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COMMIX-1B: A THREE-DIMENSIONAL TRANSIENT SINGLE-PHASE COMPUTER PROGRAM FOR THERMAL HYDRAULIC ANALYSIS OF SINGLE AND MULTICOMPONENT SYSTEMS

VOLUME II: USER'S MANUAL

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ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

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Analytical Thermal Hydraulic Research Program
Components Technology Division

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LIST OF CONTRIBUTORS

A large number of people have contributed to the development of the COMMIX code and to the preparation of this report. Since it was a team effort, there was considerable overlap in the areas of responsibility and contribution. The participants are listed below according to their area of primary activity.

Report compilation and project control	:	V. L. Shah
COMMIX-1A base	:	H. M. Domanus, R. C. Schmitt, W. T. Sha, and V. L. Shah
Code architecture and methods	:	H. M. Domanus, R. C. Schmitt, and F. F. Chen
Turbulence modeling	:	F. F. Chen
Skew-upwind differencing option	:	C. C. Miao and F. F. Chen
Code development and programming	:	H. M. Domanus, R. C. Schmitt, F. F. Chen, and C. C. Miao
Overall project directon and management	:	W. T. Sha

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ABSTRACT

The COMMIX-1B computer program is an extended version of COMMIX-1A with three major additions: (1) three more turbulence-model options for the computation of turbulent diffusivities, (2) a volume-weighted skew-upwind difference scheme to reduce numerical diffusion, and (3) a single formulation to combine semi-implicit and fully implicit solution procedures.

COMMIX-1B solves the conservation equations of mass, momentum, and energy, and transport equations of turbulence parameters. It is designed to perform steady-state/transient, single-phase, three-dimensional analysis of fluid flow with heat transfer in a single component or a multicomponent system. The program is developed for the analysis of heat transfer and fluid flow processes in a nuclear reactor system. However, it is designed in a generalized fashion such that with no or minimal modification, it can be used to analyze processes in any engineering equipment, or in any system.

An extension from COMMIX-1A to COMMIX-1B has been performed without altering the original format and structure of COMMIX-1A. Consequently, a COMMIX-1A user can run a COMMIX-1A problem on the COMMIX-1B version without any difficulty or changes in the input.

Volume I (Equations and Numerics) of this report describes in detail the capabilities, unique features, basic equations, formulations, solution procedures, rebalancing scheme, and models to describe the auxiliary phenomena. Volume II (User's Manual) contains the input instruction, sample problems, flow charts, and description of available options and boundary conditions.

FIN No.	TITLE
A2045	3-D Time-Dependent Code Development

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FIGURES (Contd.)

FIGURES (Contd.)

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EXECUTIVE SUMMARY

The COMMIX (**COM**ponent **MIX**ing) codes are designed for analyzing heat transfer and fluid flow. The COMMIX-1B computer program--an extended version of COMMIX-1A--is designed to analyze steady-state/transient, single-phase, three-dimensional compressible/incompressible flow with heat transfer in a reactor component/multicomponent system.

The three major changes that have been implemented in COMMIX-1A to develop COMMIX-1B are the following.

- Addition of three turbulence models to provide more options in the computation of turbulent diffusivities,
- Addition of a new volume-weighted skew-upwind difference scheme to reduce numerical diffusion, and
- Combination of semi-implicit and fully implicit solution procedures into one single formulation.

The COMMIX code provides detailed local velocity and temperature fields for the problems under consideration. The conservation equations of mass, momentum, and energy, and transport equations of turbulence parameters are solved as a boundary value problem in space and an initial value problem in time. The discretization equations are obtained by integrating the conservation equations over a control volume.

The code has a wide range of applicability. It is capable of solving thermal-hydraulic problems involving either a single component, such as a rod bundle, reactor plenum, piping system, heat exchanger, etc., or a multicomponent system that is a combination of these components.

COMMIX has two alternative solution schemes. One is semi-implicit and is a modification of the ICE technique. The other, a fully implicit scheme called SIMPLEST-ANL, is a modification of the numerical procedure known as SIMPLER. The option for solution schemes is implemented in such a way that a user can switch from one solution scheme to another at any time during the transient simulation of a problem.

The code has a modular structure and permits analysis using either Cartesian or cylindrical coordinate systems. It has two thermal-hydraulic property packages, one for liquid sodium and one for water. Besides these two packages, an option is available for users to input simplified thermal physical properties correlations that are valid in the desired range of applications.

Volume I (Equations and Numerics) of this report describes in detail the capabilities, unique features, basic equations, formulation, volume-weighted skew-upwind difference scheme, and the solution procedures. It also describes models used for the following phenomena:

- Momentum interaction between fluid and stationary solid structures,

- Thermal interactions between fluid and stationary solid structures,
- Turbulence, and
- Effects of wire wrap for fuel assembly applications.

In Volume II (User's Manual), we provide flow charts, description of subroutines, geometry modeling, initialization procedures, input instructions, etc. Two sample problems are also included so that readers who plan to use COMMIX-1B can become familiar with the input/output structures of the code.

1. INTRODUCTION

1.1 PURPOSE

COMMIX is a computer code for heat transfer and fluid flow analysis. Since the development of COMMIX-1 in 1976, many features have been added to augment the code's applicability. Consequently, COMMIX has become a very general-purpose computer code with a very wide range of applications. Although developed for nuclear reactor applications, with nor or minimal modifications, COMMIX can be used to analyze processes in engineering systems.

Many industries and organizations involved in design or analysis of nuclear reactors are already using COMMIX. However, due to the code's generality of formulation and its wide range of applications, people from other disciplines have also found COMMIX a very useful tool. We therefore expect the number of COMMIX users to increase in the future. Prospective users of COMMIX can benefit from a comprehensive description of the code. The purpose of the present report is to meet this need.

In describing COMMIX-1B, we have two distinct aims. One is to convey to the reader the capabilities of COMMIX, what equations are solved, and how they are solved, which we have done in the first part of this report (Volume I). The second aim is to present a step-by-step procedure on how to use COMMIX. To achieve this, we must describe the procedure with sufficient detail that a reader has no or minimum difficulty in attempting to use COMMIX. This of course is very difficult, but we are atttempting it here in Volume II.

It may be stressed here that while extending COMMIX-1A to COMMIX-1B, we have retained the original structure and format of COMMIX. Therefore, COMMIX-1A users will have no difficulty in adopting and running their problems with the COMMIX-1B version.

Volume I describes the basic equations, formulations of discretization equations, auxilliary models, solution procedures, etc. This Volume II, the User's Manual, describes all the information needed by the user, e.g., input description, flow chart, sample problems, and user options.

1.2 Organization of the Report

This part of the report (Volume II) describes the step-by-step procedure in sufficient detail that a reader unfamiliar with the COMMIX code can begin to use it with no difficulty.

We begin in Sec. 2 by describing the overall structure of the program. The first step for a user beginning numerical simulation is to model the geometry. Therefore, in Sec. 3 we describe geometrical conventions of COMMIX, recommend modeling procedures, and suggest how to prepare geometry-related input for COMMIX.

After geometrical modeling, a user needs to initialize cell and boundary values. COMMIX has several boundary-condition options that a user can select. These are described in Sec. 4.

If a flow domain under investigation contains solid structures, there will be thermal and momentum interaction between fluid and solids. The modeling of thermal interaction (between fluid and structures) through thermal structures is presented in Sec. 5. The force structure modeling to account for momentum interaction (between fluid and structures) is presented in Sec. 6.

To allow an increase in convergence rate, we have a mass-rebalancing scheme in COMMIX. The preparation of input related to mass rebalancing is presented in Sec. 7. Auxiliary input such as turbulence modeling and simplified property is presented in Sec. 8.

COMMIX requires an initial steady-state calculation, either because we want to analyze a steady-state problem or because we want to obtain an initial condition for a transient simulation. All the input required for steady-state calculation is described in Sec. 9. The details related to transient simulation are presented in Sec. 10.

In Sec. 11 we describe the input/output procedures and all related variables. Section 12 has our final concluding remarks.

Appendix A, "Input Description," contains what will be for many users the most valuable part of the whole report, for it is there that all input variables are described. In Appendix B, we list all subroutines and their functions, and Appendix C contains a list of resistance correlations.

Two sample problems along with their description, input, and output are presented in Appendices D and E. These problems have been selected to provide a good introduction to the capabilities of COMMIX-1B.

2. STRUCTURE OF COMMIX-1B

2.1 OVERALL FLOW CHART

The overall structure of the computer program can be seen from the flow chart presented in Fig. 2.1. The major steps of the program are as follows:

- We begin numerical simulation by specifying the grid and calculating all geometrical quantities that are frequently needed in later work. Reading of geometry input is done in subroutine GEOM3D. The calculation of all geometrical quantities is done in any of the three subroutines BOXES, QTRPIN, and FULPIN. The subroutines QTRPIN and FULPIN are specifically designed for hexagonal fuel assemblies with desired quarter-pin partitioning and full-pin partitioning, respectively, while subroutine BOXES is for all other geometries.

- Next, the initial values of all variables are either specified or calculated. The subroutine INITAL is the main subroutine for initialization. It sets up the default values, reads NAMELIST /DATA/, and calls appropriate subroutines (see Table 2.1) for reading input data, calculating initial values, and printing, if desired, of input and control parameters.

- After completion of initialization, subroutine OUTPUT is called to print initial values of all desired variables.

- The solution sequence, for which further details are given below, is then performed to determine the value of all dependent variables at the new time. Subroutine TIMSTP determines the sequence of calling subroutines, required during the solution sequence. When the values of all variables at the new time are determined, we return to the MAIN subroutine.

- If printing is desired at this time, subroutine OUTPUT is called and desired variables are printed.

- If the required number of time steps have been performed, or the maximum computation time or the maximum real time is reached, then computation is terminated and, if requested, the restart data are written on disk file. Otherwise, old time values are updated and execution continues for the next time step.

2.2 SOLUTION SEQUENCE

The flow diagram of the solution sequence controlled by the subroutine TIMSTP is shown in Fig. 2.2. This subroutine TIMSTP can be considered as the heart of the program. It performs what we call an outer iteration loop.

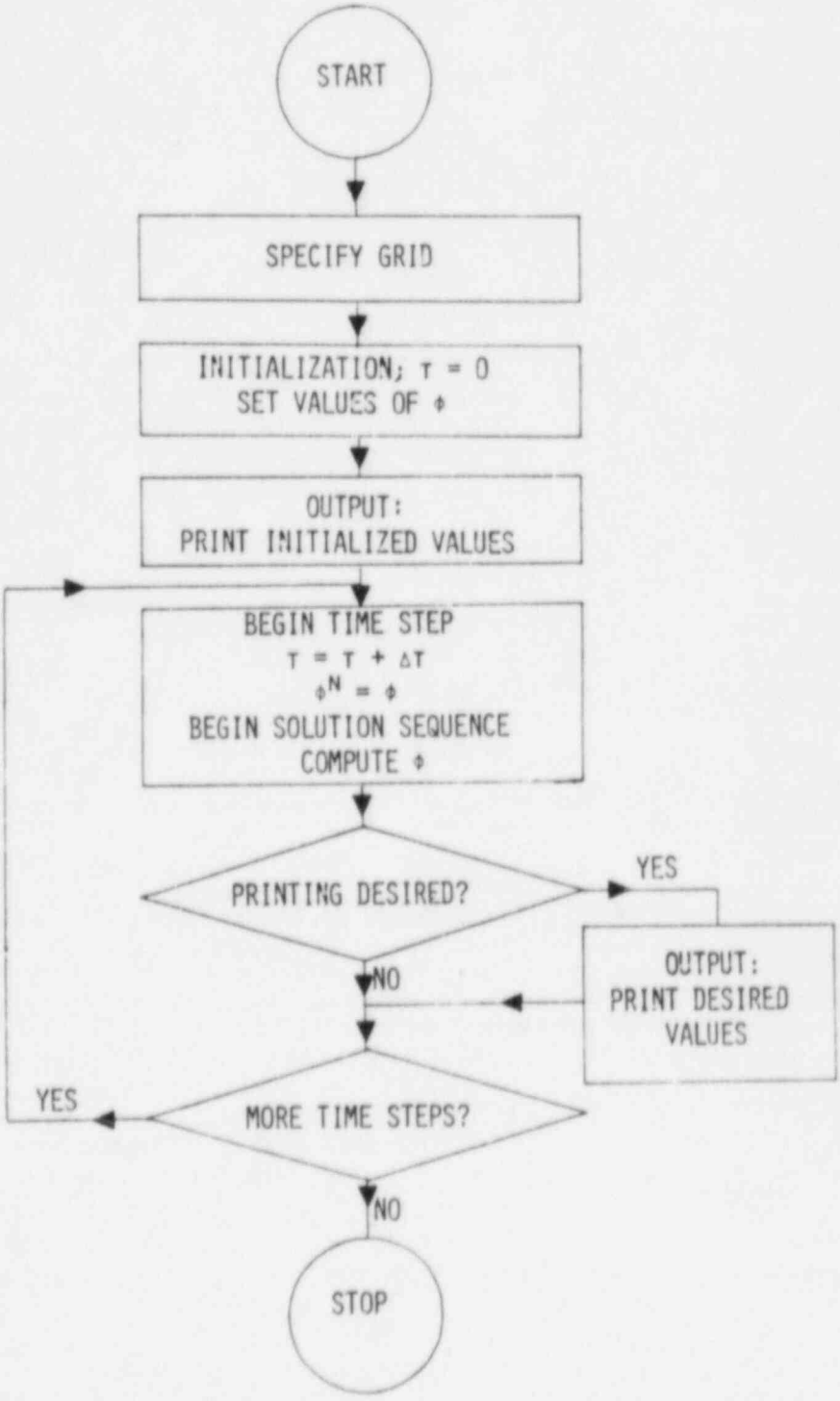

Fig. 2.1. COMMIX-1B Flow Chart

Table 2.1 List of Initializing Subroutines

Subroutine	Input Data		Function or Parameters Initialized
	NAMELIST	CARDS	
INITAL	GEOM DATA	-	Initializes default values and calls initializing subroutines
QGENER	INPUTQ	-	Rod bundle parameters
IREBAL	DATA	Rebalancing region	Rebalancing parameters
INFORC	DATA	Force structure	Force structure parameters
INPSTR	STRUCT T F M	Thermal structure prototype and location cards	Thermal structure parameters
ICTEMP	DATA	-	Boundary values of velocity temperature, heat, density, and pressure
BARIN	-	Boundary and initial value cards	Boundary and initial value of pressure, velocity, temperature, enthalpy, heat source, porosity, and surface area

Table 2.2 List of Subroutines Related to Turbulence Modeling

Controlling Parameters	Subroutines Called	Turbulence Model
ITURKE=0	-	Constant turbulent diffusivity model
ITURKE=10	INITUR, TLFIX, VISFIX VELOG	0-equation model
ITURKE=11	INITUR, ILFIX, INTURK, TURVI2 TKLOOP, TKSORC, VELCEN, TKENER WLFNCK, SOLVEN, TDLOOP	1-equation model
ITURKE=12	INITUR, INTURK, TURVI2, TKLOOP, TKSORC, VELCEN, TKENER, WLFNCK, SOLVEN, TDLOOP, TDNER	2-equation model

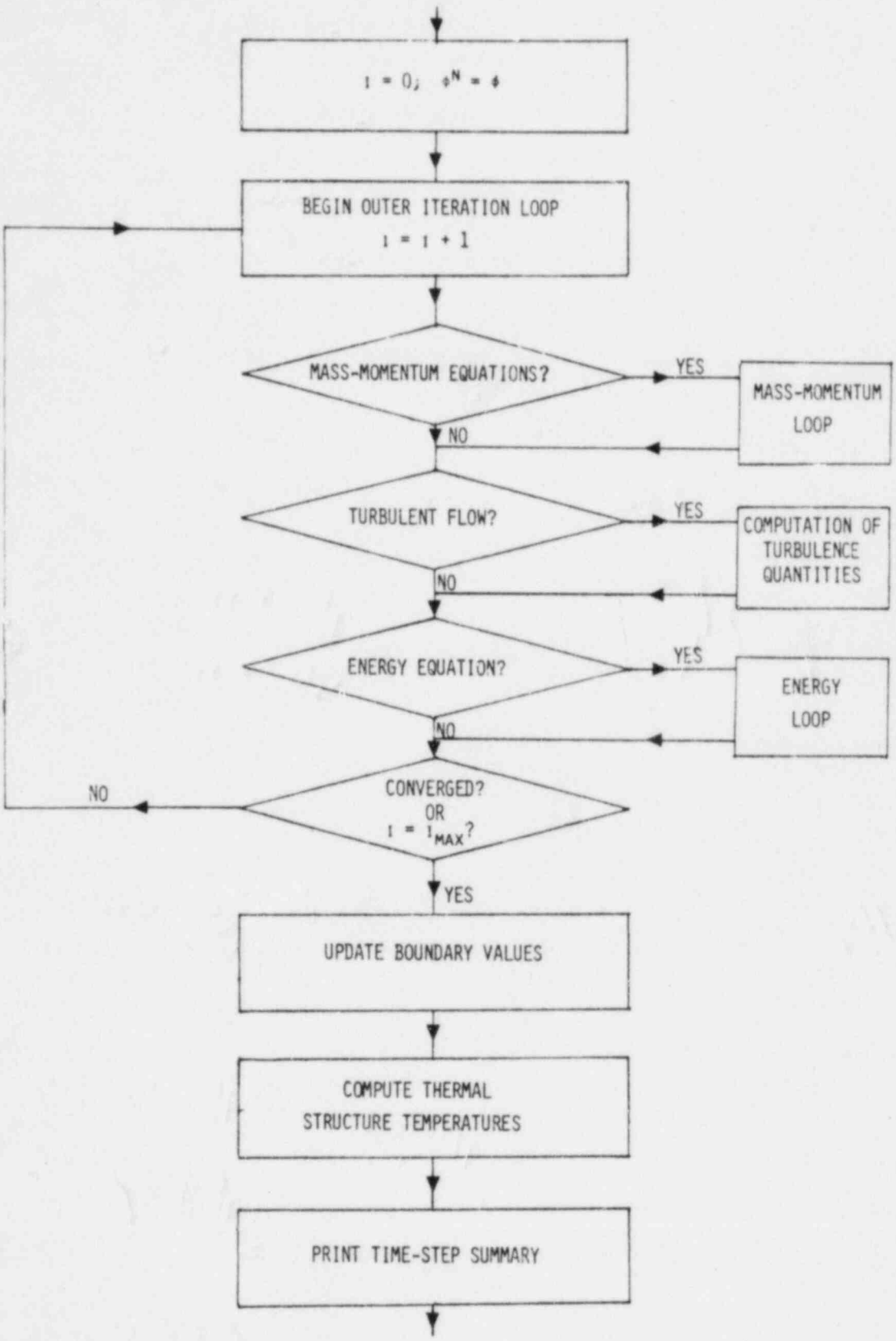

Fig. 2.2. Flow Chart of Solution Sequence in Subroutine TIMSTP

The three major loop program subroutines are called by TIMSTP. They are:

- Mass-Momentum Loop: Mass-momentum equations are solved and new values of velocities and pressures are computed. Subroutine MOLOOP calls required subroutines in sequence to solve the mass-momentum equations.

- Turbulence Loop: Appropriate subroutines are called (see Table 2.2), depending on the turbulence model selected. All required turbulence parameters are calculated.

- Energy Loop: The energy equation is solved and new values of enthalpy are calculated. Subroutine ENLOOP calls appropriate subroutines in sequence to solve the energy equation.

The mass-momentum and energy loop program subroutines are discussed in more detail in Secs. 2.3 and 2.4. The turbulence loop is discussed in Sec. 8.

2.3 MASS-MOMENTUM LOOP

The flow chart of the mass-momentum loop, as described below, is shown in Fig. 2.3. The calling sequence is performed in the subroutine MOLOOP.

- First calculate the pressure-velocity-relation coefficients $\hat{u}$, $\hat{v}$, $\hat{w}$, d^u, d^v, and d^w described in Secs. 4 and 5 of Vol. I. These calculations are performed in subroutines XMOMI, YMOMI, and ZMOMI for x (or r), y (or θ), and z directions, respectively.

- Using these pressure-velocity-relation coefficients, calculate the coefficients of pressure equation, a_0^p, a_1^p, ... a_6^p, b_0^p (see Table 5.1 of Vol. I) in subroutine PEQN.

- If rebalancing is desired, call either REBAZG or REBAZ. The subroutine REBAZG is called if the rebalancing zones are user-specified, and subroutine REBAZ if the rebalancing is to be performed in the x, y, or z direction only. Details relating to rebalancing are presented in Sec. 7.

- The pressure equation is then solved in subroutine SOLVIT and new pressure values are computed. The solution is performed using an iterative succesive overrelaxation (SOR) procedure. The iteration is continued until either the residue of the pressure equation has reached below the specified convergence criterion value or the number of iterations have reached the specified maximum value, called ITMAXP.

- Velocities are then updated in subroutine MOMENI using the new pressure values and the following relations:

$$u = \hat{u} - d^u(p_2 - p_0),$$

$$v = \hat{v} - d^v(p_4 - p_0), \text{ and}$$

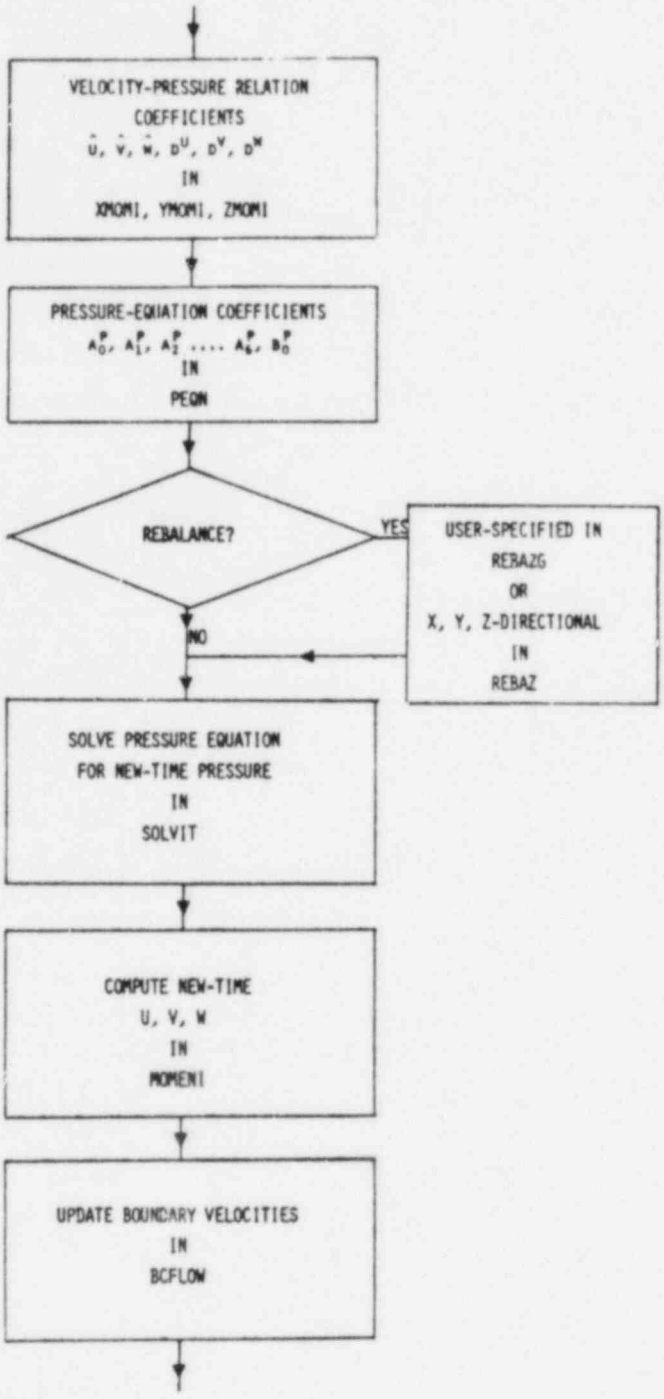

Fig. 2.3. Flow Diagram of Mass-Momentum Loop

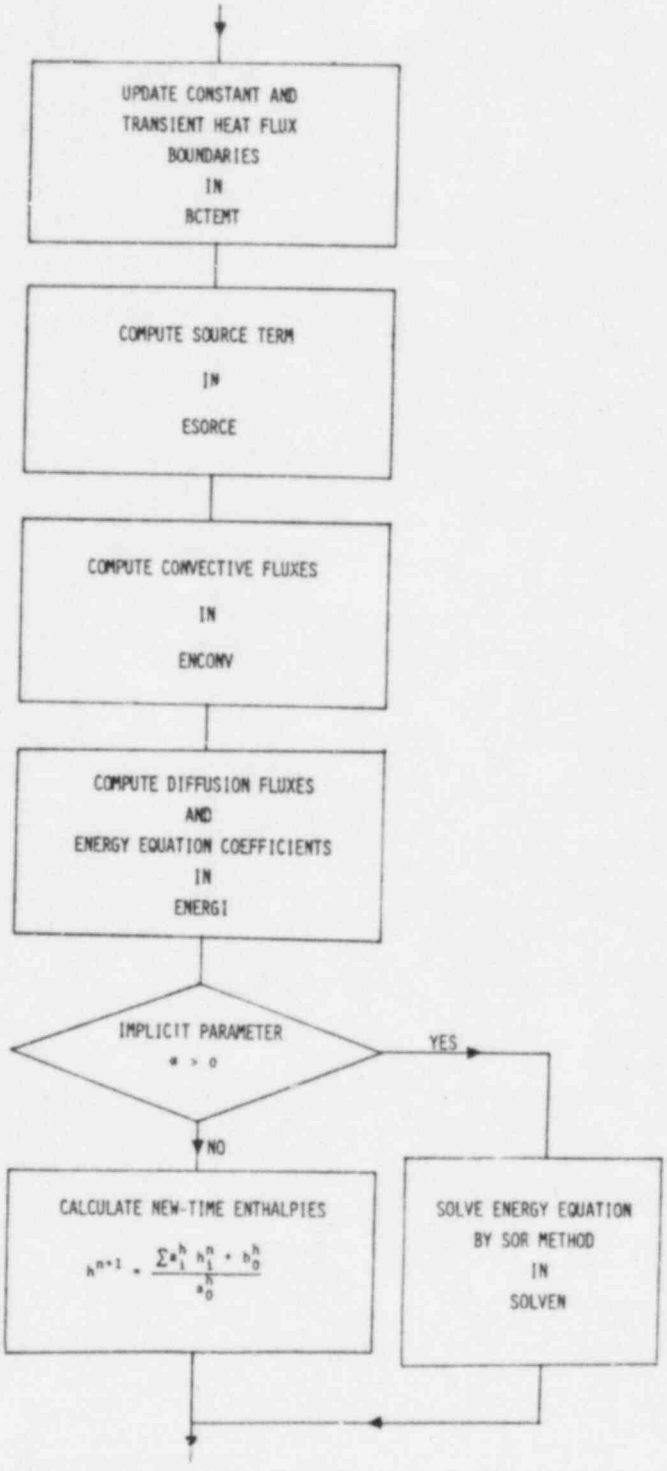

Fig. 2.4. Flow Diagram of Energy Loop

3.2 CONCEPT AND DEFINITIONS

In numerical modeling, a computational flow domain is always partitioned into a number of computational cells by means of x, y, and z grid planes in a Cartesian coordinate system or r, θ, and z in a cylindrical system, as shown in Fig. 3.1. In COMMIX we use the conventions described below to define various elements of a flow domain. A simple box geometry, shown in Fig. 3.2, is taken as an illustration.

- Computational Cell

In COMMIX, the computational cell is defined by the location of cell-volume faces with grid point placed in the geometrical center of the cell. Cell sizes can be nonuniform.

A computational cell surrounded only by other computational cells is called an internal cell. If one of the cell surfaces is a boundary surface, then it is called a boundary cell.

A user must specify the total number of computational cells required through the FORTRAN variable NM1.

- Boundary Surface

The external boundaries enveloping the flow domain are called the boundary surfaces. These may be solid walls or planes through which fluid can flow. The geometry in Fig. 3.2a has eight boundary surfaces.

A boundary surface is defined by its unit normal vector. The x, y, and z components (XNORML, YNORML and ZNORML) of a unit normal vector are specified such that it points locally into the fluid region. In Fig. 3.2a the normal vector of surface 2 has components (-1,0,0). Table 3.1 illustrates the components of the unit normal vectors of eight surfaces of the geometry in Fig. 3.2a.

Table 3.1 Components of Unit Normal Vectors of Geometry in Fig. 3.2a

Surface	XNORML	YNORML	ZNORML
1	0	1	0
2	-1	0	0
3	0	0	1
4	1	0	0
5	0	0	-1
6	0	0	-1
7	0	-1	0
8	-1	0	0

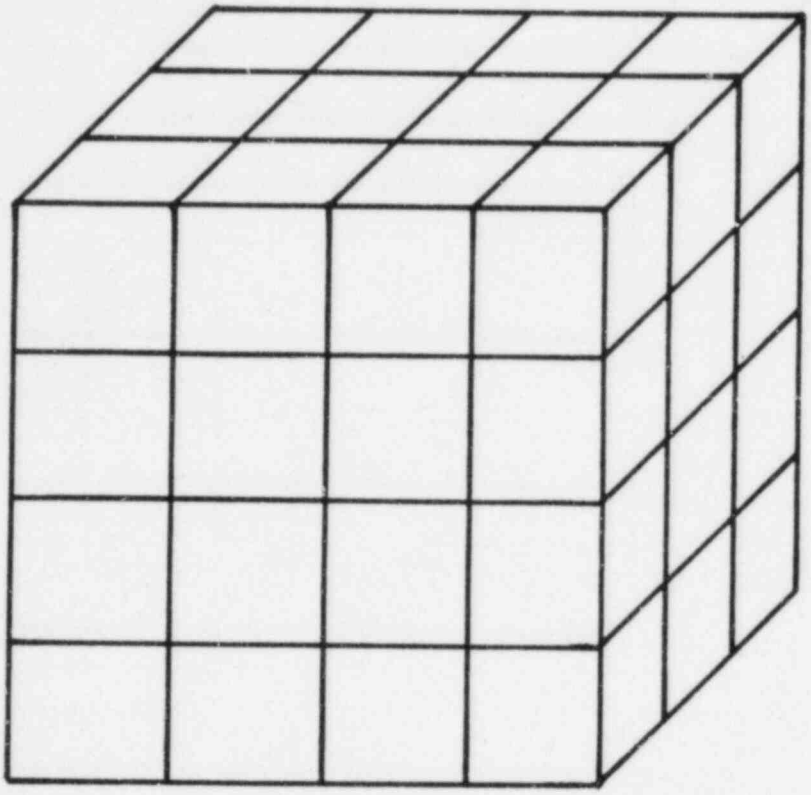

Fig. 3.1a. Partitioning in Cartesian Coordinate System

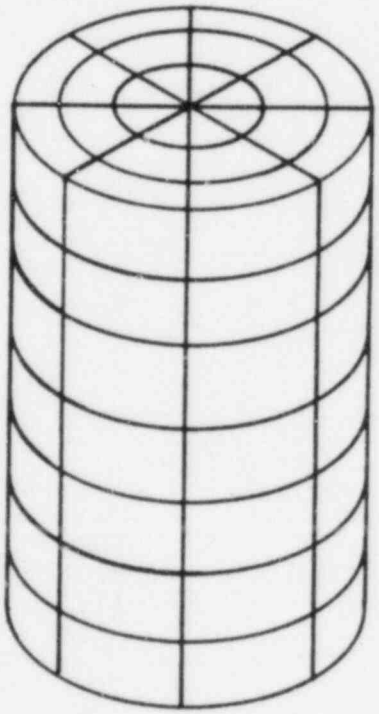

Fig. 3.1b. Partitioning in Cylindrical Coordinate System

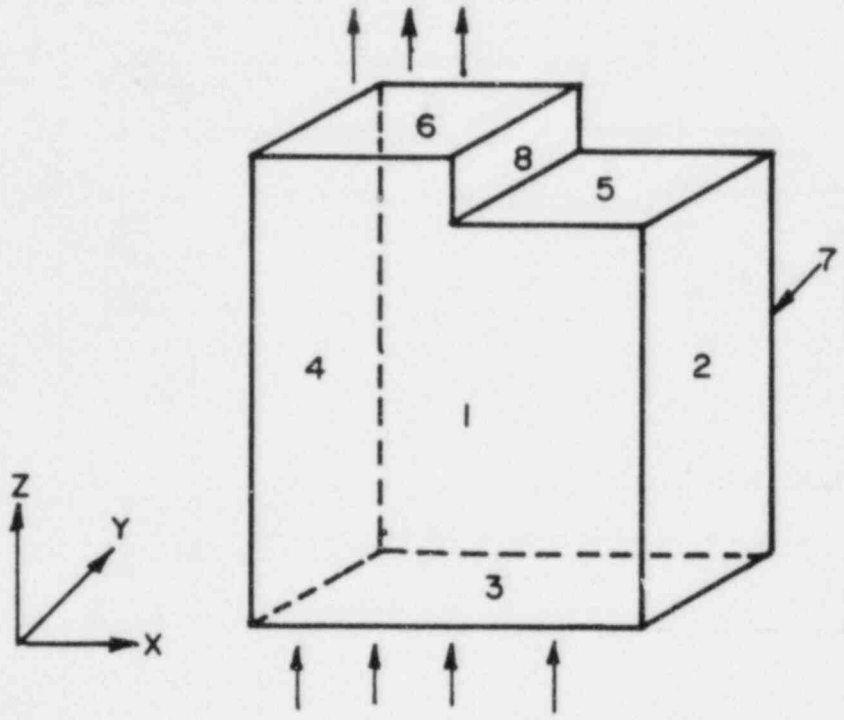

Fig. 3.2a. Model Geometry Showing Boundary Surfaces

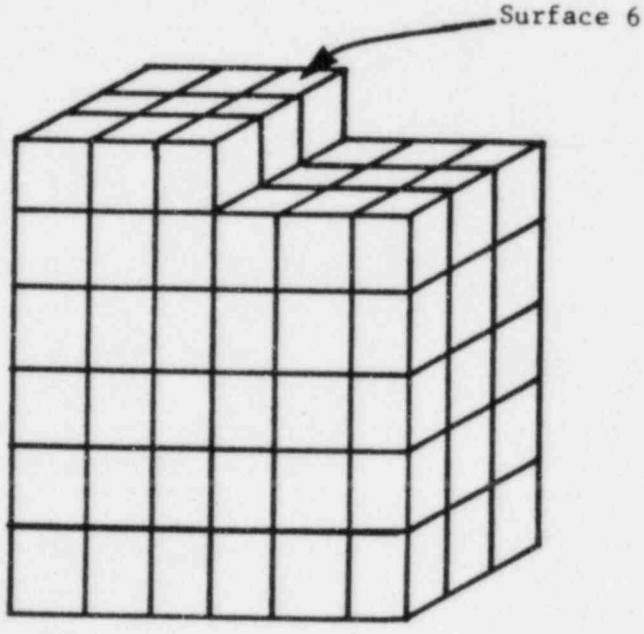

Fig. 3.2b. Partitioning of a Model Geometry Showing Surface Elements

- Regular Surface

A boundary surface coincident with any one of the grid planes is called a regular surface. The geometery of Fig. 3.2 has all regular surfaces.

- Irregular Surface

A boundary surface non-coincident with any grid plane is called an irregular surface. In Fig. 3.3a, surface 1 is an irregular surface.

- Surface Number

A user must give a surface number to every boundary surface. The same surface number can be assigned to all boundary surfaces that have

- The same unit normal vector and
- The same velocity, pressure, temperature, and heat flux boundary conditions.

For example, surfaces 2 and 8 in Fig. 3.2a are in two different planes. However, we can assign them the same surface number if they both have the same unit normal vector and same boundary conditions as illustrated in Fig. 3.4. Of course, one can also define them as two different surfaces if desired.

If surfaces 3 and 8, as illustrated in Fig. 3.5, have different boundary conditions, then we must consider them as two different surfaces, even though the surfaces may be coincident and have the same unit normal vector.

The variable NSURF is used to specify a total number of surfaces.

Note: All irregular surfaces must be numbered before other regular surfaces are numbered.

- Irregular Cell

If one surface of a computational cell is an irregular surface, then that cell is called an irregular cell.

Note: A computational cell is permitted to have only one irregular surface.

- Surface Element

A section of a surface between two pairs of consecutive grid lines is defined as a surface element. A surface can therefore have more than one surface element. For example, in Fig. 3.2b, surface 6 has nine surface elements. The variable NL1 is used to specify the total number of surface elements.

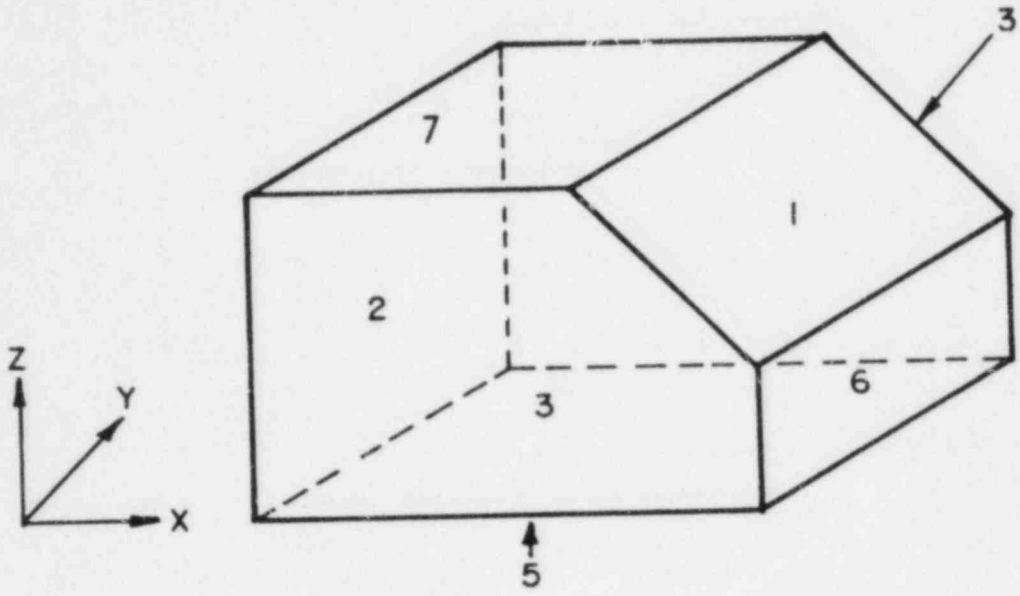

Fig. 3.3a. Model Geometry Showing an Irregular Surface

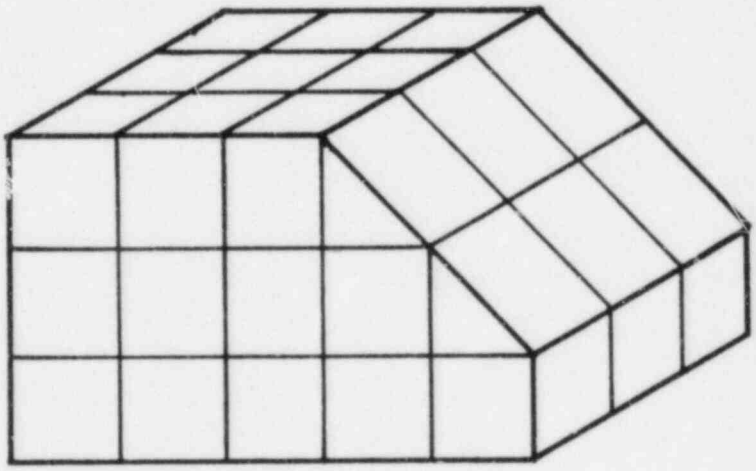

Fig. 3.3b. Model Geometry Showing Partitioning and Surface Elements

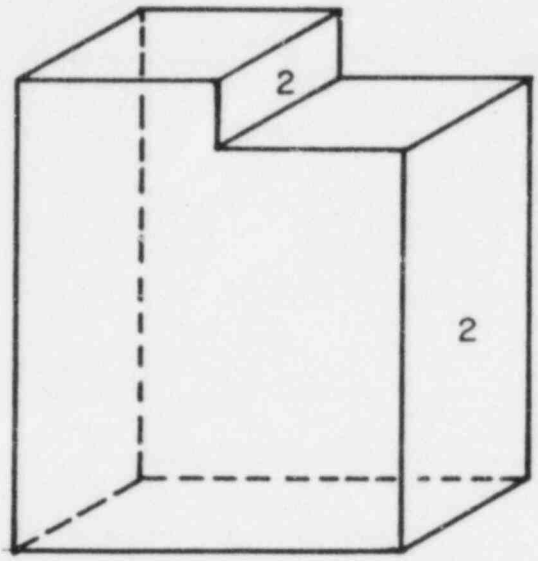

Fig. 3.4. Two Non-Coincident Surfaces with the Same Surface Number

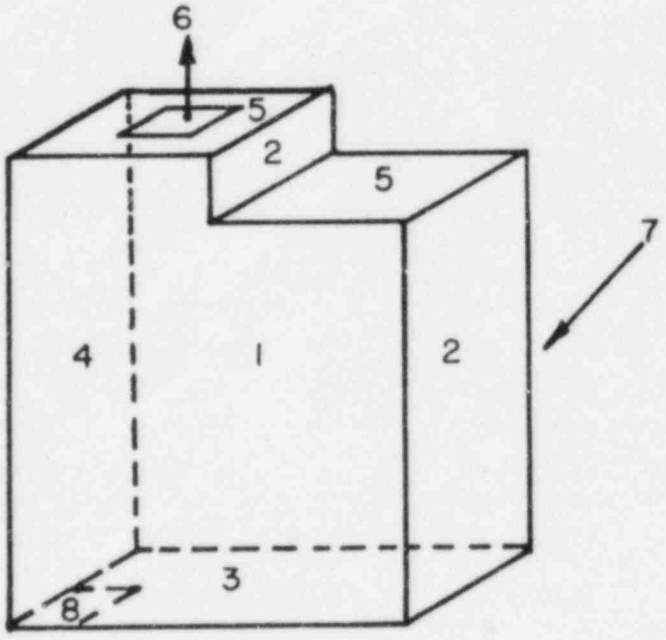

Fig. 3.5. Two Coincident Surfaces with Different Surface Numbers

- Volume Porosity

The geometrical parameter named volume porosity γ is defined as the ratio of fluid-flow volume in a cell to the total cell volume. The FORTRAN variable name for volume porosity is AL and its numerical value must lie between 0 and 1. This parameter is included to account for (1) irregularity in geometry and (2) the existence of internal solid structures. For example, the volume porosity of the computational cell due to irregular geometry (Fig. 3.6a) is

$$\gamma = AL = \frac{\Delta x\, \Delta y\, \Delta z - \text{volume of prism A}}{\Delta x\, \Delta y\, \Delta z} .$$

Similarily, the volume porosity due to an internal solid structure (Fig. 3.6b) is

$$\gamma = AL = \frac{\Delta x\, \Delta y\, \Delta z - \text{volume of half solid cylinder}}{\Delta x\, \Delta y\, \Delta z} .$$

- Directional Surface Porosity

Similar to volume porosity, the directional surface porosity γ_i is defined as the ratio of fluid flow area to total surface area. Because γ_i is a directional quantity, we have three surface porosities. The variable names are ALX, ALY, and ALZ for the x (or r), y (or θ), and z directions, respectively. For example, in Fig. 3.6a,

$$\gamma_x(i+1/2,j,k) = ALX\ (\text{cell ijk}) = (\Delta y \Delta z - \text{area A1})/(\Delta y \Delta z),$$

$$\gamma_y(i,j+1/2,k) = ALY\ (\text{cell ijk}) = 1.0, \text{ and}$$

$$\gamma_z(i,j,k+1/2) = ALZ\ (\text{cell ijk}) = (\Delta x \Delta y - \text{area A3})/(\Delta x \Delta y),$$

and in Fig. 3.6b,

$$\gamma_x(1+1/2,j,k) = ALX\ (\text{cell ijk}) = (\Delta y \Delta z - \text{area A5})/(\Delta y \Delta z),$$

$$\gamma_y(i,j+1/2,k) = ALY\ (\text{cell ijk}) = 1.0, \text{ and}$$

$$\gamma_z(i,j,k+1/2) = ALZ\ (\text{cell ijk}) = (\Delta x \Delta y - \text{area A4})/(\Delta x \Delta y).$$

We must mention here that the directional surface porosity is considered a flow-variable parameter. In the staggered grid arrangement, we define flow-variable parameters at the face of a cell. Therefore, when we describe γ_x, γ_y, and γ_z of cell (i,j,k), we mean γ_x at (i+1/2,j,k), γ_y at (i,j+1/2,k), and γ_z at (i,j,k+1/2).

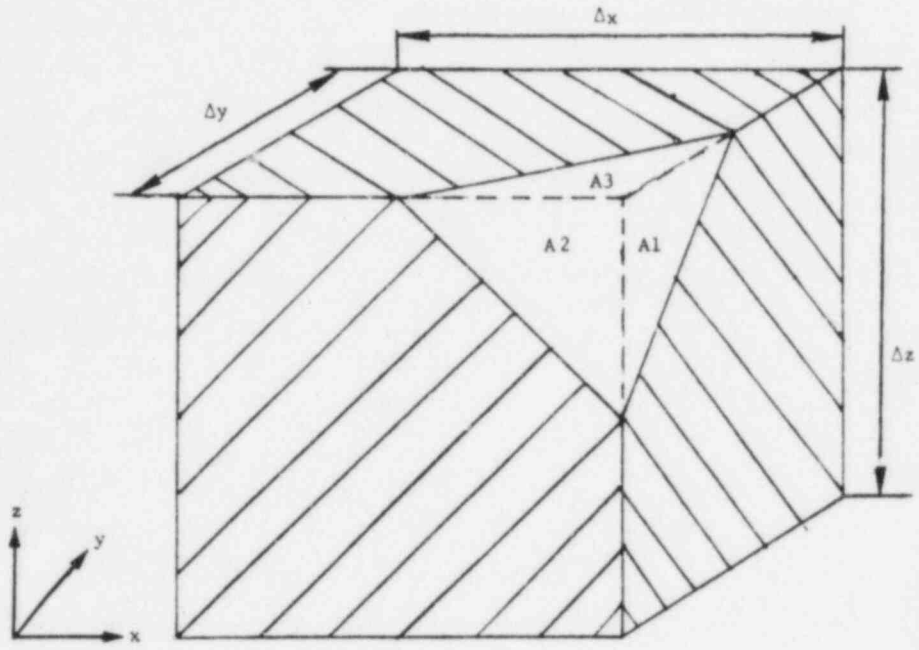

Fig. 3.6a. Volume Porosity due to Irregular Geometry

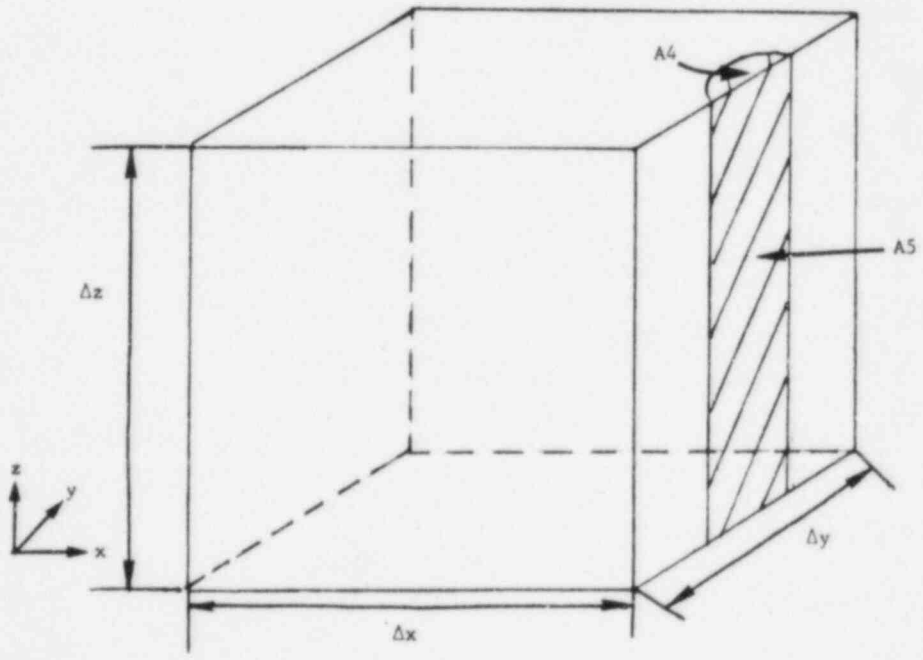

Fig. 3.6b. Volume Porosity due to Internal Solid Structure

3.3 RECOMMENDED APPROACH

The task of developing a geometrical model of a flow domain represents

- Selection of an appropriate coordinate system,
- Partitioning of a computational flow domain into a number of computational cells by means of coordinate grid planes, and
- Computation of geometrical partition sizes.

The development of a geometrical model of a physical situation requires an artful balance between an attempt to represent the geometry as accurately as possible on the one hand, and minimizing the computational cost in terms of time and storage on the other hand. This generally places an upper limit to the number of computational cells. The model must therefore try to balance homogenization of the details and accuracy in the factors that affect fluid flow and heat transfer.

Developing a model and preparing input for a complex geometry involves many decisions. There is no clear-cut procedure on modeling, as most of the decisions to be made are problem-dependent. The user must follow his or her own intuition and judgement. The following are only broad suggestions.

- Take advantage of symmetry and model the minimal required geometry.
- Determine if the geometry to be modeled is amenable to Cartesian or cylinderical coordinates and use the appropriate coordinate system.
- Use the HEX-geometry option if it is appropriate.

3.4 GEOMETRY INPUT

After all major questions relating to geometry modeling have been answered, we can start preparation of geometry input. The following is a recommended step-by-step procedure.

- Specify value of the variable IGEOM.

  IGEOM = 0 for Cartesian geometry,

  = - 1 for cylindrical geometry, and

  = > 0 for hex geometry (for value of IGEOM, see the input description.

- Partition the flow domain to be modeled by x, y, and z or r, θ, and z grid planes. Fig. 3.7 illustrates some examples. Compute and specify the following:

  IMAX, JMAX and KMAX: Maximum number of cells in x, y, and z (or r, θ, and z) directions.

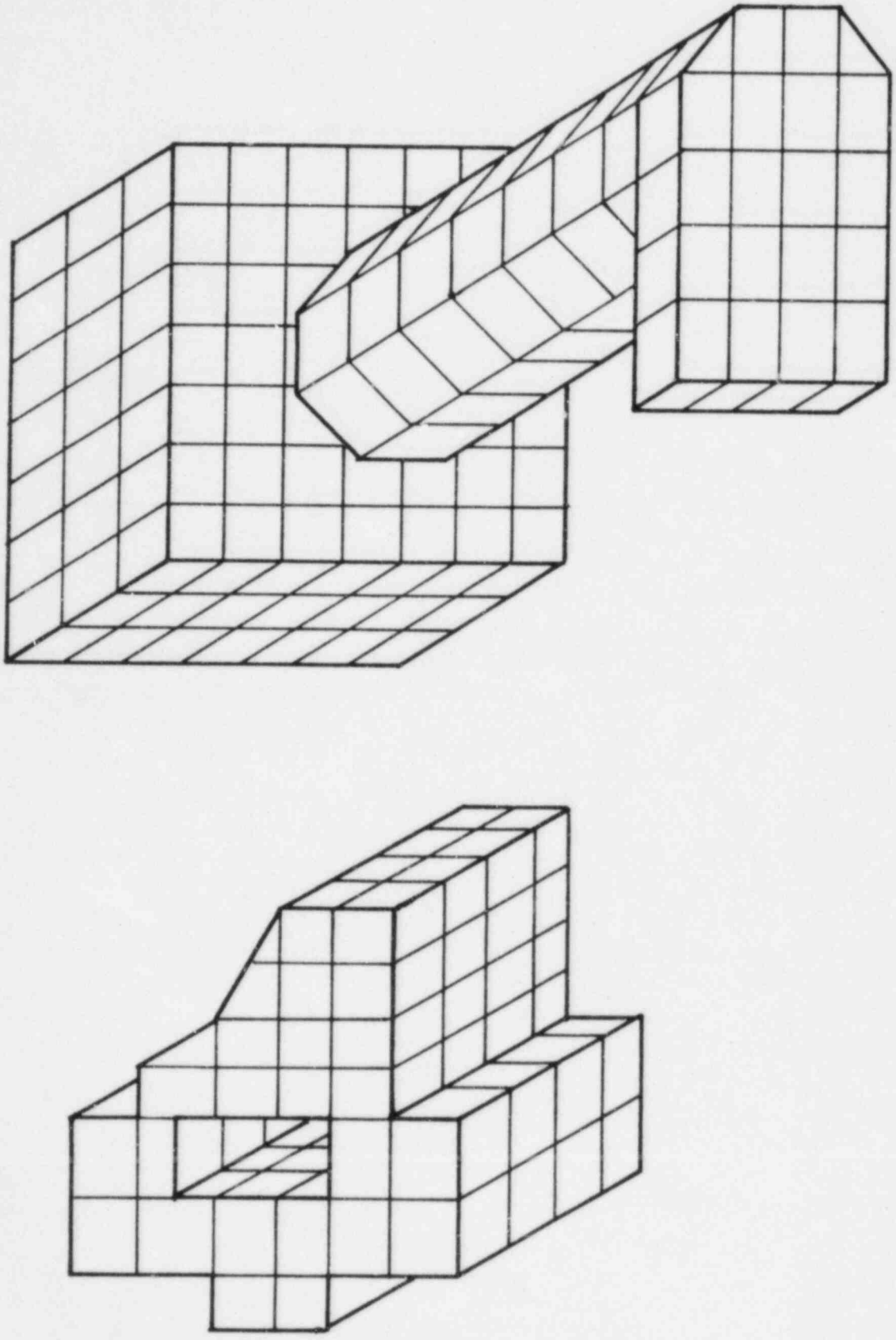

Fig. 3.7. Illustrations Showing Partitioning of Sample Geometries

DX, DY, and DZ: Partitioning distances in x, y, and z directions.

NSURF: Total number of surfaces.

NM1: Total number of computational cells.

NL1: Total number of surface elements.

- Give surface numbers to all boundary surfaces. Compute and specify XNORML, YNORML, and ZNORML (the components of unit normal vectors) for all surfaces.

Note: All irregular surfaces must be numbered first. Partitioning must be done such that each cell has a maximum of one irregular surface.

- Compute areas of (1) surface elements of all irregular surfaces, and (2) partially truncated regular surface elements of irregular cells. Prepare and supply all information relating to surface elements as described in the section on "Boundary Surface Identification Cards" in the Input Description.

- Compute volume porosity AL and directional surface porosities ALX, ALY, and ALZ and input this information according to the section on "Boundary Value Initialization Cards" in the Input Description.

4. INITIALIZATION

4.1 INTRODUCTION

After completion of the geometrical modeling, we need to assign initial values of temperature, pressure, and velocity to all cells and surfaces. If we are continuing a previous run, then this initialization is performed through the restart capability of COMMIX.

The input of all initial and boundary values at the start of the first run can generally be very tedious. In COMMIX, we have provided several simplified input procedures that simplify initialization.

A list of initialization variables is given in Table 4.1. For a more detailed description please refer to Appendix A, "Input Description."

4.2 SIMPLIFIED PROCEDURES

- In the initial input, we need to specify only the values of temperature, pressure, and velocity. The values of enthalpy and density are not required; they are calculated in the code from the equation-of-state and the prescribed pressure and temperature distributions.

Table 4.1 List of Variables for Initialization

Variable	Variable Name	Initializing Region	Input Section	Remarks
Temperature, °C	TEMPØ	Internal cell	DATA	One value for all cells
	TL	Internal cell	ICIC*	Desired internal cells
	TEMP(N)	Boundary surface	DATA	One value for each surface
	TLB	Surface element	BVIC**	Desired surface elements
Velocity, m/s	UL,VL,WL	Internal cell	ICIC	Desired internal cells
	VELOC(N)	Boundary surface	DATA	One value for each surface
	VELB	Surface element	BVIC	Desired surface elements
Pressure	PRESØ	Internal cell	DATA	Hydrostatic pressure distribution
	P	Internal cell	ICIC	Desired internal cells
	PRES(N)	Boundary surface	DATA	One value for each surface
	PB	Surface element	BVIC	Desired surface elements
Heat flux, W/m^2	TEMP(N)	Boundary surface	DATA	One value for each surface
	QBN	Surface element	BVIC	Desired surface elements
Enthalpy, J/kg	HL	Internal cell	ICIC	Desired internal cells
	HLB	Surface element	BVIC	Desired surface elements
Density, kg/m^3	RLB	Surface	BVIC	Desired surface elements
Heat source W/m^3	QSOU	Internal cell	ICIC	Desired internal cells

*ICIC: Internal Cell Initialization Cards
**BVIC: Boundary Value Initialization Cards

- We can prescribe initial hydrostatic pressure distributions in the entire flow domain by specifying only

  - one pressure value (variable name PRESØ)

  - its x, y, and z location (variables are XPRESØ, YPRESØ, and ZPRESØ), and

  - the components of the gravity vector (variables are GRAVX, GRAVY, and GRAVZ).

  The program then calculates the entire pressure field.

- Uniform temperature distribution in the entire flow domain can be obtained by specifying only one temperature value to the variable TEMPØ.

- Uniform temperature and hydrostatic pressure distributions can be overridden by using internal-cell initialization cards for desired (i,j,k) locations.

- The normal velocity, temperature, and pressure for each surface, **if uniform over a surface**, can be prescribed by specifying desired values to variables VELOC(N), TEMP(N), and PRES(N), respectively, where N is the surface number. The surface pressures need to be specified **only** for a surface with the uniform pressure boundary condition.

- Nonuniform velocity, temperature, and pressure distributions for surface elements can be specified by using the boundary-value initialization cards with variables VELB, TLB, and PB. This overrides any VELOC(N), TEMP(N), and PRES(N) values.

