THE FUEL PIN
         STARTING FROM THE CENTER NODE GOING OUTWARDS.
HCOND    GAP CONDUCTANCE INSIDE THE FUEL PIN.
Q        VOLUMETRIC HEAT GENERATION RATE IN FUEL ZONES IN WATT/M**3
QAXIAL   AXIAL HEAT DISTRIBUTION, ONE VALUE FOR EACH AXIAL LEVEL.
 ***DEBUGGING AIDS ARE PROVIDED BY THE FOLLOWING VARIABLES;
IBHAX    0--NO ENTHALPY DEBUGGING IN AXIS.
         1--ENTHALPY CALCULATION DEBUGGED IN AXIS.
IBVAX    0--NO VELOCITY DEBUGGING IN AXIS.
         1--VELOCITY CALCULATION DEBUGGED IN AXIS.
IBHSOL   0--NO ENTHALPY DEBUGGING IN SOLN.
         1--ENTHALPY CALCULATION DEBUGGED IN SOLN.
IBVSOL   0--NO VELOCITY DEBUGGING IN SOLN.
         1--VELOCITY CALCULATION DEBUGGED IN SOLN.
IBPSOL   0--NO PRESSURE DEBUGGING IN SOLN.
         1--PRESSURE CALCULATION DEBUGGED IN SOLN.
IBITER   N--PRESSURE DEBUGGING IS DONE ONLY WHEN THE ITERATION IS
            GREATER THAN OR EQUAL TO N IN SOLN.
IBLO     THE LOWEST I-INDEX FOR WHICH DEBUGGING IS TO BE PERFORMED.
IBHI     THE HIGHEST I-INDEX.
JBLO     THE LOWEST J-INDEX.
JBHI     THE HIGHEST J-INDEX.
KBLO     THE LOWEST K-INDEX.
KBHI     THE HIGHEST K-INDEX.
 ***END OF DEBUGGING VARIABLES

FAC(1)     X-VELOCITY RELAXATION FACTOR.
   (2)     Y-VELOCITY RELAXATION FACTOR.
```

```
    (3)      Z-VELOCITY RELAXATION FACTOR.
    (4)      ENTHALPY RELAXATION FACTOR.
    (5)      CELL BY CELL PRESSURE CORRECTION  PARAMETER, W1 IN
             EQUATION (77) OF THE BODYFIT DOCUMENT
    (6)      AXIAL PRESSURE CORRECTION PARAMETER, W2 IN EQUATION (78)
             OF BODYFIT DOCUMENT.
    (7)      TEMPERATURE CORRECTION PARAMETER FOR IOPT(6)=1 OR 2.
    (8)      DOWN STREAM AXIAL VELOCITY CORRECTION PARAMETER
             FOR IOPT(7)=1.
    (9)      DOWN STREAM RADIAL VELOCITY CORRECTION PARAMETER
             FOR IOPT(7)=1.
   (10)      AXIAL DUCT WALL HEAT CONDUCTION MULTIPLIER, WHEN IT IS 0,
             ALL AXIAL HEAT CONDUCTION IS NEGLECTED, WHEN IT IS 1,
             AXIAL HEAT CONDUCTION IS FULLY ACCOUNTED FOR.
   (11)      RADIAL DUCT WALL HEAT CONDUCTION MULTIPLIER. WHEN IT IS 0,
             RADIAL HEAT CONDUCTION IS NEGLECTED. WHEN IT IS 1,
             RADIAL HEAT CONDUCTION IS FULLY ACCOUNTED FOR.
   (12)      ADDITIONAL FACTOR IN THE PRESSURE CORRECTION FORMULA.
             B IN EQUATION (77) FOR PRESSURE CORRECTION FORMULA IN
             BODYFIT DOCUMENT.
C(1),C(2),C(3) COEFF FOR HEAT TRANSFER CORRELATION C(1)+C(3)*PE**C(2)
C(4),C(5),C(6) COEFF FOR FLOW RESISTANCE IN NON GRID AREA, CURRENTLY
                 THEY ARE ALL ZEROS, IT CAN BE USED TO MODEL WIRE
                 WRAPPED ROD BUNDLES.
C(7),C(8),C(9) COEFF FOR FLOW RESISTANCE IN GRID AREA, THEY ARE KF
                 IN EQUATION (99) OF THE BODYFIT DOCUMENT.
C(10)            NOT USED CURRENTLY
C(11)        SIGMA K FOR TURBULENCE ENERGY EQUATION (110). (1.0)
 (12)        SIGMA EPSILON FOR TURBULENCE EPSILON EQUATION (111).(1.3)
 (13)        CONSTANT C1 FOR TURB EPSILON EQUATION (111). (1.44)
 (14)        CONSTANT C2 FOR TURB EPSILON EQUATION (111). (1.92)
 (15)        CONSTANT C MU FOR TURB VISCOSITY IN EQUATION (109). (0.09)
 (16)        CONSTANT KARPA FOR THE LOG VELOCITY PROFILE IN EQUATION
             (113). (0.42)
 (17)        CONSTANT E FOR THE LOG VELOCITY PROFILE IN EQUATION
             (113). (9.8)
 (18)        FRACTION OF TURB KINETIC ENERGY AT INLET, F1 IN EQUTION
             (117). (0.01)
 (19)        MIXING LENGTH AS FRACTION OF HYDRAULIC DIAMETER, F2 IN
             EQUATION (117). (0.07)
 (20)        SIGMA MU FOR LAMINAR FLOW IN EQUATION (124). (1.0)
 (21)        SIGMA MU FOR TURBULENCE FLOW IN EQUATION (124). (1.0)
 (22)        SIGMA T FOR LAMINAR FLOW IN EQUATION (125). (1.0)
 (23)        SIGMA T FOR TURBULENCE FLOW IN EQUATION (125). (0.9)
IOPT(1)    1--SKIP MOMEMTUM EQUATION
    (2)    1--SKIP ENERGY EQUATION
    (3)    1--KEEP PHYSICAL PROPERTY CONSTANT
    (4)    1--KEEP FUEL-CLAD GAP CONSTANT
    (5)    2--INPUT QPIN AS FUEL PIN SURFACE HEAT FLUX
              AND QDU* AS DUCT WALL SURFACE HEAT FLUX
           1--ONLY QPIN IS COMPUTED BY THE CODE.
              QDU* IS FIXED BY THE INPUT VALUE, WHEN THIS OPTION
              IS USED QPIN SHOULD BE TAKEN OUT OF THE INPUT.
           0--QPIN AND QDU* ARE COMPUTED INTERNALLY BY THE CODE
              WHEN THIS OPTION IS USED, BOTH QPIN AND QDU* SHOULD BE
               TAKEN OUT OF THE INPUT DATA SET
```

```
     (6)   1--ALL DOWNSTREAM CELL TEMPERATURES INCREASED BY THE SAME
              AMOUNT AS THE INCREASE IN THE UPSTREAM CELL TEMPERATURE
           2--ALL DOWNSTREAM TEMPERATURE INCREASED BY THE SAME AMOUNT
              AS THE PREVIOUS PLANAR TEMPERATURE INCREASE
           ** USE THESE OPTIONS ONLY FOR STEADY STATE CALCULATION TO
            SPEED UP CONVERGENCE FOR STEADY STATE SOLUTION
     (7)   1--ALL DOWNSTREAM VELOCITIES GET CORRECTED BY THE SAME
              AMOUNT AS THE CHANGE IN THE UPSTREAM VELOCITIES
     (8)   1--NORMALIZE CELL TEMPERATURE WITH RESPECT TO INITIAL
              TEMPERATURE CALCULATED FROM 1-D HEAT BALANCE
           ** USE THIS OPTION ONLY FOR STEADY STATE CALCULATION
     (9)   0--ZERO EQUATION TURBULENCE MODEL
           1--ONE EQUATION TURBULENCE MODEL
           2--TWO EQUATION TURBULENCE MODEL
     (10)  0--IMPLICIT TIME DIFFERENCE FOR FUEL PIN MODEL
           1--SEMI-IMPLICIT TIME DIFFERENCE FOR FUEL PIN MODEL
     (11)  0--SODIUM AS COOLANT
           1--WATER AS COOLANT(NOT OPERATIONAL)
  IBUG(1)  1--DUMP COMMON BLOCKS WHEN ERROR OCCURS
     (2)   1--CHECK EACH MOMENTUM AND ENERGY CALCULATIONS
     (3)   1--WRITE RADIAL AND TOTAL HEAT CONDUCTION (CONHT,SCONHT)
     (4)   1--CHECK TEMPERATURE TO ITERATION AFTER ENTHALPY
              CALCULATION
     (5)   1--WRITE PLANAR MASS FLUX AND AVERAGE PLANAR TEMPERATURE
     (6)   1--PRINT REFERENCE CONDITION AT EACH TIME STEP
     (7)   1--PRINT INDIVIDUAL HEAT CONDUCTION TERMS FOR EACH CELL
     (8)   1--PRINT TCH,HCOE,QPIN AND QDU*
     (9)   1--PRINT TURBULENCE K,EPSILON,MU
  EPS(1)   CUTOFF FOR VELOCITY UPDATES
    (2)    CUTOFF FOR TEMPERATURE UPDATES FROM ENTHALPY CALCULATION
    (3)    ERROR ALLOWED FOR TEMPERATURE UPDATES FROM EXTRAPOLATION
           SUBROUTINE AITKEN. IT IS USUALLY SET THE SAME AS EPS(2)
    (4)    ERROR ALLOWED FOR FUEL PIN AND DUCT WALL HEAT FLUX. THIS
           ERROR DETERMINES THE NUMBER OF ITERATION BETWEEN FUEL PIN,
           DUCT WALL AND COOLANT TEMPERATURE CALCULATIONS.

*******************************************************************
```

APPENDIX D

Sample Problems

1. Output Description

Two sample problems are presented in this appendix. The output of each problem contains two parts. The first part is the coordinate generation, and the second is the solution for governing equations.

a. Part One

In the first part of the output, the coordinate generation part, a set of typical input data is given first. Since the storage requirement for the coordinate generation has to be specified by users, the number of words required versus the number of words allocated for computer storage is printed in the output. If the words allocated are not enough, the program will stop execution. In that case, the dimensions for the COMMON block SPACE and the data LENA have to be increased inside the first part of BODYFIT-1FE. The next item in the output is the boundary coordinates (x, y). Following that, the horizontal and the vertical grids (slabs) of the regions to be skipped in the coordinate computation are listed. The indices for the boundary grids (slabs) are printed. The errors for each numerical iteration and the final converged coordinates are printed. Finally, all the geometric information on coordinate transformation to be read and fed into the second part of BODYFIT-1FE is printed. The graphic display of the physical boundaries, the initial mesh structure, and the final mesh structure are also included. These graphic displays provide an easy visual check on the progress of the program when it is executed interactively.

b. Part Two

The second part of the output for each sample problem comes from the second part of BODYFIT-1FE. The input data set is printed first. Then all the indices for geometric identification as read in from the first part of the BODYFIT-1FE are printed. The initial u, v, and w velocities, temperature, and pressure arrays are printed for various vertical and horizontal cross sections. The convergence errors for u, v, w, h, and p are printed for each iteration. An option is provided for users to print out the calculated u, v, and w velocities, temperatures, and pressures at the desired intervals of iterations and time steps. The final converged solution is included also in the output for each sample problem.

2. Problem Description

a. 7-pin Hexagonal Rod Bundle

The first sample problem is a 7-pin hexagonal rod bundle with sodium as the coolant under flow rundown conditions. The experiment was performed at

the GFK Karlsruhe facility to investigate the fuel-assembly behavior after a power outage to the reactor coolant pump coincident with a failure of the reactor to trip. The complete result of the simulation is given in Ref. 16.

Figure 18 shows the axial partitioning and thermocouple locations of the model 7-pin bundle. The physical dimensions of the bundle are also given in the figure. There is an unheated entrance region 80 mm long. Following that is a heated region of 600 mm. Grids are uniformly spaced along the channel. The sodium coolant enters the assembly with a uniform velocity of 2.15 m/s and a uniform temperature of 553°C. The rods are uniformly heated by the embedded electric tape. The total heat generated by the rods is 78.6 kW. The inlet velocity drops linearly from 2.15 to 0.35 m/s in 6 s. All the other input parameters are given in the following sample outputs. The graphic printout of the physical boundaries, the initial mesh structure, and the final mesh structure are given in Figs. 19-21, respectively.

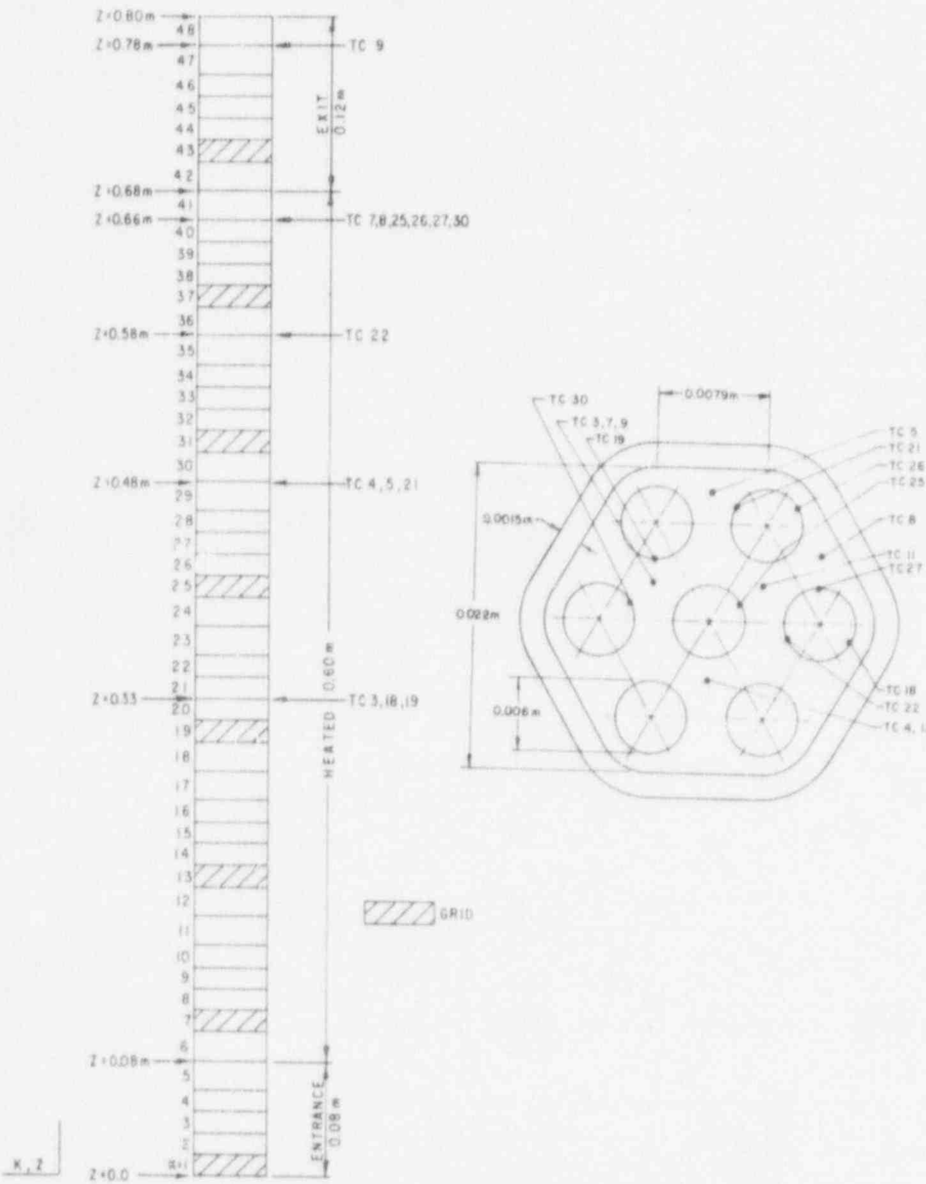


Fig. 18. Axial partitioning and thermocouple locations of the model 7-pin bundle

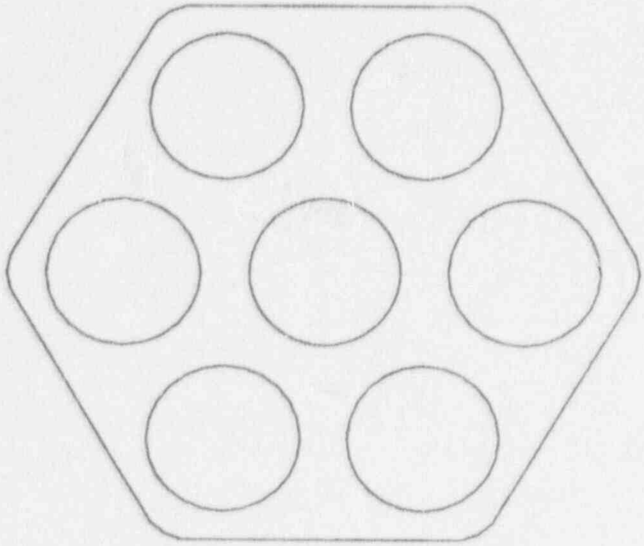


Fig. 19

Physical boundaries of a 7-pin hexagonal rod bundle

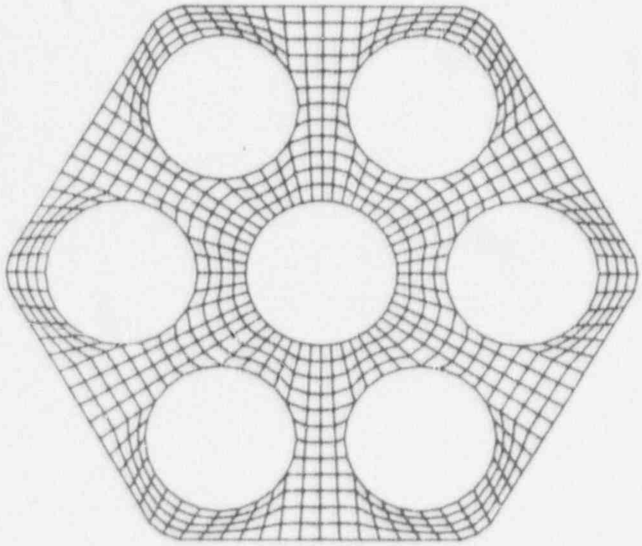


Fig. 20

An initial guess of the mesh structure for a 7-pin hexagonal rod bundle

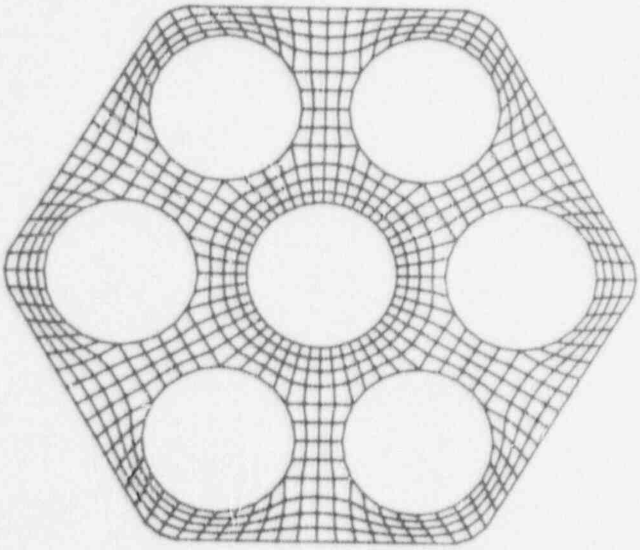


Fig. 21

A final mesh structure for a 7-pin hexagonal rod bundle

```
7 PIN HEXAGONAL ROD BUNDLE CASE #1
SIMULATION FOR GERMAN 7 PIN FLOW RUN DOWN EXP.
&SIZE NPINS=7,NROW=2,IGEO=1,&END
&SET R=0.003,CLRSI=0.0019,CLRSW=0.00116,
     SCALE=300.0,X0=7.5,Y0=5.5,&END
&SLABS IDISK=1,ISYM=1,R=1.4,1.0E-12,1.0E-12,IPLOT=30,&END
   0    0    0    0    0   19
   0    0    0   19    2    1
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    1
   0    0    0    2    3    4
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0


WORDS REQUIRED:              10135;   WORDS ALOCATED:            100000

 I (X,Y): COORDINATES OF THE BOUNDARIES AT POINT I
   1 -0.00078 -0.00290   2 -0.00115 -0.00277   3 -0.00150 -0.00260   4 -0.00183 -0.00238   5 -0.00212 -0.00212
   6 -0.00238 -0.00183   7 -0.00260 -0.00150   8 -0.00277 -0.00115   9 -0.00290 -0.00078  10 -0.00297 -0.00039
  11 -0.00300  0.00000  12 -0.00297  0.00039  13 -0.00290  0.00078  14 -0.00277  0.00115  15 -0.00260  0.00150
  16 -0.00238  0.00183  17 -0.00212  0.00212  18 -0.00183  0.00238  19 -0.00150  0.00260  20 -0.00115  0.00277
  21 -0.00078  0.00290  22 -0.00039  0.00297  23  0.00000  0.00300  24  0.00039  0.00297  25  0.00078  0.00290
  26  0.00115  0.00277  27  0.00150  0.00260  28  0.00183  0.00238  29  0.00212  0.00212  30  0.00238  0.00183
  31  0.00260  0.00150  32  0.00277  0.00115  33  0.00290  0.00078  34  0.00297  0.00039  35  0.00300  0.0
  36  0.00297 -0.00039  37  0.00290 -0.00078  38  0.00277 -0.00115  39  0.00260 -0.00150  40  0.00238 -0.00183
  41  0.00212 -0.00212  42  0.00183 -0.00238  43  0.00150 -0.00260  44  0.00115 -0.00277  45  0.00078 -0.00290
  46  0.00039 -0.00297  47  0.00000 -0.00300  48 -0.00039 -0.00297  49 -0.00150 -0.00530  50 -0.00078 -0.00500
  51  0.00000 -0.00490  52  0.00078 -0.00500  53  0.00150 -0.00530  54  0.00212 -0.00578  55  0.00260 -0.00640
  56  0.00290 -0.00712  57  0.00300 -0.00790  58  0.00290 -0.00868  59  0.00260 -0.00940  60  0.00212 -0.01002
  61  0.00150 -0.01050  62  0.00078 -0.01080  63  0.00000 -0.01090  64 -0.00078 -0.01080  65 -0.00150 -0.01050
  66 -0.00212 -0.01002  67 -0.00260 -0.00940  68 -0.00290 -0.00868  69 -0.00300 -0.00790  70 -0.00290 -0.00712
  71 -0.00260 -0.00640  72 -0.00212 -0.00578  73 -0.00534 -0.00135  74 -0.00472 -0.00183  75 -0.00424 -0.00245
  76 -0.00394 -0.00317  77 -0.00384 -0.00395  78 -0.00394 -0.00473  79 -0.00424 -0.00545  80 -0.00472 -0.00607
  81 -0.00534 -0.00655  82 -0.00607 -0.00685  83 -0.00684 -0.00695  84 -0.00762 -0.00685  85 -0.00834 -0.00655
  86 -0.00896 -0.00607  87 -0.00944 -0.00545  88 -0.00974 -0.00473  89 -0.00984 -0.00395  90 -0.00974 -0.00317
  91 -0.00944 -0.00245  92 -0.00896 -0.00183  93 -0.00834 -0.00135  94 -0.00762 -0.00105  95 -0.00684 -0.00095
  96 -0.00607 -0.00105  97 -0.00384  0.00395  98 -0.00394  0.00317  99 -0.00424  0.00245 100 -0.00472  0.00183
 101 -0.00534  0.00135 102 -0.00607  0.00105 103 -0.00684  0.00095 104 -0.00762  0.00105 105 -0.00834  0.00135
 106 -0.00896  0.00183 107 -0.00944  0.00245 108 -0.00974  0.00317 109 -0.00984  0.00395 110 -0.00974  0.00473
 111 -0.00944  0.00545 112 -0.00896  0.00607 113 -0.00834  0.00655 114 -0.00762  0.00685 115 -0.00684  0.00695
 116 -0.00607  0.00685 117 -0.00534  0.00655 118 -0.00472  0.00607 119 -0.00424  0.00545 120 -0.00394  0.00473
 121  0.00150  0.00530 122  0.00078  0.00500 123 -0.00000  0.00490 124 -0.00078  0.00500 125 -0.00150  0.00530
 126 -0.00212  0.00578 127 -0.00260  0.00640 128 -0.00290  0.00712 129 -0.00300  0.00790 130 -0.00290  0.00868
 131 -0.00260  0.00940 132 -0.00212  0.01002 133 -0.00150  0.01050 134 -0.00078  0.01080 135 -0.00000  0.01090
 136  0.00078  0.01080 137  0.00150  0.01050 138  0.00212  0.01002 139  0.00260  0.00940 140  0.00290  0.00868
 141  0.00300  0.00790 142  0.00290  0.00712 143  0.00260  0.00640 144  0.00212  0.00578 145  0.00534  0.00135
 146  0.00472  0.00183 147  0.00424  0.00245 148  0.00394  0.00317 149  0.00384  0.00395 150  0.00394  0.00473
 151  0.00424  0.00545 152  0.00472  0.00607 153  0.00534  0.00655 154  0.00607  0.00685 155  0.00684  0.00695
 156  0.00762  0.00685 157  0.00834  0.00655 158  0.00896  0.00607 159  0.00944  0.00545 160  0.00974  0.00473
```

POOR ORIGINAL

161	0.00984	0.00395	162	0.00974	0.00317	163	0.00944	0.00245	164	0.00596	0.00183	165	0.00834	0.00135
166	0.00762	0.00105	167	0.00684	0.00095	168	0.00607	0.00105	169	0.00334	-0.00395	170	0.00394	-0.00317
171	0.00424	-0.00245	172	0.00472	-0.00183	173	0.00534	-0.00135	174	0.00607	-0.00105	175	0.00684	-0.00095
176	0.00762	-0.00105	177	0.00834	-0.00135	178	0.00396	-0.00133	179	0.00944	-0.00245	180	0.00974	-0.00317
181	0.00984	-0.00395	182	0.00974	-0.00473	183	0.00944	-0.00545	184	0.00396	-0.00607	185	0.00834	-0.00555
186	0.00762	-0.00685	187	0.00684	-0.00695	188	0.00607	-0.00685	189	0.00534	-0.00655	190	0.00472	-0.00607
191	0.00424	-0.00545	192	0.00394	-0.00473	193	-0.00275	-0.01112	194	-0.00344	-0.01072	195	-0.00413	-0.01032
196	-0.00481	-0.00992	197	-0.00550	-0.00953	198	-0.00619	-0.00913	199	-0.00688	-0.00873	200	-0.00756	-0.00834
201	-0.00825	-0.00794	202	-0.00894	-0.00754	203	-0.00963	-0.00715	204	-0.01031	-0.00675	205	-0.01076	-0.00621
206	-0.01100	-0.00556	207	-0.01100	-0.00476	208	-0.01100	-0.00397	209	-0.01100	-0.00318	210	-0.01100	-0.00233
211	-0.01100	-0.00159	212	-0.01100	-0.00079	213	-0.01100	-0.00000	214	-0.01100	0.00079	215	-0.01100	0.00159
216	-0.01100	0.00238	217	-0.01100	0.00318	218	-0.01100	0.00397	219	-0.01100	0.00476	220	-0.01100	0.00556
221	-0.01076	0.00621	222	-0.01031	0.00675	223	-0.00963	0.00715	224	-0.00894	0.00754	225	-0.00825	0.00794
226	-0.00756	0.00834	227	-0.00688	0.00873	228	-0.00619	0.00913	229	-0.00550	0.00953	230	-0.00481	0.00992
231	-0.00413	0.01032	232	-0.00344	0.01072	233	-0.00275	0.01112	234	-0.00206	0.01151	235	-0.00138	0.01191
236	-0.00069	0.01231	237	-0.00000	0.01243	238	0.00069	0.01231	239	0.00138	0.01191	240	0.00206	0.01151
241	0.00275	0.01112	242	0.00344	0.01072	243	0.00413	0.01032	244	0.00481	0.00992	245	0.00550	0.00953
246	0.00619	0.00913	247	0.00688	0.00873	248	0.00756	0.00834	249	0.00825	0.00794	250	0.00894	0.00754
251	0.00963	0.00715	252	0.01031	0.00675	253	0.01076	0.00621	254	0.01100	0.00556	255	0.01100	0.00476
256	0.01100	0.00397	257	0.01100	0.00318	258	0.01100	0.00238	259	0.01100	0.00159	260	0.01100	0.00079
261	0.01100	0.00000	262	0.01100	-0.00079	263	0.01100	-0.00159	264	0.01100	-0.00233	265	0.01100	-0.00313
266	0.01100	-0.00397	267	0.01100	-0.00476	268	0.01100	-0.00556	269	0.01076	-0.00621	270	0.01031	-0.00675
271	0.00963	-0.00715	272	0.00894	-0.00754	273	0.00825	-0.00794	274	0.00756	-0.00834	275	0.00688	-0.00873
276	0.00619	-0.00913	277	0.00550	-0.00953	278	0.00481	-0.00992	279	0.00413	-0.01032	280	0.00344	-0.01072
281	0.00275	-0.01112	282	0.00206	-0.01151	283	0.00138	-0.01191	284	0.00069	-0.01231	285	0.00000	-0.01243
286	-0.00069	-0.01231	287	-0.00138	-0.01191	288	-0.00206	-0.01151						

UNIFORM ACCELERATION PARAMETER

INDICES FOR MISSING SLABS

LB1	LB2	LB3	LTYPE
9	13	5	-2
9	13	6	-2
9	13	8	-2
9	13	9	-2
9	13	19	-2
9	13	18	-2
9	13	16	-2
9	13	15	-2
9	13	21	-2
9	13	22	-2
9	13	24	-2
9	13	25	-2
9	13	35	-2
9	13	34	-2
9	13	32	-2
9	13	31	-2
9	13	37	-2
9	13	38	-2
9	13	40	-2
9	13	41	-2
9	13	51	-2
9	13	50	-2
9	13	48	-2
9	13	47	-2
9	13	53	-2
9	13	54	-2
9	13	56	-2
9	13	57	-2
9	13	67	-2

POOR ORIGINAL

9	13	66	-2
9	13	64	-2
9	13	63	-2
9	13	69	-2
9	13	70	-2
9	13	72	-2
9	13	73	-2
9	13	83	-2
9	13	82	-2
9	13	80	-2
9	13	79	-2
9	13	85	-2
9	13	86	-2
9	13	88	-2
9	13	89	-2
9	13	3	-2
9	13	2	-2
9	13	96	-2
9	13	95	-2

INDICES FOR BOUNDARY SLABS

LB1	LB2	LB3	LTYPE
96	1	13	-1
94	96	9	-1
1	10	9	-1
8	6	10	-2
10	1	5	-1
96	94	5	-1
6	8	94	-2
78	90	9	-1
8	6	90	-2
90	78	5	-1
6	8	78	-2
62	74	9	-1
8	6	74	-2
74	62	5	-1
6	8	62	-2
46	58	9	-1
8	6	58	-2
58	46	5	-1
6	8	46	-2
30	42	9	-1
8	6	42	-2
42	30	5	-1
6	8	30	-2
14	26	9	-1
8	6	26	-2
26	14	5	-1
6	8	14	-2
96	1	1	-1

7 PIN HEXAGONAL ROD BUNDLE CASE #1
SIMULATION FOR GERMAN 7 PIN FLOW RUN DOWN EXP.

7 PIN HEXAGONAL ROD BUNDLE CASE #1
SIMULATION FOR GERMAN 7 PIN FLOW RUN DOWN EXP.

COORDINATE SYSTEM TRANSFORMATION

```
FIELD PARAMETERS: # OF XI(THETA) POINTS =   96
                  # OF ETA(R) POINTS =   13
                  STEP SIZE, H =  1.00000

ITERATION PARAMETERS: G-S ACCELERATION FACTOR =  1.40000
                      MAX # OF ITERATIONS ALLOWED =  100
                      ALLOWABLE ERRORS: X:  .100000D-11
                                        Y:  .100000D-11

NUMBER OF BODIES IN FIELD=   28
```

```
ITERATION ERROR NORMS

ITERATE NO.    1, X-ERROR= 0.17646848D-03, Y-ERROR= 0.18594796D-03    W-CHANGE =0.0
ITERATE NO.    2, X-ERROR= 0.79209165D-04, Y-ERROR= 0.74117266D-04    W-CHANGE =0.0
ITERATE NO.    3, X-ERROR= 0.11215369D-03, Y-ERROR= 0.93810194D-04    W-CHANGE =0.0
ITERATE NO.    4, X-ERROR= 0.83792153D-04, Y-ERROR= 0.74577107D-04    W-CHANGE =0.0
ITERATE NO.    5, X-ERROR= 0.53325665D-04, Y-ERROR= 0.49657556D-04    W-CHANGE =0.0
ITERATE NO.    6, X-ERROR= 0.30362696D-04, Y-ERROR= 0.29809234D-04    W-CHANGE =0.0
ITERATE NO.    7, X-ERROR= 0.13991310D-04, Y-ERROR= 0.14294517D-04    W-CHANGE =0.0
ITERATE NO.    8, X-ERROR= 0.54450729D-05, Y-ERROR= 0.59301356D-05    W-CHANGE =0.0
ITERATE NO.    9, X-ERROR= 0.21216328D-05, Y-ERROR= 0.21933337D-05    W-CHANGE =0.0
ITERATE NO.   10, X-ERROR= 0.12571174D-05, Y-ERROR= 0.12000120D-05    W-CHANGE =0.0
ITERATE NO.   11, X-ERROR= 0.80721491D-06, Y-ERROR= 0.74559867D-06    W-CHANGE =0.0
ITERATE NO.   12, X-ERROR= 0.42868026D-06, Y-ERROR= 0.42424702D-06    W-CHANGE =0.0
ITERATE NO.   13, X-ERROR= 0.30165155D-06, Y-ERROR= 0.27810183D-06    W-CHANGE =0.0
ITERATE NO.   14, X-ERROR= 0.17531073D-06, Y-ERROR= 0.17555963D-06    W-CHANGE =0.0
ITERATE NO.   15, X-ERROR= 0.89422481D-07, Y-ERROR= 0.83996133D-07    W-CHANGE =0.0
ITERATE NO.   16, X-ERROR= 0.38513563D-07, Y-ERROR= 0.41287269D-07    W-CHANGE =0.0
ITERATE NO.   17, X-ERROR= 0.14139117D-07, Y-ERROR= 0.14497090D-07    W-CHANGE =0.0
ITERATE NO.   18, X-ERROR= 0.76131044D-08, Y-ERROR= 0.67641088D-08    W-CHANGE =0.0
ITERATE NO.   19, X-ERROR= 0.41554119D-08, Y-ERROR= 0.39560723D-08    W-CHANGE =0.0
ITERATE NO.   20, X-ERROR= 0.26828753D-08, Y-ERROR= 0.24002370D-08    W-CHANGE =0.0
ITERATE NO.   21, X-ERROR= 0.17072521D-08, Y-ERROR= 0.16374268D-08    W-CHANGE =0.0
ITERATE NO.   22, X-ERROR= 0.10302643D-08, Y-ERROR= 0.11028764D-08    W-CHANGE =0.0
ITERATE NO.   23, X-ERROR= 0.61784302D-09, Y-ERROR= 0.69290283D-09    W-CHANGE =0.0
ITERATE NO.   24, X-ERROR= 0.31066174D-09, Y-ERROR= 0.32254128D-09    W-CHANGE =0.0
ITERATE NO.   25, X-ERROR= 0.13767085D-09, Y-ERROR= 0.12228371D-09    W-CHANGE =0.0
ITERATE NO.   26, X-ERROR= 0.10276310D-09, Y-ERROR= 0.94730260D-10    W-CHANGE =0.0
ITERATE NO.   27, X-ERROR= 0.55640383D-10, Y-ERROR= 0.54869119D-10    W-CHANGE =0.0
ITERATE NO.   28, X-ERROR= 0.21548041D-10, Y-ERROR= 0.22925854D-10    W-CHANGE =0.0
ITERATE NO.   29, X-ERROR= 0.10876817D-10, Y-ERROR= 0.10950710D-10    W-CHANGE =0.0
ITERATE NO.   30, X-ERROR= 0.66331905D-11, Y-ERROR= 0.67524112D-11    W-CHANGE =0.0
ITERATE NO.   31, X-ERROR= 0.39765132D-11, Y-ERROR= 0.44582030D-11    W-CHANGE =0.0
ITERATE NO.   32, X-ERROR= 0.26727455D-11, Y-ERROR= 0.26895448D-11    W-CHANGE =0.0
ITERATE NO.   33, X-ERROR= 0.13136093D-11, Y-ERROR= 0.11455123D-11    W-CHANGE =0.0
ITERATE NO.   34, X-ERROR= 0.97172183D-12, Y-ERROR= 0.89729699D-12    W-CHANGE =0.0
7 PIN HEXAGONAL ROD BUNDLE CASE #1
SIMULATION FOR GERMAN 7 PIN FLOW RUN DOWN EXP.

                         FINAL VALUES

        ITERATION CONVERGES

        INITIAL ERRORS:  X: .17647D-03  Y: .18595D-03  @ ITERAT I#    1
        FINAL ERRORS:    X: .97172D-12  Y: .89730D-12  @ ITERATE #   34
        LOCATION OF MAXIMUM ERROR NORMS: X: I=   28 J=   10
                                         Y: I=   12 J=   10

        EUCLIDIAN ERROR NORMS:  X: .0            Y: .0

FINAL COORDINATES IN CELL NUMBERING ORDER
  1 -2.06D-03 -1.15D-02    2 -1.33D-03 -1.19D-02    3 -6.88D-04 -1.23D-02    4  1.57D-08 -1.24D-02    5  6.88D-04 -1.23D-02
  6  1.33D-03 -1.19D-02    7  2.06D-03 -1.15D-02    8  2.75D-03 -1.11D-02    9  3.44D-03 -1.07D-02   10  4.13D-03 -1.03D-02
 11  4.81D-03 -9.92D-03   12  5.50D-03 -9.53D-03   13  6.19D-03 -9.13D-03   14  6.88D-03 -8.73D-03   15  7.56D-03 -8.34D-03
 16  8.25D-03 -7.94D-03   17  8.94D-03 -7.54D-03   18  9.63D-03 -7.15D-03   19  1.03D-02 -6.75D-03   20  1.05D-02 -6.21D-03
 21  1.10D-02 -5.56D-03   22  1.10D-02 -4.76D-03   23  1.10D-02 -3.97D-03   24  1.10D-02 -3.13D-03   25  1.10D-02 -2.38D-03
```

POOR ORIGINAL

26	1.10D-02	-1.59D-03	27	1.10D-02	-7.94D-04	28	1.10D-02	1.30D-08	29	1.10D-02	7.94D-04	30	1.10D-02	1.59D-03
31	1.10D-02	2.38D-03	32	1.10D-02	3.18D-03	33	1.10D-02	3.97D-03	34	1.10D-02	4.76D-03	35	1.10D-02	5.56D-03
36	1.08D-02	6.21D-03	37	1.03D-02	6.75D-03	38	9.63D-03	7.15D-03	39	8.94D-03	7.54D-03	40	8.25D-03	7.94D-03
41	7.56D-03	8.34D-03	42	6.88D-03	8.73D-03	43	6.19D-03	9.13D-03	44	5.50D-03	9.53D-03	45	4.81D-03	9.92D-03
46	4.13D-03	1.03D-02	47	3.44D-03	1.07D-02	48	2.75D-03	1.11D-02	49	2.06D-03	1.15D-02	50	1.38D-03	1.19D-02
51	6.88D-04	1.23D-02	52	-7.74D-09	1.24D-02	53	-6.88D-04	1.23D-02	54	-1.38D-03	1.19D-02	55	-2.06D-03	1.15D-02
56	-2.75D-03	1.11D-02	57	-3.44D-03	1.07D-02	58	-4.13D-03	1.03D-02	59	-4.81D-03	9.92D-03	60	-5.50D-03	9.53D-03
61	-6.19D-03	9.13D-03	62	-6.88D-03	8.73D-03	63	-7.56D-03	8.34D-03	64	-8.25D-03	7.94D-03	65	-8.94D-03	7.54D-03
66	-9.63D-03	7.15D-03	67	-1.03D-02	6.75D-03	68	-1.08D-02	6.21D-03	69	-1.10D-02	5.56D-03	70	-1.10D-02	4.76D-03
71	-1.10D-02	3.97D-03	72	-1.10D-02	3.18D-03	73	-1.10D-02	2.38D-03	74	-1.10D-02	1.59D-03	75	-1.10D-02	7.94D-04
76	-1.10D-02	-8.09D-10	77	-1.10D-02	-7.94D-04	78	-1.10D-02	-1.59D-03	79	-1.10D-02	-2.38D-03	80	-1.10D-02	-3.18D-03
81	-1.10D-02	-3.97D-03	82	-1.10D-02	-4.76D-03	83	-1.10D-02	-5.56D-03	84	-1.08D-02	-6.21D-03	85	-1.03D-02	-6.75D-03
86	-9.63D-03	-7.15D-03	87	-8.94D-03	-7.54D-03	88	-8.25D-03	-7.94D-03	89	-7.56D-03	-8.34D-03	90	-6.88D-03	-8.73D-03
91	-6.19D-03	-9.13D-03	92	-5.50D-03	-9.53D-03	93	-4.81D-03	-9.92D-03	94	-4.13D-03	-1.03D-02	95	-3.44D-03	-1.07D-02
96	-2.75D-03	-1.11D-02	97	-2.09D-03	-1.11D-02	98	-1.40D-03	-1.15D-02	99	-7.00D-04	-1.18D-02	100	1.21D-08	-1.19D-02
101	7.00D-04	-1.18D-02	102	1.40D-03	-1.15D-02	103	2.09D-03	-1.11D-02	104	2.75D-03	-1.07D-02	105	3.37D-03	-1.03D-02
106	3.97D-03	-9.83D-03	107	4.55D-03	-9.41D-03	108	5.21D-03	-9.02D-03	109	5.86D-03	-8.67D-03	110	6.53D-03	-8.36D-03
111	7.22D-03	-8.06D-03	112	7.91D-03	-7.74D-03	113	8.61D-03	-7.30D-03	114	9.20D-03	-6.97D-03	115	9.90D-03	-6.52D-03
116	1.03D-02	-5.97D-03	117	1.06D-02	-5.31D-03	118	1.07D-02	-4.55D-03	119	1.07D-02	-3.77D-03	120	1.07D-02	-2.92D-03
121	1.06D-02	-2.22D-03	122	1.05D-02	-1.47D-03	123	1.04D-02	-7.37D-04	124	1.04D-02	1.18D-08	125	1.04D-02	7.37D-04
126	1.05D-02	1.47D-03	127	1.06D-02	2.22D-03	128	1.07D-02	2.92D-03	129	1.07D-02	3.77D-03	130	1.07D-02	4.55D-03
131	1.06D-02	5.31D-03	132	1.03D-02	5.97D-03	133	9.90D-03	6.52D-03	134	9.20D-03	6.97D-03	135	8.61D-03	7.30D-03
136	7.91D-03	7.74D-03	137	7.22D-03	8.06D-03	138	6.53D-03	8.36D-03	139	5.86D-03	8.67D-03	140	5.21D-03	9.02D-03
141	4.55D-03	9.41D-03	142	3.97D-03	9.83D-03	143	3.37D-03	1.03D-02	144	2.75D-03	1.07D-02	145	2.09D-03	1.11D-02
146	1.40D-03	1.15D-02	147	7.00D-04	1.18D-02	148	-7.67D-09	1.19D-02	149	-7.00D-04	1.18D-02	150	-1.40D-03	1.15D-02
151	-2.09D-03	1.11D-02	152	-2.75D-03	1.07D-02	153	-3.37D-03	1.03D-02	154	-3.97D-03	9.83D-03	155	-4.55D-03	9.41D-03
156	-5.21D-03	9.02D-03	157	-5.86D-03	8.67D-03	158	-6.53D-03	8.36D-03	159	-7.22D-03	8.06D-03	160	-7.91D-03	7.74D-03
161	-8.61D-03	7.30D-03	162	-9.20D-03	6.97D-03	163	-9.90D-03	6.52D-03	164	-1.03D-02	5.97D-03	165	-1.06D-02	5.31D-03
166	-1.07D-02	4.55D-03	167	-1.07D-02	3.77D-03	168	-1.07D-02	2.92D-03	169	-1.06D-02	2.22D-03	170	-1.05D-02	1.47D-03
171	-1.04D-02	7.37D-04	172	-1.04D-02	-1.52D-09	173	-1.04D-02	-7.37D-04	174	-1.05D-02	-1.47D-03	175	-1.06D-02	-2.22D-03
176	-1.07D-02	-2.92D-03	177	-1.07D-02	-3.77D-03	178	-1.07D-02	-4.55D-03	179	-1.06D-02	-5.31D-03	180	-1.03D-02	-5.97D-03
181	-9.90D-03	-6.52D-03	182	-9.20D-03	-6.97D-03	183	-8.61D-03	-7.30D-03	184	-7.91D-03	-7.74D-03	185	-7.22D-03	-8.06D-03
186	-6.53D-03	-8.36D-03	187	-5.86D-03	-8.67D-03	188	-5.21D-03	-9.02D-03	189	-4.58D-03	-9.41D-03	190	-3.97D-03	-9.83D-03
191	-3.37D-03	-1.03D-02	192	-2.75D-03	-1.07D-02	193	-2.10D-03	-1.08D-02	194	-1.43D-03	-1.12D-02	195	-7.18D-04	-1.14D-02
196	8.46D-09	-1.15D-02	197	7.18D-04	-1.14D-02	198	1.43D-03	-1.12D-02	199	2.10D-03	-1.08D-02	200	2.72D-03	-1.03D-02
201	3.28D-03	-9.81D-03	202	3.78D-03	-9.31D-03	203	4.32D-03	-8.86D-03	204	4.90D-03	-8.49D-03	205	5.52D-03	-8.17D-03
206	6.17D-03	-7.93D-03	207	6.86D-03	-7.75D-03	208	7.57D-03	-7.52D-03	209	8.28D-03	-7.21D-03	210	8.95D-03	-6.82D-03
211	9.55D-03	-6.34D-03	212	1.00D-02	-5.77D-03	213	1.03D-02	-5.10D-03	214	1.04D-02	-4.35D-03	215	1.04D-02	-3.57D-03
216	1.03D-02	-2.80D-03	217	1.01D-02	-2.07D-03	218	9.95D-03	-1.38D-03	219	9.84D-03	-6.92D-04	220	9.80D-03	1.07D-08
221	9.84D-03	6.92D-04	222	9.95D-03	1.38D-03	223	1.01D-02	2.07D-03	224	1.03D-02	2.80D-03	225	1.04D-02	3.57D-03
226	1.04D-02	4.35D-03	227	1.03D-02	5.10D-03	228	1.00D-02	5.77D-03	229	9.55D-03	6.34D-03	230	8.95D-03	6.82D-03
231	8.28D-03	7.21D-03	232	7.57D-03	7.52D-03	233	6.86D-03	7.75D-03	234	6.17D-03	7.93D-03	235	5.52D-03	8.17D-03
236	4.90D-03	8.49D-03	237	4.32D-03	8.86D-03	238	3.78D-03	9.31D-03	239	3.28D-03	9.81D-03	240	2.72D-03	1.03D-02
241	2.10D-03	1.08D-02	242	1.43D-03	1.12D-02	243	7.18D-04	1.14D-02	244	-7.65D-09	1.15D-02	245	-7.18D-04	1.14D-02
246	-1.43D-03	1.12D-02	247	-2.10D-03	1.08D-02	248	-2.72D-03	1.03D-02	249	-3.28D-03	9.81D-03	250	-3.78D-03	9.31D-03
251	-4.32D-03	8.86D-03	252	-4.90D-03	8.49D-03	253	-5.52D-03	8.17D-03	254	-6.17D-03	7.93D-03	255	-6.86D-03	7.75D-03
256	-7.57D-03	7.52D-03	257	-8.28D-03	7.21D-03	258	-8.95D-03	6.82D-03	259	-9.55D-03	6.34D-03	260	-1.00D-02	5.77D-03
261	-1.03D-02	5.10D-03	262	-1.04D-02	4.35D-03	263	-1.04D-02	3.57D-03	264	-1.03D-02	2.80D-03	265	-1.01D-02	2.07D-03
266	-9.95D-03	1.38D-03	267	-9.84D-03	6.92D-04	268	-9.80D-03	-2.01D-09	269	-9.84D-03	-6.92D-04	270	-9.95D-03	-1.38D-03
271	-1.01D-02	-2.07D-03	272	-1.03D-02	-2.80D-03	273	-1.04D-02	-3.57D-03	274	-1.04D-02	-4.35D-03	275	-1.03D-02	-5.10D-03
276	-1.00D-02	-5.77D-03	277	-9.55D-03	-6.34D-03	278	-8.95D-03	-6.82D-03	279	-8.28D-03	-7.21D-03	280	-7.57D-03	-7.52D-03
281	-6.86D-03	-7.75D-03	282	-6.17D-03	-7.93D-03	283	-5.52D-03	-8.17D-03	284	-4.90D-03	-8.49D-03	285	-4.32D-03	-8.86D-03
286	-3.78D-03	-9.31D-03	287	-3.28D-03	-9.81D-03	288	-2.72D-03	-1.03D-02	289	-2.12D-03	-1.06D-02	290	-1.46D-03	-1.09D-02
291	-7.42D-04	-1.11D-02	292	4.80D-09	-1.12D-02	293	7.42D-04	-1.11D-02	294	1.46D-03	-1.09D-02	295	2.12D-03	-1.06D-02
296	2.68D-03	-9.88D-03	297	3.14D-03	-9.30D-03	298	3.51D-03	-8.72D-03	299	4.01D-03	-8.22D-03	300	4.56D-03	-7.90D-03
301	5.15D-03	-7.60D-03	302	5.79D-03	-7.40D-03	303	6.49D-03	-7.37D-03	304	7.22D-03	-7.26D-03	305	7.95D-03	-7.04D-03
306	8.64D-03	-6.62D-03	307	9.25D-03	-6.20D-03	308	9.70D-03	-5.68D-03	309	9.99D-03	-4.91D-03	310	1.01D-02	-4.15D-03
311	1.01D-02	-3.37D-03	312	9.90D-03	-2.62D-03	313	9.63D-03	-1.93D-03	314	9.30D-03	-1.32D-03	315	9.16D-03	-6.61D-04
316	9.12D-03	9.55D-09	317	9.16D-03	6.62D-04	318	9.30D-03	1.32D-03	319	9.63D-03	1.93D-03	320	9.90D-03	2.62D-03
321	1.01D-02	3.37D-03	322	1.01D-02	4.15D-03	323	9.99D-03	4.91D-03	324	9.70D-03	5.60D-03	325	9.25D-03	6.20D-03

326	8.64D-03	6.68D-03	327	7.95D-03	7.04D-03	328	7.22D-03	7.26D-03	329	6.49D-03	7.37D-03	330	5.79D-03	7.40D-03
331	5.15D-03	7.60D-03	332	4.56D-03	7.90D-03	333	4.01D-03	8.26D-03	334	3.51D-03	8.72D-03	335	3.14D-03	9.30D-03
336	2.68D-03	9.82D-03	337	2.12D-03	1.04D-02	338	1.46D-03	1.08D-02	339	7.42D-04	1.11D-02	340	-7.69D-09	1.12D-02
341	-7.42D-04	1.11D-02	342	-1.46D-03	1.08D-02	343	-2.12D-03	1.04D-02	344	-2.68D-03	9.82D-03	345	-3.14D-03	9.30D-03
346	-3.51D-03	8.72D-03	347	-4.01D-03	8.26D-03	348	-4.56D-03	7.90D-03	349	-5.15D-03	7.60D-03	350	-5.79D-03	7.40D-03
351	-6.49D-03	7.37D-03	352	-7.22D-03	7.26D-03	353	-7.95D-03	7.04D-03	354	-8.64D-03	6.68D-03	355	-9.25D-03	6.20D-03
356	-9.70D-03	5.60D-03	357	-9.95D-03	4.91D-03	358	-1.01D-02	4.15D-03	359	-1.01D-02	3.37D-03	360	-9.90D-03	2.62D-03
361	-9.63D-03	1.93D-03	362	-9.30D-03	1.32D-03	363	-9.16D-03	6.62D-04	364	-9.12D-03	-2.42D-09	365	-9.16D-03	-6.62D-04
366	-9.30D-03	-1.32D-03	367	-9.63D-03	-1.93D-03	368	-9.90D-03	-2.62D-03	369	-1.01D-02	-3.37D-03	370	-1.01D-02	-4.15D-03
371	-9.99D-03	-4.91D-03	372	-9.70D-03	-5.60D-03	373	-9.25D-03	-6.20D-03	374	-8.64D-03	-6.68D-03	375	-7.95D-03	-7.04D-03
376	-7.22D-03	-7.26D-03	377	-6.49D-03	-7.37D-03	378	-5.79D-03	-7.40D-03	379	-5.15D-03	-7.60D-03	380	-4.56D-03	-7.90D-03
381	-4.01D-03	-8.26D-03	382	-3.51D-03	-8.72D-03	383	-3.14D-03	-9.30D-03	384	-2.68D-03	-9.82D-03	385	-2.12D-03	-1.08D-02
386	-1.50D-03	-1.05D-02	387	-7.76D-04	-1.08D-02	388	9.42D-10	-1.09D-02	389	7.76D-04	-1.08D-02	390	1.50D-03	-1.05D-02
391	2.12D-03	-1.00D-02	392	2.60D-03	-9.40D-03	393	2.90D-03	-8.68D-03	394	3.00D-03	-7.90D-03	395	3.63D-03	-7.57D-03
396	4.18D-03	-7.25D-03	397	4.74D-03	-6.93D-03	398	5.34D-03	-6.55D-03	399	6.07D-03	-6.85D-03	400	6.84D-03	-6.95D-03
401	7.62D-03	-6.85D-03	402	8.34D-03	-6.55D-03	403	8.93D-03	-6.07D-03	404	9.44D-03	-5.45D-03	405	9.74D-03	-4.73D-03
406	9.84D-03	-3.95D-03	407	9.74D-03	-3.17D-03	408	9.44D-03	-2.45D-03	409	8.96D-03	-1.83D-03	410	8.34D-03	-1.35D-03
411	8.37D-03	-6.40D-04	412	8.37D-03	8.35D-09	413	8.37D-03	6.40D-04	414	8.34D-03	1.35D-03	415	8.96D-03	1.83D-03
416	9.44D-03	2.45D-03	417	9.74D-03	3.17D-03	418	9.84D-03	3.95D-03	419	9.74D-03	4.73D-03	420	9.44D-03	5.45D-03
421	8.96D-03	6.07D-03	422	8.34D-03	6.55D-03	423	7.62D-03	6.85D-03	424	6.84D-03	6.95D-03	425	6.07D-03	6.85D-03
426	5.34D-03	6.55D-03	427	4.74D-03	6.93D-03	428	4.18D-03	7.25D-03	429	3.63D-03	7.57D-03	430	3.00D-03	7.90D-03
431	2.90D-03	8.68D-03	432	2.60D-03	9.40D-03	433	2.12D-03	1.00D-02	434	1.50D-03	1.05D-02	435	7.76D-04	1.08D-02
436	-7.79D-09	1.09D-02	437	-7.76D-04	1.08D-02	438	-1.50D-03	1.05D-02	439	-2.12D-03	1.00D-02	440	-2.60D-03	9.40D-03
441	-2.90D-03	8.68D-03	442	-3.00D-03	7.90D-03	443	-3.63D-03	7.57D-03	444	-4.18D-03	7.25D-03	445	-4.74D-03	6.93D-03
446	-5.34D-03	6.55D-03	447	-6.07D-03	6.85D-03	448	-6.84D-03	6.95D-03	449	-7.62D-03	6.85D-03	450	-8.34D-03	6.55D-03
451	-8.96D-03	6.07D-03	452	-9.44D-03	5.45D-03	453	-9.74D-03	4.73D-03	454	-9.84D-03	3.95D-03	455	-9.74D-03	3.17D-03
456	-9.44D-03	2.45D-03	457	-8.96D-03	1.83D-03	458	-8.34D-03	1.35D-03	459	-8.37D-03	6.40D-04	460	-8.37D-03	-2.51D-09
461	-8.37D-03	-6.40D-04	462	-8.34D-03	-1.35D-03	463	-8.96D-03	-1.83D-03	464	-9.44D-03	-2.45D-03	465	-9.74D-03	-3.17D-03
466	-9.84D-03	-3.95D-03	467	-9.74D-03	-4.73D-03	468	-9.44D-03	-5.45D-03	469	-8.96D-03	-6.07D-03	470	-8.34D-03	-6.55D-03
471	-7.62D-03	-6.85D-03	472	-6.84D-03	-6.95D-03	473	-6.07D-03	-6.85D-03	474	-5.34D-03	-6.55D-03	475	-4.74D-03	-6.93D-03
476	-4.18D-03	-7.25D-03	477	-3.63D-03	-7.57D-03	478	-3.00D-03	-7.90D-03	479	-2.90D-03	-8.68D-03	480	-2.60D-03	-9.40D-03
481	2.90D-03	-7.12D-03	482	3.34D-03	-6.86D-03	483	3.80D-03	-6.59D-03	484	4.27D-03	-6.32D-03	485	4.72D-03	-6.07D-03
486	7.62D-03	-1.05D-03	487	7.61D-03	-5.34D-04	488	7.61D-03	7.31D-09	489	7.61D-03	5.34D-04	490	7.62D-03	1.05D-03
491	4.72D-03	6.07D-03	492	4.27D-03	6.32D-03	493	3.80D-03	6.59D-03	494	3.34D-03	6.86D-03	495	2.90D-03	7.12D-03
496	-2.90D-03	7.12D-03	497	-3.34D-03	6.86D-03	498	-3.80D-03	6.59D-03	499	-4.27D-03	6.32D-03	500	-4.72D-03	6.07D-03
501	-7.62D-03	1.05D-03	502	-7.61D-03	5.34D-04	503	-7.61D-03	-2.34D-09	504	-7.61D-03	-5.34D-04	505	-7.62D-03	-1.05D-03
506	-4.72D-03	-6.07D-03	507	-4.27D-03	-6.32D-03	508	-3.80D-03	-6.59D-03	509	-3.34D-03	-6.86D-03	510	-2.90D-03	-7.12D-03
511	2.60D-03	-6.40D-03	512	3.00D-03	-6.17D-03	513	3.42D-03	-5.93D-03	514	3.85D-03	-5.68D-03	515	4.24D-03	-5.45D-03
516	6.84D-03	-9.50D-04	517	6.84D-03	-4.91D-04	518	6.84D-03	6.45D-09	519	6.84D-03	4.91D-04	520	6.84D-03	9.50D-04
521	4.24D-03	5.45D-03	522	3.85D-03	5.68D-03	523	3.42D-03	5.93D-03	524	3.00D-03	6.17D-03	525	2.60D-03	6.40D-03
526	-2.60D-03	6.40D-03	527	-3.00D-03	6.17D-03	528	-3.42D-03	5.93D-03	529	-3.85D-03	5.68D-03	530	-4.24D-03	5.45D-03
531	-6.84D-03	9.50D-04	532	-6.84D-03	4.91D-04	533	-6.84D-03	-2.09D-09	534	-6.84D-03	-4.91D-04	535	-6.84D-03	-9.50D-04
536	-4.24D-03	-5.45D-03	537	-3.85D-03	-5.68D-03	538	-3.42D-03	-5.93D-03	539	-3.00D-03	-6.17D-03	540	-2.60D-03	-6.40D-03
541	2.12D-03	-5.78D-03	542	2.53D-03	-5.53D-03	543	3.04D-03	-5.27D-03	544	3.50D-03	-5.00D-03	545	3.94D-03	-4.73D-03
546	6.07D-03	-1.05D-03	547	6.08D-03	-5.31D-04	548	6.08D-03	5.61D-09	549	6.08D-03	5.31D-04	550	6.07D-03	1.05D-03
551	3.94D-03	4.73D-03	552	3.50D-03	5.00D-03	553	3.04D-03	5.27D-03	554	2.53D-03	5.53D-03	555	2.12D-03	5.78D-03
556	-2.12D-03	5.78D-03	557	-2.53D-03	5.53D-03	558	-3.04D-03	5.27D-03	559	-3.50D-03	5.00D-03	560	-3.94D-03	4.73D-03
561	-6.07D-03	1.05D-03	562	-6.08D-03	5.31D-04	563	-6.08D-03	-1.77D-09	564	-6.08D-03	-5.31D-04	565	-6.07D-03	-1.05D-03
566	-3.94D-03	-4.73D-03	567	-3.50D-03	-5.00D-03	568	-3.04D-03	-5.27D-03	569	-2.53D-03	-5.53D-03	570	-2.12D-03	-5.78D-03
571	-7.76D-04	-5.00D-03	572	9.42D-10	-4.90D-03	573	7.76D-04	-5.00D-03	574	1.50D-03	-5.30D-03	575	2.13D-03	-4.93D-03
576	2.67D-03	-4.62D-03	577	3.20D-03	-4.31D-03	578	3.84D-03	-3.95D-03	579	3.94D-03	-3.17D-03	580	4.24D-03	-2.45D-03
581	4.72D-03	-1.83D-03	582	5.34D-03	-1.35D-03	583	5.33D-03	-6.21D-04	584	5.34D-03	4.64D-09	585	5.33D-03	6.21D-04
586	5.34D-03	1.35D-03	587	4.72D-03	1.83D-03	588	4.24D-03	2.45D-03	589	3.94D-03	3.17D-03	590	3.84D-03	3.95D-03
591	3.20D-03	4.31D-03	592	2.67D-03	4.62D-03	593	2.13D-03	4.93D-03	594	1.50D-03	5.30D-03	595	7.76D-04	5.00D-03
596	-4.02D-09	4.90D-03	597	-7.76D-04	5.00D-03	598	-1.50D-03	5.30D-03	599	-2.13D-03	4.93D-03	600	-2.67D-03	4.62D-03
601	-3.20D-03	4.31D-03	602	-3.84D-03	3.95D-03	603	-3.94D-03	3.17D-03	604	-4.24D-03	2.45D-03	605	-4.72D-03	1.83D-03
606	-5.34D-03	1.35D-03	607	-5.33D-03	6.21D-04	608	-5.34D-03	-1.23D-09	609	-5.33D-03	-6.21D-04	610	-5.34D-03	-1.35D-03
611	-4.72D-03	-1.83D-03	612	-4.24D-03	-2.45D-03	613	-3.94D-03	-3.17D-03	614	-3.84D-03	-3.95D-03	615	-3.20D-03	-4.31D-03
616	-2.67D-03	-4.62D-03	617	-2.13D-03	-4.93D-03	618	-1.50D-03	-5.30D-03	619	-6.19D-04	-4.41D-03	620	6.68D-10	-4.40D-03
621	6.19D-04	-4.41D-03	622	1.22D-03	-4.41D-03	623	1.79D-03	-4.24D-03	624	2.30D-03	-3.99D-03	625	2.78D-03	-3.67D-03

626	3.21D-03	-3.26D-03	627	3.51D-03	-2.74D-03	628	3.81D-03	-2.20D-03	629	4.13D-03	-1.67D-03	630	4.43D-03	-1.15D-03
631	4.57D-03	-5.73D-04	632	4.61D-03	3.25D-09	633	4.57D-03	5.73D-04	634	4.43D-03	1.15D-03	635	4.13D-03	1.67D-03
636	3.81D-03	2.20D-03	637	3.51D-03	2.74D-03	638	3.21D-03	3.26D-03	639	2.72D-03	3.67D-03	640	2.30D-03	3.99D-03
641	1.79D-03	4.24D-03	642	1.22D-03	4.41D-03	643	6.19D-04	4.41D-03	644	-2.14D-09	4.40D-03	645	-6.19D-04	4.41D-03
646	-1.22D-03	4.41D-03	647	-1.79D-03	4.24D-03	648	-2.30D-03	3.99D-03	649	-2.72D-03	3.67D-03	650	-3.21D-03	3.26D-03
651	-3.51D-03	2.74D-03	652	-3.81D-03	2.20D-03	653	-4.13D-03	1.67D-03	654	-4.43D-03	1.15D-03	655	-4.57D-03	5.73D-04
656	-4.61D-03	-3.89D-10	657	-4.57D-03	-5.73D-04	658	-4.43D-03	-1.15D-03	659	-4.13D-03	-1.67D-03	660	-3.81D-03	-2.20D-03
661	-3.51D-03	-2.74D-03	662	-3.21D-03	-3.26D-03	663	-2.72D-03	-3.67D-03	664	-2.30D-03	-3.99D-03	665	-1.79D-03	-4.24D-03
666	-1.22D-03	-4.41D-03	667	-5.24D-04	-3.88D-03	668	5.52D-10	-3.90D-03	669	5.24D-04	-3.88D-03	670	1.04D-03	-3.82D-03
671	1.53D-03	-3.67D-03	672	1.99D-03	-3.45D-03	673	2.41D-03	-3.16D-03	674	2.78D-03	-2.81D-03	675	3.10D-03	-2.39D-03
676	3.38D-03	-1.95D-03	677	3.62D-03	-1.49D-03	678	3.82D-03	-1.01D-03	679	3.94D-03	-5.03D-04	680	3.98D-03	1.96D-09
681	3.94D-03	5.03D-04	682	3.82D-03	1.01D-03	683	3.62D-03	1.49D-03	684	3.38D-03	1.95D-03	685	3.10D-03	2.39D-03
686	2.78D-03	2.81D-03	687	2.41D-03	3.16D-03	688	1.99D-03	3.45D-03	689	1.53D-03	3.67D-03	690	1.04D-03	3.82D-03
691	5.24D-04	3.88D-03	692	-8.01D-10	3.90D-03	693	-5.24D-04	3.88D-03	694	-1.04D-03	3.82D-03	695	-1.53D-03	3.67D-03
696	-1.99D-03	3.45D-03	697	-2.41D-03	3.16D-03	698	-2.78D-03	2.81D-03	699	-3.10D-03	2.39D-03	700	-3.38D-03	1.95D-03
701	-3.62D-03	1.49D-03	702	-3.82D-03	1.01D-03	703	-3.94D-03	5.03D-04	704	-3.98D-03	5.30D-10	705	-3.94D-03	-5.03D-04
706	-3.82D-03	-1.01D-03	707	-3.62D-03	-1.49D-03	708	-3.38D-03	-1.95D-03	709	-3.10D-03	-2.39D-03	710	-2.78D-03	-2.81D-03
711	-2.41D-03	-3.16D-03	712	-1.99D-03	-3.45D-03	713	-1.53D-03	-3.67D-03	714	-1.04D-03	-3.82D-03	715	-4.52D-04	-3.40D-03
716	6.21D-10	-3.42D-03	717	4.52D-04	-3.40D-03	718	8.96D-04	-3.32D-03	719	1.32D-03	-3.19D-03	720	1.73D-03	-2.99D-03
721	2.10D-03	-2.74D-03	722	2.43D-03	-2.44D-03	723	2.72D-03	-2.09D-03	724	2.97D-03	-1.71D-03	725	3.17D-03	-1.31D-03
726	3.33D-03	-8.86D-04	727	3.42D-03	-4.47D-04	728	3.45D-03	8.65D-10	729	3.42D-03	4.47D-04	730	3.33D-03	8.86D-04
731	3.17D-03	1.31D-03	732	2.97D-03	1.71D-03	733	2.72D-03	2.09D-03	734	2.43D-03	2.44D-03	735	2.10D-03	2.74D-03
736	1.73D-03	2.99D-03	737	1.32D-03	3.19D-03	738	8.96D-04	3.32D-03	739	4.52D-04	3.40D-03	740	1.93D-10	3.42D-03
741	-4.52D-04	3.40D-03	742	-8.96D-04	3.32D-03	743	-1.32D-03	3.19D-03	744	-1.73D-03	2.99D-03	745	-2.10D-03	2.74D-03
746	-2.43D-03	2.44D-03	747	-2.72D-03	2.09D-03	748	-2.97D-03	1.71D-03	749	-3.17D-03	1.31D-03	750	-3.33D-03	8.86D-04
751	-3.42D-03	4.47D-04	752	-3.45D-03	1.30D-09	753	-3.42D-03	-4.47D-04	754	-3.33D-03	-8.86D-04	755	-3.17D-03	-1.31D-03
756	-2.97D-03	-1.71D-03	757	-2.72D-03	-2.09D-03	758	-2.43D-03	-2.44D-03	759	-2.10D-03	-2.74D-03	760	-1.73D-03	-2.99D-03
761	-1.32D-03	-3.19D-03	762	-8.96D-04	-3.32D-03	763	-3.92D-04	-2.97D-03	764	9.42D-10	-3.00D-03	765	3.92D-04	-2.97D-03
766	7.76D-04	-2.90D-03	767	1.15D-03	-2.77D-03	768	1.50D-03	-2.60D-03	769	1.83D-03	-2.38D-03	770	2.12D-03	-2.12D-03
771	2.38D-03	-1.83D-03	772	2.60D-03	-1.50D-03	773	2.77D-03	-1.15D-03	774	2.90D-03	-7.76D-04	775	2.97D-03	-3.92D-04
776	3.00D-03	0.0	777	2.97D-03	3.92D-04	778	2.90D-03	7.76D-04	779	2.77D-03	1.15D-03	780	2.60D-03	1.50D-03
781	2.38D-03	1.83D-03	782	2.12D-03	2.12D-03	783	1.83D-03	2.38D-03	784	1.50D-03	2.60D-03	785	1.15D-03	2.77D-03
786	7.76D-04	2.90D-03	787	3.92D-04	2.97D-03	788	9.42D-10	3.00D-03	789	-3.92D-04	2.97D-03	790	-7.76D-04	2.90D-03
791	-1.15D-03	2.77D-03	792	-1.50D-03	2.60D-03	793	-1.83D-03	2.38D-03	794	-2.12D-03	2.12D-03	795	-2.38D-03	1.83D-03
796	-2.60D-03	1.50D-03	797	-2.77D-03	1.15D-03	798	-2.90D-03	7.76D-04	799	-2.97D-03	3.92D-04	800	-3.00D-03	1.80D-09
801	-2.97D-03	-3.92D-04	802	-2.90D-03	-7.76D-04	803	-2.77D-03	-1.15D-03	804	-2.60D-03	-1.50D-03	805	-2.38D-03	-1.83D-03
806	-2.12D-03	-2.12D-03	807	-1.83D-03	-2.38D-03	808	-1.50D-03	-2.60D-03	809	-1.15D-03	-2.77D-03	810	-7.76D-04	-2.90D-03

IMAX	JMAX	NBDY	NTOTS	NROW	NCHT	NPINS	ISYM	N1	IGEO	NSEG	IPQ
13	13	28	112	2	24	7	1	3	1	4	4

LSLIT(I,J) FOR I=1,IMAX FIRST AND THEN J=1,JMAX--

-10028	-10028	-10028	-10028	-10028	-10028	-10028	-10028	-10028	-10028	-10028	-10028
-10028	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	-10005	-10005	-10005	-10005	-10005	-10005	-10005	-10005
-10005	-10005	0	0	0	-10000	-10000	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10004	0	0	0	-10000	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10000	-10004	0	0	0	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10000	-10000	-10004	0	0	0	-10003	-10000	-10000	-10003
-10000	-10000	-10003	-10000	-10000	-10003	0	0	0	0	-10000	-10000
0	-10000	-10000	0	-10000	-10000	0	0	0	0	0	-10000
-10000	0	-10000	-10000	0	-10000	-10000	0	0	0	0	0
-10000	-10000	0	-10000	-10000	0	-10000	-10000	0	0	0	0
-10001	-10000	-10000	-10001	-10000	-10000	-10001	-10000	-10000	-10001	-10001	-10001
-10001											

NUN(I,J) FOR I=1,IMAX FIRST AND THEN J=1,JMAX

1	2	3	4	5	6	7	8	9	10	11	12