- If surface heat flux instead of temperature is desired to be prescribed initially, it can be done by specifying the desired value to the variable TEMP(N), which now has the units W/m^2. A nonuniform heat flux distribution can be specified by using the boundary-value initialization cards with variable QBN. This overrides any TEMP value.

- From the prescribed initial temperature and pressure fields, initial values of density and enthalpy fields are computed by code using the equation-of-state.

- For a hexagonal fuel-assembly calculation, the z axis is assumed to be aligned with the axial length. When gravity is acting along the z axis and the inlet is from the z = 0 plane, a one-dimensional initialization option is available (IFROD= 2). In this option, the initialization is performed assuming that transverse velocities are zero and all variables are functions of z only. Also, the effects of fuel assembly drag, static head forces, and internal heat sources are considered in the initialization of both pressure and temperature. This option reduces the computer running time for steady-state solution of hexagonal fuel assemblies.

The form of the BVIC and ICIC input cards is

NAME RVAL IB IE JB JE KB KE N*

For example: The boundary value initialization card

TLB 60.0 5 18 7 12 1 6 5

means that we are specifying a surface-temperature value of 60°C to all surface elements on computational cells having an I value from 5 to 18, J value from 7 to 12, and K value from 1 to 6 for surface number 5. We can see here that one input card in this example initializes temperature value to 504 surface elements.

Similarly, the internal cell initialization card

TL 60.0 5 18 7 12 1 6

means that we are specifying a cell-temperature value of 60°C to 504 internal cells having an I value from 5 to 18, J value from 7 to 12, and K value from 1-6.

- Before a program reads the input data, all variable values are made zero. Consequently, only the values other than zero need to be specified in the input data.

- The commonly occurring values of variables are provided as default values. If the default value for a given variable is acceptable, then the input for that variable need not be specified.

4.3 INPUT PREPARATION

4.3.1 Cell Variables

In the input preparation of initial cell values, we need to specify the values of the following variables:

- Three component velocities UL, VL, and WL in m/s,
- Temperature TL in °C,
- Pressure P in Pa, and
- Heat source QSOU in W/m^3.

As mentioned above, we have to specify only the non-zero values.

If we have uniform temperature and hydrostatic pressure distributions at the start, then we can make use of the simplified procedures and specify only TEMPØ and PRESØ in NAMELIST /DATA/.

In regard to the heat source, a user has an option either to use volumetric heat source QSOU or to specify it through thermal structures (see Sec. 5).

---

*N for BVIC only.

4.3.2 Boundary Surface Variables

- **Types of Boundary Condition**

In boundary value initialization, we need to specify the type of boundary as well as boundary values. The variables used for defining the types of boundary conditions are:

KFLOW: # for velocity,

KTEMP: # for temperature/heat flux, and

KPRES: # for pressure.

The types of boundary conditions are listed in Tables 4.2-4.4. Details and description of these options are given in Volume I and Appendix A.

- **Boundary Values**

The input of initial boundary values is performed through Boundary Value Initialization Cards. Table 4.5 lists six variables that can be specified through BVIC. In general, we do not have to specify all six variables. In Table 4.6, we list the variables that may need initialization.

If a given surface has a uniform value of velocity, temperature, or pressure, then we can use variables VELOC(N), TEMP(N), or PRES(N) to initialize it. These values are specified in NAMELIST /DATA/.

5. THERMAL STRUCTURE MODELING

5.1 INTRODUCTION

The purpose of implementing a thermal structure model in COMMIX is to permit consideration of heat-transfer interaction between fluid and structures. The model implemented in COMMIX solves one-dimensional heat conduction equations for all solid structures. It calculates temperature distribution in solids and heat transfer from solids to surrounding fluids. In summary, the output from the thermal structure model is a heat source/sink term for the fluid energy equation.

The basic equations, formulations, and features of the model are described in Volume I. Here, we describe only the user-related aspects of the model.

5.2 SOME CONCEPTS AND DEFINITIONS

A thermal structure is a solid structure in a fluid-flow domain having heat-transfer interaction with surrounding fluid. It can be planar, cylindrical, or spherical. The COMMIX model permits a structure axis to be aligned with only one of the three coordinate axes, as shown in Fig. 5.1. For a given flow domain, we can model as many thermal structures as desired.

Table 4.2 Options for Velocity Boundary Condition

Parameter KFLOW(N)	Boundary Condition Type	Physical Boundary	Remark
-5	Continuative mass flow outlet	Outlet	$v_n^o = \frac{(\rho A v)^{AI}}{(\rho A)^o}$ (one outlet surface element)
-4	Uniform velocity outlet	Outlet	$v_n^o = \frac{\Sigma(\rho A v)^{AI}}{\Sigma(\rho A)^o}$ (several outlet surface elements)
-3	Free slip	Symmetry surface	$v_n^o = 0.0; \frac{\partial y_T^o}{\partial n} = 0$ No momentum diffusion
-2	Continuative velocity outlet	Outlet	$v_n^o = v_n^{AI}$ For constant density and area
-1	Continuative momentum outlet	Outlet	$v_n^o = \frac{(\rho v)^{AI}}{\rho^o}$ For constant area
1	Constant velocity	Inlet, solid wall	$v_n^o \neq 0$ $v_n^o = 0$
100 + NF	Transient velocity	Inlet	$v_n^o(t) = v_n^o(0)\, f(t)$ NF = Transient function number

Superscript o - Outlet or boundary value

Superscript AI - Adjacent internal cell

Subscript n - Normal to boundary surface

Table 4.3 Options for Temperature/Heat Flux Boundary Condition

Parameter KTEMP(N)	Boundary Condition Type	Physical Boundary	Remark
1	Constant temperature	Inlet, solid wall	T_w = constant, q_w is calculated
100 + NF	Transient temperature	Inlet, solid wall	$T_w(t) = T_w(0)f(t)$, q_w is calculated
200	Constant heat flux	Solid wall	q_w = constant, T_w is calculated
300 + NF	Transient heat flux	Solid wall	$q_w(t) = q_w(0)\ f(t)$, T_w is calculated
400	Adiabatic	Outlet, symmetry	$q_w = 0.0$
500 + NF	Duct wall	Thick wall	$\dot{q}'''(t) = \dot{q}'''(0)f(t)$, $\dot{q}'''$ = volumetric heat source, NF = 0 for constant heat source This boundary condition requires additional input (see Sec. 8.6)

Table 4.4 Options for Pressure Boundary Condition

Parameter KPRES(N)	Boundary Condition	Physical Boundary	Remark
0	-	-	No pressure boundary condition is applied
1	Constant pressure	Inlet-outlet	P_w = constant
100 + NF*	Transient pressure	Inlet-outlet	$P_w(t) = P_w(0) * F(NF)$

*NF is the transient function number.
F(NF) is the NFth transient function.

Table 4.5 Variables That Can Be Specified through BVIC

Variable	FORTRAN input names	Unit
Enthalpy	HLB	J/kg
Pressure	PB	Pa
Heat flux	QBN	W/m^2
Density	RLB	kg/m^3
Temperature	TLB	°C
Normal velocity	VELB	m/s

Table 4.6 List of Surface Variables That May Require Initialization

Type of Surface	Surface Variable	Remarks
Solid Wall	TLB and/or QBN	Nothing if surface is adiabatic
Symmetry	-	No initialization
Inlet	VELB, TLB or HLB, PB	PB only if pressure boundary is prescribed
Outlet	PB	Only if pressure boundary is specified

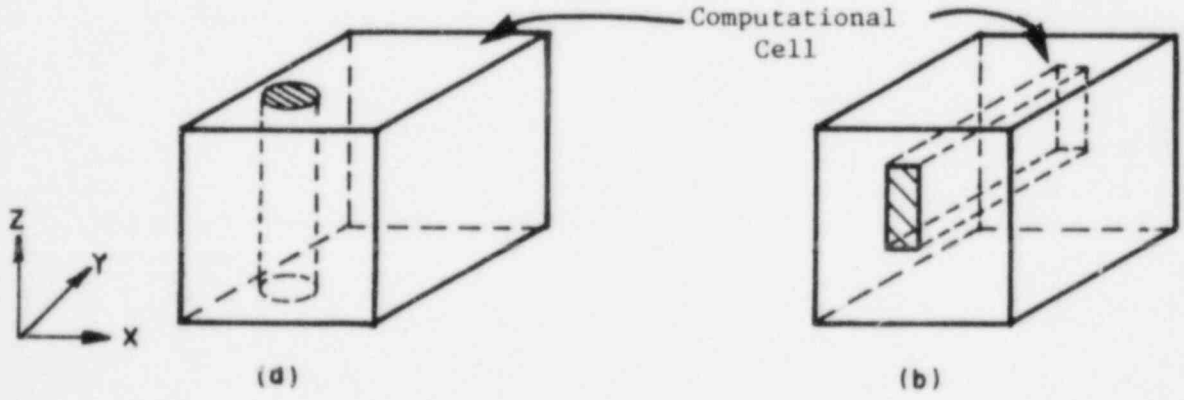

Fig. 5.1 Illustrations Showing Thermal Structure Alignment:
(a) Cylindrical Structure Aligned to z axis,
(b) Planar Structure Aligned to y axis

A thermal structure is identified by its unique geometric and physical features, i.e.

- All solid structures having the same grid axis alignment, same geometric features, and same physical characteristics, even though spread out in a physical domain, can be considered as one thermal structure, e.g., fuel pins in a nuclear reactor, flow tubes in a heat exchanger.

- One solid structure with the same geometric features but not having the same physical features throughout, cannot be modeled as one thermal structure, e.g., a fuel pin having different material composition in different axial sections.

In COMMIX computations, each thermal structure is partitioned by grid planes normal to the structure axis to form several thermal structure elements, as shown in Fig. 5.2. Each element has its own internal temperature distribution because the heat conduction equation is solved for each element.

A thermal structure has two surfaces--outer and inner. The outer surface interacts with surrounding fluid. The inner surface can either be adiabatic or interact with fluid, as shown in Fig. 5.3. **Each element surface is permitted to interact only with one fluid cell.** However, a fluid cell can interact with more than one element surface. This can be seen in Figs. 5.4 and 5.5.

Each structure can be composed of several material segments. Figure 5.6 illustrates the cross-section of a structure element having

- Outside and inside surfaces, numbered 1 and 2, respectively,

- Three different materials separated by gaps, and

- Each material region divided into a number of partitions.

5.3 THERMAL STRUCTURE SUBROUTINES

There are three major subroutines related to the thermal structure model. They are:

HSTRUC: Computes heat transfer coefficients for outer and inner surfaces of all thermal structure elements. It uses local velocities for Reynolds number and appropriate user-specified heat transfer correlation to evaluate heat transfer coefficient.

QSTRUC: Solves the heat conduction equations for each element and computes the heat source term for the fluid energy equation.

TSTRUC: Solves the heat conduction equations for each element and computes thermal-structure element temperature distribution.

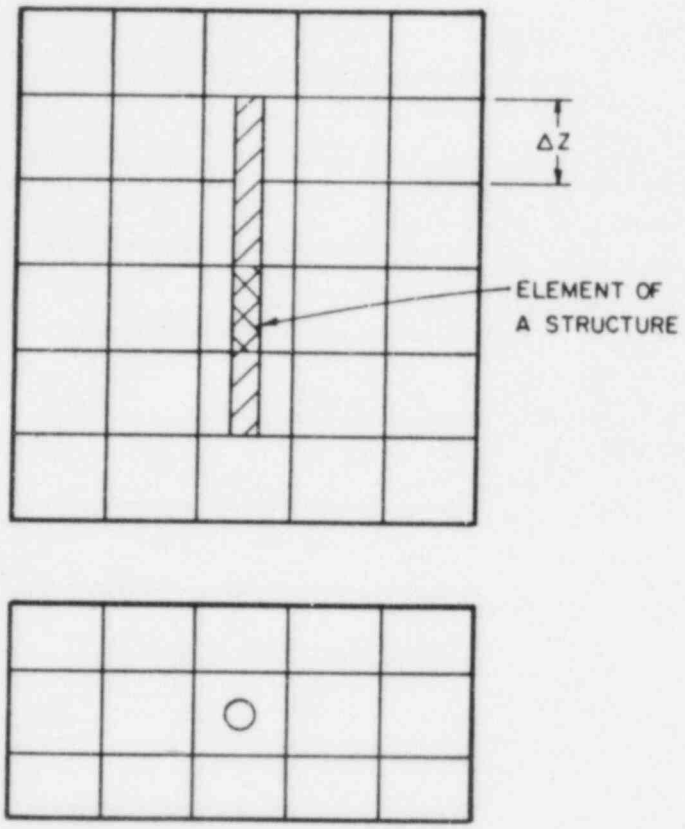

Fig. 5.2 An Element of a Thermal Structure

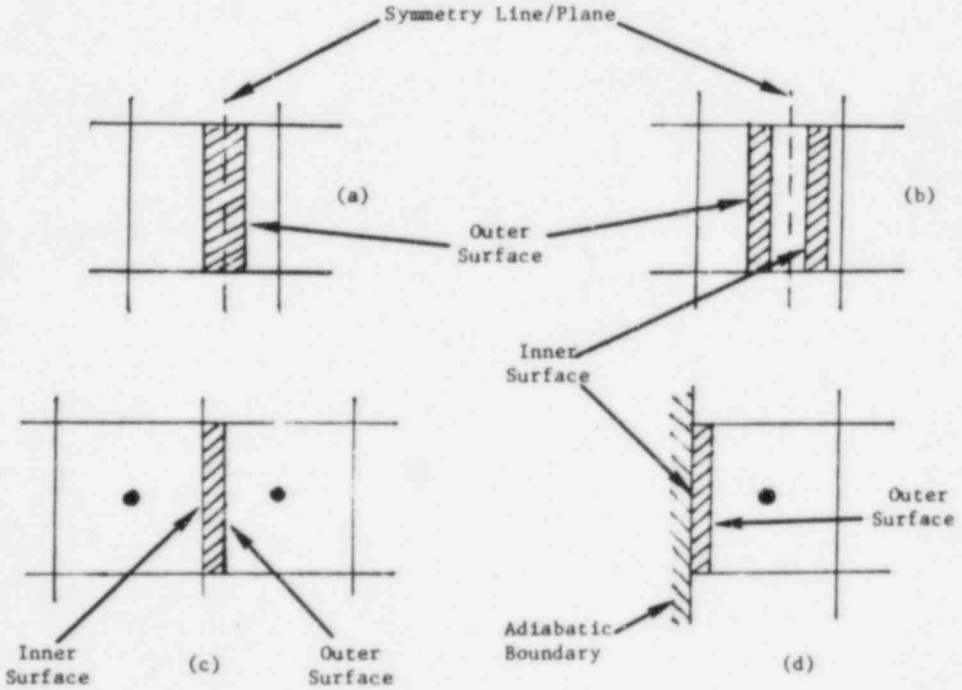

Fig. 5.3 Element of a Thermal Structure Showing Outer and Inner Surfaces

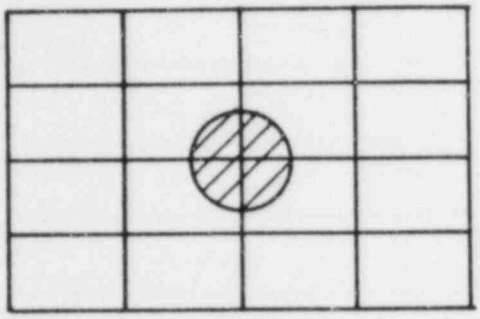

Fig. 5.4 Four Quarter Cylindrical Structures, Each Interacting with One Fluid Cell

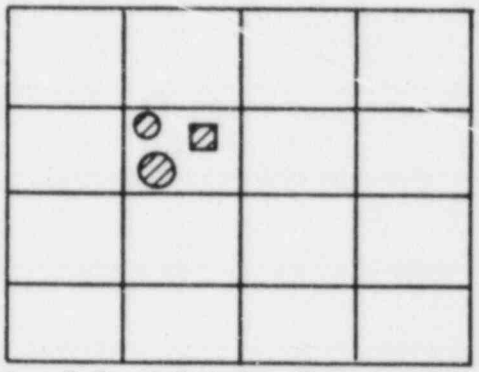

Fig. 5.5 Multiple Structures Interacting with a Single Fluid Cell

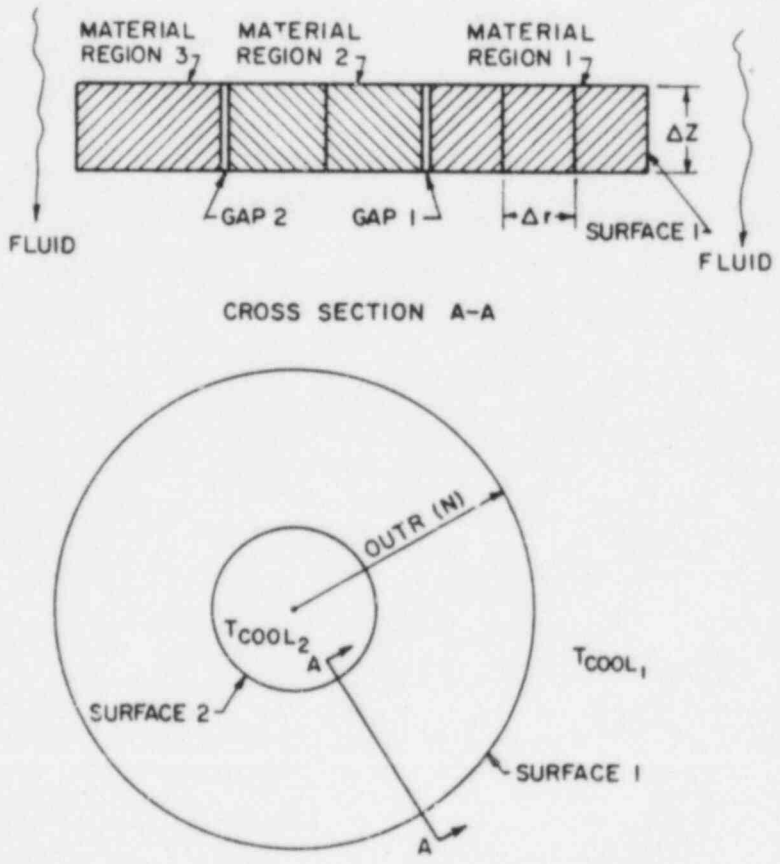

Fig. 5.6 Typical Structure Element Showing Material Regions and Gaps

The other three subroutines for this model are TSCAN, INPSTR, and PSTRUC. The functions of TSCAN are to scan input and determine storage requirements, INPSTR reads thermal-structure input and assigns appropriate markers and pointers, and PSTRUC prints results related to thermal structures.

5.4 MODELING RECOMMENDATIONS

The following is a list of recommendations relating to thermal structure modeling.

- For a steady-state analysis, we need to model only those solid structures that have heat sources.
- For a transient analysis, all solid structures, with or witout heat source, need to be modeled.
- Only plane, cylindrical, or spherical shapes are permitted in COMMIX. If a structure does not conform to one of these three shapes, then a user needs to exercise some approximations.
- COMMIX permits modeling of any multiple or fraction of a structure as one thermal structure; e.g., if there are 10 fuel pins passing through computational cells (Fig. 5.7a), we can consider the fuel pin as a thermal structure with surface area = 10 x surface area of one pin. Similarly, as shown in Fig. 5.7b, we can consider a fraction of a pin also as a thermal structure.
- A slab structure (Fig. 5.8) can be considered as either
  - a two-sided thermal structure with surface area for each side = $\Delta y \Delta z$ and thickness = t, or
  - a one-sided thermal structure, the other side (inner surface) being adiabatic, with outer surface area = $2\Delta y \Delta z$ and thickness = t/2.
- In many cases, we find that solid structures are uniformly distributed, e.g., fuel pins in a reactor core, heat exchanger tubes, etc. For modeling of such uniformly distributed thermal structures, we have provided an alternate way for specifying heat transfer surface area. This is done through

(a) (b)

Fig. 5.7 Modeling (a) a Multiple or (b) a Fraction of a Structure as One Thermal Structure

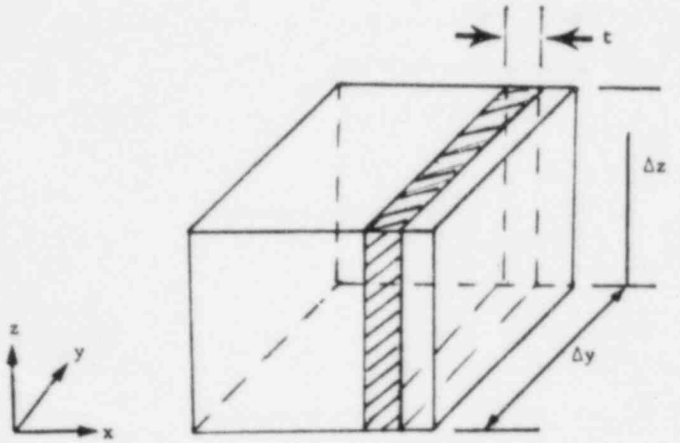

Fig. 5.8 Slab Structure Element

the variable RODFR, which has different meanings, depending on what and how we specify. We explain this through some illustrations:

Positive RODFR: COMMIX computes heat transfer surface area using the following equation:

Cylindrical Structure

$$\text{Surface Area} = \left(2\pi\ r\ \Delta\ Z_i\right) \text{RODFR}$$

Plane Structure

$$\text{Surface Area} = \text{RODFR}$$

Here, r is the surface radius (outer radius for outer surface or inner radius for inner surface), and $\Delta\ Z_i$ is the axial length of coolant cell. Therefore, the definition of RODFR is

RODFR: Number or fraction of rods interacting with coolant cell,

for a cylindrical structure, or

RODFR = surface area

for a slab-type structure. With this definition, we specify RODFR = 10 for the illustration in Fig. 5.7a, and 0.25 for the illustration in Fig. 5.7b.

Negative RODFR: If we specify a negative value, then COMMIX uses the following relation to compute heat transfer surface area

Cylindrical Structure

Surface Area = $(2\pi\ r\ \Delta\ Z_1 |RODFR|)$*(Cell area normal to structure axis.)

Plane Structure

Surface Area = $|RODFR|$*(Cell area parallel to structure surface area.)

Therefore, the definition of RODFR for negative specification is

$$|RODFR| = \frac{\text{number (or fraction) of rods}}{\text{cell cross-sectional area}}$$

or

$$|RODFR| = \frac{\text{heat transfer surface area}}{\text{cell cross-sectional area}} .$$

With this definition, we specify

RODFR = - 2/ab

for the illustration in Fig. 5.9,

$$RODFR = -\frac{1}{2\pi\ r_m\ (R_2 - r_1)}$$

$$= -\frac{1}{\pi(r_1 + r_2)\ (r_2 - r_1)}$$

for the illustration in Fig. 5.10, and

RODFR = - 1

for the illustration in Fig. 5.8.

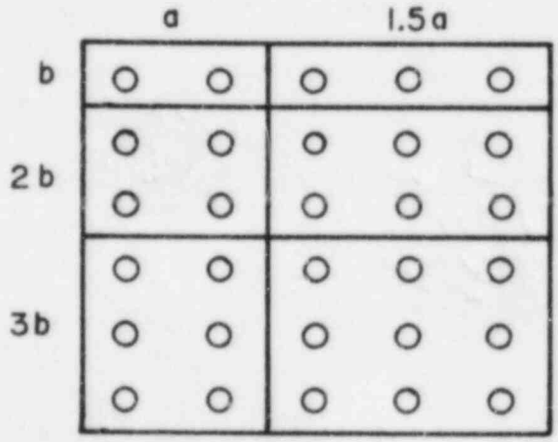

Fig. 5.9. Uniformly Distributed Rod Bundles in a Nonuniform Grid

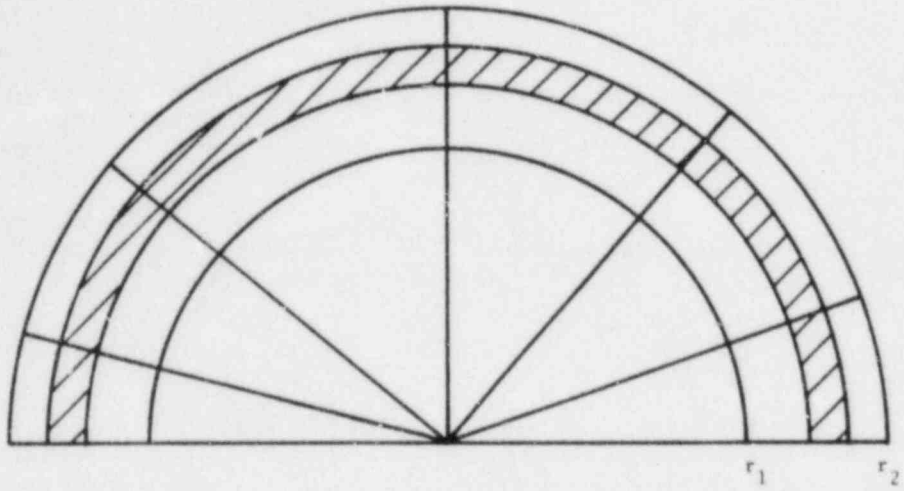

Fig. 5.10. A Cylindrical Shell with Nonuniform Azimuthal Grid

5.5 INPUT PREPARATION

5.5.1 Introduction

There are four sections of COMMIX input where we specify information that is directly related to thermal structure:

- NAMELIST /GEOM/
- NAMELIST /DATA/
- Thermal Structure Prototype Cards
- Thermal Structure Location Cards

In addition to these directly related inputs, described in the following sections, we have to supply material properties and heat transfer correlations, which are described in Sec. 8.

5.5.2 NAMELIST-Input

- NAMELIST /GEOM/: Here, we input the variable ISTRUC=1. It indicates that thermal-structure-related input is to be read and a computation is to be performed.

- NAMELIST /DATA/: Here, the TS-related variable is NEWTS. We specify NEWTS=1 only if we want to

  - Modify or update thermal-structure-related information, or

  - Input new thermal-structure-related information

  at the start of either a steady-state run (ISTATE=0) or a transient run (ISTATE=2). This variable comes into operation only with ISTRUC=1 and ISTATE=0 or 2.

5.5.3 Prototype Cards

The thermal structure prototype cards are the input cards where we input all geometric and physical information for all thermal structures. A detailed description of this input is given in Appendix A. Here we describe it briefly to explain some input-related rules.

- For each TS we have a set of input cards.
- Each set contains several NAMELIST cards. They are to be in the following order:

  &T For information related to thermal structure,

  &F For information related to outer surface fluid,

  &M For information related to material 1 and Gap 1

  &M For information related to material 2 and Gap 2

  ⋮

  (Include one NAMELIST /M/ for each material region in a thermal structure)

  ⋮

  &F For information related to inner surface fluid. This card is included only if the TS is two-sided. If the inner surface is adiabatic or a symmetry boundary, then this card is not required.

- The numbering of material regions begins as we traverse from outer surface to inner surface. To illustrate the ordering system, two examples are presented.

  Example 1: Ordering sequence of cards for TS shown in Fig. 5.11a (top):

  &T N=, IXYZ=, NT=, RODFR=, OUTR=, &END

  &F IHT=, HYD=, &END

  &M MI=, NP=, DR=, Q=, SGAP=, HGAP=, &END

  &M MI=, NP=, DR=, Q=, SGAP=, HGAP=, &END

  &F IHT=, HYD=, &END

  Example 2: Ordering sequence of cards for TS shown in Fig. 5.11b (bottom):

  &T N=, IXYZ=, NT=, RODFR=, OUTR=, &END

  &F IHT=, HYD=, &END

  &M MI=, NP=, DR=, Q=, SGAP=, HGAP=, &END

  &M MI=, NP=, DR=, Q=, SGAP=, HGAP=, &END

  &M MI=, NP=, DR=, Q=, SGAP=, HGAP=, &END

  &M MI=, NP=, DR=, Q=, SGAP=, HGAP=, &END

The meaning of all FORTRAN variables referred to in the TS prototype cards is given in Table 5.1.

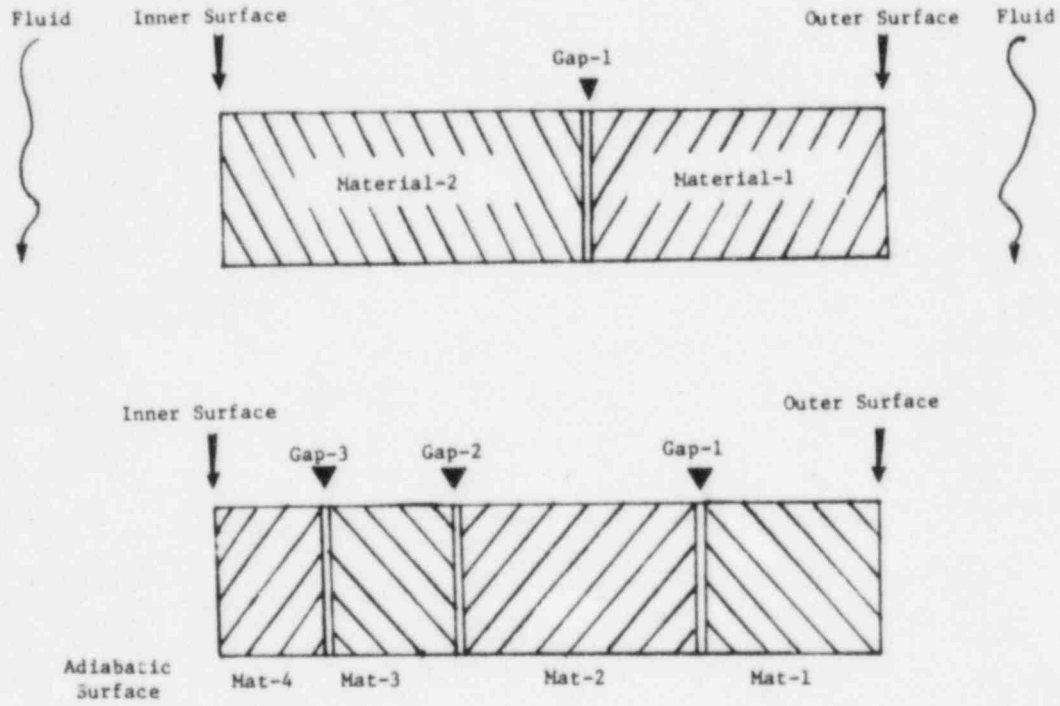

Fig. 5.11 Numbering System of Thermal Structure Material Regions

Table 5.1 List of FORTRAN Variables for TS Prototype Cards

Variable	Description
N	TS#
IXYZ	Number to describe shape and axis alignment (see Appendix A for numbers)
NT	Transient function number for heat source
RODFR	Rod fraction to specify surface area
OUTR	Outer-surface radius (m)
IHT	Heat-transfer correlation number
HYD	Hydraulic diameter to be used in the heat transfer correlation (m)
MI	Material number (see Sec. 8)
NP	Number of grid partitions in the material for finite-difference analysis
DR	Thickness of each partition (m)
Q	Volumetric heat source (W/m^3)
SGAP	Gap thickness (m)
HGAP	Gap heat transfer coefficient ($W/m^2°C$)

Note: If there is no gap between two materials, we specify a high heat transfer coefficient, e.g.,

SGAP = 0.0, HGAP = 1.E30.

5.5.4 Location Cards

The purpose of the location cards is to input TS-element location information. The format of specifying location information is very similar to that of boundary value and internal cell initialization cards. The FORMAT is (A4, 7I4), as shown below:

OUT	N	IB	IE	JB	JE	KB	KE

or

IN	N	IB	IE	JB	JE	KB	KE

For a two-sided structure, we specify OUT to describe the locations of the outer-surface cells and IN to describe the locations of the inner-surface cells. For one-sided structures, we have "OUT" cards only. The variable N stands for TS number and IB ... KE stands for the beginning and ending of i,j, and k indices.

For easy understanding of location input cards, we illustrate a simple geometry, as shown in Fig. 5.12. The input for the thermal structures in Fig. 5.12 will be as follows:

OUT	1	2	2	1	4	4	9
OUT	2	8	8	1	5	9	9
OUT	2	6	6	1	5	9	9
OUT	3	8	8	1	5	2	2
IN	3	8	8	1	5	1	1

6. FORCE-STRUCTURE MODELING

6.1 INTRODUCTION

The purpose of the force-structure modeling in COMMIX is to permit consideration of frictional resistance due to irregular geometry and the presence of solid structures in a flow domain. In COMMIX, we account for this effect by providing an additional distributed-resistance source term in the momentum equation. To include this distributed-resistance source term in computation, we need to provide the required information.

6.2 RESISTANCE CORRELATION

In the literature, the pressure drop due to obstructions is expressed in many different forms, e.g.,

$$\Delta p = 4 \frac{L}{D} \frac{1}{2} \rho v^2 \, f, \tag{6.1a}$$

$$= \frac{L}{D} \frac{1}{2} \rho v^2 \, C_D \, , \tag{6.1b}$$

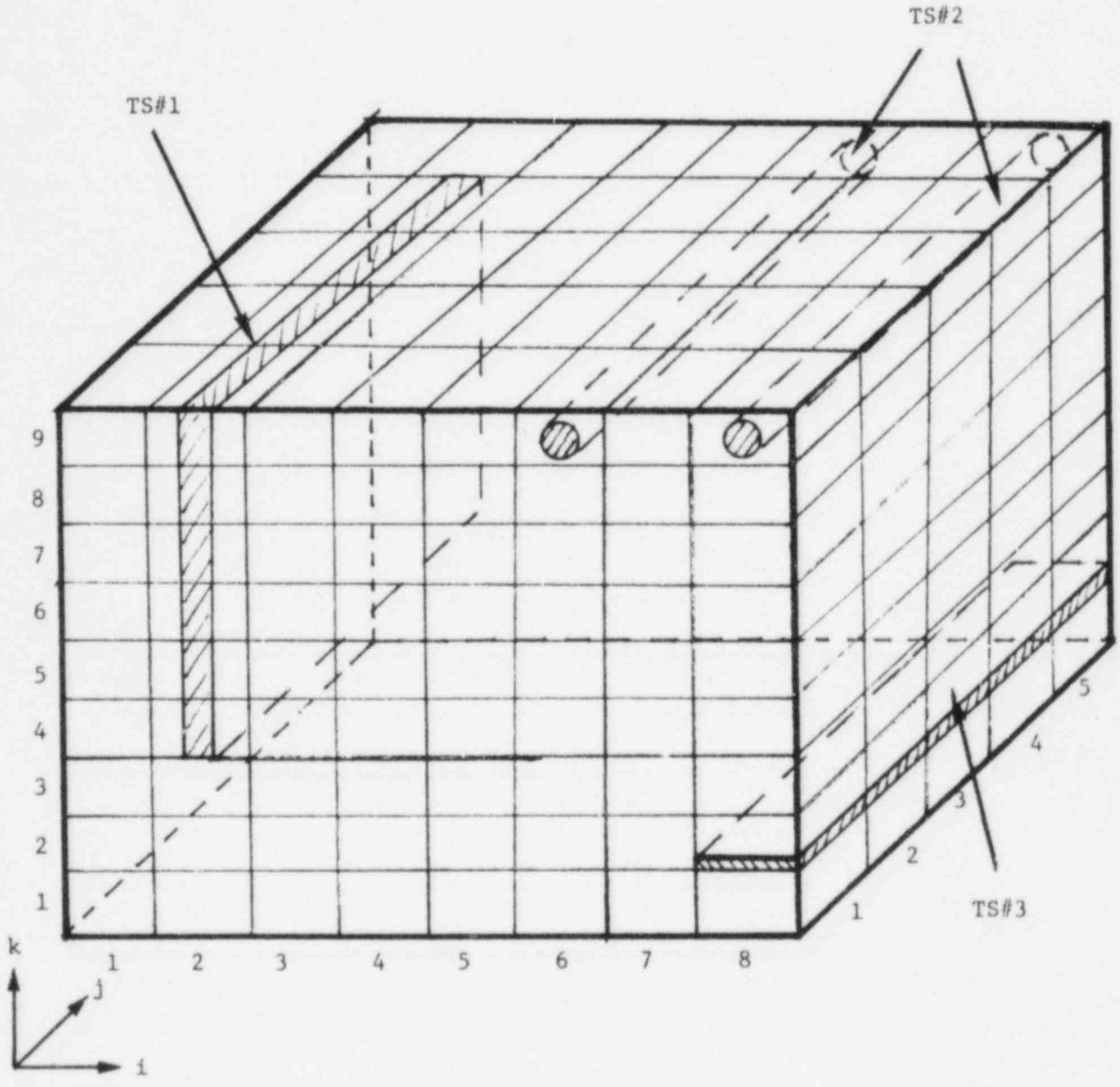

Fig. 5.12 TS Location Input

$$= \frac{1}{2} \rho v^2 \, K \, . \tag{6.1c}$$

The coefficients f, C_D, K, etc. have been given different names--Fanning friction factor, Darcy friction factor, drag coefficient, loss coefficient, etc., depending on the form of the equation.

In COMMIX, we use the following general forms.

$$\Delta p = C_1 \frac{L}{D} \rho v^2 \, f \, . \tag{6.2}$$

In terms of a distributed-resistance source R, Eq. 6.2 is

$$R = C_1 \rho \frac{v|v|}{D} f. \tag{6.3}$$

Here, L [Δx (r), Δy ($r\Delta\theta$), or Δz] is the cell length of a momentum control volume, D is the hydraulic diameter or characteristic length, and C_1 is the coefficient to account for different definitions of friction factor f.

The friction factor f in Eqs. 6.2 and 6.3 is generally a function of Reynolds number. In COMMIX we use the following form to express the friction-factor correlation:

$$f = a_\ell \, Re^{b_\ell} + c_\ell \tag{6.4a}$$

for laminar flow when the Reynolds number Re (= $\rho uL/\mu$) is less than a predefined transition Reynolds number Re_{tr}, and

$$f = a_t \, Re^{b_t} + c_t \tag{6.4b}$$

for turbulent ($Re > Re_{tr}$). The subscripts ℓ, t, and tr stand for laminar, turbulent, and transition, respectively.

6.3 INPUT REQUIREMENTS

We can see from the form of the equation in the preceding section that we need the following inputs:

- Variables C_1 (FORCEF) and D (CLENTH) to compute resistance-source term (Eq. 6.2),
- Variables a_ℓ (ACORRL), ..., c_t (CCORRT), and Re_{tr} (REYTRN) to compute the friction factor f (Eq. 6.4), and
- Reference length L (REYLEN) for Reynolds number Re.

In addition, we have added the following input requirements.

- NEWFOR A signal to inform tha' new force structure input must be read.
- NFORCE Number of force structures.
- NCORR Number of friction factor correlations.
- ICORR Linkage between a force structure and correlation number, e.g., ICORR(3)=4 means that correlation 4 4 is to be used for force structure 3.
- Force structure locations.

All input variables related to force structure are listed in Table 6.1.

Table 6.1 List of Input Variables Related to Force Structure Modeling

FORTRAN Name	Description of Variable	COMMIX Input Section	Remark
NFORCE	No. of force structures	NAMELIST /GEOM/	-----
NEWFOR	Signal for new force-structure input	NAMELIST /DATA/	= 0 for no, = 1 for yes; applicable for ISTATE=0 or ISTATE=2
CLENTH(NF)	D (Eq. 6.2)	NAMELIST /DATA/	Given a negative value if desired to use Eq. 6.1c, i.e., when L = D.
FORCEF(NF)	C_1 (Eq. 6.2)	NAMELIST /DATA/	-
NCORR	No. of correlations	NAMELIST /DATA/	
ICORR(NF)	Correlation linkage	NAMELIST /DATA/	See Sec. 6.3
ACORRL(NC)	a_ℓ (Eq. 6.4a)	NAMELIST /DATA/	-
BCORRL(NC)	b_ℓ (Eq. 6.4a)	NAMELIST /DATA/	-
CCORRL(NC)	c_ℓ (Eq. 6.4a)	NAMELIST /DATA/	-
ACORRT(NC)	a_t (Eq. 6.4b)	NAMELIST /DATA/	-
BCORRT(NC)	b_t (Eq. 6.4b)	NAMELIST /DATA/	-
CCORRT(NC)	c_t (Eq. 6.4b)	NAMELIST /DATA/	-
REYTRN(NC)	Re_{tr}	NAMELIST /DATA/	-
REYLEN	L Reference length for Reynolds number	NAMELIST /DATA/	-
XFOR, YFOR, ZFOR	Force-structure location	Force-structure specification cards	For direction and location, see Sec. 6.4

NF is a force-structure number.
NC is a correlation number.

6.4 FORCE-STRUCTURE LOCATIONS

The force-structure location information is provided through force-structure specification cards. The FORMAT is (A4,7I4), as shown below.

```
      XFOR
or
      YFOR   NF   IB   IE   JB   JE   KB   KE
or
      ZFOR
```

We specify XFOR, YFOR, or ZFOR to input the direction of force. The variable NF stands for the force-structure number, and IB .... KE stand for beginning and ending i, j, k indices of cell locations. For more details relating to force-structure location input, see Appendix A.

6.5 MODELING RECOMMENDATIONS

6.5.1 Staggered Grid System

In the finite-difference formulation, the frictional resistance due to a solid structure in a flow domain is considered an additional source term in the momentum equation. Since a staggered-grid system is used in COMMIX, the control volumes for the momentum equations are displaced, as illustrated in Fig. 6.1. It is therefore important to remember during modeling of the resistance term that:

- The distributed resistance source term is for the staggered control volume as shown in Fig. 6.1, and
- The reference velocity used in the resistance-source term equation is the velocity at the face of a cell (or at the center of a momentum control volume).

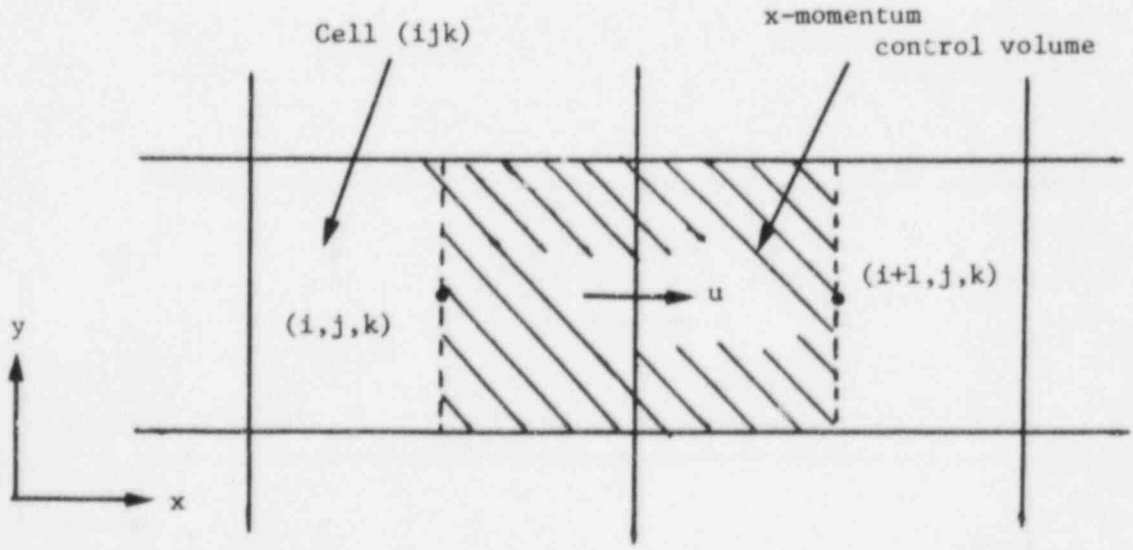

Fig. 6.1 x-Momentum Control Volume in a Staggered Grid System

To illustrate this point, we consider the case of sudden enlargement, as shown in Fig. 6.2. The pressure loss due to abrupt change in area is generally expressed in terms of the loss coefficient K_1 or K_2 depending upon which reference velocity is used.

$$\Delta p = K_1 \frac{1}{2} \rho V_1^2 ,$$

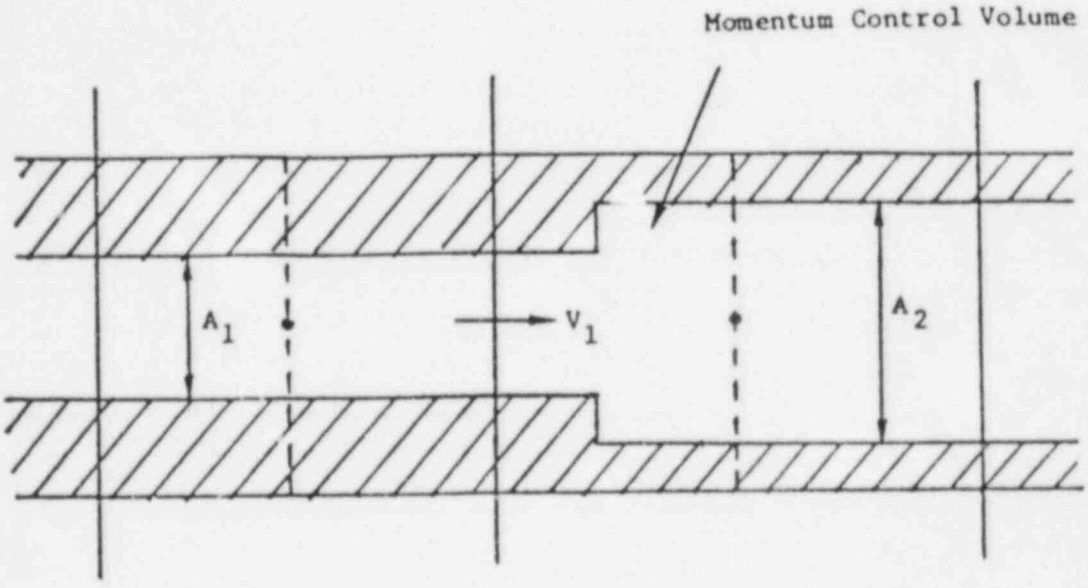

Fig. 6.2a Sudden Enlargement (Reference Velocity V_1)

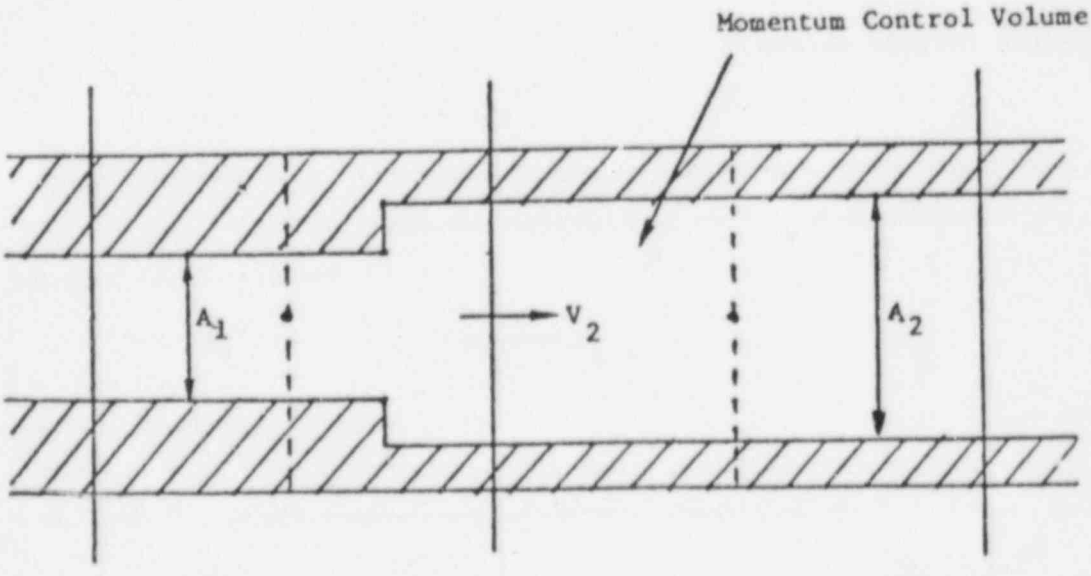

Fig. 6.2b Sudden Enlargement (Reference Velocity V_2)

$$= K_2 \frac{1}{2} \rho V_2^2 ,$$

where subscripts 1 and 2 refer to smaller and larger cross-sections, respectively. In such cases, a user has to look at the location of abrupt expansion (see Fig. 6.2) and then prescribe a suitable correlation for either K_1 or K_2.

6.5.2 Friction-Factor Library

Ocassionally, a COMMIX user may be faced with the situation that the desired correlation is not of a form described in Sec. 6.2. The user is then faced with two choices:

- Approximate the correlation to fit the input form, or
- Use the friction-factor library.

The friction-factor library has been created to accommodate up to 50 different additional correlations corresponding to values of ICORR(NF) from 50 to 99. Currently, only six correlations, as described in Volume I, have been added to the library.

A user who wishes to define an additional correlation can first examine the subroutine FORCES to see what correlation numbers are free and available. Then, with other library correlations as a guide, a new correlation can be inserted appropriately in subroutine FORCES and recompiled.

6.5.3 List of Correlations

To save the user time from searching the vast literature, we have collected a set of correlations that we feel are most commonly needed by COMMIX users. These correlations are listed in Appendix C.

We caution here that the correlations in Appendix C are not necessarily the only and best relations. We welcome feedback and comments from all users so that we can add other correlations and update the existing relations.

7. MASS REBALANCING

7.1 INTRODUCTION

The purpose of mass rebalancing in COMMIX is to expedite convergence of the SOR solution of the pressure equation and save computer running time. The description of the scheme and derivation of the mass-rebalancing equations are described in Volume I. The description presented here is aimed at guiding a reader in the use of the scheme.

7.2 DESCRIPTION

In the mass rebalancing, we form a coarse mesh domain by combining several fine mesh cells as shown in Fig. 7.1. A coarse mesh containing several computational cells is called a region. By forming a coarse mesh domain, we solve a smaller set of pressure correction equations. This helps

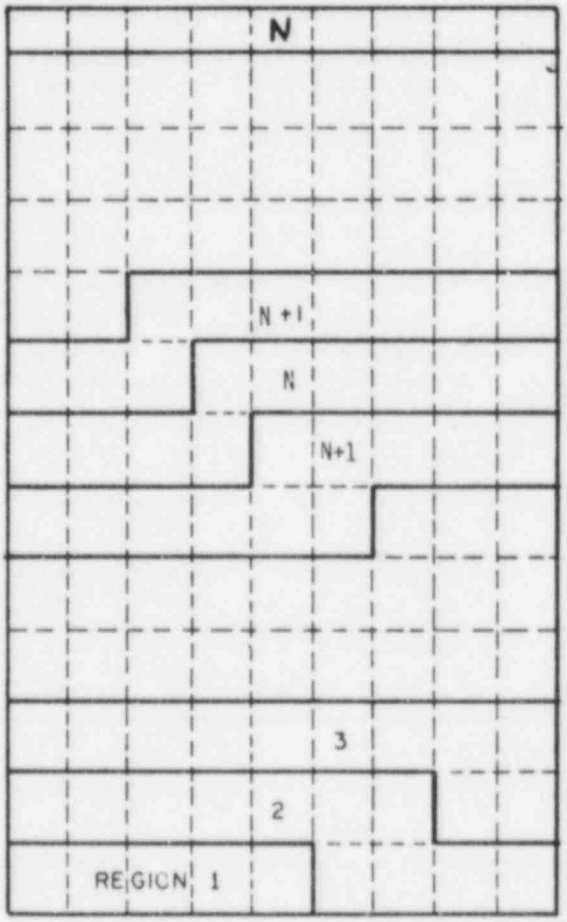

Fig. 7.1 Coarse Mesh Showing Rebalancing Regions

in resolving large-scale distributions rapidly and thus reduces the number of iterations required for the final solution of fine-mesh pressure equations.

In COMMIX, we have provided two possible options. They are:

- Plane-by-Plane Rebalancing: In this option we perform plane-by-plane rebalancing in either the x direction (IXREB=1), y direction (IYREB=1), or z direction (IZREB=1). Here, all cells of a plane (x, y, or z directional) are combined to form a region. The option is ideally suitable for simple geometries where flow is largely one-dimensional, e.g., flow through a pipe or flow through a reactor core.

- User-Specified: When a geometry is complex and flow is multi-dimensional, plane-by-plane rebalancing is not suitable. We have therefore implemented a generalized rebalancing scheme where a user can select and define the rebalancing regions.

There are three subroutines related to rebalancing:

IREBAL To perform initialization for user-specified rebalancing scheme,

REBAZ To perform plane-by-plane rebalancing, and

REBAZG To perform user-specified rebalancing.

Suggestions and samples are presented in the following sections.

7.3 RECOMMENDATIONS

- Rebalancing is recommended for all problems. If a flow domain is very complex and difficult to divide into several rebalancing zones, then we recommend rebalancing by considering the whole flow domain as one rebalancing region.

- Some rules must be followed in forming the rebalancing regions:
  - **Rebalancing regions must be within the fluid domain.**
  - **A region N must have neighboring cells only in the regions N-1 or N+1.**
  - A surface between regions N and N+1 is called surface 'n'. **Mass flow between region N and N+1 must be only through surface 'n'.** Therefore, parallel paths as separate regions are not permissible (see Fig. 7.2). However, combining all parallel paths into a one region is permissible (see Fig. 7.3).

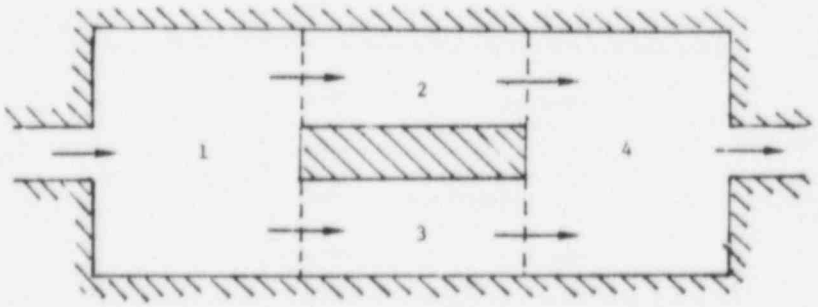

Fig. 7.2 Unacceptable Arrangement

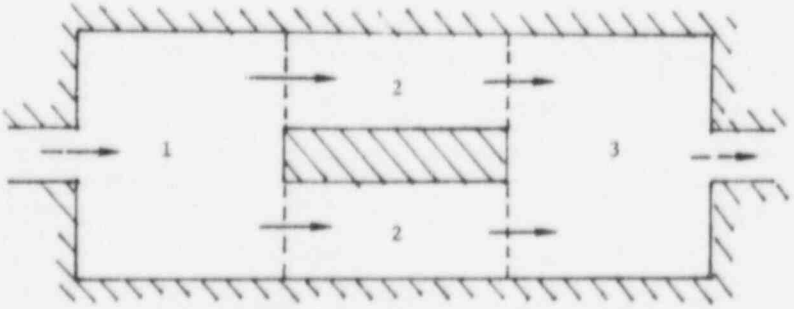

Fig. 7.3 Permissible Arrangement

- One approach to forming rebalancing regions is as follows:

  - Run a simulation for several time steps without rebalancing. Look at the resulting pressure distribution. Form rebalancing regions by placing rebalancing surfaces between regions of grossly different pressures.

7.4 INPUT PREPARATION

The input required for plane-by-plane and user-specified rebalancing are described below:

- **Plane-by-Plane**

  For plane-by-plane rebalancing, only two input variables need to be specified:

  - IXREB = 1, if rebalancing in x-direction, or

    IYREB = 1, if rebalancing in y-direction, or

    IZREB = 1, if rebalancing in z-direction,

  and

  - IREBIT = reblancing frequency; e.g., IREBIT = 1 means rebalancing every iteration, and IREBIT = 10 means rebalancing every 10th iteration.

- **User-specified**

  For a user-specified rebalancing, we must input seven variables (see Table 7.1) in NAMELIST/GEOM and NAMELIST/DATA, and location information through REBALANCING REGION CARDS. Both, the rebalancing-region location and rebalancing-surface locations must be specified. The FORMAT of the rebalancing-region location input is (A4,7I4):

  REBM NR IB IE JB JE KB KE

  We specify REBM for prescribing cells in the region NR. IB .... KE are the beginning and ending indices of cell locations.

  The FORMAT for the rebalancing-surface location input is also (A4,7I4):

  REBX
REBY
REBZ } NR IB IE JB JE KB KE

  We specify REBX, REBY, or REBZ to define whether it is the x, y, or z surface between the region NR and NR+1. The variables IB .... KE are for beginning and ending indices for a surface between regions NR and NR+1.

  For more detail relating to rebalancing-location input, see Appendix A.

Table 7.1. List of Variables for User-Specified Rebalancing

Variable	Description	Input Section
IFREB	For storage requirement. IFREB = number of cells in rebalancing regions plus number of cells on rebalancing surfaces.	GEOM
NEWREB	Signal for new rebalancing input when ISTATE = 0 or 2.	DATA
NREBRT	Number of rebalancing regions	DATA
NREBX(NR)	Number of x, y, and z surfaces between the regions NR and NR+1	DATA
NREBY(NR)		DATA
NREBZ(NR)		DATA
IREBIT	Rebalancing frequency	DATA

8. AUXILIARY INPUT

In addition to geometry specification, initialization, and model input, there are several auxiliary inputs that a user may need to provide. These inputs are briefly described here. More detailed information is presented in Appendix A.

8.1 HEAT TRANSFER CORRELATION

The purpose of the heat transfer correlation input is to provide information required in the calculation of the surface heat transfer coefficient in duct-wall and thermal-stucture models. The model equation for the heat transfer correlation in COMMIX is

$$Nu = C_1 + C_2 \, Re^{C_3} , \tag{8.1}$$

where, Nu is the Nusselt number, Re is the Reynolds number, and C_1, C_2 and C_3 are user-input constant coefficients.

The input variables related to heat-transfer correlations are:

NHEATC Number of correlations,

HEATC1(NH) Coefficient C_1 for correlation NH,

HEATC2(NH) Coefficient C_2 for correlation NH, and

HEATC3(NH) Coefficient C_3 for correlation NH.

The input section is NAMELIST /DATA/. The linkage to the duct-wall model is through variable IHTWAL(N) in NAMELIST /DATA/, and the linkage to the thermal structure model is through variable IHT in the thermal structure prototype cards NAMELIST /F/, e.g., IHTWAL(5) = 3 means heat transfer correlation 3 is to be used for surface 5, and IHT = 3 means heat transfer correlation 3 is to be used for that fluid/structure heat transfer.