```
    13      14      15      16      17      18      19      20      21      22      23      24
    25      26      27      28      29      30      31      32      33      34      35      36
    37      38      39      40      41      42      43      44      45      46      47      48
    49      50      51      52      53      54      55      56      57      58      59      60
    61      62      63      64      65       0       0       0       0       0       0       0
     0       0      66      67      68      69       0       0       0       0       0       0
     0       0       0      70      71      72      73       0       0       0       0       0
     0       0       0       0      74      75      76      77      78      79      78      79
    80      79      80      81      80      81      82      83      84      85      86      85
    86      87      86      87      88      87      88      89      90      91      92      93
    92      93      94      93      94      95      94      95      96      97      98      99
   100      99     100     101     100     101     102     101     102     103     104     105
   106     107     106     107     108     107     108     109     108     109     110     111
   112

NB(N) IN CELL NUMBERING ORDER---
  -201    -201    -201    -201    -201    -201    -201    -201    -201    -201    -201    -201
  -201       0       0       0       0       0       0       0       0       0       0       0
     0       0       0       0       0       0       0       0       0       0       0       0
     0       0       0      -4      -4      -4      -4      -4      -4      -4      -4      -4
    -7       0       0      -5   -1004   -1004   -1004   -1004   -1004   -1004   -1004   -1004
 -1004    -101       0       0      -3    -101       0       0      -3    -101       0       0
    -3    -101       0       0      -3    -201    -201    -201    -801       0       0      -6
     0       0       0       0       0       0       0       0       0       0       0       0
     0       0      -4      -4      -4      -4      -4      -4      -4   -1004   -1004   -1004
 -1004   -1004   -1004   -1004

NCHNL(N) IN CELL NUMBERING ORDER----
    18      18      18       1       1       1       1       2       2       2       2       2
     2      18      18      18       1       1       1       1       2       2       2       2
     2       2      18      18      18       1       1       1       1       2       2       2
     2       2       2      18      18      18       1       1       1       1       2       2
     2       2       2       2       0       0       0       0       0       0       0       0
     0       2       2       2       2       2       2       2       2      19      19      19
    19      19      19      19      19      24      19      19      19      19      19      19
    24      19      19      19      19      19      19      24      19      19      19      19
    19      19      24      19      19      19      19      19      19       0       0       0
     0       0       0       0

NCHTP(I) IN CHANNEL NUMBERING ORDER---
     3       2       3       3       2       3       3       2       3       3       2       3
     3       2       3       3       2       3       1       1       1       1       1       1

NFNQ(I,J) FOR J=1,6 FIRST AND THEN I=1,NPINS
     0       0       0       0       0      19       0       0       0      19       2       1
     0       0       0       0       0       0       0       0       0       0       0       0
     0       0       0       0       0       0       0       0       0       0       0       0
     0       0       0       0       0       0

X AND Y COORDINATES-----------------
  1 -2.06E-03 -1.15E-02    2 -1.38E-03 -1.19E-02    3 -6.88E-04 -1.23E-02    4  0.0       -1.24E-02    5  6.88E-04 -1.23E-02
  6  1.38E-03 -1.19E-02    7  2.06E-03 -1.15E-02    8  2.75E-03 -1.11E-02    9  3.44E-03 -1.07E-02   10  4.13E-03 -1.03E-02
 11  4.81E-03 -9.92E-03   12  5.50E-03 -9.53E-03   13  6.19E-03 -9.13E-03   14 -2.09E-03 -1.11E-02   15 -1.40E-03 -1.15E-02
 16 -7.00E-04 -1.18E-02   17  0.0       -1.19E-02   18  7.00E-04 -1.18E-02   19  1.40E-03 -1.15E-02   20  2.09E-03 -1.11E-02
 21  2.75E-03 -1.07E-02   22  3.37E-03 -1.03E-02   23  3.97E-03 -9.8[illegible]-03   24  4.58E-03 -9.41E-03   25  5.21E-03 -9.02E-03
 26  5.86E-03 -8.67E-03   27 -2.10E-03 -1.08E-02   28 -1.43E-03 -1.[illegible]E-02   29 -7.18E-04 -1.14E-02   30  0.0       -1.15E-02
 31  7.18E-04 -1.14E-02   32  1.43E-03 -1.12E-02   33  2.10E-03 -1.[illegible]8E-02   34  2.72E-03 -1.03E-02   35  3.28E-03 -9.81E-03
 36  3.78E-03 -9.31E-03   37  4.32E-03 -8.86E-03   38  4.90E-03 -8.[illegible]9E-03   39  5.52E-03 -8.17E-03   40 -2.12E-03 -1.04E-02
 41 -1.46E-03 -1.08E-02   42 -7.42E-04 -1.11E-02   43  0.0       -1.[illegible]E-02   44  7.42E-04 -1.11E-02   45  1.46E-03 -1.98E-02
 46  2.12E-03 -1.04E-02   47  2.68E-03 -9.80E-03   48  3.14E-03 -9.[illegible]0E-03   49  3.51E-03 -8.72E-03   50  4.01E-03 -8.26E-03
```

```
 51  4.56E-03 -7.90E-03   52  5.15E-03 -7.60E-03   53 -2.12E-03 -1.00E-02   54 -1.50E-03 -1.05E-02   55 -7.76E-04 -1.08E-02
 56  0.0      -1.09E-02   57  7.76E-04 -1.00E-02   58  1.50E-03 -1.05E-02   59  2.12E-03 -1.00E-02   60  2.60E-03 -9.40E-03
 61  2.90E-03 -8.63E-03   62  3.00E-03 -7.90E-03   63  3.63E-03 -7.57E-03   64  4.18E-03 -7.25E-03   65  4.74E-03 -6.93E-03
 66  2.90E-03 -7.12E-03   67  3.34E-03 -6.86E-03   68  3.80E-03 -6.57E-03   69  4.27E-03 -6.32E-03   70  2.60E-03 -6.40E-03
 71  3.00E-03 -6.17E-03   72  3.42E-03 -5.93E-03   73  3.85E-03 -5.68E-03   74  2.12E-03 -5.78E-03   75  2.58E-03 -5.53E-03
 76  3.04E-03 -5.27E-03   77  3.50E-03 -5.00E-03   78 -7.76E-04 -5.00E-03   79  0.0      -4.90E-03   80  7.76E-04 -5.00E-03
 81  1.50E-03 -5.30E-03   82  2.13E-03 -4.93E-03   83  2.67E-03 -4.62E-03   84  3.20E-03 -4.31E-03   85 -6.19E-04 -4.41E-03
 86  0.0      -4.40E-03   87  6.19E-04 -4.41E-03   88  1.22E-03 -4.41E-03   89  1.79E-03 -4.24E-03   90  2.30E-03 -3.99E-03
 91  2.78E-03 -3.67E-03   92 -5.24E-04 -3.88E-03   93  0.0      -3.90E-03   94  5.24E-04 -3.88E-03   95  1.04E-03 -3.82E-03
 96  1.53E-03 -3.67E-03   97  1.99E-03 -3.45E-03   98  2.41E-03 -3.16E-03   99 -4.52E-04 -3.40E-03  100  0.0      -3.42E-03
101  4.52E-04 -3.40E-03  102  8.96E-04 -3.32E-03  103  1.32E-03 -3.17E-03  104  1.73E-03 -2.99E-03  105  2.10E-03 -2.74E-03
106 -3.92E-04 -2.97E-03  107  0.0      -3.00E-03  108  3.92E-04 -2.97E-03  109  7.76E-04 -2.90E-03  110  1.15E-03 -2.77E-03
111  1.50E-03 -2.60E-03  112  1.83E-03 -2.38E-03

 L AND  NPIN(L) FOR L=1 TO NBDY
         1         1         2         2         3         2         4         2         5         2
         6         2         7         2         8         3         9         3        10         3
        11         3        12         4        13         4        14         4        15         4
        16         5        17         5        18         5        19         5        20         6
        21         6        22         6        23         6        24         7        25         7
        26         7        27         7        28         8

 NPQ(I,J) FOR J=1 TO 6 AND THEN I=1 TO NPINS
         0         0         0         0         0         1         0         0         0         2         3         4
         0         0         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0         0         0         0         0
         0         0         0         0         0         0
```

```
$$DATE$$
         7 PINS HEXGONAL ROD BUNDLE WITH 1/12 SYMMETRY
         SIMULATION FOR GERMAN FLOW RUN DOWN EXPERIMENT(9/25/80)
           1
        &SET NTPRNT=1.50,300,600,46*0,
         ITPRNT=50*0,NTPLOT=50*0,
         NTHPR=1302,1310,2302,2310,3104,3112,3302,3310,5104,5112,
         5301,5310,6104,6112,36*0,
         ISTPR=1302,1310,2302,2310,3104,3112,3302,3310,5104,5112,
         5301,5310,6104,6112,36*0,
         GX=0.0,GY=0.0,GZ=-1.0,
         IBHSOL=0,IBPSOL=0,IBITER=0,IBVSOL=0,IDUG=0,0,0,0,0,0,0,0,0,21*0,
         IBLO=4,IBHI=12,JBLO=1,JBHI=13,KDLO=10,KBHI=10,
         KMAX=10,IFRES=1,IFROB=1,SLIPR=0.0,DREF=0.004211,
         NSTEPS=001,IT1=20,IT2=5,ITSET=50,IT3=3,
         DTD=1.0E+20,VEL=  2.15, TENC=553.000,PENT=2.0,    PGRAD=0.0,
         TURBF=1.0,TURBK=1.00,AO=0.5,BO=0.0,NPORD=2,
         FAC=4*1.0,1.0,1.8,1.0,0.5,0.5,1.0,1.0,1.0,18*0.0,
         TOLVEL=0.0001,TOLENT=0.0001,TOLFRE=0.0001,ESUMSM=0.001,
         ZA=0.000,0.08889,0.17778,0.26667,0.35555,0.44444,0.53333,0.62222,
            0.71111,0.80000,
         XA=10*0.0,QACC=0.0,VACC=0.0,TACC=0.0,
         C=5.0,0.025,0.8,6*0.0,0.0,1.0,1.3,1.44,1.92,0.09,
           0.42,9.8,0.01,0.07,1.0,1.0,1.0,1.3,0.09,6*0.0,
         KA=10*0,
         NC=7,NTFU=3, HCOND=1.30,   IOPT=0,0,0,1,2,0,0,0,0,0,20*0,
           QRAD=7*1.0,QAXIAL=0.0,8*1.0,0.0,
         QPIN=40*0.993E+06,
         DECH=0.0054694,0.0043237,0.0026566,AVHTF=0.993E+06,
         EPS=1.0E-10,0.2E-05,0.2E-07,1.0E-03,26*0.0,
        WDUC=0.0015,TOLTDU=1.0E-02,
        &END
7 PINS HEXGONAL ROD BUNDLE WITH 1/12 SYMMETRY
SIMULATION FOR GERMAN FLOW RUN DOWN EXPERIMENT(9/25/80)
   IMAX     JMAX     NBDY     NTOT     NROW     NCHT    NPINS      ISY       N1     IGEO     NBEG    IPQ
     13       13       28      112        2       24        7        1        3        1        4        4
LSLIT(I,J) IN I=1 TO IMAX AND THEN J=1 TO JMAX
 -10028   -10028   -10028   -10028   -10028   -10028   -10028   -10028   -10028   -10028   -10028   -10028
 -10028        0        0        0        0        0        0        0        0        0        0        0
      0        0        0        0        0        0        0        0        0        0        0        0
      0        0        0        0        0        0        0        0        0        0        0        0
      0        0        0        0   -10005   -10005   -10005   -10005   -10005   -10005   -10005   -10005
 -10005   -10005        0        0        0   -10000   -10000   -10000   -10000   -10000   -10000   -10000
 -10000   -10000   -10004        0        0        0   -10000   -10000   -10000   -10000   -10000   -10000
 -10000   -10000   -10000   -10004        0        0        0   -10000   -10000   -10000   -10000   -10000
 -10000   -10000   -10000   -10000   -10004        0        0        0   -10003   -10000   -10000   -10003
 -10000   -10000   -10003   -10000   -10000   -10003        0        0        0        0   -10000   -10000
      0   -10000   -10000        0   -10000   -10000        0        0        0        0        0   -10000
 -10000        0   -10000   -10000        0   -10000   -10000        0        0        0        0        0
 -10000   -10000        0   -10000   -10000        0   -10000   -10000        0        0        0        0
 -10001   -10000   -10000   -10001   -10000   -10000   -10001   -10000   -10000   -10001   -10001   -10001
 -10001
 N(I,J) IN I=1 TO IMAX AND THEN J=1 TO JMAX
      1        2        3        4        5        6        7        8        9       10       11       12
     13       14       15       16       17       18       19       20       21       22       23       24
     25       26       27       28       29       30       31       32       33       34       35       36
     37       38       39       40       41       42       43       44       45       46       47       48
     49       50       51       52       53       54       55       56       57       58       59       60
     61       62       63       64       65        0        0        0        0        0        0        0
```

```
       0       0      66      67      68      69       0       0       0       0       0       0
       0       0       0      70      71      72      73       0       0       0       0       0
       0       0       0       0      74      75      76      77      78      79      78      79
      80      79      80      81      80      81      82      83      84      85      86      85
      85      87      86      87      83      87      83      89      90      91      92      93
      92      93      94      93      94      95      94      95      96      97      98      99
     100      99     100     101     100     101     102     101     102     103     104     105
     106     107     106     107     108     107     108     109     108     109     110     111
     112
 NBOUND(I) FOR I=1 TO NTOT
    -201    -201    -201    -201    -201    -201    -201    -201    -201    -201    -201    -201
    -201       0       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0       0       0
       0       0       0      -4      -4      -4      -4      -4      -4      -4      -4      -4
      -7       0       0      -5   -1004   -1004   -1004   -1004   -1004   -1004   -1004   -1004
   -1004    -101       0       0      -3    -101       0       0      -3    -101       0       0
      -3    -101       0       0      -3    -201    -201    -201    -801       0       0      -6
       0       0       0       0       0       0       0       0       0       0       0       0
       0       0      -4      -4      -4      -4      -4      -4      -4   -1004   -1004   -1004
   -1004   -1004   -1004   -1004
 NCHNL(I) FOR I=1 TO NTOT
      18      18      18       1       1       1       1       2       2       2       2       2
       2      18      18      18       1       1       1       1       2       2       2       2
       2       2      18      18      18       1       1       1       1       2       2       2
       2       2       2      18      18      18       1       1       1       1       2       2
       2       2       2       2       0       0       0       0       0       0       0       0
       0       2       2       2       2       2       2       2       2      19      19      19
      19      19      19      19      19      24      19      19      19      19      19      19
      24      19      19      19      19      19      19      24      19      19      19      19
      19      19      24      19      19      19      19      19      19       0       0       0
       0       0       0       0
 NCHTP(I) FOR I=1 TO NCHT
       3       2       3       3       2       3       3       2       3       3       2       3
       3       2       3       3       2       3       1       1       1       1       1       1
 NPNQ(I,J) FOR J=1 TO 6 AND THEN I=1 TO NPINS
       0       0       0       0       0      19       0       0       0      19       2       1
       0       0       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0
 L AND NPIN(L) FOR L=1 TO NBDY
       1       1       2       2       3       2       4       2       5       2       6       2
       7       2       8       3       9       3      10       3      11       3      12       4
      13       4      14       4      15       4      16       5      17       5      18       5
      19       5      20       6      21       6      22       6      23       6      24       7
      25       7      26       7      27       7      28       8
 NPQ(I,J) FOR J=1 TO 6 AND THE  I=1 TO NPINS
       0       0       0       0       0       1       0       0       0       2       3       4
       0       0       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0       0       0       0       0       0       0
       0       0       0       0       0       0
I0=  4    I8= 11    I9= 12    J0=  1    J8= 13    J9= 13

  K    ALFA        BETA        GAMA        ARC          DZDARC

  1  1.0000E+00   0.0         0.0         0.0          4.7373E-02
  2  1.0000E+00   0.0         0.0         2.1109E+01   4.7373E-02
  3  1.0000E+00   0.0         0.0         4.2218E+01   4.7373E-02
  4  1.0000E+00   0.0         0.0         6.3327E+01   4.7379E-02
  5  1.0000E+00   0.0         0.0         8.4434E+01   4.7373E-02
  6  1.0000E+00   0.0         0.0         1.0554E+02   4.7373E-02
```

```
 7  1.0000E+00  0.0         0.0         1.2665E+02  4.7373E-02
 8  1.0000E+00  0.0         0.0         1.4776E+02  4.7373E-02
 9  1.0000E+00  0.0         0.0         1.6887E+02  4.7373E-02
10  1.0000E+00  0.0         0.0         1.8993E+02  4.7373E-02

 10 AXIAL PLANES,    1 TIME STEPS,    20 ITERATIONS PER TIME STEP FOR FIRST    50 STEPS THEN      5 ITERATIONS PER STEP.

INITIAL CONDITIONS :
                     FLOW AREA (M2)             - 1.83556403E-05
                     VELOCITY (M/S)             - 2.14999962E+00
                     FLOWRATE (M3/S)            - 3.94646195E-05
                     REYNOLDS NUMBER            - 3.38175820E+04
                     PRANDTL NUMBER             - 4.23042153E-03
                     ENTRANCE PRESSURE (ATM)    - 2.00000000E+00
                     ENTRANCE TEMPERATURE (C)   - 5.53000000E+02
                     TIME STEP (S)                1.00000002E+20
                     TIME STEP (DIMENSIONLESS)- 5.10567325E+22

ACCELERATION PARAMETERS :
                      X-VELOCITY : 1.00000000
                      Y-VELOCITY : 1.00000000
                      Z-VELOCITY : 1.00000000
                      ENTHALPY :   1.00000000
                      PRESSURE :   1.00000000

CONVERGENCE TOLERANCES :
                     VELOCITY : 0.10000000E-03
                     ENTHALPY : 0.10000000E-03
                     PRESSURE : 0.10000000E-03

AXIS POINTS :            X             Z
                0.0               0.0
                0.0              21.1089935
                0.0              42.2179718
                0.0              63.3269806
                0.0              84.4335937
                0.0             105.542587
                0.0             126.651596
                0.0             147.760574
                0.0             168.869568
                0.0             189.978577

FIELD SIZE (I,J,K) :( 13, 13, 10)

GRAVITATIONAL UNIT VECTOR :
   GX :    0.0
   GY :    0.0
   GZ :   -1.0000

FROUDE NUMBER :   1.0580E+01

REFERENCE CONDITIONS :
                    ENTHALPY(J/KG    )      - 0.10812880E+07
                    DENSITY(KG/M3)          - 0.81950562E+03
                    TEMPERATURE(KELVIN)     - 0.86046094E+03
                    PRESSURE(ATM)           - 0.37386257E-01
                    SPECIFIC HEAT(J/KG/C) - 0.12566379E+04
                    VISCOSITY(PA-S)         - 0.21939813E-03
                    CONDUCTIVITY(J/S/M/C) - 0.64410446E+02
                    VELOCITY(M/S)           - 0.21499996E+01
```

DIAMETER(M) - 0.42110011E-02

NON-DIMENSIONAL ENTRANCE CONDITIONS :
TEMPERATURE - 0.96012479
DENSITY - 1.00000000

ENERGY RATIO (V2/H) - 0.42749916E-05
FUEL PIN HEAT FLUX AT VARIOUS LEVEL

0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01
0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01
0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01
0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01	0.754478E-01

DUCT WALL HEAT FLUX AT VARIOUS LEVEL IN THE ORDER OF QDCL(J,K), QDUR(J,K), QDUT(I,K), AND QDUD(I,K)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
HEATED PARAMETER(H)= 0.1084343E-01
  PLANE=   INITIAL AV. TEMP.=
       1      0.5529998E+03
       2      0.5765503E+03
       3      0.6002903E+03
       4      0.6242117E+03
       5      0.6483142E+03
       6      0.6725894E+03
       7      0.6970309E+03
       8      0.7216292E+03
       9      0.7463792E+03
      10      0.7463792E+03

******************* BEGINNING OF OUTPUT FOR STEP     0 AT   0.0    SECONDS, ITERATION    0*******************


                       U VELOCITY  (NON DIMENSIONAL)

    K=  2
    I-->   1       2       3       4       5       6       7       8       9      10      11      12
  J
  13    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  12    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  11    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  10    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   9    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   8    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   7    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   6    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   5    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   4    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   3    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   2    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   1    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
    I-->  13
  J
  13    0.0
  12    0.0
  11    0.0
  10    0.0
   9    0.0
   8    0.0
   7    0.0
   6    0.0
   5    0.0
   4    0.0
   3    0.0
   2    0.0
   1    0.0


                       U VELOCITY  (NON DIMENSIONAL)

    K= 10
    I-->   1       2       3       4       5       6       7       8       9      10      11      12
  J
```

13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

I-->	13
J	
13	0.0
12	0.0
11	0.0
10	0.0
9	0.0
8	0.0
7	0.0
6	0.0
5	0.0
4	0.0
3	0.0
2	0.0
1	0.0

V VELOCITY (NON DIMENSIONAL)

K= 2

I-->	1	2	3	4	5	6	7	8	9	10	11	12
J												
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

I-->	13
J	
13	0.0
12	0.0
11	0.0
10	0.0
9	0.0
8	0.0
7	0.0
6	0.0
5	0.0

4	0.0
3	0.0
2	0.0
1	0.0

V VELOCITY (NON DIMENSIONAL)

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13
13	0.0
12	0.0
11	0.0
10	0.0
9	0.0
8	0.0
7	0.0
6	0.0
5	0.0
4	0.0
3	0.0
2	0.0
1	0.0

W VELOCITY (NON DIMENSIONAL)

I= 4

J \ K-->	1	2	3	4	5	6	7	8	9	10
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
11	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
10	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
3	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
2	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00

1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

W VELOCITY (NON DIMENSIONAL)

I= 12

J \ K-->	1	2	3	4	5	6	7	8	9	10
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
11	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
10	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
9	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
8	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
7	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
6	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
5	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
4	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
3	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
2	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

W VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
11	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
10	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
4	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
3	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
2	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13
13	0.0
12	1.273E+00
11	1.273E+00
10	1.273E+00
9	1.273E+00
8	1.273E+00
7	1.273E+00
6	1.273E+00
5	1.273E+00
4	1.273E+00
3	1.273E+00
2	1.273E+00
1	0.0

W VELOCITY (NON DIMENSIONAL)

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
11	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
10	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.273E+00	1.273E+00
4	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
3	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
2	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00	1.273E+00
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13
13	0.0
12	1.273E+00
11	1.273E+00
10	1.273E+00
9	1.273E+00
8	1.273E+00
7	1.273E+00
6	1.273E+00
5	1.273E+00
4	1.273E+00
3	1.273E+00
2	1.273E+00
1	0.0

TEMPERATURE (NON DIMENSIONAL) T

I= 4

J \ K-->	1	2	3	4	5	6	7	8	9	10
13	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
12	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
11	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
10	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
9	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
8	1.224389	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864
7	1.224389	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864
6	1.224389	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864
5	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
4	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
3	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
2	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
1	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864

TEMPERATURE (NON DIMENSIONAL) T

I= 12

J \ K-->	1	2	3	4	5	6	7	8	9	10
13	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
12	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
11	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
10	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
9	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
8	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
7	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
6	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
5	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
4	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
3	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
2	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864
1	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.184864

TEMPERATURE (NON DIMENSIONAL) T

K= 1

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
12	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
11	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
10	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
9	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
8	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	0.960125	0.960125	0.960125
7	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	0.960125	0.960125	0.960125
6	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	1.224389	0.960125	0.960125	0.960125
5	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
4	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
3	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
2	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
1	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125

J \ I-->	13
13	0.960125
12	0.960125
11	0.960125
10	0.960125
9	0.960125
8	0.960125
7	0.960125
6	0.960125
5	0.960125
4	0.960125
3	0.960125
2	0.960125
1	0.960125

TEMPERATURE (NON DIMENSIONAL) T

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12

13	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
12	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
11	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
10	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
9	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
8	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
7	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
6	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
5	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
4	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
3	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
2	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864
1	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864

I-->	13
J	
13	1.184864
12	1.184864
11	1.184864
10	1.184864
9	1.184864
8	1.184864
7	1.184864
6	1.184864
5	1.184864
4	1.184864
3	1.184864
2	1.184864
1	1.184864

PRESSURE (NON DIMENSIONAL) P

I= 4

K-->	1	2	3	4	5	6	7	8	9	10
J										
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.185E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1.185E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.185E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PRESSURE (NON DIMENSIONAL) P

I= 12

K-->	1	2	3	4	5	6	7	8	9	10
J										
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
10  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 9  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 8  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 7  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 6  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 5  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 4  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 3  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 2  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0

********************      END OF OUTPUT FOR STEP     0 AT   0.0    SECONDS, ITERATION    0********************


 MAX. MASS RESIDUE AT   11    3    9 =  -1.69723078E+21
 MAX. PRES CORREC. AT   11    3    9 =   2.13623047E-04
*****    1 -0.11361686E-02 -0.11705002E-02  0.46481609E+00  0.46930909E-02  0.21362305E-03  0.0          0.0          *****
 MAX. MASS RESIDUE AT   11    3    1 =   1.42914836E+21
 MAX. PRES CORREC. AT   11    3    1 =  -1.79607872E-04
*****    2  0.12818421E-02  0.88205049E-03 -0.23297405E+00 -0.28142929E-02 -0.17960787E-03  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.48368034E+21
 MAX. PRES CORREC. AT   11    4    9 =   1.16348267E-04
*****    3 -0.10142750E-02 -0.87734964E-03  0.21540165E+00  0.38890839E-02  0.11634827E-03  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    2    1 =  -1.30863949E+21
 MAX. PRES CORREC. AT   11    4    1 =  -1.19985561E-04
*****    4  0.62817428E-03  0.61807665E-03 -0.11059952E+00  0.25768280E-02 -0.11998556E-03  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.37974192E+21
 MAX. PRES CORREC. AT   11    3    1 =  -9.74086579E-05
*****    5  0.43437327E-03  0.38226531E-03 -0.53411454E-01  0.33617020E-02 -0.97408658E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.37456053E+21
 MAX. PRES CORREC. AT   11    3    1 =  -8.66318537E-05
*****    6 -0.58959564E-03 -0.62897732E-03  0.35531990E-01  0.22697449E-02 -0.86631859E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.30413296E+21
 MAX. PRES CORREC. AT   11    3    1 =  -9.49613750E-05
*****    7  0.43932535E-03  0.59038401E-03 -0.29822350E-01  0.17509460E-02 -0.94961375E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.31427619E+21
 MAX. PRES CORREC. AT   11    3    1 =  -8.19128472E-05
*****    8  0.32756245E-03 -0.51438389E-03  0.18295288E-01  0.16021729E-02 -0.81912847E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.27445339E+21
 MAX. PRES CORREC. AT   11    3    1 =  -7.94727821E-05
*****    9  0.15990986E-03  0.24833996E-03  0.10347366E-01  0.58450699E-02 -0.79472782E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.26085674E+21
 MAX. PRES CORREC. AT   11    3    1 =  -7.83912838E-05
*****   10  0.26102783E-03  0.37965574E-03 -0.66738129E-02  0.25434494E-02 -0.78391284E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.24196133E+21
 MAX. PRES CORREC. AT   11    3    1 =  -7.42611010E-05
*****   11  0.19570719E-03  0.18416857E-03 -0.52709579E-02  0.22010803E-02 -0.74261101E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.23214039E+21
 MAX. PRES CORREC. AT   11    3    1 =  -7.13707414E-05
*****   12  0.19533699E-03 -0.15959459E-03  0.33025742E-02  0.19149780E-02 -0.71370741E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.21174471E+21
 MAX. PRES CORREC. AT   11    9    1 =  -7.00252131E-05
*****   13 -0.19718416E-03 -0.31152740E-03 -0.42734146E-02  0.13952255E-02 -0.70025213E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.19674406E+21
 MAX. PRES CORREC. AT   11    9    1 =  -6.73949253E-05
*****   14  0.18133503E-03  0.20685047E-03 -0.33073425E-02  0.90885162E-03 -0.67394925E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    6    3    1 =  -1.18504287E+21
 MAX. PRES CORREC. AT   11    9    1 =  -6.32435549E-05
```

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*****   15  0.15436416E-03  0.22844145E-03  0.42867661E-02  0.83732605E-03 -0.63243555E-04  0.0             0.0             *****
 MAX. MASS RESIDUE AT    6     3     1 =  -1.16855491E+21
 MAX. PRES CORREC. AT   11     9     1 =  -6.30742870E-05
*****   16  0.17250329E-03  0.23309467E-03  0.35934448E-02 -0.12168884E-02 -0.63074287E-04  0.0             0.0             *****
 MAX. MASS RESIDUE AT    5     3     1 =  -1.15543827E+21
 MAX. PRES CORREC. AT   11     9     1 =  -6.13725279E-05
*****   17  0.20761904E-03  0.34197536E-03 -0.27494431E-02  0.21371841E-02 -0.61372528E-04  0.0             0.0             *****
 MAX. MASS RESIDUE AT    5     3     1 =  -1.14353065E+21
 MAX. PRES CORREC. AT   11     9     1 =  -5.92814758E-05
*****   18  0.18111616E-03  0.23334759E-03 -0.39815903E-02  0.20790100E-02 -0.59281476E-04  0.0             0.0             *****
 MAX. MASS RESIDUE AT    5     3     1 =  -1.13535465E+21
 MAX. PRES CORREC. AT   11     9     1 =  -5.74600417E-05
*****   19  0.18162280E-03 -0.25034021E-03  0.29573441E-02  0.12664795E-02 -0.57460042E-04  0.0             0.0             *****
 MAX. MASS RESIDUE AT    5     3     1 =  -1.12863050E+21
 MAX. PRES CORREC. AT   11     9     1 =  -5.59391920E-05
*****0.020  0.23939121E-03 -0.21296879E-03  0.35600562E-02  0.85735321E-03 -0.55939192E-04  0.0             0.0             *****


******************** BEGINNING OF OUTPUT FOR STEP      1 AT********* SECONDS, ITERATION   20********************
```

U VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	-1.285E-03	2.057E-04	-1.285E-03	2.057E-04	1.285E-03	2.057E-04	1.285E-03	1.831E-03	1.285E-03	1.831E-03	1.681E-03	1.057E-03
11	-1.818E-03	3.331E-04	-1.818E-03	3.331E-04	1.818E-03	3.331E-04	1.818E-03	2.492E-03	1.818E-03	2.492E-03	2.635E-03	1.714E-03
10	-1.998E-03	3.264E-04	-1.998E-03	3.264E-04	1.998E-03	3.264E-04	1.998E-03	2.522E-03	1.998E-03	2.522E-03	1.891E-03	2.444E-04
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.363E-04	-7.505E-04
8	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-3.163E-04	-9.842E-04
7	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	3.164E-04	-2.793E-04
6	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	9.055E-04	5.469E-04
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.541E-04	-1.443E-04
4	0.0	0.0	-8.264E-04	-1.572E-07	8.264E-04	1.490E-03	2.330E-03	3.467E-03	4.072E-03	3.506E-03	2.065E-03	-9.195E-04
3	0.0	0.0	-9.115E-04	-2.442E-07	9.115E-04	1.768E-03	2.648E-03	4.019E-03	5.050E-03	4.427E-03	2.418E-03	-1.344E-03
2	0.0	0.0	-8.090E-04	6.751E-07	8.090E-04	1.630E-03	2.331E-03	3.475E-03	4.616E-03	4.464E-33	2.505E-03	-7.997E-04
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13
13	-8.660E-11
12	-5.039E-04
11	2.164E-04
10	-1.227E-03
9	-1.460E-03
8	-1.466E-03
7	-8.413E-04
6	-4.640E-04
5	-1.443E-03
4	-4.115E-03
3	-4.873E-03
2	-4.131E-03
1	-8.660E-11

U VELOCITY (NON DIMENSIONAL)

```
$$DATE$$
        7 PINS HEXGONAL ROD BUNDLE WITH 1/12 SYMMETRY
        SIMULATION FOR GERMAN FLOW RUN DOWN EXPERIMENT(9/25/80)
          3
       &SET NTPRNT=4,50,300,600,46*0,
        ITPRNT=50*0,NTPLOT=50*0,
        NTHPR=1302,1310,2302,2310,3104,3112,3302,3310,5104,5112,
        5301,5310,6104,6112,36*0,
        ISTPR=1302,1310,2302,2310,3104,3112,3302,3310,5104,5112,
        5301,5310,6104,6112,36*0,
        GX=0.0,GY=0.0,GZ=-1.0,
        IBHSOL=0,IBPSOL=0,IBITER=0,IBVSOL=0,IBUG=0,0,0,0,0,0,0,0,0,21*0,
        IBLO=4,IBHI=12,JBLO=1,JBHI=13,KBLO=10,KBHI=10,
        KMAX=16,IPRES=1,IPRC3=1,SLIPR=0.0,DREF=0.004211,
        NSTEPS=004,IT1=30,IT2=5,ITSET=50,IT3=3,
        DTO=1.0E+20,VEL=  2.15, TENC=553.000,PENT=2.0,    FGRAD=0.0,
        TURBF=1.0,TURBK=1.00,AO=0.5,BO=0.0,NPORD=2,
        FAC=4*0.8,1.0,1.8,1.0,0.5,0.5,1.0,1.0,1.0,18*0.0,
        TOLVEL=0.0001,TOLENT=0.0001,TOLPRE=0.0001,ESUMSM=0.001,
        ZA=0.000,0.08889,0.17778,0.26667,0.35555,0.44444,0.53333,0.62222,
           0.71111,0.80000,
        XA=10*0.0,QACC=0.0,VACC=0.0,TACC=0.0,
        C=5.0,0.025,0.8,6*0.0,0.0,1.0,1.3,1.44,1.92,0.09,
          0.42,9.8,0.01,0.07,1.0,1.0,1.0,1.3,0.09,6*0.0,
        KA=10*0,
        NC=7,NTFU=3, HCOND=1.30,   IOPT=0,0,0,1,2,0,0,0,0,0,20*0,
          QRAD=7*1.0,QAXIAL=0.0,8*1.0,0.0,
        QPIN=40*0.993E+06,
        DECH=0.0054694,0.0043237,0.0026566,AVHTF=0.993E+06,
        EPS=1.0E-10,0.2E-05,0.2E-07,1.0E-03,26*0.0,
       WDUC=0.0015,TOLTDU=1.0E-02,
       &END
 7 PINS HEXGONAL ROD BUNDLE WITH 1/12 SYMMETRY
 SIMULATION FOR GERMAN FLOW RUN DOWN EXPERIMENT(9/25/80)

**** JOB RESTARTED AFTER ITERATION   20 OF TIME STEP    3 *****


&SET
NTHPR=       1302,       1310,       2302,       2310,       3104,       3112,       3302,       3310,       5104,       5112,
        5301,       5310,       6104,       6112,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,ISTPR=     1302,       1310,       2302,
        2310,       3104,       3112,       3302,       3310,       5104,       5112,       5301,       5310,       6104,       6112,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,NTPRNT=         4,         50,        300,        600,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,ITPRNT=
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
           0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
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         0,          0,          0,          0,          0,          0,NTPLOT=          0,          0,          0,          0,
         0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
         0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
         0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
         0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
         0,          0,IT1=        30,IT2=         5,IT3=         3,ITSET=        50,SLIFR=  .0          ,KMAX=         10,
NSTEPS=         4,IBMAX=         0,IBVAX=         0,IBNSOL=        0,IBVSOL=        0,ICPSOL=        0,IBITER=         0,
IBLO=         4,IBHI=        12,JBLO=         1,JBHI=        13,KBLO=        10,IPRES=         1,KBHI=        10,DTD=
 .100000002E+21,VEL=  2.14999962   ,TENC=  553.000000   ,PENT=  2.00000000   ,TURBF=  1.00000000   ,TURBK=  1.00000000   ,GX=
 .0            ,DREF=  .421100110E-02,ISWEEP=          0,GY=  .0             ,GZ= -1.00000000   ,AO=  .500000000   ,P/=
 .0            ,EPS=  .999999944E-10,  .199999977E-05,  .200000017E-07,  .999999931E-03,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,NPORD=         2,FAC=  .800000012   ,  .800000012   ,  .800000012   ,
 .800000012    ,  1.00000000    ,  1.80000019    ,  1.00000000    ,  .500000000    ,  .500000000    ,  1.00000000    ,
 1.00000000    ,  1.00000000    ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,TOLVEL=  .100000005E-03,
TOLENT=  .100000005E-03,TOLPRE=  .100000005E-03,XA=  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,ZA=  .0            ,
 .888900161E-01,  .177779973    ,  .266669989    ,  .355549991    ,  .444440007    ,  .533330023    ,  .622219980    ,
 .711109996    ,  .800000012    ,QDUL=  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
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 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,QDUR=  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
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 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,QDUT=  .0            ,  .0            ,  .0            ,  .0            ,
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.0         , .0         , .0         , .0         , .0         , .0         , .0         ,
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.0         , .0         , .0         , .0         , .0         , .0         , .0         ,
.0         , .0         , .0         , .0         , .0         , .0         , .0         ,QDUB=
.0         , .0         , .0         , .0         , .0         , .0         , .0         ,
.0         , .0         , .0         , .0         , .0         , .0         , .0         ,
.0         , .0         , .0         , .0         , .0         , .0         , .0         ,
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.0         , .0         , .0         , .0         , .0         , .0         , .0         ,
.0         , .0         , .0         , .0         , .0         , .0         , .0         ,
.0         , .0         , .0         , .0         ,PGRAD=  .0          ,QPIN=  .754477978E-01,  .754477978E-01,
.754477978E-01,  .754477978E-01,  .754477978E-01,  .754477978E-01,  .754477978E-01,  .754477978E-01,  .754477978E-01,
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.754477978E-01,  .754477978E-01,  .754477978E-01,AVHTF=  993000.000    ,ESUMSM=  .999999931E-03,IPROB=          1,IDUG=
       0,         0,         0,         0,         0,         0,         0,         0,         0,         0,         0,
       0,         0,         0,         0,         0,         0,         0,         0,         0,         0,         0,
       0,         0,         0,         0,         0,         0,         0,         0,QACC=  .0             ,VACC=
.0             ,TACC=  .0             ,DECH=  1.29833575    ,  1.02676201    ,  .630871356    ,KA=          0,        0,
       0,         0,         0,         0,         0,         0,         0,         0,C=  5.00000000    ,  .249999985E-01,
.800000012    , .0            , .0            , .0            , .0            , .0            , .0            ,
.0            , 1.00000000    , 1.30000019    , 1.43999958    , 1.92000003    , .899999738E-01, .420000017    ,
9.80000019    , .100000016E-01, .699999928E-01, 1.00000000    , 1.00000000    , 1.00000000    , 1.30000019    ,
.899999738E-01, .0            , .0            , .0            , .0            , .0            , .0            ,IOPT=
       0,         0,         0,         1,         2,         0,         0,         0,         0,         0,         0,
       0,         0,         0,         0,         0,         0,         0,         0,         0,         0,         0,
       0,         0,         0,         0,         0,         0,         0,         0,NC=          7,NTFU=          3,
RADIAL=  .0            , .0            , .0            , .0            , .0            , .0            , .0            ,
HCCND=  1.30000019    ,Q=  .0            , .0            , .0            , .0            , .0            , .0            ,
 .0             ,QRAD=  1.00000000    , 1.00000000    , 1.00000000    , 1.00000000    , 1.00000000    , 1.00000000    ,
 1.00000000     ,QAXIAL=  .0            , 1.00000000    , 1.00000000    , 1.00000000    , 1.00000000    , 1.00000000    ,
 1.00000000     , 1.00000000    , 1.00000000    , .0            ,NDUC=  .150000001E-02,TOLTDU=  .100000016E-01
```

```
&END
 MAX. MASS RESIDUE AT     5     4     1 =  -9.65919100E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.53591347E-05
*****    1 -0.15333203E-03 -0.15756277E-03  0.15415451E-02 -0.48351288E-03 -0.45359135E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.63762631E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.49244377E-05
*****    2 -0.13456809E-03 -0.16360133E-03  0.13017454E-02  0.84972382E-03 -0.44924440E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.61770159E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.44846228E-05
*****    3  0.12571295E-03  0.15398045E-03 -0.16984940E-02 -0.50163269E-03 -0.44484623E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.60356310E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.43628523E-05
*****    4  0.14105682E-03 -0.13230089E-03 -0.18510318E-02 -0.54645538E-03 -0.44362852E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.57839235E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.41661105E-05
*****    5  0.14768828E-03 -0.16191536E-03 -0.23078910E-02  0.39577484E-03 -0.44166110E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.53563756E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.33375364E-05
*****    6  0.25903224E-03  0.33713776E-03  0.12539429E-02 -0.67615509E-03 -0.43837586E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.51435242E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.36797272E-05
*****    7 -0.36443723E-03 -0.48857857E-03 -0.22277832E-02  0.43487549E-03 -0.43679727E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.48494392E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.35467809E-05
*****    8 -0.17924048E-03 -0.17618354E-03  0.23183823E-02  0.37288666E-03 -0.43546781E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.44370220E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.32260106E-05
*****    9  0.25680591E-03  0.45850780E-03  0.19245140E-02  0.56457520E-03 -0.43226011E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.42700792E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.30548098E-05
*****   10  0.42461907E-03  0.49161771E-03  0.30107498E-02  0.32901764E-03 -0.43054810E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.38379006E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.30839136E-05
*****   11 -0.27043768E-03 -0.45019202E-03 -0.17461777E-02  0.89931488E-03 -0.43083914E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.36937874E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.29586597E-05
*****   12 -0.10711560E-03 -0.17672851E-03 -0.19292831E-02 -0.53310394E-03 -0.42958651E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.33168079E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.26051467E-05
*****   13  0.28163614E-03  0.41891355E-03 -0.22907257E-02 -0.53215027E-03 -0.42605447E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.29885671E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.25465405E-05
*****   14  0.12511294E-03  0.15142676E-03  0.15821457E-02  0.10371887E-02 -0.42546540E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.28155354E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.22783196E-05
*****   15  0.15157321E-03  0.14921394E-03 -0.29563904E-02  0.14333725E-02 -0.42278320E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.23421727E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.19802964E-05
*****   16 -0.37180795E-03 -0.50503924E-03 -0.23632050E-02 -0.62179565E-03 -0.41980296E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.18599216E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.17083502E-05
*****   17  0.26705535E-03  0.38333051E-03  0.26283264E-02  0.46634674E-03 -0.41708350E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.15926847E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.17344272E-05
*****   18  0.11678837E-03 -0.14913117E-03 -0.15153035E-02 -0.90789795E-03 -0.41734427E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.11965414E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.15593396E-05
*****   19 -0.12028392E-03  0.14798276E-03 -0.27389526E-02  0.83637238E-03 -0.41559339E-04  0.0             0.0           *****
 MAX. MASS RESIDUE AT     5     4     1 =  -9.01858210E+20
 MAX. PRES CORREC. AT    11     9     1 =  -4.25912440E-05
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*****  20 -0.32058195E-03 -0.52559865E-03  0.13472672E-02  0.44441223E-03 -0.42591244E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.99013935E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.32245433E-05
*****  21  0.15682913E-03 -0.18563643E-03 -0.14142990E-02  0.35381317E-03 -0.43224543E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.95792425E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.32766974E-05
*****  22  0.25269855E-03  0.46757492E-03  0.20713606E-02  0.33569336E-03 -0.43276697E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.90160955E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.30569053E-05
*****  23 -0.12424994E-03  0.11275093E-03  0.15125275E-02  0.32138824E-03 -0.43056905E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.85902520E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.27998602E-05
*****  24 -0.12252033E-03  0.13920413E-03 -0.24299622E-02 -0.44536591E-03 -0.42799860E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.85471300E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.24124300E-05
*****  25 -0.17883845E-03 -0.14370689E-03 -0.23107529E-02  0.35667419E-03 -0.42412430E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.78238239E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.21069562E-05
*****  26  0.11859751E-03  0.11939439E-03 -0.22239685E-02  0.32806396E-03 -0.42106956E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.73713527E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.24012542E-05
*****  27  0.96075004E-04 -0.18342469E-03 -0.20923615E-02  0.30422211E-03 -0.42401254E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.72071684E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.23118472E-05
*****  28 -0.15152877E-03  0.15569205E-03  0.26426315E-02  0.33760071E-03 -0.42311847E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.70516253E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.17642295E-05
*****  29  0.11465853E-03  0.10458985E-03 -0.13129349E-02  0.29659271E-03 -0.41764230E-04  0.0          0.0          *****
 MAX. MASS RESIDUE AT    5    4    1 =  -8.64537725E+20
 MAX. PRES CORREC. AT   11    9    1 =  -4.17530537E-05
*****0.030 -0.94762436E-04 -0.15537112E-03  0.16050339E-02  0.32043457E-03 -0.41753054E-04  0.0          0.0          *****


******************** BEGINNING OF OUTPUT FOR STEP     4 AT********* SECONDS, ITERATION   30********************
```

U VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	-1.290E-03	2.039E-04	-1.290E-03	2.039E-04	1.290E-03	2.039E-04	1.290E-03	1.733E-03	1.290E-03	1.733E-03	1.524E-03	1.029E-03
11	-1.753E-03	3.362E-04	-1.753E-03	3.362E-04	1.753E-03	3.362E-04	1.753E-03	2.249E-03	1.753E-03	2.249E-03	2.201E-03	1.314E-03
10	-1.979E-03	3.333E-04	-1.979E-03	3.333E-04	1.979E-03	3.333E-04	1.979E-03	1.875E-03	1.979E-03	1.875E-03	5.795E-04	-9.409E-04
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.644E-03	-2.450E-03
8	-8.660E-11	-8.650E-11	-8.660E-11	-8.650E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-2.986E-03	-3.743E-03
7	-8.660E-11	-8.650E-11	-8.660E-11	-8.650E-11	-8.660E-11	-8.650E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-2.639E-03	-3.626E-03
6	-8.650E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-2.120E-03	-3.537E-03
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.340E-03	-3.494E-03
4	0.0	0.0	-3.205E-03	4.353E-07	3.205E-03	6.302E-03	8.420E-03	8.856E-03	7.682E-03	5.730E-03	2.077E-03	-3.970E-03
3	0.0	0.0	-3.133E-03	6.402E-07	3.133E-03	6.651E-03	9.600E-03	1.132E-02	1.111E-02	8.124E-03	3.956E-03	-3.197E-03
2	0.0	0.0	-2.219E-03	1.165E-06	2.219E-03	5.168E-03	7.971E-03	1.022E-02	1.093E-02	9.198E-03	4.834E-03	-1.200E-03
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13
13	-8.660E-11
12	-6.319E-04

11	3.779E-04
10	-1.809E-03
9	-2.663E-03
8	-3.399E-03
7	-3.971E-03
6	-3.589E-03
5	-5.188E-03
4	-9.524E-03
3	-9.394E-03
2	-7.381E-03
1	-8.660E-11

U VELOCITY (NON DIMENSIONAL)

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.668E-04	-5.684E-06	1.668E-04	-5.684E-06	-1.668E-04	-5.684E-06	-1.668E-04	6.424E-06	-1.668E-04	6.424E-06	-4.923E-06	-4.818E-05
11	8.538E-05	4.800E-06	8.538E-05	4.800E-06	-8.538E-05	4.800E-06	-8.538E-05	2.327E-05	-8.535E-05	2.327E-05	1.021E-04	-8.292E-05
10	3.603E-05	-7.816E-06	3.603E-05	-7.816E-06	-3.603E-05	-7.816E-06	-3.603E-05	1.153E-04	-3.603E-05	1.153E-04	2.030E-04	1.071E-04
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.569E-04	2.254E-04
8	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-7.403E-05	1.358E-05
7	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-2.982E-04	-2.278E-04
6	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-2.183E-04	-5.519E-06
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.776E-04	-5.210E-05
4	0.0	0.0	-5.508E-05	9.967E-06	5.508E-05	2.963E-04	3.271E-04	2.369E-04	4.236E-05	-2.372E-04	-2.104E-04	-1.413E-04
3	0.0	0.0	-1.839E-04	1.805E-05	1.839E-04	1.833E-04	2.945E-04	2.641E-04	2.194E-04	-7.591E-05	2.359E-05	1.002E-04
2	0.0	0.0	-8.579E-05	3.852E-05	8.579E-05	4.731E-05	1.833E-04	3.607E-04	2.076E-04	1.724E-04	6.133E-05	1.382E-04
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13
13	-8.660E-11
12	6.364E-05
11	3.721E-05
10	-8.534E-05
9	2.013E-04
8	-3.043E-05
7	-3.215E-04
6	-1.750E-04
5	1.035E-04
4	-2.247E-05
3	-2.255E-05
2	-1.034E-04
1	-8.660E-11

V VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000E-10	0.0
12	-1.389E-03	-1.378E-03	-1.389E-03	-1.378E-03	-1.389E-03	-1.378E-03	-1.389E-03	-1.423E-03	-1.389E-03	-1.423E-03	-1.610E-03	-9.821E-04
11	-1.125E-03	-1.013E-03	-1.125E-03	-1.013E-03	-1.125E-03	-1.013E-03	-1.125E-03	-1.202E-03	-1.125E-03	-1.202E-03	-8.347E-04	-1.434E-04
10	2.167E-04	2.506E-04	2.167E-04	2.506E-04	2.167E-04	2.506E-04	2.167E-04	4.047E-04	2.167E-04	4.047E-04	1.754E-03	2.055E-03
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.024E-03	4.364E-03

J												
8	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	5.649E-03	6.481E-03
7	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	6.198E-03	6.256E-03
6	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	5.369E-03	6.213E-03
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.764E-03	6.015E-03
4	0.0	0.0	1.826E-03	9.751E-04	1.826E-03	4.107E-03	6.905E-03	9.779E-03	9.942E-03	9.204E-03	9.793E-03	6.905E-03
3	0.0	0.0	1.645E-03	8.350E-04	1.645E-03	3.656E-03	6.477E-03	9.354E-03	1.096E-02	1.008E-02	8.553E-03	5.551E-03
2	0.0	0.0	7.846E-04	2.015E-04	7.846E-04	2.307E-03	4.344E-03	6.729E-03	8.190E-03	7.857E-03	5.731E-03	2.103E-03
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000E-10	0.0

J	I--> 13
13	5.000E-11
12	2.125E-03
11	2.324E-03
10	3.751E-04
9	3.436E-03
8	5.410E-03
7	5.338E-03
6	4.520E-03
5	4.542E-03
4	3.100E-03
3	8.553E-04
2	-1.321E-03
1	5.000E-11

V VELOCITY (NON DIMENSIONAL)

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000E-10	0.0
12	1.813E-04	8.468E-05	1.813E-04	8.468E-05	1.813E-04	8.468E-05	1.813E-04	2.076E-04	1.813E-04	2.076E-04	7.633E-05	1.406E-04
11	-8.748E-05	1.171E-04	-8.748E-05	1.171E-04	-8.748E-05	1.171E-04	-8.748E-05	-5.685E-05	-8.748E-05	-5.685E-05	-1.601E-05	4.241E-05
10	1.209E-04	5.640E-05	1.209E-04	5.640E-05	1.209E-04	5.640E-05	1.209E-04	-5.439E-05	1.209E-04	-5.439E-05	-1.914E-05	-1.346E-04
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.031E-04	-3.652E-04
8	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	-2.445E-04	-1.235E-04
7	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	-1.991E-04	-1.727E-04
6	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	-7.606E-05	-1.594E-04
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.221E-04	2.304E-04
4	0.0	0.0	-1.463E-04	1.061E-06	-1.463E-04	-7.665E-05	-2.794E-03	2.236E-04	1.369E-04	3.357E-06	9.552E-05	3.006E-04
3	0.0	0.0	-1.948E-04	-2.143E-04	-1.948E-04	3.433E-05	3.364E-05	1.827E-04	2.547E-04	2.507E-06	1.242E-05	-3.863E-05
2	0.0	0.0	3.531E-05	1.434E-05	3.531E-05	6.403E-05	-5.063E-06	7.311E-05	1.398E-04	-1.000E-04	8.404E-05	-7.080E-05
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000E-10	0.0

J	I--> 13
13	5.000E-11
12	-4.243E-05
11	9.647E-05
10	-1.861E-04
9	1.334E-04
8	3.179E-05
7	-1.587E-04
6	-1.511E-04
5	-2.649E-04
4	-2.300E-04
3	-1.422E-05
2	-1.109E-05
1	5.000E-11

W VELOCITY (NON DIMENSIONAL)

I= 4

J \ K-->	1	2	3	4	5	6	7	8	9	10
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.273E+00	1.220E+00	1.227E+00	1.220E+00	1.223E+00	1.225E+00	1.233E+00	1.239E+00	1.249E+00	1.259E+00
11	1.273E+00	1.475E+00	1.491E+00	1.493E+00	1.490E+00	1.496E+00	1.502E+00	1.512E+00	1.524E+00	1.535E+00
10	1.273E+00	1.323E+00	1.325E+00	1.330E+00	1.324E+00	1.332E+00	1.335E+00	1.345E+00	1.355E+00	1.365E+00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.273E+00	7.402E-01	5.548E-01	5.425E-01	5.173E-01	5.300E-01	5.251E-01	5.330E-01	5.365E-01	5.400E-01
3	1.273E+00	8.903E-01	6.755E-01	6.552E-01	6.274E-01	6.408E-01	6.356E-01	6.447E-01	6.490E-01	6.533E-01
2	1.273E+00	7.983E-01	6.056E-01	5.879E-01	5.627E-01	5.742E-01	5.699E-01	5.777E-01	5.811E-01	5.846E-01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

W VELOCITY (NON DIMENSIONAL)

I= 12

J \ K-->	1	2	3	4	5	6	7	8	9	10
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.273E+00	1.360E+00	1.438E+00	1.427E+00	1.450E+00	1.445E+00	1.461E+00	1.467E+00	1.479E+00	1.490E+00
11	1.273E+00	1.738E+00	1.855E+00	1.878E+00	1.897E+00	1.902E+00	1.916E+00	1.928E+00	1.943E+00	1.958E+00
10	1.273E+00	1.829E+00	1.953E+00	2.003E+00	2.019E+00	2.032E+00	2.044E+00	2.059E+00	2.075E+00	2.091E+00
9	1.273E+00	1.712E+00	1.799E+00	1.839E+00	1.852E+00	1.864E+00	1.876E+00	1.890E+00	1.905E+00	1.922E+00
8	1.273E+00	1.578E+00	1.606E+00	1.623E+00	1.627E+00	1.635E+00	1.645E+00	1.657E+00	1.670E+00	1.684E+00
7	1.273E+00	1.513E+00	1.528E+00	1.523E+00	1.519E+00	1.525E+00	1.533E+00	1.544E+00	1.557E+00	1.570E+00
6	1.273E+00	1.599E+00	1.642E+00	1.633E+00	1.637E+00	1.639E+00	1.650E+00	1.663E+00	1.678E+00	1.693E+00
5	1.273E+00	1.727E+00	1.836E+00	1.854E+00	1.872E+00	1.878E+00	1.893E+00	1.909E+00	1.927E+00	1.944E+00
4	1.273E+00	1.806E+00	1.977E+00	2.027E+00	2.055E+00	2.073E+00	2.089E+00	2.107E+00	2.125E+00	2.143E+00
3	1.273E+00	1.743E+00	1.912E+00	1.960E+00	1.995E+00	2.013E+00	2.031E+00	2.048E+00	2.065E+00	2.082E+00
2	1.273E+00	1.431E+00	1.536E+00	1.562E+00	1.595E+00	1.604E+00	1.623E+00	1.634E+00	1.648E+00	1.663E+00
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

W VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.242E+00	1.220E+00	1.242E+00	1.220E+00	1.242E+00	1.220E+00	1.242E+00	1.291E+00	1.242E+00	1.291E+00	1.338E+00	1.360E+00
11	1.518E+00	1.475E+00	1.518E+00	1.475E+00	1.518E+00	1.475E+00	1.518E+00	1.607E+00	1.518E+00	1.607E+00	1.698E+00	1.738E+00
10	1.390E+00	1.323E+00	1.390E+00	1.323E+00	1.390E+00	1.323E+00	1.390E+00	1.512E+00	1.390E+00	1.512E+00	1.735E+00	1.829E+00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.496E+00	1.712E+00
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.361E+00	1.570E+00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.306E+00	1.513E+00
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.355E+00	1.599E+00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.493E+00	1.727E+00
4	1.273E+00	1.273E+00	6.888E-01	7.402E-01	6.888E-01	6.147E-01	6.580E-01	8.307E-01	1.074E+00	1.325E+00	1.656E+00	1.806E+00
3	1.273E+00	1.273E+00	8.360E-01	8.903E-01	8.360E-01	7.341E-01	7.429E-01	8.950E-01	1.146E+00	1.423E+00	1.648E+00	1.743E+00

J												
2	1.273E+00	1.273E+00	7.545E-01	7.983E-01	7.545E-01	6.514E-01	6.204E-01	7.270E-01	9.265E-01	1.166E+00	1.354E+00	1.431E+00
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13
13	0.0
12	1.338E+00
11	1.698E+00
10	1.735E+00
9	1.496E+00
8	1.361E+00
7	1.306E+00
6	1.335E+00
5	1.493E+00
4	1.656E+00
3	1.643E+00
2	1.354E+00
1	0.0

W VELOCITY (NON DIMENSIONAL)

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.297E+00	1.259E+00	1.297E+00	1.259E+00	1.297E+00	1.259E+00	1.297E+00	1.330E+00	1.297E+00	1.380E+00	1.458E+00	1.490E+00
11	1.604E+00	1.535E+00	1.604E+00	1.535E+00	1.604E+00	1.535E+00	1.604E+00	1.749E+00	1.604E+00	1.749E+00	1.897E+00	1.958E+00
10	1.461E+00	1.365E+00	1.461E+00	1.365E+00	1.461E+00	1.365E+00	1.461E+00	1.646E+00	1.461E+00	1.646E+00	1.961E+00	2.091E+00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.657E+00	1.922E+00
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.447E+00	1.634E+00
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.344E+00	1.570E+00
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.452E+00	1.693E+00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.657E+00	1.944E+00
4	1.273E+00	1.273E+00	5.002E-01	5.400E-01	5.002E-01	4.519E-01	5.291E-01	7.663E-01	1.115E+00	1.477E+00	1.941E+00	2.143E+00
3	1.273E+00	1.273E+00	6.096E-01	6.533E-01	6.096E-01	5.338E-01	5.737E-01	7.846E-01	1.145E+00	1.575E+00	1.935E+00	2.082E+00
2	1.273E+00	1.273E+00	5.493E-01	5.846E-01	5.493E-01	4.696E-01	4.695E-01	6.045E-01	8.846E-01	1.242E+00	1.544E+00	1.663E+00
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13
13	0.0
12	1.458E+00
11	1.297E+00
10	1.961E+00
9	1.657E+00
8	1.447E+00
7	1.344E+00
6	1.452E+00
5	1.657E+00
4	1.941E+00
3	1.936E+00
2	1.544E+00
1	0.0

TEMPERATURE (NON DIMENSIONAL) T

I= 4

K--> 1 2 3 4 5 6 7 8 9 10

J										
13	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.213628
12	0.995823	1.021750	1.043640	1.064780	1.086410	1.109634	1.134318	1.160485	1.187555	1.214625
11	0.992226	1.017941	1.039835	1.060963	1.082551	1.105648	1.130282	1.156357	1.183300	1.210243
10	0.991863	1.017419	1.039424	1.060528	1.082067	1.10[illegible]24	1.128693	1.155720	1.182613	1.209507
9	0.995498	1.021149	1.043169	1.064332	1.085368	1.108958	1.133570	1.159612	1.186541	1.213470
8	1.253214	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864
7	1.253214	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864
6	1.253214	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864
5	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.213628
4	0.989796	1.021458	1.051819	1.079519	1.106556	1.133968	1.162042	1.190332	1.218887	1.247442
3	0.986691	1.018216	1.048585	1.076240	1.103610	1.130769	1.158826	1.187081	1.215601	1.244121
2	0.984636	1.015985	1.046411	1.074043	1.101457	1.128530	1.156681	1.184804	1.213412	1.242021
1	0.983809	1.015004	1.045465	1.073135	1.100539	1.127651	1.155775	1.183854	1.212491	1.241128

TEMPERATURE (NON DIMENSIONAL) T

I= 12

K--> J	1	2	3	4	5	6	7	8	9	10
13	0.960125	0.987494	1.015084	1.042885	1.070896	1.099108	1.127512	1.156100	1.184864	1.213628
12	0.994694	1.020082	1.041933	1.063068	1.084534	1.107650	1.132135	1.158101	1.185011	1.211921
11	0.990301	1.015182	1.037009	1.058129	1.079565	1.102494	1.126849	1.152698	1.179437	1.206176
10	0.988283	1.012538	1.034430	1.055521	1.076867	1.099634	1.123834	1.149502	1.176098	1.202694
9	0.988604	1.012739	1.034593	1.055671	1.077014	1.099687	1.123781	1.149330	1.175821	1.202312
8	0.989741	1.013911	1.035774	1.056920	1.078303	1.100986	1.125057	1.150566	1.177049	1.203531
7	0.990371	1.014277	1.036079	1.057337	1.078822	1.101593	1.125721	1.151249	1.177739	1.204229
6	0.989046	1.012042	1.033611	1.054955	1.076526	1.099369	1.123546	1.149054	1.175519	1.201984
5	0.985864	1.007658	1.028822	1.050116	1.071758	1.094678	1.118860	1.144352	1.170788	1.197224
4	0.982354	1.003255	1.024020	1.045240	1.066933	1.090044	1.114314	1.139876	1.166344	1.192811
3	0.979130	0.999502	1.020025	1.041221	1.063057	1.086242	1.110659	1.136312	1.162863	1.189414
2	0.977348	0.997661	1.018171	1.039427	1.061349	1.084680	1.109221	1.134987	1.161632	1.188276
1	0.976938	0.997441	1.018041	1.039389	1.061406	1.084846	1.109503	1.135367	1.162098	1.188828

TEMPERATURE (NON DIMENSIONAL) T

K= 1

I--> J	1	2	3	4	5	6	7	8	9	10	11	12
13	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
12	0.995823	0.995823	0.995823	0.995823	0.995500	0.995823	0.995500	0.995033	0.995500	0.995033	0.994694	0.994694
11	0.992226	0.992226	0.992226	0.992226	0.991658	0.992226	0.991658	0.990376	0.991658	0.990376	0.990301	0.990301
10	0.991863	0.991863	0.991863	0.991863	0.990908	0.991863	0.990908	0.989484	0.990908	0.989484	0.988283	0.988283
9	0.995498	0.995498	0.995498	0.995498	0.994300	0.995498	0.994300	0.991764	0.994300	0.991764	0.988604	0.988604
8	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	0.993733	0.989741	0.989741
7	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	0.994030	0.990371	0.990371
6	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	1.253214	0.992606	0.989046	0.989046
5	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.989589	0.985864	0.985864
4	0.960125	0.960125	0.989796	0.989796	0.989362	0.989401	0.988378	0.987504	0.987371	0.985437	0.982354	0.982354
3	0.960125	0.960125	0.986691	0.986691	0.987002	0.986786	0.985636	0.983953	0.982342	0.980631	0.979130	0.979130
2	0.960125	0.960125	0.984636	0.984636	0.985089	0.985151	0.984791	0.982413	0.980354	0.978557	0.977348	0.977348
1	0.960125	0.960125	0.983809	0.983809	0.984266	0.984570	0.983882	0.982194	0.980072	0.978139	0.976938	0.976938

I--> J	13
13	0.960125
12	0.960125

11	0.960125
10	0.960125
9	0.960125
8	0.960125
7	0.960125
6	0.960125
5	0.960125
4	0.960125
3	0.960125
2	0.960125
1	0.960125

TEMPERATURE (NON DIMENSIONAL) T

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
13	1.213628	1.213628	1.213628	1.213628	1.213628	1.213628	1.213628	1.213628	1.213628	1.213628	1.213628	1.213628
12	1.214625	1.214625	1.214625	1.214625	1.213806	1.214625	1.213806	1.212640	1.213806	1.212640	1.211921	1.211921
11	1.210243	1.210243	1.210243	1.210243	1.208973	1.210243	1.208973	1.207392	1.208973	1.207392	1.206176	1.206176
10	1.209507	1.209507	1.209507	1.209507	1.207537	1.209507	1.207537	1.204844	1.207537	1.204844	1.202694	1.202694
9	1.213470	1.213470	1.213470	1.213470	1.211565	1.213470	1.211565	1.206811	1.211565	1.206811	1.202312	1.202312
8	1.184364	1.184364	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.208399	1.203531	1.203531
7	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.184864	1.208506	1.204229	1.204229
6	1.184864	1.184864	1.184864	1.184864	1.184864	1.184854	1.184864	1.184864	1.184864	1.205137	1.201984	1.201984
5	1.213628	1.213623	1.213623	1.213628	1.213628	1.213628	1.213628	1.213628	1.213628	1.202007	1.197224	1.197224
4	1.213628	1.213628	1.247442	1.247442	1.244289	1.236092	1.223783	1.212271	1.205018	1.198561	1.192811	1.192811
3	1.213628	1.213628	1.244121	1.244121	1.242101	1.235635	1.224306	1.212030	1.201830	1.194327	1.189414	1.189414
2	1.213628	1.213628	1.242021	1.242021	1.240726	1.235557	1.225632	1.213395	1.201982	1.193285	1.188276	1.188276
1	1.213628	1.213628	1.241128	1.241128	1.240289	1.236235	1.227492	1.215672	1.203652	1.194153	1.188828	1.188828

J \ I-->	13
13	1.213628
12	1.213628
11	1.213628
10	1.213628
9	1.213628
8	1.213628
7	1.213628
6	1.213628
5	1.213628
4	1.213628
3	1.213628
2	1.213628
1	1.213628

PRESSURE (NON DIMENSIONAL) P

I= 4

J \ K-->	1	2	3	4	5	6	7	8	9	10
13	0.0	-2.413E+00	-4.491E+00	-6.600E+00	-8.602E+00	-1.065E+01	-1.266E+01	-1.468E+01	-1.670E+01	-1.872E+01
12	-1.714E-03	-2.415E+00	-4.490E+00	-6.600E+00	-8.601E+00	-1.065E+01	-1.266E+01	-1.468E+01	-1.670E+01	-1.872E+01
11	-2.139E-03	-2.414E+00	-4.490E+00	-6.600E+00	-8.601E+00	-1.065E+01	-1.266E+01	-1.468E+01	-1.670E+01	-1.872E+01
10	-2.536E-03	-2.414E+00	-4.490E+00	-6.600E+00	-8.601E+00	-1.065E+01	-1.266E+01	-1.468E+01	-1.670E+01	-1.872E+01
9	-2.066E-03	-2.414E+00	-4.490E+00	-6.600E+00	-8.601E+00	-1.065E+01	-1.266E+01	-1.468E+01	-1.670E+01	-1.872E+01

```
 8    1.214E+00 0.0       -2.413E+00-4.491E+00-6.600E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01
 7    1.214E+00 0.0       -2.413E+00-4.491E+00-6.600E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01
 6    1.214E+00 0.0       -2.413E+00-4.491E+00-6.600E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01
 5    0.0       -2.413E+00-4.491E+00-6.600E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 4    3.420E-03-2.413E+00-4.491E+00-6.600E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 3    3.909E-03-2.413E+00-4.491E+00-6.600E+00-8.601E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 2    4.039E-03-2.413E+00-4.491E+00-6.600E+00-8.601E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 1    3.751E-03-2.413E+00-4.491E+00-6.600E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01


                         PRESSURE (NON DIMENSIONAL)     P

   I= 12
   K-->   1         2         3         4         5         6         7         8         9        10
 J
13    0.0       -2.413E+00-4.491E+00-6.600E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
12   -1.991E-03-2.415E+00-4.490E+00-6.600E+00-8.601E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
11   -2.874E-03-2.414E+00-4.490E+00-6.600E+00-8.601E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
10   -4.519E-03-2.413E+00-4.491E+00-6.599E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 9   -4.662E-03-2.412E+00-4.491E+00-6.599E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 8   -3.680E-03-2.413E+00-4.491E+00-6.599E+00-8.601E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 7   -2.710E-03-2.413E+00-4.490E+00-6.600E+00-8.601E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 6   -2.558E-03-2.413E+00-4.490E+00-6.600E+00-8.601E+00-1.065E+01-1.265E+01-1.463E+01-1.670E+01-1.872E+01
 5   -2.999E-03-2.412E+00-4.491E+00-6.600E+00-8.601E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 4   -3.740E-03-2.412E+00-4.492E+00-6.599E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 3   -3.602F-03-2.411E+00-4.492E+00-6.599E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 2   -2.196E-03-2.412E+00-4.491E+00-6.600E+00-8.602E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01
 1   -1.401E-03-2.413E+00-4.491E+00-6.600E+00-8.601E+00-1.065E+01-1.266E+01-1.468E+01-1.670E+01-1.872E+01

********************       END OF OUTPUT FOR STEP     4 AT********* SECONDS, ITERATION   30********************


********** RESTART TAPE WRITTEN **********
```

b. <u>19-pin Hexagonal Rod Bundle</u>

The geometric dimensions of the second sample problem are identical to the ones in the first problem, except that there are no spacer grids in the 19-pin fuel assembly, and there are 19 pins instead of 7 pins. Also the fuel-pin temperature calculation is bypassed. This sample problem is included here so users can check their geometric information as printed by the code. Correctness of all the arrays for geometric identification is essential in getting the correct calculational results. The graphic printout of the physical boundaries, the initial mesh structure and the final mesh structure are given in Figs. 22-24, respectively.