8.2 MATERIAL PROPERTIES

The material properties input provides thermophysical properties of **solids**, e.g., stainless steel, used in the thermal-structure and duct-wall models.

The model equations for thermophysical properties in COMMIX are

$$k = c_o^k + c_1^k T + c_2^k T^2 \quad (W/m\text{-}°C) , \tag{8.2}$$

$$c_p = c_0^{c_p} + c_1^{c_p} T + c_2^{c_p} T^2 \quad (J/kg\text{-}°C) , \text{ and} \tag{8.3}$$

$$\rho = c_0^\rho + c_1^\rho T + c_2^\rho T^2 \quad (kg/m^3) . \tag{8.4}$$

Here, k, c_p, and ρ are thermal conductivity, specific heat, and density respectively, c_0, c_1, and c_2 are the user-specified coefficients, and T is the temperature in °C.

The input variables related to material properties are:

NMATER — Number of solid materials,

CØK(NM), C1K(NM), C2K(NM) — Conductivity-equation coefficients,

CØCP(NM), C1CP(NM), C2CP(NM) — Specific-heat-equation coefficients, and

CØRO(NM), C1RO(NM), C2RØ(NM) — Density-equation coefficients.

The input section is NAMELIST /DATA/. The linkages to the duct-wall model is through the variable MATWAL(N) in NAMELIST /DATA/; and linkage to the thermal-structure model is through MI in the thermal-structure prototype card NAMELIST /M/; e.g., MATWAL(3) = 5 means use the property values of material 5 for surface 3.

8.3 SIMPLIFIED PROPERTIES

The simplified properties input provides thermophysical properties of a **fluid** being considered for numerical simulation.

There are two built-in property packages in COMMIX--for liquid sodium and for liquid water. The simplified-property package is provided as an option for simulating fluids different from liquid sodium or liquid water.

The model equations for thermophysical properties are:

$$h = c_\emptyset^h + c_1^h T \quad (J/kg) , \tag{8.5}$$

$$\rho = C_{\emptyset}^{\rho} + C_1^{\rho} T \qquad (kg/m^3) , \qquad (8.6)$$

$$k = C_{\emptyset}^{k} + C_1^{k} T \qquad (W/m\text{-}^{\circ}C) , \text{ and} \qquad (8.7)$$

$$\mu = C_{\emptyset}^{\mu} + C_1^{\mu} T \qquad (Pa.s) . \qquad (8.8)$$

Here, h, ρ, k, μ, and T are enthalpy, density, conductivity, viscosity, and temperature respectively. C_0 and C_1 are the user-specified coefficients.

The input variables are:

FCØH,FC1H Coefficients of enthalpy equation,

FCØRO,FC1RO Coefficients of density equation,

FCØK,FC1K Coefficients of conductivity equation, and

FCØMU,FC1MU Coefficients of viscosity equation.

Additional variables are:

IFPROP 1 for simplified properties option and

FCTLO, FCTHI A small property table is printed with five temperature values ranging from FCTLO to FCTHI at pressure PRESØ.

The input section is NAMELIST /DATA/.

8.4 TURBULENCE MODELING

In COMMIX-1B, we have provided four turbulence-model options for simulating turbulent flows. They are

- Constant diffusivity model,
- Zero-equation model,
- One-equation model, and
- Two-equation model.

The theory and equations relating to these models are described in Volume I. Here, we present only the information needed by the user.

8.4.1 Signal Parameter

The variable ITURKE in NAMELIST /GEOM/ specifies which turbulence model is to be used.

ITURKE 0 No turbulence model (laminar flow) or constant diffusivity model,

10 Zero-equation model,

11 One-equation model, and

12 Two-equation model.

8.4.2 Constant-Diffusivity Model

In the constant-diffusivity model (ITURKE=0), a user needs to specify the values of turbulent viscosity (μ_{tur}) and turbulent conductivity (λ_{tur}) in NAMELIST /DATA/. The corresponding FORTRAN variables are TURBV and TURBC, respectively.

It is recommended that values be prescribed that have been obtained from the experimental data. If such values are not available, then a user can either estimate or use Eq. 6.4 of Volume I to compute μ_{tur} and then prescribe.

If the information about turbulent conductivity is not available or can not be estimated, then a user can prescribe values for

CHARRE Characteristic Reynolds number and

CHART Characteristic temperature (°C)

in NAMELIST /DATA/. The code then uses Eq. 6.10 of Volume I to compute the turbulent conductivity.

8.4.3 Zero-Equation Model

In the zero-equation model (ITURKE=10), turbulent diffusivities are computed using the following equations:

$$\mu_{tur} = \rho \ell^2 \text{ (velocity gradient) and} \tag{8.9}$$

$$\lambda_{tur} = \frac{C_p \mu_{tur}}{Pr_{tur}} . \tag{8.10}$$

Here, the mixing length ℓ is related to the distance y from the nearest wall as

$$\ell = \kappa y \qquad (\text{for } y < y_{cutoff} = 0.175\ D_h), \tag{8.11}$$

$$= \kappa y_{cutoff} \quad (\text{for } y > y_{cutoff} = 0.175\ D_h). \tag{8.12}$$

Pr_{tur} is the turbulent Prandtl number, and κ is the Von Karman constant with recommended value of $\kappa = 0.42$.

Therefore, the input requirements for the 0-equation model in NAMELIST /DATA/ are the following.

AKAPPA Von Karman constant k with default value 0.42.

HYDIN Hydraulic diameter D_h. (For hex-geometry option, IGEOM > 0, this variable is internally computed.)

PRNDLH Turbulent Prandtl number Pr_{tur}.

8.4.4 One-Equation Model

In the 1-equation model (ITURKE=11), we solve the transport equation for turbulence kinetic energy k and compute turbulent diffusivities using the relations

$$\mu_{tur} = \frac{C_D \rho k^2}{\varepsilon} \tag{8.13}$$

and

$$\lambda_{tur} = \frac{c_p \mu_{tur}}{Pr_{tur}} . \tag{8.14}$$

Here, C_D is the user-specified coefficient, c_p is the specific heat, Pr_{tur} is the user-specified turbulent Prandtl number, and

$$\varepsilon = \frac{C_D^{3/4} k^{3/2}}{\ell} \tag{8.15}$$

is the dissipation rate of turbulent kinetic energy. The mixing-length scale ℓ in Eq. 8.15 is calculated by

$$\begin{aligned} \ell &= \kappa y \qquad (\text{for } y < y_{cutoff}) \\ &= \kappa y_{cutoff} \quad (\text{for } y > y_{cutoff}). \end{aligned} \tag{8.16}$$

Here, κ is the von Karman constant, y is the distance from the nearest surface,

$$y_{cutoff} = 0.175\ D_h \tag{8.17}$$

is the cutoff value for the distance y, and D_h is the hydraulic diameter.

For this model, we therefore need to input the following variables:

AKAPPA Von Karman constant κ,

CDTURB Coefficient C_D in Eq. 8.13,

HYDIN Hydraulic diameter D_h, and

PRNDLH Turbulent Prandtl number Pr_t.

In addition, we need to input several variables that are needed for the solution of the k equation. They are:

CHARRE Characteristic Reynolds number,

CHART Characteristic temperature (°C),

EE Coefficient for shear stress near wall (Eq. 6.32 of Volume I),

PRNDLK Turbulent Prandtl number for k diffusivity used in Eq. 6.21 of Volume I,

TDIN Coefficient in the computation of inlet dissipation rate

$$\varepsilon_{in} = (TDIN)\ k^{1.5} , \text{ and} \tag{8.18}$$

TKIN Coefficient in the computation of inlet turbulence kinetic energy.

8.4.5 Two-Equation Model

In the two-equation model (ITURKE=12), we solve the transport equations of turbulence kinetic energy k and dissipation rate of turbulence kinetic energy ε. These turbulent diffusivities are calculated using the following relations:

$$\mu_{tur} = \frac{C_D \rho k^2}{\varepsilon} \quad \text{and} \tag{8.19}$$

$$\lambda_{tur} = \frac{c_p \mu_{tur}}{Pr_{tur}} . \tag{8.20}$$

Input required to compute turbulent diffusivities includes:

CDTURB Coefficient C_D in Eq. 8.19 and

PRNDLH Turbulent Prandtl number Pr_{tur}.

Additional input is required relating to the transport equations of k and ε:

AKAPPA, HYDIN: Von Karman constant κ and hydraulic diameter D_h for length scale calculation,

CHARRE: Characteristic Reynolds number,

CHART: Characteristic temperature (°C),

CT1, CT2: Constants used in the transport equation for dissipation rate ε (Eq. 6.25 in Volume I),

EE: Coefficient used in the computation of wall shear stress (Eq. 6.32 in Volume I),

PRNDLD: Turbulent Prandtl number for ε diffisuvity used ir the transport equation for ε,

PRNDLK: Turbulent Prandtl number for k diffusivity used in the transport equation for k, and

TDIN, TKIN: Coefficients used in the equations for computation of inlet values of ε and k, respectively.

8.4.6 Auxiliary Input

In addition to the inputs described in the previous sections, there are several inputs that a user may need for the turbulence model. The purpose of such input is to perform some secondary functions, e.g., to control and monitor the solution, etc. These inputs are briefly described in Table 8.1.

Table 8.1 Possible Additional Inputs for Turbulence Model

Variable	Function	Models
ITMAXK	Maximum number of iterations for k equation	1- and 2-equation
NTJUMP	Frequency of calling turbulence subroutines	1- and 2-equation
OMEGAT	Relaxation factor for turbulent viscosity	0, 1, and 2-equation
OMEGAK	Relaxation factor used in the solution of k equation	1- and 2-equation
OMEGAD	Relaxation factor used in the solution of ϵ equation	2-equation
RELAXK	Relaxation factor for k	1- and 2-equation
EPS6	Convergence criterion for the k equation and ϵ equation	1- and 2-equation

8.5 DUCT-WALL MODEL

The duct-wall model input permits consideration of the thermal inertia (transient thermal response) of a boundary wall of finite thickness. If a user desires, one could alternatively account for the thermal inertia of a duct wall through thermal-structure modeling.

The following is a list of variables that need specification for the application of a duct-wall boundary condition.

WALLDX(N) Wall thickness (m).

MATWAL(N) Material type number; e.g., MATWAL(4) = 3, means that surface 4 has Material Type 3.

WALLQS(N) Average volumetric heat source $\dot{Q}_0$ (W/m^3).

QK(K) Axial-distribution function.

QIJ(I,J) Radial-distribution function.

IHTWAL(N) Heat-transfer correlation number for calculation of heat transfer coefficient h_{wf}.

HYDWAL(N) Characteristic length for heat transfer correlation.

HSINK(N) Heat-transfer coefficient h_{ws} ($W/m^2\,°C$).

TSINK(N) Surrounding temperature T_{sink} (°C).

The input section is NAMELIST /DATA/. The linkage to the duct wall is through temperature boundary condition specification, e.g., KTEMP(N) = 500 + NF means the transient function is to be used for duct-wall surface N.

8.6 NUMERICAL DIFFUSION

When flow is inclined to grid lines, and the pure-upwind scheme is used to formulate convection terms, numerical diffusion may result. To reduce numerical diffusion, we have provided two additional options in COMMIX-1B--the skew-upwind difference scheme and the volume-weighted skew-upwind difference scheme. The variables that a user needs to input to use these options are:

IESKEW Signal select the desired option and

ISKBAR To determine whether we desire to use two or four surrounding velocities for computing convection terms.

Detailed explanations of these variables are given in Appendix A.

8.7 TIME-STEP SIZE

COMMIX performs thermal-hydraulic calculations by marching in time. The values of the dependent variables at a given time t and time step n are known. The values of the dependent variables at time $t+\Delta t$ and time step n+1 are calculated. By repeating this procedure, the thermal-hydraulic conditions are determined for the desired time span.

For a steady-state calculation, the same procedure is followed. We start with an initial state and continue the marching-in-time process until the values of all dependent variables become slowly varying. The time step size for the implicit-steady-state calculation can be very large, e.g., as large as 10-20 times the Courant time step criterion.

In COMMIX, there are two options for selecting the time step size.

- A user can prescribe the desired time step size as input. The details of this input are given in Appendix A.
- The automatic time step option can be used.

In the automatic time step option, the time step size is evaluated based on the Courant condition:

$$\Delta t = C_1 \Delta t_C, \tag{8.21}$$

where C_1 is the user-prescribed coefficient, and Δt_C is the time step size evaluated from the Courant condition. The Courant time step size is the minimum time required for fluid to be convected through a cell.

The following list of input variables are related to time step size.

IDTIME Signals whether user-specified or Courant time step.

DT(1), DT(2), LASTDT: DT(1) is the time step size for steps 1 through LASTDT. DT(2) is the time step size for steps after LASTDT.

RDTIME Factor C_1 used for multiplying the Courant time step size (Eq. 8.21).

TIMAX, NTMAX — Variables to define limits on maximum time and/or maximum number of time steps before stopping computation.

8.8 RELAXATION PARAMETERS

The finite-difference discretization equations in COMMIX have been constructed such that, if there were no interlinkages and nonlinearities, convergence would be certain. However, because the equations of interest almost always contain nonlinear and interlinked influences, care has to be taken to prevent divergence. One simple strategy is to slow down the changes that would occur from iteration to iteration. This is accomplished via underrelaxation.

8.8.1 Implicit Underrelaxation

The general finite-difference discretization equation of COMMIX is

$$a_0^{\phi}\phi_0 = \sum_{\ell} a_{\ell}^{\phi}\phi_{\ell} + a_0^{\phi 0}\phi_0^0 + b_0^{\phi} , \tag{8.22}$$

where the subscript ℓ denotes the neighbor points. This equation can be modified as follows. From Eq. 8.22 we can write

$$\phi_0 = \sum_{\ell} \frac{a_{\ell}^{\phi}}{a_0^{\phi}}\phi_{\ell} + \frac{a_0^{\phi 0}\phi_0^0}{a_0^{\phi}} + \frac{b_0^{\phi}}{a_0^{\phi}} . \tag{8.23}$$

Also, let

$$\phi_0^{new} = \omega\phi_0 + (1 - \omega)\,\phi_0^{*} , \tag{8.24}$$

where ϕ_0^{*} denotes the last iteration value of ϕ_0, ϕ_0 denotes the value obtained directly if Eq. 8.22 is solved, and ω is the underrelaxation factor. Substitution of Eq. 8.23 in Eq. 8.24 and rearrangement gives

$$\left(a_0^{\phi}/\omega\right)\phi_0^{new} = \sum_{\ell} a_{\ell}^{\phi}\phi_{\ell} + a_0^{\phi 0}\phi_0^0 + b_0^{\phi} + (1 - \omega)\left(a_0^{\phi}/\omega\right)\phi_0^{*} . \tag{8.25}$$

When ϕ_0 becomes equal to ϕ_0^{*} (i.e., the iterations converge), Eq. 8.25 becomes identical to Eq. 8.22. In the meantime, however, Eq. 8.25 would have a tendency to keep the resulting ϕ_0^{new} closer to ϕ_0^{*} than Eq. 8.22 would provided the relaxation factor ω is less than 1. A value of ω close to zero would indicate very heavy underrelaxation.

For the velocity components, a conservative value of $\omega = 0.7$ can be used. The energy equation can be conservatively underrelaxed by using $\omega = 0.8$. These values should be regarded as only initial suggestions; a proper set of ω values should be obtained by actual experience for a given class of problems. In COMMIX, the input parameters OMEGAV, OMEGAE, OMEGAK, and OMEGAD are provided for implicit underrelaxing velocities u, v, and w, enthalphy h, turbulence kinetic energy k, and dissipation rate of turbulence kinetic energy ε, respectively.

8.8.2 Successive Over Relaxation Factors

The following SOR relaxation factors have been included in COMMIX:

OMEGA for pressure,

RELAXE for enthalpy h, and

RELAXK for turbulence kinetic energy k.

8.9 OUTPUT

An input procedure, described in Appendix A, is provided for printing array values of a range of variables at given locations (specified plane) and at a given time or time step.

9. STEADY-STATE CALCULATION

9.1 INTRODUCTION

In COMMIX, even if we are analyzing a transient problem, we need to first obtain a steady-state solution to generate an initial condition for the transient problem.

To perform a steady-state calculation, we consider the problem as if it were a transient problem. We prescribe an estimated distribution of dependent variables as our initial condition and continue marching in time until the distribution becomes slowly varying.

9.2 INPUT PREPARATION

To start a steady-state calculation, we prescribe:

- Control flag ISTATE=0.
- Control flag IFRES=1.
- ALPHA=1; for steady-state simulation, we recommend the fully-implicit procedure.
- Geometrical information.
- Constant-value boundary conditions.
- Our best estimated values as initial conditions; to save computer running time, it is recommended that initial estimated values be prescribed as close as possible to the expected solution,
- Number of iterations IT=1. As we are performing a steady-state simulation, each time-step represents a steady-state iteration; therefore, more iterations per time step are not required.

- Time step size DT can be large. We recommend starting with DT=1000 sec. If it brings a convergence problem, then it can be reduced to, say, 100 sec or 10 sec or even less.
- Other ancillary information, e.g., output printing desired.
- Force-structure input, if any.
- Thermal structure modeling with heat source, if any.

Note: For a steady-state calculation, only the thermal structures with heat source need to be considered.

The control flag IFRES=1 implies that we are starting a new case and that at the end of the run we want the results to be written on a restart file. If we do not desire a restart file to be written, then we prescribe IFRES=0. For continuation of a steady-state run, we specify

- ISTATE=1 and
- IFRES=3

in the continuation-run input.

9.3 STEADY-STATE CONVERGENCE CRITERION

We define a steady-state solution as having been achieved when the following steady-state criteria are satisfied simultaneously:

$$\left(\frac{|\Delta h|}{h}\right)_{max} < \varepsilon_3 ,$$

$$\left(\frac{|\Delta u|}{VELMAX}\right)_{max} < \varepsilon_3 ,$$

$$\left(\frac{|\Delta v|}{VELMAX}\right)_{max} < \varepsilon_3 ,$$

$$\left(\frac{|\Delta w|}{VELMAX}\right)_{max} < \varepsilon_3 , \text{ and}$$

$$|\delta|_{max} < DCONV .$$

Here, Δu, ... Δh are the changes between successive time steps, δ is the mass residue, ε_3 is the steady-state convergence criterion, VELMAX is the maximum of all velocity magnitudes, and DCONV is the convergence parameter calculated using the relation

$$DCONV = \varepsilon_1 \left[\left(\frac{\rho u}{\Delta x} + \frac{\rho v}{\Delta y} + \frac{\rho w}{\Delta z}\right)_{max} + \varepsilon_2\right] . \qquad (9.1)$$

The default values of the convergence parameters ε_1, ε_2, and ε_3, are 1.0E-4, 1.0E-6, and 5.0E-5, respectively.

10. TRANSIENT CALCULATIONS

10.1 INTRODUCTION

We consider that in COMMIX any one or a combination of the following conditions can make a problem transient:

- Transient velocity boundary condition,
- Transient temperature boundary condition,
- Transient pressure boundary condition, and/or
- Transient heat source.

10.2 PROCEDURE

For running a transient problem, we recommend the following procedure

- Obtain a steady-state solution using constant-value boundary conditions and guessed initial distributions, and write the results on a restart file. The constant values to be used for specifying the boundary conditions must be the values at time t = 0 of the transient problem.
- Run the transient problem, using the restart data and the following additional input:
  - ISTATE = 2.
  - TSTART = starting time of the transient.
  - KFLOW(N) = 100+NF; this is for the transient velocity boundary condition. NF defines the transient function number to be used for the transient condition on surface N.
  - KTEMP(N) = 100+NF or 300+NF; this is for the transient temperature or heat flux boundary condition. NF defines the transient function number to be used for transient condition on surface N.
  - NOFQT: A transient function number to be used to describe the normalized heat source.
  - TVAL: Values of the independent variable (time) of the transient functions.
  - FVAL: Values of the dependent variable of the transient functions.

- NEND(N): Number of point values used to prescribe the transient function #N.

- Other ancillary information--time step size, output, etc.

10.3 TRANSIENT FUNCTIONS

In COMMIX we use the relation

$$F(t) = F(0) * f(t) \qquad (14.2)$$

to prescribe the desired variation of a function with time. Here, F(0) is the value of a function at time t = 0 and f(t) is the transient function. The following information is useful relative to transient functions in COMMIX:

- A set of f and t values must be prescribed for each transient function. Cubic spline-fit coefficients are evaluated to approximate a transient function as a polynomial.

- Up to 25 functions consisting of up to 100 points can be defined.

- All transient functions should be normalized with respect to values at time t = 0.

- FVAL and TVAL are the FORTRAN variable names for prescribing discrete values of f and t, respectively.

- NEND(NF) is the number of discrete f and t values prescribed for transient function #NF.

- FVAL and TVAL are one-dimensional arrays; the first value of the second transient function immediately follows the last value of the first function. The same pattern is followed for all subsequent transient functions.

- Discontinuities in a function can be indicated by specifying the same t value twice with the same or different f values.

10.4 DECOUPLED TRANSIENT CALCULATION

In a normal transient simulation, all three (mass, momentum, and energy) coupled conservation equations are solved at every time step. However, by decoupling* the mass-momentum and energy equations, one may save some computer running time because

- At a given time-step, we are now only solving either the mass-momentum equations or the energy equation,

---

*Here, decoupling means solving either the mass-momentum or the energy equation only at a given time step.

- Decoupling reduces the number of iterations required per time-step, and
- With decoupling, we can use a larger time-step size.

Therefore, we have provided a decoupling option that permits the solution of the

- mass-momentum equation, or
- energy equation, or
- mass-momentum and energy equations

at any time step.

The decoupling option is ideal for:

- A very long transient that might normally require prohibitively long computer running time, but which we are willing to consider as a quasi-transient problem,
- A transient with slowly varying velocity field, or
- A transient with slowly varying energy field.

The input parameters for invoking the decoupled calculation are ISETMO and ISETEN. The positive (negative) integer value of these parameters indicate the time step frequency with which the corresponding equation is solved (or not solved); e.g.,

- When ISETMO = 1 and ISETEN = 3, the mass-momentum equations are solved every time step and the energy equation is solved every third time step as indicated in the following table:

Time Step	1	2	3	4	5	6	7
Equations Solved	M	M	M E	M	M	M E	M

- When ISETMO = 3 and ISETEN = -3, the mass-momentum equation is solved every third time step and the energy equation is not solved at every third time-step. The following table describes the decoupling sequence:

Time Step	1	2	3	4	5	6	7
Equations Solved	E	E	M	E	E	M	E

With proper combinations of ISETMO and ISETEN, a user can set any desired order of decoupling.

The decoupling procedure can save a significant amount of computer running time. However, a user should be aware that the decoupled solution can drift from a true solution in cases where significant changes in the energy (velocity) field occur before the energy (mass-momentum) equation is once again solved. The optimum values of ISETMO, ISETEN, and the time step size are, of course, problem-dependent and should be obtained by actual experience for a given class of problems.

11. OPERATING COMMIX-1B

11.1 LOAD MODULE CREATION

To ease the task of creating load modules (binary files) to fit the size of the problem being considered, we have implemented a quasi-dynamic storage allocation scheme. Space for most of the geometry-dependent variables is allocated in the variable S of COMMON /SPACE/. The address of each variable is computed at the beginning of each run. These addresses are then passed into subroutines where the variables are named and variably dimensioned. The total length necessary to run a problem is compared with the storage available in COMMON /SPACE/. If the available storage is inadequate, execution terminates with a message indicating the space required. By changing the dimension of S in SUBROUTINE ALTER to the value indicated, and then recompiling and relinking ALTER to the existing load module, a new load module of the required size can be obtained.

Our practice is to maintain what we refer to as a base-load module in which the COMMON /SPACE/ variable S has a small value. By executing a problem on the base-load module, one can determine from the output the exact size of S needed to execute a problem. By specifying the appropriate dimension of S in SUBROUTINE ALTER, compiling and relinking with the base load module, one can obtain the required load module quickly and inexpensively.

11.2 INPUT/OUTPUT

11.2.1 Input Data File 5

The input for File 5 is described in Appendix A. The most current version of the input description is generally distributed with the code.

The input contains a mixture of NAMELIST and formatted data. It is rewound to allow for multiple passes through the file. A user may wish to change the file number of the read statements if the user's system does not provide for rewinding File 5.

11.2.2 Printed Output File 6

The printed output from COMMIX is written to File 6. A 133-character line length is assumed, with column 1 being the carriage control. The input data from File 5 and summary information, depending on the problem, are always printed. But the bulk of the output is user-specified and controlled by parameters such as ISTPR, NTHPR, NTPRNT, and TPRNT, which are described in Appendix A.

11.2.3 Restart Information Files 9 and 10

The restart capabilities of COMMIX are programmed in SUBROUTINE RESTAR. Blocks of information are written to File 10, which can be read by a subsequent job from File 9 to permit continued processing from the point at which the restart file was written.

Restart files are written optionally (see IFRES in Appendix A) in any of the following three events:

- Steady state is reached,
- The time specified for the job has elapsed,
- A specified time or time step has been reached.

The first event is indirectly controlled by the convergence parameters. The second and third events can be controlled by variables described in the "Restart Option" section under "NAMELIST /GEOM/" and the "Time and Time Step Related Parameter" section under "NAMELIST /DATA/" in Appendix A.

After the restart information has been written to File 10, several additional records are written. These records contain, in effect, a snapshot of the simulation as it existed when the restart was written. This information can then be used, by interfacing with the user's graphics programs, to obtain graphic plots, e.g., vector and isotherm.

11.2.4 Plot Tape File 76

Prior to reaching steady state, it is generally adequate to obtain plots only for points in time at which restart files are written.

Once steady state has been reached and a driving transient turned on, however, it is often desirable to save a complete history of the flow and temperature fields. SUBROUTINE PLTAPE provides this optional capability (see NTPLOT in Appendix A). At the beginning of File 76, a group of records containing geometry and properties information is written. Then, at user-controlled time steps, the entire velocity and temperature fields are written. This file can then be used to interface with the user's plotting routines.

11.3 COMMIX ERROR DETECTION AND DIAGNOSTICS

It is generally impossible to anticipate all the possible error conditions that one might encounter while using COMMIX. However, an attempt has been made to provide information that will guide the user through abnormal terminations.

There are many places where key variables are tested for meaningful values or where certain paths of a branch statement indicate error conditions. Some of these have been coded to call SUBROUTINE ERRCHK. This subroutine prints short error messages and determines whether processing can continue or must terminate.

The "Error Messages" section in Appendix A contains expanded explanations of the errors encountered.

12. CONCLUDING REMARKS

The development of COMMIX began in 1976, with emphasis on the analysis of fuel assemblies, specifically, under natural-circulation conditions. However, as the development progressed, and the structure of COMMIX started to evolve, it became apparent that COMMIX could be made a user-oriented general-purpose code with a wide range of capabilities and applicabilities.

The development of COMMIX then became a continuously evolving dynamic process. New modifications and improvements were implemented continuously in response to

- new physical models and solution procedures,
- feedback from users, and
- a desire to streamline the code, make it more user-oriented, and increase its generalities and capabilities.

The first version of COMMIX, named COMMIX-1, was released in March 1978. Development then continued, with many more features being added, such as thermal and force structure models, cylindrical geometry option, and rebalancing. In December 1983, the advanced version of the code, COMMIX-1A, was released. Since then we have added three more features, and release it now as an extended version called COMMIX-1B.

Since the inception of COMMIX development, code verification has been performed in parallel with the development. Extensive simulations have been performed to check and verify every step of development. It is generally felt that COMMIX is a very well tested computer code. However, because COMMIX is so large and general-purpose, some bugs might have been overlooked. We certainly welcome feedback from any user who may come across a bug or have other suggestions.

Within the constraints of available time and manpower, we have made every effort to make COMMIX a user-oriented computer code. But, there still are many more improvements that could be implemented to make it even more user-oriented. The following are examples

- Implement more error detections and diagnostics to provide information that will guide a user through abnormal terminations.
- Develop a software package for computing all geometry-related information (e.g., mesh size, volume and directional surface porosity, and surface area) and generating input for COMMIX.
- Develop an interactive input processor for auxiliary input information, e.g., boundary conditions, thermal and force structures.

- Develop an outprocessor connecting COMMIX output to plot processors for generating vector and isotherm plots.

If time and program funds permit, efforts will be made in these directions.

The development of COMMIX has been a very long and arduous task. It has taken nine years and the effort of a large group to bring it to the COMMIX-1B level. Seeing the code at the COMMIX-1B level of completion and releasing it through USNRC brings us a strong feeling of fulfillment. Furthermore, its acceptance as a viable tool by many organizations (more than 100 in the U.S. and abroad) is even more gratifying.

We hope that COMMIX will remain a vaiable analytical tool for a long time, and that increasing numbers of organizations will use it and take advantage of its capabilities and generality.

ACKNOWLEDGMENTS

Developing an operational code with such a wide range of applicability requires several years of cooperative effort, and the technical and moral support of many individuals.

We are indebted to all COMMIX users for whom this document is written. Their questions, suggestions, and criticisms have served in making COMMIX-1B a user-oriented computer code.

We acknowledge our special thanks to all our colleagues in the Analytical Thermal Hydraulic Research Program and specifically to Drs. B. C-J. Chen, H-N. Chi, and R. W. Lyczkowski for their contributions in the development, model improvement, and analysis work. We also acknowledge our thanks to Drs. W. L. Baumann and M. Bottoni of KfK-Germany, Dr. B. C. Cha, E. Gelbard, and G. K. Leaf of ANL, and to Profs. B. T. Chao and S. L. Soo of the University of Illinois-Urbana, and to Prof. A. Schor of MIT, for their stimulating discussions and for their constructive comments; and to Mrs. S. A. Moll for her patience, attention to detail, and typing of all reports, including this one.

The development of a code is never complete without validation. Here, we would like to express our sincere thanks to Drs. J. Chao, J. Kim, W. Loewenstein, and B. Sehgal of EPRI, and to H. Alter of the U. S. Department of Energy for providing support, guidance, and encouragement in the validation work.

Finally, COMMIX-1B would never have been developed without the guidance, faith, and support of Drs. R. T. Curtis and C. N. Kelber, and Mr. P. M. Wood, of the United States Nuclear Regulatory Commission.

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APPENDIX A. INPUT DESCRIPTION

ATHRP-020

COMMIX-1B

A Three-Dimensional Transient Single-Phase
Computer Program for Thermal Hydraulic Analysis
of Single and Multicomponent Systems

developed in the

Analytical Thermal Hydraulic Research Program
Components Technology Division
Argonne National Laboratory

under sponsorship of the

United States Nuclear Regulatory Commission
Office of Nuclear Regulatory Research

contact	phone
H. M. Domanus	312-972-5931
W. T. Sha	312-972-5910
R. C. Schmitt	312-972-5914
V. L. Shah	312-972-8049
F. F. Chen	312-972-6359

at

Building 308
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

Version 3.0 September 30, 1985

ATHRP-020

COMMIX-1B INPUT DESCRIPTION

September 18, 1985

Preface

'By making something absolutely clear,
you will confuse somebody.'
Murphy

'There is no such thing as instant experience.'
Oppenheimer's Law

Preface to COMMIX-1B

The starting point for COMMIX-1B was the most advanced version of COMMIX-1A (version 12.6). Several cosmetic changes were made, some restrictions on the input order and form were relaxed, and two new models were added. COMMIX-1B should therefore, have all the capabilities of COMMIX-1A plus the ability to handle turbulent flow and to deal with numerical diffusion. The experienced COMMIX-1A user should have no difficulties adjusting to the changes. All users, both new and experienced, would be well advised to follow this document carefully when setting up their first few simulation.
In addition, users are encouraged to check the summaries printed out near the beginning of each run whenever input values are changed.

Although the future development of the COMMIX code is uncertain we would like to encourage user feedback. If you find obvious coding errors or modeling weaknesses or if you have requests or suggestions for features that you feel might help other users please communicate them to us. We will include those which we feel are appropriate in future versions which may evolve.

+--------------------+
| Table of Contents |
+--------------------+

General Comments

The units used in COMMIX-1B are meter, kilogram, second, and degrees Celsius. These and other derived units are indicated after the description of variables requiring them.

Default values are indicated either by an asterisk or a value in parentheses after the variable description.

Arrays are indicated by the use of a subscript following the variable name. The ranges of the subscripts are indicated in the following table. An asterisk in the 'Current Limit' column indicates that storage is allocated at execution time according to the value in the 'Range' column.

Index	Range		Current Limit
I	IMAX		99
IND	IMAX*JMAX	IND=I*(J-1)*IMAX	100
J	JMAX		99
K	KMAX		99
N	NSURF		99
NH	NHEATC		10
NM	NMATER		10
NP			50
NR	NREBRT		50
NF	NFORCE		*
NC	NCORR		20

Some Terminology

The computational area is partitioned into a number of computational cells, each bounded by consecutive X, Y, and Z direction grid planes. Surfaces (portions of a plane or cylinder) may be defined both on the exterior, bounding the computational area, and in the interior. The intersection of a surface and consecutive grid planes outlines a surface element. Surfaces which coincide with a grid plane are called regular surfaces, otherwise, they are called irregular surfaces. A regular cell is one with all faces coinciding with grid planes. Irregular cells have one irregular surface element.

General Input Structure

Input for COMMIX-1B can be described in one of two ways:

1. Box Geometry: IGEOM=0 or IGEOM=-1
2. Hex Geometry: IGEOM>0

The box geometry option allows the user to describe the geometry in terms of the cells formed by the X, Y, and Z grid planes. In this case a typical input structure is as follows:

Problem Description Cards	(Optional)
NAMELIST /GEOM/	
Boundary Surface Identification Cards	(Optional)
NAMELIST /DATA/	
NAMELIST /INPUTQ/	(Optional)
Rebalancing Region Cards	(Optional)
Force Structure Specification Cards	(Optional)
Thermal Structure Prototype Cards	(Optional)
Thermal Structure Location Cards	(Optional)
Boundary Value Initialization Cards	
Internal Cell Initialization Cards	

The hex geometry option is used when analyzing hexagonal fuel assemblies only. Several conventions must be noted.

1. Axial length is along the Z-direction and one hex flat lies on the X-axis.
2. IMAX, JMAX, DX(I), and DY(J) are automatically determined by quarter pin and full pin partitioning.
3. Surfaces have the following locations:

Surface Number	Surface Location
1	Lower left diagonal in X-Y plane
2	Upper left diagonal in X-Y plane
3	Lower right diagonal in X-Y plane
4	Upper right diagonal in X-Y plane
5	Lower flat along X-axis
6	Upper flat
7	Entrance plane (Z=0.0)
8	Exit plane

A typical input structure for this case is as follows:

Problem Description Cards	(Optional)
NAMELIST /GEOM/	
NAMELIST /DATA/	
NAMELIST /INPUTQ/	
Rebalancing Region Cards	(Optional)
Force Structure Specification Cards	(Optional)
Thermal Structure Prototype Cards	(Optional)
Thermal Structure Location Cards	(Optional)
Boundary Value Initialization Cards	
Internal Cell Initialization Cards	

+----------------------+
| Reserved Key Words |
+----------------------+

Columns 1-4 of each line of input is compared with the list of key words below. When a match is found the line is reread in the appropriate format. If no match is found the card is ignored or, in effect, treated as a comment card.

REG	IREG	REBM	REBX	REBY	REBZ
XFOR	YFOR	ZFOR	&T	&F	&M
OUT	IN	HLB	PB	QBN	RLB
TLB	VELB	AL	ALX	ALY	ALZ
HL	P	QSOU	TL	UL	VL
WL					

****
* PROBLEM DESCRIPTION CARDS *
****

Any number of cards with user comments can precede NAMELISTs or be interspersed between non-NAMELIST input as long as columns 1-4 do not contain any of the above key words.

8

****
* NAMELIST /GEOM/ *
****

IMPORTANT !!

The following variables are used to allocate space.
It is important that they are specified correctly.
The variables preceded by an asterisk can be
approximated by a value larger than actually needed.
The minimum values are printed after they are computed.
Any of these variables that remain unchanged for a
subsequent restart run need not be respecified since
they are read from the restart file.

	*NM1	*NL1	NFORCE	IMAX	JMAX
	KMAX	IWIRE	ITURKE	*IFREB	ISTRUC
	IGEOM				

IGEOM 0..Regular box geometry option. (*)
-1..Cylindrical geometry option using box geometry input.
Note 1. A surface must be dedicated to R=0.0 when the origin is present. Set KFLOW(N)=-3 and KTEMP(N)=400 for that surface.
Note 2. For full 2.0*PI radian geometries J=1 and J=JMAX are automatically linked thus no surfaces need be defined at Y=0.0 and Y=2.0*PI.
>0..Hex geometry option. Set IGEOM to the number of pins in the hexagonal fuel assembly. The following values are acceptable: 7,19,37,61,91,127,169,217,271.

NL1 Total number of surface elements. (0)

NM1 Total number of computational cells. (0)
Note. Both NL1 and NM1 can be approximated by values larger than actually required. However, if this is done they must not be included in NAMELIST /GEOM/ when restarting (ISTATE>0). Storage will be allocated according to the values specified in the input rather than the minimum storage needed. The minimum values are printed when computed. If one desires to change NM1 and/or NL1, it must be done only at the start of a steady-state run (ISTATE=0).

+----------------------+
| Rebalancing Option |
+----------------------+

IFREB 0..No user-specified-region rebalancing. (*)
>0..Rebalancing is performed over user defined rebalancing regions and rebalancing surfaces. The value of IFREB is used to allocate storage for pointers and must be at least as large as the total number of cells in the rebalancing regions plus the total number of cells used to specify rebalancing surfaces. A value of 2 * NM1 should be adequate space for most cases. The exact value needed will be printed in the Rebalancing Summary. The input defining the rebalancing regions i.e., the Rebalancing Option section of NAMELIST /DATA/ and the REBALANCING REGION CARDS must be included at the start of a steady state run (ISTATE=0) when IFREB > 0. These two sections can be completely redefined at the beginning of a transient run (ISTATE=2) by seting NEWREB=1 in NAMELIST /DATA/.
Note. In addition to rebalancing over user specified regions, plane-by-plane rebalancing is available and controlled by the variables IXREB, IYREB, and IZREB in the Rebalancing Option section of NAMELIST /DATA/.

+-----------------+
| Restart Option |
+-----------------+

There are two ways to force the code to write a restart file. The first is to allow the job to "max time". This is done by specifying large values for NTMAX and TIMAX. The amount of time remaining for the job is checked at the end of each iteration using the Argonne system routine TLEFT. (See the appendix section entitled MACHING DEPENDENT ROUTINES.) If the amount of time remaining is greater than TREST, an input parameter in NAMELIST /DATA/, another iteration is performed. if not, a restart file is written.

The second way to obtain a restart file is to set NTMAX or TIMAX to a time step or time which will be reached before the CPU job time expires. A restart file will be written at this time step or time. After a restart file is written, execution terminates.

When restarting from a previous run make sure that ISTATE is set to the appropriate value. Also, it is advisable to delete all input for variables that one does not intend to change. In some cases variables will be reset back to their initial values if the input specification remains in the input stream. In short, the minimum input necessary is the correct input for restart cases.

IFRES
0..New case with no restart written. (*)
1..New case with restart written to Tape 10.
2..Restart of previous run read from Tape 9 with no restart written.
3..Restart of previous run read from Tape 9 with restart written to Tape 10.

ITURKE
In this version of COMMIX-1B four turbulence models are included. For all of the details of input requirements for these options see the Turbulence Models in NAMELIST /DATA/.
0..Constant turbulent viscosity model (*).
10..Zero-equation turbulence model.
11..One-equation turbulence model.
12..Two-equation turbulence model.

LMPRNT
0..Cell number and surface number arrays are not printed. (*) Specifying LMPRNT=1 or LMPRNT=2 causes excessive geometry debugging information to be printed and execution to terminate. This information is of little use to the casual user and is not recommended.
1..Cell number array is printed. Use LMPRNT=0.
2..Cell number and surface number arrays are printed. Use LMPRNT=0.

NFORCE
Number of force structures. (0) The input defining the force structures, i.e., the Force Structure section of NAMELIST /DATA/ and the FORCE STRUCTURE SPECIFICATION CARDS, must be included at the start of a steady-state run (ISTATE=0) when NFORCE > 0. These two sections can be completely redefined at the beginning of a transient run (ISTATE=2) by setting NEWFOR=1 in NAMELIST /DATA/.

ISTRUC
0..No thermal structures are used. (*) Do not include THERMAL STRUCTURE PROTOTYPE CARDS or THERMAL STRUCTURE LOCATION CARDS in the input.
1..The input defining the thermal structures, i.e., THERMAL STRUCTURE PROTOTYPE CARDS and and THERMAL STRUCTURE LOCATION CARDS must be included at the start of a steady-state run (ISTATE=0) when ISTRUC=1. These two sections can be completely redefined at the beginning of a transient (ISTATE=2) by setting NEWTS=1 in NAMELIST /DATA/.

ISTBUG
0--The storage layout table is not printed. (*)
1--The storage layout table is printed.

IBSBUG
0--The BOUNDARY SURFACE SUMMARY is not printed. (*)
1--The BOUNDARY SURFACE SUMMARY is printed after which execution continues. For a description of the BOUNDARY SURFACE SUMMARY see the section entitled FINDING HOLES IN THE BOUNDARY in the appendix.
2--The BOUNDARY SURFACE SUMMARY is printed after which execution terminates.

For IGEOM=0 or IGEOM=-1 the following variables must be included in NAMELIST /GEOM/

IMAX — The maximum number of cells in the X-direction (R). (1)

JMAX — The maximum number of cells in the Y-direction (THETA). (1)

KMAX — The maximum number of cells in the Z-direction. (1)

NSURF — The number of unique surfaces enclosing the calculational area. Unique surfaces are determined by a unique combination of the following three characteristics:

1. Velocity Boundary Condition
2. Temperature Boundary Condition
3. The unit normal vector to the surface.

DX(I) — The calculational cell sizes along the X-axis, m.

DY(J) — The calculational cell sizes along the Y-axis, m or rad.

DZ(K) — The calculational cell sizes along the Z-axis, m.

The unit normal vectors referred to by the following three variables are those pointing into the calculational area.

XNORML(N) — The X-component of the unit normal vector to surface N.

YNORML(N) — The Y-component of the unit normal vector to surface N.

ZNORML(N) — The Z-component of the unit normal vector to surface N.

| For IGEOM>0 the following variables |
| must be included in NAMELIST /GEOM/ |

IPART — 0..Quarter pin partitioning is used. (*)
1..Full pin partitioning is used.

IWIRE — 0..No wire wrap option used. (*)
1..Smeared wire wrap option used. This option is suggested for low Reynolds number cases. The total wire wrap area and total wetted perimeter over an axial cross section are distributed over the cross section such that there are two mean hydraulic diameters, one for cells not adjacent to a side wall and one for cells adjacent to side walls. The effect of wire wrap induced flow is ignored.
2..Cell integrated wire wrap force option used. This option requires input for CWIREX, CWIREY, and CWIREZ in NAMELIST /DATA/.

KMAX — The maximum number of cells in the Z-direction. (1)

CLADOD — Fuel pin diameter, m.

DZ(K) — The calculational cell sizes along the Z-axis, m.

PITCH — Distance between pin centers, m.

WALLCL — Wall clearance or distance between pin wall and duct wall, m.

WODIN — Wire wrap outside diameter for all wire wraps except those next to the duct wall, m.

WODOUT — Wire wrap outside diameter of wire wraps next to the duct wall, m.

CWIREI — Scale factor for wire wrap force model for cells not adjacent to side wall.

CWIREO — Scale factor for wire wrap force model for cells adjacent to side walls.

ZATO — Axial (Z) height where wire wrap is positioned along the positive X-axis relative to the rod center, m.

WIREP — Wire wrap pitch, m. Positive WIREP indicates counter-clockwise rotation when looking in the negative Z-direction. Negative WIREP indicates clockwise rotation.

****
* BOUNDARY SURFACE IDENTIFICATION CARDS *
****

This set of cards must be present only at the start of steady-state runs (ISTATE=0) when IGEOM=0 or IGEOM=-1.

The purpose of this set of cards is to specify a set of boundary surfaces which completely enclose the calculational region and to define any other boundary surfaces inside the calculational region. These interior boundary surfaces must completely surround a surface, a cell, or a group of cells. To completely surround a surface one must specify two boundary surfaces with normals in opposite directions. A single sided boundary surface is not allowed in the interior of the calculational region. Also be sure that all surfaces specified bound calculational cells. Each boundary surface is defined by specifying one or more BOUNDARY SURFACE IDENTIFICATION CARDS, each of which contains the following variables in FORMAT (A4,F10.3,7I4):

NAME AREA IB IE JB JE KB KE N

NAME — REG ..The surface is a regular surface.
Regular surfaces lie on grid planes.
IREG..The surface is an irregular surface.
Irregular surfaces do not lie on grid planes.

AREA — <0.0..The area of each surface element is set to its actual geometrical value, either DX*DY, DY*DZ, or DX*DZ, whichever is appropriate.
>0.0..The area of each surface element is assigned a value of AREA.

IB,IE
JB,JE
KB,KE — These six variables are the beginning and ending I-, J-, and K-indices that define a rectangular solid composed of one or more cells. The rectangular solid that defines or partially defines a surface is the one adjacent to and on the side pointed to by the surface normal. (Keep in mind that the surface normals XNORML, YNORML, and ZNORML always point into the calculational region.) The intersection of each cell and the surface defines a surface element.

N — The surface number. All surfaces with the same combination of the following three characteristics can be assigned the same surface number:

1. Velocity boundary condition,
2. Temperature boundary condition,
3. Unit normal vector to the surface.

Note 1. It is possible for two surface elements to lie in the same surface and have either the same or different surface numbers as well as for two surface elements to lie in different surfaces and have the same or different surface numbers.

Note 2. The order of the BOUNDARY SURFACE IDENTIFICATION CARDS must be as follows:

1. All IREG cards (irregular surfaces) must precede all REG cards (regular surfaces).
2. The surface numbers, N, of all IREG cards and REG cards must be in the order of increasing value.

Note 3. When using cylindrical geometry (IGEOM=-1), a surface must be specified at the origin when calculational cells are bounded by the origin. When an annular region is being modeled, a surface should not be defined at the origin but rather at the boundary of the first (counting from the center) calculational cell. Set KFLOW(N)=-3 and KTEMP(N)=400 for surfaces defined at the origin.

Note 4. When using cylindrical geometry (IGEOM=-1), with 2.0*PI radian geometries, J=1 and J=JMAX are automatically linked, thus, no surfaces need be defined at Y=0.0 and Y=2.0*PI.

Note 5. The scheme to indicate surfaces in the BOUNDARY SURFACE IDENTIFICATION CARDS is the same as that used to indicate surfaces in the BOUNDARY VALUE INITIALIZATION CARDS. This, however, is different from the scheme used to indicate surfaces in the INTERNAL CELL INITIALIZATION CARDS. In the former case, surface elements are indicated by the cell which is adjacent to and on the side pointed to by the surface normal. In the latter case, cell (I,J,K) indicates the surface between cell (I,J,K) and either cell (I+1,J,K), cell (I,J+1,K), or cell (I,J,K+1), whichever is appropriate for the variable being initialized. Surfaces lying on boundaries must not be initialized using the INTERNAL CELL INITIALIZATION CARDS but rather the BOUNDARY VALUE INITIALIZATION CARDS.

****
* NAMELIST /DATA/ *
****

ALPHA 0.0..Semi-implicit time advancement for both momentum and energy equations.
1.0..Fully-implicit time advancement for both momentum and energy equations. (*)

IBOIL 0..Do not check for boiling. (*)
1..Check for boiling each timestep. If boiling occurs execution terminates.

IDTIME 0..The time step size is taken from the user specified variable DT.
1..The time step size is computed internally as the product of the largest allowable time increment given the conditions (Courant time step size) and a user specified variable, RDTIME. (*)

IFENER 0..No energy calculation.
1..Energy calculation is performed. (*)
2..Energy calculation is performed with porosity adjusted conduction length. This option is usually used when analyzing hexagonal fuel assemblies (IGEOM>0).

IFPROP 0..Fluid properties are computed using rigorous equation-of-state subroutines. Packages for both sodium and water are included with the source. Only the desired package should be included when creating the load module since the same function names are used in both packages. Other property packages can be easily installed by the user. (*)
1..Fluid properties are computed using faster running simplified straight-line approximations to the state equations. This option requires additional input described under the Simplified Properties Option.

IFROD 0..No fuel rods are included. (*)
1..Fuel rods are included but no default initialization is done. NAMELIST /INPUTQ/ is required in input.
2..Fuel rods are included and a default initialization is done. This initialization sets pressure, temperature, density, enthalpy, and the Z-component of velocity from a solution of the coupled mass, moment and energy equations assuming no transverse velocities. NAMELIST /INPUTQ/ is required in input.

ITIBUG 1..Iteration information printed after each time step.
0..No iteration debugging information printed. (*)

The two variables below give the user some control over the frequency that the momentum and energy calculations are performed. The need for this control might arise in cases when one of the two fields (velocity or energy) varies slowly compared to the other. The intent is to be able to perform one of the calculations (momentum or energy) every time step while performing the other only occasionally resulting in a savings of CPU time. Before the user activates these variables it is highly recommended that s/he understand the full implications of this approximation. The following combinations are allowed:

ISETMO=1 and ISETEN=N where N is any nonzero integer.
ISETMO=N and ISETEN=1 where N is any nonzero integer.
ISETMO=M and ISETEN=N where one of the following conditions is satisfied: (1) M < 0 and N divides M or (2) N < 0 and M divides N.

ISETEN
- N..When N is less than zero the energy calculation is turned off ever -Nth timestep.
- N..When N is greater than zero the energy calculation is turned on only every Nth timestep. (1)

ISETMO
- N..When N is less than zero the momentum calculation is turned off every -Nth timestep.
- N..When N is greater than zero the momentum calculation is turned on only every Nth timestep. (1)

ISTATE
- 0..Start of steady-state run. Geometry, boundary conditions, and initial conditions are specified from the input stream. Other parameters take default values or zero. (*)
- 1..Continuation of a steady-state run. Initial conditions are read from the restart tape of a previous run in which steady-state has not yet been achieved. Some parameters may be changed in the input stream.
- 2..Beginning of a transient run. Initial conditions are read from the restart tape of a previous run. It is desirable that this previous run has achieved steady-state although not necessary. Some parameters may be changed in the input stream.
- 3..Continuation of a transient run. Initial conditions are read from the restart tape of a previous beginning-of-transient run or continuation-of-transient run. Limited changes may be made in the input stream.

The defaults for the following three values is 1 when ISTATE=0 and 0 when ISTATE=2. In other cases these variables are ignored.

NEWTS
- 0--No new thermal structure input is read.
- 1--New thermal structure information is read if ISTRUC=1 and ISTATE=0 or ISTATE=2.

NEWREB
- 0--No new rebalancing information is read.
- 1--New rebalancing information is read if IFREB>0 and ISTATE=0 or ISTATE=2.

NEWFOR
- 0--No new force structure information is read.
- 1--New force structure information is read if NFORCE>0 and ISTATE=0 or ISTATE=2.

Time and Time Step Related Parameters

TSTART — Initial time, s. (0.0) This value should be reset to zero at the beginning of a transient run, ISTATE=2.

IDTIME — 0..The time step size is taken from the user specified variable DT.
1..The time step size is computed internally as the product of the largest allowable time increment given the conditions (Courant time step size) and a user specified variable, RDTIME. (*)

DT(1) — Time step size for time steps 1 through LASTDT, s. (0.1) This value is used only if IDTIME=0.

DT(2) — Time step size for time steps after LASTDT, s. (0.1) This value is used only if IDTIME=0.

LASTDT — This variable in combination with DT allows the user to change the time step size during a run. The time step size for all time steps through LASTDT is taken from DT(1). After step number LASTDT, the time step size is taken from DT(2). (99999) This value is used only if IDTIME=0.

RDTIME — The time step size is computed internally as the product of the largest allowable time increment given the conditions and the variable, RDTIME. (0.8) This value is used only if IDTIME=1.

NTHCON — Up to ten values to specify the time step numbers to call SUBROUTINE GDCONV to calculate convergence criteria and the allowable time step size. The following are acceptable values of NTHCON:
0..No further calls to GDCONV.
>0..Time step number for which GDCONV is called. After the Nth positive time step number in NTHCON has been processed, the N+1th value of NTHCON is used to determine subsequent calls to GDCONV.
<0..A value of -N indicates that GDCONV is to be called every Nth time step. No subsequent values of NTHCON are considered. (-1)
See NTPRNT and NTPLOT for examples.

NTMAX — The maximum time step number for this run. Normal termination occurs after completion of this time step. (99999)

TIMAX — The maximum time of this run. Normal termination occurs after this time has been reached, s. (3.6E+7) TIMAX refers to the simulation or problem time and not the computer CPU time needed to run the problem.

TREST — The amount of time remaining for the job is checked at the end of each iteration. If the amount of time remaining is greater than TREST another iteration is performed. If not, the restart file is written.
When running long jobs or jobs requiring several seconds per iteration, one might wish to choose a larger more conservative value of TREST, s. (20.0)
This implementation depends on the Argonne system routine TLEFT which returns the time left until the total job time as specified on the JOB card has elapsed.

Iteration Control Parameters

The general definitions and default values of control parameters are given in this section. For a diagram showing the loop to which each variable relates, see the CONTROL PARAMETERS AT A GLANCE section in the appendix.

IT(1) Number of iterations for time steps 1 through LASTIT. (1)

IT(2) Number of iterations for time steps after LASTIT. (1) During a transient (ISTATE=2 or ISTATE=3) the number of iterations within a timestep should be increased to insure that the solution is converged within each timestep. This can be verified by assuring that the number of iterations, printed under the heading "IT" in the time step summary, is less than the input value of IT. Before increasing IT beyond 100, however, the user is encouraged to examine the input and results for possible improvements. The iteration summary within each timestep is printed when ITIBUG=1.

LASTIT This variable in combination with IT allows the user to change the number of iterations per time step during a run. The number of iterations for all time steps through LASTIT is taken from IT(1). After step number LASTIT, the number of iterations is taken from IT(2). (99999)

ITMAXP Number of iterations in the pressure iteration loop. (99)

ITMAXE Number of iterations in the energy iteration loop. (99)

OMEGAV Under-relaxation factor for the momentum equation coefficients. (0.8)

OMEGAE Under-relaxation factor for the energy equation coefficients. (0.8)

OMEGA Relaxation factor for pressure solution. (1.5)

RELAXE Relaxation factor for energy solution. (0.95)

EPS1 Convergence criterion parameter. (1.0E-4)

EPS3 Convergence criterion parameter. (5.0E-5)

EPS5 Convergence criterion parameter. (1.0E-5)

+---------------------------+
| Boundary Condition Types |
+---------------------------+

All external surfaces must have a velocity boundary condition type and a temperature|heat flux boundary condition type. Internal surfaces may also be assigned boundary condition types.

KFLOW(N) Type of velocity boundary condition. (The default for all NSURF surfaces is 1)

-5..Continuative mass flow outlet.
-4..Uniform velocity outlet.
-3..Free slip boundary.
-2..Continuative velocity outlet.
-1..Continuative momentum outlet.
1..Constant velocity boundary with normal velocity set from VELOC(N) or explicitly specified by the BOUNDARY VALUE INITIALIZATION CARDS. The tangential component is in effect zero. The presence of a solid wall (no slip boundary) must be indicated by using this type of boundary condition (KFLOW(N)=1) with the constant velocity set to 0.0. (*)
100+NF..Uniform transient velocity boundary with normal velocity set from the product of the NFth transient function and VELOC(N).

KTEMP(N) Type of temperature|heat flux boundary condition. (The default for all NSURF surfaces is 1)

1..Specified constant temperature boundary with temperature set from TEMP(N) or the BOUNDARY VALUE INITIALIZATION CARDS. (*) The surface heat flux is nominally computed considering the fluid conduction but not the presence of a wall. If one wishes to account for both the fluid convection and a wall conduction, the following four variables from the Wall Model section below must be specified: IHTWAL(N), HYDWAL(N), WALLDX(N), and MATWAL(N).
100+NF..Uniform transient temperature boundary with temperature set from the product of the NFth transient function and TEMP(N). The surface heat flux is computed with the options as specified above for KTEMP(N)=1.
200 ..Specified constant heat flux boundary with normal heat flux set from TEMP(N) or the BOUNDARY VALUE INITIALIZATION CARDS.
300+NF..Uniform transient heat flux boundary with normal heat flux set from the product of the NFth transient function and TEMP(N).
400 ..Adiabatic or zero diffusive heat flux boundary.
500+NF..Duct wall temperature boundary. This boundary condition type accounts for fluid convection, thermal capacity of the wall, and the heat transfer to the surrounding atmosphere or medium. The variables in the Wall Model section below must be specified. The transient fuction defined by NF is a multiplier of the volumetric heat source in the wall. If a constant volumetric heat source is desired, simply specify a value of 500 for KTEMP(N).

20

KPRES(N) Type of pressure boundary condition. Pressure boundary conditions are applied to the cells adjacent and interior to the boundary surface specified. (The default for all NSURF surfaces is 0)

0..No pressure boundary condition is applied. (*)

1..Uniform constant pressure boundary with pressure set from PRES(N).

100+NF..Uniform transient pressure boundary with pressure set from the product of the NFth transient function and PRES(N).

Boundary and Cell Initialization

The following three variables allow easy specification of uniform velocity, temperature|heat flux, and pressure values at boundaries at the beginning of a run (ISTATE=0). To change surface values of velocity, temperature, or pressure on subsequent restarts (ISTATE=1, 2, or 3) the BOUNDARY VALUE INITIALIZATION CARDS must be used. Nonuniform distributions can also be specified by using the BOUNDARY VALUE INITIALIZATION CARDS.

VELOC(N)	Initial velocity at surface N in the direction indicated by XNORML(N), YNORML(N), and ZNORML(N), m/s. (0.0)
TEMP(N)	Initial temperature for surface N, C. (0.0) For a constant or transient heat flux boundary, TEMP(N) contains the heat flux, W/m**2. (0.0)
PRES(N)	Initial pressure for surface N, Pa. (0.0)
TEMPO	Initial temperature of all internal cells, C. (0.0)
PRESO	Initial pressure at the pressure reference point located at (XPRESO,YPRESO,ZPRESO), Pa. (1.01353E+5) The inital static head pressure at any point is computed with respect to the pressure reference point.
XPRESO	X-coordinate of the pressure reference point, m. (0.0)
YPRESO	Y-coordinate of the pressure reference point, m. (0.0)
ZPRESO	Z-coordinate of the pressure reference point, m. (0.0)
GRAVX	X-component of gravity vector, m/s**2. (0.0)
GRAVY	Y-component of gravity vector, m/s**2. (0.0)
GRAVZ	Z-component of gravity vector, m/s**2. (0.0)

+------------+
| Wall Model |
+------------+

The variables in this section are used when specifying temperature boundary condition type 1, 100+NF, or 500+NF.

WALLDX(N) Wall thickness, m. (1.0)

MATWAL(N) Material type for surface N. The value of this variable is used as the index NM in the Material Properties (Solids) section below. (1)

IHTWAL(N) Heat-transfer correlation number for the calculation of heat-transfer between coolant and wall. The value of this variable is used as the index NH in the Fluid-Structure Heat Transfer section below. (0)
Note. If the default value is taken, then the coolant to wall heat-transfer coefficient, if used, is evaluated simply as the fluid conductivity divided by the fluid conduction length.

HYDWAL(N) Hydraulic diameter or characteristic length associated with surface N. (0)

The transient volumetric heat source is given by the product the following three variables and the transient function NF.

WALLQS(N) Average wall volumetric heat source, W/m**3. (0.0)

QK(K) Normalized axial distribution. (1.0)

TSINK(N) Temperature of surrounding atmosphere or medium, C. (0.0)

HSINK(N) Heat-transfer coefficient from wall to surrounding atmosphere or medium, W/(m**2-C). (0.0)

DTWALL Time step size used for with temperature boundary condition type 500+NF. This time step size is used only until steady-state is reached. s, (1.0E+40)

+--------------------------------+
| Fluid-Structure Heat Transfer |
+--------------------------------+

Heat transfer correlations are defined by specifying coefficients to compute the Nusselt number. These coefficients and thus the heat transfer correlations are indexed by the values of IHTWAL in the Wall Model and IHTSTR in the THERMAL STRUCTURE PROTOTYPE CARDS. The Nusselt number (NU) is computed from the following equation:

NU=HEATC1(NH)+HEATC2(NH)*RE**HEATC3(NH)
where RE is the Reynolds number.

NHEATC — Number of heat transfer correlations. (1) This value must be at least as large as the largest value of IHTSTR and IHTWAL.

HEATC1(NH) — Nusselt number coefficient. Since the Nusselt number, NU, must always be positive, HEATC1(NH) should be positive to accomodate a zero flow situation. (5.0)

HEATC2(NH) — Nusselt number coefficient. (4.02E-4)

HEATC3(NH) — Nusselt number coefficient. (0.8)

The Nusselt number is used to specify the heat transfer cofficient (h) in the following equation:

h=(k/D)*Nu
where k is conductivity and
D is the reference length.

h is in turn used to compute the Fluid-Structure heat transfer (q) as follows:

q=A*h*(Ts-Tf)
where A is the area,
Ts is the temperature of the structure, and
Tf is the temperature of the fluid.

+-------------------------------+
| Material Properties (Solids) |
+-------------------------------+

The following equations are used to define the thermal conductivity, specific heat, and density of materials other than the coolant.

```
CONDUCTIVITY =C0K (NM)+C1K (NM)*TC+C2K (NM)*TC**2  W/(m-C)
SPECIFIC HEAT=C0CP(NM)+C1CP(NM)*TC+C2CP(NM)*TC**2  J/(kg-C)
DENSITY      =C0RO(NM)+C1RO(NM)*TC+C2RO(NM)*TC**2  kg/m**3
```

where TC is the temperature in degrees Celsius and NM is the number of the material region.

The coefficients listed below are indexed by values of MATWAL from the Wall Model section of NAMELIST /DATA/ and MATERL from from the THERMAL STRUCTURE PROTOTYPE CARDS.

NMATER — Number of materials. (0) This value must be at least as large as the largest value of MATWAL and MATERL.

C0K(NM) — Conductivity coefficient. (0.0)
C1K(NM) — Conductivity coefficient. (0.0)
C2K(NM) — Conductivity coefficient. (0.0)

C0CP(NM) — Specific heat coefficient. (0.0)
C1CP(NM) — Specific heat coefficient. (0.0)
C2CP(NM) — Specific heat coefficient. (0.0)

C0RO(NM) — Density coefficient. (0.0)
C1RO(NM) — Density coefficient. (0.0)
C2RO(NM) — Density coefficient. (0.0)

```
+--------------------+
| Rebalancing Option |
+--------------------+
```

Large scale pressure distributions such as those which exist in an initial static state or which occur during overall velocity transients are most effectively addressed with the mass rebalancing scheme. This rebalancing is effective in reducing the number of iterations required to achieve mass convergence. Rebalancing has been implemented in two different modes which can be applied separately or in combination. Plane-by-plane rebalancing in the X-, Y-, or Z-direction can be applied simply by specifying the appropriate values for IXREB, IYREB, and IZREB. Only one Plane-by-plane rebalancing option can be specified.

IXREB
- 0..No X-direction plane-by-plane rebalancing. (*)
- 1..Plane-by-plane mass rebalancing in the X-direction is performed.

IYREB
- 0..No Y-direction plane-by-plane rebalancing. (*)
- 1..Plane-by-plane mass rebalancing in the Y-direction is performed.

IZREB
- 0..No Z-direction plane-by-plane rebalancing. (*)
- 1..Plane-by-plane mass rebalancing in the Z-direction is performed.

User-defined-region rebalancing requires the user to define rebalancing regions within the fluid domain. The regions must be chosen such that region N has neighboring cells only contained in regions N-1 and N+1. Mass leaving region N and entering region N+1 does so through rebalancing surface N. Mass leaving the last region goes into the remaining cells (there must be at least one) which are not in any rebalancing region and where no rebalancing is performed. Region 1 is required to have neighboring cells only in region 2. One approach to choosing rebalancing regions is to exclude all cells adjacent to exits and then group the remaining cells into as many rebalancing regions as possible. Another guideline is to put rebalancing surfaces between regions of grossly different pressures. In each rebalancing region the pressure is adjusted uniformly in such a way to force the net mass nonconservation to vanish. If user-defined-region rebalancing is desired, IFREB must be assigned an appropriate positive value in NAMELIST /GEOM/ and REBALANCING REGION CARDS must be supplied. Additionally, the following group of variables must be defined.

NREBRT Number of user-defined rebalancing regions. (0)

NREBM(NR) Number of cells in rebalancing region NR. (0) Rebalancing regions are generally chosen in such a way that all the cells in a given region have nearly equal pressure. Also, one cell may not be included in more than one rebalancing region.

NREBX(NR) Number of internal X-surfaces between region NR and NR+1. (0) Interfaces between rebalancing regions often correspond to a physical structure which might cause a large pressure change.

NREBY(NR) Number of internal Y-surfaces between region NR and NR+1. (0)

NREBZ(NR) Number of internal Z-surfaces between region NR and NR+1. (0)

The frequency at which rebalancing occurs is specified by the following variable.

IREBIT Rebalancing is performed before every IREBITth iteration. In order to improve convergence, the number of iterations should be one less than a multiple of IREBIT. That is, IT or ITMAXP=(N*IREBIT)-1. (50)

+-------------------------------+
| Simplified Properties Option | To be included if and only if IFPROP=1.
+-------------------------------+

IFPROP 0..Fluid properties are computed using rigorous equation-of-state subroutines. Packages for both sodium and water are included with the source. Only the desired package should be included when creating the load module since the same function names are used in both packages. Other property packages can be easily installed by the user. (*)

1..Fluid properties are computed using faster running simplified straight-line approximations to the state equations. This option requires additional specification as described below.

The following linear equations are used to approximate the state equations where TC is the temperature in degrees C.

ENTHALPY	= FC0H + FC1H * TC	J/kg
DENSITY	= FC0RO + FC1RO * TC	kg/m**3
CONDUCTIVITY	= FC0K + FC1K * TC	W/(m-C)
VISCOSITY	= FC0MU + FC1MU * TC	Pa-s
TEMPERATURE	= FC0T + FC1T * H	C

The coefficients listed below must be user specified.
The coefficients FC0T and FC1T are computed from FC0H and FC1H.

FC0H Enthalpy coefficient. (0.0)
FC1H Enthalpy coefficient. (0.0)
FC0RO Density coefficient. (0.0)
FC1RO Density coefficient. (0.0)
FC0K Conductivity coefficient. (0.0)
FC1K Conductivity coefficient. (0.0)
FC0MU Viscosity coefficient. (0.0)
FC1MU Viscosity coefficient. (0.0)

FCTLO
FCTHI To allow the user to spot check property values a small table is printed with five temperature values ranging from FCTLO to FCTHI at a pressure PRES0. When the sodium package is present, the default values of FCTLO and FCTHI are 300.0 and 700.0. When the water package is present, the default values are 20.0 and 100.0, C.

28

+----------------------+
| Transient Functions |
+----------------------+

All transient driving functions are input into the following three variables. They must be input at the beginning of the transient (ISTATE=2) even if they have been input previously. Each function is defined by a user specified set of points. Cubic spline fit coefficients are then generated in SUBROUTINE FITIT. Fifty equally spaced values are printed to allow the user to check the adequacy of the input distribution. Ten to fifteen values with points concentrated at rapidly changing Y-values should be adequate. Currently the total number of points allowed for the specification of transient functions is one hundred.

TVAL(NP) The independent variable, usually time, for the transient functions.

FVAL(NP) The dependent variable for the transient functions. The first value of the second function immediately follows the last value of the first function. The same pattern must be followed for all subsequent functions. Make sure that the entire range of the function used lies within the range input as the fitting routine does not extrapolate. Discontinuities are indicated by specifying the same X-coordinate twice with the same or different Y-coordinate values.

NEND(NF) The number of points in the NFth transient function

NTOTS In order to simplify thermal structure input in certain cases, the heat source transient function numbers can be overridden in NAMELIST /DATA/. These values are input into the variable NTOTS in the order in which the thermal structure prototypes were defined. Any values specified in NTOTS will override all other input and previous values. If no values of NTOTS are defined, no changes to the heat source transient function numbers are made.

NOFQT Number of the transient function which is used as a multiplier of the heat source for the coolant when thermal structures are present and as a multiplier of total heat source when no thermal structures are present. (0)

```
+------------------+
| Plot Tape Option |
+------------------+
```

NTPLOT Up to 25 values to specify when plotting information is to be written to tape 76. The following are acceptable values of NTPLOT:

0..No more plotting information is written to tape. (*)

>0..Time step number for which plotting information is written to tape 76. After the Nth positive time step in NTPLOT has been processed, the N+1th value of NTPLOT is used to determine subsequent writes to the tape.

<0..A value -N indicates that information is written to tape 76 every Nth time step. No subsequent values of NTPLOT are considered.

Example. NTPLOT=-5 indicates that every 5th step is to be processed. NTPLOT=5,10,-20 indicates that steps 5, 10, 20, 40, 60, etc., are to be processed. NTPLOT=10,20,0 indicates that only steps 10 and 20 are to be processed.

+-----------------+
| Printing Option |
+-----------------+

Calls to SUBROUTINE OUTPUT are controlled by the two variables NTPRNT and TPRNT. They can be used individually or together. The information printed at each call to SUBROUTINE OUTPUT is determined by the variables ISTPR and NTHPR described below.

NTPRNT Up to 50 time step numbers at which SUBROUTINE OUTPUT is to be called. The following are acceptable values for NTPRNT:

0..No more calls to SUBROUTINE OUTPUT. When restarting, previous specification of NTPRNT values may be overridden by specifying the desired new values followed by a zero in NTPRNT.

>0..Time step number for which SUBROUTINE OUTPUT is to be called. After the Nth positive time step in NTPRNT has been processed the N+1th value of NTPRNT is used to determine subsequent calls to OUTPUT.

<0..A value -N indicates that SUBROUTINE OUTPUT is called every Nth time step. No subsequent values of NTPRNT are considered.

-9999..SUBROUTINE OUTPUT is called just before the run is terminated. (*)

Example. NTPRNT=0 indicates that after initialization, SUBROUTINE OUTPUT is never called. NTPRNT=5,10,-9999 indicates that SUBROUTINE OUTPUT is called at steps 5, 10, and just before termination.

TPRNT Up to 50 times (problem time in seconds) at which SUBROUTINE OUTPUT is to be called. The following are acceptable values of TPRNT:

0.0..No more call to SUBROUTINE OUTPUT. (*) When restarting, previous specification of TPRNT values may be overridden by specifying the desired new values followed by a zero in TPRNT.

>0.0..Times at or after which SUBROUTINE OUTPUT is to be called. When or after the Nth positive time in TPRNT has been processed, the N+1th value of TPRNT is used to determine subsequent calls to OUTPUT.

<0.0..A value of -T indicates that SUBROUTINE OUTPUT is to be called at T-second intervals. If the Nth value is negative, then the N+1th value stores the next time value at which OUTPUT is to be called. This is nominally set to zero but can be specified by the user. No subsequent values of TPRNT are considered.

Example. TPRNT=1.0,5.0,-10.0 indicates that OUTPUT is to be called at or after times 1.0, 5.0, 10.0, 20.0, . . . etc.. TPRNT=-5.0,10.0 indicates that OUTPUT is to be called at times 10.0,15.0,20.0,. . . etc..

ISTPR Up to fifty coded values which specify the arrays to be printed in the first call to SUBROUTINE OUTPUT. (0)

NTHPR Up to fifty coded values which specify the arrays to be printed in all calls after the first call to OUTPUT.

For internal arrays, each value of ISTPR and NTHPR is a signed five digit integer of the form 'SVVPLL' which is coded according to the following rules:

S
- +..Only the plane specified by 'VVPLL' is printed. (*) A plus sign is assumed and need not be specified.
- -..All planes between the values of 'LL' on the current and following values of ISTPR or NTHPR are printed.

VV
- 01..UL U-component of velocity.
- 02..VL V-component of velocity.
- 03..WL W-component of velocity.
- 04..HL Enthalpy.
- 05..TL Temperature.
- 06..AL Volume porosity.
- 07..RL Density.
- 08..P Static Pressure.
- 09..DL Residual mass.
- 10..ALX X-direction surface permeability.
- 11..ALY Y-direction surface permeability.
- 12..ALZ Z-direction surface permeability.
- 13..DRDT d(RL)/d(TIME).
- 14..TURK Turbulent kinetic energy.
- 15..QSOUR Volumetric heat source.
- 16..PSTAT0 Initial Static pressure.
- 17.. P-PSTAT0
- 18..DDDPOT d(DL)/d(P).
- 19..DDDH d(DL)/d(HL).
- 20..TURCON Turbulent conductivity.
- 21..TURVIS Trubulent viscosity.
- 22..TKED Dissipation of turbulent kinetic energy.

P
- 1..An I-plane is printed.
- 2..A J-plane is printed.
- 3..A K-plane is printed.

LL Specific plane to be printed. If S is +, only one plane is indicated. If S is -, the 'LL' values in the current and next values of ISTPR or NTHPR indicate the range of planes to be printed.

For thermal structure information, each value of ISTPR and NTHPR is a signed five digit integer of the form 'S8NNNN' which is coded according to the following rules:

S +..Only structure number 'NNNN' is printed. (*)
   A plus sign is assumed and need not be specified.
   -..All structure between the values of 'NNNN' in the current and following values of ISTPR and NTHPR are printed.

NNNN Specific structure to be printed. If S is '+', only one structure is indicated. If S is '-', the 'NNNN' values in the current and next values of ISTPR or NTHPR indicate the range of surfaces to be printed.

For surface arrays, each value of ISTPR and NTHPR is a signed five digit integer of the form 'S9VVLL' which is coded according to the following rules:

S +..Only the surface number 'LL' is printed. (*)
   A plus sign is assumed and need not be specified.
   -..All surfaces between the values of 'LL' in the current and following values of ISTPR or NTHPR are printed.

VV 01..VELBN Normal surface velocity.
    02..QBN Normal surface heat flux.
    03..MB Adjacent internal cell number.
    04..HLB Surface enthalpy.
    05..TLB Surface temperature.
    06..AREA Surface element area.
    07..RLB Surface density.
    08..PB Surface pressure.
    09..IJK Adjacent internal cell indices. Each value is of the form 'IIJJKK' where II is the I index, JJ is the J index, and KK is the K index.
    10.. Overall heat transfer coefficient from coolant to wall as used in the transient duct wall model (KTEMP(LL)=500).

LL Specific surface to be printed. If S is +, only one surface is indicated. If S is -, the 'LL' values in the current and next values of ISTPR or NTHPR indicate the range of surfaces to be printed.

Example. ISTPR=06105,-10301,-10305,
NTHPR=01105,-02301,-02305,90101,-90501,-90505,

indicates that the first call to OUTPUT will print the I=5 plane of volume porosity and K-planes 1 through 5 of the X-direction surface permeability. On all subsequent calls, to OUTPUT, the I=5 plane of the U component of velocity, K-planes 1 through 5 of the V component of velocity, the boundary velocity for surface 1, and surface temperature for surfaces 1 through 5.

+------------------+
| Force Structures |
+------------------+

The Force Structures parameters are required only when NFORCE of NAMELIST /GEOM/ is greater than zero. The locations of the Force Structures are specified in the FORCE STRUCTURE SPECIFICATION CARDS.

The Force Structure is a mechanism whereby a force can be applied to the fluid across a cell face between two computational cells. For a convenient collection of resistance correlations that are most commonly needed by COMMIX users see reference number three.

Force correlations have been provided to model several specific structures. These can be used by specifying the appropriate correlation number in ICORR for each structure. Users may define additional force correlations in SURBOUTINE FORCES. Correlation numbers 50 through 99 are reserved for this purpose. The force correlation library consists of the following:

ICORR(NF) 90..CRBR fuel assembly
91..CRBR blanket assembly
92..DRHX (Direct Reactor Heat Exchanger)
93..CRBR chimney assembly
94..FFTF pin bundles
95..CRBR control assembly

Alternatively, one may use a generic force correlation. In this case, drag or resistance forces (Pa/m) of one of the following forms are computed:

DPDX=-FORCEF(NF)*RL*ABS(UL)*UL*FCORR/CLENTH(NF)
DPDY=-FORCEF(NF)*RL*ABS(VL)*VL*FCORR/CLENTH(NF)
DPDZ=-FORCEF(NF)*RL*ABS(WL)*WL*FCORR/CLENTH(NF)

where FCORR=ACORRL(NC)*RE**BCORRL(NC)+CCORRL(NC)
when RE < REYTRN(NC), and
FCORR=ACORRT(NC)*RE**BCORRT(NC)+CCORRT(NC)
when RE >= REYTRN(NC), and
RE=RL*SQRT(UL**2+VL**2+WL**2)*REYLEN(NC)/VIS, and
RL is the local density,
UL, VL, and WL are local velocities, and
VIS is the local viscosity.

FORCEF(NF) Force coefficient for force structure NF.
REYLEN(NF) Length used to compute the Reynolds number for force structure N, m.
CLENTH(NF) >0.0..The value input is used as the characteristic length in the above equation.
<0.0..A characteristic length computed from either DX, DY, or DZ, whichever is appropriate, is used for CLENTH(NF) in the above equation.
ICORR(NF) The correlation type of force structure NF. The values of ICORR must be less than 50 and are used as indices of the user specified correlation variables below.

NCORR	The number of correlation types available for force structures. This value must equal or exceed the maximum value specified in ICORR but be less than 50.
REYTRN(NC)	The transition Reynolds number.
ACORRL(NC) BCORRL(NC) CCORRL(NC)	Correlation coefficients when the Reynolds number above, RE, is in the laminar regime, i.e., when RE < REYTRN(NC).
ACORRT(NC) BCORRT(NC) CCORRT(NC)	Correlation coefficients when the Reynolds number above, RE, is in the turbulent regime, i.e., when RE >= REYTRN(NC).

+------------------------------+
| Reducing Numerical Diffusion |
+------------------------------+

When the direction of the flow is highly oblique to the grid lines, numerical diffusion may be significant. Several options to reduce this numerical diffusion are currently under assessment. To date, these options are only programmed for problems using a rectangular coordinate system. The default for computing the convective flux terms of the energy equation is the pure-upwind differencing scheme (IESKEW=0). If, however, the user feels that reducing numerical diffusion is necessary for a specific problem then the skew-upwind (IESKEW=1) or the volume-weighted skew-upwind (IESKEW=2) differencing schemes are available. The skew-upwind scheme may give overshoots and undershoots in some circumstances. The volume-weighted skew-upwind scheme attempts to remove these overshoot and undershoot possibilities.

IESKEW The convective flux terms of the energy equation are computed in the following ways:
0..Pure-upwind. (*)
1..Skew-upwind.
2..Volume-weighted skew-upwind.
3..Length-adjusted volume-weighted skew-upwind. The maximum length of the surrounding cells are set to the length of the center cell in the convective coefficients of the energy equation.

ISKBAR 0..The computation of the cell surface velocity components is performed using only the two velocity components in the upwind direction. (*)
1..The computation of the cell surface velocity components is performed using the four surrounding velocity components.

Turbulence Modeling

In all of the following turbulence models an effective viscosity is used in the diffusion term of the momentum equation. This effective viscosity is the sum of the turbulent viscosity and the the molecular viscosity. Similarly an effective thermal conductivity is used in the diffusion term of the energy equation which is likewise the sum of the turbulent thermal conductivity and the molecular thermal conductivity.

Constant Turbulent Diffusivity Model

The turbulent viscosity and turbulent conductivity are assumed constant everywhere. If TURBV=0, both turbulent viscosity and turbulent conductivity are zero. When a positive value is specified for TURBV, the thermal conductivity can be specified directly in TURBC or indirectly by specifying values for CHART and CHARRE.

For this option the following input must be specified:

ITURKE 0..Turbulent kinetic energy flag must be zero. (*)
The variable ITURKE must be input in NAMELIST /GEOM/.

CHARRE Characteristic Reynolds number. (0.0)
CHART Characteristic temperature, C. (0.0)
TURBC Turbulent conductivity, W/(m-C). (0.0)
Turbulent conductivity can be specified directly in TURBC or by setting TURBC to zero and specifying values for CHARRE and CHART.
TURBV Turbulent viscosity, Pa-s. (0.0) This must be set to some non-negative value.

+---------------------------------+
| Zero-Equation Turbulence Model |
+---------------------------------+

This option does not solve any governing equations involving turbulent quantities. The turbulent viscosity is computed from the following equation:

TURVIS=RO*LENSCA**2*VELOG
where RO is the local density,
LENSCA is the length scale (AKAPPA*YDIST),
YDIST is the distance to the nearest wall (a cutoff value of 0.175*HYDIN is used in the code), and
VELOG is a velocity gradient.

For this option the following input must be specified:
Note. The user must override the default value for HYDIN.

ITURKE 10..Turbulent kinetic energy flag must be 10.
The variable ITURKE must be input in NAMELIST /GEOM/.

AKAPPA Van Karman constant used as described above. (0.4)
HYDIN Hydraulic diameter, m. (0.0). HYDIN is internally computed when IGEOM > 0.
OMEGAT Relaxation factor for turbulent viscosity. (0.9)
PRNDLH Turbulence Prandtl number for thermal energy transfer. (0.9)

+--------------------------------+
| One-Equation Turbulence Model |
+--------------------------------+

The equation for turbulent kinetic energy is solved. Wall function corrections are applied to cells adjacent to solid walls for both the turbulent kinetic energy equation and the momentum equations. The turbulent viscosity is computed from the following equation:

TURVIS=CDTURB*RO*TURK**2/TKED
where CDTURB is the coefficient for computation of turbulent viscosity,
RO is the local density,
TURK is the local turbulent kinetic energy, and
TKED is the dissipation of turbulent kinetic energy computed from the following equation:
TKED=CDTURB**0.75*TURK**1.5/LENSCA
where LENSCA is the length scale (AKAPPA*YDIST), and
YDIST is the distance to the nearest wall (a cutoff value of 0.175*HYDIN is used in the code).

For this option the following input must be specified:
Note. The user must override the default values HYDIN and TDIN.

ITURKE 11..Turbulent kinetic energy flag must be 11.
The variable ITURKE must be input in NAMELIST /GEOM/.

AKAPPA	Von Karman constant used in the one-equation turbulence model. (0.4)
CDTURB	Coefficient for computation of turbulent viscosity. (0.09)
EE	Coefficient for computation of shear stress near the wall. (9.0)
EPS6	Convergence criterion parameter for turbulent kinetic energy equation. (1.0E-5)
HYDIN	Hydraulic diameter, m. (0.0) HYDIN is internally computed when IGEOM > 0.
ITMAXK	Maximum number of iterations for turbulent kinetic energy. equations. (29)
NTJUMP	This parameter controls the frequency with which the turbulence subroutines are called. The turbulence subroutines are called every NTJUMPth time step. (1)
OMEGAK	Relaxation factor for the turbulent kinetic energy equation coefficients. (0.95)
OMEGAT	Relaxation factor for turbulent viscosity. (0.9)

PRNDLH	Turbulence Prandtl number for thermal energy transfer. (0.9)
PRNDLK	Turbulence Prandtl number for turbulent kinetic energy (1.0)
RELAXK	Relaxation factor for turbulent kinetic energy solution (0.8).
TDIN	The inlet dissipation of turbulent kinetic energy is computed from the following equation: TKEDIN=TDIN*TURK**1.5 where TURK is the inlet turbulent kinetic energy and TDIN can be either determined empirically or by using the following equation: TDIN=CDTURB**0.75/(AKAPPA*0.175*HYDIN)
TKIN	Coefficient to compute inlet turbulent kinetic energy. (0.001)

+--------------------------------+
| Two-Equation Turbulence Model |
+--------------------------------+

This is the most rigorous turbulence model.
Both the equation for turbulent kinetic energy (TURK)
and the equation for dissipation of turbulent kinetic energy
(TKED) are solved. Wall function corrections are applied to
cells adjacent to solid walls for both the turbulent kinetic
energy equation and momentum equations. The turbulent
viscosity is computed using the following equation:

TURVIS=CDTURB*RO*TURK**2/TKED
where CDTURB is the coefficient for computation of shear
stress near the wall,
RO is the local density,
TURK is the local turbulent kinetic energy, and
TKED is the dissipation of turbulent kinetic energy.

For this option the following input must be specified:
Note. The user must override the default values for
HYDIN and TDIN.

ITURKE 12..Turbulent kinetic energy flag must be 12.
The variable ITURKE must be input in NAMELIST /GEOM/.

AKAPPA	Von Karman constant used in the one-equation turbulence model. (0.4)
CDTURB	Coefficient for computation of shear stress near the wall. (0.09)
CT1	Empirical constant used in the equation to compute turbulent kinetic energy. (1.44)
CT2	Empirical constant used in the equation to compute the dissipation of turbulent kinetic energy. (1.92)
EE	Coefficient for computation of shear stress near the wall. (9.0)
EPS6	Convergence criterion parameter for turbulent kinetic energy equation. (1.0E-5)
HYDIN	Hydraulic diameter, m. (0.0) HYDIN is internally computed when IGEOM > 0.

ITMAXK	Maximum number of iterations for turbulent kinetic energy. equations. (29)
NTJUMP	This parameter controls the frequency with which the turbulence subroutines are called. The turbulence subroutines are called every NTJUMPth time step. (1)
OMEGAD	Relaxation factor for equation to compute dissipation of turbulent kinetic energy. (0.7)
OMEGAK	Relaxation factor for equation to compute the turbulent kinetic energy. (0.95)
OMEGAT	Relaxation factor for turbulent viscosity. (0.9)
PRNDLD	Turbulence Prandtl number for dissipation of turbulent kinetic energy. (1.3)
PRNDLH	Turbulence Prandtl number for thermal energy transfer. (0.9)
PRNDLK	Turbulence Prandtl number for turbulent kinetic energy (1.0)
RELAXK	Relaxation factor for turbulent kinetic energy solution (0.8).
TDIN	The inlet dissipation of turbulent kinetic energy is computed from the following equation: TKEDIN=TDIN*TURK**1.5 where TURK is the inlet turbulent kinetic energy and TDIN can be either determined empirically or by using the following equation: TDIN=CDTURB**0.75/(AKAPPA*0.175*HYDIN)
TKIN	Coefficient to compute inlet turbulent kinetic energy. (0.001)

+----------------------------------+
| Cell Integrated Wire Wrap Force | These parameters are
+----------------------------------+ used only when IWIRE=2.

CWIREX Coefficient of wire force in X-direction. (0.5)
CWIREY Coefficient of wire force in Y-direction. (0.5)
CWIREZ Coefficient of wire force in Z-direction. (0.5)

+---------------------------+
| Fuel Assembly Drag Model |
+---------------------------+

The current implementation of the fuel assembly drag model is probably inoperative. The treatment of WETLEN needs to be reworked. Subroutines to look at include QGENER and TKENER. This model is intended to be used when analyzing rod bundle problems to provide flow resistances.

IDRAG 0..No flow resistance due to fuel assembly drag model (*).
1..Nominal fuel assembly drag forces applied.
2..Fuel assembly drag forces are applied as in option 1 except that the cross flow drag is multiplied by AL/ALX or AL/ALY where AL is the volume porosity and ALX and ALY are surface permeabilities. This option should be used when fuel assembly drag forces are desired and the cell integrated wire wrap force option is used (IWIRE=2).

CDRAGX Multiplier of drag force in X-direction. (1.0)
CDRAGY Multiplier of drag force in Y-direction. (1.0)
CDRAGZ Multiplier of drag force in Z-direction. (1.0)

WETLEN needs to be defined correctly to use the fuel assembly drag model.

****
* NAMELIST /INPUTQ/ * This namelist is read only when IFROD>0.
****

IQ	0..The axial power distribution is specified by the user in the variable QK(K). (*) 1..A cosine axial power distribution is initialized in the variable QK(K). 2..A mu*sin(mu) axial power distribution skewed toward the top is initialized in the variable QK(K). 3..A mu*sin(mu) axial power distribution skewed toward the bottom is initialized in the variable QK(K).
QK(K)	Axial power distribution. Nominally QK(K)=1.0 for all K between KLHS and KHHS and 0.0 for all other K.
KLHS	Lowest heated K-plane. (0)
KHHS	Highest heated K-plane. (0)
FNZ	Axial nuclear hot-channel factor used for IQ=1, 2, or 3. This is the ratio of maximum-to-average axial power density. (0)
QFLUX	Average constant heat flux, W/m**2. (0.0)
QSCOOL	Volumetric heat source for coolant, W/m**3. (0.0)
NOFQT	Number of the transient function which is used as a multiplier of the heat source for the coolant when thermal structures are present and as a multiplier of total heat source when no thermal structures are present. (0)
QIN(IND)	Normalized radial power distribution. To obtain the index, IND, from the cell indices, (I,J), the following relationship is used: IND=I+IMAX*(J-1).

When IGEOM > 0 the following variables must be considered:

CLADOD Clad outside diameter, m.

PITCHX Pitch in the X-direction, m. The default is DX(2) when IPART=1 and 2.0*DX(2) when IPART=0.

PITCHY Pitch in the Y-direction, m. The default is DY(2) when IPART=1 and 2.0*DY(2) when IPART=0

All flow areas, cell wetted perimeters and fraction-of-pin-in-cell values are initially set to values computed from a standard hexagonal fuel bundle geometry. If the user is considering a case which deviates from this default, any or all of these parameters can be reset by using the following four variables:

IJTYPE(IND) Cell type. Cell types are positive integers less than five and are used as indices of the following three variables. If a nonnegative value is given to any of the following three variables, then the corresponding value parameter will be set to that value in all cells of that type. To obtain the index, IND, from the cell indices, (I,J), the following relationship is used: IND=I+IMAX*(J-1).

PINAF(IJ) Fraction of pin in cells of type IJ where IJ=IJTYPE(IND). (-1.0)

FLOWA(IJ) Flow area of cells of type IJ where IJ=IJTYPE(IND), m**2. (-1.0)

WETLN(IJ) Wetted perimeter of cells of type IJ where IJ=IJTYPE(IND), m. (-1.0)

An example might help to clarify the input for the four variables above. Consider a case with IMAX=JMAX=10.

IJTYPE=15*1,10*2, indicates that cells (1,1) through (5,2) are assigned type 1 and cells (6,2) through (5,3) are assigned type 2.

PINAF=0.5,0.25, Cells of type 1 and 2 are given pin fraction values of 0.5 and 0.25 respectively.

FLOWA(2)=0.028, Cells of type 2 are assigned flow areas of 0.028 while cells of type 1 retain their default value as in a standard hexagonal geometry. Cells of type 1 and 2 also retain their standard hexagonal wetted perimeter values.

****
* REBALANCING REGION CARDS *
****

This set of cards must be included only when IFREB>0 in NAMELIST /GEOM/ and NEWREB=1 in NAMELIST /DATA/.

These cards are used to specify the location of rebalancing regions and rebalancing surfaces. Additional input is required in the Rebalancing Option section of NAMELIST /DATA/. Each card in this section contains the following variables in FORMAT (A4,7 FORMAT (A4,7I4).

NAME N IB IE JB JE KB KE

NAME
- REBM The cells defined on this card form (part of) a rebalancing region. At least one card of this type is required for each region.
- REBX The cells defined on this card define a rebalancing surface which coincides with an I grid plane. The surface defined by cell (I,J,K) is the surface between cell (I,J,K) and cell (I+1,J,K).
- REBY The cells defined on this card define a rebalancing surface which coincides with a J grid plane. The surface defined by cell (I,J,K) is the surface between cell (I,J,K) and cell (I,J+1,K).
- REBZ The cells defined on this card define a rebalancing surface which coincides with a K grid plane. The surface defined by cell (I,J,K) is the surface between cell (I,J,K) and cell (I,J,K+1).

N — Rebalancing region number.

IB,IE
JB,JE
KB,KE — These six variables are the beginning and ending I-, J-, and K-indices used to define a rectangular solid of cells which constitute (part of) a rebalancing region or a plane of cells adjacent to a rebalancing surface.

Note 1. Internal surfaces having zero-permeabilities should not be included as rebalancing surfaces.

Note 2. The number of cells and surfaces input in these cards must exactly match the numbers specified in the variables NREBRT, NREBM, NREBX, NREBY, and NREBZ in the Rebalancing Option section of NAMELIST /DATA/.

****
* FORCE STRUCTURE SPECIFICATION CARDS *
****

This set of cards must be included only when NFORCE>0 and NEWFOR=1 in NAMELIST /GEOM/.

These cards are used to locate the force structures described in the Force Structure section of NAMELIST /DATA/. These forces can be applied at cell faces between two computational cells. The locations therefore correspond to portions of grid planes. Each card in this section contains the following variables in the FORMAT (A4,7I4).

NAME N IB IE JB JE KB KE

NAME	XFOR	X-direction force.
	YFOR	Y-direction force.
	ZFOR	Z-direction force.
N		Force structure number.
IB,IE JB,JE KB,KE		These six variables are the beginning and ending I-, J-, and K-indices used to define a plane of cells. The cell face defined by cell (I,J,K) for an X-direction force is that one between cells (I,J,K) and (I+1,J,K). For a Y-direction force, it is the one between cells (I,J,K) and (I,J+1,K), and for a Z-direction force, it is the one between cells (I,J,K) and (I,J,K+1).

```
****************************************
* THERMAL STRUCTURE PROTOTYPE CARDS *
****************************************
```

This set of cards is included when ISTRUCT=1 in NAMELIST /GEOM/ and NEWTS=1 in NAMELIST /DATA/.

A thermal structure is a collection of thermal structure elements each of which has the same characteristics as specified by a thermal structure prototype. Thermal structure prototypes are defined using TYPE, FLUID, and MATERIAL namelists with the names T, F, and M respectively. The order in which these namelists are input indicates the the construction of the thermal structures and must conform to the following rules:

1. A TYPE namelist must begin the definition of each thermal structure prototype.
2. If fluid interacts with surface one, a FLUID namelist must be present after the TYPE namelist (before the first MATERIAL namelist). If, in addition, fluid interacts with surface two, a FLUID namelist must also be present after the last MATERIAL namelist.
3. A gap exists after each material except the last. The gap parameters are specified in the MATERIAL namelist.
4. The initial default for all namelist variables is zero. Subsequent defaults are the values in effect after reading the previous namelist. If, for example, the geometrical type is the same for all thermal structure prototypes, IXYZ need be specified only on the first TYPE namelist.
5. The definition of thermal structure prototype N+1 must follow the definition of thermal structure prototype N.
6. Blank cards or comment cards may be interspersed as desired.

The precise definition of each card is as follows:

```
+---------------------+
| TYPE   NAMELIST /T/ |
+---------------------+
```

N — Thermal structure prototype number. This number does not need to correspond to its index or ordinal number.

IXYZ — Geometrical type or characteristic.

- 1..Rods (cylinders) with axis aligned in the I-direction.
- 2..Rods (cylinders) with axis aligned in the J-direction.
- 3..Rods (cylinders) with axis aligned in the K-direction.
- 11..Slab with the normal aligned in the I-direction.
- 12..Slab with the normal aligned in the J-direction.
- 13..Slab with the normal aligned in the K-direction.
- 101..Sphere aligned in the I-direction.
- 102..Sphere aligned in the J-direction.
- 103..Sphere aligned in the K-direction.

The alignment specification is included in the spherical option to allow the normalized axial power distribution multiplier, QK, to be operative.

NT The number of the transient function to be used as a multiplier for the heat source.

RODFR Rods or cylindrical thermal structures:
>0..Number or fraction of actual rods interacting with each associated coolant cell.
<0..The absolute value is the number or fraction of rods per unit area (m**2) interacting with each associated coolant cell. The rods are perpendicular to the cell area.
Slab thermal structures:
>0..Slab area in each associated coolant cell, m**2.
<0..The absolute value is the slab area divided by the cell area. In the case of two sided thermal structures this value is equivalent to a solid permeability for the structure.
Spherical thermal structures:
>0..Number or fraction of spheres interacting with each associated coolant cell.
<0..The absolute value is the number or fraction of spheres per unit volume (m**3) interacting with each associated coolant cell.

OUTR Thermal structure outer radius, m. This is not used for slab type thermal structures.

| FLUID NAMELIST /F/ |

IHT Heat transfer correlation index. This value is used as the index, NH, of the variables HEATC1, HEATC2, and HEATC3 described in the Fluid-Structure Heat Transfer section of NAMELIST /DATA/.

HYD Hydraulic diameter or reference length. this value is used as D, the reference length, as described in the Fluid-Structure Heat Transfer Section of NAMELIST /DATA/.

| MATERIAL NAMELIST /M/ |

MI Material type index. This value is used as the index NM described in the Material Properties (Solids) Section of NAMELIST /DATA/.

NP Number of partitions in the material. A thermal structure temperature will be computed for each material partition.

DR Partition size, m.

Q Volumetric heat source for the material region, W/m**3.

The following gap properties must be correctly specified or defaulted only when another material follows. If a fluid follows, the gap properties are ignored.

SGAP Gap size, m.

HGAP Gap heat transfer coefficient, W/(m**2-C).

```
****************************************
* THERMAL STRUCTURE LOCATION CARDS *
****************************************
```

This set of cards is included if and only if ISTRUCT=1 in NAMELIST /GEOM/ and NEWTS=1 in NAMELIST /DATA/

Once the thermal structure prototypes have been defined the location of the thermal structure elements are specified by the THERMAL STRUCTURE LOCATION CARDS. These cards contain the following variables in FORMAT (A4,7I4)

LOC NUM IB IE JB JE KB KE

LOC — OUT ..The cells specified interact with the outside or surface 1.
IN ..The cells specified interact with the inside or surface 2.

NUM — Thermal structure prototype number.

IB,IE / JB,JE / KB,KE — These six variables are the beginning and ending I-, J-, and K-indices that define a rectangular (cylindrical) solid composed of one or more cells which are to interact with thermal structure NUM.

Note 1. A cell should not be specified twice by the indices unless the true intention is to have two occurrences of the thermal structure prototype NUM.

Note 2. Many THERMAL STRUCTURE LOCATION CARDS may be needed to define all the cells interacting with a given thermal structure prototype.

Note 3. The order in which cells are specified is arbitrary except when the thermal structure prototype has fluid cells interacting with both surfaces. In this case cells are paired off in the order in which they are specified. The number of cells interacting with one surface must equal the number of cells interacting with the other surface.

50

****
* BOUNDARY VALUE INITIALIZATION CARDS *
****

The purpose of this set of input cards is to permit initialization of boundary values of any of the arrays listed below. Uniform temperature and velocity boundary conditions can be more easily specified using the variables TEMP and VELOC in NAMELIST /DATA/. Each card in this section contains the following variables in the FORMAT (A4,F10.3,7I4).

NAME RVAL IB IE JB JE KB KE N

NAME
- HLB ..Enthalpy, J/kg.
- PB ..Pressure, Pa.
- QBN ..Heat flux, W/m**2.
- RLB ..Density, kg/m**3.
- TLB ..Temperature, C.
- VELB..Magnitude of the velocity normal to the surface in the direction indicated by XNORML(N), YNORML(N), and ZNORML(N), m/s.

RVAL — The value to be assigned to the variable named.

IB,IE / JB,JE / KB,KE — These six variables are the beginning and ending I-, J-, and K-indices that define a rectangular solid composed of one or more cells. The rectangular solid that defines or partially defines a surface is the one which is totally interior and adjacent to, or partially interior to and intersecting that surface.

Note. The scheme to indicate surfaces in the BOUNDARY SURFACE IDENTIFICATION CARDS is the same as that used to indicate surfaces in the BOUNDARY VALUE INITIALIZATION CARDS. This, however, is different from the scheme used to indicate surfaces in the INTERNAL CELL INITIALIZATION CARDS. In the former case, surface elements are indicated by the cell which is adjacent to and on the side pointed to by the surface normal. In the latter case, cell (I,J,K) indicates the surface between cell (I,J,K) and either cell (I+1,J,K), cell (I,J+1,K), or cell (I,J,K+1), whichever is appropriate for the variable being initialized. Surfaces lying on boundaries must not be initialized using the INTERNAL CELL INITIALIZATION CARDS but rather the BOUNDARY VALUE INITIALIZATION CARDS.

N — The surface number of the boundary being set.

****
* INTERNAL CELL INITIALIZATION CARDS *
****

The purpose of this set of input cards is to permit initialization of internal cell values of any of the arrays listed below. Each card of this section contains the following variables in the FORMAT (A4,F10.3,6I4):

NAME RVAL IB IE JB JE KB KE

NAME
- AL ..Volume porosity, the dimensionless ratio of fluid volume in a cell to total cell volume. (1.0)
- ALX ..Surface permeability, the dimensionless ratio of free flow area to the total surface element area, between cell (I,J,K) and cell (I+1,J,K). (1.0)
- ALY ..Surface permeability, the dimensionless ratio of free flow area to the total surface element area, between cell (I,J,K) and cell (I,J+1,K). (1.0)
- ALZ ..Surface permeability, the dimensionless ratio of free flow area to the total surface element area, between cell (I,J,K) and cell (I,J,K+1). (1.0)
- HL ..Enthalpy, J/kg.
- P ..Pressure minus initial static pressure, Pa. (0.0)
- QSOU..Volumetric heat source per computational cell volume DX(I)*DY(J)*DZ(K), W/m**3. (0.0)
- TL ..Temperature, C. (0.0)
- UL ..U-component of velocity, m/s. (0.0)
- VL ..V-component of velocity, m/s. (0.0)
- WL ..W-component of velocity, m/s. (0.0)

RVAL — The value to be assigned to the variable named.

IB,IE
JB,JE
KB,KE — These six variables are the beginning and ending I-, J-, and K-indices that define a rectangular solid composed of one or more cells.

Note. The scheme to indicate surfaces in the BOUNDARY SURFACE IDENTIFICATION CARDS is the same as that used to indicate surfaces in the BOUNDARY VALUE INITIALIZATION CARDS. This, however, is different from the scheme used to indicate surfaces in the INTERNAL CELL INITIALIZATION CARDS. In the former case, surface elements are indicated by the cell which is adjacent to and on the side pointed to by the surface normal. In the latter case, cell (I,J,K) indicates the surface between cell (I,J,K) and either cell (I+1,J,K), cell (I,J+1,K), or cell (I,J,K+1), whichever is appropriate for the variable being initialized. Surfaces lying on boundaries must not be initialized using the INTERNAL CELL INITIALIZATION CARDS but rather the BOUNDARY VALUE INITIALIZATION CARDS.

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* *                                                                 * *
* *               END OF COMMIX-1B INPUT DESCRIPTION                * *
* *                                                                 * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

BEHIND THE SCENES . . .

An Appendix to the COMMIX-1B Input Description

CONTROL PARAMETERS AT A GLANCE

The two tables below are included to clarify the role of some of the control parameters. The values indicated, while not guaranteed, are ones that have been found to work in many applications. The user is encouraged to optimize these parameters according to application.
A value enclosed in brackets '[]' indicates that the default value is different and that this value must be explicitly specified in the input. For example, the default for RDTIME is 0.8. When running with ALPHA=1.0 however, the recommended value of RDTIME is 10.0. Therefore in NAMELIST /DATA/ the specification 'RDTIME=10.0' must appear.

```
      +-------------------------------------------+
      | Semi-Implicit Time Advancement (ALPHA=0.0) |
      +-------------------------------------------+

+--Time Step Loop
|  NTMAX          99999
|  TIMAX         3.6E+7
|  IDTIME             1
|  TSTART           0.0
|  DT(1)            0.1
|  DT(2)            0.1
|  LASTDT         99999
|  RDTIME           0.8
|  NTHCON            -1
|
|     +--Mass-Momentum Iteration
|     |
|     |  IT(1)              1
|     |  IT(2)              1
|     |  LASTIT         99999
|     |  OMEGA          [0.95]
|     |  EPS1          1.0E-4
|     +--End of Mass-Momentum Iteration
|
|     +--Energy Solution
|     |
|     +--End of Energy Solution
|
+--End of Time Step Loop
```

```
      +-----------------------------------------------+
      | Fully-Implicit Time Advancement (ALPHA=1.0) |
      +-----------------------------------------------+

+--Time Step Loop
|  NTMAX          99999
|  TIMAX         3.6E+7
|  IDTIME             1
|  TSTART           0.0
|  DT(1)            0.1
|  DT(2)            0.1
|  LASTDT         99999
|  RDTIME         [10.0]
|  NTHCON            -1
|
|     +--Outer Iteration Loop
|     |  IT(1)              1
|     |  IT(2)              1
|     |  LASTIT         99999
|     |
|     |        OMEGAV              0.8
|     |     +--Pressure Iteration Loop
|     |     |
|     |     |  ITMAXP              99
|     |     |  OMEGA              1.5
|     |     |  EPS1            1.0E-4
|     |     +--End of Pressure Iteration Loop
|     |
|     |        OMEGAE              0.8
|     |     +--Energy Iteration Loop
|     |     |
|     |     |  ITMAXE              99
|     |     |  RELAXE            0.95
|     |     |  EPS5            1.0E-5
|     |     +--End of Energy Iteration Loop
|     |
|     |  EPS3           5.0E-5
|     +--End of Outer Iteration Loop
|
+--End of Time Step Loop
```

```
*******************************
* STEADY-STATE DEFINITION *
*******************************
```

Steady-state is reached when the following conditions are met:

1. DL < 1.0 where DL=maximum cell residue/DCONV, DCONV=EPS1*UVWMAX+1.0E-6, and UVWMAX is computed in SUBROUTINE CUTOFF.
2. The change of the U-velocity component divided by the maximum velocity magnitude in the entire field is less than EPS3.
3. The change of the V-velocity component divided by the maximum velocity magnitude in the entire field is less than EPS3.
4. The change of the W-velocity component divided by the maximum velocity magnitude in the entire field is less than EPS3.
5. Maximum (DH/H) < EPS3
   where H is the current enthalpy and DH is the change in enthalpy over two consecutive time steps.

****
* ERROR MESSAGES *
****

'If something can go wrong, it will,
and usually at the worst posible time.'

Murphy

The following table gives a listing of the error messages processed by SUBROUTINE ERRCHK. It is intended that this section will be ever expanding thus making the running of COMMIX-1B easier. In many cases, relevant information is printed out in the line(s) before the error message block. When appropriate, the error messages below refer to the variables in this information line. Variables are identified by their type (R for real, I for integer, and A for literal) and their relative position (1 through 12) in the line. For example, A1,R2,I3,I4,I5,I6,I7,I8,I9 would be used to refer to variables printed in the following line:

ALX 1.0 3 4 2 8 1 9 6

IER	SUBROUTINE	ERROR DESCRIPTION
1	RESTAR	In reading the restart file, a block from COMMON /SPACE/ was found to have a length different from that specified on the restart file.
2	AMAIN	Boiling is starting to occur.
3	AMAIN	DTIME is less than or equal to zero. Check NAMELIST /DATA/ array DT for user specified time step size or IDTIME and RDTIME for code determined time step size. In order to run with IDTIME=1 there must be a nonzero velocity somewhere on the boundary or in the interior. If none exists then one must set IDTIME=0 and specify a time step size in DT.
4	BARIN	An invalid input card has been encountered either in the BOUNDARY VALUE INITIALIZATION CARDS or the INTERNAL CELL INITIALIZATION CARDS. One of the following necessary conditions has not been satisfied: 1 <= IB <= IMAX, 1 <= IE <= IMAX, 1 <= JB <= JMAX, 1 <= JE <= JMAX, 1 <= KB <= KMAX, 1 <= KE <= KMAX, 1 <= N <= NSURF, IB <= IE, JB <= JE, KB <= KE, 0.0 < volume porosity (AL) <= 1.0, or 0.0 <= surface permeability (ALX, ALY, ALZ) <= 1.0. The card printed above the error message is ignored and processing continues.
5	BARIN	The surface indicated on a BOUNDARY VALUE INITIALIZATION CARD has no surface element or area.
6	BARIN	Invalid variable name on BOUNDARY VALUE INITIALIZATION CARD.
7	BARIN	BOUNDARY VALUE INITIALIZATION CARD contains an INTERNAL CELL INITIALIZATION CARD variable name.
8	BARIN	Invalid variable name on INTERNAL CELL INITIALIZATION CARD.

9	BARIN	INTERNAL CELL INITIALIZATION CARD contains a BOUNDARY VALUE INITIALIZATION CARD name.
10	ALLOC	The DIMENSION of variable S in COMMON /SPACE/ in SUBROUTINE ALTER is too small for the input values for this run. Change this DIMENSION to the value indicated in the printout, recompile, relink, and rerun.
11	BOXES	One of the indices of the above BOUNDARY SURFACE SPECIFICATION CARD is outside of one of the following ranges: I=1,IMAX J=1,JMAX K=1,KMAX N=1,NSURF, or one or more of the beginning indices is greater than the corresponding ending index. I.e., IB > IE or JB > JE or KB > KE.
12	BOXES	While processing the card printed above the error box a surface element was found to be specified as being contained in two surfaces. The cell and surface identifiers are (I1,I2,I3) and I4 and I5 on the second line.
13	BOXES	On BOUNDARY SURFACE IDENTIFICATION CARDS, surfaces must be specified so that surface numbers are in increasing sequential order with all irregular surfaces preceding regular surfaces.
14	ERRCHK	Only fifteen calls to ERRCHK are allowed before termination. This number can be increased by changing the value of NCALLS in SUBROUTINE ERRCHK.
15	FILLM	One of the indices I, J, or K is outside of its expected range 1-IMAX, 1-JMAX, or 1-KMAX respectively. This error usually occurs when the BOUNDARY SURFACE IDENTIFICATION CARDS have left a hole in the boundary. Recheck the BOUNDARY SURFACE IDENTIFICATION CARDS for an undefined or incorrectly defined surface and see the appendix section entitled FINDING HOLES IN THE BOUNDARY.
16	ERRCHK	Only fifteen calls to ERRCHK are allowed before termination.
17	FILLM	The total number of cells counted in FILLM has exceeded the upper bound of IMAX*JMAX*KMAX. Recheck the BOUNDARY SURFACE IDENTIFICATION CARDS.
18	FILLM	Excessive wrap around in the THETA direction. Recheck the BOUNDARY SURFACE IDENTIFICATION CARDS. Also assure that all surface normals are pointing into the calculational area.
19	FILLM	Time has run out while attempting to number the cells in FILLM. This probably has been caused by an input error in the BOUNDARY SURFACE IDENTIFICATION CARDS.
20	BOXES FULPIN QTRPIN	The number of surface elements has exceeded the value of NL1 as specified in NAMELIST /GEOM/. If the input value is correct check the BOUNDARY SURFACE IDENTIFICATION CARDS for possible errors.
21	BOXES FILLM FULPIN QTRPIN	The number of cells has exceeded the value of NM1 as specified in NAMELIST /GEOM/. If the input value is correct check the BOUNDARY SURFACE IDENTIFICATION CARDS for possible errors.
23	ALLOC	Changes in NM1, NL1, IMAX, JMAX, and KMAX are not allowed when restarting (IFRES=2 or IFRES=3).

24	INITAL	When using the Simplified Properties Option you must input nonzero values for FC0H, FC1H, FC0RO, FC0K, and FC0MU. Be aware that the Simplified Properties Option computes properties as a linear function of temperature only and as such must be used with extreme caution!
25	INITAL	All surfaces, N, with a transient duct wall temperature boundary condition, KTEMP(N)=500, must have positive values input for: the material number, MATWAL(N); the fluid-structure heat transfer correlation number, IHTWAL(N); the duct wall thickness, WALLDX(N); and the characteristic length, HYDWAL(N). N, MATWAL(N), IHTWAL(N), WALLDX(N), and HYDWAL(N) are printed above the error message as I1, I2, I3, R4, and R5.
26	INITAL	A nonpositive value of TEMP0 has been found in INITAL. Set TEMP0 to some positive value in NAMELIST /DATA/.
27	INFORC	An invalid input card has been encountered in SUBROUTINE INFORC while reading the FORCE STRUCTURE SPECIFICATION CARDS. The first field must contain either 'XFOR', 'YFOR', or 'ZFOR'. The indices IB and IE, JB and JE, and KB and KE must be in the ranges 1 through IMAX, 1 through JMAX, and 1 through KMAX respectively. The invalid card printed above the message is ignored and execution continues.
28	IREBAL	An invalid input card has been encountered in the REBALANCING REGION CARDS. One of the following errors has been sensed: Strings other than 'REBM', 'REBX', 'REBY', or 'REBZ' in columns 1 through 4; One of the indices N, IB, IE, JB, JE, KB, or KE is out of its appropriate range (1-NREBRT), (1,IMAX), (1,JMAX), (1,KMAX); IB > IE, JB > JE, or KB > KE. The card printed above the error message is ignored and processing continues.
29	IREBAL	A cell number (M) could not be found for the cell with indices (I,J,K), where I=I9, J=I10, and K=I11 from the line printed above the error message. Execution continues at the next cell.
30	IREBAL	More cells have been found in the rebalancing region (surface) specified in the REBALANCING REGION CARDS than specified by NREBM (NREBX, NREBY, or NREBZ) in the Rebalancing Option section of NAMELIST /DATA/. Execution terminates.
31	IREBAL	The rebalancing regions and surfaces as specified by the variables of the Rebalancing Option section of NAMELIST /DATA/ are inconsistent with the regions and surfaces as specified by the REBALANCING REGION CARDS. A comparison of the totals can be found in the tables above the error message. Execution terminates.
32	INITAL	ISTATE has been found to be 0 while attempting to restart from a previous run. It has been reset by the code to 1. Verify that this is an acceptable fix. Execution continues.
33	IREBAL	The value of IFREB must be at least as large as the sum of NREBM(N), NREBX(N), NREBY(N) and NREBZ(N) for all regions N. The input value and minimum acceptable value are printed in the Rebalancing Summary above the error message. Reset IFREB and rerun.

60

34	INITAL	NL1 and NM1 must not be specified in NAMELIST /GEOM/ when restarting from a previous run with ISTATE>0. Remove NL1 and NM1 from NAMELIST /GEOM/ and rerun.
35	OUTPUT	The value I1 is an invalid value of ISTPR or NTHPR. specifically, the VV field is not defined. The value is ignored and processing continues.
36	INPSTR	The gap type (IGAP(NG)) last printed is outside the expected range of 1 through NGAPTY. Execution terminates.
37	INPSTR	The material type (MATERL(NRI)) last printed is outside the expected range of 1 through NMATER. Execution terminates.
38	INPSTR	The partition size (DRPAR(NRI)) last printed must have a positive value. Execution terminates.
39	HLIQ	The water property routine HLIQ was called with a temperature greater than 340.0 degrees C. This is out of the range of the current version of HLIQ. Execution terminates.
40	HLIQ	The water property routine HLIQ has failed to converge in one hundred iterations. Execution terminates. This error is probably caused by bad values being fed into the arguments of HLIQ.
41	TLIQ	The sodium property function TLIQ has failed to converge in one hundred iterations. R1, R2, R3, R4, and R5 are the given enthalpy, pressure, initial temperature guess, last guess of enthalpy, and specific heat respectively. Execution terminates.
42	TSAT2	The sodium property function TSAT2 was unable to compute the saturation temperature given pressure. R1 and R2 are the pressure and the last iterate of saturation temperature. Execution terminates.
43	TSCAN	On of the following input rules for thermal structures has been violated: TYPE namelists can only appear first, after FLUID namelist and after MATERIAL namelists. The geometrical characteristics, IXYZ, must be one of the following values: 1, 2, 3, 11, 12, 13, 101, 102, 103. FLUID namelists can only appear after TYPE and MATERIAL namelists. Each thermal structure must have at least one material region.
44	INPSTR	When computing areas and volumes of the partitions of the thermal structure material regions an inner radius was found to be less than -1.0E+4*OUTR, where OUTR was te outer radius as specified on the TYPE card. Check the thermal structure input for OUTR, DRPAR, and NMPAR. If no errors are found here check the entire thermal structure prototype input. The negative radius is reset to zero and execution continues. See error number 45 for a list of the variables printed above the error block.