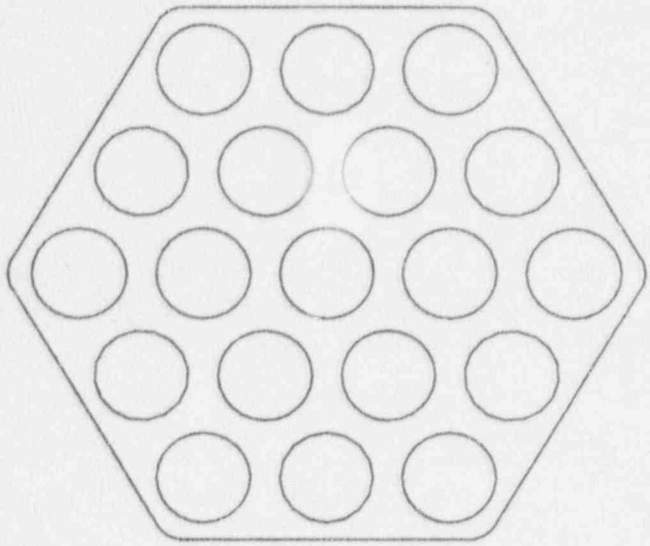

Fig. 22

Physical boundaries for a 19-pin hexagonal rod bundle

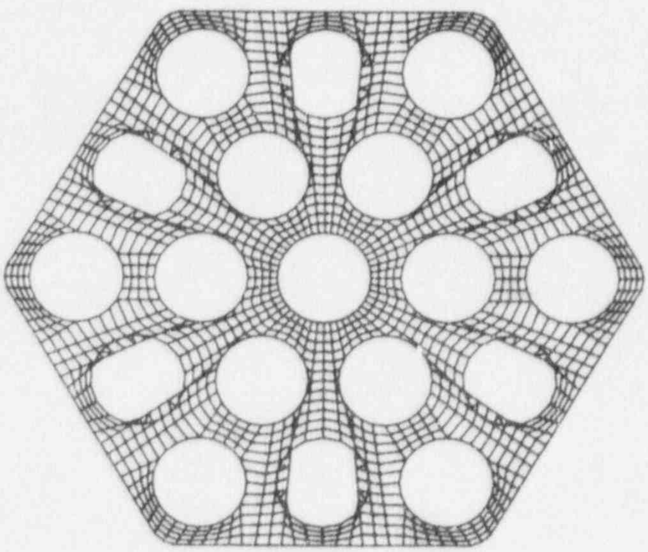

Fig. 23

An initial guess of the mesh structure for a 19-pin hexagonal rod bundle

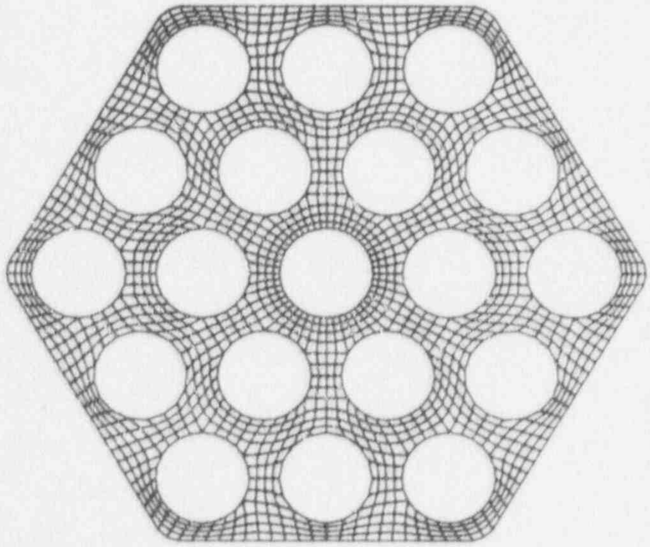

Fig. 24

A final mesh structure of a 19-pin hexagonal rod bundle

```
19 PIN HEXAGONAL ROD BUNDLE CASE #1
SAME GEOMETRY FOR GERMAN 7 PIN FLOW RUN DOWN EXP.
&SIZE NPINS=19,NROW=3,IGEO=1,&END
&SET R=0.003,CLRSI=0.0019,CLRSW=0.00116,
     SCALE=200.0,X0=7.5,Y0=5.5,&END
&SLABS IDISK=1,ISYM=1,R=1.4,1.0E-12,1.0E-12,IPLOT=30,&END
   0    0    0    0    0   43
   0    0    0   43   26   25
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0   25    2    1
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   2   25   26    0    0    0
   0    0    0    0    0    1
   0    0    0    2    3    4
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    5    6    7
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   0    0    0    0    0    0
   8    9   10    0    0    0


WORDS REQUIRED:              22195;   WORDS ALOCATED:              30000

  I (X,Y): COORDINATES OF THE BOUNDARIES AT POINT I
   1  -0.00078  -0.00290    2  -0.00115  -0.00277    3  -0.00150  -0.00260    4  -0.00183  -0.00238    5  -0.00212  -0.00212
   6  -0.00238  -0.00183    7  -0.00260  -0.00150    8  -0.00277  -0.00115    9  -0.00290  -0.00078   10  -0.00297  -0.00039
  11  -0.00300   0.00000   12  -0.00297   0.00039   13  -0.00290   0.00078   14  -0.00277   0.00115   15  -0.00260   0.00150
  16  -0.00238   0.00183   17  -0.00212   0.00212   18  -0.00183   0.00238   19  -0.00150   0.00260   20  -0.00115   0.00277
  21  -0.00078   0.00290   22  -0.00039   0.00297   23   0.00000   0.00300   24   0.00039   0.00297   25   0.00078   0.00290
  26   0.00115   0.00277   27   0.00150   0.00260   28   0.00183   0.00238   29   0.00212   0.00212   30   0.00238   0.00183
  31   0.00260   0.00150   32   0.00277   0.00115   33   0.00290   0.00078   34   0.00297   0.00039   35   0.00300   0.0
  36   0.00297  -0.00039   37   0.00290  -0.00078   38   0.00277  -0.00115   39   0.00260  -0.00150   40   0.00238  -0.00183
```

41	0.00212	-0.00212	42	0.00183	-0.00238	43	0.00150	-0.00260	44	0.00115	-0.00277	45	0.00078	-0.00290
46	0.00039	-0.00297	47	0.00000	-0.00300	48	-0.00039	-0.00297	49	-0.00150	-0.00530	50	-0.00078	-0.00590
51	0.00000	-0.00190	52	0.00078	-0.00500	53	0.00150	-0.00530	54	0.00212	-0.00578	55	0.00260	-0.00640
56	0.00290	-0.00712	57	0.00300	-0.00790	58	0.00290	-0.00868	59	0.00260	-0.00940	60	0.00212	-0.01002
61	0.00150	-0.01050	62	0.00073	-0.01030	63	0.00000	-0.01090	64	-0.00078	-0.01080	65	-0.00150	-0.01050
66	-0.00212	-0.01002	67	-0.00260	-0.00940	68	-0.00290	-0.00868	69	-0.00300	-0.00790	70	-0.00290	-0.00712
71	-0.00260	-0.00640	72	-0.00212	-0.00578	73	-0.00534	-0.00135	74	-0.00472	-0.00183	75	-0.00424	-0.00245
76	-0.00394	-0.00317	77	-0.00324	-0.00395	78	-0.00394	-0.00473	79	-0.00424	-0.00545	80	-0.00472	-0.00607
81	-0.00534	-0.00655	82	-0.00607	-0.00685	83	-0.00684	-0.00695	84	-0.00762	-0.00685	85	-0.00834	-0.00655
86	-0.00896	-0.00607	87	-0.00944	-0.00545	88	-0.00974	-0.00473	89	-0.00984	-0.00395	90	-0.00974	-0.00317
91	-0.00944	-0.00245	92	-0.00396	-0.00183	93	-0.00334	-0.00135	94	-0.00762	-0.00105	95	-0.00684	-0.00095
96	-0.00607	-0.00105	97	-0.00384	0.00395	98	-0.00394	0.00317	99	-0.00424	0.00245	100	-0.00472	0.00183
101	-0.00534	0.00135	102	-0.00607	0.00105	103	-0.00684	0.00075	104	-0.00762	0.00105	105	-0.00834	0.00135
106	-0.00896	0.00183	107	-0.00944	0.00245	108	-0.00974	0.00317	109	-0.00984	0.00395	110	-0.00974	0.00473
111	-0.00944	0.00545	112	-0.00896	0.00607	113	-0.00334	0.00655	114	-0.00762	0.00655	115	-0.00684	0.00595
116	-0.00607	0.00685	117	-0.00534	0.00555	118	-0.00472	0.00607	119	-0.00424	0.00545	120	-0.00394	0.00473
121	0.00150	0.00530	122	0.00078	0.00500	123	-0.00000	0.00490	124	-0.00078	0.00500	125	-0.00150	0.00530
126	-0.00212	0.00578	127	-0.00260	0.00640	128	-0.00290	0.00712	129	-0.00300	0.00790	130	-0.00290	0.00868
131	-0.00260	0.00940	132	-0.00212	0.01002	133	-0.00150	0.01050	134	-0.00078	0.01080	135	-0.00000	0.01090
136	0.00078	0.01080	137	0.00150	0.01050	138	0.00212	0.01002	139	0.00260	0.00940	140	0.00290	0.00868
141	0.00300	0.00790	142	0.00290	0.00712	143	0.00260	0.00640	144	0.00212	0.00578	145	0.00534	0.00135
146	0.00472	0.00183	147	0.00424	0.00245	148	0.00394	0.00317	149	0.00384	0.00395	150	0.00394	0.00473
151	0.00424	0.00545	152	0.00472	0.00607	153	0.00534	0.00655	154	0.00607	0.00685	155	0.00684	0.00695
156	0.00762	0.00685	157	0.00834	0.00655	158	0.00896	0.00607	159	0.00944	0.00545	160	0.00974	0.00473
161	0.00984	0.00395	162	0.00974	0.00317	163	0.00944	0.00245	164	0.00896	0.00183	165	0.00334	0.00135
166	0.00762	0.00105	167	0.00684	0.00095	168	0.00607	0.00105	169	0.00384	-0.00395	170	0.00394	-0.00317
171	0.00424	-0.00245	172	0.00472	-0.00183	173	0.00534	-0.00135	174	0.00607	-0.00105	175	0.00684	-0.00095
176	0.00762	-0.00105	177	0.00834	-0.00135	178	0.00896	-0.00183	179	0.00944	-0.00245	180	0.00974	-0.00317
181	0.00984	-0.00395	182	0.00974	-0.00473	183	0.00944	-0.00545	184	0.00896	-0.00607	185	0.00834	-0.00655
186	0.00762	-0.00685	187	0.00684	-0.00695	188	0.00607	-0.00685	189	0.00534	-0.00655	190	0.00472	-0.00607
191	0.00424	-0.00545	192	0.00394	-0.00473	193	-0.00150	-0.01320	194	-0.00078	-0.01290	195	0.00000	-0.01280
196	0.00078	-0.01290	197	0.00150	-0.01320	198	0.00212	-0.01368	199	0.00260	-0.01430	200	0.00290	-0.01502
201	0.00300	-0.01580	202	0.00290	-0.01658	203	0.00260	-0.01730	204	0.00212	-0.01792	205	0.00150	-0.01840
206	0.00078	-0.01870	207	0.00000	-0.01880	208	-0.00078	-0.01870	209	-0.00150	-0.01840	210	-0.00212	-0.01792
211	-0.00260	-0.01730	212	-0.00290	-0.01658	213	-0.00300	-0.01580	214	-0.00290	-0.01502	215	-0.00260	-0.01430
216	-0.00212	-0.01368	217	-0.00762	-0.00895	218	-0.00645	-0.00923	219	-0.00534	-0.00925	220	-0.00446	-0.01002
221	-0.00394	-0.01107	222	-0.00387	-0.01224	223	-0.00424	-0.01335	224	-0.00502	-0.01423	225	-0.00607	-0.01475
226	-0.00723	-0.01482	227	-0.00834	-0.01445	228	-0.00922	-0.01368	229	-0.00974	-0.01263	230	-0.00982	-0.01146
231	-0.00944	-0.01035	232	-0.00867	-0.00947	233	-0.01218	-0.00530	234	-0.01156	-0.00578	235	-0.01109	-0.00640
236	-0.01079	-0.00712	237	-0.01068	-0.00790	238	-0.01079	-0.00868	239	-0.01109	-0.00940	240	-0.01156	-0.01002
241	-0.01218	-0.01050	242	-0.01291	-0.01080	243	-0.01368	-0.01090	244	-0.01446	-0.01080	245	-0.01518	-0.01050
246	-0.01580	-0.01002	247	-0.01628	-0.00940	248	-0.01658	-0.00868	249	-0.01668	-0.00790	250	-0.01658	-0.00712
251	-0.01628	-0.00640	252	-0.01580	-0.00578	253	-0.01518	-0.00530	254	-0.01446	-0.00500	255	-0.01368	-0.00490
256	-0.01291	-0.00500	257	-0.01156	0.00212	258	-0.01091	0.00115	259	-0.01068	-0.00000	260	-0.01091	-0.00115
261	-0.01156	-0.00212	262	-0.01254	-0.00277	263	-0.01368	-0.00300	264	-0.01483	-0.00277	265	-0.01580	-0.00212
266	-0.01645	-0.00115	267	-0.01668	-0.00000	268	-0.01645	0.00115	269	-0.01580	0.00212	270	-0.01483	0.00277
271	-0.01368	0.00300	272	-0.01254	0.00277	273	-0.01068	0.00790	274	-0.01079	0.00712	275	-0.01109	0.00640
276	-0.01156	0.00578	277	-0.01218	0.00530	278	-0.01291	0.00500	279	-0.01368	0.00490	280	-0.01446	0.00500
281	-0.01518	0.00530	282	-0.01580	0.00578	283	-0.01628	0.00640	284	-0.01658	0.00712	285	-0.01668	0.00790
286	-0.01658	0.00868	287	-0.01628	0.00940	288	-0.01580	0.01002	289	-0.01518	0.01050	290	-0.01446	0.01080
291	-0.01368	0.01090	292	-0.01291	0.01080	293	-0.01218	0.01050	294	-0.01156	0.01002	295	-0.01109	0.00940
296	-0.01079	0.00868	297	-0.00394	0.01107	298	-0.00446	0.01002	299	-0.00534	0.00925	300	-0.00645	0.00923
301	-0.00762	0.00895	302	-0.00867	0.00947	303	-0.00944	0.01035	304	-0.00982	0.01146	305	-0.00974	0.01263
306	-0.00922	0.01368	307	-0.00834	0.01445	308	-0.00723	0.01482	309	-0.00607	0.01475	310	-0.00502	0.01423
311	-0.00424	0.01335	312	-0.00387	0.01224	313	0.00150	0.01320	314	0.00078	0.01290	315	-0.00000	0.01280
316	-0.00078	0.01290	317	-0.00150	0.01320	318	-0.00212	0.01368	319	-0.00260	0.01430	320	-0.00290	0.01502
321	-0.00300	0.01580	322	-0.00290	0.01658	323	-0.00260	0.01730	324	-0.00212	0.01792	325	-0.00150	0.01840
326	-0.00078	0.01870	327	-0.00000	0.01880	328	0.00078	0.01870	329	0.00150	0.01840	330	0.00212	0.01792
331	0.00260	0.01730	332	0.00290	0.01658	333	0.00300	0.01580	334	0.00290	0.01502	335	0.00260	0.01430
336	0.00212	0.01368	337	0.00762	0.00895	338	0.00645	0.00923	339	0.00534	0.00925	340	0.00446	0.01002

341	0.00394	0.01107	342	0.00387	0.01224	343	0.00424	0.01335	344	0.00502	0.01423	345	0.00607	0.01475
346	0.00723	0.01482	347	0.00334	0.01445	348	0.00922	0.01368	349	0.00974	0.01263	350	0.00982	0.01165
351	0.00944	0.01035	352	0.00867	0.00947	353	0.01218	0.00530	354	0.01156	0.00578	355	0.01139	0.00640
356	0.01079	0.00712	357	0.01068	0.00790	358	0.01079	0.00368	359	0.01109	0.00940	360	0.01136	0.01002
361	0.01218	0.01050	362	0.01291	0.01080	363	0.01363	0.01090	364	0.01446	0.01080	365	0.01518	0.01050
366	0.01580	0.01002	367	0.01628	0.00940	368	0.01653	0.00868	369	0.01668	0.00790	370	0.01653	0.00712
371	0.01628	0.00640	372	0.01580	0.00578	373	0.01518	0.00530	374	0.01446	0.00500	375	0.01363	0.00490
376	0.01291	0.00500	377	0.01156	-0.00212	378	0.01091	-0.00115	379	0.01068	0.00000	380	0.01091	0.00115
381	0.01156	0.00212	382	0.01254	0.00277	383	0.01368	0.00300	384	0.01483	0.00277	385	0.01580	0.00212
386	0.01645	0.00115	387	0.01668	0.00000	388	0.01645	-0.00115	389	0.01580	-0.00212	390	0.01483	-0.00277
391	0.01368	-0.00300	392	0.01254	-0.00277	393	0.01068	-0.00790	394	0.01079	-0.00712	395	0.01139	-0.00640
396	0.01156	-0.00578	397	0.01218	-0.00530	398	0.01291	-0.00500	399	0.01368	-0.00490	400	0.01446	-0.00500
401	0.01518	-0.00530	402	0.01580	-0.00578	403	0.01628	-0.00640	404	0.01653	-0.00712	405	0.01668	-0.00790
406	0.01658	-0.00868	407	0.01628	-0.00940	408	0.01580	-0.01002	409	0.01518	-0.01050	410	0.01446	-0.01080
411	0.01368	-0.01090	412	0.01291	-0.01080	413	0.01218	-0.01050	414	0.01156	-0.01002	415	0.01139	-0.00940
416	0.01079	-0.00868	417	0.00394	-0.01107	418	0.00446	-0.01002	419	0.00534	-0.00925	420	0.00645	-0.00858
421	0.00762	-0.00895	422	0.00867	-0.00947	423	0.00944	-0.01035	424	0.00932	-0.01166	425	0.00974	-0.01263
426	0.00922	-0.01368	427	0.00334	-0.01445	428	0.00723	-0.01482	429	0.00607	-0.01475	430	0.00502	-0.01423
431	0.00424	-0.01335	432	0.00387	-0.01224	433	-0.00595	-0.01717	434	-0.00669	-0.01674	435	-0.00743	-0.01631
436	-0.00818	-0.01588	437	-0.00892	-0.01545	438	-0.00967	-0.01502	439	-0.01041	-0.01459	440	-0.01115	-0.01416
441	-0.01190	-0.01374	442	-0.01264	-0.01331	443	-0.01338	-0.01288	444	-0.01413	-0.01245	445	-0.01487	-0.01202
446	-0.01561	-0.01159	447	-0.01636	-0.01116	448	-0.01710	-0.01073	449	-0.01758	-0.01015	450	-0.01784	-0.00944
451	-0.01784	-0.00858	452	-0.01784	-0.00773	453	-0.01784	-0.00687	454	-0.01784	-0.00601	455	-0.01784	-0.00515
456	-0.01784	-0.00429	457	-0.01784	-0.00343	458	-0.01784	-0.00258	459	-0.01784	-0.00172	460	-0.01784	-0.00086
461	-0.01784	-0.00000	462	-0.01784	0.00086	463	-0.01784	0.00172	464	-0.01784	0.00258	465	-0.01784	0.00343
466	-0.01784	0.00429	467	-0.01784	0.00515	468	-0.01784	0.00601	469	-0.01784	0.00687	470	-0.01784	0.00773
471	-0.01784	0.00858	472	-0.01784	0.00944	473	-0.01759	0.01015	474	-0.01710	0.01073	475	-0.01636	0.01116
476	-0.01561	0.01159	477	-0.01487	0.01202	478	-0.01413	0.01245	479	-0.01338	0.01288	480	-0.01264	0.01331
481	-0.01190	0.01374	482	-0.01115	0.01416	483	-0.01041	0.01459	484	-0.00967	0.01502	485	-0.00892	0.01545
486	-0.00818	0.01588	487	-0.00743	0.01631	488	-0.00669	0.01674	489	-0.00595	0.01717	490	-0.00520	0.01760
491	-0.00446	0.01803	492	-0.00372	0.01846	493	-0.00297	0.01889	494	-0.00223	0.01932	495	-0.00149	0.01975
496	-0.00074	0.02017	497	-0.00000	0.02031	498	0.00074	0.02017	499	0.00149	0.01975	500	0.00223	0.01932
501	0.00297	0.01889	502	0.00372	0.01846	503	0.00446	0.01803	504	0.00520	0.01760	505	0.00595	0.01717
506	0.00669	0.01674	507	0.00743	0.01631	508	0.00818	0.01588	509	0.00892	0.01545	510	0.00967	0.01502
511	0.01041	0.01459	512	0.01115	0.01416	513	0.01190	0.01374	514	0.01264	0.01331	515	0.01338	0.01288
516	0.01413	0.01245	517	0.01487	0.01202	518	0.01561	0.01159	519	0.01636	0.01116	520	0.01710	0.01073
521	0.01758	0.01015	522	0.01784	0.00944	523	0.01784	0.00858	524	0.01784	0.00773	525	0.01784	0.00687
526	0.01784	0.00601	527	0.01784	0.00515	528	0.01784	0.00429	529	0.01784	0.00343	530	0.01784	0.00258
531	0.01784	0.00172	532	0.01784	0.00086	533	0.01784	0.00000	534	0.01784	-0.00086	535	0.01784	-0.00172
536	0.01784	-0.00258	537	0.01784	-0.00343	538	0.01784	-0.00429	539	0.01784	-0.00515	540	0.01784	-0.00601
541	0.01784	-0.00687	542	0.01784	-0.00773	543	0.01784	-0.00858	544	0.01784	-0.00944	545	0.01759	-0.01015
546	0.01710	-0.01073	547	0.01636	-0.01116	548	0.01561	-0.01159	549	0.01487	-0.01202	550	0.01413	-0.01245
551	0.01338	-0.01288	552	0.01264	-0.01331	553	0.01190	-0.01374	554	0.01115	-0.01416	555	0.01041	-0.01459
556	0.00967	-0.01502	557	0.00892	-0.01545	558	0.00818	-0.01588	559	0.00743	-0.01631	560	0.00669	-0.01674
561	0.00595	-0.01717	562	0.00520	-0.01760	563	0.00446	-0.01803	564	0.00372	-0.01846	565	0.00297	-0.01889
566	0.00223	-0.01932	567	0.00149	-0.01975	568	0.00074	-0.02017	569	0.00000	-0.02031	570	-0.00074	-0.02017
571	-0.00149	-0.01975	572	-0.00223	-0.01932	573	-0.00297	-0.01889	574	-0.00372	-0.01846	575	-0.00446	-0.01803
576	-0.00520	-0.01760												

UNIFORM ACCELERATION PARAMETER

INDICES FOR MISSING SLABS

LB1	LB2	LB3	LTYPE
9	21	9	-2
9	21	10	-2
9	21	12	-2
9	21	13	-2
17	21	11	-2
17	21	14	-2
17	21	16	-2

17	21	17	-2
9	21	31	-2
9	21	30	-2
9	21	28	-2
9	21	27	-2
17	21	29	-2
17	21	26	-2
17	21	24	-2
17	21	23	-2
9	21	33	-2
9	21	34	-2
9	21	36	-2
9	21	37	-2
17	21	35	-2
17	21	38	-2
17	21	40	-2
17	21	41	-2
9	21	55	-2
9	21	54	-2
9	21	52	-2
9	21	51	-2
17	21	53	-2
17	21	50	-2
17	21	43	-2
17	21	47	-2
9	21	57	-2
9	21	58	-2
9	21	60	-2
9	21	61	-2
17	21	59	-2
17	21	62	-2
17	21	64	-2
17	21	65	-2
9	21	79	-2
9	21	78	-2
9	21	76	-2
9	21	75	-2
17	21	77	-2
17	21	74	-2
17	21	72	-2
17	21	71	-2
9	21	81	-2
9	21	82	-2
9	21	84	-2
9	21	85	-2
17	21	83	-2
17	21	86	-2
17	21	88	-2
17	21	89	-2
9	21	103	-2
9	21	102	-2
9	21	100	-2
9	21	99	-2
17	21	101	-2
17	21	98	-2
17	21	96	-2
17	21	95	-2
9	21	105	-2
9	21	106	-2
9	21	108	-2

9	21	109	-2
17	21	107	-2
17	21	110	-2
17	21	112	-2
17	21	113	-2
9	21	127	-2
9	21	126	-2
9	21	124	-2
9	21	123	-2
17	21	125	-2
17	21	122	-2
17	21	120	-2
17	21	119	-2
9	21	129	-2
9	21	130	-2
9	21	132	-2
9	21	133	-2
17	21	131	-2
17	21	134	-2
17	21	136	-2
17	21	137	-2
9	21	7	-2
9	21	6	-2
9	21	4	-2
9	21	3	-2
17	21	5	-2
17	21	2	-2
17	21	144	-2
17	21	143	-2

INDICES FOR BOUNDARY SLABS

LB1	LB2	LB3	LTYPE
144	1	21	-1
142	144	17	-1
1	18	17	-1
16	14	18	-2
18	1	13	-1
144	142	13	-1
14	16	142	-2
118	138	17	-1
16	14	138	-2
138	118	13	-1
14	16	118	-2
94	114	17	-1
16	14	114	-2
114	94	13	-1
14	16	94	-2
70	90	17	-1
16	14	90	-2
90	70	13	-1
14	16	70	-2
46	66	17	-1
16	14	66	-2
66	46	13	-1
14	16	46	-2
22	42	17	-1
16	14	42	-2
42	22	13	-1
14	16	22	-2
2	14	9	-1

8	6	14	-2
14	2	5	-1
6	8	2	-2
138	142	9	-1
8	6	142	-2
142	138	5	-1
6	8	138	-2
122	134	9	-1
8	6	134	-2
134	122	5	-1
6	8	122	-2
114	118	9	-1
8	6	118	-2
118	114	5	-1
6	8	114	-2
98	110	9	-1
8	6	110	-2
110	98	5	-1
6	8	98	-2
90	94	9	-1
8	6	94	-2
94	90	5	-1
6	8	90	-2
74	86	9	-1
8	6	86	-2
86	74	5	-1
6	8	74	-2
66	70	9	-1
8	6	70	-2
70	66	5	-1
6	8	66	-2
50	62	9	-1
8	6	62	-2
62	50	5	-1
6	8	50	-2
42	46	9	-1
8	6	46	-2
46	42	5	-1
6	8	42	-2
26	38	9	-1
8	6	38	-2
38	26	5	-1
6	8	26	-2
18	22	9	-1
8	6	22	-2
22	18	5	-1
6	8	18	-2
144	1	1	-1

19 PIN HEXAGONAL ROD BUNDLE CASE #1
SAME GEOMETRY FOR GERMAN 7 PIN FLOW RUN DOWN EXP.

19 PIN HEXAGONAL ROD BUNDLE CASE #1
SAME GEOMETRY FOR GERMAN 7 PIN FLOW RUN DOWN EXP.

COORDINATE SYSTEM TRANSFORMATION

FIELD PARAMETERS: # OF XI(THETA) POINTS = 144

```
          # OF ETA(R) POINTS =    21
          STEP SIZE, H =  1.00000

ITERATION PARAMETERS: G-S ACCELERATION FACTOR =  1.40000
                      MAX # OF ITERATIONS ALLOWED =  100
                      ALLOWABLE ERRORS: X: .10000D-11
                                        Y: .10000D-11

NUMBER OF BODIES IN FIELD=   76
```

```
ITERATION ERROR NORMS

ITERATE NO.    1, X-ERROR= 0.82043195D-03, Y-ERROR= 0.80240409D-03     H-CHANGE =0.0
ITERATE NO.    2, X-ERROR= 0.35493962D-03, Y-ERROR= 0.35065201D-03     H-CHANGE =0.0
ITERATE NO.    3, X-ERROR= 0.31191119D-03, Y-ERROR= 0.34592500D-03     H-CHANGE =0.0
ITERATE NO.    4, X-ERROR= 0.19709560D-03, Y-ERROR= 0.20277995D-03     H-CHANGE =0.0
ITERATE NO.    5, X-ERROR= 0.13359945D-03, Y-ERROR= 0.13200044D-03     H-CHANGE =0.0
ITERATE NO.    6, X-ERROR= 0.77732592D-04, Y-ERROR= 0.71833493D-04     H-CHANGE =0.0
ITERATE NO.    7, X-ERROR= 0.43327956D-04, Y-ERROR= 0.41763249D-04     H-CHANGE =0.0
ITERATE NO.    8, X-ERROR= 0.22933913D-04, Y-ERROR= 0.20303035D-04     H-CHANGE =0.0
ITERATE NO.    9, X-ERROR= 0.97491311D-05, Y-ERROR= 0.85561426D-05     H-CHANGE =0.0
ITERATE NO.   10, X-ERROR= 0.40025764D-05, Y-ERROR= 0.39293378D-05     H-CHANGE =0.0
ITERATE NO.   11, X-ERROR= 0.21484579D-05, Y-ERROR= 0.22183567D-05     H-CHANGE =0.0
ITERATE NO.   12, X-ERROR= 0.11745507D-05, Y-ERROR= 0.11601985D-05     H-CHANGE =0.0
ITERATE NO.   13, X-ERROR= 0.61111111D-06, Y-ERROR= 0.57490120D-06     H-CHANGE =0.0
ITERATE NO.   14, X-ERROR= 0.30512283D-06, Y-ERROR= 0.37515985D-06     H-CHANGE =0.0
ITERATE NO.   15, X-ERROR= 0.25489962D-06, Y-ERROR= 0.25132083D-06     H-CHANGE =0.0
ITERATE NO.   16, X-ERROR= 0.15367265D-06, Y-ERROR= 0.14621350D-06     H-CHANGE =0.0
ITERATE NO.   17, X-ERROR= 0.78009592D-07, Y-ERROR= 0.75760532D-07     H-CHANGE =0.0
ITERATE NO.   18, X-ERROR= 0.25428126D-07, Y-ERROR= 0.26430941D-07     H-CHANGE =0.0
ITERATE NO.   19, X-ERROR= 0.16464709D-07, Y-ERROR= 0.16522585D-07     H-CHANGE =0.0
ITERATE NO.   20, X-ERROR= 0.10427074D-07, Y-ERROR= 0.10080156D-07     H-CHANGE =0.0
ITERATE NO.   21, X-ERROR= 0.50618217D-08, Y-ERROR= 0.47429000D-08     H-CHANGE =0.0
ITERATE NO.   22, X-ERROR= 0.15617397D-08, Y-ERROR= 0.15506609D-08     H-CHANGE =0.0
ITERATE NO.   23, X-ERROR= 0.83756515D-09, Y-ERROR= 0.64410711D-09     H-CHANGE =0.0
ITERATE NO.   24, X-ERROR= 0.47571879D-09, Y-ERROR= 0.35039761D-09     H-CHANGE =0.0
ITERATE NO.   25, X-ERROR= 0.22379091D-09, Y-ERROR= 0.19858801D-09     H-CHANGE =0.0
ITERATE NO.   26, X-ERROR= 0.15457984D-09, Y-ERROR= 0.13684607D-09     H-CHANGE =0.0
ITERATE NO.   27, X-ERROR= 0.89260304D-10, Y-ERROR= 0.84209129D-10     H-CHANGE =0.0
ITERATE NO.   28, X-ERROR= 0.42821564D-10, Y-ERROR= 0.38800249D-10     H-CHANGE =0.0
ITERATE NO.   29, X-ERROR= 0.17908731D-10, Y-ERROR= 0.16169650D-10     H-CHANGE =0.0
ITERATE NO.   30, X-ERROR= 0.98555678D-11, Y-ERROR= 0.90810259D-11     H-CHANGE =0.0
ITERATE NO.   31, X-ERROR= 0.55471678D-11, Y-ERROR= 0.49355181D-11     H-CHANGE =0.0
ITERATE NO.   32, X-ERROR= 0.29796851D-11, Y-ERROR= 0.29726516D-11     H-CHANGE =0.0
ITERATE NO.   33, X-ERROR= 0.17682375D-11, Y-ERROR= 0.17221571D-11     H-CHANGE =0.0
ITERATE NO.   34, X-ERROR= 0.10831362D-11, Y-ERROR= 0.11215499D-11     H-CHANGE =0.0
ITERATE NO.   35, X-ERROR= 0.68850047D-12, Y-ERROR= 0.65376177D-12     H-CHANGE =0.0
19 PIN HEXAGONAL ROD BUNDLE CASE #1
SAME GEOMETRY FOR GERMAN 7 PIN FLOW RUN DOWN EXP.


                              FINAL VALUES

            ITERATION CONVERGES

            INITIAL ERRORS:  X: .82043D-03  Y: .80240D-03  @ ITERAT #   1
            FINAL ERRORS:    X: .68850D-12  Y: .65376D-12  @ ITERATE #  35
            LOCATION OF MAXIMUM ERROR NORMS: X: I=   64 J=   10
                                             Y: I=  111 J=   10

            EUCLIDIAN ERROR NORMS:  X: .0            Y: .0

FINAL COORDINATES IN CELL NUMBERING ORDER
  1 -5.20D-03 -1.76D-02   2 -4.46D-03 -1.80D-02   3 -3.72D-03 -1.85D-02   4 -2.97D-03 -1.89D-02   5 -2.23D-03 -1.93D-02
  6 -1.49D-03 -1.97D-02   7 -7.43D-04 -2.02D-02   8  2.56D-08 -2.03D-02   9  7.43D-04 -2.02D-02  10  1.49D-03 -1.97D-02
 11  2.23D-03 -1.93D-02  12  2.97D-03 -1.89D-02  13  3.72D-03 -1.85D-02  14  4.46D-03 -1.80D-02  15  5.20D-03 -1.76D-02
 16  5.95D-03 -1.72D-02  17  6.69D-03 -1.67D-02  18  7.43D-03 -1.63D-02  19  8.18D-03 -1.59D-02  20  8.92D-03 -1.55D-02
```