45	INPSTR	When computing areas and volumes of the partitions of the thermal structure material regions an inner radius was found to be larger than the outer radius. Check the thermal structure input. The inner radius is reset to the outer radius end execution continues. The parameters printed above the error block are: N - structure number, IREG - region number, IPAR - partition number, OUTR(N) - outer radius, DR - region size, ROUT - outside radius, RIN - inner radius.
46	TSCAN	An invalid THERMAL STRUCTURE LOCATION card has been found. Either an index is out of range, or the LOC value is invalid (must be either 'OUT' or 'IN'), or the NUM value does not match the number of any THERMAL STRUCTURE PROTOTYPE.
47	TSCAN	A THERMAL STRUCTURE PROTOTYPE has been encountered which has fluid cells interacting at both outside and and inside surfaces, however, the number of cells interacting with the outside surface does not equal the number of cells interacting with the inside surface. I1, I2, I3, and I4 are the structure number, surface interaction code, number of cells interacting with surface 1, and number of cells interacting with surface 2.
48	TSCAN	THERMAL STRUCTURE PROTOTYPE CARDS are inconsistent with the THERMAL STRUCTURE LOCATION CARDS. Either the TSP cards specify only cells interacting with the outside surface and the TSL cards specify some cells interacting with the inside surface, or the TSP cards specify only cells interacting with the inside surface and the TSL cards specify some cells interacting with the outside surface. The values printed above the error message are the same as those identified in error 47.
49	INPSTR	The THERMAL STRUCTURE LOCATION CARD printed above the error message box indicates a cell within the ranges of the indices which is not a valid calculational cell. The specific I, J, and K indices are printed out as I9, I10, and I11. This cell is ignored and execution continues. The results which follow are likely incorrect.
50	INITAL	New thermal structures, rebalancing regions and force structures can be input only at the beginning of a run (ISTATE=0) or the beginning of a transient (ISTATE=2). NEWTS, NEWREB, and NEWFOR have been reset to zero and execution continues.
51	FILLM	The BOUNDARY SURFACE IDENTIFICATION CARDS have defined a single sided interior boundary surface between cells I1 and I2. Check to see that all surfaces you have defined bound calculational cells. Also be sure that any interior surface has calculational cells on both sides of it. Reread the BOUNDARY SURFACE IDENTIFICATION CARD input section and check your input. Execution continues however subsequent results are questionable.

53	TSCAN	Currently only 100 thermal structure prototypes are allowed. If more is needed, changes must be made in COMMON /REBALS/ in subroutine ALLOC and INPSTR Execution terminates.
54	TSCAN	Errors have been found in the order of the thermal structure prototype input. These must be resolved before execution can continue.
55	INITAL	The momentum calculation scheme and the energy calculation scheme must both be run in the same mode. That is, either both must be specified implicit or both must be specified explicit. See variables ISETEN and ISETMO in NAMELIST /DATA/ to control the frequency with which the energy and momentum calculations are performed.
56	INITAL	Incorrect values have been specified for ISETEN and/or ISETMO. See NAMELIST /DATA/ for description.
57	RESTAR	An attempt has been made to switch from explicit to implicit mode before the completion of a timestep. Rerun an explicit restart to complete the current timestep and then run an implicit restart.
58	INITAL	Irregular surfaces must have no flow or pressure boundary condition applied across them. That is, KFLOW(N)=1, VELOC(N)=0.0, AND KPRES(N)=0 for all irregular surfaces N. When specifying transient boundary conditions, the transient function number, NF, must be nonzero. That is, KFLOW(N)=100, KTEMP(N)=100, KTEMP(N)=300, and KPRES(N)=100 are all invalid boundary condition types. Valid types, assuming properly defined transient functions, would be, for example, KFLOW(N)=101 and KTEMP(N)=102.
59	GEOM3D	DX(I), DY(J), and DZ(K) must be nonzero for I=1 through IMAX, J=1 through JMAX, and K=1 through KMAX.
60	GEOM3D	The length of the normal vectors defined by XNORML(N), YNORML(N), and ZNORML(N) must be within one percent of 1.0.
61	INITAL	Specifying gravity in the radial (GRAVX) or theta (GRAVY) direction for cylindrical geometry may not be meaningful.

****
* STORAGE ALLOCATION *
****

In order to ease the task of creating load modules (binary files) to fit the size of the problem being considered, a quasi-dynamic storage allocation scheme has been implemented. Space for most of the geometry dependent variables is allocated in the variable S of COMMON /SPACE/. The address of each variable is computed at the beginning of each run. These addresses are then passed into called subroutines where the variables are named and variably dimensioned. The total length necessary to run the problem is compared with the storage available in COMMON /SPACE/. If the available storage is inadequate, execution terminates with a message indicating the space required. By changing the dimension of S in SUBROUTINE ALTER to the value indicated, and then recompiling and relinking ALTER to the existing load module, a new load module of the required size can be obtained.

Tables showing the variables with space allocated in variable S of COMMON /SPACE/ can be obtained by setting ISTBUG=1 in NAMELIST /GEOM/. The length, index of IS containing the the relative address, and the relative address of each variable are present in these tables.

****
* CALLING SEQUENCE *
****

The following table indicates the structure of COMMIX-1B by showing the calling sequence of the subroutines. Calls to the properties routines and ERRCHK are not indicated. Also multiple calls may not be indicated. An asterisk following a name indicates that the calls from that routine have been previously listed.

```
MAIN
        RUNID
        NAMELS
        LOCF
        CLEAR
                LOCF
        TSCAN
        ALTER
                LOCF
        STOSUM
        AMAIN
                GEOM3D
                        BOXES
                                FILLM
                                        SHOME
                                        TLEFT
                        QTRPIN
                                FILLM   *
                                RARRAY
                                INTWIR
                                        WIRE
                                        WIRVOL
                                                WIRE
                                        RARRAY
                                        GETWIR
                                        THETAS
                        FULPIN
                                FILLM   *
                                RARRAY
                        TLEFT
                        MARRAY
                        IARRAY
                        RARRAY
                INITAL
                        NPROPS
                        DEFAUL
                        RESTAR
                                LOCF
                                PLTAPE
                        NAMELS
                        FITIT
                                ICSSCU
                        GETF
```

65

```
                QGENER
                        AXHEF
                        RARRAY
                IREBAL
                INFORC
                INPSTR
                ICTEMP
                BARIN
                        DSET3
                        RSET3
                        ISET3
                        DSET2
                        RSET2
                        ISET2
                        REDEF
                BCFLOT
                        GETF
                INTURK
                BCTEMT
                        GETF
                BCTEMO
                        GETF
                        QDUCTW
                                GETF
                BCTEMP
                        DUCTWA
                                GETF
                BCFLOW
                BCPRES
                        GETF
        HSTRUC
        TSTRUC
                GETF
        QSTRUC
                GETF
        INITZ1
                BCPRES  *
                BCTEMO  *
                BCTEMP  *
                BCFLOT  *
                HSTRUC
                TSTRUC  *
                QSTRUC  *
        INITUR
                TLFIX
                INTURK
                VISFIX
                        VELOG
                                VELCEN
                TURV12
```

```
OUTPUT
        RUNID
        GETF
        RARRAY
        RSURFO
        ISURFO
        PSTRUC
GDCONV
PLTAPE
TLEFT
WATSTP
GDCONV
TIMSTP
        BCPRES  *
        MOLOOP
                BCFLOT  *
                XMOMI
                        WLFNCV
                        FORCES
                YMOMI
                        WLFNCV
                        FORCES
                ZMOMI
                        WLFNCV
                        FORCES
                PEQN
                GETDL
                REBAZG
                        GETDL
                        TDMA
                REBAZ
                        GETDL
                        TDMA
                GETDL
                SOLVIT
                        REBAZG  *
                        REBAZ   *
                GETDL
                MOMENI
                BCFLOW
        VISFIX
        BCTURB
        TKLOOP
                TKSORC
                        VELCEN
                TKENER
                        WLFNCK
                SOLVEN
        TDLOOP
                TDNER
                SOLVEN
        TURV12
```

```
ENLOOP
        BCTEMT  *
        HSTRUC
        ESORCE
                GETF
                BCTEMO  *
                QSTRUC  *
        ENCONV
                GETMS
                VBARX
                SKCOFX
                        VOWAT
                                VOACT
                VBARY
                SKCOFY
                        VOWAT *
                VBARZ
                SKCOFZ
                        VOWAT *
        ENERGI
        SOLVEN
TLEFT
BCTEMP  *
TSTRUC  *
WATSTP
PLTAPE
BOIL
WATSTP
WATTIM
OUTPUT  *
TLEFT
RESTAR  *
WATSTP
OUTPUT  *
```

****
* MACHINE DEPENDENT ROUTINES *
****

Two machine dependent functions are used in COMMIX-1A.

+-------+
| LOCF |
+-------+

This function returns the absolute address of the variable which is passed as the argument. It is used both in determining the length of blocks to be written to the restart tape and in performing initialization. This function is used extensively in the code and thus its functional equivalent must be supplied when implemented on other systems. An assembly language listing of LOCF for the IBM maching is given below.

```
*             Return location of a variable as 32 big integer.
*
*             I=LOCF(X)
*
LOCF     CSECT
         SAVE  (14,12),,LOCF
         L     0,0(1)              Load the address.
         SLL   0,1                 Remove the sign bit.
         SRL   0,1
         MVI   12(13),X'FF'        Signal return.
         SR    15,15               Return code.
         BR    14                  Return.
         END
```

+--------+
| TLEFT |
+--------+

This function returns the CPU time left in the current run in units of 0.01 seconds. This time starts at the time specified on the JOB card and ends at zero when the job is terminated by the system. It is used for timing and to determine when to terminate and write a restart file. For interactive systems the following function may be substituted. This will eliminate meaningful timing measures and the MAXTIME restart capabilities however it will not effect the codes results.

```
      FUNCTION TLEFT (TIME)
      DATA T /100000.0/
      T=T-2.0
      TLEFT=T
      RETURN
      END
```

****
* FINDING HOLES IN THE BOUNDARY *
****

The BOUNDARY SURFACE SUMMARY is intended to aid the user in finding holes in the boundary surfaces. It is obtained by setting IBSBUG in NAMELIST /GEOM/.
The boundary surface summary consists of two parts.
First is a table of binary strings and their corresponding printed character. Following this table are JMAX planes with each calculational cell being represested by one of the characters from the first table. The binary string associated with each character indicates the location of the surface elements in the following way. Each bit in the binary string corresponds to a face of the calculational cell. The first bit corresponds to the face in the I minus (I-) direction. This is the surface between celi (I,J,K) and cell (I-1,J,K). The second bit corresponds to the face in the I+ direction, the third in the J-, the fourth in the J+, the fifth in the K-, and the sixth in the K+ direction. A surface element is defined at a cell face if the bit corresponding to that face has a value of 1.

For example,
suppose "F" is printed at the location for cell (I,J,K).
"F" corresponds to the binary string "011000". This indicates that a surface element has been defined in the I+ and J- directions, that is, between cells (I,J,K) and (I+1,J,K) and between cells (I,J,K) and (I,J-1,K)

In order for this scheme to be effective the table should contain 62 different printable characters. A blank corresponds to string "000000" and string "111111" should never occur. While we have a laser printer with both upper and lower case at ANL, the printers usually used are impact printers with only about 58 different characters. Therefore, the current implementation uses the character "?" to correspond to all of the following binary strings: "111110", "111101", "111011", "110111", "101111", "011111", and "111111". This does introduce some ambiguity however the impact is probably not serious. For those users who wish to eliminate these duplications, changes must be made in SUBROUTINE SHOME.

****
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****

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ATHRP-020

C O M M I X - 1 B

A Three-Dimensional Transient Single-Phase
Computer Program for Thermal Hydraulic Analysis
of Single and Multicomponent Systems

developed in the

Analytical Thermal Hydraulic Research Program
Components Technology Division
Argonne National Laboratory

under sponsorship of the

United States Nuclear Regulatory Commission
Office of Nuclear Regulatory Research

contact	phone
H. M. Domanus	312-972-5931
W. T. Sha	312-972-5910
R. C. Schmitt	312-972-5914
V. L. Shah	312-972-8049
F. F. Chen	312-972-6359

at

Building 308
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

Version 3.0 September 30, 1985

APPENDIX B. LIST OF COMMIX-1B SUBROUTINES

Subroutine	Calling Subroutine	Descriptions
MAIN		Computes addresses for numerous variables and passes control to AMAIN
ALTER	MAIN	Used for altering the size of variable S in COMMON/SPACE/. It is the only subroutine that needs to be recompiled to create an expanded load module.
AMAIN	MAIN	Main calling program. See the overall flow chart, Fig 2.1.
AXHEF	QGENER	Calculates axial heat flux distribution.
BARIN	INITAL	Reads the boundary and internal cell initialization cards.
BCFLOT	INITAL INITZ1 MOLOOP	Updates boundary velocities on surfaces with transient flow boundary condition.
BCFLOW	INITAL MOLOOP	Updates boundary velocities during iterations.
BCPRES	INITAL INITZ1 TIMSTP	Sets specified pressure values at cells adjacent to surface having pressure boundary conditions.
BCTEMP	INITAL INITZ1 TIMSTP	Updates boundary values of heat flux, temperature, density, and enthaply.
BCTEMT	INITAL ENLOOP	Updates boundary values of temperature, pressure, and density for constant and transient heat flux boundary conditions.
BCTEMØ	INITAL ESORCE INITZ1	Computes boundary values of pressure, heat flux, and density for constant or transient temperature boundary condition.
BCTURB	TIMSTP	Updates boundary values of turbulent kinetic energy.
BOIL	AMAIN	Checks every cell for temperature and pressure and prints out IJK locations where boiling occurs. If boiling has occurred, then IBOIL is set equal to 2 to terminate the run.

Subroutine	Calling Subroutine	Descriptions
BOXES	GEOM3D	Reads surface specification cards input for the box geometry option.
CLEAR	MAIN	Zeros out the values of all variables between the two arguments passed.
DUCTWA	BCTEMP	Computes surface temperature and related values accounting for thermal inertia of a finite-thickness wall.
ENCONV	ENLOOP	Computes convective fluxes of the energy equation.
ENERGI	ENLOOP	Computes coefficients of the energy equation.
ENLOOP	TIMSTP	Calls required subroutines in sequence for solution of energy equation.
ERRCHK	Several	Processes error conditions and prints error messages.
ESORCE	ENLOOP	Computes the source term for energy equation.
FILLM	BOXES QTRPIN FULPIN	Initalizes the cell and adjacent cell pointers.
FITIT	INITAL	Computes the coefficients of cubic spline fit for input transient functions.
FORCES	XMOMI YMOMI ZMOMI	Computes user-imposed drag forces.
FULPIN	GEOM3D	Determines geometric information for hexagonal geometry with full-pin partitioning.
GDCONV	AMAIN	Computes DCONV, the convergence criteria based on the maximum velocity in the region.
GEOM3D	AMAIN	Determines essential geometric information.
GETDL	MOLOOP REBAZG REBAZ	Mass residual is evaluated from pressure equation as: $DL = \left(A_o^p P_o - \sum^{6} A_g^p P_g - B_o^p\right)/(DX\ DY\ DZ)$

Subroutine	Calling Subroutine	Descriptions
GETF	several	Determines the value of transient function NF at the current time.
GETMS	ENCONV	Stores pointers to nearby cells.
GETWIR	INTWIR	Computes the force contribution due to the wire wrap in hexagonal fuel assemblies.
HSTRUC	AMAIN ENLOOP INITZ1	Computes heat transfer coefficients for thermal structure elements.
IARRAY	GEOM3D	Prints out a constant K plane of integer variable.
ICSSCU	FITIT	Computes cubic spline fit coefficients of transient functions.
ICTEMP	INITAL	Initializes temperature, heat flux, velocity, density, and pressure on the boundary and sets boundary density.
INFORC	INITAL	Reads input related to force structure and prints corresponding input summary.
INITAL	AMAIN	Calls required subroutines in sequence to initialize internal-cell and boundary values of all variables.
INITUR	AMAIN	Performs turbulence model initialization.
INITZ1	AMAIN	Performs initialization for a hexagonal fuel assembly. It computes heat source, sets U and V velocities to zero, and performs a 1-D, steady-state, axial dependent initialization for temperature, density, etc.
INPSTR	INITAL	Reads thermal structure input data, computes required geometrical and physical information, and prints thermal structure input summary.
INTURK	INITAL INITUR	Computes initial boundary and internal cell values of turbulent kinetic energy.
INTWIR	QTRPIN	Computes the wire wrap coefficients.
IREBAL	INITAL	Performs initialization for user-specified rebalancing option.

Subroutine	Calling Subroutine	Descriptions
ISURFO	OUTPUT	Prints surface array IVAR for surface number NSUR.
MARRAY	GEOM3D	Prints the M array.
MOLOOP	TIMSTP	Calls required subroutines in sequence to solve mass-momentum equations.
MOMENI	MOLOOP	Calculates new-time velocity using new-time values of pressure.
OUTPUT	AMAIN	Prints global balances and requested array information.
PEQN	MOLOOP	Computes coefficients of pressure equations.
PLTAPE	AMAIN RESTAR	Writes plotting information.
PSTRUC	OUTPUT	Prints temperature fields and heat transfer information relating to thermal structures.
QDUCTW	BCTEMO	Computes transient heat flux from duct walls.
QGENER	INITAL	Performs rod bundle initialization.
QSTRUC	AMAIN INITZ1 ESORCE	Solves heat conduction equations and computes effective heat source from thermal structures to the coolant.
QTRFIN	GEOM3D	Determines geometric information for hexagonal geometry with quarter-pin partitioning.
RARRAY	Several	Prints a two-dimensional array of values on any i, j, or k plane.
REBAZ	MOLOOP SOLVIT	Performs plane-by-plane rebalancing from inlet to outlet in either x, y, or z direction.
REBAZG	MOLOOP SOLVIT	Performs user-specified rebalancing.
REDEF	BARIN	Redefines porosities and permeabilities that are R dependent for cylindrical geometry.
RESTAR	INITAL AMAIN	Writes or reads a restart dataset.
RSET2	BARIN	Performs interior cell value initialization.

Subroutine	Calling Subroutine	Descriptions
RSET3	BARIN	Performs boundary value initialization.
RSURFO	OUTPUT	Prints a specified surface array.
SHOME	FILLM	Prints graphical representation of the boundary surface identification cards.
SKCOFX	ENCONV	Computes x-direction coefficients for skew-upwind and volume-weighted skew-upwind difference schemes.
SKCOFY	ENCONV	Computes y-direction coefficients for skew-upwind and volume-weighted skew-upwind difference schemes.
SKCOFZ	ENCONV	Computes z-direction coefficients for skew-upwind and volume-weighted skew-upwind difference schemes.
SOLVEN	ENLOOP TDLOOP TKLOOP	Solves a set of equations by the SOR procedure.
SOLVIT	MOLOOP	Solves the pressure equation by the SOR procedure.
SOPROP	several	Sodium properties package.
TDMA	REBAZ REBAZG	Solves a set of equations by tridiagonal matrix algorithm.
TDLOOP	TIMSTP	Computes the dissipation of turbulent kinetic energy ε for one- and two-equation models.
TDNER	TDLOOP	Computes the coefficients of the ε (dissipation of turbulent kinetic energy) equation.
TIMSTP	AMAIN	Calls required subroutines in sequence to bring variable values from time t to time $t+\Delta t$.
TKENER	TKLOOP	Calculates the coefficients of the turbulent kinetic energy equation.
TKLOOP	TIMSTP	Computes turbulent kinetic energy k.
TKSORC	TKLOOP	Computes the source terms in the turbulent kinetic energy (k) equation.
TLFIX	INITUR	Fixes the turbulence length scale for one-equation turbulence model.

Subroutine	Calling Subroutine	Descriptions
TSCAN	MAIN	Scans the thermal structure input to determine the amount of storage needed to run this problem.
TSTRUC	AMAIN TIMSTP INITZ1	Solves heat conduction equation and computes thermal structure temperature, TTS.
TURVI2	INITUR TIMSTP	Computes turbulent viscosity and thermal conductivity for one- and two-equation turbulence models.
VBARX VBARY VBARZ	ENCONV	Computes averge velocity components on given cell surface.
VELCEN	TKSORC VELOG	Computes cell-centered velocity.
VELOG	VISFIX	Computes the velocity gradient for the zero-equation turbulence model.
VISFIX	INITUR TIMSTP	Computes the turbulent viscosity for the zero-equation model of turbulence.
VOACT	VOWAT	Computes parameters related to skew-upwind and volume-weighted skew-upwind schemes.
VOWAT	SKCOFX SKCOFY SKCOFZ	Computes parameters related to skew-upwind and volume-weighted skew-upwind schemes.
WAPROP	several	Water properties package.
WATSTP	AMAIN	Determines when information is to be written to output or plottape.
WATTIM	AMAIN	Determines when information is to be written to output or plottape.
WIRE	INTWIR WIRVOL	Determines the wire wrap location and appropriate axial areas.
WIRVOL	INTWIR	Determines the volume of wire along with blocked wire areas.
WLFNCK	TKENER	Calculates wall functions for the energy equation.

Subroutine	Calling Subroutine	Descriptions
WLFNCV	XMOMI YMOMI ZMOMI	Calculates wall functions for the momentum equations.
XMOMI	MOLOOP	Computes coefficients of x-momentum equations.
YMOMI	MOLOOP	Computes coefficients of y-momentum equations.
ZMOMI	MOLOOP	Computes coefficients of z-momentum equations.

APPENDIX C. RESISTANCE CORRELATIONS

C.1 INTRODUCTION

This appendix provides a convenient collection of resistance correlations that are most commonly needed by COMMIX users. It is written with a desire to save the user from having to search vast literature. It is also hoped that this will serve as a starting reference to new users.

We caution here that the correlations presented are not necessarily the only and final relations. We welcome feedback and comments from all users so that we can add other correlations, update the existing relations, and improve the information presented here.

C.2 AXIAL FLOW IN ROD BUNDLE ASSEMBLY

C.2.1 Generalized Correlation

- Laminar Flow

For a laminar axial flow in a rod bundle assembly, Rehme and Trippe [3] have recommended the following generalized correlation:

$$f = \frac{\Delta p}{L} \frac{d_h}{\frac{1}{2}\rho v^2} = \frac{C}{Re} , \qquad (C.1)$$

where C is a geometric parameter, V is the axial velocity, d_h is the hydraulic diameter, and Re is the Reynolds number.

$$Re = \frac{\rho v d_h}{\mu} . \qquad (C.2)$$

The central, wall, and corner subchannels in a rod bundle assembly are shown in Fig. C.1. The value of geometric parameter C is a function of

- P/D for central subchannel (Fig. C.2),
- W/D for corner subchannel (Fig. C.2), and
- P/D and W/D for wall subchannel (Fig. C.3).

From the values of geometric parameter for various subsections, we can calculate the value of parameter C for total assembly

$$\frac{1}{C_{tot}} = \sum_i \frac{1}{C_i} \left(\frac{S_{tot}}{S_i}\right)^2 \left(\frac{A_i}{A_{tot}}\right)^3 , \qquad (C.3)$$

where S is the wetted perimeter, A is the flow cross section, subscript i is for the individual subchannel, and subscript "tot" is for the total rod bundle.

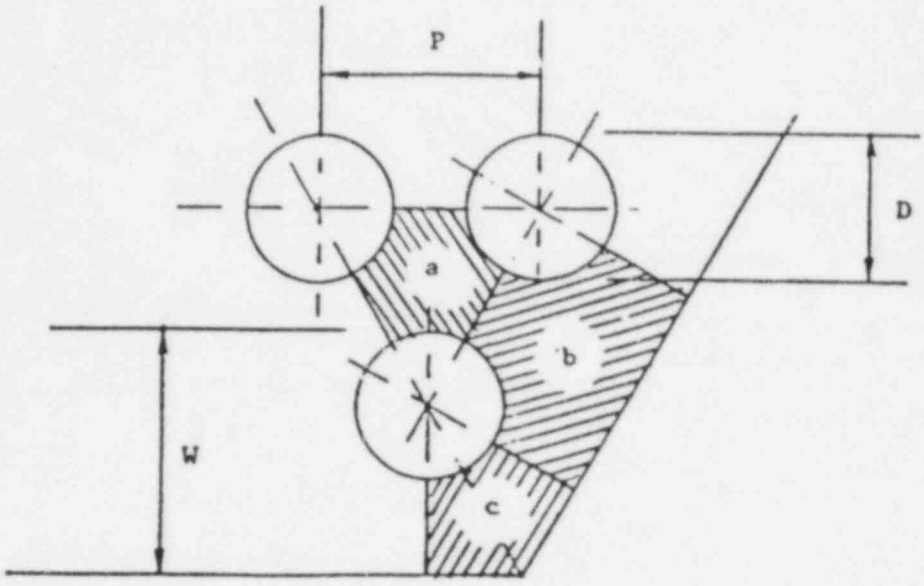

Fig. C.1. Subchannels of Rod Bundles: (a) Central, (b) Wall, and (c) Corner

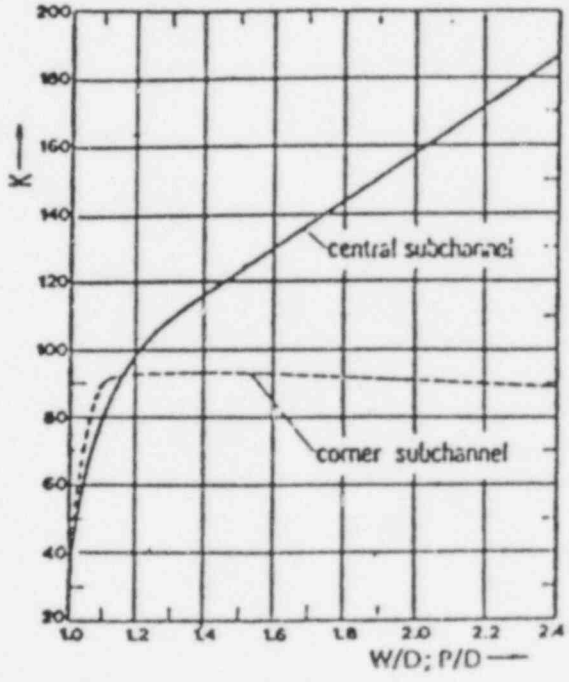

Fig. C.2. Pressure Drop Parameter C in Central and Corner Subchannels for Laminar Flow

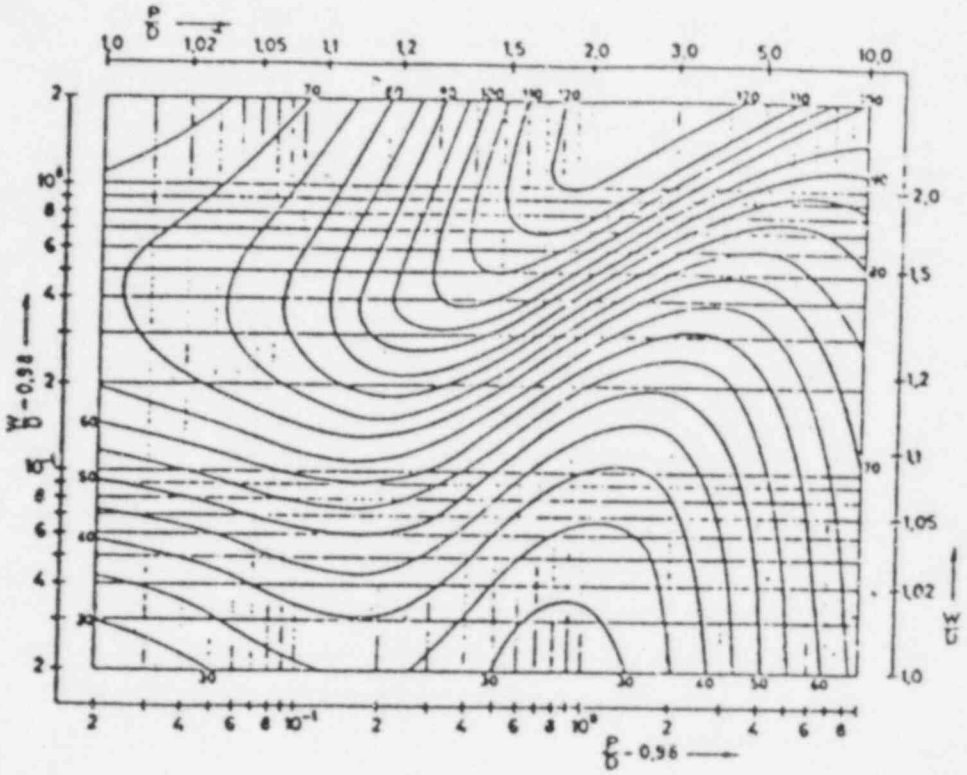

Fig. C.3. Pressure Drop Parameter C in Wall Subchannels for Laminar Flow

- Turbulent Flow

Rehme [4] has recommended the following equation for the turbulent friction factor in a rod bundle assembly:

$$\left(\frac{8}{f}\right)^{1/2} = A^{*}\left\{2.5\ \mathrm{Log}_{e}\left[\mathrm{Re}\left(\frac{f}{8}\right)^{1/2}\right] + 5.5\right\} - G^{*}. \qquad (C.4)$$

The two empirical factors, G* and A*, are functions of geometric parameter C (Sec. C.2.1) as shown in Figs. C.4 and C.5.

C.2.2 Generalized Correlations for Wire-Wrapped Bundles

- Engel, Markley, and Bishop

Based on limited experimental data, Engel, Markley, and Bishop [5] have recommended the following generalized correlation for hexagonal fuel assembly applicable in the range P/D $\underline{F}$ 1.27 and H < 30 cms:

$$f = \frac{A}{Re}\left(1 - \chi\right)^{1/2} + \frac{0.48}{Re^{0.25}}\chi^{1/2} \ . \qquad (C.5)$$

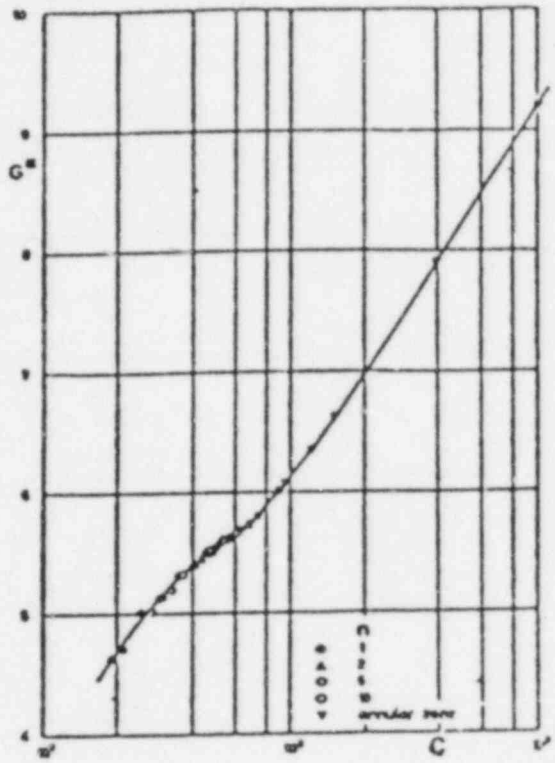

Fig. C.4. Geometry Parameter G*

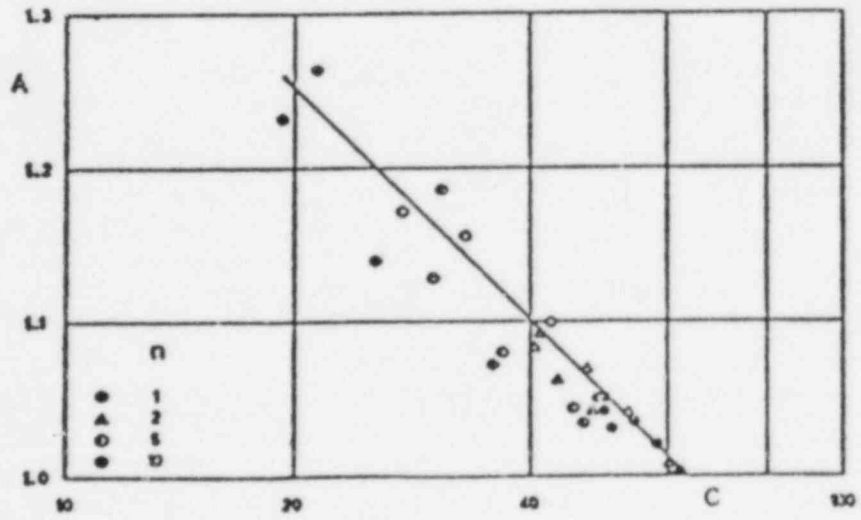

Fig. C.5. Geometry Parameter A*

Here,

$$\chi = 0.0, \text{ for } Re \leq 400, \tag{C.6a}$$

$$\chi = \frac{Re - 400}{4600}, \text{ for } 400 < Re < 5000, \text{ and} \tag{C.6b}$$

$$\chi = 1.0, \quad \text{for } Re \geq 5000, \tag{C.6c}$$

and the coefficient A is a function of wire-wrap lead H and pitch to rod diameter ratio.

$$A = \frac{320}{\sqrt{H}} \left(P/D\right)^{1.5} . \tag{C.7}$$

Note that the wire-wrap lead H in Eq. C.7 is in centimeters.

- Chan and Todreas

Recently, Chan and Todreas [6] developed the following generalized correlations applicable to a wide range of wire-wrapped hexagonal fuel assemblies:

$$f = \frac{C_{19}}{Re} \quad \text{(for } Re \leq 400\text{), and} \tag{C.8}$$

$$f = \frac{C_{19}}{Re} \left(1 + C_{18}\, Re^{1.222}\right)^{0.671} \quad \text{(for } Re > 400\text{).} \tag{C.9}$$

Here, Re $\left(= \rho u d_h/\mu\right)$ is the bundle Reynolds number and the coefficients C_{18} and C_{19} are functions of the number of rods in a bundle N, pitch to rod (pin) diameter ratio P/D, and lead length to rod (pin) diameter ratio H/D.

$$C_{18} = A\,(N)^{B} \left(P/D\right)^{C} \left(H/D\right)^{E} \tag{C.10}$$

and

$$C_{19} = 251\,(N)^{0.007} \left(P/D\right)^{0.997} \left(H/D\right)^{-0.354} . \tag{C.11}$$

The values of the constants A, B, C, and E are given in Table C.1.

For a hexagonal assembly, the flow area and hydraulic diameter, d_h, can be calculated using the relationships:

$$\text{Flow area} = \frac{\sqrt{3}}{2} \left(d_{f-f}\right)^2 - \frac{N\pi}{4} \left(D^2 + D_w^2\right), \tag{C.12}$$

Table C.1 Values of Constants in Equation C.10

$D \geq 0.35"$	$D > 0.35"$		
A = 0.00221	A = 0.000584		
B = 0.166	B = 0.185		1. $H/D \leq 4$
C = 8.297	C = 8.247	for	2. $P/D \geq 1.2$ & $H/D \leq 8$
E = -1.457	E = -1.818		3. $P/D \geq 1.343$ & $H/D \leq 12$.
A = 0.0000395	A = 0.000278		
B = 0.063	B = -0.084		
C = 0.174	C = 0.289	for	others.
E = 0.178	E = -0.268		

$$\text{Perimeter} = \left(2\sqrt{3}\, d_{f-f}\right) + \pi N \left(D + D_w\right), \text{ and} \tag{C.13}$$

$$d_h = 4 * \text{flow area/perimeter}. \tag{C.14}$$

Here, d_{f-f} is the distance between the flat surfaces of hexagonal assembly, D is the pin diameter, D_w is wire-wrap diameter, and N is the number of pins in a bundle.

- Rehme

Rehme [7] has recommended the following correlations for wire-wrapped rod bundles.

$$f = F \frac{S_b}{S_t}\left[\frac{64}{Re\sqrt{F}} + \frac{0.0816}{\left(Re\sqrt{F}\right)^{0.133}}\right]. \tag{C.15}$$

Here, S_b is the wetted perimeter of a rod bundle (rods and wires), S_t is the total wetted perimeter (rods, wires, and casing), and F is the geometric factor.

$$F = \left(\frac{P}{D}\right)^{0.5} + \left[7.6\,\frac{D_w}{H}\left(\frac{P}{D}\right)^2\right]^{2.16}. \tag{C.16}$$

C.2.3 Rod Bundles in CRBR

In the Clinch River Breeder Reactor (CRBR) Plant, there are several different types of hexagonal rod bundles. The important geometrical characteristics of these bundles are presented in Table C.2.

Table C.2 Important Parameters of CRBR Hexagonal Assemblies

Assembly	No. of Pins	P/D	H/D	D, mm	D, in	d_h, mm
Fuel	217	1.24	51.74	5.842	0.23	3.254
Blanket	61	1.072	7.905	12.852	0.506	3.399
Primary control	37	1.05	21.18	15.291	0.602	6.862
Secondary control	31	1.05	10.87	14.036	0.552	15.981
Reactor shield	19	1.0	-	25.197	0.992	1.357

- Fuel Assemblies (CRBR, FFTF)

Based on the experimental measurements [8-11], the following correlations are recommended for CRBR and Fast Flux Test Facility (FFTF) fuel assemblies. The same correlations are applicable to both FFTF and CRBR fuel assemblies, because geometrical features are the same.

$$f = \frac{84}{Re} \qquad \text{for } Re \leq 1000 . \tag{C.17}$$

$$f = f_c \left[1.075 + 0.1876 \left(\frac{1000}{Re}\right)^2 + 0.0801 \left(\frac{1000}{Re}\right)^4\right] \qquad \text{for } Re > 1000. \tag{C.18}$$

Here, f_c is the Colebrook friction factor for a smooth tube.

$$\frac{1}{\sqrt{f_c}} = -0.8686 \, \text{Log}_e \left[\frac{2.51}{(Re \sqrt{f_c})}\right] . \tag{C.19}$$

The above correlations (C.17 and C.18) are provided as an option (ICORR=94) in COMMIX.

Alternatively, one can use anyone of the two sets of generalized equations to determine friction factor in fuel assemblies. In COMMIX, an additional option (ICORR=90) is provided for determining friction factor.

$$f = \frac{81.7}{Re} (1 - \chi)^{1/2} + \frac{0.48}{Re^{0.25}} \chi^{1/2} \tag{C.20}$$

for CRBR fuel assemblies. Equation C.20 is derived from Eqs. C.5 and C.6 using the values P/D = 1.24 and H = 30.227 cm for evaluating the coefficient A = 81.7.

- Blanket Assembly

Engel, Markley, and Bishop [5] have recommended the following correlations for the blanket assembly:

$$f = \frac{99}{Re}(1 - \chi)^{1/2} + \frac{0.48}{Re^{0.25}}\chi^{1/2}. \qquad (C.21)$$

Equation C.21 is provided as an option (ICORR=91) in COMMIX.

- Control Assembly

For CRBR control assembly, if we use the generalized correlations C.5 through C.7, we obtain

$$f = \frac{60.68}{Re}(1 - \chi)^{1/2} + \frac{0.48}{Re^{0.25}}\chi^{1/2}. \qquad (C.22)$$

Equation C.22 is provided as an option (ICORR=95) in COMMIX for evaluating friction factor in the CRBR control assemblies.

C.2.4 Rod Bundles in EBR-II

For EBR-II rod bundles, Baumann et al. [12] used the correlation

$$f = a\,Re^{b}, \qquad (C.23)$$

derived from the experimental measurements. The major dimensions and the values of constants a and b for different types of assemblies are given in Tables C.3 and C.4. The constants a and b, given in Tables C.3 and C.4, are derived from the measurements of total pressure drop across full length of an assembly without separating the effects of various sub-sections, e.g., inlet nozzle, orifice shield, rod bundle, outlet nozzle, etc. Therefore, one correlation, Eq. C.23, is applicable over the entire length of the assembly.

C.3 SPACER GRIDS

C.3.1 Plane Grid

For a plane grid with sharp edged orifices (Fig. C.6), Idelchik [13] has given the values of loss coefficient as a function of area ratio (Table C.5).

$$\Delta p = \left(K\,\frac{1}{2}\rho v^{2}\right)n. \qquad (C.24)$$

Here, n is the number of grids; K, the loss coefficient for a grid, is a function of area ratio A_o/A_1; A_o is the flow area through grid; and A_1 is the flow area without grid.

Table C.3 Important Parameters of EBR-II Assemblies

Assembly	No. of Rods	D, mm	P/D	H/D
Driver (fuel)	91	4.42	~1.30	3.45
Blanket	19	12.52	~1.0	-
Reflector	1*	-	-	-

*Hexagonal cross section

Table C.4 Values of Constants a and b for EBR-II Assemblies

Assembly	a	b	Range
Driver	26.33	-0.85	$Re < 557.5$
Driver	0.1922	-0.072	$Re \geq 557.5$
Reflector	6.48	-0.03	-
Blanket	2.574	-0.269	-

Table C.5 Loss Coefficient for a Plane Grid

A_o/A_1	K	A_o/A_1	K	A_o/A_1	K
0.02	7000	0.22	40.6	0.50	4.00
0.03	3100	0.24	32.0	0.52	3.48
0.04	1670	0.26	26.8	0.55	2.85
0.05	1050	0.28	22.3	0.60	2.00
0.06	730	0.30	18.2	0.65	1.41
0.08	400	0.32	15.6	0.70	0.97
0.10	245	0.34	13.1	0.75	0.65
0.12	165	0.36	11.6	0.80	0.42
0.14	117	0.38	9.55	0.85	0.25
0.16	86.0	0.40	8.25	0.90	0.13
0.18	65.5	0.43	6.62	0.95	0.05
0.20	51.5	0.47	4.95	1.00	0.00

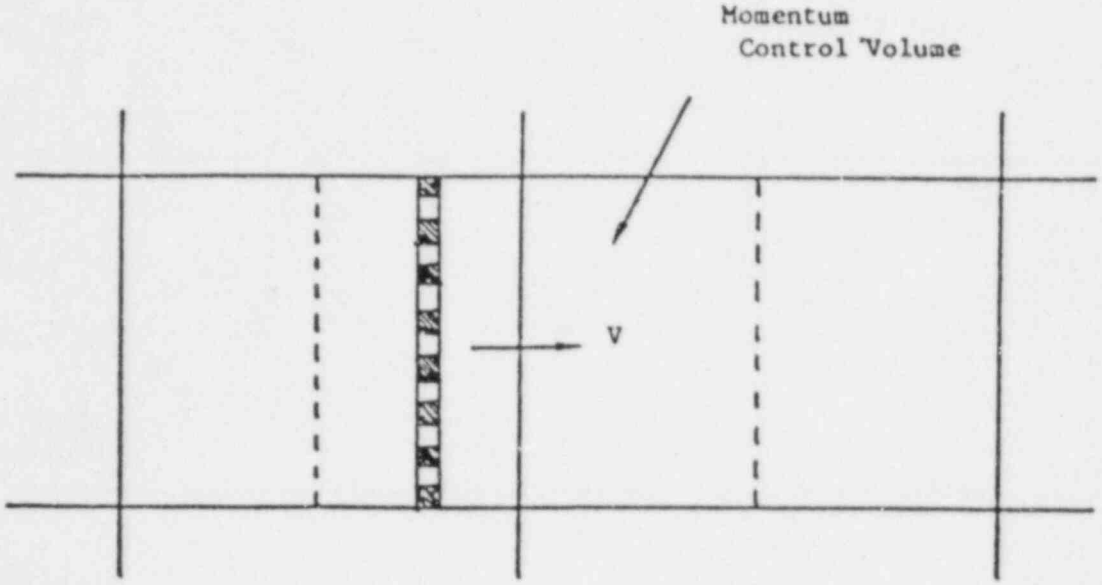

Fig. C.6. Plane Grid with Sharp-edged Orifices

C.3.2 Grid Type Spacer

For a grid type spacer, such as used in a rod bundle assembly, Fig. C.7, Rehme [7] gives the following correlation:

$$\frac{\Delta p}{\frac{1}{2}\rho v_1^2} = K = c_v \left(1 - \frac{A_o}{A_1}\right)^2 \quad . \tag{C.25}$$

Here, the coefficient c_v has a value between 6 and 7, v_1 is the average flow velocity, A_o is the flow area through a spacer, and A_1 is the flow area through an undisturbed section.

C.4 CROSSFLOW IN TUBE OR ROD BUNDLE

C.4.1 Generalized Correlation

For crossflow over tubes, Gunter and Shaw [14] have proposed the following correlations for friction factor.

- Laminar Flow (Re < 200)

$$f = \frac{\Delta p \; d_v}{L \; \frac{1}{2}\rho v^2} = \frac{180}{Re} \left(\frac{d_v}{P_T}\right)^{0.4} \left(\frac{P_L}{P_T}\right)^{0.6} \quad . \tag{C.26}$$

- Turbulent Flow (Re $\geq$ 200)

$$f = \frac{1.92}{Re^{0.145}} \left(\frac{d_v}{P_T}\right)^{0.4} \left(\frac{P_L}{P_T}\right)^{0.6} \quad . \tag{C.27}$$

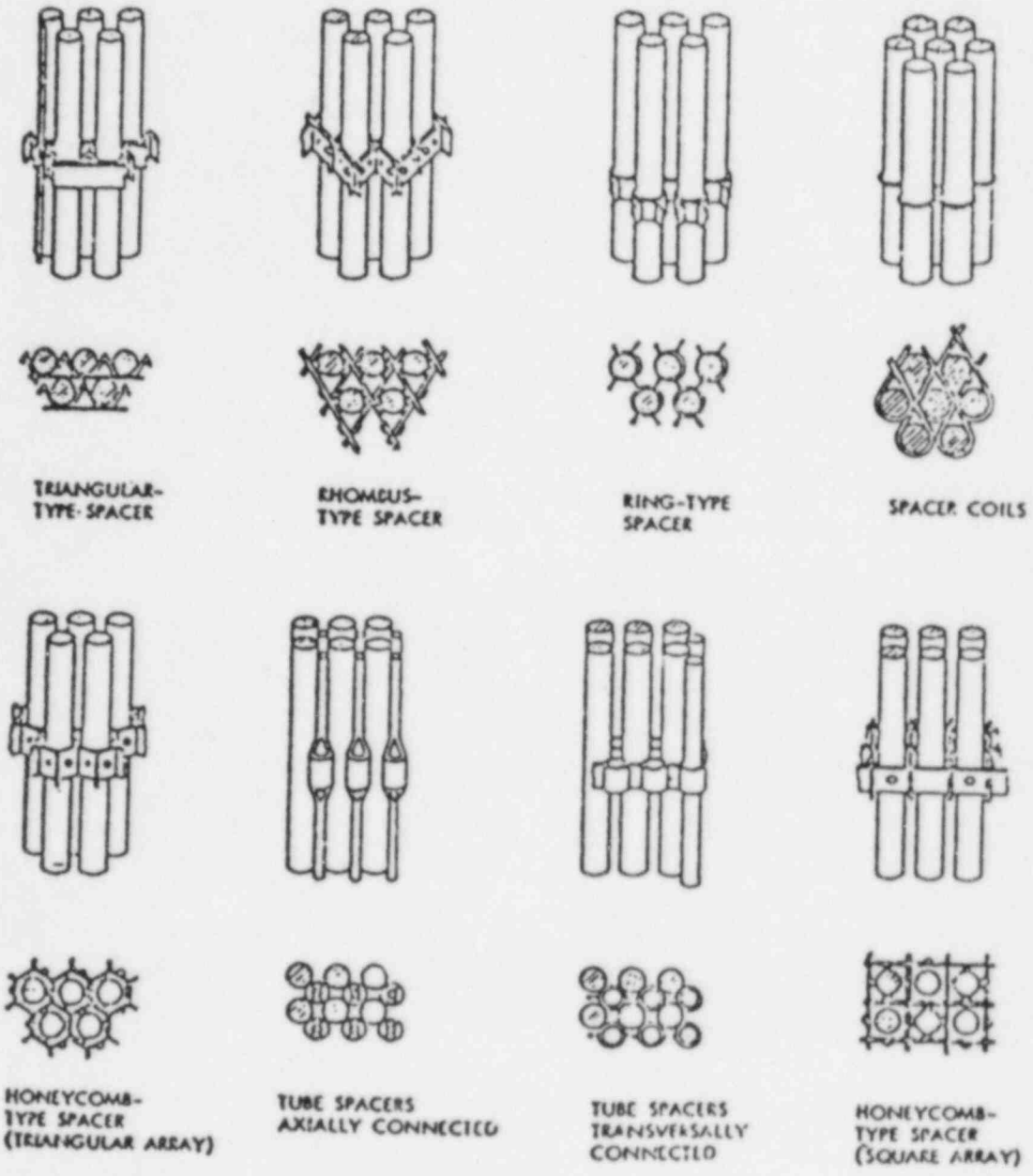

Fig. C.7. Grid-type Spacers

Here,

$$d_v = \frac{4 \times \text{net free volume}}{\text{friction surface}} \tag{C.28}$$

is the volumetric hydraulic diameter, P_L is the longitudinal pitch (center to center distance from a tube in one row to the nearest tube in the next transverse row), P_T is the transverse pitch (center to center distance from a tube to the next tube in one transverse row), and

$$R_e = \frac{\rho v d_v}{\mu} \tag{C.29}$$

is the Reynolds number based on volumetric hydraulic diameter.

C.4.2 Square Array

For flow across a square array, as shown in Fig. C.8, Idelchik [13] has recommended the following correlation for pressure loss coefficient:

$$K = \frac{\Delta p_{loss}}{\frac{1}{2}\rho v^2} = \left(a\ Re^m\right) n\ . \tag{C.30}$$

Here, v is the mean velocity in the bundle cross section, Re is the Reynolds number based on mean velocity v and rod diameter D, and n is the number of transverse rows of tubes (e.g. n = 3 in Fig. C.8). The coefficient a and exponent m are functions of pitch to diameter ratio P/D and are given in Tables C.6 and C.7.

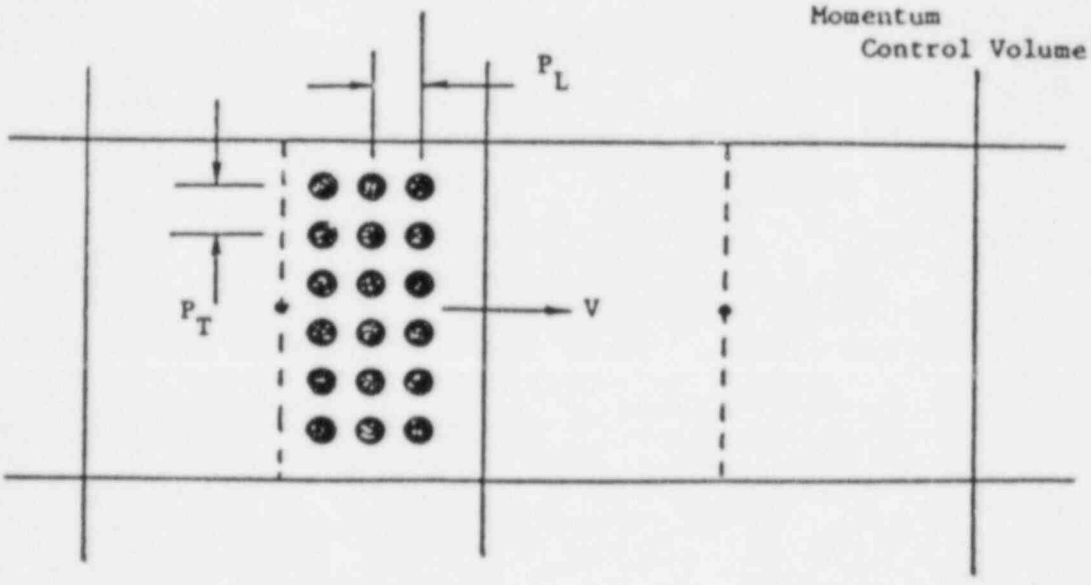

Fig. C.8. Crossflow over Square Array to Tube or Rod Bundle

Table C.6 Coefficient "a" for Square Array (Fig. C.8)

$\left(\frac{P_T - D}{P_L - D}\right)^{P_T/D}$	1.2	1.4	1.6	1.8	2.2	2.6	3.0	3.4	3.6	4.2
0.1	5.376	3.792	3.120	2.688	2.184	1.872	1.704	1.560	1.440	1.344
0.2	4.704	3.318	2.730	2.352	1.911	1.638	1.491	1.365	1.260	1.176
0.4	4.077	2.876	2.366	2.038	1.656	1.420	1.292	1.183	1.092	1.019
0.6	3.808	2.686	2.210	1.904	1.547	1.326	1.207	1.105	1.020	0.952
0.8	3.539	2.496	2.054	1.770	1.438	1.232	1.122	1.027	0.948	0.885
1.0	3.405	2.402	1.976	1.702	1.383	1.186	1.079	0.988	0.912	0.851
1.2	1.613	1.138	0.936	0.806	0.655	0.562	0.511	0.468	0.432	0.403
1.6	0.918	0.648	0.533	0.459	0.373	0.320	0.291	0.266	0.246	0.230
2.0	0.672	0.474	0.390	0.336	0.273	0.234	0.213	0.195	0.180	0.168
2.4	0.538	0.379	0.312	0.269	0.218	0.187	0.170	0.156	0.144	0.134
2.8	0.470	0.332	0.273	0.235	0.191	0.164	0.149	0.137	0.126	0.118
3.2	0.381	0.269	0.221	0.190	0.155	0.133	0.121	0.111	0.102	0.0952
3.6	0.336	0.237	0.195	0.168	0.137	0.117	0.107	0.0975	0.090	0.0840
4.0	0.314	0.221	0.182	0.157	0.127	0.109	0.0994	0.0910	0.040	0.0784
4.2	0.314	0.221	0.182	0.157	0.127	0.109	0.0994	0.0910	0.040	0.0784

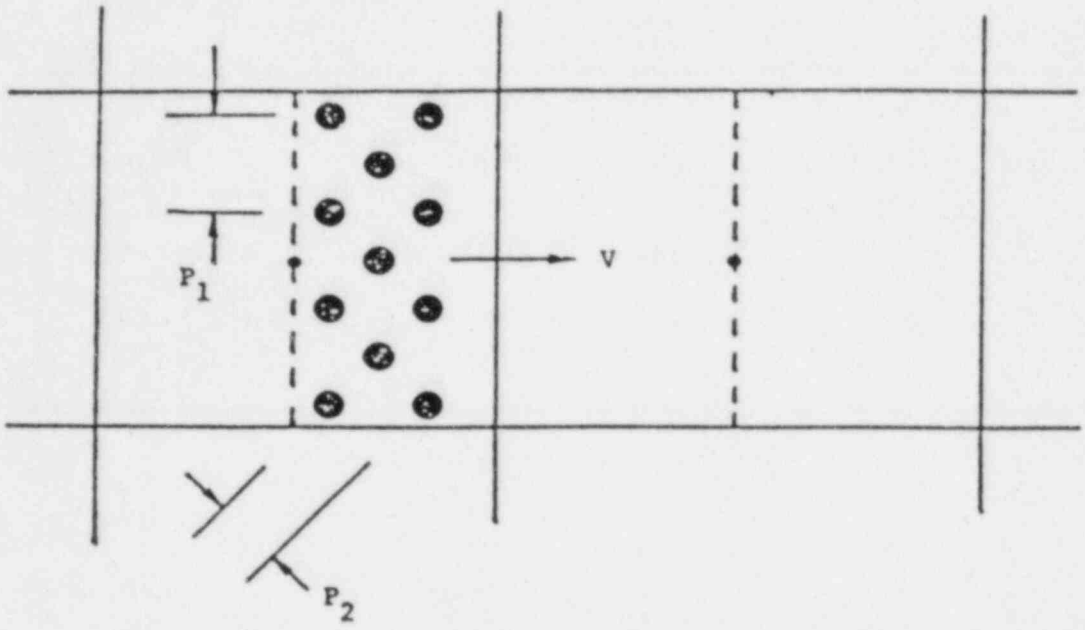

Fig. C.9. Crossflow over Staggered Tube or Rod Bundle

Table C.7 Coefficient "m" for Square Array (Fig. C.8)

$\frac{P_T - D}{P_L - D}$	m	$\frac{P_T - D}{P_L - D}$	m
0.1		1.2	-0.139
0.2		1.6	-0.078
0.4		2.0	-0.050
0.6	-0,2	2.4	-0.0347
0.8		2.8	-0.0255
1.0		3.2	-0.0195
		3.6	-0.0154
		4.0	-0.0125
		4.2	-0.0113

C.4.3 Triangular (Staggered) Rod Bundle

For flow across a staggered rod bundle, as shown in Fig. C.9, Idelchik [13] recommends the following correlation for loss coefficient:

$$K = \left(a \, Re^{-0.27} \right) (n+1). \qquad (C.31)$$

Here, Re is the Reynolds number based on mean velocity v, and rod diameter D, and n is the number of transverse rows of tubes. The coefficient a is a function of pitch to diameter ratios and is given in Table C.8.

C.5 SUDDEN ENLARGEMENT AND CONTRACTION

The pressure loss due to abrupt change in area is generally expressed in terms of the loss coefficient K.

$$\Delta p = K_1 \frac{1}{2} \rho v_1^2 \qquad \text{(C.32a)}$$

$$= K_2 \frac{1}{2} \rho v_2^2 \quad , \qquad \text{(C.32b)}$$

where K_1 and K_2 are the pressure loss coefficients, and v_1 and v_2 refer to the velocity in the smaller and larger cross sections, respectively.

For abrupt expansion, the loss coefficient K is given by the expression [15-16]

$$K_1 = \left(1 - \frac{A_1}{A_2}\right)^2 , \qquad \text{(C.33)}$$

where A_1 and A_2 are the small and large areas as shown in Fig. C.10. With the abrupt expansion models as shown in Fig. C.10, Eqs. C.32a and C.33 can be used directly to evaluate f and c of Eq. 6.3.