1521	6.19D-04	-4.41D-03	1522	1.22D-03	-4.41D-03	1523	1.79D-03	-4.24D-03	1524	2.30D-03	-3.99D-03	1525	2.78D-03	-3.67D-03
1526	3.21D-03	-3.26D-03	1527	3.51D-03	-2.74D-03	1528	3.81D-03	-2.20D-03	1529	4.13D-03	-1.67D-03	1530	4.43D-03	-1.15D-03
1531	4.57D-03	-5.73D-04	1532	4.61D-03	3.27D-09	1533	4.57D-03	5.73D-04	1534	4.43D-03	1.15D-03	1535	4.13D-03	1.67D-03
1536	3.81D-03	2.20D-03	1537	3.51D-03	2.74D-03	1538	3.21D-03	3.26D-03	1539	2.78D-03	3.67D-03	1540	2.30D-03	3.99D-03
1541	1.79D-03	4.24D-03	1542	1.22D-03	4.41D-03	1543	6.19D-04	4.41D-03	1544	-2.14D-09	4.40D-03	1545	-6.19D-04	4.41D-03
1546	-1.22D-03	4.41D-03	1547	-1.79D-03	4.24D-03	1548	-2.30D-03	3.99D-03	1549	-2.78D-03	3.67D-03	1550	-3.21D-03	3.26D-03
1551	-3.51D-03	2.74D-03	1552	-3.81D-03	2.20D-03	1553	-4.13D-03	1.67D-03	1554	-4.43D-03	1.15D-03	1555	-4.57D-03	5.73D-04
1556	-4.61D-03	-3.91D-10	1557	-4.57D-03	-5.73D-04	1558	-4.43D-03	-1.15D-03	1559	-4.13D-03	-1.67D-03	1560	-3.81D-03	-2.20D-03
1561	-3.51D-03	-2.74D-03	1562	-3.21D-03	-3.26D-03	1563	-2.78D-03	-3.67D-03	1564	-2.30D-03	-3.99D-03	1565	-1.79D-03	-4.24D-03
1566	-1.22D-03	-4.41D-03	1567	-5.24D-04	-3.88D-03	1568	5.52D-10	-3.90D-03	1569	5.24D-04	-3.88D-03	1570	1.04D-03	-3.81D-03
1571	1.53D-03	-3.67D-03	1572	1.99D-03	-3.45D-03	1573	2.41D-03	-3.16D-03	1574	2.78D-03	-2.81D-03	1575	3.10D-03	-2.39D-03
1576	3.38D-03	-1.95D-03	1577	3.62D-03	-1.49D-03	1578	3.82D-03	-1.01D-03	1579	3.94D-03	-5.08D-04	1580	3.98D-03	1.96D-09
1581	3.94D-03	5.08D-04	1582	3.82D-03	1.01D-03	1583	3.62D-03	1.49D-03	1584	3.38D-03	1.95D-03	1585	3.10D-03	2.39D-03
1586	2.78D-03	2.81D-03	1587	2.41D-03	3.16D-03	1588	1.99D-03	3.45D-03	1589	1.53D-03	3.67D-03	1590	1.04D-03	3.81D-03
1591	5.24D-04	3.88D-03	1592	-8.00D-10	3.90D-03	1593	-5.24D-04	3.88D-03	1594	-1.04D-03	3.81D-03	1595	-1.53D-03	3.67D-03
1596	-1.99D-03	3.45D-03	1597	-2.41D-03	3.16D-03	1598	-2.78D-03	2.81D-03	1599	-3.10D-03	2.39D-03	1600	-3.38D-03	1.95D-03
1601	-3.62D-03	1.49D-03	1602	-3.82D-03	1.01D-03	1603	-3.94D-03	5.08D-04	1604	-3.98D-03	5.29D-10	1605	-3.94D-03	-5.08D-04
1606	-3.82D-03	-1.01D-03	1607	-3.62D-03	-1.49D-03	1608	-3.38D-03	-1.95D-03	1609	-3.10D-03	-2.39D-03	1610	-2.78D-03	-2.81D-03
1611	-2.41D-03	-3.16D-03	1612	-1.99D-03	-3.45D-03	1613	-1.53D-03	-3.67D-03	1614	-1.04D-03	-3.81D-03	1615	-4.52D-04	-3.40D-03
1616	6.21D-10	-3.42D-03	1617	4.52D-04	-3.40D-03	1618	8.96D-04	-3.32D-03	1619	1.32D-03	-3.19D-03	1620	1.73D-03	-2.99D-03
1621	2.10D-03	-2.74D-03	1622	2.43D-03	-2.44D-03	1623	2.72D-03	-2.09D-03	1624	2.97D-03	-1.71D-03	1625	3.17D-03	-1.31D-03
1626	3.33D-03	-8.86D-04	1627	3.42D-03	-4.47D-04	1628	3.45D-03	8.65D-10	1629	3.42D-03	4.47D-04	1630	3.33D-03	8.86D-04
1631	3.17D-03	1.31D-03	1632	2.97D-03	1.71D-03	1633	2.72D-03	2.09D-03	1634	2.43D-03	2.44D-03	1635	2.10D-03	2.74D-03
1636	1.73D-03	2.99D-03	1637	1.32D-03	3.19D-03	1638	8.96D-04	3.32D-03	1639	4.52D-04	3.40D-03	1640	1.98D-10	3.42D-03
1641	-4.52D-04	3.40D-03	1642	-8.96D-04	3.32D-03	1643	-1.32D-03	3.19D-03	1644	-1.73D-03	2.99D-03	1645	-2.10D-03	2.74D-03
1646	-2.43D-03	2.44D-03	1647	-2.72D-03	2.09D-03	1648	-2.97D-03	1.71D-03	1649	-3.17D-03	1.31D-03	1650	-3.33D-03	8.86D-04
1651	-3.42D-03	4.47D-04	1652	-3.45D-03	1.30D-09	1653	-3.42D-03	-4.47D-04	1654	-3.33D-03	-8.86D-04	1655	-3.17D-03	-1.31D-03
1656	-2.97D-03	-1.71D-03	1657	-2.72D-03	-2.09D-03	1658	-2.43D-03	-2.44D-03	1659	-2.10D-03	-2.74D-03	1660	-1.73D-03	-2.99D-03
1661	-1.32D-03	-3.19D-03	1662	-8.96D-04	-3.32D-03	1663	-3.92D-04	-2.97D-03	1664	9.42D-10	-3.00D-03	1665	3.92D-04	-2.97D-03
1666	7.76D-04	-2.90D-03	1667	1.15D-03	-2.77D-03	1668	1.50D-03	-2.60D-03	1669	1.83D-03	-2.38D-03	1670	2.12D-03	-2.12D-03
1671	2.38D-03	-1.83D-03	1672	2.60D-03	-1.50D-03	1673	2.77D-03	-1.15D-03	1674	2.90D-03	-7.76D-04	1675	2.97D-03	-3.92D-04
1676	3.00D-03	0.0	1677	2.97D-03	3.92D-04	1678	2.90D-03	7.76D-04	1679	2.77D-03	1.15D-03	1680	2.60D-03	1.50D-03
1681	2.38D-03	1.83D-03	1682	2.12D-03	2.12D-03	1683	1.83D-03	2.38D-03	1684	1.50D-03	2.60D-03	1685	1.15D-03	2.77D-03
1686	7.76D-04	2.90D-03	1687	3.92D-04	2.97D-03	1688	9.42D-10	3.00D-03	1689	-3.92D-04	2.97D-03	1690	-7.76D-04	2.90D-03
1691	-1.15D-03	2.77D-03	1692	-1.50D-03	2.60D-03	1693	-1.83D-03	2.38D-03	1694	-2.12D-03	2.12D-03	1695	-2.38D-03	1.83D-03
1696	-2.60D-03	1.50D-03	1697	-2.77D-03	1.15D-03	1698	-2.90D-03	7.76D-04	1699	-2.97D-03	3.92D-04	1700	-3.00D-03	1.85D-09
1701	-2.97D-03	-3.92D-04	1702	-2.90D-03	-7.76D-04	1703	-2.77D-03	-1.15D-03	1704	-2.60D-03	-1.50D-03	1705	-2.38D-03	-1.83D-03
1706	-2.12D-03	-2.12D-03	1707	-1.83D-03	-2.38D-03	1708	-1.50D-03	-2.60D-03	1709	-1.15D-03	-2.77D-03	1710	-7.76D-04	-2.90D-03

IMAX	JMAX	NBDY	NTOTS	NROW	NCHT	NPINS	ISYM	N1	IGEO	NBEG	IFQ
21	21	76	238	3	48	19	1	3	1	8	10

LSLIT(I,J) FOR I=1,IMAX FIRST AND THEN J=1,JMAX--

-10076	-10076	-10076	-10076	-10076	-10076	-10076	-10076	-10076	-10076	-10076	-10076
-10076	-10076	-10076	-10076	-10076	-10076	-10076	-10076	-10076	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	-10030	-10030	-10030	-10030	-10030	-10030	-10030	-10030	-10030	-10030	-10030
-10030	-10030	0	0	0	-10074	-10074	-10074	-10074	0	-10031	-10000
-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10029	0
0	0	-10075	-10000	-10000	-10000	0	-10031	-10000	-10000	-10000	-10000
-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10029	0	0	0	-10075
-10000	-10000	-10000	0	-10031	-10000	-10000	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10000	-10000	-10029	0	0	0	-10075	-10000	-10000	-10000
0	-10028	-10000	-10000	-10028	-10000	-10000	-10028	-10000	-10000	-10028	-10000
-10000	-10028	0	0	0	-10072	-10072	-10072	-10072	0	0	-10000
-10000	0	-10000	-10000	0	-10000	-10000	0	-10000	-10000	0	0

0	0	0	0	0	0	0	0	-10000	-10000	0	-10000
-10000	0	-10000	-10000	0	-10000	-10000	0	0	0	0	0
0	0	0	0	0	-10000	-10000	0	-10000	-10000	0	-10000
-10000	0	-10000	-10000	0	0	0	0	0	0	0	0
-10005	-10005	-10000	-10000	-10005	-10000	-10000	-10005	-10000	-10000	-10005	-10000
-10000	-10005	-10005	-10005	-10005	-10005	0	0	0	-10000	-10000	-10000
-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10004	0	0	0	-10000	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10004
0	0	0	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10004	0	0	0
-10003	-10000	-10000	-10000	-10000	-10000	-10000	-10003	-10000	-10000	-10000	-10000
-10000	-10000	-10003	-10000	-10000	-10003	0	0	0	0	-10000	-10000
-10000	-10000	-10000	-10000	0	-10000	-10000	-10000	-10000	-10000	-10000	0
-10000	-10000	0	0	0	0	0	-10000	-10000	-10000	-10000	-10000
-10000	0	-10000	-10000	-10000	-10000	-10000	-10000	0	-10000	-10000	0
0	0	0	0	-10000	-10000	-10000	-10000	-10000	-10000	0	-10000
-10000	-10000	-10000	-10000	-10000	0	-10000	-10000	0	0	0	0
-10001	-10000	-10000	-10000	-10000	-10000	-10000	-10001	-10000	-10000	-10000	-10000
-10000	-10000	-10001	-10000	-10000	-10001	-10001	-10001	-10001			

MUM(I,J) FOR I=1,IMAX FIRST AND THEN J=1,JMAX

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	0
0	0	0	0	0	0	0	0	0	0	108	109
110	111	112	0	0	0	113	114	0	0	0	0
0	0	0	0	0	0	0	115	116	117	118	119
0	0	0	120	121	0	0	0	0	0	0	0
0	0	0	0	122	123	124	125	126	0	0	0
127	128	129	128	129	130	129	130	131	130	131	132
131	132	133	134	135	136	137	138	139	140	141	142
141	142	143	142	143	144	143	144	145	144	145	146
147	148	149	150	151	152	153	154	155	154	155	156
155	156	157	156	157	158	157	158	159	160	161	162
163	164	165	166	167	168	167	168	169	168	169	170
169	170	171	170	171	172	173	174	175	176	177	178
179	180	181	180	181	182	181	182	183	182	183	184
183	184	185	186	187	188	189	190	191	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	192	193	194	195	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	196
197	198	199	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	200	201	202	203
204	205	0	0	0	0	204	205	206	0	0	0
0	205	206	207	206	207	208	209	210	211	212	0
0	0	0	211	212	213	0	0	0	0	212	213
214	213	214	215	216	217	218	219	0	0	0	0
218	219	220	0	0	0	0	219	220	221	220	221
222	223	224	225	226	0	0	0	0	225	226	227
0	0	0	0	226	227	228	227	228	229	230	231
232	233	0	0	0	0	232	233	234	0	0	0
0	233	234	235	234	235	236	237	238			

NB(N) IN CELL NUMBERING ORDER---

-201	-201	-201	-201	-201	-201	-201	-201	-201	-201	-201	-201
-201	-201	-201	-201	-201	-201	-201	-201	-201	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	-5	-4	-4	-4	-4	-4	-4	-4	-4
-4	-4	-4	-4	-7	0	0	-5	-4	-4	-4	-4
-3	-1005	-1004	-1004	-1004	-1004	-1004	-1004	-1004	-1004	-1004	-1004
-1004	-101	0	0	-3	-1005	-1004	-1004	-1004	-3	-1003	-101
0	0	-3	-1003	-3	-1003	-101	0	0	-3	-1003	-3
-1003	-101	0	0	-3	-1003	-6	-201	-201	-201	-201	-801
0	0	-5	-201	-201	-201	-201	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	-4	-4	-4
-4	-4	-4	-4	-4	-4	-7	0	0	-5	-1004	-1004
-1004	-1004	-1004	-1004	-1004	-1004	-1004	-101	0	0	-3	-101
0	0	-3	-101	0	0	-3	-101	0	0	-3	-201
-201	-201	-801	0	0	-6	0	0	0	0	0	0
0	0	0	0	0	0	0	0	-4	-4	-4	-4
-4	-4	-4	-1004	-1004	-1004	-1004	-1004	-1004	-1004		

NCHNL(N) IN CELL NUMBERING ORDER----

23	23	23	24	24	24	24	1	1	1	1	2
2	2	2	2	2	2	2	3	3	23	23	23
24	24	24	24	1	1	1	1	2	2	2	2
2	2	2	2	3	3	23	23	23	24	24	24
24	1	1	1	1	2	2	2	2	2	2	2
2	3	3	23	23	23	24	24	24	24	1	1
1	1	2	2	2	2	2	2	2	2	3	3
23	0	0	0	0	0	0	0	0	0	0	0
0	2	2	2	2	0	0	0	0	23	0	2
2	2	2	0	42	0	25	25	25	25	0	42
0	25	25	25	25	0	42	42	42	25	25	25
25	25	25	26	26	26	26	42	42	42	25	25
25	25	25	25	26	26	25	26	42	42	42	25
25	25	25	25	25	26	26	26	26	42	42	42
25	25	25	25	25	25	26	26	26	26	0	0
0	0	0	0	0	0	0	25	26	26	26	26
26	26	26	43	43	43	43	43	43	43	43	48
43	43	43	43	43	43	48	43	43	43	43	43
43	48	43	43	43	43	43	43	48	43	43	43
43	43	43	0	0	0	0	0	0	0		

NCHTP(I) IN CHANNEL NUMBERING ORDER---

3	2	2	3	3	2	2	3	3	2	2	3
3	2	2	3	3	2	2	3	3	2	2	3
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1

NPNQ(I,J) FOR J=1,6 FIRST AND THEN I=1,NPINS

0	0	0	0	0	43	0	0	0	43	26	25
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	25	2	1
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

2	25	26	0	0	0

X AND Y COORDINATES------------------

1	-5.20E-03	-1.76E-02	2	-4.46E-03	-1.80E-02	3	-3.72E-03	-1.85E-02	4	-2.97E-03	-1.89E-02	5	-2.23E-03	-1.93E-02
6	-1.49E-03	-1.97E-02	7	-7.43E-04	-2. 2E-02	8	0.0	-2.03E-02	9	7.43E-04	-2.02E-02	10	1.49E-03	-1.97E-02
11	2.23E-03	-1.93E-02	12	2.97E-03	-1.89E-02	13	3.72E-03	-1.85E-02	14	4.46E-03	-1.80E-02	15	5.20E-03	-1.76E-02
16	5.95E-03	-1.72E-02	17	6.69E-03	-1.67E-02	18	7.43E-03	-1.63E-02	19	8.13E-03	-1.59E-02	20	8.92E-03	-1.55E-02
21	9.67E-03	-1.50E-02	22	-4.89E-03	-1.71E-02	23	-4.21E-03	-1.76E-02	24	-3.57E-03	-1.80E-02	25	-2.91E-03	-1.85E-02
26	-2.22E-03	-1.90E-02	27	-1.49E-03	-1.94E-02	28	-7.47E-04	-1.97E-02	29	0.0	-1.93E-02	30	7.45E-04	-1.97E-02
31	1.49E-03	-1.94E-02	32	2.22E-03	-1.90E-02	33	2.91E-03	-1.85E-02	34	3.57E-03	-1.80E-02	35	4.21E-03	-1.76E-02
36	4.89E-03	-1.71E-02	37	5.60E-03	-1.67E-02	38	6.36E-03	-1.63E-02	39	7.16E-03	-1.60E-02	40	7.97E-03	-1.56E-02
41	8.77E-03	-1.52E-02	42	9.54E-03	-1.47E-02	43	-4.55E-03	-1.66E-02	44	-3.94E-03	-1.71E-02	45	-3.40E-03	-1.76E-02
46	-2.83E-03	-1.81E-02	47	-2.19E-03	-1.86E-02	48	-1.49E-03	-1.90E-02	49	-7.53E-04	-1.93E-02	50	0.0	-1.94E-02
51	7.53E-04	-1.93E-02	52	1.49E-03	-1.90E-02	53	2.19E-03	-1.86E-02	54	2.83E-03	-1.81E-02	55	3.40E-03	-1.76E-02
56	3.94E-03	-1.71E-02	57	4.55E-03	-1.66E-02	58	5.24E-03	-1.63E-02	59	6.00E-03	-1.59E-02	60	6.85E-03	-1.56E-02
61	7.75E-03	-1.53E-02	62	8.62E-03	-1.49E-02	63	9.42E-03	-1.44E-02	64	-4.18E-03	-1.61E-02	65	-3.60E-03	-1.65E-02
66	-3.19E-03	-1.71E-02	67	-2.73E-03	-1.77E-02	68	-2.16E-03	-1.83E-02	69	-1.50E-03	-1.87E-02	70	-7.62E-04	-1.90E-02
71	0.0	-1.91E-02	72	7.62E-04	-1.90E-02	73	1.50E-03	-1.87E-02	74	2.16E-03	-1.83E-02	75	2.73E-03	-1.77E-02
76	3.19E-03	-1.71E-02	77	3.60E-03	-1.65E-02	78	4.18E-03	-1.61E-02	79	4.84E-03	-1.58E-02	80	5.59E-03	-1.55E-02
81	6.51E-03	-1.52E-02	82	7.51E-03	-1.51E-02	83	8.45E-03	-1.47E-02	84	9.31E-03	-1.40E-02	85	-3.73E-03	-1.55E-02
86	-3.00E-03	-1.58E-02	87	-2.90E-03	-1.66E-02	88	-2.60E-03	-1.73E-02	89	-2.12E-03	-1.79E-02	90	-1.50E-03	-1.84E-02
91	-7.76E-04	-1.87E-02	92	0.0	-1.88E-02	93	7.76E-04	-1.87E-02	94	1.50E-03	-1.84E-02	95	2.12E-03	-1.79E-02
96	2.60E-03	-1.73E-02	97	2.90E-03	-1.66E-02	98	3.00E-03	-1.58E-02	99	3.73E-03	-1.55E-02	100	4.37E-03	-1.52E-02
101	5.07E-03	-1.50E-02	102	6.07E-03	-1.47E-02	103	7.23E-03	-1.40E-02	104	8.34E-03	-1.44E-02	105	9.22E-03	-1.37E-02
106	-3.39E-03	-1.48E-02	107	-2.90E-03	-1.50E-02	108	2.90E-03	-1.58E-02	109	3.39E-03	-1.48E-02	110	3.89E-03	-1.45E-02
111	4.41E-03	-1.44E-02	112	5.02E-03	-1.42E-02	113	-3.02E-03	-1.41E-02	114	-2.60E-03	-1.43E-02	115	2.60E-03	-1.43E-02
116	3.02E-03	-1.41E-02	117	3.45E-03	-1.39E-02	118	3.87E-03	-1.36E-02	119	4.24E-03	-1.33E-02	120	-2.61E-03	-1.34E-02
121	-2.12E-03	-1.37E-02	122	2.12E-03	-1.37E-02	123	2.61E-03	-1.34E-02	124	3.07E-03	-1.30E-02	125	3.49E-03	-1.27E-02
126	3.87E-03	-1.22E-02	127	-2.27E-03	-1.27E-02	128	-1.50E-03	-1.32E-02	129	-7.76E-04	-1.29E-02	130	0.0	-1.28E-02
131	7.76E-04	-1.29E-02	132	1.50E-03	-1.32E-02	133	2.27E-03	-1.27E-02	134	2.85E-03	-1.23E-02	135	3.37E-03	-1.18E-02
136	3.94E-03	-1.11E-02	137	4.46E-03	-1.00E-02	138	5.34E-03	-9.25E-03	139	6.45E-03	-8.88E-03	140	-2.16E-03	-1.19E-02
141	-1.47E-03	-1.22E-02	142	-7.50E-04	-1.23E-02	143	0.0	-1.23E-02	144	7.50E-04	-1.23E-02	145	1.47E-03	-1.22E-02
146	2.16E-03	-1.19E-02	147	2.76E-03	-1.15E-02	148	3.31E-03	-1.09E-02	149	3.85E-03	-1.02E-02	150	4.41E-03	-9.41E-03
151	5.11E-03	-8.86E-03	152	5.94E-03	-8.52E-03	153	-2.12E-03	-1.12E-02	154	-1.45E-03	-1.16E-02	155	-7.42E-04	-1.18E-02
156	0.0	-1.18E-02	157	7.42E-04	-1.18E-02	158	1.45E-03	-1.16E-02	159	2.12E-03	-1.12E-02	160	2.71E-03	-1.07E-02
161	3.24E-03	-1.01E-02	162	3.72E-03	-9.46E-03	163	4.24E-03	-8.85E-03	164	4.85E-03	-8.40E-03	165	5.54E-03	-8.07E-03
166	-2.11E-03	-1.06E-02	167	-1.46E-03	-1.10E-02	168	-7.50E-04	-1.12E-02	169	0.0	-1.13E-02	170	7.50E-04	-1.12E-02
171	1.46E-03	-1.10E-02	172	2.11E-03	-1.06E-02	173	2.67E-03	-1.01E-02	174	3.13E-03	-9.43E-03	175	3.49E-03	-8.76E-03
176	3.97E-03	-8.24E-03	177	4.54E-03	-7.85E-03	178	5.15E-03	-7.56E-03	179	-2.12E-03	-1.00E-02	180	-1.50E-03	-1.05E-02
181	-7.76E-04	-1.05E-02	182	0.0	-1.09E-02	183	7.76E-04	-1.09E-02	184	1.50E-03	-1.05E-02	185	2.12E-03	-1.00E-02
186	2.60E-03	-9.40E-03	187	2.90E-03	-8.68E-03	188	3.00E-03	-7.90E-03	189	3.62E-03	-7.55E-03	190	4.17E-03	-7.23E-03
191	4.73E-03	-6.91E-03	192	2.90E-03	-7.12E-03	193	3.34E-03	-6.85E-03	194	3.80E-03	-6.59E-03	195	4.26E-03	-6.32E-03
196	2.60E-03	-6.40E-03	197	3.00E-03	-6.17E-03	198	3.42E-03	-5.92E-03	199	3.85E-03	-5.65E-03	200	2.12E-03	-5.78E-03
201	2.59E-03	-5.53E-03	202	3.04E-03	-5.27E-03	203	3.59E-03	-5.00E-03	204	-7.76E-04	-5.00E-03	205	0.0	-4.90E-03
206	7.76E-04	-5.00E-03	207	1.50E-03	-5.30E-03	208	2.13E-03	-4.93E-03	209	2.67E-03	-4.62E-03	210	3.20E-03	-4.31E-03
211	-6.19E-04	-4.41E-03	212	0.0	-4.40E-03	213	6.19E-04	-4.41E-03	214	1.22E-03	-4.41E-03	215	1.79E-03	-4.24E-03
216	2.30E-03	-3.99E-03	217	2.78E-03	-3.67E-03	218	-5.24E-04	-3.88E-03	219	0.0	-3.90E-03	220	5.24E-04	-3.88E-03
221	1.04E-03	-3.81E-03	222	1.53E-03	-3.67E-03	223	1.99E-03	-3.45E-03	224	2.41E-03	-3.16E-03	225	-4.52E-04	-3.40E-03
226	0.0	-3.42E-03	227	4.52E-04	-3.40E-03	228	8.96E-04	-3.32E-03	229	1.32E-03	-3.19E-03	230	1.73E-03	-2.99E-03
231	2.10E-03	-2.74E-03	232	-3.92E-04	-2.97E-03	233	0.0	-3.00E-03	234	3.92E-04	-2.97E-03	235	7.76E-04	-2.90E-03
236	1.15E-03	-2.77E-03	237	1.50E-03	-2.60E-03	238	1.83E-03	-2.33E-03						

L AND NPIN(L) FOR L=1 TO NBDY

1	1	2	2	3	2	4	2	5	2
6	2	7	2	8	3	9	3	10	3
11	3	12	4	13	4	14	4	15	4
16	5	17	5	18	5	19	5	20	6
21	6	22	6	23	6	24	7	25	7
26	7	27	7	28	8	29	8	30	8
31	8	32	9	33	9	34	9	35	9

36	10	37	10	38	10	39	10	40	11
41	11	42	11	43	11	44	12	45	12
46	12	47	12	48	13	49	13	50	13
51	13	52	14	53	14	54	14	55	14
56	15	57	15	58	15	59	15	60	16
61	16	62	16	63	16	64	17	65	17
66	17	67	17	68	18	69	18	70	18
71	18	72	19	73	19	74	19	75	19
76	20								

NPQ(I,J) FOR J=1 TO 6 AND THEN I=1 TO NPINS

0	0	0	0	0	1	0	0	0	2	3	4
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	5	6	7
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
8	9	10	0	0	0						

```
$$DATE$$
          19 PINS HEXGONAL ROD BUNDLE WITH 1/12 SYMMETRY
          SAME GEOMETRY FOR GERMAN FLOW RUN DOWN EXPERIMENT(9/25/80)
             1
         &SET NTPRNT=1,50,300,600.46*0,
          ITPRNT=50*0,NTPLOT=50*0,
          NTHPR=1302,1310,2302,2310,3108,3121,3302,3310,5108,5121,
          5301,5310,6108,6121,20302,20310,34*0,
          ISTPR=1302,1310,2302,2310,3108,3121,3302,3310.5108,5121,
          5301,5310,6108.6121,20302,20310.34*0,
          GX=0.0,GY=0.0.GZ=-1.0,
          IBNSOL=0,IBPSOL=0,IBITER=0,IBVSOL=0,ISUG=0,0,0,0,0,0,0,0,0,21*0,
          IBLO=8,IBHI=21,JBLO=1,JBHI=21,KBLO=10,KBHI=10,
          KMAX=10,IFRES=1,IFROB=1,SLIFR=0.0,DREF=0.004211,
          NSTEPS=001,IT1=5,IT2=5,ITSET=50,IT3=3,
          DTD=1.0E+20,VEL=  2.15, TENC=553.000,PENT=2.0,    FGRAD=0.0,
          TURBF=1.0,WUPBK=1.00,AO=0.5,BO=0.0,NPORD=2,
          FAC=4*1.0,1.0,1.8,1.0,0.5,0.5,1.0,1.0,1.0,18*0.0,
          TOLVEL=0.001,TOLENT=0.0001,TOLFRE=0.0001,ESUMSM=0.001,
          ZA=0.000,0.08889,0.17778,0.26667,0.35555,0.44444,0.53333,0.62222,
            0.71111,0.80000,
          XA=10*0.0,QACC=0.0,VACC=0.0,TACC=0.0,
          C=5.0,0.025,0.8,6*0.0,0.0,1.0,1.3,1.44,1.92,0.09,
            0.42,9.8,0.01,0.07,1.0,1.0,1.0,1.3,0.09,6*0.0,
          KA=10*0,
          NC=7,NTFU=3, NCOND=1.30,   IOPT=0,0,0,1,1,0,0.0,0,0,20*0,
          RADIAL=0.0,0.00146,0.00175,0.00227,0.00235.0.003,0.0,
          Q=0.0,6.40E+09,5*0.0,
            QRAD=19*1.0,QAXIAL=0.0,8*1.0,0.0,
          DECH=0.0054694,0.0043237,0.0026566,AVHTF=0.993E+06,
          EPS=1.0E-10,0.2E-05,0.2E-07,1.0E-03,26*0.0,
         WDUC=0.0015,TOLTOU=1.0E-02,
         &END
 19 PINS HEXGONAL ROD BUNDLE WITH 1/12 SYMMETRY
 SAME GEOMETRY FOR GERMAN FLOW RUN DOWN EXPERIMENT(9/25/80)
     IMAX      JMAX      NBDY      NTOT      NROW      NCHT     NPINS       ISY        N1      IGEO      NBEG   IPQ
       21        21        76       238         3        48        19         1         3         1         8      10
 LSLIT(I,J) IN I=1 TO IMAX AND THEN J=1 TO JMAX
   -10076    -10076    -10076    -10076    -10076    -10076    -10076    -10076    -10076    -10076    -10076    -10076
   -10076    -10076    -10076    -10076    -10076    -10076    -10076    -10076    -10076         0         0         0
        0         0         0         0         0         0         0         0         0         0         0         0
        0         0         0         0         0         0         0         0         0         0         0         0
        0         0         0         0         0         0         0         0         0         0         0         0
        0         0         0         0         0         0         0         0         0         0         0         0
        0         0         0         0         0         0         0         0         0         0         0         0
        0    -10030    -10030    -10030    -10030    -10030    -10030    -10030    -10030    -10030    -10030    -10030
   -10030    -10030         0         0         0    -10074    -10074    -10074    -10074         0    -10031    -10000
   -10000    -10000    -10000    -10000    -10000    -10000    -10000    -10000    -10000    -10000    -10029         0
        0         0    -10075    -10000    -10000    -10000         0    -10031    -10000    -10000    -10000    -10000
   -10000    -10000    -10000    -10000    -10000    -10000    -10000    -10029         0         0         0    -10075
   -10000    -10000    -10000         0    -10031    -10000    -10000    -10000    -10000    -10000    -10000    -10000
   -10000    -10000    -10000    -10000    -10029         0         0         0    -10075    -10000    -10000    -10000
        0    -10028    -10000    -10000    -10028    -10000    -10000    -10028    -10000    -10000    -10028    -10000
   -10000    -10028         0         0         0    -10072    -10072    -10072    -10072         0         0    -10000
   -10000         0    -10000    -10000         0    -10000    -10000         0    -10000    -10000         0         0
        0         0         0         0         0         0         0         0    -10000    -10000         0    -10000
   -10000         0    -10000    -10000         0    -10000    -10000         0         0         0         0         0
        0         0         0         0         0    -10000    -10000         0    -10000    -10000         0    -10000
   -10000         0    -10000    -10000         0         0         0         0         0         0         0         0
```

-10005	-10005	10000	-10000	-10005	-10000	-10000	-10005	-10000	-10000	-10005	-10000
-10000	-10005	10005	-10005	-10005	-10005	0	0	0	-10000	-10000	-10000
-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10004	0	0	0	-10000	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10004
0	0	0	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000
-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10000	-10004	0	0	0
-10003	-10000	-10000	-10000	-10000	-10000	-10000	-10003	-10000	-10000	-10000	-10000
-10000	-10000	-10003	-10000	-10000	-10003	0	0	0	0	-10000	-10000
-10000	-10000	-10000	-10000	0	-10000	-10000	-10000	-10000	-10000	-10000	0
-10000	-10000	0	0	0	0	0	-10000	-10000	-10000	-10000	-10000
-10000	0	-10000	-10000	-10000	-10000	-10000	-10000	0	-10000	-10000	0
0	0	0	0	-10000	-10000	-10000	-10000	-10000	-10000	0	-10000
-10000	-10000	-10000	-10000	-10000	0	-10000	-10000	0	0	0	0
-10001	-10000	-10000	-10000	-10000	-10000	-10000	-10001	-10000	-10000	-10000	-10000
-10000	-10000	-10001	-10000	-10000	-10001	-10001	-10001	-10001			

N(I,J) IN I=1 TO IMAX AND THEN J=1 TO JMAX

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	0
0	0	0	0	0	0	0	0	0	0	108	109
110	111	112	0	0	0	113	114	0	0	0	0
0	0	0	0	0	0	0	115	116	117	118	119
0	0	0	120	121	0	0	0	0	0	0	0
0	0	0	0	122	123	124	125	126	0	0	0
127	128	129	128	129	130	129	130	131	130	131	132
131	132	133	134	135	136	137	138	139	140	141	142
141	142	143	142	143	144	143	144	145	144	145	146
147	148	149	150	151	152	153	154	155	154	155	156
155	156	157	156	157	158	157	158	159	160	161	162
163	164	165	166	167	168	167	168	169	168	169	170
169	170	171	170	171	172	173	174	175	176	177	178
179	180	181	180	181	182	181	182	183	182	183	184
183	184	185	186	187	188	189	190	191	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	192	193	194	195	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	196
197	198	199	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	200	201	202	203
204	205	0	0	0	0	204	205	206	0	0	0
0	205	206	207	206	207	208	209	210	211	212	0
0	0	0	211	212	213	0	0	0	0	212	213
214	213	214	215	216	217	218	219	0	0	0	0
218	219	220	0	0	0	0	219	220	221	220	221
222	223	224	225	226	0	0	0	0	225	226	227
0	0	0	0	226	227	228	227	228	229	230	231
232	233	0	0	0	0	232	233	234	0	0	0
0	233	234	235	234	235	236	237	238			

NBOUND(I) FOR I=1 TO NTOT

-201	-201	-201	-201	-201	-201	-201	-201	-201	-201	-201	-201
-201	-201	-201	-201	-201	-201	-201	-201	-201	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

0	0	0	-5	-4	-4	-4	-4	-4	-4	-4	-4
-4	-4	-4	-4	-7	0	0	-5	-4	-4	-4	-4
-3	-1005	-1004	-1004	-1004	-1004	-1004	-1004	-1004	-1004	-1004	-1004
-1004	-101	0	0	-3	-1005	-1004	-1004	-1004	-3	-1003	-101
0	0	-3	-1003	-3	-1003	-101	0	0	-3	-1003	-3
-1003	-101	0	0	-3	-1003	-6	-201	-201	-201	-201	-801
0	0	-6	-201	-201	-201	-201	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	-4	-4	-4
-4	-4	-4	-4	-4	-4	-7	0	0	-5	-1004	-1004
-1004	-1004	-1004	-1004	-1004	-1004	-1004	-101	0	0	-3	-101
0	0	-3	-101	0	0	-3	-101	0	0	-3	-201
-201	-201	-801	0	0	-6	0	0	0	0	0	0
0	0	0	0	0	0	0	0	-4	-4	-4	-4
-4	-4	-4	-1004	-1004	-1004	-1004	-1004	-1004	-1004		