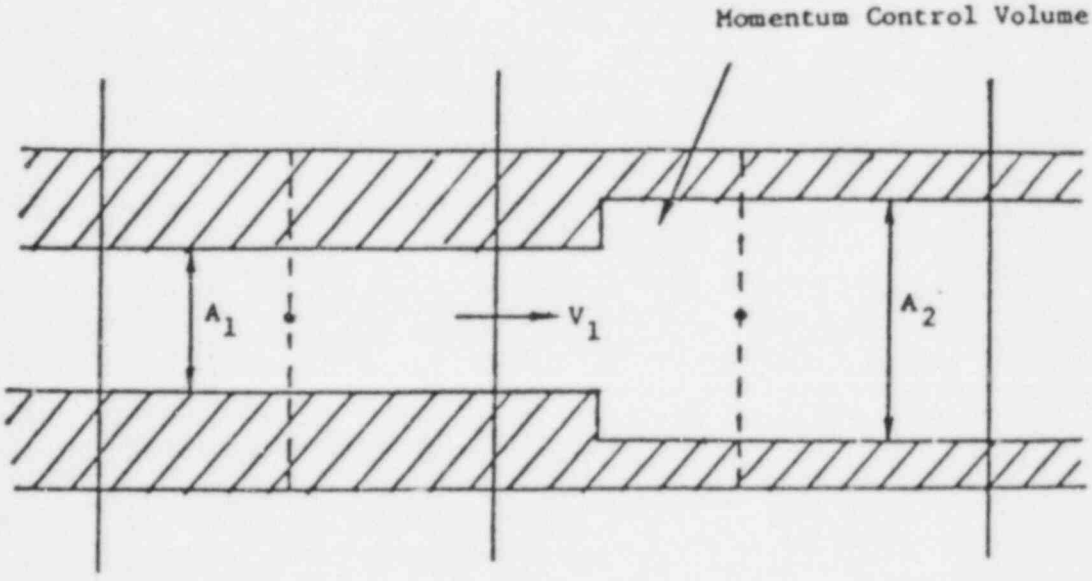

Fig. C.10. Sudden Enlargement (Reference Velocity V_1)

Table C.8 Coefficient "a" for Staggered Bundle (Fig. C.9)

$\left(\frac{P_T - D}{P_L - D}\right)$	$\frac{P_T}{D}$ 1.2	1.4	1.6	1.8	2.2	2.6	3.0	3.4	3.8	4.2
0.14	6.578	5.733	4.889	4.044	3.20	3.20	3.20	3.20	3.20	3.20
0.2	6.448	5.636	4.824	4.012	3.20	3.20	3.20	3.20	3.20	3.20
0.4	6.016	5.312	4.608	3.904	3.20	3.20	3.20	3.20	3.20	3.20
0.6	5.584	4.988	4.392	3.796	3.20	3.20	3.20	3.20	3.20	3.20
0.8	5.152	4.664	4.176	3.688	3.20	3.20	3.20	3.20	3.20	3.20
1.0	4.720	4.340	3.960	3.580	3.20	3.20	3.20	3.20	3.20	3.20
1.2	4.288	4.016	3.744	3.472	3.20	3.20	3.20	3.20	3.20	3.20
1.6	3.424	3.368	3.312	3.256	3.20	3.20	3.20	3.20	3.20	3.20
1.7	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
1.8	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43
2.0	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96
2.4	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06	5.06
2.8	6.34	6.34	6.34	6.34	6.34	6.34	6.34	6.34	6.34	6.34
3.2	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70
3.6	9.32	9.32	9.32	9.32	9.32	9.32	9.32	9.32	9.32	9.32
4.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
4.4	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
4.8	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
5.2	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.9

If the abrupt expansion is modeled as shown in Fig. C.11, the reference velocity used in COMMIX to evaluate pressure drop now corresponds to the velocity in the larger cross-section. Therefore, we have to use Eq. C.32b with the loss coefficient K_2, given by

$$K_2 = \left(\frac{A_2}{A_1} - 1\right)^2 . \qquad (C.34)$$

For abrupt contraction, as shown in Figs. C.12 and C.13, the values of loss coefficient [17] are presented in Table C.9.

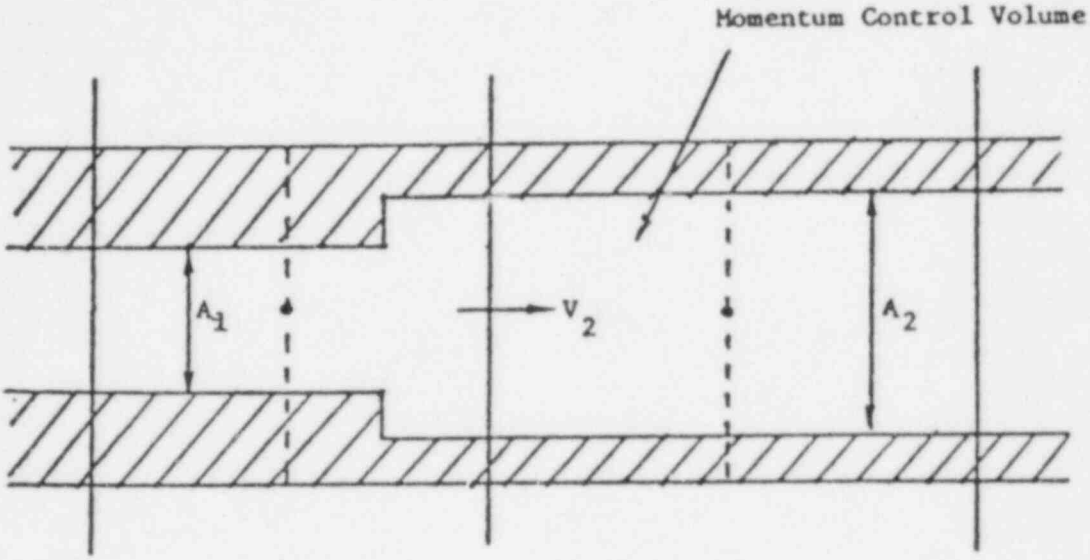

Fig. C.11. Sudden Enlargement (Reference Velocity V_2)

Table C.9 Loss Coefficient for Sudden Contraction [17]

A_1/A_2	C_c	K_1	K_2
0.1	0.624	0.363	36.3
0.2	0.632	0.339	8.475
0.3	0.643	0.308	3.422
0.4	0.659	0.268	1.675
0.5	0.681	0.219	0.876
0.6	0.712	0.164	0.456
0.7	0.755	0.105	0.214
0.8	0.813	0.053	0.083
0.9	0.892	0.015	0.019
1.0	1.0	0	0

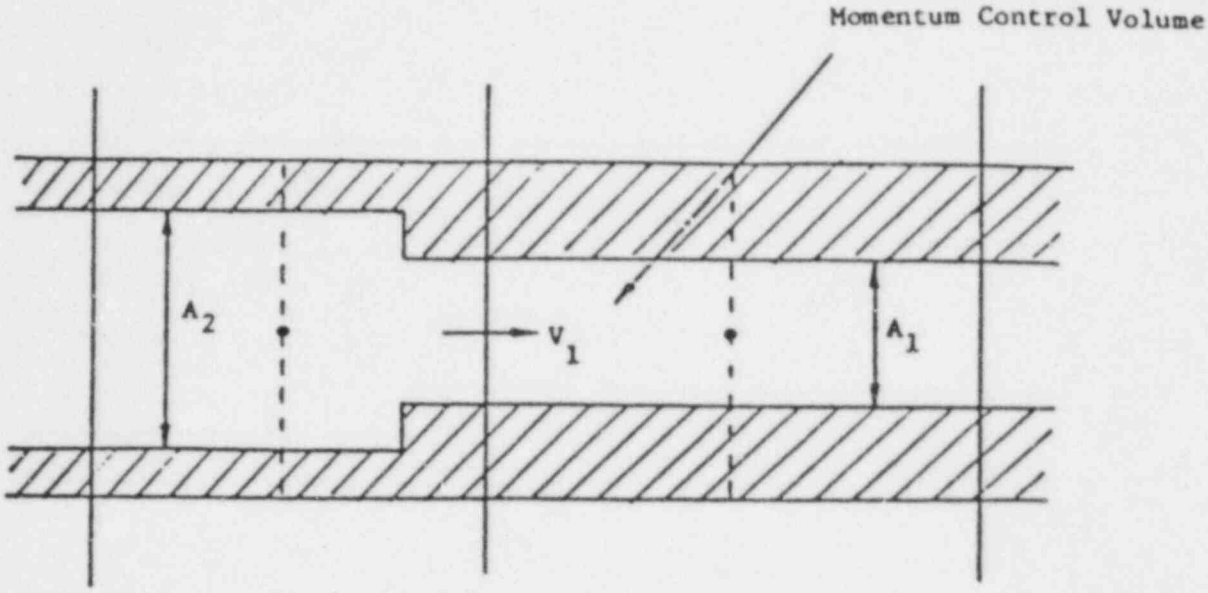

Fig. C.12. Sudden Contraction (Reference Velocity V_1)

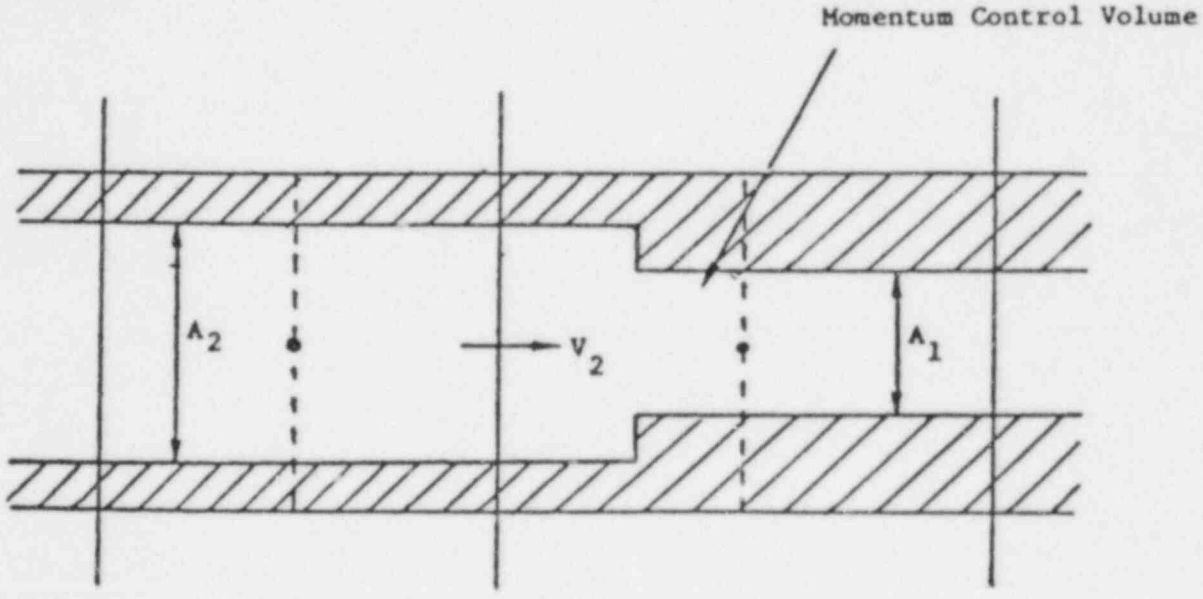

Fig. C.13. Sudden Contraction (Reference Velocity V_2)

C.6 VENTURI NOZZLE AND ORIFICE

C.6.1 Venturi

For Venturi, we define the pressure loss as

$$\Delta p_{loss} = K_1 \frac{1}{2} \rho v_1^2 \qquad \text{(C.35a)}$$

$$= K_2 \frac{1}{2} \rho v_2^2 \quad , \qquad \text{(C.35b)}$$

where K_1 and K_2 are the loss coefficients in reference to kinetic energy in the small and large cross-sections, respectively.

The loss coefficients for Venturi, as shown in Figs. C.14 and C.15, can be expressed as:

$$K_1 = \left[1 - \left(\frac{A_1}{A_2}\right)^2\right]\left(\frac{1}{C_v^2} - 1\right) \qquad \text{(C.36)}$$

and

$$K_2 = \left[\left(\frac{A_2}{A_1}\right)^2\right] - 1\left(\frac{1}{C_v^2} - 1\right) \quad , \qquad \text{(C.37)}$$

where the velocity coefficient c_v is a function of Reynolds number $(\rho v_1 D_1/\mu)$ (Table C.10). The Reynolds number in Table C.10 is based on velocity and diameter of smaller cross-sections.

Table C.10 Velocity Coefficient c_v for Venturi [18]

Log_{10}Re	c_v
3.2	0.9
3.5	0.925
4.0	0.950
4.5	0.966
5.0	0.977
5.5	0.985
6.0	0.989
6.5	0.992

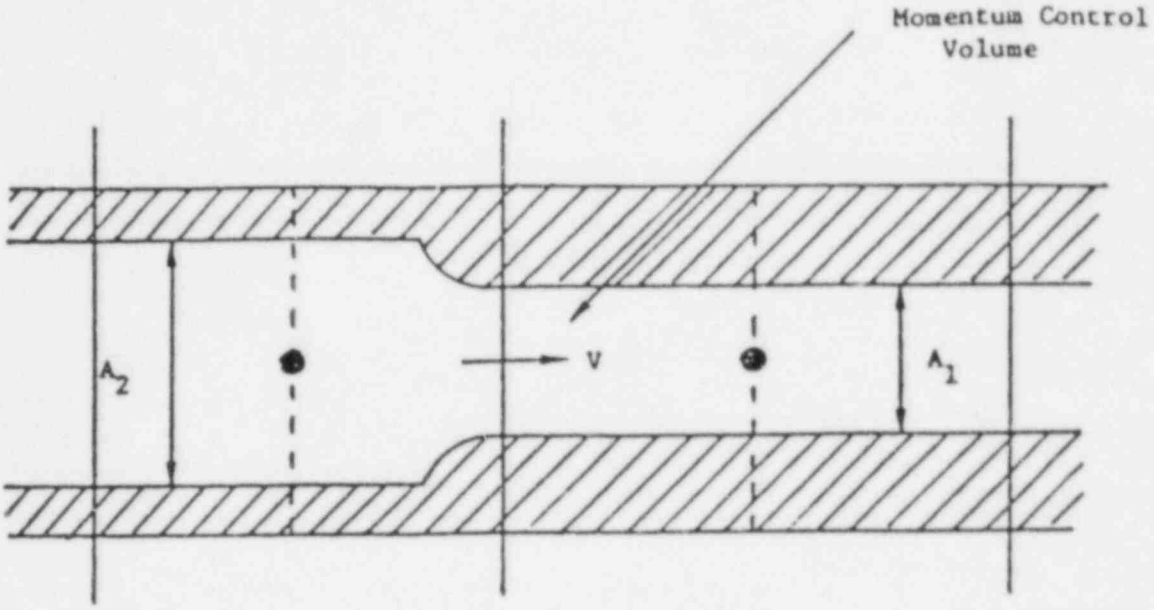

Fig. C.14. Venturi in a Momentum Control Volume
(Reference Velocity V_1)

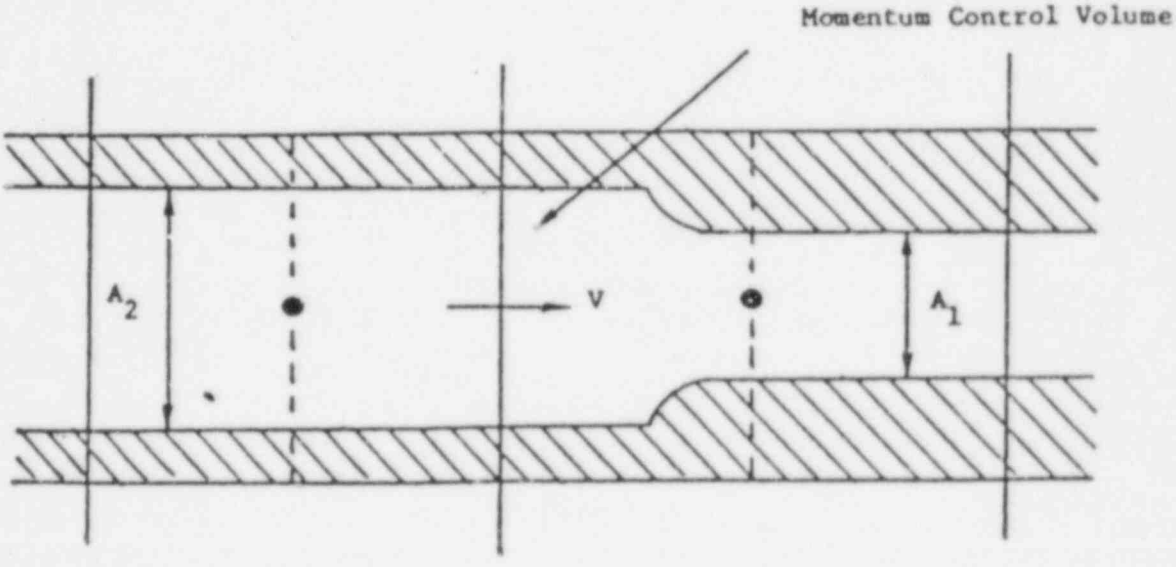

Fig. C.15. Venturi in a Momentum Control Volume
(Reference Velocity V_2)

C.6.2 Nozzle and Orifice

For a nozzle and orifice, as shown in Figs. C.16 and C.17, we express the pressure loss as:

$$\Delta p = K \frac{1}{2} \rho v^2 \ , \tag{C.38}$$

where

$$K = \frac{1}{C^2} \left(\frac{A_2}{A_1} \right)^2 \ . \tag{C.39}$$

Here, the discharge coefficient C is a function of area ratio and Reynolds number. The curves for the discharge coefficient of German (VDI) standard nozzles and orifice are given in Figs. C.18 and C.19.

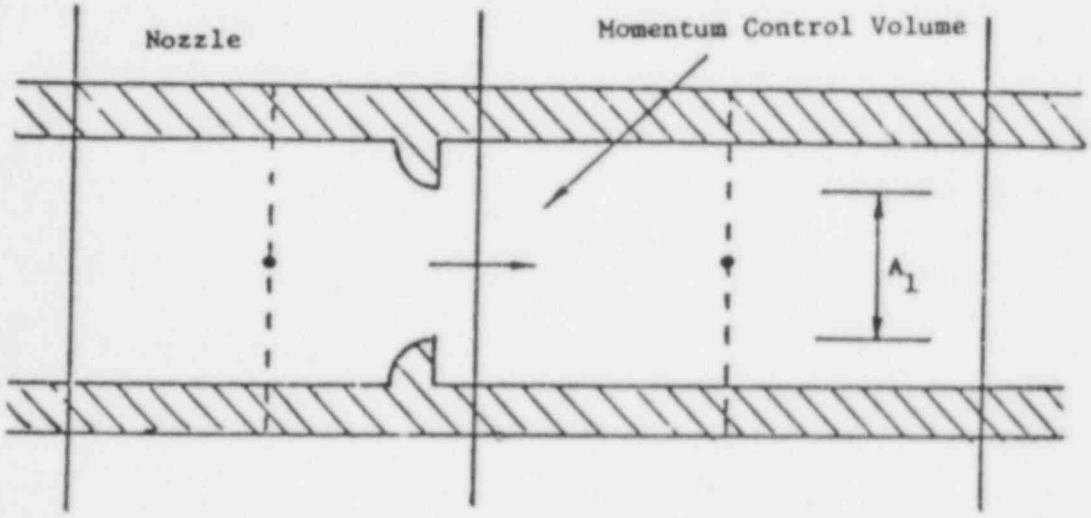

Fig. C.16. Nozzle in a Momentum Control Volume

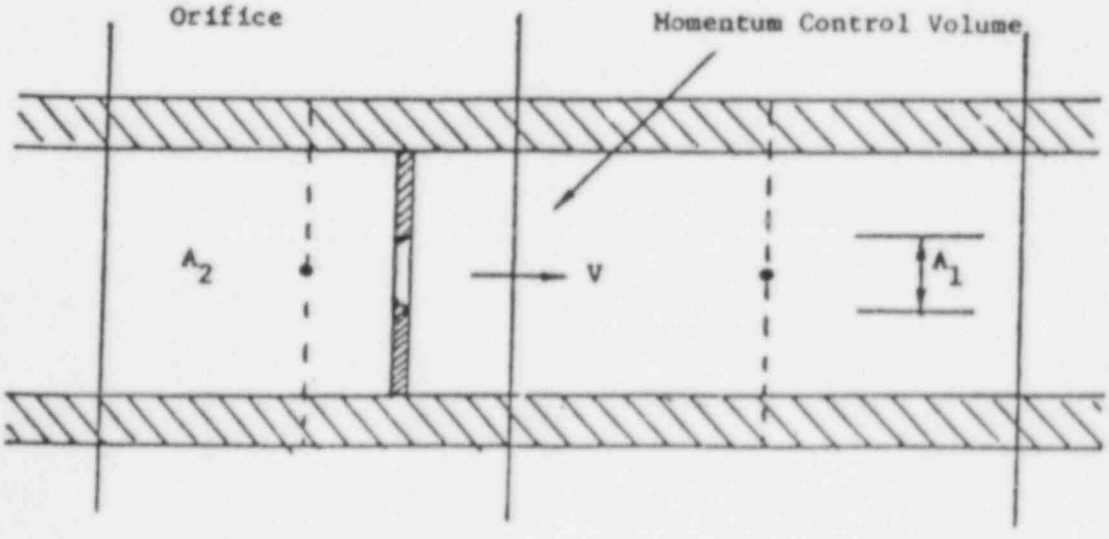

Fig. C.17. Orifice in a Momentum Control Volume

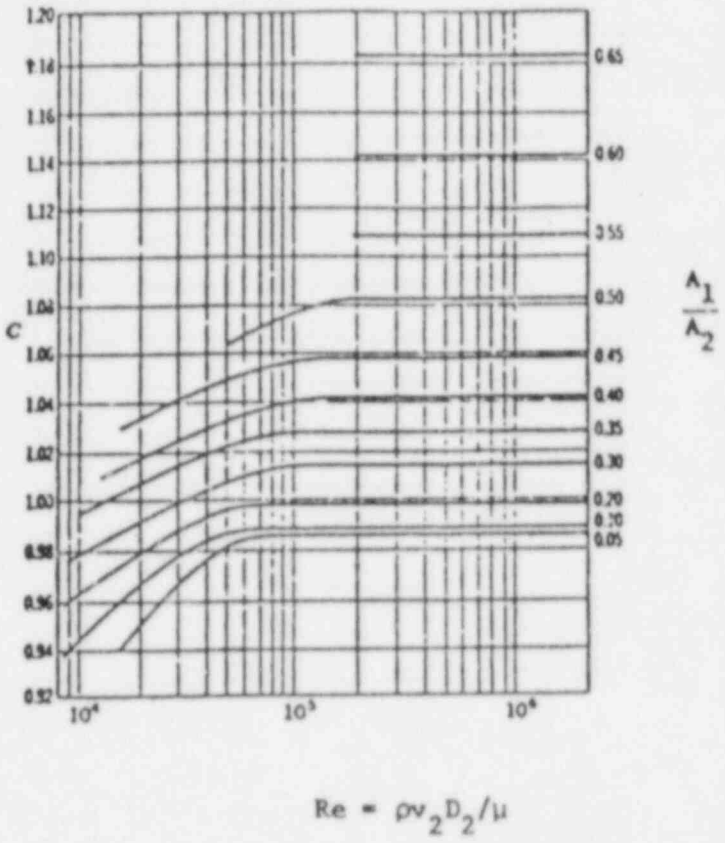

Fig. C.18. Discharge Coefficient for VDI Nozzle [17]

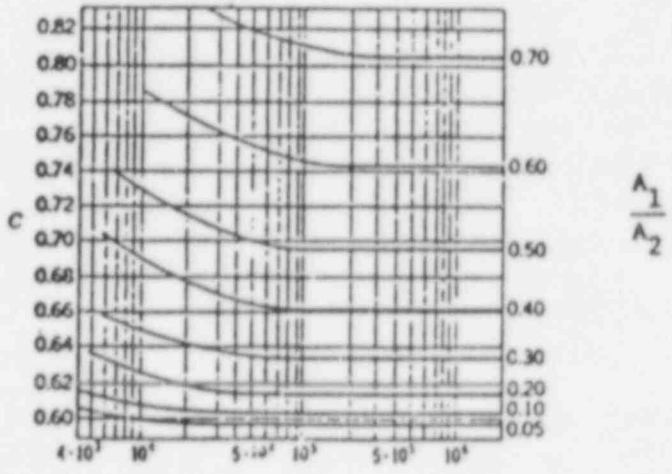

Fig. C.19. Discharge Coefficient for VDI Orifice [17]

C.7 SUBMERGED BODY

The pressure loss due to a submerged object, as shown in Fig. C.20, is given by

$$\Delta p = C_D \frac{A_p}{A_o} \left(\frac{1}{2} \rho v^2\right) . \qquad (C.40)$$

Here, A_p is the projected area of a submerged object, A_o is the flow area, and C_D, the drag coeffcient, is a function of Reynolds number based on velocity v and object diameter D. Figure C.21 gives the variation of C_D with Reynolds number for a few common shapes.

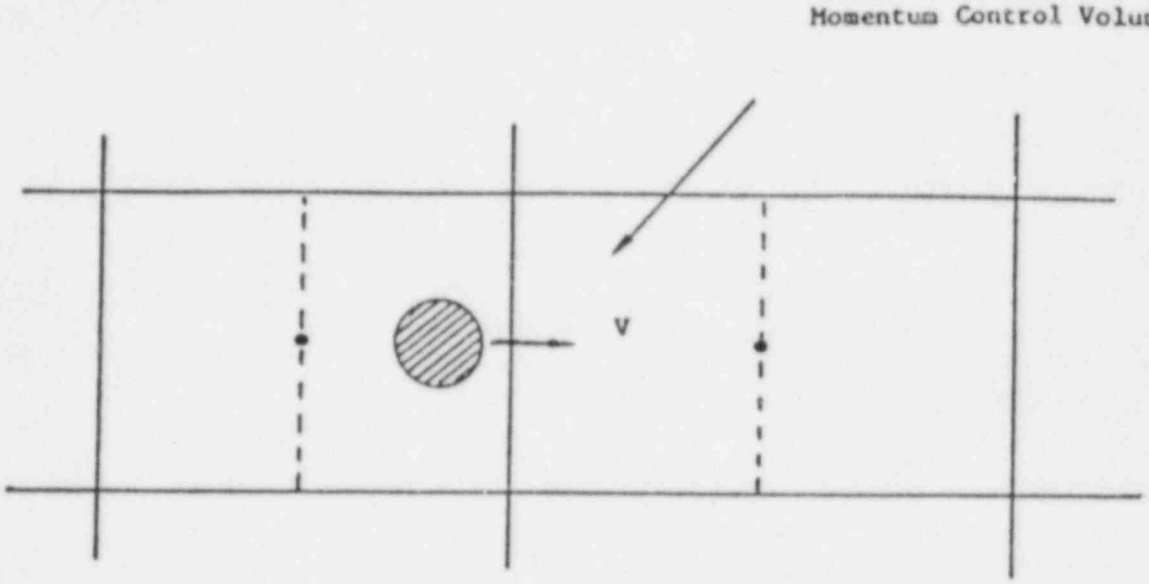

Fig. C.20. Submerged Object in a Momentum Control Volume

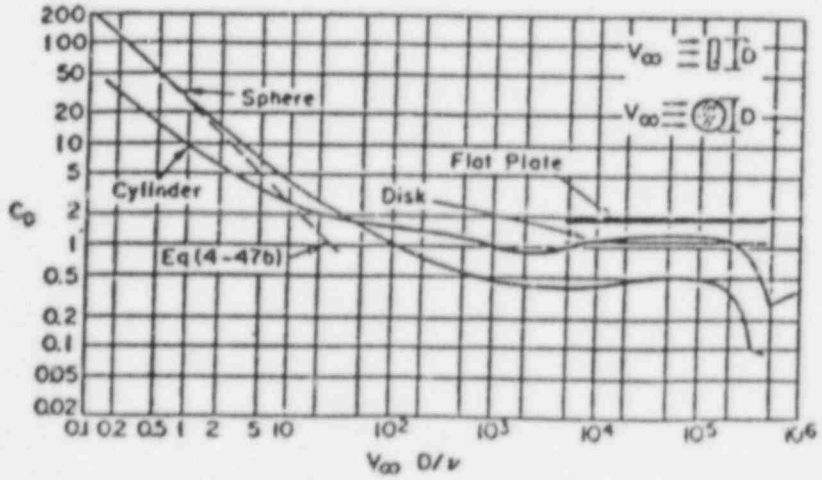

Fig. C.21. Drag Coefficient for Common Shapes [17]

C.8 POROUS MEDIUM

For a packing material deposited at random, as shown in Fig. C.22, Idelchik [13] has recommended the following correlatio:

$$\Delta p = K \frac{1}{2} \rho v^2 \ , \tag{C.41}$$

where

$$K = \frac{1.53}{\lambda^{4.2}} \left(\frac{\ell}{d}\right) \left[\frac{75}{0.45} \frac{(1-\lambda)\lambda^{1/2}}{Re} + \frac{15\,(1-\lambda)^{1/2}\,\lambda^{1/4}}{(0.45)^{1/2}\,Re^{1/2}} + 1\right]$$

$$= \frac{\ell}{d} \left[\frac{255\,(1-\lambda)\lambda^{-3.7}}{Re} + \frac{34.21\,(1-\lambda)^{1/2}\,\lambda^{-3.95}}{Re^{1/2}} + \frac{1.53}{\lambda^{4.2}}\right] \ , \tag{C.42}$$

and,

ℓ = length of porous section,

d = average diameter of solid in porous region,

λ = porosity (free volume fraction) in the porous region, and

$Re = \rho v d/\mu$.

C.9 STRAIGHT DUCT

For flow through a duct, Fig. C.23, the pressure loss is expressed as

$$\Delta p = \frac{L}{d_h} \left(\frac{1}{2} \rho v^2\right) f \ . \tag{C.43}$$

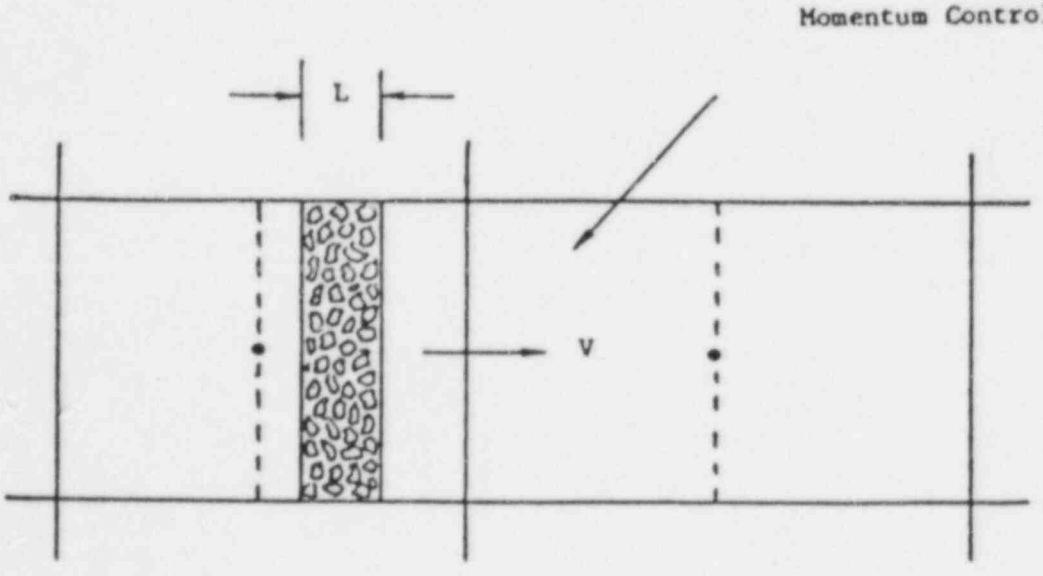

Fig. C.22. Porous Medium in a Momentum Control Volume

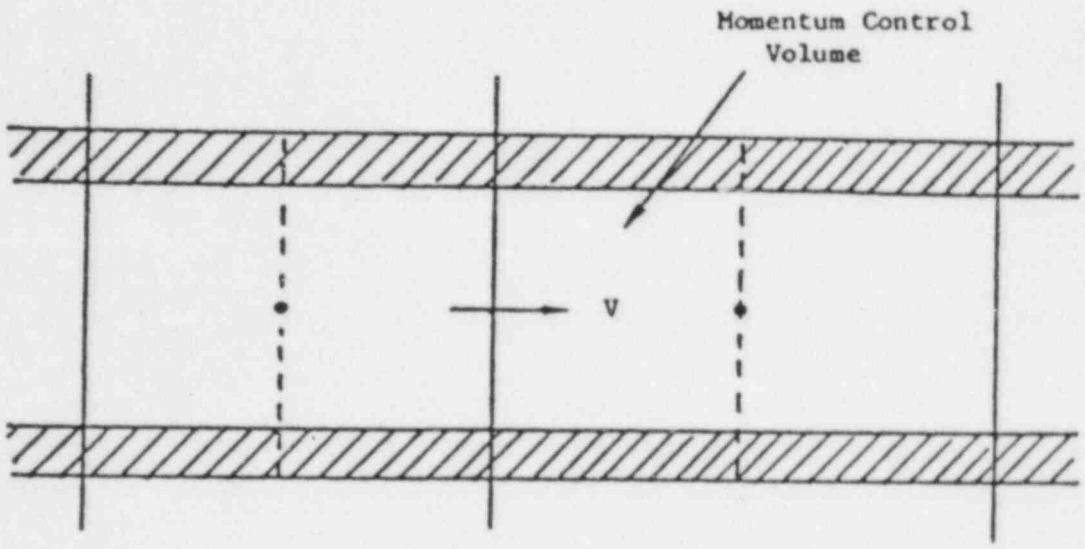

Fig. C.23. Straight Duct in a Momentum Control Volume

Here, L is the length of control volume, d_h is the hydraulic diameter, and the friction factor f is a function of Reynolds number.

- Laminar Flow

  For a circular duct, the fully developed friction factor is given by

$$f = \frac{64}{Re} . \qquad (C.44)$$

The fully developed friction factor for a family of rectangular ducts extending from a square to flow between parallel plates is plotted in Fig. C.24. Similarly, in Figs. C.25 and C.26, the friction factor for flow between concentric annuli and a family of circular annular sectors are presented.

- Turbulent Flow

  For a turbulent flow in a straight duct, the friction factor is

$$f = \frac{0.3164}{Re^{0.25}} . \qquad (C.45)$$

Here,

$$Re = \rho v \, d_h / \mu . \qquad (C.46)$$

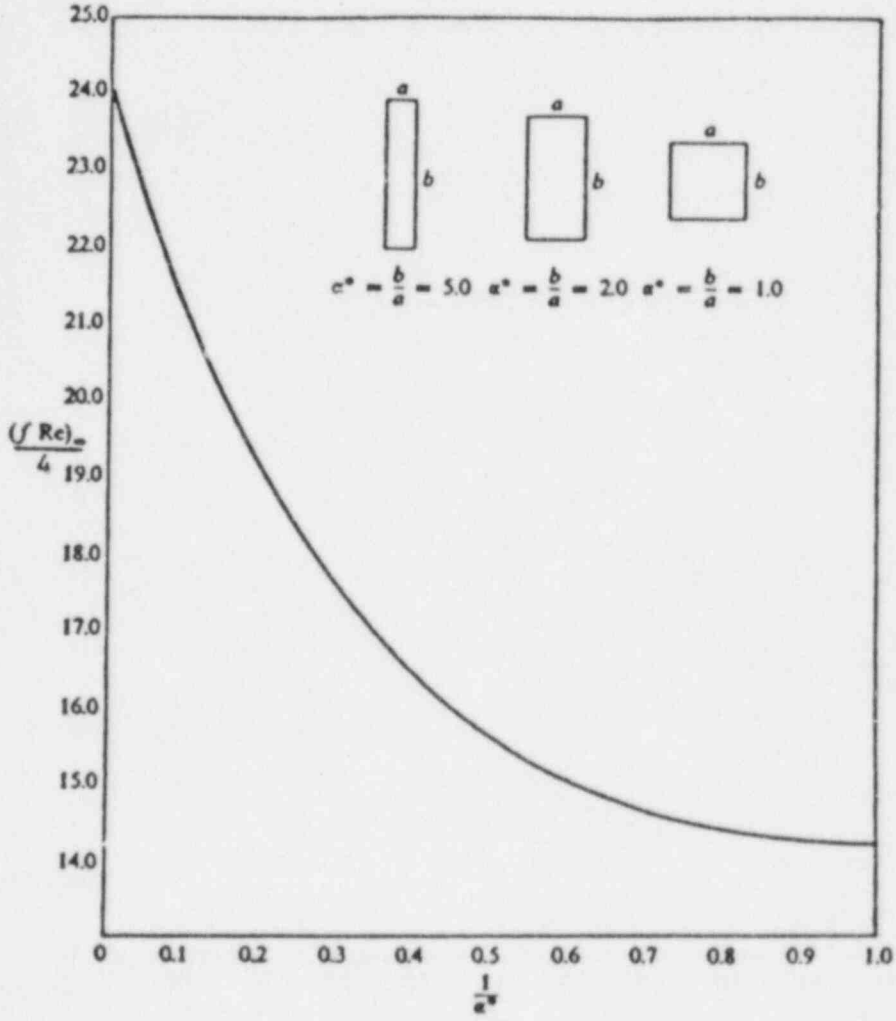

Fig. C.24. Friction Coefficients for Fully-Developed Laminar Flow in Rectangular Tubes [20]

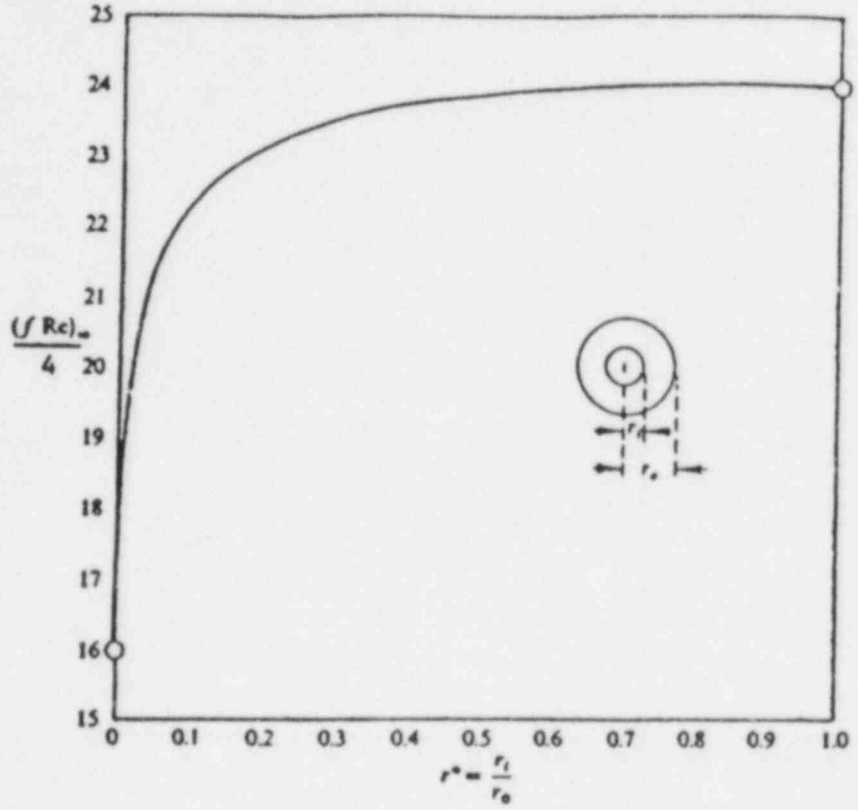

Fig. C.25. Friction Coefficients for Fully-Developed Flow in Circular Tube Annuli [20]

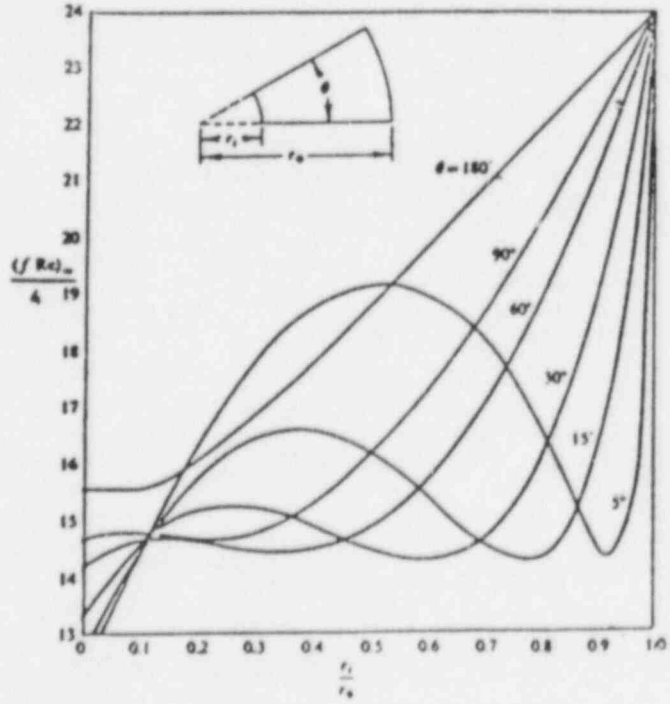

Fig. C.26. Friction Coefficients for Fully-Developed Laminar Flow in an Annular Sector [20]

C.10 PIPE FITTINGS

The pressure loss due to pipe fitting is expressed as

$$\Delta p = K \frac{1}{2} \rho v^2 \quad . \tag{C.47}$$

A summary of representative head loss coefficients K for typical fittings, published by Crane Company [21] is given in Table C.11.

Table C.11 Head Loss Coefficients K for Various Fittings

Fitting	K
Globe valve (fully open)	10.0
Angle valve (fully open)	5.0
Swing check valve (fully open)	2.5
Gate valve (fully open)	0.19
Close return bend	2.2
Standard tee	1.8
Standard elbow	0.9
Medium sweep elbow	0.75
Long sweep elbow	0.60

C.11 CONCLUDING REMARKS

We have presented here a set of pressure loss correlations only for geometrical situations that we feel a COMMIX user is most likely to face. There are so many geometries and so many correlations, that it is impossible to cover them all in this appendix. For other geometries not included here, we recommend Refs. 13, 21, and 22.

If experimental measurements are available for the geometry under consideration, then it is preferable to use those data rather than a correlation from the literature.

The time spent in writing this appendix will be considered well spent if the appendix

- Saves the user time in searching the literature,
- Prevents the user from getting confused with so many different types and forms of possible correlations, and
- Serves as a starting reference.

APPENDIX D. SAMPLE PROBLEM 1.

NUMERICAL DIFFUSION TEST

PURPOSE: To exemplify the skew-upwind differencing option.

PROBLEM DESCRIPTION: Two parallel fluid streams are uniformly flowing at a 45° angle to the grid. Fluid streams are nonconducting and at different temperatures.

Stream A: Temperature - 50°C
Velocity - 0.1 m/s

Stream B: Temperature - 150°C
Velocity - 0.1 m/s

Grid: 15 (x-direction)*15 (y-direction)*1 (z-direction).

COMMIX-1B

THE THREE-DIMENSIONAL TRANSIENT SINGLE-PHASE
COMPUTER PROGRAM FOR THERMAL HYDRAULIC ANALYSIS
OF SINGLE AND MULTICOMPONENT SYSTEMS

DEVELOPED IN THE

ANALYTICAL THERMAL HYDRAULIC RESEARCH PROGRAM
COMPONENTS TECHNOLOGY DIVISION
ARGONNE NATIONAL LABORATORY

Version 3.0 September 30, 1985

NOTICE

The contents of the COMMIX computer program and the calculated output of COMMIX are for use by United States Nuclear Regulatory Commission Office of Nuclear Regulatory Research program participants only. The right to use information originating from the research work of USNRC programs is limited to persons and undertakings specifically given this right by the USNRC. Therefore, the COMMIX computer program and the contents of its output should not be disclosed to others unless written permission to do so has been obtained from the appropriate USNRC office.

********** DATE: 9/18/85 TIME: 13.12.11 COMMIX-1B (3.0) LAST UPDATED: 09/30/85 ID# 3.000001 **********

```
+-----------------------------------------+
|       COMMIX-1B Sample Problem #1       |
|         Numerical Diffusion Test        |
|                15x15x1                  |
|          September 10, 1985             |
+-----------------------------------------+

 &GEOM
  NL1=510,NM1=225,
  IMAX=15,JMAX=15,KMAX=1,
  NSURF=6,
  XNORML= 1.0,-1.0, 0.0, 0.0, 0.0, 0.0,
  YNORML= 0.0, 0.0, 0.0, 0.0,-1.0, 1.0,
  ZNORML= 0.0, 0.0,-1.0, 1.0, 0.0, 0.0,
  DX=15*0.1,
  DY=15*0.1,
  DZ= 1*0.1,
 &END
REG     -1.      1   1   1  15   1   1   1     INLET -X
REG     -1.     15  15   1  15   1   1   2     EXIT  +X
REG     -1.      1  15   1  15   1   1   3     BACK  +Z
REG     -1.      1  15   1  15   1   1   4     FRONT-Z
REG     -1.      1  15  15  15   1   1   5     BACK
REG     -1.      1  15   1   1   1   1   6     INLET -Y FRONT
 &DATA
  IDTIME=0,DT=10.0,
  IFENER=1,ISETMD=100,IESKEW=2,
  NTMAX=200,

  KFLOW=    1,   -5,   -3,   -3,   -5,    1,
  KTEMP=    1,  400,  400,  400,  400,    1,
  VELOC=  0.1, -0.1,  0.0,  0.0, -0.1,  0.1,
  TEMP=  50.0, 50.0, 50.0, 50.0,150.0,150.0,
  TEMP0=100.0,PRES0=1.013E+07,

  IFPROP=1,
  FC0H= 1.275E+6,FC1H= 5.350E+3,
  FC0RO=1.0E+3,  FC1RO=0.0,
  FC0K= 1.0E-20, FC1K=+1.0E-20,
  FC0MU=1.0E-9,  FC1MU=0.0,

  NTPRNT=-9999,
  ISTPR=1301,4301,5301,
  NTHPR=1301,4301,5301,
 &END
UL   0.1         1  15   1  15   1   1
VL   0.1         1  15   1  15   1   1
TL  100.0        1  15   1  15   1   1
- - - - - - - END OF DATA - - - - - - -
```

********** DATE: 9/18/85 TIME: 13.12.11 COMMIX-1B (3.0) LAST UPDATED: 09/30/85 ID# 3.000001 **********

********** STORAGE ALLOCATION SUMMARY **********

THE FOLLOWING VARIABLES DETERMINE STORAGE ALLOCATION. IT IS IMPORTANT THAT THEY ARE ADEQUATELY SPECIFIED.

NM1	225	COMPUTATIONAL CELLS	IWIRE	0	WIRE WRAP OPTION FLAG
NL1	510	SURFACE ELEMENTS	ITURKE	0	TURBULENCE MODEL FLAG
NFORCE	0	FORCE STRUCTURES	IMAX	15	CELLS IN THE X- OR R-DIRECTION
JMAX	15	CELLS IN THE Y- OR THETA DIRECTION	IFREB	0	REBALANCING FLAG
KMAX	1	CELLS IN THE Z-DIRECTION	ISTRUC	0	THERMAL STRUCTURES FLAG
			IGEOM	0	GEOMETRY FLAG

16517 IS THE MINIMUM DIMENSION OF S NEEDED FOR THE ABOVE VALUES.
110000 IS THE CURRENT DIMENSION OF S IN COMMON /SPACE/ IN SUBROUTINE ALTER.

BLOCK LENGTH OF COMMON /SPACE/ (DETERMINED FROM INPUT) 12466 0 0 0 0 0 4050

CELLS AND SURFACE ELEMENTS HAVE BEEN COUNTED. CHECK THESE VALUES AGAINST YOUR EXPECTED TOTALS.

NM	0	IRREGULAR COMPUTATIONAL CELLS
NM1	225	COMPUTATIONAL CELLS (TOTAL)
NL	0	IRREGULAR SURFACE ELEMENTS
NL1	510	SURFACE ELEMENTS (TOTAL)

TIME LEFT TO END OF RUN IS 119.02 SECONDS.

********** GRID SUMMARY **********

	IMAX= 15		JMAX= 15		KMAX= 1		
	X	DX	Y	DY	Z	DZ	
1	5.0000000E-02	1.0000000E-01	5.0000000E-02	1.0000000E-01	5.0000000E-02	1.0000000E-01	1
2	1.5000000E-01	1.0000000E-01	1.5000000E-01	1.0000000E-01			2
3	2.5000000E-01	1.0000000E-01	2.5000000E-01	1.0000000E-01			3
4	3.5000000E-01	1.0000000E-01	3.5000000E-01	1.0000000E-01			4
5	4.5000000E-01	1.0000000E-01	4.5000000E-01	1.0000000E-01			5
6	5.5000000E-01	1.0000000E-01	5.5000000E-01	1.0000000E-01			6
7	6.5000000E-01	1.0000000E-01	6.5000000E-01	1.0000000E-01			7
8	7.5000000E-01	1.0000000E-01	7.5000000E-01	1.0000000E-01			8
9	8.5000000E-01	1.0000000E-01	8.5000000E-01	1.0000000E-01			9
10	9.5000000E-01	1.0000000E-01	9.5000000E-01	1.0000000E-01			10
11	1.0500000E+00	1.0000000E-01	1.0500000E+00	1.0000000E-01			11
12	1.1500000E+00	1.0000000E-01	1.1500000E+00	1.0000000E-01			12
13	1.2500000E+00	1.0000000E-01	1.2500000E+00	1.0000000E-01			13
14	1.3500000E+00	1.0000000E-01	1.3500000E+00	1.0000000E-01			14
15	1.4500000E+00	1.0000000E-01	1.4500000E+00	1.0000000E-01			15

********** SURFACE-SURFACE ELEMENT SUMMARY **********

SURFACE TYPE	SURFACE NUMBER	NUMBER OF SURFACE	UNIT NORMAL VECTOR

ELEMENTS

REGULAR	1	15	1.0000 I	0.0000 J	0.0000 K
REGULAR	2	15	-1.0000 I	0.0000 J	0.0000 K
REGULAR	3	225	0.0000 I	0.0000 J	-1.0000 K
REGULAR	4	225	0.0000 I	0.0000 J	1.0000 K
REGULAR	5	15	0.0000 I	-1.0000 J	0.0000 K
REGULAR	6	15	0.0000 I	1.0000 J	0.0000 K

********** BOUNDARY CONDITIONS SUMMARY **********

SURFACE	KTEMP	KFLOW	KPRES	MATWAL	IHTWAL	TEMP	VELOC	PRES	WALLDX	HYDWAL	WALLQS	TSINK	HSINK
1	1	1	0	0	0	5.000E+01	1.000E-01	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	400	-5	0	0	0	5.000E+01	-1.000E-01	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	400	-3	0	0	0	5.000E+01	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	400	-3	0	0	0	5.000E+01	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	400	-5	0	0	0	1.500E+02	-1.000E-01	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	1	1	0	0	0	1.500E+02	1.000E-01	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

********** FLAG SUMMARY **********

IBOIL =	0			IDRAG =	0	IDTIME=	0	IESKEW=	2	IFENER=	1
		IFPROP=	1	IFREB =	0	IFRES =	0	IFROD =	0	IGEOM =	0
IMAX =	15	IPART =	0	IREBIT=	50	ISETEN=	1	ISETMO=	100	ISKBAR=	0
ISTATE=	0	ISTRUC=	0			ITENMX=	1	ITMAXE=	99	ITMAXP=	99
ITURKE=	0	IT(1) =	1	IT(2) =	1	IWIRE =	0	IXREB =	0	IYREB =	0
IZREB =	0	JMAX =	15	KMAX =	1	LASTDT=	99999	LASTIT=	99999	LMFPNT=	0
NCORR =	0	NEWFOR=	1	NEWREB=	1	NEWTS =	1	NFORCE=	0	NNEATC=	1
NL1 =	510	NMATER=	0	NM1 =	225	NREBRT=	0	NSURF =	6	NTMAX =	200

********** SIMPLIFIED PROPERTIES SUMMARY **********

COOLANT PROPERTIES ARE COMPUTED WITH THE FOLLOWING FUNCTIONS:

```
ENTHALPY     =  1.2750E+06 + TC *   5.3500E+03
DENSITY      =  1.0000E+03 + TC *   0.0000E+00
CONDUCTIVITY=  1.0000E-20 + TC *   1.0000E-20
VISCOSITY    =  1.0000E-09 + TC *   0.0000E+00
TEMPERATURE = -2.3332E+02 + H  *   1.8692E-04
```

THE FOLLOWING VALUES WERE COMPUTED FROM THESE FUNCTIONS:

TEMPERATURE	ENTHALPY	DENSITY	CONDUCTIVITY	VISCOSITY	TEMPERATURE
3.000E+02	2.880E+06	1.000E+03	3.010E-18	1.000E-09	3.000E+02
4.000E+02	3.415E+06	1.000E+03	4.010E-18	1.000E-09	4.000E+02
5.000E+02	3.950E+06	1.000E+03	5.010E-18	1.000E-09	5.000E+02
6.000E+02	4.485E+06	1.000E+03	6.010E-18	1.000E-09	6.000E+02
7.000E+02	5.020E+06	1.000E+03	7.010E-18	1.000E-09	7.000E+02

********** FLUID-STRUCTURE HEAT TRANSFER CORRELATIONS SUMMARY **********

NUMBER OF HEAT TRANSFER CORRELATIONS SPECIFIED (NOHEATC) = 1
THE NUSSELT NUMBER IS COMPUTED WITH THE FOLLOWING FUNCTION:

NUSSELT = HEATC1 + HEATC2 * REYNOLDS NUMBER ** NHEATC3

CORRELATION	HEATC1	HEATC2	HEATC3
1	5.000E+00	4.020E-04	8.000E-01

********** SURFACE AREA SUMMARY **********

SURFACE	AREA (M**2)
1	1.499999E-01
2	1.499999E-01
3	2.249908E+00
4	2.249908E+00
5	1.499999E-01
6	1.499999E-01

TOTAL SURFACE AREA = 5.099815E+00 M**2 TOTAL VOLUME = 2.249978E-01 M**3

********** DATE: 9/18/85 TIME: 13.12.15 COMMIX-1B (3.0) LAST UPDATED: 09/30/85 ID# 3.000001 **********

GLOBAL BALANCES AT TIME= 0.000E+00 SECONDS

SURFACE NUMBER	MASS CONVECTED (KG/SEC)	ENERGY CONVECTED (WATT)	ENERGY CONDUCTED (WATT)	AVERAGE VELOCITY (M/SEC)	AVERAGE ENTHALPY (J/KG)	AVERAGE TEMPERATURE (CELSIUS)	BULK TEMPERATURE (CELSIUS)
N= 1	1.500000E+01	2.313749E+07	-1.514998E-16	9.999996E-02	1.542499E+06	4.999998E+01	4.999988E+01
N= 2	-1.500000E+01	-2.714999E+07	0.000000E+00	-9.999996E-02	1.809999E+06	9.999998E+01	9.999986E+01
N= 3	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.809999E+06	9.999998E+01	0.000000E+00
N= 4	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.809999E+06	9.999998E+01	0.000000E+00
N= 5	-1.500000E+01	-2.714999E+07	0.000000E+00	-9.999996E-02	1.809999E+06	9.999998E+01	9.999986E+01
N= 6	1.500000E+01	3.116249E+07	1.514998E-16	9.999996E-02	2.077499E+06	1.499999E+02	1.499999E+02

********** MASS BALANCE **********

MASS ACCUMULATION RATE: DMASDT= 0.000000E+00 (KG/SEC)
NET MASS CONVECTED INTO CONFIGURATION: FLOSUM= 0.000000E+00 (KG/SEC)

GLOBAL CONSERVATION OF MASS: (DMASDT-FLOSUM)= 0.000000E+00 (KG/SEC) DLSUM= 0.000000E+00

********** ENERGY BALANCE **********

ENERGY ACCUMULATION RATE: DEDT= 0.000000E+00 (WATT)
NET ENERGY CONVECTED INTO CONFIGURATION: EINSUM= 0.000000E+00 (WATT)
NET ENERGY CONDUCTED INTO CONFIGURATION: QINSUM= 0.000000E+00 (WATT)
ENERGY GENERATED WITHIN CONFIGURATION: QSOURC= 0.000000E+00 (WATT)
ENERGY EXCESS DUE TO MASS RESIDUE: EDLSUM= 0.000000E+00 (WATT)

GLOBAL CONSERVATION OF ENERGY: (DEDT-EINSUM-QINSUM-QSOURC-EDLSUM)= 0.000000E+00 (WATT)

UL (M/S) : VELOCITY IN X-DIRECTION AT TIME= 0.000E+00 SECONDS

********** CONSTANT K PLANE K= 1 **********

J	I-->	1	2	3	4	5	6	7	8	9	10
15		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
14		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
13		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
12		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
11		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
10		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
9		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
8		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
7		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
6		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
5		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
4		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
3		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01
2		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01

1	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01

********** CONSTANT K PLANE K= 1 **********

J	I-->	11	12	13	14	15
15		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
14		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
13		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
12		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
11		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
10		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
9		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
8		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
7		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
6		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
5		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
4		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
3		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
2		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
1		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00

HL (J/KG) : ENTHALPY AT TIME= 0.000E+00 SECONDS

********** CONSTANT K PLANE K= 1 **********

J	I-->	1	2	3	4	5	6	7	8	9	10
15		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
14		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
13		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
12		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
11		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
10		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
9		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
8		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
7		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
6		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
5		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
4		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
3		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
2		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
1		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06

********** CONSTANT K PLANE K= 1 **********

J	I-->	11	12	13	14	15
15		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
14		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
13		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
12		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
11		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
10		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
9		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
8		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
7		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
6		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06
5		1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06	1.81000E+06

```
4       1.81000E+06 1.81000E+06 1.81000E+06 1.81000E+06 1.81000E+06
3       1.81000E+06 1.81000E+06 1.81000E+06 1.81000E+06 1.81000E+06
2       1.81000E+06 1.81000E+06 1.81000E+06 1.81000E+06 1.81000E+06
1       1.81000E+06 1.81000E+06 1.81000E+06 1.81000E+06 1.81000E+06
```