NCHNL(I) FOR I=1 TO NTOT

23	23	23	24	24	24	24	1	1	1	1	2
2	2	2	2	2	2	2	3	3	23	23	23
24	24	24	24	1	1	1	1	2	2	2	2
2	2	2	2	3	3	23	23	23	24	24	24
24	1	1	1	1	2	2	2	2	2	2	2
2	3	3	23	23	23	24	24	24	24	1	1
1	1	2	2	2	2	2	2	2	2	3	3
23	0	0	0	0	0	0	0	0	0	0	0
0	2	2	2	2	0	0	0	0	23	0	2
2	2	2	0	42	0	25	25	25	25	0	42
0	25	25	25	25	0	42	42	42	25	25	25
25	25	25	26	26	26	26	42	42	42	25	25
25	25	25	25	26	26	26	26	42	42	42	25
25	25	25	25	25	26	26	26	26	42	42	42
25	25	25	25	25	25	26	26	26	26	0	0
0	0	0	0	0	0	0	26	26	26	26	26
26	26	26	43	43	43	43	43	43	43	43	48
43	43	43	43	43	43	48	43	43	43	43	43
43	48	43	43	43	43	43	43	48	43	43	43
43	43	43	0	0	0	0	0	0	0		

NCHTP(I) FOR I=1 TO NCHT

3	2	2	3	3	2	2	3	3	2	2	3
3	2	2	3	3	2	2	3	3	2	2	3
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1

NPHQ(I,J) FOR J=1 TO 6 AND THEN I=1 TO NPINS

0	0	0	0	0	43	0	0	0	43	26	25
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	25	2	1
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
2	25	26	0	0	0						

L AND NPIN(L) FOR L=1 TO NBDY

1	1	2	2	3	2	4	2	5	2	6	2
7	2	8	3	9	3	10	3	11	3	12	4
13	4	14	4	15	4	16	5	17	5	18	5
19	5	20	6	21	6	22	6	23	6	24	7
25	7	26	7	27	7	28	8	29	8	30	8
31	8	32	9	33	9	34	9	35	9	36	10
37	10	38	10	39	10	40	11	41	11	42	11

```
     43      11      44      12      45      12      46      12      47      12      48      13
     49      13      50      13      51      13      52      14      53      14      54      14
     55      14      56      15      57      15      58      15      59      15      60      16
     61      16      62      16      63      16      64      17      65      17      66      17
     67      17      68      18      69      18      70      18      71      18      72      19
     73      19      74      19      75      19      76      20
 NPQ(I.J) FOR J=1 TO 6 AND THE  I=1 TO NPINS
      0       0       0       0       0       1       0       0       0       2       3       4
      0       0       0       0       0       0       0       0       0       0       0       0
      0       0       0       0       0       0       0       0       0       0       0       0
      0       0       0       0       0       0       0       0       0       5       6       7
      0       0       0       0       0       0       0       0       0       0       0       0
      0       0       0       0       0       0       0       0       0       0       0       0
      0       0       0       0       0       0       0       0       0       0       0       0
      0       0       0       0       0       0       0       0       0       0       0       0
      0       0       0       0       0       0       0       0       0       0       0       0
      8       9      10       0       0       0
I0=  8    I8= 19    I9= 20    J0=  1    J8= 21    J9= 21

  K    ALFA        BETA        GAMA        ARC        DZDARC

  1  1.0000E+00  0.0         0.0        0.0         4.7373E-02
  2  1.0000E+00  0.0         0.0        2.1109E+01  4.7373E-02
  3  1.0000E+00  0.0         0.0        4.2218E+01  4.7373E-02
  4  1.0000E+00  0.0         0.0        6.3327E+01  4.7372E-02
  5  1.0000E+00  0.0         0.0        8.4435E+01  4.7373E-02
  6  1.0000E+00  0.0         0.0        1.0554E+02  4.7373E-02
  7  1.0000E+00  0.0         0.0        1.2665E+02  4.7373E-02
  8  1.0000E+00  0.0         0.0        1.4776E+02  4.7373E-02
  9  1.0000E+00  0.0         0.0        1.6887E+02  4.7373E-02
 10  1.0000E+00  0.0         0.0        1.8998E+02  4.7373E-02

  10 AXIAL PLANES,    1 TIME STEPS,    5 ITERATIONS PER TIME STEP FOR FIRST   50 STEPS THEN     5 ITERATIONS PER STEP.

INITIAL CONDITIONS :
                     FLOW AREA (M2)            - 4.72508372E-05
                     VELOCITY (M/S)            - 2.14909962E+00
                     FLOWRATE (M3/S)           - 1.01610771E-04
                     REYNOLDS NUMBER           - 3.33175220E+04
                     PRANDTL NUMBER            - 4.20042180E-03
                     ENTRANCE PRESSURE (ATM)   - 2.00000000E+00
                     ENTRANCE TEMPERATURE (C)  - 5.53000000E+02
                     TIME STEP (S)               1.00000002E+20
                     TIME STEP (DIMENSIONLESS)- 5.10557325E+22

ACCELERATION PARAMETERS :
                      X-VELOCITY : 1.00000000
                      Y-VELOCITY : 1.00000000
                      Z-VELOCITY : 1.00000000
                      ENTHALPY :   1.00000000
                      PRESSURE :   1.00000000

CONVERGENCE TOLERANCES :
                      VELOCITY : 0.99999993E-03
                      ENTHALPY : 0.10000000E-03
                      PRESSURE : 0.10000000E-03

AXIS POINTS :                  ·                Z
                  0.0          0.0
                  0.0          21.1089935
```

0.0	42.2179718
0.0	63.3269806
0.0	84.4335937
0.0	105.542537
0.0	126.651596
0.0	147.760574
0.0	168.869568
0.0	189.978577

FIELD SIZE (I,J,K) :(21, 21, 10)

GRAVITATIONAL UNIT VECTOR :
GX : 0.0
GY : 0.0
GZ : -1.0000

FROUDE NUMBER : 1.0580E+01

REFERENCE CONDITIONS :

ENTHALPY(J/KG)	- 0.10812880E+07
DENSITY(KG/M3)	- 0.81950562E+03
TEMPERATURE(KELVIN)	- 0.80946094E+03
PRESSURE(ATM)	- 0.37306257E-01
SPECIFIC HEAT(J/KG/C)	- 0.12566379E+04
VISCOSITY(PA-S)	- 0.21939818E-03
CONDUCTIVITY(J/S/M/C)	- 0.64410446E+02
VELOCITY(M/S)	- 0.21499995E+01
DIAMETER(M)	- 0.42110011E-02

NON-DIMENSIONAL ENTRANCE CONDITIONS :
TEMPERATURE - 0.96012479
DENSITY - 1.00000000

ENERGY RATIO (V2/H) - 0.42749916E-05
FUEL PIN HEAT FLUX AT VARIOUS LEVEL

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DUCT WALL HEAT FLUX AT VARIOUS LEVEL IN THE ORDER OF QUCL(J,K), QDUR(J,K), QOUT(I,K), AND QDUB(I,K)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HEATED PARAMETER(M)= 0.2907657E-01
PLANE= INITIAL AV. TEMP.=

1	0.5529998E+03
2	0.5775269E+03
3	0.6022590E+03
4	0.6271830E+03
5	0.6523130E+03
6	0.6776235E+03
7	0.7031123E+03
8	0.7287715E+03
9	0.7545925E+03
10	0.7545925E+03

******************** BEGINNING OF OUTPUT FOR STEP 0 AT 0.0 SECONDS, ITERATION 0********************

U VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13	14	15	16	17	18	19	20	21
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
  3   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  2   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  1   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
FUEL PIN TEMPERATURE IN ((TCL(I,K,MPQ),I=1,NC),K=LL1,LL2)
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03  0.577527E+03
FUEL PIN TEMPERATURE IN ((TCL(I,K,MPQ),I=1,NC),K=LL1,LL2)
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03 -0.754593E+03  0.754593E+03
  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03  0.754593E+03

********************       END OF OUTPUT FOR STEP     0 AT   0.0    SECONDS, ITERATION    0********************


 MAX. MASS RESIDUE AT   15    3    6 =  -1.37393172E+21
 MAX. PRES CORREC. AT   15    4    6 =   1.87873840E-04
*****    1  0.11757705E-02 -0.12745699E-02 -0.50129110E+00  0.60598433E-01  0.18787384E-03  0.0            0.0           *****
 MAX. MASS RESIDUE AT   16    4    8 =   1.36196199E+21
 MAX. PRES CORREC. AT   15    4    1 =  -1.87166995E-04
*****    2  0.15809350E-02  0.14963031E-02 -0.36911678E+00  0.30355453E-01 -0.18716700E-03  0.0            0.0           *****
 MAX. MASS RESIDUE AT   10    3    1 =  -1.53203734E+21
 MAX. PRES CORREC. AT   15    4    9 =  -1.68800354E-04
*****    3 -0.13123336E-02  0.13766508E-02  0.22154331E+00  0.18948555E-01 -0.16880035E-03  0.0            0.0           *****
 MAX. MASS RESIDUE AT   15    1    9 =   1.60974216E+21
 MAX. PRES CORREC. AT   15    1    9 =  -1.81198120E-04
*****    4 -0.12117797E-02 -0.14929429E-02 -0.14175320E+00  0.13444901E-01 -0.18119812E-03  0.0            0.0           *****
 MAX. MASS RESIDUE AT   10    3    1 =  -1.43316684E+21
 MAX. PRES CORREC. AT   14    4    9 =   1.52587891E-04
*****1.005000.68455236E-03  0.83982036E-03  0.11019516E+00  0.10188103E-01  0.15256789E-03  0.0            0.0           *****

 MAX. MASS RESIDUE AT    9    3    1 =  -1.48607698E+21
 MAX. PRES CORREC. AT   14    3    9 =  -9.72747803E-05
*****    1  0.56940247E-03  0.79810352E-03  0.46667099E-01  0.82855225E-02 -0.97274780E-04  0.0            0.0           *****
 MAX. MASS RESIDUE AT    9    3    1 =  -1.46953666E+21
 MAX. PRES CORREC. AT    8    2    1 =   7.45148864E-05
*****    2  0.43500005E-03 -0.35305391E-03  0.31112671E-01  0.68912506E-02  0.74514886E-04  0.0            0.0           *****
 MAX. MASS RESIDUE AT    9    3    1 =  -1.42286361E+21
 MAX. PRES CORREC. AT    8    2    1 =   7.19218515E-05
*****    3 -0.47246832E-03 -0.44309860E-03  0.22347710E-01  0.59556961E-02  0.71921851E-04  0.0            0.0           *****
 MAX. MASS RESIDUE AT    9    3    1 =  -1.41454855E+21
 MAX. PRES CORREC. AT    8    2    1 =   7.11854092E-05
*****    4 -0.24548895E-03 -0.25854097E-03  0.12075421E-01  0.52728653E-02  0.71185408E-04  0.0            0.0           *****
 MAX. MASS RESIDUE AT    9    3    1 =  -1.39425956E+21
```

MAX. PRES CORREC. AT 8 2 1 = 6.96685165E-05
*****5.135200.32963557E-03 0.32260432E-03 -0.87823868E-02 0.47378540E-02 0.69668517E-04 0.0 0.0 *****

******************** BEGINNING OF OUTPUT FOR STEP 1 AT********* SECONDS, ITERATION 5********************

U VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
21	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11
20	-7.387E-04	1.313E-04	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-7.387E-04	1.313E-04	7.387E-04	-8.660E-11	-8.660E-11	-8.660E-11
19	-1.042E-03	1.973E-04	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-1.042E-03	1.973E-04	1.042E-03	-8.660E-11	-8.660E-11	-8.660E-11
18	-1.140E-03	2.0[illegible]E-04	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-1.140E-03	2.061E-04	1.140E-03	-8.660E-11	-8.660E-11	-8.660E-11
17	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11
16	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
15	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
14	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	-9.283E-04	0.0	-9.283E-04	6.717E-07	-9.283E-04	6.717E-07	9.283E-04	6.717E-07	9.283E-04	7.257E-04
11	0.0	0.0	-1.156E-03	0.0	-1.156E-03	1.070E-06	-1.156E-03	1.070E-06	1.156E-03	1.070E-06	1.156E-03	1.167E-03
10	6.0	0.0	-1.123E-03	0.0	-1.123E-03	8.315E-08	-1.123E-03	8.315E-08	1.123E-03	8.315E-08	1.123E-03	1.189E-03
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
7	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
6	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	-3.429E-04	-2.309E-06	3.429E-04	4.843E-04	8.112E-04	1.545E-03
3	0.0	0.0	0.0	0.0	0.0	0.0	-4.808E-04	-2.621E-07	4.808E-04	7.535E-04	1.073E-03	1.908E-03
2	0.0	0.0	0.0	0.0	0.0	0.0	-5.397E-04	1.755E-06	5.397E-04	8.633E-04	1.100E-03	1.786E-03
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13	14	15	16	17	18	19	20	21
21	-8.660E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.6	-8.660E-11
20	-8.660E-11	1.313E-04	7.387E-04	1.072E-03	7.387E-04	1.072E-03	1.028E-03	6.848E-04	-1.107E-05
19	-8.660E-11	1.973E-04	1.042E-03	1.465E-03	1.042E-03	1.465E-03	1.509E-03	9.993E-04	3.272E-04
18	-8.660E-11	2.0[illegible]E-04	1.140E-03	1.411E-03	1.140E-03	1.411E-03	1.024E-03	4.343E-05	-8.834E-04
17	-8.660E-11	0.0	0.0	0.0	0.0	0.0	3.459E-05	-4.993E-04	-9.205E-04
16	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-1.833E-04	-5.103E-04	-7.676E-04
15	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	2.653E-04	-1.330E-06	-2.118E-04
14	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	9.107E-04	6.543E-04	-8.727E-05
13	0.0	0.0	0.0	0.0	0.0	0.0	1.141E-03	8.317E-04	3.344E-04
12	9.283E-04	7.257E-04	8.817E-05	-3.542E-05	4.792E-04	9.241E-04	9.170E-04	3.711E-05	-1.044E-03
11	1.156E-03	1.167E-03	3.674E-04	-3.652E-04	-2.958E-04	1.976E-04	2.666E-04	-5.564E-04	-1.164E-03
10	1.123E-03	1.189E-03	1.452E-04	-9.893E-04	-1.021E-03	-4.719E-04	-1.233E-05	-4.976E-04	-7.870E-04
9	0.0	0.0	-4.021E-04	-1.310E-03	-1.178E-03	0.0	0.0	0.0	-8.660E-11
8	-8.660E-11	0.0	-4.048E-04	-9.493E-04	-1.003E-03	0.0	-8.660E-11	-8.660E-11	-8.660E-11
7	-8.660E-11	0.0	1.970E-04	-1.165E-04	-3.787E-04	0.0	-8.660E-11	-8.660E-11	-8.660E-11
6	-8.660E-11	0.0	5.319E-04	1.471E-04	-1.709E-04	0.0	-8.660E-11	-8.660E-11	-8.660E-11
5	0.0	0.0	6.616E-04	-3.133E-04	-1.407E-03	0.0	0.0	0.0	-8.660E-11
4	2.138E-03	1.97[illegible]E-03	9.487E-04	-1.330E-03	-3.303E-03	-3.416E-03	-1.991E-03	-9.332E-04	-1.191E-03
3	2.634E-03	2.195E-03	5.436E-04	-2.117E-03	-3.859E-03	-3.483E-03	-1.915E-03	-8.216E-04	-1.514E-03
2	2.501E-03	2.138E-03	4.076E-04	-1.870E-03	-3.118E-03	-2.640E-03	-1.287E-03	-4.084E-04	-1.485E-03
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-8.660E-11

```
$$DATE$$
          19 PINS HEXGONAL ROD BUNDLE WITH 1/12 SYMMETRY
          SAME GEOMETRY FOR GERMAN FLOW RUN DOWN EXPERIMENT(9/25/80)
            3
         &SET NTPRNT=4,50,300,600,46*0,
          ITPRNT=50*0,NTPLOT=50*0,
          NTHPR=1302,1310,2302,2310,3108,3121,3302,3310,5108,5121,
          5301,5310,6108,6121,20302,20310,34*0,
          ISTPR=1302,1310,2302,2310,3108,3121,3302,3310,5108,5121,
          5301,5310,6108,6121,20302,20310,34*6,
          GX=0.0,GY=0.0,GZ=-1.0,
          IBHSOL=0,IBPSOL=0,IBITER=0,IBVSOL=0,IBUG=0,0,0,0,0,0,0,0,0,21*0,
          IBLO=8,IBHI=21,JBLO=1,JBHI=21,KBLO=10,KBHI=10,
          KMAX=10,IPRES=1,IPROB=1,SLIPR=0.0,DREF=0.004211,
          NSTEPS=004,IT1=10,IT2=5,ITSET=50,IT3=3,
          DTD=1.0E+20,VEL=  2.15, TENC=553.000,PENT=2.0,    PGRAD=0.0,
          TURBF=1.0,TURBK=1.00,AO=0.5,BO=0.0,NPORD=2,
          FAC=4*0.6,1.0,1.8,1.0,0.5,0.5,1.0,1.0,1.0,18*0.0,
          TOLVEL=0.001,TOLENT=0.0001,TOLPRE=0.0001,ESUMSM=0.001,
          ZA=0.000,0.03889,0.17778,0.26667,0.35555,0.44444,0.53333,0.62222,
             0.71111,0.80000,
          XA=10*0.0,QACC=0.0,VACC=0.0,TACC=0.0,
          C=5.0,0.025,0.8,6*0.0,0.0,1.0,1.3,1.44,1.92,0.09,
            0.42,9.8,0.01,0.07,1.0,1.0,1.0,1.3,0.09,6*0.0,
          KA=10*0,
          NC=7,NTFU=3, HCOND=1.30,   IOPT=0,0,0,1,1,0,0,0,0,0,20*0,
          RADIAL=0.0,0.00146,0.00175,0.00227,0.00235,0.003,0.0,
          Q=0.0,6.40E+09,5*0.0,
            QRAD=19*1.0,QAXIAL=0.0,8*1.0,0.0,
          DECH=0.0054694,0.0043237,0.0026566,AVHTF=0.993E+06,
          EPS=1.0E-10,0.2E-05,0.2E-07,1.0E-03,26*0.0,
         WDUC=0.0015,TOLTDU=1.0E-02,
         &END
 19 PINS HEXGONAL ROD BUNDLE WITH 1/12 SYMMETRY
 SAME GEOMETRY FOR GERMAN FLOW RUN DOWN EXPERIMENT(9/25/80)


**** JOB RESTARTED AFTER ITERATION   20 OF TIME STEP    3 *****


&SET
NTHPR=       1302,       1310,       2302,       2310,       3108,       3121,       3302,       3310,       5108,       5121,
       5301,       5310,       6108,       6121,      20302,      20310,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,ISTPR=       1302,       1310,       2302,
       2310,       3108,       3121,       3302,       3310,       5108,       5121,       5301,       5310,       6108,       6121,
      20302,      20310,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,NTPRNT=          4,         50,        300,        600,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,ITPRNT=
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
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        0.          0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
        0.          0.          0.          0.          0.          0.NTPLOT=         0.          0.          0.          0.
        0.          0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
        0.          0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
        0.          0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
        0.          0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
        0.          0.IT1=        10.IT2=         5.IT3=          3.ITSET=         50.SLIFR=  .0                ,KMAX=          10,
NSTEPS=        4.IBMAX=         0.IBVAX=         0.IBMSOL=        0.IBVSOL=        0.ICPSOL=        0.IBITER=        0,
IBLO=          8.IBHI=         21.JBLO=          1.JBHI=         21.KBLO=         10.IPRES=          1.KBHI=         10.DTD=
 .100000002E+21,VEL=  2.14999962    ,TENC=  553.000000    ,PENT=  2.00000000    ,TURBF=  1.00000000    ,TURBK=  1.00000000    ,GX=
 .0            ,DREF=  .421100110E-02,ISWEEP=          0,GY=  .0            ,GZ= -1.00000000    ,AO=  .500000000    ,BO=
 .0            ,EPS=  .999999944E-10,  .199999977E-05,  .200000017E-07,  .999999931E-03,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .0            ,  .0            ,  .0            ,NPORD=          2,FAC=  .600000024    ,  .600000024    ,  .600000024    ,
 .600000024    ,  1.00000000    ,  1.80000019    ,  1.00000000    ,  .500000000    ,  .500000000    ,  1.00000000    ,
 1.00000000    ,  1.00000000    ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
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 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
TOLENT=  .100000005E-03,TOLPRE=  .100000005E-03,XA=  .0            ,  .0            ,  .0            ,TOLVEL=  .999999931E-03,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
 .838900161E-01,  .177779973    ,  .266669989    ,  .355549991    ,  .444440007    ,  .0            ,ZA=  .0            ,
 .711109996    ,  .800000012    ,QDUL=  .0            ,  .0            ,  .0            ,  .533330023    ,  .622219980    ,
 .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,  .0            ,
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 .0          ,VACC=  .0          ,TACC=  .0          ,DECH=  1.29853575    , 1.02676201    , .630371356    ,KA=        0,
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        7,NTFU=        3,RADIAL=  .0          , .145999994E-02, .175000005E-02, .227000006E-02, .234999997E-02,
 .300000003E-02, .0          ,HCOND=  1.30000019    ,Q=  .0          , .640000000E+10, .0          , .0          ,
 .0          , .0          , .0          ,QRAD=  1.00000000    , 1.00000000    , 1.00000000    , 1.00000000    ,
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 1.00000000    ,QAXIAL=  .0          , 1.00000000    , 1.00000000    , 1.00000000    , 1.00000000    , 1.00000000    ,
 1.00000000    , 1.00000000    , 1.00000000    , .0          ,HDUC=  .150000001E-02,TOLTDU=  .100000016E-01
&END
 MAX. MASS RESIDUE AT    9    4    1 =  -1.04091557E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.43644822E-05
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*****    1  0.84513455E-04 -0.10466044E-03  0.13790131E-02 -0.33825391E-02  0.44364482E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.04044044E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.42452729E-05
*****    2  0.13022978E-03  0.19142429E-03 -0.15411377E-02 -0.18186569E-02  0.44245273E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.03570153E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.40701842E-05
*****    3  0.10661787E-03  0.16052794E-03 -0.12111664E-02 -0.13408661E-02  0.44070184E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.03474310E+21
 MAX. FRES CORREC. AT    8    2    1 =   4.41446900E-05
*****    4 -0.10385925E-03 -0.14014657E-03 -0.15359604E-02 -0.11053085E-02  0.44144690E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.03319162E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.41595912E-05
*****    5 -0.99994242E-04 -0.17535908E-03 -0.11253357E-02 -0.10108948E-02  0.44159591E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.02933063E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.35908209E-05
*****    6  0.77454373E-04  0.10934658E-03 -0.16107559E-02 -0.21924973E-02  0.43898321E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.02715117E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.38466668E-05
*****    7  0.85849009E-04 -0.94403193E-04  0.15263326E-02 -0.18091202E-02  0.43846667E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.02685315E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.37386334E-05
*****    8  0.12912441E-03  0.97457785E-04 -0.14925003E-02 -0.22420883E-02  0.43738633E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.02495566E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.33959067E-05
*****    9  0.13622755E-03  0.21697739E-03 -0.15544891E-02 -0.88024139E-03  0.43395907E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.02364117E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.32096422E-05
*****9.910990.10176748E-03  0.12301556E-03 -0.15687943E-02  0.14381409E-02  0.43209642E-04  0.0        0.0        *****

 MAX. MASS RESIDUE AT    9    4    1 =  -1.02300870E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.31798393E-05
*****    1  0.89725247E-04 -0.11198092E-03  0.15068054E-02  0.34141541E-02  0.43179840E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.02078617E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.29376960E-05
*****    2 -0.11420716E-03 -0.19529954E-03  0.15039444E-02  0.13656616E-02  0.42937696E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.01957076E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.27961349E-05
*****    3  0.10944880E-03  0.13286450E-03  0.14781952E-02 -0.13065338E-02  0.42796135E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.01756300E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.26992774E-05
*****    4  0.11828705E-03  0.19896672E-03  0.14820099E-02  0.12826920E-02  0.42699277E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.01532162E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.26173210E-05
*****    5  0.11163240E-03  0.16681559E-03  0.13685226E-02  0.74195862E-03  0.42617321E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.01343574E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.24981117E-05
*****    6 -0.13354401E-03 -0.16333732E-03  0.12512207E-02  0.80108643E-03  0.42498112E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.01189128E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.24124300E-05
*****    7  0.23034995E-03  0.32432657E-03 -0.15382767E-02  0.66280365E-03  0.42412430E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.00880744E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.24198806E-05
*****    8  0.10388577E-03  0.13969187E-03 -0.11806488E-02 -0.26378632E-02  0.42419831E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.00597017E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.23416495E-05
*****    9 -0.77651115E-04  0.10636114E-03 -0.14057159E-02 -0.12369156E-02  0.42341650E-04  0.0        0.0        *****
 MAX. MASS RESIDUE AT    9    4    1 =  -1.00369952E+21
 MAX. PRES CORREC. AT    8    2    1 =   4.22149397E-05
*****4.310160.16214626E-03  0.14322796E-03  0.14531680E-02  0.12683868E-02  0.42214990E-04  0.0        0.0        *****
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******************** BEGINNING OF OUTPUT FOR STEP 4 AT********* SECONDS, ITERATION 10********************

U VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
21	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11
20	-1.650E-03	2.887E-04	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-1.650E-03	2.887E-04	1.650E-03	-8.660E-11	-8.660E-11	-8.660E-11
19	-2.241E-03	4.407E-04	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-2.241E-03	4.407E-04	2.241E-03	-8.660E-11	-8.660E-11	-8.660E-11
18	-2.449E-03	4.648E-04	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-2.449E-03	4.648E-04	2.449E-03	-8.660E-11	-8.660E-11	-8.660E-11
17	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11
16	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
15	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
14	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	-9.959E-04	0.0	-9.959E-04	-5.797E-08	-9.959E-04	-5.797E-08	9.959E-04	-5.797E-08	9.959E-04	7.565E-04
11	0.0	0.0	-1.190E-03	0.0	-1.190E-03	5.948E-10	-1.190E-03	5.948E-10	1.190E-03	5.948E-10	1.190E-03	9.226E-04
10	0.0	0.0	-1.413E-03	0.0	-1.413E-03	1.096E-08	-1.413E-03	1.096E-08	1.413E-03	1.096E-08	1.413E-03	3.774E-04
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.650E-11	-8.660E-11
7	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
6	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	-3.352E-03	-2.244E-06	3.352E-03	6.358E-03	8.170E-03	8.344E-03
3	0.0	0.0	0.0	0.0	0.0	0.0	-3.437E-03	-1.143E-06	3.437E-03	7.034E-03	9.692E-03	1.100E-02
2	0.0	0.0	0.0	0.0	0.0	0.0	-2.568E-03	1.410E-06	2.568E-03	5.758E-03	8.438E-03	1.033E-02
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13	14	15	16	17	18	19	20	21
21	-8.660E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-8.660E-11
20	-8.660E-11	2.887E-04	1.650E-03	2.278E-03	1.650E-03	2.278E-03	2.040E-03	1.409E-03	-2.408E-05
19	-8.660E-11	4.407E-04	2.241E-03	3.020E-03	2.241E-03	3.020E-03	3.220E-03	2.167E-03	6.903E-04
18	-8.660E-11	4.648E-04	2.449E-03	2.941E-03	2.449E-03	2.941E-03	2.313E-03	3.523E-04	-1.465E-03
17	-8.660E-11	0.0	0.0	0.0	0.0	0.0	2.191E-04	-5.859E-04	-1.217E-03
16	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-2.873E-04	-7.418E-04	-1.186E-03
15	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	5.006E-04	1.744E-06	-3.688E-04
14	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	1.253E-03	8.819E-04	-3.290E-04
13	0.0	0.0	0.0	0.0	0.0	0.0	1.372E-03	1.005E-03	-6.925E-04
12	9.959E-04	7.565E-04	4.338E-04	8.640E-04	1.680E-03	1.982E-03	1.462E-03	-3.456E-04	-2.592E-03
11	1.190E-03	9.226E-04	5.916E-05	-1.809E-04	5.042E-04	1.179E-03	9.686E-04	-1.195E-03	-3.004E-03
10	1.413E-03	3.774E-04	-1.567E-03	-1.932E-03	-1.163E-03	2.766E-05	7.746E-04	-7.631E-04	-2.517E-03
9	0.0	0.0	-2.524E-03	-3.307E-03	-1.926E-03	0.0	0.0	0.0	-8.660E-11
8	-8.660E-11	0.0	-3.690E-03	-4.348E-03	-2.921E-03	0.0	-8.660E-11	-8.660E-11	-8.660E-11
7	-8.660E-11	0.0	-3.322E-03	-4.278E-03	-4.377E-03	0.0	-8.660E-11	-8.660E-11	-8.660E-11
6	-8.660E-11	0.0	-2.933E-03	-4.629E-03	-4.605E-03	0.0	-8.660E-11	-8.660E-11	-8.660E-11
5	0.0	0.0	-2.193E-03	-4.333E-03	-6.415E-03	0.0	0.0	0.0	-8.660E-11
4	7.333E-03	5.592E-03	1.263E-03	-5.242E-03	-1.036E-02	-1.077E-02	-8.839E-03	-4.088E-03	-6.806E-03
3	1.048E-02	7.123E-03	2.206E-03	-5.522E-03	-1.109E-02	-1.179E-02	-9.396E-03	-4.314E-03	-7.961E-03
2	1.043E-02	7.946E-03	2.591E-03	-4.073E-03	-8.928E-03	-9.749E-03	-7.360E-03	-3.290E-03	-7.039E-03
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-8.660E-11

U VELOCITY (NON DIMENSIONAL)

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
21	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11
20	-1.091E-06	6.768E-05	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-1.091E-06	6.768E-05	1.091E-06	-8.660E-11	-8.660E-11	-8.660E-11
19	4.621E-05	2.274E-05	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	4.621E-05	2.274E-05	-4.621E-05	-8.660E-11	-8.660E-11	-8.660E-11
18	6.221E-05	-2.180E-03	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	6.221E-05	-2.180E-05	-6.221E-05	-8.660E-11	-8.660E-11	-8.660E-11
17	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11
16	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
15	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
14	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	2.038E-04	0.0	2.038E-04	-1.215E-06	2.038E-04	-1.215E-06	-2.038E-04	-1.215E-06	-2.038E-04	-2.200E-04
11	0.0	0.0	2.574E-04	0.0	2.574E-04	-6.829E-08	2.574E-04	-6.829E-08	-2.574E-04	-6.829E-08	-2.574E-04	-1.476E-04
10	0.0	0.0	1.613E-04	0.0	1.613E-04	-3.018E-07	1.613E-04	-3.018E-07	-1.613E-04	-3.018E-07	-1.613E-04	-1.644E-04
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
7	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
6	0.0	0.0	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	-2.871E-05	3.570E-05	2.871E-05	-8.409E-05	-9.011E-05	-6.575E-05
3	0.0	0.0	0.0	0.0	0.0	0.0	-4.373E-05	-3.762E-06	4.373E-05	-8.377E-05	-3.383E-05	-7.653E-05
2	0.0	0.0	0.0	0.0	0.0	0.0	-2.364E-06	1.705E-06	2.364E-06	-4.771E-05	-3.461E-05	-1.205E-04
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13	14	15	16	17	18	19	20	21
21	-8.660E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-8.660E-11
20	-8.660E-11	6.768E-05	1.091E-06	-1.410E-04	1.091E-06	-1.410E-04	-2.129E-04	-2.041E-04	3.770E-05
19	-8.660E-11	2.274E-05	-4.621E-05	-2.373E-04	-4.621E-05	-2.373E-04	-2.335E-04	-2.578E-04	-1.632E-05
18	-8.660E-11	-2.180E-05	-6.221E-05	-1.215E-04	-6.221E-05	-1.215E-04	-6.693E-05	-8.092E-05	-1.627E-04
17	-8.660E-11	0.0	0.0	0.0	0.0	0.0	1.500E-04	2.120E-04	2.093E-04
16	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	1.476E-04	8.241E-05	6.342E-05
15	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	1.183E-04	-7.531E-05	-1.833E-04
14	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	-8.660E-11	0.0	-3.152E-05	-5.666E-05	-9.380E-05
13	0.0	0.0	0.0	0.0	0.0	0.0	-2.412E-04	-3.595E-04	-3.445E-04
12	-2.038E-04	-2.200E-04	-4.429E-04	-4.727E-04	-5.007E-04	-4.869E-04	-4.714E-04	-5.567E-04	-8.778E-04
11	-2.574E-04	-1.476E-04	-2.577E-04	-3.114E-04	-5.235E-04	-4.475E-04	-4.758E-04	-4.370E-04	-1.045E-03
10	-1.613E-04	-1.644E-04	7.942E-05	1.686E-04	-7.613E-05	-2.390E-04	-3.173E-04	-3.514E-04	-6.941E-04
9	0.0	0.0	3.011E-04	3.544E-04	2.834E-04	0.0	0.0	0.0	-8.660E-11
8	-8.660E-11	0.0	3.916E-04	5.069E-04	3.774E-04	0.0	-8.660E-11	-8.660E-11	-8.660E-11
7	-8.660E-11	0.0	2.754E-04	3.768E-04	2.962E-04	0.0	-8.660E-11	-8.660E-11	-8.660E-11
6	-8.660E-11	0.0	4.671E-05	2.552E-04	3.172E-04	0.0	-8.660E-11	-8.660E-11	-8.660E-11
5	0.0	0.0	-4.903E-05	2.566E-04	3.363E-04	0.0	0.0	0.0	-8.660E-11
4	-2.096E-04	-2.273E-04	-7.977E-05	2.555E-04	3.456E-04	1.574E-04	-5.294E-05	5.211E-05	4.215E-05
3	-2.081E-04	-2.392E-04	-2.765E-05	1.827E-04	2.899E-04	1.549E-04	-1.031E-04	4.735E-05	7.368E-05
2	-9.124E-05	-3.064E-04	-5.753E-05	1.227E-04	2.159E-04	1.275E-04	-1.188E-04	-9.910E-05	-2.329E-04
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-8.660E-11

V VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
21	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	0.0	0.0	5.000E-11	5.000E-11	5.000E-11
20	-9.625E-04	-1.001E-03	5.000E-11	5.000E-11	5.000E-11	5.000E-11	-9.625E-04	-1.001E-03	-9.625E-04	5.000E-11	5.000E-11	5.000E-11
19	-8.973E-04	-7.513E-04	5.000E-11	5.000E-11	5.000E-11	5.000E-11	-8.973E-04	-7.513E-04	-8.973E-04	5.000E-11	5.000E-11	5.000E-11
18	2.097E-04	1.099E-04	5.000E-11	5.000E-11	5.000E-11	5.000E-11	2.097E-04	1.099E-04	2.097E-04	5.000E-11	5.000E-11	5.000E-11
17	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	0.0	0.0	5.000E-11	5.000E-11	5.000E-11