TL (DEGREES CELSIUS) : TEMPERATURE AT TIME= 0.000E+00 SECONDS

********** CONSTANT K PLANE K= 1 **********

```
J  I-->     1           2           3           4           5           6           7           8           9           10
15      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
14      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
13      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
12      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
11      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
10      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
9       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
8       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
7       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
6       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
5       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
4       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
3       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
2       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
1       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
```

********** CONSTANT K PLANE K= 1 **********

```
J  I-->     11          12          13          14          15
15      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
14      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
13      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
12      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
11      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
10      1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
9       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
8       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
7       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
6       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
5       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
4       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
3       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
2       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
1       1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02 1.00000E+02
```

********** CONTROL SUMMARY **********

```
DTENER  1.0000E+01   EPS1    1.0000E-04   DTIME   1.0000E+01                          CDRAGX  1.0000E+00
EPS5    1.0000E-05   EPS2    1.0000E-06   DTFUEL  1.0000E+01                          CDRASY  1.0000E+00
ITERMX          1    EPS3    5.0000E-05   DTMALL  1.0000E+40   GRAVX   0.0000E+00     CDRAGZ  1.0000E+00
ITMAXE         99    INCBIT         50    DT(1)   1.6000E+01   GRAVY   0.0000E+00
OMEGAE  8.0000E-01   ITERMX          1    DT(2)   1.0000E-01   GRAVZ   0.0000E+00     CHARPE  0.0000E+00
OMEGAU  1.0000E+00   ITMAXP         99    LASTDT      99999    PRESO   1.0130E+07     CHART   0.0000E+00
RELAXE  9.5000E-01                        RDTIME  8.0000E-01   TEMPO   1.0300E+02
                                          TIMAX   3.6000E+07   ACCELO  0.0000E+00     CWIREX  5.0000E-01
```

IT(1)	1	TIMEUP	113.82	YPRESO	0.0000E+00	CWIREY	5.0000E-01
IT(2)	1	TREST	20.00	ZPRESO	0.0000E+00	CWIREZ	5.0000E-01
LASTIT	99999	TSTART	0.0000E+00			HYDALL	0.0000E+00
OMEGA	1.5000E+00					HYDIN	1.4500E+00
OMEGAV	8.0000E-01					HYDOUT	0.0000E+00
ALPHA	1.0000E+00						

	NT	TIME	DTIME	IT	MAX(DL)/ DCONV	MAX(DU)/ VELMAX	MAX(DV)/ VELMAX	MAX(DH)/ VELMAX	MAX(DH/H)	TLEFT	COURDT	DCONV	VELMAX
#	1	1.0000E+01	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.01E-01	118.67	1.00E+00	1.00E-01	1.41E-01
#	2	2.0000E+01	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-5.66E-02	118.53	1.00E+00	1.00E-01	1.41E-01
#	3	3.0000E+01	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-4.20E-02	118.39	1.00E+00	1.00E-01	1.41E-01
#	4	4.0000E+01	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-3.48E-02	118.25	1.00E+00	1.00E-01	1.41E-01
#	5	5.0000E+01	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-3.04E-02	118.11	1.00E+00	1.00E-01	1.41E-01
#	6	6.0000E+01	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-2.73E-02	117.97	1.00E+00	1.00E-01	1.41E-01
#	7	7.0000E+01	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-2.48E-02	117.83	1.00E+00	1.00E-01	1.41E-01
#	8	8.0000E+01	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-2.27E-02	117.68	1.00E+00	1.00E-01	1.41E-01
#	9	9.0000E+01	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-2.06E-02	117.55	1.00E+00	1.00E-01	1.41E-01
#	10	1.0000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.86E-02	117.41	1.00E+00	1.00E-01	1.41E-01
#	11	1.1000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.63E-02	117.28	1.00E+00	1.00E-01	1.41E-01
#	12	1.2000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.35E-02	117.14	1.00E+00	1.00E-01	1.41E-01
#	13	1.3000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.00E-02	117.01	1.00E+00	1.00E-01	1.41E-01
#	14	1.4000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-7.98E-03	116.87	1.00E+00	1.00E-01	1.41E-01
#	15	1.5000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-5.83E-03	116.74	1.00E+00	1.00E-01	1.41E-01
#	16	1.6000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-3.98E-03	116.61	1.00E+00	1.00E-01	1.41E-01
#	17	1.7000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-2.56E-03	116.47	1.00E+00	1.00E-01	1.41E-01
#	18	1.8000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.56E-03	116.34	1.00E+00	1.00E-01	1.41E-01
#	19	1.9000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-9.47E-04	116.21	1.00E+00	1.00E-01	1.41E-01
#	20	2.0000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-5.48E-04	116.07	1.00E+00	1.00E-01	1.41E-01
#	21	2.1000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-3.05E-04	115.95	1.00E+00	1.00E-01	1.41E-01
#	22	2.2000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.64E-04	115.82	1.00E+00	1.00E-01	1.41E-01
#	23	2.3000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-8.52E-05	115.69	1.00E+00	1.00E-01	1.41E-01
#	24	2.4000E+02	1.00E+01	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-4.20E-05	115.56	1.00E+00	1.00E-01	1.41E-01

```
#  **************************************************************
#  *****  STEADY STATE HAS BEEN REACHED TO WITHIN EPS3= 5.000E-05  *****
#  **************************************************************
```

********** DATE: 9/18/85 TIME: 13.12.29 COMMIX-1B (3.0) LAST UPDATED: 09/30/85 ID# 3.000001 **********

GLOBAL BALANCES AT TIME= 2.400E+02 SECONDS

SURFACE NUMBER	MASS CONVECTED (KG/SEC)	ENERGY CONVECTED (WATT)	ENERGY CONDUCTED (WATT)	AVERAGE VELOCITY (M/SEC)	AVERAGE ENTHALPY (J/KG)	AVERAGE TEMPERATURE (CELSIUS)	BULK TEMPERATURE (CELSIUS)
N= 1	1.500000E+01	2.313749E+07	-1.327442E-17	9.999996E-02	1.542499E+06	4.999998E+01	4.999988E+01
N= 2	-1.500000E+01	-3.031732E+07	0.000000E+00	-9.999956E-02	2.021155E+06	1.396682E+02	1.396682E+02
N= 3	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.809994E+06	9.999881E+01	0.000000E+00
N= 4	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.809994E+06	9.999881E+01	0.000000E+00
N= 5	-1.500000E+01	-2.398242E+07	0.000000E+00	-9.999996E-02	1.598828E+06	6.052851E+01	6.052858E+01
N= 6	1.500000E+01	3.116249E+07	1.782659E-17	9.999996E-02	2.077499E+06	1.499999E+02	1.499999E+02

********** MASS BALANCE **********

MASS ACCUMULATION RATE: DMASDT= 0.000000E+00 (KG/SEC)
NET MASS CONVECTED INTO CONFIGURATION: FLOSUM= 0.000000E+00 (KG/SEC)

GLOBAL CONSERVATION OF MASS: (DMASDT-FLOSUM)= 0.000000E+00 (KG/SEC) DLSUM= 0.000000E+00

********** ENERGY BALANCE **********

ENERGY ACCUMULATION RATE: DEDT= 0.000000E+00 (WATT)
NET ENERGY CONVECTED INTO CONFIGURATION: EINSUM= 2.340000E+02 (WATT)
NET ENERGY CONDUCTED INTO CONFIGURATION: QINSUM= 3.752171E-18 (WATT)
ENERGY GENERATED WITHIN CONFIGURATION: QSOURC= 0.000000E+00 (WATT)
ENERGY EXCESS DUE TO MASS RESIDUE: EDLSUM= 0.000000E+00 (WATT)

GLOBAL CONSERVATION OF ENERGY: (DEDT-EINSUM-QINSUM-QSOURC-EDLSUM)=-2.340000E+02 (WATT)

UL (M/S) : VELOCITY IN X-DIRECTION AT TIME= 2.400E+02 SECONDS

********** CONSTANT K PLANE K= 1 **********

J I-->	1	2	3	4	5	6	7	8	9	10
15	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
14	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
13	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
12	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
11	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
10	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
9	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
8	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
7	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
6	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
5	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
4	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
3	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01
2	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01	1.000000E-01

1	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01

********** CONSTANT K PLANE K= 1 **********

J	I-->	11	12	13	14	15
15		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
14		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
13		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
12		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
11		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
10		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
9		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
8		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
7		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
6		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
5		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
4		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
3		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
2		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00
1		1.00000E-01	1.00000E-01	1.00000E-01	1.00000E-01	0.00000E+00

HL (J/KG) : ENTHALPY AT TIME= 2.400E+02 SECONDS

********** CONSTANT K PLANE K= 1 **********

J	I-->	1	2	3	4	5	6	7	8	9	10
15		1.54250E+06	1.54250E+06	1.54251E+06	1.54256E+06	1.54279E+06	1.54359E+06	1.54582E+06	1.55097E+06	1.56119E+06	1.57835E+06
14		1.54250E+06	1.54250E+06	1.54253E+06	1.54267E+06	1.54327E+06	1.54512E+06	1.54984E+06	1.55982E+06	1.57788E+06	1.60630E+06
13		1.54250E+06	1.54251E+06	1.54258E+06	1.54292E+06	1.54421E+06	1.54790E+06	1.55650E+06	1.57314E+06	1.60066E+06	1.64034E+06
12		1.54250E+06	1.54252E+06	1.54269E+06	1.54349E+06	1.54620E+06	1.55330E+06	1.56828E+06	1.59463E+06	1.63422E+06	1.68612E+06
11		1.54250E+06	1.54257E+06	1.54299E+06	1.54480E+06	1.55033E+06	1.56338E+06	1.58817E+06	1.62743E+06	1.68059E+06	1.74356E+06
10		1.54251E+06	1.54268E+06	1.54372E+06	1.54768E+06	1.55851E+06	1.58129E+06	1.61985E+06	1.67426E+06	1.74009E+06	1.80999E+06
9		1.54254E+06	1.54300E+06	1.54547E+06	1.55384E+06	1.57402E+06	1.61135E+06	1.66692E+06	1.73601E+06	1.80999E+06	1.87989E+06
8		1.54262E+06	1.54384E+06	1.54958E+06	1.56646E+06	1.60176E+06	1.65827E+06	1.73114E+06	1.80999E+06	1.88397E+06	1.94572E+06
7		1.54287E+06	1.54605E+06	1.55885E+06	1.59095E+06	1.64789E+06	1.72515E+06	1.80999E+06	1.88885E+06	1.95307E+06	2.00013E+06
6		1.54360E+06	1.55167E+06	1.57883E+06	1.63517E+06	1.71755E+06	1.80999E+06	1.89434E+06	1.96172E+06	2.00864E+06	2.03870E+06
5		1.54550E+06	1.56562E+06	1.61919E+06	1.70750E+06	1.81000E+06	1.90244E+06	1.97210E+06	2.01823E+06	2.04597E+06	2.05140E+06
4		1.55241E+06	1.59854E+06	1.69331E+06	1.81000E+06	1.91249E+06	1.98482E+06	2.02905E+06	2.05354E+06	2.06616E+06	2.07232E+06
3		1.57222E+06	1.67138E+06	1.81000E+06	1.92668E+06	2.00081E+06	2.04117E+06	2.06115E+06	2.07042E+06	2.07452E+06	2.07627E+06
2		1.63167E+06	1.81000E+06	1.94870E+06	2.02136E+06	2.05438E+06	2.06932E+06	2.07395E+06	2.07615E+06	2.07699E+06	2.07731E+06
1		1.81000E+06	1.98833E+06	2.04773E+06	2.06759E+06	2.07420E+06	2.07640E+06	2.07713E+06	2.07738E+06	2.07746E+06	2.07749E+06

********** CONSTANT K PLANE K= 1 **********

J	I-->	11	12	13	14	15
15		1.60536E+06	1.64290E+06	1.68396E+06	1.74144E+06	1.80999E+06
14		1.64553E+06	1.69538E+06	1.75153E+06	1.80999E+06	1.87853E+06
13		1.69101E+06	1.74915E+06	1.80999E+06	1.85845E+06	1.93101E+06
12		1.74655E+06	1.80999E+06	1.87879E+06	1.92660E+06	1.97700E+06
11		1.80999E+06	1.87342E+06	1.92897E+06	1.97409E+06	2.01413E+06
10		1.87662E+06	1.93326E+06	1.97964E+06	2.01308E+06	2.04113E+06
9		1.93939E+06	1.98577E+06	2.01932E+06	2.04211E+06	2.05879E+06
8		1.97220E+06	2.02536E+06	2.04650E+06	2.06016E+06	2.06902E+06
7		2.03721E+06	2.05170E+06	2.06314E+06	2.07015E+06	2.07417E+06
6		2.05041E+06	2.06669E+06	2.07209E+06	2.07406E+06	2.07535E+06
5		2.06916E+06	2.07379E+06	2.07579E+06	2.07672E+06	2.07720E+06

4	2.07520E+06	2.07650E+06	2.07707E+06	2.07732E+06	2.07743E+06
3	2.07700E+06	2.07730E+06	2.07742E+06	2.07747E+06	2.07749E+06
2	2.07743E+06	2.07747E+06	2.07749E+06	2.07749E+06	2.07750E+06
1	2.07749E+06	2.07750E+06	2.07750E+06	2.07750E+06	2.07750E+06

TL (DEGREES CELSIUS) : TEMPERATURE AT TIME= 2.400E+02 SECONDS

********** CONSTANT K PLANE K= 1 **********

J	I-->	1	2	3	4	5	6	7	8	9	10
15		4.99996E+01	4.99996E+01	5.00013E+01	5.00114E+01	5.00548E+01	5.02045E+01	5.06198E+01	5.15829E+01	5.34930E+01	5.67946E+01
14		4.99996E+01	5.00004E+01	5.00050E+01	5.00323E+01	5.01429E+01	5.04904E+01	5.13719E+01	5.32379E+01	5.66122E+01	6.19244E+01
13		4.99999E+01	5.00013E+01	5.00138E+01	5.00785E+01	5.03185E+01	5.10099E+01	5.26158E+01	5.57262E+01	6.08712E+01	6.82870E+01
12		5.00001E+01	5.00043E+01	5.00360E+01	5.01854E+01	5.06923E+01	5.20189E+01	5.48192E+01	5.97435E+01	6.71429E+01	7.68453E+01
11		5.00006E+01	5.00123E+01	5.00914E+01	5.04283E+01	5.14628E+01	5.39020E+01	5.85370E+01	6.58744E+01	7.58114E+01	8.75807E+01
10		5.00023E+01	5.00343E+01	5.02277E+01	5.09674E+01	5.29923E+01	5.72506E+01	6.44581E+01	7.46278E+01	8.69323E+01	9.99979E+01
9		5.00074E+01	5.00936E+01	5.05558E+01	5.21188E+01	5.59124E+01	6.28685E+01	7.32552E+01	8.61708E+01	9.99982E+01	1.13064E+02
8		5.00226E+01	5.02511E+01	5.13231E+01	5.44779E+01	6.10773E+01	7.16383E+01	8.52587E+01	9.99984E+01	1.13826E+02	1.25369E+02
7		5.00682E+01	5.06627E+01	5.30553E+01	5.90553E+01	6.96989E+01	8.41393E+01	9.99987E+01	1.14738E+02	1.26742E+02	1.35539E+02
6		5.02054E+01	5.17142E+01	5.67897E+01	6.73214E+01	8.27203E+01	9.99987E+01	1.15858E+02	1.28359E+02	1.37129E+02	1.42747E+02
5		5.06168E+01	5.43204E+01	6.43341E+01	8.08407E+01	9.99989E+01	1.17278E+02	1.30299E+02	1.38921E+02	1.44107E+02	1.47005E+02
4		5.18514E+01	6.04933E+01	7.81886E+01	9.99991E+01	1.19158E+02	1.32677E+02	1.40943E+02	1.45520E+02	1.47879E+02	1.49031E+02
3		5.55553E+01	7.40736E+01	9.99994E+01	1.21810E+02	1.35664E+02	1.43209E+02	1.46943E+02	1.48676E+02	1.49443E+02	1.49771E+02
2		6.66664E+01	9.99996E+01	1.25925E+02	1.39505E+02	1.45678E+02	1.48285E+02	1.49336E+02	1.49748E+02	1.49905E+02	1.49964E+02
1		9.99998E+01	1.33333E+02	1.44444E+02	1.48148E+02	1.49382E+02	1.49794E+02	1.49931E+02	1.49977E+02	1.49992E+02	1.49997E+02

********** CONSTANT K PLANE K= 1 **********

J	I-->	11	12	13	14	15
15		6.18431E+01	6.87657E+01	7.73756E+01	8.71857E+01	9.99977E+01
14		6.93251E+01	7.85745E+01	8.90707E+01	9.99974E+01	1.12809E+02
13		7.77587E+01	8.86334E+01	9.99977E+01	1.10924E+02	1.22619E+02
12		8.81415E+01	9.99979E+01	1.11362E+02	1.21421E+02	1.31229E+02
11		9.99979E+01	1.11854E+02	1.22237E+02	1.30670E+02	1.38152E+02
10		1.12415E+02	1.23151E+02	1.31709E+02	1.39071E+02	1.43201E+02
9		1.24185E+02	1.32853E+02	1.39125E+02	1.43384E+02	1.46503E+02
8		1.34122E+02	1.40253E+02	1.44271E+02	1.46759E+02	1.48414E+02
7		1.41460E+02	1.45178E+02	1.47381E+02	1.48625E+02	1.49378E+02
6		1.46095E+02	1.47979E+02	1.48988E+02	1.49507E+02	1.49793E+02
5		1.48535E+02	1.49306E+02	1.49679E+02	1.49855E+02	1.49943E+02
4		1.49569E+02	1.49813E+02	1.49920E+02	1.49966E+02	1.49987E+02
3		1.49907E+02	1.49963E+02	1.49985E+02	1.49994E+02	1.49997E+02
2		1.49937E+02	1.49985E+02	1.49998E+02	1.49999E+02	1.49999E+02
1		1.49999E+02	1.49999E+02	1.50000E+02	1.50000E+02	1.50000E+02

APPENDIX E. SAMPLE PROBLEM 2.

TWO-EQUATION k-ϵ TURBULENCE MODELING TEST

PURPOSE: To exemplify the two-equation turbulence model option.

PROBLEM DESCRIPTION: Developing flow in the inlet region of a straight circular pipe.

Inlet velocity: 100 m/s
Temperature: Isothermal flow
Reynolds number: 3.38×10^5
Geometry: 0.25 m diameter
12.5 m long

Grid: 10 (r-direction)*1 (θ-direction)*50 (z-direction)

COMMIX-1B

THE THREE-DIMENSIONAL TRANSIENT SINGLE-PHASE COMPUTER PROGRAM FOR THERMAL HYDRAULIC ANALYSIS OF SINGLE AND MULTICOMPONENT SYSTEMS

DEVELOPED IN THE

ANALYTICAL THERMAL HYDRAULIC RESEARCH PROGRAM
COMPONENTS TECHNOLOGY DIVISION
ARGONNE NATIONAL LABORATORY

Version 3.0 September 30, 1985

NOTICE

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********** DATE: 9/18/85 TIME: 14.31.15 COMMIX-1B (3.0) LAST UPDATED: 09/30/85 ID# 3.000001 **********

```
+-------------------------------------------------+
|          COMMIX-1B Sample Problem #2E           |
|   Two Equation K-E Turbulence Modeling Test     |
| Isothermal Air with Reynolds Number of 3.38E+5  |
|          500 Calculational Cells                |
|            September 10, 1985                   |
+-------------------------------------------------+
```

```
 &GEOM
  IGEON=-1,
  NL1=120,NM1=500,
  ITURKE=12,
  IMAX=10,JMAX=1,KMAX=50,
  NSURF=4,
  DX=10*0.0125,DY=6.2832,DZ=50*0.25,
  XNORML= 0.0, 0.0,-1.0, 1.0,
  YNORML= 0.0, 0.0, 0.0, 0.0,
  ZNORML= 1.0,-1.0, 0.0, 0.0,
 &END
REG  -1.0        1  10   1   1   1   1   1    INLET PLANE
REG  -1.0        1  10   1   1  50  50   2    OUTLET PLANE
REG  -1.0       10  10   1   1   1  50   3    OUTER WALL
REG  -1.0        1   1   1   1   1  50   4    CENTER LINE
 &DATA
  IOTIME=0,DT=10.0,
  IFENER=0,IZREB=1,
  NTMAX=500,

  KFLOW=    1,   -5,    1,   -3,
  KTEMP=    1,  400,    1,  400,
  VELOC=100.0,  0.0,  0.0,  0.0,
  TEMP=  25.0, 25.0, 25.0, 25.0,
  TEMP0=25.0,

  IFPROP=1,
  FC0H=  1.2750E6,  FC1H=1.0,
  FC0RO= 1.0,
  FC0K=  1.0E-5,
  FC0EU= 7.3960E-5,

  ISTPR=21201,20201,14201,22201,
  NTHFR=1201,3201,21201,20201,14201,22201,

  ITMAXK=9,
  TDIN=9.3895, HYDIN=0.25,
 &END
- - - - - - - END OF DATA - - - - - - -
```

********** DATE: 9/18/85 TIME: 14.31.15 COMMIX-1B (3.0) LAST UPDATED: 09/30/85 ID# 3.000001 **********

********** STORAGE ALLOCATION SUMMARY **********

THE FOLLOWING VARIABLES DETERMINE STORAGE ALLOCATION. IT IS IMPORTANT THAT THEY ARE ADEQUATELY SPECIFIED.

NM1	500	COMPUTATIONAL CELLS	INWRE	0	WIRE WRAP OPTION FLAG
NL1	120	SURFACE ELEMENTS	ITURKE	12	TURBULENCE MODEL FLAG
NFORCE	0	FORCE STRUCTURES	IMAX	10	CELLS IN THE X- OR R-DIRECTION
JMAX	1	CELLS IN THE Y- OR THETA DIRECTION	IFREB	0	REBALANCING FLAG
KMAX	50	CELLS IN THE Z-DIRECTION	ISTRUC	0	THERMAL STRUCTURES FLAG
			IGEOM	-1	GEOMETRY FLAG

32321 IS THE MINIMUM DIMENSION OF S NEEDED FOR THE ABOVE VALUES.
110000 IS THE CURRENT DIMENSION OF S IN COMMON /SPACE/ IN SUBROUTINE ALTER.

BLOCK LENGTH OF COMMON /SPACE/ (DETERMINED FROM INPUT) 18500 0 0 4740 0 0 9000

CELLS AND SURFACE ELEMENTS HAVE BEEN COUNTED. CHECK THESE VALUES AGAINST YOUR EXPECTED TOTALS.

NM	0	IRREGULAR COMPUTATIONAL CELLS
NM1	500	COMPUTATIONAL CELLS (TOTAL)
NL	0	IRREGULAR SURFACE ELEMENTS
NL1	120	SURFACE ELEMENTS (TOTAL)

TIME LEFT TO END OF RUN IS 118.95 SECONDS.

********** GRID SUMMARY **********

	IMAX= 10		JMAX= 1		KMAX= 50		
	X	DX	Y	DY	Z	DZ	
1	6.2500000E-03	1.2500000E-02	3.1416000E+00	6.2832000E+00	1.2500000E-01	2.5000000E-01	1
2	1.8750000E-02	1.2500000E-02			3.7500000E-01	2.5000000E-01	2
3	3.1250000E-02	1.2500000E-02			6.2500000E-01	2.5000000E-01	3
4	4.3750000E-02	1.2500000E-02			8.7500000E-01	2.5000000E-01	4
5	5.6250000E-02	1.2500000E-02			1.1250000E+00	2.5000000E-01	5
6	6.8750000E-02	1.2500000E-02			1.3750000E+00	2.5000000E-01	6
7	8.1250000E-02	1.2500000E-02			1.6250000E+00	2.5000000E-01	7
8	9.3750000E-02	1.2500000E-02			1.8750000E+00	2.5000000E-01	8
9	1.0625000E-01	1.2500000E-02			2.1250000E+00	2.5000000E-01	9
10	1.1875000E-01	1.2500000E-02			2.3750000E+00	2.5000000E-01	10
11					2.6250000E+00	2.5000000E-01	11
12					2.8750000E+00	2.5000000E-01	12
13					3.1250000E+00	2.5000000E-01	13
14					3.3750000E+00	2.5000000E-01	14
15					3.6250000E+00	2.5000000E-01	15
16					3.8750000E+00	2.5000000E-01	16
17					4.1250000E+00	2.5000000E-01	17
18					4.3750000E+00	2.5000000E-01	18
19					4.6250000E+00	2.5000000E-01	19
20					4.8750000E+00	2.5000000E-01	20
21					5.1250000E+00	2.5000000E-01	21
22					5.3750000E+00	2.5000000E-01	22

23	5.6250000E+00	2.5000000E-01	23
24	5.8750000E+00	2.5000000E-01	24
25	6.1250000E+00	2.5000000E-01	25
26	6.3750000E+00	2.5000000E-01	26
27	6.6250000E+00	2.5000000E-01	27
28	6.8750000E+00	2.5000000E-01	28
29	7.1250000E+00	2.5000000E-01	29
30	7.3750000E+00	2.5000000E-01	30
31	7.6250000E+00	2.5000000E-01	31
32	7.8750000E+00	2.5000000E-01	32
33	8.1250000E+00	2.5000000E-01	33
34	8.3750000E+00	2.5000000E-01	34
35	8.6250000E+00	2.5000000E-01	35
36	8.8750000E+00	2.5000000E-01	36
37	9.1250000E+00	2.5000000E-01	37
38	9.3750000E+00	2.5000000E-01	38
39	9.6250000E+00	2.5000000E-01	39
40	9.8750000E+00	2.5000000E-01	40
41	1.0125000E+01	2.5000000E-01	41
42	1.0375000E+01	2.5000000E-01	42
43	1.0625000E+01	2.5000000E-01	43
44	1.0875000E+01	2.5000000E-01	44
45	1.1125000E+01	2.5000000E-01	45
46	1.1375000E+01	2.5000000E-01	46
47	1.1625000E+01	2.5000000E-01	47
48	1.1875000E+01	2.5000000E-01	48
49	1.2125000E+01	2.5000000E-01	49
50	1.2375000E+01	2.5000000E-01	50

********** SURFACE-SURFACE ELEMENT SUMMARY **********

SURFACE TYPE	SURFACE NUMBER	NUMBER OF SURFACE ELEMENTS	UNIT NORMAL VECTOR
REGULAR	1	10	0.0000 I 0.0000 J 1.0000 K
REGULAR	2	10	0.0000 I 0.0000 J -1.0000 K
REGULAR	3	50	-1.0000 I 0.0000 J 0.0000 K
REGULAR	4	50	1.0000 I 0.0000 J 0.0000 K

********** BOUNDARY CONDITIONS SUMMARY **********

SURFACE	KTEMP	KFLOW	KPRES	MATWAL	INTWAL	TEMP	VELOC	PRES	WALLOX	HYDWAL	WALLQS	TSINK	HSINK
1	1	1	0	0	0	2.500E+01	1.000E+02	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	400	-5	0	0	0	2.500E+01	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	1	1	0	0	0	2.500E+01	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	400	-3	0	0	0	2.500E+01	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

********** FLAG SUMMARY **********

IDOIL =	0			IDRAG =	0	IDTIME=	0	IDSKEW=	0	IFENER=	0
		IFDROP=	1	[illegible] =	0	[illegible] =	0	[illegible] =	0	[illegible] =	-1
IMAX =	10	[illegible] =	0	[illegible]=	50	[illegible]	1	[illegible]=	1	[illegible]=	0

```
ISTATE=     0   ISTRUC=    0                  ITEMAX=     1   ITMAXE=    99   ITMAXP=    99
ITURVE=    12   IT(1) =    1   IT(2) =     1  INWRE =     0   IXREB =     0   IYREB =     0
IZREB =     1   JMAX  =    1   KMAX  =    50  LASTDT= 99999   LASTIT= 99999   LMFRNT=     0
NCORR =     0   NEIFOR=    1   NEIPEB=     1  NEWFS =     1   NFORCE=     0   NHEATC=     1
  1   =   120   NWATER=    0   NI1   =   500  NREDRT=     0   NSURF =     4   NTMAX =   500
```

********** SIMPLIFIED PROPERTIES SUMMARY **********

COOLANT PROPERTIES ARE COMPUTED WITH THE FOLLOWING FUNCTIONS:

```
ENTHALPY     =  1.2750E+06 + TC *   1.0000E+00
DENSITY      =  1.0000E+00 + TC *   0.0000E+00
CONDUCTIVITY=   1.0000E-05 + TC *   0.0000E+00
VISCOSITY    =  7.3960E-05 + TC *   0.0000E+00
TEMPERATURE  = -1.2750E+06 + H  *   1.0000E+00
```

THE FOLLOWING VALUES WERE COMPUTED FROM THESE FUNCTIONS:

TEMPERATURE	ENTHALPY	DENSITY	CONDUCTIVITY	VISCOSITY	TEMPERATURE
3.000E+02	1.275E+06	1.000E+00	1.000E-05	7.396E-05	3.000E+02
4.000E+02	1.275E+06	1.000E+00	1.000E-05	7.396E-05	4.000E+02
5.000E+02	1.276E+06	1.000E+00	1.000E-05	7.396E-05	5.000E+02
6.000E+02	1.276E+06	1.000E+00	1.000E-05	7.396E-05	6.000E+02
7.000E+02	1.276E+06	1.000E+00	1.000E-05	7.396E-05	7.000E+02

********** FLUID-STRUCTURE HEAT TRANSFER CORRELATIONS SUMMARY **********

NUMBER OF HEAT TRANSFER CORRELATIONS SPECIFIED (NHEATC) = 1
THE NUSSELT NUMBER IS COMPUTED WITH THE FOLLOWING FUNCTION:

NUSSELT = HEATC1 + HEATC2 * REYNOLDS NUMBER ** HHEATC3

CORRELATION	HEATC1	HEATC2	HEATC3
1	5.000E+00	4.0[illegible]E-0[illegible]	8.000E-01

********** SURFACE AREA SUMMARY **********

SURFACE	AREA (M**2)
1	4.908748E-02
2	4.908748E-02
3	9.817461E+00
4	0.000000E+00

TOTAL SURFACE AREA = 9.915635E+00 M**2   TOTAL VOLUME = 6.135775E-01 M**3

********** TURBULENCE MODEL SUMMARY **********

```
ITURBE=   12   ALPHA=  4.0000E-01   EPS6  =  1.0000E-05   FTURLD=  1.3000E+00   CT1   =  1.4700E+00   TURBV =  0.0000E+00
ITMAX =    9   CSTUR2= 9.0000E-02   C[illegible]= 7.0000E-01   F[illegible]= 1.0000E+00   CT2   =  1.9200E+00   TU[illegible] =  0.0000E+00
ITREG3=    0   EE    = 9.0000E+00   C[illegible]= 7.0000E-01   F[illegible]= 9.0000E-01   TWIN  =  9.[illegible]E+00   CH[illegible]=  0.0000E+00
ITREG3=    0   K[illegible] = 2.5000E-01   [illegible]= 7.0000E-01                        TKIN  =  1.0000E-03   CH[illegible] =  0.0000E+00
NTJK[illegible]=    1                         RELAX =  8.0000E-01                                              TU[illegible]=  0.0000E+00
```

********** DATE: 9/18/85 TIME: 14.31.18 CONVEX-1D (3.0) LAST UPDATED: 09/30/85 ID# 3.000001 **********

****

GLOBAL BALANCES AT TIME= 0.000E+00 SECONDS

SURFACE NUMBER	MASS CONVECTED (KG/SEC)	ENERGY CONVECTED (WATT)	ENERGY CONDUCTED (WATT)	AVERAGE VELOCITY (M/SEC)	AVERAGE ENTHALPY (J/KG)	AVERAGE TEMPERATURE (CELSIUS)	BULK TEMPERATURE (CELSIUS)
N= 1	4.908748E+00	6.258776E+06	0.000000E+00	9.999998E+01	1.275024E+06	2.499998E+01	2.499998E+01
N= 2	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.275024E+06	2.499998E+01	0.000000E+00
N= 3	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.275024E+06	2.499998E+01	0.000000E+00
N= 4	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00

********** MASS BALANCE **********

MASS ACCUMULATION RATE: DMASDT= 0.000000E+00 (KG/SEC)
NET MASS CONVECTED INTO CONFIGURATION: FLOSUM= 4.908748E+00 (KG/SEC)

GLOBAL CONSERVATION OF MASS: (DMASDT-FLOSUM)=-4.908748E+00 (KG/SEC) DLSUM= 0.000000E+00

********** ENERGY BALANCE **********

ENERGY ACCUMULATION RATE: DEDT= 0.000000E+00 (WATT)
NET ENERGY CONVECTED INTO CONFIGURATION: EINSUM= 6.258776E+06 (WATT)
NET ENERGY CONDUCTED INTO CONFIGURATION: QINSUM= 0.000000E+00 (WATT)
ENERGY GENERATED WITHIN CONFIGURATION: QSOURC= 0.000000E+00 (WATT)
ENERGY EXCESS DUE TO MASS RESIDUE: EDLSUM= 0.000000E+00 (WATT)

GLOBAL CONSERVATION OF ENERGY: (DEDT-EINSUM-QINSUM-QSOURC-EDLSUM)=-6.258775E+06 (WATT)

****

TURVIS (Pa*s) : TURBULENT VISCOSITY AT TIME= 0.000E+00 SECONDS

********** CONSTANT J PLANE J= 1 **********

K	I--> 1	2	3	4	5	6	7	8	9	10
50	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
49	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
48	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
47	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
46	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
45	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
44	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
43	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
42	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
41	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
40	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
39	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
38	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
37	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
36	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11
35	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11	3.031106E-11

34	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
33	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
32	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
31	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
30	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
29	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
28	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
27	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
26	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
25	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
24	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
23	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
22	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
21	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
20	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
19	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
18	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
17	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
16	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
15	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
14	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
13	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
12	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
10	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
9	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
8	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
7	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
6	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
5	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
4	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
3	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
2	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11	3.03110E-11
1	1.51555E-03	1.51555E-03	1.51555E-03	1.51555E-03	1.51555E-03	1.51555E-03	1.51555E-03	1.51555E-03	1.51555E-03	1.51555E-03

TURCON (J/(s*m*K)) : TURBULENT CONDUCTIVITY AT TIME= 0.000E+00 SECONDS

********** CONSTANT J PLANE J= 1 **********

K I-->	1	2	3	4	5	6	7	8	9	10
50	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
49	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
48	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
47	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
46	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
45	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
44	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
43	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
42	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
41	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
40	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
39	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
38	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
37	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
36	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
35	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
34	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
33	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

K										
32	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
31	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
30	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
29	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
28	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
27	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
26	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
25	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
24	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
23	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
22	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
21	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
20	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
19	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
18	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
17	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
16	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
15	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
14	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
13	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
12	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
11	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
10	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
9	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
8	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
7	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
6	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
5	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
4	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

TURK (u**2/s**2) : TURBULENT KINETIC ENERGY AT TIME= 0.000E+00 SECONDS

********** CONSTANT J PLANE J= 1 **********

K	I-->	1	2	3	4	5	6	7	8	9	10
50		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
49		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
48		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
47		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
46		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
45		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
44		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
43		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
42		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
41		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
40		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
39		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
38		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
37		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
36		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
35		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
34		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
33		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
32		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
31		1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15

30	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
29	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
28	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
27	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
26	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
25	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
24	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
23	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
22	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
21	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
20	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
19	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
18	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
17	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
16	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
14	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
13	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
12	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
11	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
10	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
9	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
8	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
7	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
6	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
5	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
4	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
3	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
2	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15	1.00000E-15
1	2.50000E+00	2.50000E+00	2.50000E+00	2.50000E+00	2.50000E+00	2.50000E+00	2.50000E+00	2.50000E+00	2.50000E+00	2.50000E+00

TKED (m**2/s**3) : DISSIPATION OF TURBULENT KINETIC ENERGY AT TIME= 0.000E+00 SECONDS

********** CONSTANT J PLANE J= 1 **********

K I-->	1	2	3	4	5	6	7	8	9	10
50	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
49	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
48	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
47	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
46	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
45	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
44	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
43	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
42	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
41	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
40	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
39	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
38	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
37	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
36	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
35	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
34	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
33	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
32	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
31	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
30	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
29	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21

28	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
27	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
26	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
25	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
24	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
23	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
22	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
20	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
19	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
18	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
17	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
16	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
15	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
14	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
13	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
12	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
11	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
10	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
9	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
8	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
7	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
6	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
5	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
4	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
3	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
2	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21	2.96922E-21
1	3.71152E+02	3.71152E+02	3.71152E+02	3.71152E+02	3.71152E+02	3.71152E+02	3.71152E+02	3.71152E+02	3.71152E+02	3.71152E+02

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********** CONTROL SUMMARY **********

				DTIME	1.0000E+01			CDRAGX	1.0000E+00
DTENER	1.0000E+01	EPS1	1.0000E-04	DTFUEL	1.0000E+01			CDRAGY	1.0000E+00
EPS5	1.0000E-05	EPS2	1.0000E-06	DTHALL	1.0000E+40	GRAVX	0.0000E+00	CDRAGZ	1.0000E+00
ITENMX	1	EPS3	5.0000E-05	DT(1)	1.0000E+01	GRAVY	0.0000E+00		
ITMAXE	99	IREBIT	50	DT(2)	1.0000E-01	GRAVZ	0.0000E+00	CHARRE	0.0000E+00
OMEGAE	8.0000E-01	ITERMX	1	LASTDT	99999	FRES0	1.0135E+05	CHART	0.0000E+00
OMEGAR	1.0000E+00	ITMAXP	99	RDTIME	8.0000E-01	TEMP0	2.5000E+01		
RELAXE	9.5000E-01			TIMAX	3.6000E+07	XPRES0	0.0000E+00	CWIREX	5.0000E-01
		IT(1)	1	TIMEUP	118.59	YPRES0	0.0000E+00	CWIREY	5.0000E-01
		IT(2)	1	TREST	20.00	ZPRES0	0.0000E+00	CWIREZ	5.0000E-01
		LASTIT	99999	TSTART	0.0000E+00			HYDALL	0.0000E+00
		OMEGA	1.5000E+00					HYDIN	2.5000E-01
		OMEGAV	8.0000E-01					HYDOUT	0.0000E+00
		ALPHA	1.0000E+00						

	NT	TIME	DTIME	IT	MAX(DL)/ DCONV	MAX(DU)/ VELMAX	MAX(DV)/ VELMAX	MAX(DW)/ VELMAX	MAX(DH/H)	TLEFT	COURDT	DCONV	VELMAX
#	1	1.0000E+01	1.00E+01	1	5.91E-01	4.44E-02	0.00E+00	3.25E+00	0.00E+00	117.04	2.50E-03	4.00E-02	5.00E+01
#	2	2.0000E+01	1.00E+01	1	-9.60E-01	1.11E-02	0.00E+00	-2.39E-01	0.00E+00	115.58	1.54E-03	6.51E-02	1.63E+02
#	3	3.0000E+01	1.00E+01	1	-9.45E-01	7.87E-03	0.00E+00	-2.30E-01	0.00E+00	114.13	1.54E-03	6.51E-02	1.63E+02
#	4	4.0000E+01	1.00E+01	1	9.76E-01	5.38E-03	0.00E+00	-1.89E-01	0.00E+00	112.63	1.54E-03	6.51E-02	1.63E+02
#	5	5.0000E+01	1.00E+01	1	9.09E-01	3.80E-03	0.00E+00	-1.44E-01	0.00E+00	111.13	1.57E-03	6.35E-02	1.59E+02
#	6	6.0000E+01	1.00E+01	1	8.61E-01	2.75E-03	0.00E+00	-1.12E-01	0.00E+00	109.67	1.69E-03	5.93E-02	1.48E+02
#	7	7.0000E+01	1.00E+01	1	9.86E-01	2.00E-03	0.00E+00	-8.95E-02	0.00E+00	108.46	1.83E-03	5.45E-02	1.36E+02
#	8	8.0000E+01	1.00E+01	1	9.08E-01	1.45E-03	0.00E+00	-8.27E-02	0.00E+00	107.60	2.00E-03	5.00E-02	1.25E+02
#	9	9.0000E+01	1.00E+01	1	9.27E-01	-1.23E-03	0.00E+00	-7.86E-02	0.00E+00	106.75	2.17E-03	4.61E-02	1.15E+02
#	10	1.0000E+02	1.00E+01	1	-4.40E-01	-1.02E-03	0.00E+00	-7.16E-02	0.00E+00	105.88	2.23E-03	4.49E-02	1.12E+02
#	11	1.1000E+02	1.00E+01	1	-4.04E-01	-9.00E-04	0.00E+00	-6.39E-02	0.00E+00	105.02	2.22E-03	4.50E-02	1.12E+02
#	12	1.2000E+02	1.00E+01	1	-3.23E-01	-7.76E-04	0.00E+00	-5.75E-02	0.00E+00	104.16	2.22E-03	4.51E-02	1.13E+02
#	13	1.3000E+02	1.00E+01	1	-3.35E-01	-7.06E-04	0.00E+00	-5.18E-02	0.00E+00	103.31	2.22E-03	4.51E-02	1.13E+02
#	14	1.4000E+02	1.00E+01	1	-2.19E-01	-6.43E-04	0.00E+00	-4.62E-02	0.00E+00	102.46	2.22E-03	4.51E-02	1.13E+02
#	15	1.5000E+02	1.00E+01	1	2.04E-01	-5.95E-04	0.00E+00	-4.13E-02	0.00E+00	101.62	2.22E-03	4.50E-02	1.12E+02
#	16	1.6000E+02	1.00E+01	1	2.33E-01	-5.56E-04	0.00E+00	-3.65E-02	0.00E+00	100.76	2.22E-03	4.50E-02	1.12E+02
#	17	1.7000E+02	1.00E+01	1	1.89E-01	-5.28E-04	0.00E+00	-3.58E-02	0.00E+00	99.92	2.21E-03	4.53E-02	1.13E+02
#	18	1.8000E+02	1.00E+01	1	1.41E-01	-4.85E-04	0.00E+00	-3.85E-02	0.00E+00	99.06	2.20E-03	4.55E-02	1.14E+02
#	19	1.9000E+02	1.00E+01	1	1.12E-01	-4.66E-04	0.00E+00	-4.14E-02	0.00E+00	98.21	2.19E-03	4.57E-02	1.14E+02
#	20	2.0000E+02	1.00E+01	1	9.65E-02	-4.28E-04	0.00E+00	-4.39E-02	0.00E+00	97.36	2.18E-03	4.59E-02	1.15E+02
#	21	2.1000E+02	1.00E+01	1	9.72E-02	-4.06E-04	0.00E+00	-4.53E-02	0.00E+00	96.50	2.17E-03	4.61E-02	1.15E+02
#	22	2.2000E+02	1.00E+01	1	1.60E-01	-3.70E-04	0.00E+00	-4.50E-02	0.00E+00	95.64	2.16E-03	4.62E-02	1.16E+02
#	23	2.3000E+02	1.00E+01	1	2.85E-01	-3.50E-04	0.00E+00	-5.05E-02	0.00E+00	94.78	2.16E-03	4.63E-02	1.16E+02
#	24	2.4000E+02	1.00E+01	1	2.64E-01	-3.33E-04	0.00E+00	-5.24E-02	0.00E+00	93.92	2.16E-03	4.64E-02	1.16E+02
#	25	2.5000E+02	1.00E+01	1	1.30E-01	-3.13E-04	0.00E+00	-4.52E-02	0.00E+00	93.07	2.16E-03	4.64E-02	1.16E+02
#	26	2.6000E+02	1.00E+01	1	9.53E-01	-2.92E-04	0.00E+00	-3.41E-02	0.00E+00	92.26	2.15E-03	4.65E-02	1.16E+02
#	27	2.7000E+02	1.00E+01	1	-3.29E-01	-2.95E-04	0.00E+00	-3.26E-02	0.00E+00	91.42	2.14E-03	4.67E-02	1.17E+02
#	28	2.8000E+02	1.00E+01	1	-4.87E-01	-2.50E-04	0.00E+00	-3.55E-02	0.00E+00	90.58	2.14E-03	4.68E-02	1.17E+02
#	29	2.9000E+02	1.00E+01	1	-9.24E-01	-2.34E-04	0.00E+00	-3.73E-02	0.00E+00	89.75	2.13E-03	4.70E-02	1.17E+02
#	30	3.0000E+02	1.00E+01	1	-1.35E-01	-2.25E-04	0.00E+00	-3.83E-02	0.00E+00	88.91	2.12E-03	4.72E-02	1.18E+02
#	31	3.1000E+02	1.00E+01	1	-1.21E-01	-2.07E-04	0.00E+00	-4.24E-02	0.00E+00	88.05	2.11E-03	4.73E-02	1.18E+02
#	32	3.2000E+02	1.00E+01	1	-8.76E-01	-1.95E-04	0.00E+00	-4.86E-02	0.00E+00	87.22	2.11E-03	4.75E-02	1.19E+02
#	33	3.3000E+02	1.00E+01	1	-9.86E-02	-1.76E-04	0.00E+00	-4.60E-02	0.00E+00	86.37	2.10E-03	4.76E-02	1.19E+02
#	34	3.4000E+02	1.00E+01	1	1.03E-01	-1.62E-04	0.00E+00	-2.96E-02	0.00E+00	85.52	2.09E-03	4.78E-02	1.20E+02
#	35	3.5000E+02	1.00E+01	1	1.92E-01	-1.55E-04	0.00E+00	-2.57E-02	0.00E+00	84.68	2.05E-03	4.81E-02	1.20E+02
#	36	3.6000E+02	1.00E+01	1	1.05E-01	-1.44E-04	0.00E+00	-2.97E-02	0.00E+00	83.83	2.07E-03	4.83E-02	1.21E+02
#	37	3.7000E+02	1.00E+01	1	-7.04E-02	-1.36E-04	0.00E+00	-2.92E-02	0.00E+00	82.98	2.07E-03	4.84E-02	1.21E+02
#	38	3.8000E+02	1.00E+01	1	8.61E-01	-1.24E-04	0.00E+00	-1.96E-02	0.00E+00	82.16	2.06E-03	4.85E-02	1.21E+02
#	39	3.9000E+02	1.00E+01	1	7.07E-01	-1.15E-04	0.00E+00	-1.58E-02	0.00E+00	81.34	2.05E-03	4.88E-02	1.22E+02
#	40	4.0000E+02	1.00E+01	1	-4.31E-01	-1.02E-04	0.00E+00	-1.73E-02	0.00E+00	80.52	2.04E-03	4.89E-02	1.22E+02
#	41	4.1000E+02	1.00E+01	1	-5.84E-01	-9.39E-05	0.00E+00	-1.41E-02	0.00E+00	79.73	2.04E-03	4.90E-02	1.23E+02
#	42	4.2000E+02	1.00E+01	1	3.27E-01	-8.55E-05	0.00E+00	-8.03E-03	0.00E+00	78.92	2.03E-03	4.92E-02	1.23E+02
#	43	4.3000E+02	1.00E+01	1	-7.28E-01	-8.03E-05	0.00E+00	-8.71E-03	0.00E+00	78.12	2.02E-03	4.94E-02	1.23E+02
#	44	4.4000E+02	1.00E+01	1	-3.42E-01	-7.17E-05	0.00E+00	-7.75E-03	0.00E+00	77.32	2.02E-03	4.95E-02	1.24E+02
#	45	4.5000E+02	1.00E+01	1	-3.37E-01	-6.58E-05	0.00E+00	6.93E-03	0.00E+00	76.52	2.01E-03	4.97E-02	1.24E+02
#	46	4.6000E+02	1.00E+01	1	-6.54E-01	-5.76E-05	0.00E+00	6.65E-03	0.00E+00	75.74	2.01E-03	4.99E-02	1.25E+02
#	47	4.7000E+02	1.00E+01	1	-8.75E-01	-5.18E-05	0.00E+00	6.25E-03	0.00E+00	74.98	2.00E-03	5.00E-02	1.25E+02
#	48	4.8000E+02	1.00E+01	1	-8.71E-01	-4.57E-05	0.00E+00	5.85E-03	0.00E+00	74.24	1.99E-03	5.02E-02	1.26E+02
#	49	4.9000E+02	1.00E+01	1	-9.10E-01	-3.69E-05	0.00E+00	5.35E-03	0.00E+00	73.47	1.98E-03	5.04E-02	1.26E+02
#	50	5.0000E+02	1.00E+01	1	-5.92E-01	-3.38E-05	0.00E+00	4.85E-03	0.00E+00	72.75	1.98E-03	5.06E-02	1.26E+02

	NT	TIME	DTIME	IT	MAX(DL)/ DCONV	MAX(DU)/ VELMAX	MAX(DV)/ VELMAX	MAX(DW)/ VELMAX	MAX(DH/H)	TLEFT	COURDT	DCONV	VELMAX
#	51	5.1000E+02	1.00E+01	1	-8.09E-01	-2.75E-05	0.00E+00	4.29E-03	0.00E+00	71.97	1.97E-03	5.07E-02	1.27E+02
#	52	5.2000E+02	1.00E+01	1	-7.24E-01	-2.44E-05	0.00E+00	3.67E-03	0.00E+00	71.23	1.97E-03	5.09E-02	1.27E+02
#	53	5.3000E+02	1.00E+01	1	-8.04E-01	-1.94E-05	0.00E+00	3.13E-03	0.00E+00	70.44	1.96E-03	5.10E-02	1.27E+02
#	54	5.4000E+02	1.00E+01	1	-9.89E-01	-1.77E-05	0.00E+00	2.56E-03	0.00E+00	69.71	1.96E-03	5.11E-02	1.28E+02
#	55	5.5000E+02	1.00E+01	1	-9.21E-01	1.51E-05	0.00E+00	2.08E-03	0.00E+00	68.94	1.95E-03	5.12E-02	1.28E+02
#	56	5.6000E+02	1.00E+01	1	-6.12E-01	1.42E-05	0.00E+00	1.63E-03	0.00E+00	68.20	1.95E-03	5.13E-02	1.28E+02
#	57	5.7000E+02	1.00E+01	1	-7.00E-01	1.32E-05	0.00E+00	-1.32E-03	0.00E+00	67.49	1.95E-03	5.13E-02	1.28E+02
#	58	5.8000E+02	1.00E+01	1	-7.35E-01	1.18E-05	0.00E+00	-1.43E-03	0.00E+00	66.72	1.95E-03	5.14E-02	1.28E+02
#	59	5.9000E+02	1.00E+01	1	-7.15E-01	1.11E-05	0.00E+00	-1.46E-03	0.00E+00	66.00	1.95E-03	5.14E-02	1.28E+02
#	60	6.0000E+02	1.00E+01	1	-6.48E-01	1.05E-05	0.00E+00	-1.47E-03	0.00E+00	65.29	1.94E-03	5.14E-02	1.29E+02
#	61	6.1000E+02	1.00E+01	1	-9.94E-01	9.63E-06	0.00E+00	-1.44E-03	0.00E+00	64.57	1.94E-03	5.14E-02	1.29E+02
#	62	6.2000E+02	1.00E+01	1	-6.83E-01	9.07E-06	0.00E+00	-1.39E-03	0.00E+00	63.81	1.94E-03	5.15E-02	1.29E+02
#	63	6.3000E+02	1.00E+01	1	4.06E-01	8.65E-06	0.00E+00	-1.35E-03	0.00E+00	63.09	1.94E-03	5.15E-02	1.29E+02
#	64	6.4000E+02	1.00E+01	1	3.26E-01	8.22E-06	0.00E+00	-1.30E-03	0.00E+00	62.37	1.94E-03	5.15E-02	1.29E+02
#	65	6.5000E+02	1.00E+01	1	-7.11E-01	7.70E-06	0.00E+00	-1.24E-03	0.00E+00	61.64	1.94E-03	5.15E-02	1.29E+02
#	66	6.6000E+02	1.00E+01	1	-9.35E-01	7.52E-06	0.00E+00	-1.17E-03	0.00E+00	60.90	1.94E-03	5.15E-02	1.29E+02
#	67	6.7000E+02	1.00E+01	1	-8.52E-01	7.29E-06	0.00E+00	-1.11E-03	0.00E+00	60.18	1.94E-03	5.15E-02	1.29E+02
#	68	6.8000E+02	1.00E+01	1	-8.86E-01	6.99E-06	0.00E+00	-1.07E-03	0.00E+00	59.45	1.94E-03	5.15E-02	1.29E+02
#	69	6.9000E+02	1.00E+01	1	-5.42E-01	6.75E-06	0.00E+00	-1.01E-03	0.00E+00	58.73	1.94E-03	5.15E-02	1.29E+02
#	70	7.0000E+02	1.00E+01	1	-6.85E-01	6.44E-06	0.00E+00	-9.56E-04	0.00E+00	58.00	1.94E-03	5.15E-02	1.29E+02
#	71	7.1000E+02	1.00E+01	1	-8.48E-01	6.33E-06	0.00E+00	-9.03E-04	0.00E+00	57.28	1.94E-03	5.15E-02	1.29E+02
#	72	7.2000E+02	1.00E+01	1	-5.29E-01	6.03E-06	0.00E+00	-8.59E-04	0.00E+00	56.56	1.94E-03	5.15E-02	1.29E+02
#	73	7.3000E+02	1.00E+01	1	-3.37E-01	5.79E-06	0.00E+00	-8.21E-04	0.00E+00	55.84	1.94E-03	5.15E-02	1.29E+02
#	74	7.4000E+02	1.00E+01	1	2.57E-01	5.61E-06	0.00E+00	-7.85E-04	0.00E+00	55.12	1.94E-03	5.15E-02	1.29E+02
#	75	7.5000E+02	1.00E+01	1	-3.16E-01	5.41E-06	0.00E+00	-7.43E-04	0.00E+00	54.41	1.94E-03	5.15E-02	1.29E+02
#	76	7.6000E+02	1.00E+01	1	-4.37E-01	5.12E-06	0.00E+00	-7.14E-04	0.00E+00	53.68	1.94E-03	5.15E-02	1.29E+02
#	77	7.7000E+02	1.00E+01	1	1.76E-01	4.90E-06	0.00E+00	-6.83E-04	0.00E+00	52.96	1.94E-03	5.15E-02	1.29E+02
#	78	7.8000E+02	1.00E+01	1	2.11E-01	4.66E-06	0.00E+00	-6.52E-04	0.00E+00	52.24	1.94E-03	5.15E-02	1.29E+02
#	79	7.9000E+02	1.00E+01	1	2.77E-01	4.44E-06	0.00E+00	-6.19E-04	0.00E+00	51.54	1.94E-03	5.15E-02	1.29E+02
#	80	8.0000E+02	1.00E+01	1	-1.71E-01	4.22E-06	0.00E+00	-5.90E-04	0.00E+00	50.83	1.94E-03	5.15E-02	1.29E+02
#	81	8.1000E+02	1.00E+01	1	-1.51E-01	3.95E-06	0.00E+00	-5.59E-04	0.00E+00	50.12	1.94E-03	5.15E-02	1.29E+02
#	82	8.2000E+02	1.00E+01	1	2.20E-01	3.72E-06	0.00E+00	-5.29E-04	0.00E+00	49.40	1.94E-03	5.15E-02	1.29E+02
#	83	8.3000E+02	1.00E+01	1	2.14E-01	3.46E-06	0.00E+00	-4.96E-04	0.00E+00	48.69	1.94E-03	5.15E-02	1.29E+02
#	84	8.4000E+02	1.00E+01	1	2.20E-01	3.23E-06	0.00E+00	-4.66E-04	0.00E+00	47.97	1.94E-03	5.15E-02	1.29E+02
#	85	8.5000E+02	1.00E+01	1	-2.51E-01	3.00E-06	0.00E+00	-4.37E-04	0.00E+00	47.26	1.94E-03	5.15E-02	1.29E+02
#	86	8.6000E+02	1.00E+01	1	2.42E-01	2.78E-06	0.00E+00	-4.08E-04	0.00E+00	46.53	1.94E-03	5.15E-02	1.29E+02
#	87	8.7000E+02	1.00E+01	1	2.28E-01	2.61E-06	0.00E+00	-3.81E-04	0.00E+00	45.80	1.94E-03	5.15E-02	1.29E+02
#	88	8.8000E+02	1.00E+01	1	2.60E-01	2.37E-06	0.00E+00	-3.52E-04	0.00E+00	45.06	1.94E-03	5.15E-02	1.29E+02
#	89	8.9000E+02	1.00E+01	1	2.94E-01	2.17E-06	0.00E+00	-3.26E-04	0.00E+00	44.33	1.94E-03	5.15E-02	1.29E+02
#	90	9.0000E+02	1.00E+01	1	3.49E-01	2.00E-06	0.00E+00	-3.01E-04	0.00E+00	43.61	1.94E-03	5.15E-02	1.29E+02
#	91	9.1000E+02	1.00E+01	1	-4.76E-01	1.82E-06	0.00E+00	-2.75E-04	0.00E+00	42.88	1.94E-03	5.15E-02	1.29E+02
#	92	9.2000E+02	1.00E+01	1	3.55E-01	1.63E-06	0.00E+00	-2.50E-04	0.00E+00	42.16	1.94E-03	5.15E-02	1.29E+02
#	93	9.3000E+02	1.00E+01	1	3.40E-01	1.46E-06	0.00E+00	-2.28E-04	0.00E+00	41.44	1.94E-03	5.15E-02	1.29E+02
#	94	9.4000E+02	1.00E+01	1	-4.10E-01	1.39E-06	0.00E+00	-2.05E-04	0.00E+00	40.72	1.94E-03	5.15E-02	1.29E+02
#	95	9.5000E+02	1.00E+01	1	-5.87E-01	1.81E-06	0.00E+00	-1.85E-04	0.00E+00	40.00	1.94E-03	5.15E-02	1.29E+02
#	96	9.6000E+02	1.00E+01	1	9.61E-01	-2.24E-06	0.00E+00	-1.65E-04	0.00E+00	39.28	1.94E-03	5.15E-02	1.29E+02
#	97	9.7000E+02	1.00E+01	1	-3.04E-01	1.24E-06	0.00E+00	-1.47E-04	0.00E+00	38.55	1.94E-03	5.15E-02	1.29E+02
#	98	9.8000E+02	1.00E+01	1	3.09E-01	7.98E-07	0.00E+00	-1.23E-04	0.00E+00	37.83	1.94E-03	5.15E-02	1.29E+02
#	99	9.9000E+02	1.00E+01	1	-2.57E-01	7.46E-07	0.00E+00	-1.11E-04	0.00E+00	37.11	1.94E-03	5.15E-02	1.29E+02
#	100	1.0000E+03	1.00E+01	1	-3.47E-01	-7.49E-07	0.00E+00	-9.61E-05	0.00E+00	36.39	1.94E-03	5.15E-02	1.29E+02

	NT	TIME	DTIME	IT	MAX(DL)/ DCONV	MAX(DU)/ VELMAX	MAX(DV)/ VELMAX	MAX(DH)/ VELMAX	MAX(DH/H)	TLEFT	COURDT	DCONV	VELMAX
#	101	1.0100E+03	1.00E+01	1	-2.60E-01	-9.14E-07	0.00E+00	-8.40E-05	0.00E+00	35.68	1.94E-03	5.15E-02	1.29E+02
#	102	1.0200E+03	1.00E+01	1	4.43E-01	-1.12E-06	0.00E+00	-7.32E-05	0.00E+00	34.97	1.94E-03	5.15E-02	1.29E+02
#	103	1.0300E+03	1.00E+01	1	-4.99E-01	-1.09E-06	0.00E+00	-6.42E-05	0.00E+00	34.25	1.94E-03	5.15E-02	1.29E+02
#	104	1.0400E+03	1.00E+01	1	-5.79E-01	1.50E-06	0.00E+00	-5.41E-05	0.00E+00	33.53	1.94E-03	5.15E-02	1.29E+02
#	105	1.0500E+03	1.00E+01	1	7.69E-01	-1.43E-06	0.00E+00	-4.38E-05	0.00E+00	32.81	1.94E-03	5.15E-02	1.29E+02

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# ************************************************************
# *****  STEADY STATE HAS BEEN REACHED TO WITHIN EPS3= 5.000E-05  *****
# ************************************************************
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********** DATE: 9/18/35 TIME: 14.43.57 COMMIX-1B (3.0) LAST UPDATED: 09/30/85 ID# 3.000001 **********

GLOBAL BALANCES AT TIME= 1.050E+03 SECONDS

SURFACE NUMBER	MASS CONVECTED (KG/SEC)	ENERGY CONVECTED (WATT)	ENERGY CONDUCTED (WATT)	AVERAGE VELOCITY (M/SEC)	AVERAGE ENTHALPY (J/KG)	AVERAGE TEMPERATURE (CELSIUS)	BULK TEMPERATURE (CELSIUS)
N= 1	4.908748E+00	6.258776E+06	0.000000E+00	9.999998E+01	1.275024E+06	2.499998E+01	2.499998E+01
N= 2	-4.908750E+00	-6.258779E+06	0.000000E+00	-1.000000E+02	1.275024E+06	2.499998E+01	2.499998E+01
N= 3	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.275024E+06	2.499998E+01	0.000000E+00
N= 4	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00

********** MASS BALANCE **********

MASS ACCUMULATION RATE: DMASDT= 0.000000E+00 (KG/SEC)
NET MASS CONVECTED INTO CONFIGURATION: FLOSUM=-1.937151E-06 (KG/SEC)

GLOBAL CONSERVATION OF MASS: (DMASDT-FLOSUM)= 1.937151E-06 (KG/SEC) DLSUM= 5.573404E-06

********** ENERGY BALANCE **********

ENERGY ACCUMULATION RATE: DEDT= 0.000000E+00 (WATT)
NET ENERGY CONVECTED INTO CONFIGURATION: EINSUM=-3.152344E+00 (WATT)
NET ENERGY CONDUCTED INTO CONFIGURATION: QINSUM= 0.000000E+00 (WATT)
ENERGY GENERATED WITHIN CONFIGURATION: QSOURC= 0.000000E+00 (WATT)
ENERGY EXCESS DUE TO MASS RESIDUE: EDLSUM= 7.106350E+00 (WATT)

GLOBAL CONSERVATION OF ENERGY: (DEDT-EINSUM-QINSUM-QSOURC-EDLSUM)=-3.954006E+00 (WATT)

UL (M/S) : VELOCITY IN X-DIRECTION AT TIME= 1.050E+03 SECONDS

********** CONSTANT J PLANE J= 1 **********

K	I--> 1	2	3	4	5	6	7	8	9	10
50	1.03684E-02	1.89733E-02	2.76269E-02	3.61183E-02	4.41541E-02	5.13027E-02	5.62786E-02	5.49478E-02	3.40884E-02	0.00000E+00
49	9.98941E-03	1.93097E-02	2.83938E-02	3.71723E-02	4.56333E-02	5.37209E-02	6.05272E-02	6.29998E-02	3.64670E-02	0.00000E+00
48	1.44059E-03	2.64951E-03	3.50440E-03	3.93502E-03	3.95614E-03	3.57293E-03	2.76777E-03	1.58441E-03	3.35087E-04	0.00000E+00
47	7.69353E-04	1.30261E-03	1.50402E-03	1.23569E-03	7.51370E-04	1.08752E-04	-3.87419E-04	-5.67475E-04	-3.01423E-04	0.00000E+00
46	1.08390E-03	1.89263E-03	2.21547E-03	2.02046E-03	1.42022E-03	6.39790E-04	-1.49789E-05	-2.68513E-04	-1.68604E-04	0.00000E+00
45	1.51805E-03	2.68379E-03	3.24077E-03	3.12503E-03	2.44623E-03	1.40954E-03	5.76976E-04	7.14203E-05	-2.27282E-05	0.00000E+00
44	2.01639E-03	3.62034E-03	4.46378E-03	4.44336E-03	3.69940E-03	2.52045E-03	1.32510E-03	5.13953E-04	1.57734E-04	0.00000E+00
43	2.62311E-03	4.70939E-03	5.83133E-03	5.98205E-03	5.16335E-03	3.76519E-03	2.24219E-03	1.06121E-03	4.04375E-04	0.00000E+00
42	3.31022E-03	5.95417E-03	7.49310E-03	7.73381E-03	6.83529E-03	5.19710E-03	3.31662E-03	1.74018E-03	7.06010E-04	0.00000E+00
41	4.05121E-03	7.36566E-03	9.20073E-03	9.68056E-03	8.71063E-03	6.81127E-03	4.53956E-03	2.51267E-03	1.03525E-03	0.00000E+00
40	4.80279E-03	8.86166E-03	1.12490E-02	1.20070E-02	1.07509E-02	8.50324E-03	5.90093E-03	3.35069E-03	1.43569E-03	0.00000E+00
39	5.58493E-03	1.05165E-02	1.33540E-02	1.40513E-02	1.29027E-02	1.04916E-02	7.38613E-03	4.31952E-03	1.85341E-03	0.00000E+00
38	6.76735E-03	1.22703E-02	1.58066E-02	1.64747E-02	1.52184E-02	1.24259E-02	8.92517E-03	5.37915E-03	2.30739E-03	0.00000E+00
37	7.82637E-03	1.41153E-02	1.78506E-02	1.89189E-02	1.75712E-02	1.45193E-02	1.05100E-02	6.37371E-03	2.78935E-03	0.00000E+00
36	8.89054E-03	1.60035E-02	2.02099E-02	2.13545E-02	1.98043E-02	1.65350E-02	1.20914E-02	7.39831E-03	3.25332E-03	0.00000E+00
35	9.95391E-03	1.78513E-02	2.24598E-02	2.36731E-02	2.20477E-02	1.84465E-02	1.35935E-02	8.32062E-03	3.70332E-03	0.00000E+00

34	1.09608E-02	1.95568E-02	2.44971E-02	2.57721E-02	2.40632E-02	2.01859E-02	1.49767E-02	9.30214E-03	4.11384E-03	0.00000E+00
33	1.18353E-02	2.09971E-02	2.61772E-02	2.75007E-02	2.57119E-02	2.16637E-02	1.61650E-02	1.00922E-02	4.46831E-03	0.00000E+00
32	1.24292E-02	2.19734E-02	2.73212E-02	2.87079E-02	2.69303E-02	2.28060E-02	1.71185E-02	1.07350E-02	4.75876E-03	0.00000E+00
31	1.25434E-02	2.22240E-02	2.76880E-02	2.92410E-02	2.76163E-02	2.35507E-02	1.78089E-02	1.12226E-02	4.97436E-03	0.00000E+00
30	1.19457E-02	2.14103E-02	2.70418E-02	2.89424E-02	2.76771E-02	2.38665E-02	1.82048E-02	1.15344E-02	5.12136E-03	0.00000E+00
29	1.03695E-02	1.92337E-02	2.51482E-02	2.76811E-02	2.70539E-02	2.37197E-02	1.83174E-02	1.16794E-02	5.20342E-03	0.00000E+00
28	7.56944E-03	1.54194E-02	2.18631E-02	2.53745E-02	2.57135E-02	2.31091E-02	1.81455E-02	1.16918E-02	5.21115E-03	0.00000E+00
27	3.48188E-03	9.80284E-03	1.69479E-02	2.19415E-02	2.36286E-02	2.20318E-02	1.77108E-02	1.15500E-02	5.15307E-03	0.00000E+00
26	-1.48484E-03	2.55151E-03	1.04806E-02	1.73179E-02	2.07732E-02	2.04918E-02	1.70076E-02	1.12760E-02	5.05558E-03	0.00000E+00
25	-6.60571E-03	-5.81178E-03	2.44931E-03	1.14683E-02	1.70878E-02	1.84593E-02	1.60496E-02	1.08723E-02	4.93163E-03	0.00000E+00
24	-1.10750E-02	-1.44164E-02	-6.95540E-03	4.27636E-03	1.24793E-02	1.58640E-02	1.47692E-02	1.03271E-02	4.71912E-03	0.00000E+00
23	-1.46252E-02	-2.23726E-02	-1.73102E-02	-4.35095E-03	6.78960E-03	1.25318E-02	1.31055E-02	9.59335E-03	4.41311E-03	0.00000E+00
22	-1.73459E-02	-2.91201E-02	-2.80132E-02	-1.44314E-02	-1.70299E-04	8.50555E-03	1.10090E-02	8.61315E-03	4.01334E-03	0.00000E+00
21	-1.93217E-02	-3.44406E-02	-3.82196E-02	-2.58838E-02	-8.52222E-03	3.44812E-03	8.32753E-03	7.28701E-03	3.50585E-03	0.00000E+00
20	-2.06825E-02	-3.84847E-02	-4.72111E-02	-3.84150E-02	-1.84563E-02	-2.78681E-03	4.83418E-03	5.55916E-03	2.79188E-03	0.00000E+00
19	-2.16324E-02	-4.15688E-02	-5.46543E-02	-5.12575E-02	-3.03031E-02	-1.03835E-02	4.92633E-04	3.25314E-03	1.76736E-03	0.00000E+00
18	-2.24847E-02	-4.39257E-02	-6.06374E-02	-6.34187E-02	-4.41950E-02	-1.96542E-02	-5.00920E-03	1.30725E-04	3.08281E-04	0.00000E+00
17	-2.34380E-02	-4.58371E-02	-6.53453E-02	-7.41072E-02	-5.97694E-02	-3.10402E-02	-1.17192E-02	-3.82282E-03	-1.56851E-03	0.00000E+00
16	-2.43513E-02	-4.77397E-02	-6.92311E-02	-8.30343E-02	-7.59491E-02	-4.50349E-02	-2.00048E-02	-8.71215E-03	-3.84011E-03	0.00000E+00
15	-2.50263E-02	-4.95920E-02	-7.26634E-02	-9.05815E-02	-9.13606E-02	-6.22618E-02	-3.03309E-02	-1.48636E-02	-6.72342E-03	0.00000E+00
14	-2.57176E-02	-5.14426E-02	-7.59582E-02	-9.70047E-02	-1.05095E-01	-8.22971E-02	-4.32836E-02	-2.24855E-02	-1.04438E-02	0.00000E+00
13	-2.67742E-02	-5.34205E-02	-7.93102E-02	-1.02829E-01	-1.17101E-01	-1.03714E-01	-5.98048E-02	-3.18814E-02	-1.51115E-02	0.00000E+00
12	-2.80143E-02	-5.56728E-02	-8.28751E-02	-1.08477E-01	-1.27755E-01	-1.24532E-01	-8.09563E-02	-4.33620E-02	-2.07745E-02	0.00000E+00
11	-2.92137E-02	-5.82134E-02	-8.68018E-02	-1.14262E-01	-1.37523E-01	-1.43527E-01	-1.06909E-01	-5.73275E-02	-2.76059E-02	0.00000E+00
10	-3.05411E-02	-6.10303E-02	-9.11593E-02	-1.20415E-01	-1.48832E-01	-1.60745E-01	-1.35810E-01	-7.48739E-02	-3.58008E-02	0.00000E+00
9	-3.21321E-02	-6.41896E-02	-9.59992E-02	-1.27114E-01	-1.58279E-01	-1.76704E-01	-1.64754E-01	-9.79095E-02	-4.55924E-02	0.00000E+00
8	-3.39300E-02	-6.77567E-02	-1.01395E-01	-1.34527E-01	-1.66221E-01	-1.92015E-01	-1.91981E-01	-1.27999E-01	-5.73412E-02	0.00000E+00
7	-3.59315E-02	-7.17486E-02	-1.07443E-01	-1.42743E-01	-1.76974E-01	-2.07204E-01	-2.17437E-01	-1.64559E-01	-7.19250E-02	0.00000E+00
6	-3.81346E-02	-7.61704E-02	-1.14155E-01	-1.51795E-01	-1.88649E-01	-2.22732E-01	-2.41052E-01	-2.04734E-01	-9.15919E-02	0.00000E+00
5	-4.05939E-02	-8.11592E-02	-1.21674E-01	-1.61896E-01	-2.01561E-01	-2.39281E-01	-2.66315E-01	-2.46037E-01	-1.20159E-01	0.00000E+00
4	-4.34902E-02	-8.69960E-02	-1.30387E-01	-1.73623E-01	-2.16451E-01	-2.57917E-01	-2.92230E-01	-2.88462E-01	-1.62420E-01	0.00000E+00
3	-4.68452E-02	-9.36530E-02	-1.40381E-01	-1.87071E-01	-2.33434E-01	-2.78944E-01	-3.20053E-01	-3.32655E-01	-2.22243E-01	0.00000E+00
2	-4.98224E-02	-9.96391E-02	-1.49453E-01	-1.99228E-01	-2.48866E-01	-2.98027E-01	-3.44926E-01	-3.73683E-01	-2.98205E-01	0.00000E+00
1	-4.81071E-02	-9.63056E-02	-1.44678E-01	-1.93271E-01	-2.42149E-01	-2.91226E-01	-3.39912E-01	-3.81700E-01	-3.62999E-01	0.00000E+00

WL (M/S) : VELOCITY IN Z-DIRECTION AT TIME= 1.050E+03 SECONDS

********** CONSTANT J PLANE J= 1 **********

K	I-->	1	2	3	4	5	6	7	8	9	10
50		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
49		1.22614E+02	1.22027E+02	1.20798E+02	1.18874E+02	1.16153E+02	1.12474E+02	1.07459E+02	1.00305E+02	8.85779E+01	7.29063E+01
48		1.23011E+02	1.22408E+02	1.21170E+02	1.19236E+02	1.16511E+02	1.12817E+02	1.07777E+02	1.00514E+02	8.81640E+01	7.22155E+01
47		1.23057E+02	1.22459E+02	1.21211E+02	1.19266E+02	1.16529E+02	1.12823E+02	1.07771E+02	1.00495E+02	8.81412E+01	7.22093E+01
46		1.23093E+02	1.22494E+02	1.21226E+02	1.19270E+02	1.16523E+02	1.12812E+02	1.07760E+02	1.00492E+02	8.81444E+01	7.22151E+01
45		1.23141E+02	1.22520E+02	1.21209E+02	1.19278E+02	1.16519E+02	1.12800E+02	1.07748E+02	1.00485E+02	8.81453E+01	7.22184E+01
44		1.23201E+02	1.22571E+02	1.21264E+02	1.19294E+02	1.16519E+02	1.12788E+02	1.07733E+02	1.00477E+02	8.81440E+01	7.22190E+01
43		1.23202E+02	1.22640E+02	1.21333E+02	1.19319E+02	1.16521E+02	1.12775E+02	1.07715E+02	1.00463E+02	8.81377E+01	7.22162E+01
42		1.23387E+02	1.22731E+02	1.21399E+02	1.19355E+02	1.16529E+02	1.12764E+02	1.07694E+02	1.00444E+02	8.81261E+01	7.22087E+01
41		1.23519E+02	1.22845E+02	1.21483E+02	1.19403E+02	1.16544E+02	1.12753E+02	1.07669E+02	1.00419E+02	8.81082E+01	7.21955E+01
40		1.23621E+02	1.22987E+02	1.21539E+02	1.19465E+02	1.16565E+02	1.12743E+02	1.07641E+02	1.00389E+02	8.80831E+01	7.21759E+01
39		1.23576E+02	1.23155E+02	1.21717E+02	1.19542E+02	1.16594E+02	1.12734E+02	1.07610E+02	1.00350E+02	8.80405E+01	7.21409E+01
38		1.24105E+02	1.23361E+02	1.21869E+02	1.19635E+02	1.16633E+02	1.12728E+02	1.07575E+02	1.00305E+02	8.80077E+01	7.21137E+01
37		1.24330E+02	1.23595E+02	1.22047E+02	1.19745E+02	1.16678E+02	1.12723E+02	1.07538E+02	1.00252E+02	8.79564E+01	7.20693E+01
36		1.24693E+02	1.23870E+02	1.22258E+02	1.19870E+02	1.16732E+02	1.12720E+02	1.07495E+02	1.00191E+02	8.78956E+01	7.20172E+01
35		1.25043E+02	1.24175E+02	1.22479E+02	1.20012E+02	1.16794E+02	1.12720E+02	1.07450E+02	1.00124E+02	8.78250E+01	7.19555E+01
34		1.25446E+02	1.24522E+02	1.22733E+02	1.20169E+02	1.16869E+02	1.12721E+02	1.07402E+02	1.00049E+02	8.77455E+01	7.18757E+01
33		1.25835E+02	1.24897E+02	1.23003E+02	1.20337E+02	1.16948E+02	1.12724E+02	1.07352E+02	9.99676E+01	8.76575E+01	7.18075E+01

32	1.26355E+02	1.25299E+02	1.23300E+02	1.20517E+02	1.17023E+02	1.12729E+02	1.07300E+02	9.98811E+01	8.75621E+01	7.17228E+01
31	1.26855E+02	1.25720E+02	1.23604E+02	1.20705E+02	1.17111E+02	1.12737E+02	1.07248E+02	9.97907E+01	8.74608E+01	7.16327E+01
30	1.27357E+02	1.26145E+02	1.23913E+02	1.20899E+02	1.17205E+02	1.12749E+02	1.07197E+02	9.96977E+01	8.73550E+01	7.15353E+01
29	1.27836E+02	1.26556E+02	1.24220E+02	1.21097E+02	1.17305E+02	1.12766E+02	1.07148E+02	9.96039E+01	8.72463E+01	7.14412E+01
28	1.28251E+02	1.26931E+02	1.24515E+02	1.21298E+02	1.17414E+02	1.12792E+02	1.07105E+02	9.95113E+01	8.71364E+01	7.13428E+01
27	1.28553E+02	1.27241E+02	1.24792E+02	1.21504E+02	1.17535E+02	1.12828E+02	1.07069E+02	9.94220E+01	8.70266E+01	7.12442E+01
26	1.28692E+02	1.27456E+02	1.25042E+02	1.21715E+02	1.17670E+02	1.12879E+02	1.07044E+02	9.93377E+01	8.69186E+01	7.11464E+01
25	1.28633E+02	1.27544E+02	1.25253E+02	1.21931E+02	1.17823E+02	1.12949E+02	1.07032E+02	9.92607E+01	8.68135E+01	7.10505E+01
24	1.28370E+02	1.27477E+02	1.25405E+02	1.22151E+02	1.17999E+02	1.13041E+02	1.07037E+02	9.91932E+01	8.67129E+01	7.09572E+01
23	1.27926E+02	1.27241E+02	1.25468E+02	1.22368E+02	1.18201E+02	1.13160E+02	1.07052E+02	9.91379E+01	8.66183E+01	7.08680E+01
22	1.27339E+02	1.26840E+02	1.25411E+02	1.22565E+02	1.18429E+02	1.13311E+02	1.07112E+02	9.90976E+01	8.65314E+01	7.07843E+01
21	1.26644E+02	1.26294E+02	1.25205E+02	1.22716E+02	1.18682E+02	1.13500E+02	1.07192E+02	9.90757E+01	8.64548E+01	7.07079E+01
20	1.25873E+02	1.25633E+02	1.24839E+02	1.22779E+02	1.18952E+02	1.13730E+02	1.07307E+02	9.90761E+01	8.63916E+01	7.06415E+01
19	1.25048E+02	1.24881E+02	1.24321E+02	1.22711E+02	1.19225E+02	1.14005E+02	1.07464E+02	9.91037E+01	8.63456E+01	7.05839E+01
18	1.24181E+02	1.24063E+02	1.23674E+02	1.22476E+02	1.19463E+02	1.14329E+02	1.07667E+02	9.91637E+01	8.63217E+01	7.05555E+01
17	1.23278E+02	1.23192E+02	1.22923E+02	1.22065E+02	1.19608E+02	1.14704E+02	1.07922E+02	9.92595E+01	8.63262E+01	7.05496E+01
16	1.22342E+02	1.22279E+02	1.22090E+02	1.21491E+02	1.19597E+02	1.15114E+02	1.08242E+02	9.93966E+01	8.63656E+01	7.05788E+01
15	1.21374E+02	1.21329E+02	1.21192E+02	1.20780E+02	1.19387E+02	1.15511E+02	1.08643E+02	9.95848E+01	8.64483E+01	7.06513E+01
14	1.20374E+02	1.20340E+02	1.20241E+02	1.19955E+02	1.18967E+02	1.15813E+02	1.09139E+02	9.98346E+01	8.65846E+01	7.07794E+01
13	1.19341E+02	1.19313E+02	1.19241E+02	1.19040E+02	1.18356E+02	1.15928E+02	1.09727E+02	1.00163E+02	8.67862E+01	7.09777E+01
12	1.18268E+02	1.18246E+02	1.18192E+02	1.18049E+02	1.17582E+02	1.15795E+02	1.10354E+02	1.00598E+02	8.70671E+01	7.12636E+01
11	1.17149E+02	1.17134E+02	1.17094E+02	1.16990E+02	1.16671E+02	1.15401E+02	1.10909E+02	1.01184E+02	8.74435E+01	7.16571E+01
10	1.15982E+02	1.15971E+02	1.15942E+02	1.15867E+02	1.15647E+02	1.14769E+02	1.11256E+02	1.01957E+02	8.79377E+01	7.21803E+01
9	1.14759E+02	1.14751E+02	1.14730E+02	1.14677E+02	1.14524E+02	1.13932E+02	1.11298E+02	1.02895E+02	8.85888E+01	7.28583E+01
8	1.13473E+02	1.13468E+02	1.13454E+02	1.13417E+02	1.13311E+02	1.12918E+02	1.11012E+02	1.03882E+02	8.94666E+01	7.37225E+01
7	1.12117E+02	1.12113E+02	1.12105E+02	1.12080E+02	1.12009E+02	1.11751E+02	1.10422E+02	1.04735E+02	9.06620E+01	7.48086E+01
6	1.10680E+02	1.10679E+02	1.10674E+02	1.10659E+02	1.10613E+02	1.10448E+02	1.09564E+02	1.05283E+02	9.22365E+01	7.61714E+01
5	1.09155E+02	1.09155E+02	1.09154E+02	1.09147E+02	1.09120E+02	1.09019E+02	1.08467E+02	1.05430E+02	9.41505E+01	7.79068E+01
4	1.07531E+02	1.07532E+02	1.07533E+02	1.07532E+02	1.07519E+02	1.07463E+02	1.07148E+02	1.05152E+02	9.62373E+01	8.01836E+01
3	1.05791E+02	1.05792E+02	1.05795E+02	1.05798E+02	1.05796E+02	1.05771E+02	1.05616E+02	1.04454E+02	9.82277E+01	8.32610E+01
2	1.03917E+02	1.03920E+02	1.03924E+02	1.03929E+02	1.03934E+02	1.03929E+02	1.03872E+02	1.03331E+02	9.97831E+01	8.74720E+01
1	1.01924E+02	1.01927E+02	1.01931E+02	1.01938E+02	1.01945E+02	1.01951E+02	1.01945E+02	1.01798E+02	1.00502E+02	9.31222E+01

TURVIS (Pa*s) : TURBULENT VISCOSITY AT TIME= 1.050E+03 SECONDS

************ CONSTANT J PLANE J= 1 ************

K	I--> 1	2	3	4	5	6	7	8	9	10
50	6.56486E-02	6.40941E-02	6.14852E-02	5.82139E-02	5.42191E-02	4.91185E-02	4.25060E-02	3.41753E-02	2.25163E-02	1.60014E-02
49	6.58158E-02	6.42641E-02	6.16477E-02	5.83363E-02	5.42230E-02	4.88383E-02	4.15951E-02	3.20053E-02	1.95112E-02	2.34621E-02
48	6.60033E-02	6.44648E-02	6.18702E-02	5.85756E-02	5.44589E-02	4.90486E-02	4.17919E-02	3.22969E-02	1.97381E-02	2.33905E-02
47	6.61776E-02	6.46592E-02	6.20939E-02	5.88358E-02	5.47267E-02	4.92893E-02	4.19729E-02	3.24014E-02	1.97627E-02	2.33908E-02
46	6.63291E-02	6.48350E-02	6.23180E-02	5.90972E-02	5.50041E-02	4.95417E-02	4.21625E-02	3.25092E-02	1.97897E-02	2.33919E-02
45	6.64451E-02	6.49810E-02	6.25194E-02	5.93565E-02	5.52920E-02	4.98132E-02	4.23712E-02	3.26310E-02	1.98212E-02	2.33922E-02
44	6.65088E-02	6.50797E-02	6.26835E-02	5.96028E-02	5.55830E-02	5.00958E-02	4.25977E-02	3.27658E-02	1.98569E-02	2.33914E-02
43	6.64918E-02	6.51103E-02	6.28077E-02	5.98221E-02	5.58730E-02	5.03946E-02	4.28387E-02	3.29131E-02	1.98970E-02	2.33892E-02
42	6.63741E-02	6.50486E-02	6.28560E-02	5.99978E-02	5.61414E-02	5.06838E-02	4.30904E-02	3.30706E-02	1.99411E-02	2.33853E-02
41	6.61233E-02	6.48665E-02	6.28097E-02	6.01103E-02	5.63764E-02	5.09715E-02	4.33397E-02	3.32344E-02	1.99883E-02	2.33795E-02
40	6.57053E-02	6.45322E-02	6.26422E-02	6.01397E-02	5.65609E-02	5.12299E-02	4.35845E-02	3.34001E-02	2.00375E-02	2.33714E-02
39	6.50810E-02	6.40111E-02	6.23241E-02	6.00609E-02	5.66730E-02	5.14492E-02	4.38121E-02	3.35619E-02	2.00871E-02	2.33610E-02
38	6.42095E-02	6.32641E-02	6.18233E-02	5.98425E-02	5.67003E-02	5.16131E-02	4.40112E-02	3.37134E-02	2.01352E-02	2.33480E-02
37	6.30422E-02	6.22495E-02	6.11064E-02	5.94758E-02	5.66131E-02	5.17041E-02	4.41692E-02	3.38473E-02	2.01799E-02	2.33322E-02
36	6.15223E-02	6.08233E-02	6.01387E-02	5.89140E-02	5.63904E-02	5.17036E-02	4.42731E-02	3.39562E-02	2.02187E-02	2.33130E-02
35	5.96160E-02	5.92405E-02	5.88330E-02	5.81381E-02	5.60087E-02	5.15932E-02	4.43050E-02	3.40324E-02	2.02500E-02	2.32929E-02
34	5.72490E-02	5.71525E-02	5.73165E-02	5.71198E-02	5.54458E-02	5.13550E-02	4.42573E-02	3.40690E-02	2.02712E-02	2.32695E-02
33	5.43771E-02	5.46365E-02	5.54037E-02	5.58371E-02	5.46210E-02	5.09733E-02	4.41347E-02	3.40603E-02	2.02809E-02	2.32441E-02
32	5.09808E-02	5.16511E-02	5.31291E-02	5.42719E-02	5.36279E-02	5.04351E-02	4.39038E-02	3.40019E-02	2.02730E-02	2.32170E-02
31	[illegible]	4.81932E-02	5.04352E-02	5.24128E-02	[illegible]	4.97313E-02	4.35694E-02	3.39914E-02	2.02619E-02	2.31805E-02

30	4.24924E-02	4.42942E-02	4.74823E-02	5.02555E-02	5.10399E-02	4.88572E-02	4.31286E-02	3.37277E-02	2.02325E-02	2.31591E-02
29	3.76020E-02	4.00174E-02	4.41409E-02	4.78038E-02	4.93541E-02	4.78117E-02	4.25813E-02	3.35112E-02	2.01902E-02	2.31293E-02
28	3.25539E-02	3.54892E-02	4.05009E-02	4.50681E-02	4.74342E-02	4.65961E-02	4.19282E-02	3.32425E-02	2.01355E-02	2.30993E-02
27	2.77330E-02	3.08973E-02	3.66169E-02	4.20650E-02	4.52362E-02	4.52128E-02	4.11702E-02	3.29220E-02	2.00686E-02	2.30696E-02
26	2.35503E-02	2.64946E-02	3.25637E-02	3.88148E-02	4.29164E-02	4.36630E-02	4.03064E-02	3.25491E-02	1.99898E-02	2.30405E-02
25	2.03993E-02	2.25813E-02	2.84512E-02	3.53414E-02	4.03293E-02	4.19450E-02	3.93342E-02	3.21221E-02	1.98986E-02	2.30122E-02
24	1.84100E-02	1.96503E-02	2.44523E-02	3.16757E-02	3.75274E-02	4.00541E-02	3.82478E-02	3.16371E-02	1.97942E-02	2.29851E-02
23	1.75013E-02	1.73031E-02	2.08089E-02	2.78748E-02	3.45110E-02	3.79820E-02	3.70389E-02	3.10887E-02	1.96747E-02	2.29597E-02
22	1.74145E-02	1.61840E-02	1.77965E-02	2.40453E-02	3.12826E-02	3.57181E-02	3.56966E-02	3.04691E-02	1.95378E-02	2.29366E-02
21	1.78470E-02	1.59727E-02	1.56446E-02	2.03728E-02	2.78546E-02	3.32489E-02	3.42067E-02	2.97687E-02	1.93799E-02	2.29166E-02
20	1.85443E-02	1.64285E-02	1.44602E-02	1.71227E-02	2.42645E-02	3.05638E-02	3.25535E-02	2.89755E-02	1.91966E-02	2.29003E-02
19	1.93415E-02	1.72710E-02	1.42032E-02	1.45725E-02	2.06156E-02	2.76517E-02	3.07189E-02	2.80756E-02	1.89828E-02	2.28910E-02
18	2.01494E-02	1.82671E-02	1.47005E-02	1.29158E-02	1.71192E-02	2.45019E-02	2.88861E-02	2.70537E-02	1.87327E-02	2.28892E-02
17	2.09333E-02	1.92742E-02	1.56861E-02	1.22112E-02	1.40741E-02	2.11282E-02	2.64439E-02	2.59928E-02	1.84410E-02	2.28975E-02
16	2.16857E-02	2.02305E-02	1.68868E-02	1.23355E-02	1.17645E-02	1.76290E-02	2.39714E-02	2.45938E-02	1.81101E-02	2.29189E-02
15	2.24110E-02	2.11225E-02	1.81095E-02	1.32438E-02	1.03552E-02	1.42405E-02	2.12290E-02	2.31478E-02	1.77414E-02	2.29571E-02
14	2.31164E-02	2.19586E-02	1.92624E-02	1.45035E-02	9.87043E-03	1.12965E-02	1.81924E-02	2.15452E-02	1.73373E-02	2.30165E-02
13	2.38057E-02	2.27537E-02	2.03246E-02	1.58954E-02	1.02233E-02	9.08643E-03	1.49367E-02	1.97638E-02	1.69035E-02	2.31023E-02
12	2.44917E-02	2.35213E-02	2.13098E-02	1.72554E-02	1.12202E-02	7.73998E-03	1.17061E-02	1.77525E-02	1.64497E-02	2.32205E-02
11	2.51664E-02	2.42727E-02	2.22418E-02	1.85276E-02	1.25833E-02	7.23766E-03	8.85562E-03	1.54511E-02	1.59866E-02	2.33782E-02
10	2.58304E-02	2.50116E-02	2.31433E-02	1.97198E-02	1.40626E-02	7.48369E-03	6.67342E-03	1.28782E-02	1.55126E-02	2.35830E-02
9	2.64782E-02	2.57389E-02	2.40309E-02	2.08642E-02	1.55294E-02	8.32693E-03	5.25048E-03	1.02137E-02	1.49862E-02	2.38451E-02
8	2.71015E-02	2.64504E-02	2.49139E-02	2.19951E-02	1.69653E-02	9.56449E-03	4.51262E-03	7.75122E-03	1.43133E-02	2.41779E-02
7	2.76897E-02	2.71375E-02	2.57936E-02	2.31437E-02	1.84089E-02	1.10202E-02	4.34180E-03	5.74683E-03	1.33873E-02	2.46019E-02
6	2.82309E-02	2.77873E-02	2.66625E-02	2.43238E-02	1.99174E-02	1.26282E-02	4.65610E-03	4.30518E-03	1.21730E-02	2.51492E-02
5	2.87142E-02	2.83947E-02	2.75035E-02	2.55378E-02	2.15471E-02	1.44355E-02	5.43152E-03	3.38207E-03	1.07441E-02	2.58572E-02
4	2.91324E-02	2.89139E-02	2.82895E-02	2.67649E-02	2.33406E-02	1.65722E-02	6.72640E-03	2.87625E-03	9.22060E-03	2.63091E-02
3	2.94951E-02	2.93634E-02	2.89856E-02	2.79527E-02	2.53021E-02	1.92347E-02	8.77342E-03	2.73470E-03	7.66435E-03	2.79626E-02
2	2.97826E-02	2.97317E-02	2.95572E-02	2.90095E-02	2.73411E-02	2.26423E-02	1.22317E-02	3.09770E-03	6.01741E-03	2.88377E-02
1	3.00464E-02	3.00345E-02	2.99883E-02	2.98173E-02	2.91731E-02	2.67642E-02	1.87780E-02	5.12022E-03	4.23210E-03	2.68601E-02

TURCON (J/s*m*C) : TURBULENT CONDUCTIVITY AT TIME= 1.050E+03 SECONDS

********** CONSTANT J PLANE J= 1 **********

K	I-->	1	2	3	4	5	6	7	8	9	10
50		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
49		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
48		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
47		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
46		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
45		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
44		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
43		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
42		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
41		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
40		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
39		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
38		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
37		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
36		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
35		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
34		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
33		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
32		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
31		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
30		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
29		0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

K	1	2	3	4	5	6	7	8	9	10
28	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
27	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
26	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
25	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
24	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
23	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
22	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
21	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
20	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
19	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
18	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
17	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
16	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
15	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
14	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
13	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
12	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
11	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
10	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
9	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
8	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
7	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
6	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
5	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
4	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

TURK (m**2/s**2) : TURBULENT KINETIC ENERGY AT TIME= 1.050E+03 SECONDS

************ CONSTANT J PLANE J= 1 ************

K	I--> 1	2	3	4	5	6	7	8	9	10
50	3.51397E+01	3.69392E+01	4.05012E+01	4.57188E+01	5.24734E+01	6.07631E+01	7.09119E+01	8.36747E+01	9.30972E+01	1.36562E+02
49	3.53819E+01	3.71935E+01	4.07685E+01	4.59874E+01	5.27074E+01	6.08911E+01	7.08536E+01	8.39491E+01	1.03327E+02	2.93592E+02
48	3.55446E+01	3.74786E+01	4.10890E+01	4.63490E+01	5.31129E+01	6.13693E+01	7.15366E+01	8.52270E+01	1.04454E+02	2.91800E+02
47	3.59126E+01	3.77697E+01	4.14161E+01	4.67081E+01	5.34352E+01	6.17208E+01	7.18563E+01	8.54778E+01	1.04564E+02	2.91805E+02
46	3.61857E+01	3.80708E+01	4.17601E+01	4.70839E+01	5.38768E+01	6.20955E+01	7.21647E+01	8.57083E+01	1.04677E+02	2.91833E+02
45	3.64572E+01	3.83783E+01	4.21234E+01	4.75019E+01	5.43078E+01	6.25071E+01	7.25150E+01	8.59722E+01	1.04806E+02	2.91839E+02
44	3.67149E+01	3.86816E+01	4.24979E+01	4.79421E+01	5.47817E+01	6.29627E+01	7.29077E+01	8.62700E+01	1.04949E+02	2.91818E+02
43	3.69437E+01	3.89569E+01	4.28724E+01	4.84006E+01	5.52555E+01	6.34570E+01	7.33393E+01	8.65999E+01	1.05105E+02	2.91762E+02
42	3.71247E+01	3.92175E+01	4.32328E+01	4.88657E+01	5.58116E+01	6.39819E+01	7.38029E+01	8.69568E+01	1.05271E+02	2.91665E+02
41	3.72355E+01	3.94131E+01	4.35610E+01	4.93228E+01	5.63367E+01	6.45261E+01	7.42395E+01	8.73336E+01	1.05442E+02	2.91520E+02
40	3.72497E+01	3.95296E+01	4.38339E+01	4.97540E+01	5.68752E+01	6.50753E+01	7.47852E+01	[illegible]	1.05613E+02	2.91320E+02
39	3.71361E+01	3.95392E+01	4.40399E+01	5.01380E+01	5.73773E+01	6.56114E+01	7.52781E+01	8.81055E+01	1.05774E+02	2.91059E+02
38	3.68539E+01	3.94096E+01	4.41373E+01	5.04503E+01	5.78305E+01	6.61139E+01	7.57468E+01	8.84736E+01	1.05919E+02	2.90735E+02
37	3.63772E+01	3.91041E+01	4.40994E+01	5.06625E+01	5.82005E+01	6.65570E+01	7.61720E+01	8.88090E+01	1.06039E+02	2.90344E+02
36	3.56447E+01	3.85319E+01	4.38910E+01	5.07428E+01	5.84321E+01	6.69206E+01	7.65318E+01	8.90942E+01	1.06123E+02	2.89836E+02
35	3.46115E+01	3.77931E+01	4.34730E+01	5.05561E+01	5.86195E+01	6.71715E+01	7.68038E+01	8.93121E+01	1.06163E+02	2.89365E+02
34	3.32252E+01	3.67059E+01	4.28036E+01	5.03640E+01	5.85371E+01	6.72834E+01	7.69665E+01	8.94470E+01	1.06152E+02	2.88785E+02
33	3.14350E+01	3.52570E+01	4.18393E+01	4.98268E+01	5.83505E+01	6.72305E+01	7.70004E+01	8.94359E+01	1.06034E+02	2.88135E+02
32	2.92027E+01	3.34157E+01	4.05374E+01	4.90041E+01	5.78703E+01	6.69290E+01	7.68904E+01	8.94192E+01	1.05957E+02	2.87451E+02
31	2.65321E+01	3.11518E+01	3.83587E+01	4.78577E+01	5.71403E+01	6.65403E+01	7.66261E+01	8.92422E+01	1.05769E+02	2.86777E+02
30	2.34379E+01	2.84616E+01	3.67723E+01	4.63533E+01	5.61128E+01	6.59712E+01	7.62015E+01	8.89534E+01	1.05523E+02	2.86051E+02
29	2.00420E+01	[illegible]	3.42616E+01	4.44333E+01	5.47775E+01	[illegible]	7.56152E+01	[illegible]	1.05224E+02	2.85314E+02
28	1.65434E+01	2.23035E+01	[illegible]	4.21731E+01	5.31213E+01	[illegible]	[illegible]	8.80433E+01	1.04874E+02	2.84578E+02
27	1.32033E+01	1.84900E+01	2.89183E+01	3.94823E+01	5.11342E+01	6.24687E+01	7.39538E+01	8.74412E+01	1.04478E+02	2.83845E+02

25	1.03104E+01	1.50532E+01	2.44022E+01	3.63822E+01	4.88049E+01	6.09490E+01	7.28812E+01	8.67284E+01	1.04038E+02	2.83128E+02	
25	8.04631E+00	1.19471E+01	2.06200E+01	3.28930E+01	4.61177E+01	5.89673E+01	7.16323E+01	8.59090E+01	1.03556E+02	2.82932E+02	
24	6.43993E+00	9.37539E+00	1.65850E+01	2.90512E+01	4.30516E+01	5.68008E+01	7.01950E+01	8.49747E+01	1.03023E+02	2.81768E+02	
23	5.39496E+00	7.93163E+00	1.34462E+01	2.49487E+01	3.95810E+01	5.43172E+01	6.85477E+01	8.39125E+01	1.02451E+02	2.81146E+02	
22	4.76499E+00	6.85695E+00	1.05334E+01	2.07465E+01	3.56907E+01	5.14739E+01	6.66598E+01	8.27026E+01	1.01817E+02	2.80581E+02	
21	4.41550E+00	5.23094E+00	8.28050E+00	1.66866E+01	3.13993E+01	4.82177E+01	6.44903E+01	8.13189E+01	1.01114E+02	2.80091E+02	
20	4.24805E+00	4.73169E+00	6.60851E+00	1.30605E+01	2.67717E+01	4.45028E+01	6.19904E+01	7.97259E+01	1.00328E+02	2.79706E+02	
19	4.20005E+00	4.47485E+00	5.65735E+00	1.01899E+01	2.19943E+01	4.02730E+01	5.91028E+01	7.78314E+01	9.94404E+01	2.79465E+02	
18	4.23222E+00	4.37623E+00	5.04944E+00	7.93148E+00	1.73907E+01	3.54817E+01	5.57747E+01	7.57373E+01	9.84333E+01	2.79421E+02	
17	4.31058E+00	4.28311E+00	4.73612E+00	6.46792E+00	1.33477E+01	3.01641E+01	5.19235E+01	7.32622E+01	9.73033E+01	2.79625E+02	
16	4.44618E+00	4.45986E+00	4.61742E+00	5.57524E+00	1.01547E+01	2.45414E+01	4.74294E+01	7.04283E+01	9.60585E+01	2.80149E+02	
15	4.60503E+00	4.58687E+00	4.62516E+00	5.09517E+00	7.85930E+00	1.90562E+01	4.21425E+01	6.71875E+01	9.47125E+01	2.81035E+02	
14	4.79055E+00	4.75201E+00	4.71716E+00	4.89339E+00	6.43963E+00	1.42897E+01	3.60097E+01	6.34508E+01	9.32901E+01	2.82538E+02	
13	4.93533E+00	4.94803E+00	4.86855E+00	4.87159E+00	5.61295E+00	1.06035E+01	2.92486E+01	5.90903E+01	9.18366E+01	2.84668E+02	
12	5.22319E+00	5.17067E+00	5.06500E+00	4.96655E+00	5.22198E+00	8.88044E+00	2.24793E+01	5.38107E+01	9.04211E+01	2.87570E+02	
11	5.47773E+00	5.41756E+00	5.29819E+00	5.14164E+00	5.11834E+00	6.54081E+00	1.65114E+01	4.73719E+01	8.91135E+01	2.91488E+02	
10	5.74719E+00	5.68757E+00	5.56357E+00	5.37651E+00	5.19889E+00	5.72527E+00	1.19296E+01	3.98517E+01	8.78884E+01	2.96619E+02	
9	6.03685E+00	5.98036E+00	5.85874E+00	5.66002E+00	5.40112E+00	5.40534E+00	8.84867E+00	3.18526E+01	8.64691E+01	3.03247E+02	
8	6.34744E+00	6.29627E+00	6.18270E+00	5.98628E+00	5.69139E+00	5.41629E+00	7.01908E+00	2.44467E+01	8.42748E+01	3.11771E+02	
7	6.63025E+00	6.63618E+00	6.53535E+00	6.35221E+00	6.05230E+00	5.64354E+00	6.09854E+00	1.83796E+01	8.06785E+01	3.22802E+02	
6	7.03724E+00	7.00160E+00	6.91724E+00	6.75640E+00	6.47455E+00	6.02229E+00	5.81337E+00	1.40253E+01	7.54980E+01	3.37325E+02	
5	7.42142E+00	7.39490E+00	7.32956E+00	7.19807E+00	6.95261E+00	6.51729E+00	5.98239E+00	1.12508E+01	6.91967E+01	3.56059E+02	
4	7.83728E+00	7.81972E+00	7.77429E+00	7.67683E+00	7.48207E+00	7.10839E+00	6.48310E+00	9.71165E+00	6.24530E+01	3.83321E+02	
3	8.29139E+00	8.28164E+00	8.25482E+00	8.19258E+00	8.05772E+00	7.77866E+00	7.24356E+00	9.07627E+00	5.52883E+01	4.17019E+02	
2	8.79525E+00	8.78928E+00	8.77718E+00	8.74633E+00	8.67246E+00	8.50573E+00	8.16135E+00	9.08012E+00	4.60011E+01	4.45067E+02	
1	9.35623E+00	9.35530E+00	9.35225E+00	9.34337E+00	9.31896E+00	9.25722E+00	9.12603E+00	9.46414E+00	3.06497E+01	3.84781E+02	

TKED (m**2/s**3) : DISSIPATION OF TURBULENT KINETIC ENERGY AT TIME= 1.050E+03 SECONDS

********** CONSTANT J PLANE J= 1 **********

K	I-->	1	2	3	4	5	6	7	8	9	10
50		1.69389E+03	1.91721E+03	2.40254E+03	3.23336E+03	4.57291E+03	6.76808E+03	1.06506E+04	1.84423E+04	3.46475E+04	1.04893E+05
49		1.71277E+03	1.93833E+03	2.42772E+03	3.26432E+03	4.61309E+03	6.83516E+03	1.08654E+04	1.98214E+04	4.92517E+04	3.30643E+05
48		1.73323E+03	1.96190E+03	2.45696E+03	3.30204E+03	4.66372E+03	6.91277E+03	1.10232E+04	2.02444E+04	4.97532E+04	3.27623E+05
47		1.75561E+03	1.98634E+03	2.48683E+03	3.33832E+03	4.70586E+03	6.95944E+03	1.10735E+04	2.02975E+04	4.97951E+04	3.27631E+05
46		1.77719E+03	2.01251E+03	2.51925E+03	3.37773E+03	4.75065E+03	7.00613E+03	1.11181E+04	2.03389E+04	4.98341E+04	3.27676E+05
45		1.80069E+03	2.04043E+03	2.55485E+03	3.42202E+03	4.80184E+03	7.06030E+03	1.11706E+04	2.03874E+04	4.98770E+04	3.27736E+05
44		1.82445E+03	2.06954E+03	2.59332E+03	3.47116E+03	4.85966E+03	7.12233E+03	1.12316E+04	2.04440E+04	4.99230E+04	3.27650E+05
43		1.84759E+03	2.09910E+03	2.63411E+03	3.52475E+03	4.92266E+03	7.19204E+03	1.13007E+04	2.05081E+04	4.99703E+04	3.27556E+05
42		1.86893E+03	2.12813E+03	2.67642E+03	3.58218E+03	4.98135E+03	7.26859E+03	1.13775E+04	2.05783E+04	5.00172E+04	3.27393E+05
41		1.88724E+03	2.15535E+03	2.71925E+03	3.64259E+03	5.03875E+03	7.35192E+03	1.14610E+04	2.06550E+04	5.00610E+04	3.27146E+05
40		1.90065E+03	2.17934E+03	2.76126E+03	3.70466E+03	5.14733E+03	7.43978E+03	1.15494E+04	2.07350E+04	5.00993E+04	3.26811E+05
39		1.90715E+03	2.19812E+03	2.80059E+03	3.76698E+03	5.22793E+03	7.53056E+03	1.16410E+04	2.08164E+04	5.01288E+04	3.26372E+05
38		1.90429E+03	2.20949E+03	2.83600E+03	3.82754E+03	5.38047E+03	7.62203E+03	1.17330E+04	2.08963E+04	5.01462E+04	3.25827E+05
37		1.88917E+03	2.21082E+03	2.86434E+03	3.88393E+03	5.35639E+03	7.71139E+03	1.18226E+04	2.09716E+04	5.01479E+04	3.25170E+05
36		1.85847E+03	2.19901E+03	2.88297E+03	3.93347E+03	5.45264E+03	7.79547E+03	1.19066E+04	2.10369E+04	5.01308E+04	3.24401E+05
35		1.80851E+03	2.17052E+03	2.88593E+03	3.97232E+03	5.52109E+03	7.87082E+03	1.19814E+04	2.10946E+04	5.00915E+04	3.23526E+05
34		1.73544E+03	2.12149E+03	2.87699E+03	3.99865E+03	5.57156E+03	7.93367E+03	1.20438E+04	2.11356E+04	5.00289E+04	3.22550E+05
33		1.63570E+03	2.04788E+03	2.84383E+03	4.00171E+03	5.60375E+03	7.98053E+03	1.20906E+04	2.11594E+04	4.99411E+04	3.21497E+05
32		1.50867E+03	1.94577E+03	2.78370E+03	3.98223E+03	5.61435E+03	8.00726E+03	1.21165E+04	2.11641E+04	4.98281E+04	3.20373E+05
31		1.34810E+03	1.81219E+03	2.69183E+03	3.93285E+03	5.59241E+03	8.01275E+03	1.21233E+04	2.11491E+04	4.96913E+04	3.19186E+05
30		1.16351E+03	1.64594E+03	2.56302E+03	3.84795E+03	5.55209E+03	7.99039E+03	1.21173E+04	2.11144E+04	4.95325E+04	3.17925E+05
29		9.61420E+02	1.44902E+03	2.39341E+03	3.72286E+03	5.47171E+03	7.91650E+03	1.20810E+04	2.10609E+04	4.93546E+04	3.16757E+05
28		7.56200E+02	1.22015E+03	2.18136E+03	3.55259E+03	5.35413E+03	7.80389E+03	1.20034E+04	2.09797E+04	4.91603E+04	3.15502E+05
27		5.65773E+02	9.62780E+02	1.92457E+03	3.33523E+03	5.17437E+03	7.67892E+03	1.19063E+04	2.08820E+04	4.89523E+04	3.14315E+05
26		4.06102E+02	7.69740E+02	1.61570E+03	3.08913E+03	4.95511E+03	7.63185E+03	1.18084E+04	2.07722E+04	4.87333E+04	3.13123E+05
25		2.85960E+02	5.62875E+02	1.34499E+03	2.75500E+03	4.70631E+03	7.46073E+03	1.17406E+04	2.06763E+04	4.85027E+04	3.11970E+05

24	2.02745E+02	4.06719E+02	1.04936E+03	2.39798E+03	4.44501E+03	7.24945E+03	1.15944E+04	2.05411E+04	4.82633E+04	3.10871E+05
23	1.49677E+02	2.87267E+02	7.81978E+02	2.00967E+03	4.08562E+03	6.99099E+03	1.14174E+04	2.03342E+04	4.80141E+04	3.09842E+05
22	1.17340E+02	2.06043E+02	5.61103E+02	1.61102E+03	3.66430E+03	6.67617E+03	1.12033E+04	2.02032E+04	4.77540E+04	3.08907E+05
21	9.83230E+01	1.54178E+02	3.94449E+02	1.23005E+03	3.18556E+03	6.29330E+03	1.09423E+04	1.99924E+04	4.74806E+04	3.08099E+05
20	8.76119E+01	1.22652E+02	2.78437E+02	8.96538E+02	2.65342E+03	5.83108E+03	1.06241E+04	1.97429E+04	4.71911E+04	3.07464E+05
19	8.21169E+01	1.04347E+02	2.02807E+02	6.31256E+02	2.11186E+03	5.27697E+03	1.02342E+04	1.94438E+04	4.68820E+04	3.07067E+05
18	8.00046E+01	9.43850E+01	1.56098E+02	4.38357E+02	1.59993E+03	4.62435E+03	9.75989E+03	1.90825E+04	4.65506E+04	3.06995E+05
17	8.01941E+01	8.97074E+01	1.28699E+02	3.08328E+02	1.13929E+03	3.87578E+03	9.17582E+03	1.86562E+04	4.62075E+04	3.07330E+05
16	8.20432E+01	8.84865E+01	1.13630E+02	2.25869E+02	7.88371E+02	3.07476E+03	8.44539E+03	1.81514E+04	4.58555E+04	3.08194E+05
15	8.51697E+01	8.96460E+01	1.06313E+02	1.76420E+02	5.40954E+02	2.29745E+03	7.53022E+03	1.75513E+04	4.55059E+04	3.09737E+05
14	8.93493E+01	9.25534E+01	1.03966E+02	1.48590E+02	3.78118E+02	1.62635E+03	6.41488E+03	1.68230E+04	4.51785E+04	3.12145E+05
13	9.44589E+01	9.69397E+01	1.04960E+02	1.34373E+02	2.77353E+02	1.11354E+03	5.15463E+03	1.59002E+04	4.49053E+04	3.15649E+05
12	1.00445E+02	1.02297E+02	1.08348E+02	1.28655E+02	2.18733E+02	7.59227E+02	3.88521E+03	1.46798E+04	4.47327E+04	3.20522E+05
11	1.07306E+02	1.08826E+02	1.13587E+02	1.28418E+02	1.87373E+02	5.31994E+02	2.77069E+03	1.30715E+04	4.47067E+04	3.27094E+05
10	1.15085E+02	1.16400E+02	1.20372E+02	1.31929E+02	1.72981E+02	3.94201E+02	1.91932E+03	1.10989E+04	4.48147E+04	3.35769E+05
9	1.23872E+02	1.25057E+02	1.28553E+02	1.38190E+02	1.69066E+02	3.15909E+02	1.34214E+03	8.95706E+03	4.49026E+04	3.47085E+05
8	1.33797E+02	1.34889E+02	1.38038E+02	1.46625E+02	1.71838E+02	2.76048E+02	9.82592E+02	6.93921E+03	4.46579E+04	3.61622E+05
7	1.45047E+02	1.46052E+02	1.49023E+02	1.56914E+02	1.79083E+02	2.60110E+02	7.70945E+02	5.29039E+03	4.37556E+04	3.81194E+05
6	1.57878E+02	1.58778E+02	1.61513E+02	1.68904E+02	1.89421E+02	2.55479E+02	6.53245E+02	4.11217E+03	4.21418E+04	4.07206E+05
5	1.72631E+02	1.73389E+02	1.75796E+02	1.82596E+02	2.01905E+02	2.64817E+02	5.93022E+02	3.36845E+03	4.01092E+04	4.43034E+05
4	1.89757E+02	1.90334E+02	1.92282E+02	1.98172E+02	2.15861E+02	2.74413E+02	5.63242E+02	2.95122E+03	3.80706E+04	4.93271E+05
3	2.09843E+02	2.10217E+02	2.11550E+02	2.16103E+02	2.30946E+02	2.83118E+02	5.38242E+02	2.71111E+03	3.58949E+04	5.59726E+05
2	2.33657E+02	2.33841E+02	2.34579E+02	2.37334E+02	2.47578E+02	2.87565E+02	4.90096E+02	2.39554E+03	3.16496E+04	6.17135E+05
1	2.62212E+02	2.62264E+02	2.62496E+02	2.63500E+02	2.67914E+02	2.88170E+02	3.99168E+02	1.57440E+03	1.99773E+04	4.96092E+05

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R. E. Scholl, URS, 150 Fourth Street, San Francisco, California 94103
J. Weisman, U. of Cincinnati, Cincinnati, Ohio 45221

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1. REPORT NUMBER (Assigned by TIDC, add Vol., Supp., Rev.)

NUREG/CR4348, Vol. II
ANL-85-42, Vol. II

2. TITLE AND SUBTITLE

COMMIX-1B: A THREE-DIMENSIONAL TRANSIENT SINGLE-PHASE COMPUTER PROGRAM FOR THERMAL HYDRAULIC ANALYSIS OF SINGLE AND MULTICOMPONENT SYSTEMS, VOL. II: USER'S MANUAL

3. LEAVE BLANK

4. DATE REPORT COMPLETED

MONTH: September | YEAR: 1985

5. AUTHOR(S)

Analytical Thermal Hydraulic Research Program

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7. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)

Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

8. PROJECT/TASK/WORK UNIT NUMBER

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U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

11a. TYPE OF REPORT

Technical

b. PERIOD COVERED (Inclusive dates)

1/1/83 - 9/31/85

12. SUPPLEMENTARY NOTES

13. ABSTRACT (200 words or less)

The COMMIX-1B computer program, an extended version of COMMIX-1A, is designed to analyze steady-state/transient, single-phase, three-dimensional fluid flow with heat transfer in reactor components and multicomponent systems. The concepts of volume porosity, directional surface permeability, distributed resistance, and distributed heat source or sink is used to model a flow domain with stationary structures. The new porous-medium formulation permits simulation of either a single component or a multicomponent system. The conservation equations of mass, momentum, and energy based on the new porous-medium formulation are solved as a boundary-value problem in space and an initial-value problem in time.

Volume I of this report, entitled "Equations and Numerics," describes in detail, the basic equations, formulations, solution procedures, rebalancing scheme for faster convergence, models to describe the auxiliary phenomena, etc. Volume II, entitled "Users Manual," describes in detail, flow chart, available options, input instructions, sample problems, etc.

14. DOCUMENT ANALYSIS - a. KEYWORDS/DESCRIPTORS

Thermal Hydraulics
Numerical Analysis
Finite-Difference Procedures
Computer Codes

b. IDENTIFIERS/OPEN-ENDED TERMS

15. AVAILABILITY STATEMENT

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16. SECURITY CLASSIFICATION

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