J												
16	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
15	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
14	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	-7.911E-04	0.0	-7.911E-04	-7.213E-04	-7.911E-04	-7.213E-04	-7.911E-04	-7.213E-04	-7.911E-04	-8.341E-04
11	0.0	0.0	-6.176E-04	0.0	-6.176E-04	-4.625E-04	-6.176E-04	-4.625E-04	-6.176E-04	-4.625E-04	-6.176E-04	-5.393E-04
10	0.0	0.0	7.010E-05	0.0	7.010E-05	4.942E-04	7.010E-05	4.942E-04	7.010E-05	4.942E-04	7.010E-05	6.769E-04
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
7	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
6	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	2.048E-03	1.209E-03	2.048E-03	4.433E-03	7.038E-03	9.879E-03
3	0.0	0.0	0.0	0.0	0.0	0.0	1.868E-03	9.840E-04	1.868E-03	3.992E-03	6.816E-03	9.605E-03
2	0.0	0.0	0.0	0.0	0.0	0.0	8.706E-04	2.049E-04	8.706E-04	2.578E-03	4.643E-03	6.944E-03
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13	14	15	16	17	18	19	20	21
21	5.000E-11	0.0	0.0	0.0	0.0	0.0	1.000E-10	0.0	5.000E-11
20	5.000E-11	-1.001E-03	-9.625E-04	-9.775E-04	-9.625E-04	-9.775E-04	-1.205E-03	-5.952E-04	2.369E-03
19	5.000E-11	-7.513E-04	-8.973E-04	-1.093E-03	-8.973E-04	-1.093E-03	-1.052E-03	-4.658E-04	3.314E-03
18	5.000E-11	1.099E-04	2.097E-04	8.000E-05	2.097E-04	8.000E-05	3.562E-04	6.696E-05	-1.825E-03
17	5.000E-11	0.0	0.0	0.0	0.0	0.0	1.279E-03	1.124E-03	4.493E-04
16	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	1.536E-03	1.305E-03	1.017E-03
15	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	1.358E-04	2.604E-05	-3.651E-04
14	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	-1.103E-03	-6.012E-04	1.637E-03
13	0.0	0.0	0.0	0.0	0.0	0.0	7.470E-06	-1.478E-05	-1.184E-03
12	-7.911E-04	-8.341E-04	-8.157E-04	-5.401E-05	1.180E-03	2.144E-03	2.149E-03	1.032E-03	-1.918E-04
11	-6.176E-04	-5.393E-04	-1.805E-04	-1.705E-04	7.680E-04	2.183E-03	2.909E-03	2.189E-03	6.158E-04
10	7.010E-05	6.769E-04	2.648E-03	2.109E-03	1.088E-03	1.364E-03	2.460E-03	1.379E-03	5.590E-04
9	0.0	0.0	5.313E-03	4.737E-03	2.920E-03	0.0	1.000E-10	0.0	5.000E-11
8	5.000E-11	0.0	6.833E-03	7.452E-03	5.829E-03	0.0	5.000E-11	5.000E-11	5.000E-11
7	5.000E-11	0.0	6.885E-03	7.276E-03	6.531E-03	0.0	5.000E-11	5.000E-11	5.000E-11
6	5.000E-11	0.0	5.812E-03	6.836E-03	5.091E-03	0.0	5.000E-11	5.000E-11	5.000E-11
5	0.0	0.0	7.290E-03	6.145E-03	4.389E-03	0.0	1.000E-10	0.0	5.000E-11
4	9.825E-03	9.195E-03	1.009E-02	6.436E-03	2.227E-03	-1.578E-03	-2.756E-03	-8.580E-04	-6.277E-03
3	1.077E-02	9.595E-03	7.919E-03	4.330E-03	-7.559E-04	-3.549E-03	-3.768E-03	-1.760E-03	-6.253E-03
2	7.907E-03	6.933E-03	4.250E-03	3.918E-04	-2.900E-03	-4.349E-03	-3.873E-03	-2.083E-03	-4.435E-03
1	0.0	0.0	0.0	0.0	0.0	0.0	1.000E-10	0.0	5.000E-11

V VELOCITY (NON DIMENSIONAL)

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
21	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	0.0	0.0	5.000E-11	5.000E-11	5.000E-11
20	1.605E-04	2.383E-05	5.000E-11	5.000E-11	5.000E-11	5.000E-11	1.605E-04	2.383E-05	1.605E-04	5.000E-11	5.000E-11	5.000E-11
19	1.334E-04	5.451E-05	5.000E-11	5.000E-11	5.000E-11	5.000E-11	1.334E-04	5.451E-05	1.334E-04	5.000E-11	5.000E-11	5.000E-11
18	-2.970E-05	-1.319E-04	5.000E-11	5.000E-11	5.000E-11	5.000E-11	-2.970E-05	-1.319E-04	-2.970E-05	5.000E-11	5.000E-11	5.000E-11
17	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	0.0	0.0	5.000E-11	5.000E-11	5.000E-11
16	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
15	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
14	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	1.712E-04	0.0	1.712E-04	1.058E-04	1.712E-04	1.058E-04	1.712E-04	1.058E-04	1.712E-04	1.664E-04
11	0.0	0.0	1.233E-04	0.0	1.233E-04	1.272E-04	1.233E-04	1.272E-04	1.233E-04	1.272E-04	1.233E-04	6.837E-05
10	0.0	0.0	5.933E-05	0.0	5.933E-05	-1.560E-05	5.933E-05	-1.560E-05	5.933E-05	-1.560E-05	5.933E-05	-2.510E-06
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J												
8	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
7	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
6	0.0	0.0	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	-1.479E-04	-2.358E-04	-1.479E-04	-1.706E-04	-1.254E-04	-1.264E-04
3	0.0	0.0	0.0	0.0	0.0	0.0	-1.290E-04	-1.632E-04	-1.290E-04	-7.576E-05	-1.726E-04	-1.414E-04
2	0.0	0.0	0.0	0.0	0.0	0.0	3.592E-06	4.515E-05	3.592E-06	-7.937E-05	-5.541E-05	-6.272E-05
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13	14	15	16	17	18	19	20	21
21	5.000E-11	0.0	0.0	0.0	0.0	0.0	1.000E-10	0.0	5.000E-11
20	5.000E-11	2.383E-05	1.605E-04	1.445E-04	1.605E-04	1.445E-04	1.665E-04	3.123E-05	-2.676E-04
19	5.000E-11	5.451E-05	1.334E-04	1.721E-04	1.334E-04	1.721E-04	1.160E-04	2.446E-05	-2.602E-04
18	5.000E-11	-1.319E-04	-2.970E-05	-1.343E-04	-2.970E-05	-1.343E-04	-1.492E-04	-2.032E-04	1.664E-05
17	5.000E-11	0.0	0.0	0.0	0.0	0.0	-3.402E-04	-1.956E-04	2.447E-04
16	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	-3.435E-04	-2.669E-04	2.933E-04
15	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	-2.857E-04	-2.301E-04	2.453E-04
14	5.000E-11	5.000E-11	5.000E-11	5.000E-11	5.000E-11	0.0	-9.011E-05	-1.908E-04	1.776E-05
13	0.0	0.0	0.0	0.0	0.0	0.0	-2.585E-04	-1.468E-04	-7.963E-05
12	1.712E-04	1.664E-04	-6.295E-05	-4.088E-04	-6.697E-04	-7.122E-04	-7.414E-04	-3.951E-04	-3.753E-05
11	1.233E-04	6.839E-05	-1.505E-04	-4.927E-04	-6.821E-04	-7.571E-04	-9.318E-04	-6.445E-04	5.385E-05
10	5.933E-05	-2.510E-06	-3.109E-04	-5.294E-04	-6.633E-04	-6.179E-04	-6.182E-04	-5.561E-04	3.433E-05
9	0.0	0.0	-6.031E-04	-4.947E-04	-4.470E-04	0.0	1.000E-10	0.0	5.000E-11
8	5.000E-11	0.0	-6.815E-04	-6.834E-04	-4.447E-04	0.0	5.000E-11	5.000E-11	5.000E-11
7	5.000E-11	0.0	-4.221E-04	-4.654E-04	-4.449E-04	0.0	5.000E-11	5.000E-11	5.000E-11
6	5.000E-11	0.0	-3.293E-04	-2.461E-04	-1.443E-04	0.0	5.000E-11	5.000E-11	5.000E-11
5	0.0	0.0	-7.146E-05	-7.525E-05	1.364E-04	0.0	1.000E-10	0.0	5.000E-11
4	-2.958E-04	-3.747E-04	-4.006E-04	-1.927E-04	8.814E-05	7.326E-05	-1.811E-05	-5.334E-05	3.679E-05
3	-3.163E-04	-1.931E-04	-3.222E-04	-2.297E-04	-2.113E-05	1.405E-04	-2.267E-05	-6.467E-05	8.227E-05
2	-1.789E-04	-1.875E-04	-1.371E-04	-2.330E-04	1.117E-04	2.104E-04	1.566E-04	8.100E-05	-2.269E-04
1	0.0	0.0	0.0	0.0	0.0	0.0	1.000E-10	0.0	5.000E-11

W VELOCITY (NON DIMENSIONAL)

I= 8

J \ K-->	1	2	3	4	5	6	7	8	9	10
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	1.257E+00	1.116E+00	1.091E+00	1.083E+00	1.082E+00	1.083E+00	1.087E+00	1.093E+00	1.099E+00	1.104E+00
19	1.257E+00	1.348E+00	1.327E+00	1.324E+00	1.318E+00	1.322E+00	1.324E+00	1.333E+00	1.339E+00	1.345E+00
18	1.257E+00	1.206E+00	1.177E+00	1.176E+00	1.169E+00	1.174E+00	1.174E+00	1.183E+00	1.188E+00	1.193E+00
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.257E+00	1.154E+00	1.137E+00	1.130E+00	1.133E+00	1.136E+00	1.142E+00	1.150E+00	1.155E+00	1.161E+00
11	1.257E+00	1.369E+00	1.359E+00	1.357E+00	1.357E+00	1.362E+00	1.367E+00	1.377E+00	1.384E+00	1.390E+00
10	1.257E+00	1.214E+00	1.196E+00	1.196E+00	1.195E+00	1.200E+00	1.203E+00	1.213E+00	1.218E+00	1.223E+00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.257E+00	6.532E-01	4.738E-01	4.677E-01	4.482E-01	4.612E-01	4.555E-01	4.639E-01	4.645E-01	4.650E-01
3	1.257E+00	7.872E-01	5.782E-01	5.669E-01	5.452E-01	5.592E-01	5.529E-01	5.625E-01	5.637E-01	5.650E-01
2	1.257E+00	7.060E-01	5.193E-01	5.080E-01	4.895E-01	5.012E-01	4.960E-01	5.043E-01	5.053E-01	5.064E-01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

W VELOCITY (NON DIMENSIONAL)

I= 21

J \ K-->	1	2	3	4	5	6	7	8	9	10
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	1.257E+00	1.226E+00	1.255E+00	1.245E+00	1.258E+00	1.251E+00	1.262E+00	1.267E+00	1.274E+00	1.281E+00
19	1.257E+00	1.557E+00	1.615E+00	1.623E+00	1.631E+00	1.631E+00	1.640E+00	1.649E+00	1.658E+00	1.667E+00
18	1.257E+00	1.590E+00	1.658E+00	1.675E+00	1.682E+00	1.687E+00	1.694E+00	1.705E+00	1.714E+00	1.723E+00
17	1.257E+00	1.377E+00	1.403E+00	1.411E+00	1.417E+00	1.421E+00	1.429E+00	1.438E+00	1.446E+00	1.454E+00
16	1.257E+00	1.247E+00	1.236E+00	1.237E+00	1.238E+00	1.241E+00	1.247E+00	1.254E+00	1.262E+00	1.269E+00
15	1.257E+00	1.181E+00	1.155E+00	1.151E+00	1.147E+00	1.150E+00	1.153E+00	1.162E+00	1.168E+00	1.174E+00
14	1.257E+00	1.240E+00	1.235E+00	1.230E+00	1.229E+00	1.229E+00	1.234E+00	1.243E+00	1.250E+00	1.256E+00
13	1.257E+00	1.345E+00	1.373E+00	1.376E+00	1.380E+00	1.379E+00	1.388E+00	1.397E+00	1.405E+00	1.412E+00
12	1.257E+00	1.526E+00	1.573E+00	1.583E+00	1.593E+00	1.593E+00	1.602E+00	1.612E+00	1.620E+00	1.623E+00
11	1.257E+00	1.524E+00	1.560E+00	1.567E+00	1.576E+00	1.578E+00	1.586E+00	1.596E+00	1.605E+00	1.613E+00
10	1.257E+00	1.226E+00	1.228E+00	1.226E+00	1.235E+00	1.234E+00	1.242E+00	1.249E+00	1.255E+00	1.262E+00
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5.000E-11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.257E+00	6.820E-01	5.768E-01	5.645E-01	5.530E-01	5.627E-01	5.586E-01	5.673E-01	5.687E-01	5.701E-01
3	1.257E+00	7.630E-01	6.318E-01	6.175E-01	6.035E-01	6.146E-01	6.094E-01	6.190E-01	6.203E-01	6.225E-01
2	1.257E+00	6.376E-01	5.153E-01	5.048E-01	4.917E-01	5.020E-01	4.971E-01	5.054E-01	5.067E-01	5.080E-01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

W VELOCITY (NON DIMENSIONAL)

K= 2

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	1.137E+00	1.116E+00	0.0	0.0	0.0	0.0	1.137E+00	1.116E+00	1.137E+00	0.0	0.0	0.0
19	1.389E+00	1.348E+00	0.0	0.0	0.0	0.0	1.389E+00	1.348E+00	1.389E+00	0.0	0.0	0.0
18	1.270E+00	1.206E+00	0.0	0.0	0.0	0.0	1.270E+00	1.206E+00	1.270E+00	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.257E+00	1.257E+00	1.202E+00	1.257E+00	1.202E+00	1.154E+00	1.202E+00	1.154E+00	1.202E+00	1.154E+00	1.202E+00	1.270E+00
11	1.257E+00	1.257E+00	1.437E+00	1.257E+00	1.437E+00	1.369E+00	1.437E+00	1.369E+00	1.437E+00	1.369E+00	1.437E+00	1.564E+00
10	1.257E+00	1.257E+00	1.295E+00	1.257E+00	1.295E+00	1.214E+00	1.295E+00	1.214E+00	1.295E+00	1.214E+00	1.295E+00	1.436E+00
9	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	6.083E-01	6.532E-01	6.083E-01	5.425E-01	5.907E-01	7.662E-01
3	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	7.385E-01	7.872E-01	7.385E-01	6.472E-01	6.705E-01	8.372E-01
2	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	6.661E-01	7.060E-01	6.661E-01	5.722E-01	5.675E-01	6.893E-01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

I--> 13 14 15 16 17 18 19 20 21

J

21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	1.116E+00	1.137E+00	1.183E+00	1.137E+00	1.183E+00	1.226E+00	1.246E+00	1.226E+00
19	0.0	1.348E+00	1.389E+00	1.472E+00	1.389E+00	1.472E+00	1.557E+00	1.594E+00	1.557E+00
18	0.0	1.206E+00	1.270E+00	1.386E+00	1.270E+00	1.386E+00	1.598E+00	1.655E+00	1.598E+00
17	0.0	0.0	0.0	0.0	0.0	0.0	1.377E+00	1.579E+00	1.377E+00
16	0.0	0.0	0.0	0.0	0.0	0.0	1.247E+00	1.440E+00	1.247E+00
15	0.0	0.0	0.0	0.0	0.0	0.0	1.181E+00	1.368E+00	1.181E+00
14	0.0	0.0	0.0	0.0	0.0	0.0	1.240E+00	1.434E+00	1.240E+00
13	0.0	0.0	0.0	0.0	0.0	0.0	1.345E+00	1.562E+00	1.345E+00
12	1.202E+00	1.270E+00	1.267E+00	1.209E+00	1.188E+00	1.268E+00	1.526E+00	1.661E+00	1.526E+00
11	1.437E+00	1.564E+00	1.620E+00	1.530E+00	1.410E+00	1.411E+00	1.524E+00	1.596E+00	1.524E+00
10	1.295E+00	1.436E+00	1.725E+00	1.630E+00	1.341E+00	1.148E+00	1.226E+00	1.292E+00	1.226E+00
9	0.0	0.0	1.487E+00	1.572E+00	1.243E+00	0.0	0.0	0.0	0.0
8	0.0	0.0	1.286E+00	1.449E+00	1.223E+00	0.0	0.0	0.0	0.0
7	0.0	0.0	1.213E+00	1.393E+00	1.197E+00	0.0	0.0	0.0	0.0
6	0.0	0.0	1.303E+00	1.499E+00	1.292E+00	0.0	0.0	0.0	0.0
5	0.0	0.0	1.452E+00	1.630E+00	1.353E+00	0.0	0.0	0.0	0.0
4	1.017E+00	1.279E+00	1.602E+00	1.665E+00	1.393E+00	9.646E-01	6.820E-01	5.602E-01	6.820E-01
3	1.097E+00	1.366E+00	1.556E+00	1.566E+00	1.366E+00	1.054E+00	7.630E-01	6.456E-01	7.630E-01
2	9.058E-01	1.135E+00	1.272E+00	1.259E+00	1.100E+00	8.649E-01	6.376E-01	5.536E-01	6.376E-01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

W VELOCITY (NON DIMENSIONAL)

K= 10

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	1.138E+00	1.104E+00	0.0	0.0	0.0	0.0	1.138E+00	1.104E+00	1.138E+00	0.0	0.0	0.0
19	1.408E+00	1.345E+00	0.0	0.0	0.0	0.0	1.408E+00	1.345E+00	1.408E+00	0.0	0.0	0.0
18	1.281E+00	1.193E+00	0.0	0.0	0.0	0.0	1.281E+00	1.193E+00	1.281E+00	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1.257E+00	1.257E+00	1.236E+00	1.257E+00	1.236E+00	1.161E+00	1.236E+00	1.161E+00	1.236E+00	1.161E+00	1.236E+00	1.344E+00
11	1.257E+00	1.257E+00	1.492E+00	1.257E+00	1.492E+00	1.390E+00	1.492E+00	1.390E+00	1.492E+00	1.390E+00	1.492E+00	1.682E+00
10	1.257E+00	1.257E+00	1.333E+00	1.257E+00	1.333E+00	1.223E+00	1.333E+00	1.223E+00	1.333E+00	1.223E+00	1.333E+00	1.600E+00
9	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1.257E+00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	4.313E-01	4.650E-01	4.313E-01	3.906E-01	4.684E-01	7.012E-01
3	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	5.266E-01	5.650E-01	5.266E-01	4.620E-01	5.149E-01	7.382E-01
2	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	1.257E+00	4.745E-01	5.064E-01	4.745E-01	4.048E-01	4.226E-01	5.822E-01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

J \ I-->	13	14	15	16	17	18	19	20	21
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	1.104E+00	1.138E+00	1.211E+00	1.138E+00	1.211E+00	1.281E+00	1.309E+00	1.281E+00
19	0.0	1.345E+00	1.408E+00	1.537E+00	1.408E+00	1.537E+00	1.667E+00	1.721E+00	1.667E+00
18	0.0	1.193E+00	1.281E+00	1.445E+00	1.281E+00	1.445E+00	1.723E+00	1.837E+00	1.723E+00
17	0.0	0.0	0.0	0.0	0.0	0.0	1.454E+00	1.637E+00	1.454E+00
16	0.0	0.0	0.0	0.0	0.0	0.0	1.269E+00	1.477E+00	1.269E+00
15	0.0	0.0	0.0	0.0	0.0	0.0	1.174E+00	1.371E+00	1.174E+00
14	0.0	0.0	0.0	0.0	0.0	0.0	1.256E+00	1.465E+00	1.256E+00

13	0.0	0.0	0.0	0.0	0.0	0.0	1.412E+00	1.653E+00	1.412E+00
12	1.236E+00	1.344E+00	1.333E+00	1.234E+00	1.194E+00	1.298E+00	1.628E+00	1.801E+00	1.628E+00
11	1.492E+00	1.683E+00	1.767E+00	1.621E+00	1.440E+00	1.439E+00	1.613E+00	1.724E+00	1.613E+00
10	1.333E+00	1.606E+00	1.926E+00	1.787E+00	1.395E+00	1.148E+00	1.262E+00	1.368E+00	1.262E+00
9	0.0	0.0	1.630E+00	1.730E+00	1.323E+00	0.0	0.0	0.0	0.0
8	0.0	0.0	1.335E+00	1.528E+00	1.279E+00	0.0	0.0	0.0	0.0
7	0.0	0.0	1.214E+00	1.408E+00	1.202E+00	0.0	0.0	0.0	0.0
6	0.0	0.0	1.338E+00	1.557E+00	1.339E+00	0.0	0.0	0.0	0.0
5	0.0	0.0	1.588E+00	1.810E+00	1.476E+00	0.0	0.0	0.0	0.0
4	1.048E+00	1.4[illegible]E+00	1.857E+00	1.929E+00	1.553E+00	9.415E-01	5.701E-01	4.170E-01	5.701E-01
3	1.107E+00	1.513E+00	1.805E+00	1.809E+00	1.489E+00	1.004E+00	6.225E-01	4.822E-01	6.225E-01
2	8.798E-01	1.221E+00	1.433E+00	1.403E+00	1.152E+00	7.941E-01	5.080E-01	4.090E-01	5.080E-01
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TEMPERATURE (NON DIMENSIONAL) T

I= 8

J \ K-->	1	2	3	4	5	6	7	8	9	10
21	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
20	1.200151	1.071063	1.061174	1.059826	1.064252	1.075438	1.092707	1.114895	1.139970	1.165045
19	1.114569	1.066092	1.057792	1.056526	1.060905	1.071994	1.089130	1.111142	1.136115	1.161088
18	1.073759	1.062664	1.057465	1.056633	1.061021	1.071984	1.088979	1.110795	1.135680	1.160565
17	1.058384	1.063726	1.060687	1.060337	1.064873	1.075894	1.092876	1.114632	1.139559	1.164496
16	1.264074	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409
15	1.264074	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409
14	1.264074	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409
13	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
12	0.960320	0.983936	1.001313	1.018221	1.035513	1.054331	1.075068	1.097941	1.122569	1.147197
11	0.960298	0.980362	0.997618	1.014479	1.031767	1.050565	1.071258	1.094075	1.118668	1.143260
10	0.960281	0.980107	0.997363	1.014199	1.031503	1.050287	1.070992	1.093790	1.118377	1.142963
9	0.960273	0.983838	1.001231	1.018068	1.035436	1.054276	1.075044	1.097909	1.122577	1.147244
8	1.264074	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409
7	1.264074	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409
6	1.264074	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409
5	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
4	0.960957	0.992034	1.023220	1.050327	1.077647	1.104280	1.132318	1.160509	1.189331	1.218252
3	0.961022	0.988995	1.020083	1.047270	1.074576	1.101268	1.129294	1.157405	1.186292	1.215178
2	0.961314	0.987103	1.018145	1.045363	1.072651	1.099383	1.127407	1.155535	1.184299	1.213064
1	0.960954	0.986447	1.017388	1.044599	1.071917	1.098621	1.126683	1.154839	1.183561	1.212284

TEMPERATURE (NON DIMENSIONAL) T

I= 21

J \ K-->	1	2	3	4	5	6	7	8	9	10
21	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
20	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
19	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
18	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
17	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
16	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
15	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
14	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
13	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
12	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418

11	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
10	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
9	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
8	1.264074	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409
7	1.264074	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409
6	1.264074	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409
5	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
4	0.960125	0.988629	1.917372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
3	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
2	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418
1	0.960125	0.988629	1.017372	1.046344	1.075543	1.104959	1.134581	1.164401	1.194409	1.224418

TEMPERATURE (NON DIMENSIONAL) T

K= 1

J \ I-->	1	2	3	4	5	6	7	8	9	10	11	12
21	0.960125	0.960125	1.264074	1.264074	1.264074	1.264074	0.960125	0.960125	0.960125	1.264074	1.264074	1.264074
20	1.200151	1.200151	1.264074	1.264074	1.264074	1.264074	1.200151	1.200151	1.117414	1.264074	1.264074	1.264074
19	1.114569	1.114569	1.264074	1.264074	1.264074	1.264074	1.114569	1.114569	1.033371	1.264074	1.264074	1.264074
18	1.073759	1.073759	1.264074	1.264074	1.264074	1.264074	1.073759	1.073759	1.056209	1.264074	1.264074	1.264074
17	1.058334	1.058334	1.264074	1.264074	1.264074	1.264074	1.058334	1.058334	1.040740	1.264074	1.264074	1.264074
16	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074
15	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074
14	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074
13	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
12	0.960125	0.960125	0.960320	0.960125	0.960320	0.960320	0.960320	0.960320	0.960403	0.960320	0.960403	0.960551
11	0.960125	0.960125	0.960298	0.960125	0.960298	0.960298	0.960298	0.960293	0.960345	0.960293	0.960345	0.960431
10	0.960125	0.960125	0.960281	0.960125	0.960281	0.960281	0.960281	0.960281	0.960309	0.960281	0.960309	0.960350
9	0.960125	0.960125	0.960273	0.960125	0.960273	0.960273	0.960273	0.960273	0.960286	0.960273	0.960286	0.960295
8	0.960125	0.960125	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074
7	0.960125	0.960125	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074
6	0.960125	0.960125	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074	1.264074
5	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
4	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960957	0.960957	0.960678	0.960395	0.960773	0.960525
3	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.961022	0.961022	0.960499	0.960593	0.960559	0.960606
2	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.961314	0.961314	0.961109	0.960934	0.960883	0.960640
1	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960954	0.960954	0.960919	0.960914	0.960907	0.960633

J \ I-->	13	14	15	16	17	18	19	20	21
21	1.264074	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125	0.960125
20	1.264074	1.200151	1.117414	1.078656	1.117414	1.078656	1.062436	1.062436	0.960125
19	1.264074	1.114569	1.033371	1.061515	1.033371	1.061515	1.050219	1.050219	0.960125
18	1.264074	1.073759	1.056209	1.041519	1.056209	1.041519	1.033152	1.033152	0.960125
17	1.264074	1.058334	1.040740	1.022373	1.040740	1.022373	1.015254	1.015254	0.960125
16	1.264074	1.264074	1.264074	1.264074	1.264074	1.001875	0.999561	0.999561	0.960125
15	1.264074	1.264074	1.264074	1.264074	1.264074	0.987236	0.986338	0.986338	0.960125
14	1.264074	1.264074	1.264074	1.264074	1.264074	0.976293	0.976308	0.976308	0.960125
13	0.960125	0.960125	0.960125	0.960125	0.960125	0.969425	0.969710	0.969710	0.960125
12	0.960403	0.960551	0.960963	0.961724	0.963015	0.965129	0.965835	0.965835	0.960125
11	0.960345	0.960431	0.960697	0.961160	0.961936	0.963015	0.963779	0.963779	0.960125
10	0.960309	0.960350	0.960495	0.960834	0.961334	0.962146	0.962833	0.962833	0.960125
9	0.960286	0.960295	0.960363	0.960575	0.960937	0.961643	0.962483	0.962483	0.960125
8	1.264074	0.960262	0.960279	0.960339	0.960480	0.960125	1.264074	1.264074	1.264074
7	1.264074	0.960222	0.960224	0.960233	0.960255	0.960125	1.264074	1.264074	1.264074
6	1.264074	0.960214	0.960210	0.960204	0.960205	0.960125	1.264074	1.264074	1.264074
5	0.960125	0.960222	0.960211	0.960206	0.960220	0.960125	0.960125	0.960125	0.960125
4	0.960345	0.960261	0.960225	0.960227	0.960289	0.960409	0.960604	0.960604	0.960125

3	0.960338	0.960286	0.960239	0.960250	0.960318	0.960439	0.960626	0.960626	0.960125
2	0.960401	0.960294	0.960252	0.960259	0.960322	0.960377	0.960630	0.960630	0.960125
1	0.960407	0.960299	0.960259	0.960269	0.960343	0.960396	0.960622	0.960622	0.960125

TEMPERATURE (NON DIMENSIONAL)   T

K= 10

I--> J	1	2	3	4	5	6	7	8	9	10	11	12
21	1.224418	1.224418	1.194409	1.194409	1.194409	1.194409	1.224418	1.224418	1.224418	1.194409	1.194409	1.194409
20	1.165045	1.165045	1.194409	1.194409	1.194409	1.194409	1.165045	1.165045	1.164501	1.194409	1.194409	1.194409
19	1.161088	1.161088	1.194409	1.194409	1.194409	1.194409	1.161088	1.161088	1.160054	1.194409	1.194409	1.194409
18	1.160565	1.160565	1.194409	1.194409	1.194409	1.194409	1.160565	1.160565	1.158803	1.194409	1.194409	1.194409
17	1.164496	1.164496	1.194409	1.194409	1.194409	1.194409	1.164496	1.164496	1.162695	1.194409	1.194409	1.194409
16	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409
15	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409
14	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409
13	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418
12	1.224418	1.224418	1.147197	1.224418	1.147197	1.147197	1.147197	1.147197	1.145721	1.147197	1.145721	1.145202
11	1.224418	1.224418	1.143260	1.224418	1.143260	1.143260	1.143260	1.143260	1.141518	1.143260	1.141518	1.140194
10	1.224418	1.224418	1.142963	1.224418	1.142963	1.142963	1.142963	1.142963	1.140672	1.142963	1.140672	1.138013
9	1.224418	1.224418	1.147244	1.224418	1.147244	1.147244	1.147244	1.147244	1.145554	1.147244	1.145554	1.140437
8	1.224418	1.224418	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409
7	1.224418	1.224418	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409
6	1.224418	1.224418	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409	1.194409
5	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418
4	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.218252	1.218252	1.213257	1.201478	1.185334	1.169924
3	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.215178	1.215178	1.211411	1.201342	1.186069	1.169913
2	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.213064	1.213064	1.210209	1.201825	1.187643	1.171234
1	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.212284	1.212284	1.210492	1.203150	1.189267	1.173139

I--> J	13	14	15	16	17	18	19	20	21
21	1.194409	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418	1.224418
20	1.194409	1.165045	1.164501	1.163610	1.164501	1.163610	1.162974	1.162974	1.224418
19	1.194409	1.161088	1.160054	1.158627	1.160054	1.158627	1.157557	1.157557	1.224418
18	1.194409	1.160565	1.158803	1.156325	1.158803	1.156325	1.154306	1.154306	1.224418
17	1.194409	1.164496	1.162695	1.157962	1.162695	1.157962	1.153646	1.153646	1.224418
16	1.194409	1.194409	1.194409	1.194409	1.194409	1.158816	1.154092	1.154092	1.224418
15	1.194409	1.194409	1.194409	1.194409	1.194409	1.158047	1.153577	1.153577	1.224418
14	1.194409	1.194409	1.194409	1.194409	1.194409	1.155332	1.151340	1.151340	1.224418
13	1.224418	1.224418	1.224418	1.224418	1.224418	1.151248	1.146966	1.146966	1.224418
12	1.145721	1.145202	1.146165	1.147845	1.148351	1.146873	1.143030	1.143030	1.224418
11	1.141518	1.140194	1.140689	1.142440	1.143609	1.142082	1.141153	1.141153	1.224418
10	1.140672	1.138013	1.137670	1.140030	1.142871	1.143599	1.142834	1.142834	1.224418
9	1.145554	1.140437	1.137616	1.139790	1.145205	1.147609	1.147373	1.147373	1.224418
8	1.194409	1.145418	1.140222	1.140831	1.145395	1.224418	1.194409	1.194409	1.194409
7	1.194409	1.147626	1.143205	1.143192	1.147031	1.224418	1.194409	1.194409	1.194409
6	1.194409	1.148460	1.143997	1.143883	1.148061	1.224418	1.194409	1.194409	1.194409
5	1.224418	1.148344	1.142745	1.142533	1.148244	1.224418	1.224418	1.224418	1.224418
4	1.159171	1.148600	1.141578	1.141882	1.149636	1.158311	1.168369	1.168369	1.224418
3	1.156611	1.146814	1.140902	1.141493	1.148035	1.156866	1.165876	1.165876	1.224418
2	1.156912	1.146733	1.141346	1.142013	1.147964	1.156478	1.164522	1.164522	1.224418
1	1.158134	1.147513	1.142310	1.143079	1.148751	1.156753	1.163791	1.163791	1.224418

PRESSURE (NON DIMENSIONAL)   P

```
   I=  8
   K-->   1          2          3          4          5          6          7          8          9          10
 J
21    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
20    -6.818E-04-2.066E+00-3.890E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
19    -9.389E-04-2.066E+00-3.890E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
18    -1.305E-03-2.066E+00-3.891E+00-5.728E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
17    -9.972E-04-2.066E+00-3.891E+00-5.728E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
16     1.224E+00 0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01
15     1.224E+00 0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01
14     1.224E+00 0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01
13    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
12    -1.393E-03-2.065E+00-3.890E+00-5.729E+00-7.482E+00-9.271E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
11    -1.781E-03-2.065E+00-3.890E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
10    -2.067E-03-2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 9    -1.542E-03-2.065E+00-3.890E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 8     1.224E+00 0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01
 7     1.224E+00 0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.370E+00-1.104E+01-1.282E+01-1.457E+01
 6     1.224E+00 0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01
 5    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 4     4.757E-03-2.064E+00-3.892E+00-5.728E+00-7.483E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 3     5.490E-03-2.064E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 2     5.717E-03-2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 1     5.268E-03-2.064E+00-3.892E+00-5.728E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01


                              PRESSURE (NON DIMENSIONAL)     ?

   I= 21
   K-->   1          2          3          4          5          6          7          8          9          10
 J
21    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
20    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
19    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
18    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
17    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
16    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
15    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
14    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
13    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
12    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
11    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
10    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 9    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 8     1.224E+00 0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01
 7     1.224E+00 0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01
 6     1.224E+00 0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01
 5    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 4    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 3    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 2    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
 1    0.0       -2.065E+00-3.891E+00-5.729E+00-7.482E+00-9.270E+00-1.104E+01-1.282E+01-1.457E+01-1.632E+01
FUEL PIN TEMPERATURE IN ((TCL(I,K,NPQ),I=1,NC),K=LL1,LL2)
  0.825116E+03  0.825116E+03  0.751165E+03  0.670409E+03  0.654996E+03  0.641349E+03  0.628329E+03
  0.825116E+03  0.825116E+03  0.751165E+03  0.670409E+03  0.654996E+03  0.641349E+03  0.628329E+03
  0.774497E+03  0.774497E+03  0.700545E+03  0.619790E+03  0.604377E+03  0.590729E+03  0.578185E+03
  0.766610E+03  0.766611E+03  0.692659E+03  0.611903E+03  0.596490E+03  0.582843E+03  0.570325E+03
  0.766610E+03  0.766611E+03  0.692659E+03  0.611903E+03  0.596490E+03  0.582843E+03  0.570325E+03
  0.761384E+03  0.761385E+03  0.687433E+03  0.606678E+03  0.591265E+03  0.577616E+03  0.567010E+03
```

```
 0.767316E+03  0.767316E+03  0.693365E+03  0.612607E+03  0.597197E+03  0.583549E+03  0.575945E+03
 0.761384E+03  0.761385E+03  0.687433E+03  0.606678E+03  0.591265E+03  0.577610E+03  0.567010E+03
 0.766610E+03  0.766611E+03  0.692659E+03  0.611903E+03  0.596490E+03  0.582843E+03  0.570325E+03
 0.774497E+03  0.774497E+03  0.700545E+03  0.619790E+03  0.604377E+03  0.590729E+03  0.578135E+03
FUEL PIN TEMPERATURE IN ((TCL(I,K,MPQ),I=1,NC),K=LL1,LL2)
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.723132E+03
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.723132E+03
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.712561E+03
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.709654E+03
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.709654E+03
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.714593E+03
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.762016E+03
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.714693E+03
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.709654E+03
 0.568436E-13  0.568435E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.568434E-13  0.712561E+03

********************       END OF OUTPUT FOR STEP     4 AT********* SECONDS, ITERATION    10********************



********** RESTARY TAPE WRITTEN **********
```

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